A Report to

The Metropolitan Television Alliance

Regarding

Field Test Results for the New York City Prototype Distributed Transmission System

June 27, 2008

Prepared By:

Mr. William Meintel
Mr. Gary Sgrignoli
Mr. Dennis Wallace
Meintel, Sgrignoli, & Wallace, LLC
1282 Smallwood Drive
Suite 372
Waldorf, Maryland 20603
(202) 251-7589

EXECUTIVE SUMMARY

INTRODUCTION

The Metropolitan Television Alliance, LLC (**MTVA** or "**Alliance**") was formed after September 11, 2001, when many New York City television stations' digital and analog transmission facilities were lost in the collapse of the North Tower of the World Trade Center (**WTC**). The television stations, working cooperatively under the aegis of the MTVA, quickly installed digital and analog transmission facilities on top of the Empire State Building (**ESB**) as well as other locations such as 4 Times Square and a tower in Alpine, NJ. While these facilities are the best currently available, regional broadcast from the ESB may not be the optimal solution for the distribution of digital television signals. The existing facilities are outdated, crowded and perhaps inadequate to serve as a long term home for digital broadcast by all MTVA members. And in an era of unprecedented construction in the city, new high rise buildings in the region, impede or block signals, interfering with reception and creating "shadows" that may extend across parts of the city and surrounding areas, depriving viewers of an over-the-air service.

At Empire, with a crowded antenna mast structure (originally designed as a mooring for dirigibles), many of the digital television (**DTV**) antennas were side-mounted and located at lower elevations than their previous locations on the north tower of the WTC. Physical limitations on the mast, in terms of both real estate and loading capacity, required partially-obstructed antennas at ESB. The result is that some areas in the New York City metropolitan area have DTV television coverage (signal levels) and service (reception) inferior to that which was available from the former WTC site, and, in most cases, than is currently available from the analog facilities at ESB.

On March 22, 2007 the National Telecommunications and Information Administration (**NTIA**) approved the MTVA's application for a grant to support the design and deployment of a temporary digital television broadcast system for its member stations in the greater New York City region. The program was authorized as part of The Digital Television Transition and Public Safety Act of 2005 (Title III of the Deficit Reduction Act of 2005, Public Law 109-171).

The grant application contemplated a Distributed Transmission System (**DTS**) in New York City. Distributed transmission (**DTx**) for DTV signals has been standardized by the Advanced Television Systems Committee (**ATSC**), the same standards body that defined and adopted the broadcast technology now specified by the FCC for digital broadcast in the United States. If this approach proves feasible, a system could be developed where a network of synchronized low-power transmitters are installed to augment the coverage provided from the ESB by filling in areas cast in shadow or otherwise hampered in receiving the digital signals. The MTVA membership is particularly interested in developing a system that would allow viewers currently utilizing *indoor* antennas for analog television reception to continue utilizing indoor antennas for digital television reception.

Phase One saw the MTVA deploy a small-scale prototype Distributed Transmission System to determine the viability of using this technique in a densely-built, urban environment. The Alliance tested both indoor and outdoor reception of digital television signals using set-top receivers designed in conformance with the NTIA's Coupon Eligible Converter Box (**CECB**) program. This report documents the experimental work performed under the NTIA's agreement with the MTVA and shall serve as the Alliance's report to the NTIA on the technical results of Phase One testing.

To determine if the DTS concept was feasible in this market, the MTVA has undertaken a project to deploy a small-scale (5-transmitter) *prototype* implementation of a DTx system for DTV using UHF CH 33, UHF CH 65, and high-VHF CH 12. It is anticipated that this small-scale prototype system project would enable MTVA to determine the *capability* and *feasibility* for subsequent deployment of a large-scale system using distributed transmission in New York City by the February 2009 cessation of *full-service* analog television transmissions.

To assist in this undertaking, the MTVA retained the services of John F.X. Browne & Associates, P.C., to develop strategies to augment coverage as well as design the prototype DTx network. Axcera, LLC was selected to handle the detailed system design of the prototype network, and to implement and support the prototype network on a turnkey basis. The firm of Meintel, Sgrignoli, & Wallace, LLC (**MSW**) was retained to *characterize* the receive system aspect of the project, *develop* a field test plan, and *perform* the actual field measurements.

As part of the overall DTS project, MTVA first commissioned **MSW** to complete a series of smaller projects: (1) perform anechoic chamber testing to determine the RF performance of consumer *indoor antennas* likely to be used by typical DTV viewers, (2) perform laboratory testing to determine the RF performance of two state-of-the-art consumer *DTV receivers* likely to be used by typical DTV viewers, (3) develop appropriate urban *planning factors* for the prediction of both indoor and outdoor DTV *coverage* and *service* of the New York City DTx system, (4) create a detailed DTx *field test plan*, and (5) execute the DTV *field test* , along with subsequent data analysis and documentation.

After the MTVA reviewed and approved the *initial* prototype DTS field test plan document (dated **October 31, 2007**) and completed the construction of the prototype DTx system in early January 2008, official field testing began on **January 15,**

2008 and was completed on **May 9, 2008**. This written field test report describes the DTx network design and implementation, the final field test *plan*, and the detailed data analysis of the field test *results*.

The *general* goal of the DTS field test was to use this small prototype DTx system in Brooklyn to determine the *capability* and *feasibility* of a large-scale DTx system in New York City built around the current DTV transmission site at ESB. It was important to ascertain whether an increased percentage of viewers will be able to watch over-the-air DTV after February 17, 2009 when *full-service* analog NTSC television has been turned off. While *indoor* reception was ultimately the primary interest in these field tests, a majority of the New York City field testing was performed *outdoors* due to practical considerations (i.e., the difficulty in finding a large number of indoor test site volunteers). Nevertheless, some indoor test sites were visited and evaluated along with many outdoor test sites.

The *specific* field test goals were:

Determine and compare DTV coverage, service, margin, and ease of reception (antenna adjustment range) from ESB signals on CH 12 & CH 33 ***with*** and ***without*** an active DTx network.

Determine DTV coverage and service performance of a DTx system on CH 65 with no ESB source.

Determine any RF *self*-interference effects caused by the DTx system.

SYSTEM DESIGN

The main transmitters, commercial station WPIX CH 33 and a temporary CH 12 (operating with a Special Temporary Authorization, or STA), were located at the top of ESB. The 137 kW ERP (average) CH 33 DTV signal was radiated from its side-mounted, partially-obstructed *omni*-directional antenna, while a temporary 1 kW (average) CH 12 DTV signal was radiated from a temporary *directional* antenna aimed towards Brooklyn. The 4 low-power gap filler transmitter sites were in nearby Brooklyn, and were typically within 10 miles of ESB.

The gap filler transmitters, located in a square approximately **3 miles** on a side and referred to as the Brooklyn test "box," radiated low power DTV signals (1000 W, average ERP for CH 33 and CH 65 and 100 W, average ERP for CH 12). All five DTV transmitters were synchronized and time-delay adjusted using the principles found in the ATSC A/110B Distributed Transmission Standard (see **Appendix 1**). *Most* of the gap filler transmitter antennas were omni-directional.

The goal was to provide a consistently large DTV signal level to Brooklyn using all 5 distributed and synchronized transmitters, while keeping the self-interference to a minimum and within the interference mask recommended by the ATSC A/74 guidelines.

FIELD TEST PLAN

The field test plan called for selecting a vast majority of the outdoor and indoor test sites within the Brooklyn "box," as defined by the locations of the 4 low-power gap filler transmitters. It is within this area that the overlapping signal regions exist, and careful design of the DTx network was required to avoid destructive *self*-interference. While the main goal was to evaluate *indoor* DTV reception in Brooklyn with and without DTx, a majority of the field test sites were outdoors due to the difficulty of finding appropriate indoor test site volunteers within the Brooklyn test "box."

A total of **132** test sites were visited (**109** outdoor, **23** indoor). The following is the breakdown of the MTVA field test sites:

Outdoor Test Sites (109):

80 were "**Grid**" measurements sites, *inside* the box

10 were "**Driveway**" measurement sites, *inside* the box

6 were "**Interference**" measurement sites (predicted), *outside* the box

13 were "**Driveway**" measurement sites, *outside* the box

Indoor Test Sites (23):

10 were "**Indoor**" measurement sites, *inside* the box

13 were "**Indoor**" measurement sites, *outside* the box

The outdoor test sites were measured with two separate field test vehicles (vans), each capable of hydraulically extending a mast up to 30' above ground level (**AGL**). Each vehicle was equipped with the same test equipment: a mast compass, a GPS receiver, a broadband directional log periodic antenna (high-VHF through UHF), downlead cable, a calibrated variable turret step attenuator, a preamplifier, a 4-way splitter, a spectrum analyzer (with channel-power measurement capability), an RF Watermark Identification analyzer (**TxID**), two fifth generation (**5G**) DTV receivers, and audio/video monitors.

The *outdoor* field test plan called for 12 measurement scenarios at *each* test site: three different RF channels (CH 33, CH 12, and CH 65) at two different receive antenna heights (30' AGL and 15' AGL) with both DTx inactive and DTx active. The basic measurements performed for each test scenario were as follows:

DTV field strength measurement (in dBµV/m) at the antenna orientation that provided a maximum (peaked) signal level.

DTV service (3 "hits" or less in 3 minutes) at the antenna orientation that provided a maximum (peaked) signal level.

Range of antenna rotation (in degrees) for acceptable DTV reception.

The *indoor* field test plan also called for 12 measurement scenarios at *each* test site: three different RF channels (CH 33, CH 12, and CH 65) using two different receive antennas (primary dipole and secondary directional) with both DTx inactive and DTx active. The same field strength, service, and range of rotation measurements were made at each indoor test site, similar to each outdoor test site. Additionally, a smart antenna was also used with each DTV receiver to evaluate its indoor performance with DTx active and inactive.

TEST RESULTS

The CH 33 *outdoor* field strength measurements at the **90** test sites within the Brooklyn "box" indicated that there were fairly consistent DTV field strength levels when the directional receive antenna angle was selected for *maximum* signal level at 30' AGL and 15' AGL. Throughout the Brooklyn "box," CH 33 DTV signals were found to be, on the average, in the range of **73 dBµV/m** (DTx OFF) to **80 dBµV/m** (DTx ON) for a 30' AGL receive antenna and they were about **3 dB** lower (DTx OFF and DTx ON) at 15'AGL. These CH 33 signal levels were not only large enough to produce SNR values (**>40 dB** for DTx OFF and **>47 dB** for DTx ON) at the receiver inputs that were above the required 15-dB white-noise threshold, but they also easily covered an additional 5 dB to 8 dB of possible noise threshold degradation due to the presence of naturally-occurring or DTx-induced multipath. The CH 33 outdoor DTV service numbers increased a modest amount from about **81%** (without DTx) to more than **85%** (with DTx). Also, significant margin and range of antenna rotation were observed at many test sites, providing *evidence* for successful long-term *outdoor* DTV service (i.e., accounting for signal level time variability) on CH 33.

Similarly, the CH 12 *outdoor* antenna-maximized field strength values were found to range between **59 dBµV/m** (DTx OFF) to **70 dBµV/m** (DTx ON) at 30' AGL, and they were about **2.5 dB** lower (DTx OFF and DTx ON) at 15' AGL, both producing a very high average SNR value. The CH 12 outdoor DTV service numbers increased a modest amount from about **75%** (DTx OFF) to **80%** (DTx ON), and significant margin and range of antenna rotation were likewise observed. This provided *evidence* for successful long-term *outdoor* DTV service on CH 12.

Finally, the CH 65 *outdoor* results with DTx active (since there was no CH 65 ESB transmitter, this was the only mode possible to test) showed that the average field strength was a strong **76 dBµV/m** at 30' AGL and **2 dB** less at 15' AGL, and produced SNR values in excess of **40 dB**. The CH 65 DTV service was a significant **94%** (Rx) and **85%** (Rx2), with respectable margins around **20 dB**. This provided *evidence* for successful long-term *outdoor* DTV service on CH 65.

Even though there were not enough *indoor* test sites within the DTx "box" for statistical relevancy, the **23** indoor test sites did provide field strength results on CH 33 that showed similar trends as the outdoor results. For the existing WPIX CH 33 commercial station operating at full allocated DTV power, with its partially-obstructed "omni-directional" antenna on ESB, the average indoor field strength value with DTx *inactive* for all **23** indoor test sites (including those *outside* the "box") was **69 dBµV/m**. This is a very respectable number for the average *indoor* field strength value in the New York City metropolitan area, providing an average SNR value of **38 dB** for CH 33. These **23** sites with DTx *inactive* exhibited good service (**70%** for Rx1 and **65%** for Rx2), with good margin and range of antenna rotation. Note that CH 12 and CH 65 were *not* analyzed with DTx inactive for indoor field strength using all **23** indoor test sites since (1) the CH 12 ESB transmit antenna was not omni-directional but rather directional, specifically pointing towards the Brooklyn "box," and (2) there was no CH 65 transmitter on ESB.

Analysis of all **23** indoor sites and their companion outdoor driveway sites showed that the signal attenuation experienced from outdoor to indoor averaged around **6 dB** for CH 33, which is much lower than the traditionally-presumed 10-dB to 20-dB values for two-story single-dwelling residences. However, this is partially explained by the fact that many of the **23** indoor test sites were *above* 15' AGL, and some were even above 30' AGL (i.e., test sites located on upper stories of buildings that were higher than the outdoor antenna heights used in the field test). Therefore, these attenuation results must be viewed under these special circumstances.

While all **23** indoor (and driveway) test sites were used in the CH 33 DTx-*inactive* analysis, DTx system evaluation was performed on *only* the **10** indoor test sites within the Brooklyn "box." The reason for this is that the other test sites (i.e., "outside-the-box") did *not* gain much benefit (and perhaps even experienced detrimental *self*-interference effects) from the DTx gap-filler transmitters. Any analysis that would have included the **13** "outside-the-box" test sites would have unfairly biased the results negatively for DTx evaluation since the DTx prototype test system was specifically designed to study its performance inside the Brooklyn "box."

For DTx *inactive*, the indoor field strengths at these **10** Brooklyn "box" test sites were approximately **66 dBµV/m** (CH 33) and **51 dBµV/m** (CH 12). These are very respectable field strength numbers for indoor DTV sites *without* benefit of DTx gap filler transmitters. Indoor DTV reception measurements resulted in about **65%** (CH 33) and **15%** (CH 12) service and *average* margins of **12 dB** (CH 33) and **3 dB** (CH 12).

For DTx active, the indoor field strengths at these **10** Brooklyn "box" test sites increased by about **7 dB** (CH 33) and **9 dB** (CH 12), meaning that these **10** sites exhibited average field strengths of about **73 dBµV/m** (CH 33) and **60 dBµV/m** (CH 12). Indoor DTV service increased to **85%** (CH 33) and **30%** (CH 12) of the test sites and the *average* margins were found to increase to approximately **17 dB** (CH 33) and **9 dB** (CH 12). As a comparison, the average CH 65 field strength with DTx active was about **65 dBµV/m**, with **90%** DTV service and an *average* margin of **16 dB**. The difference in performance between CH 33 and CH 12 is not entirely understood at this time.

An interesting side note is that the secondary *directional* indoor test antennas, which also performed well, did not do quite as well as the primary *dipole* indoor test antennas (with their figure-8 azimuth pattern). This indicates that *perhaps* the recent receiver equalizer innovations and updated algorithms now use the echoes of the signal (which typically occur more often with dipole antennas that have no front-to-back attenuation) for mitigating the multipath effect.

The two 5G DTV receivers (Rx1 and Rx2) both did well in these field tests, and are significantly better than past generations. However, it was clear that Rx1 consistently did better than Rx2 in providing service, margin, and range of rotation. While both units were 5G, Rx1's multipath equalizer apparently is a little more robust, being able to handle slightly stronger and more dynamic multipath conditions than Rx2.

CONCLUSIONS

This MTVA project, starting with the design, followed by implementation, and ending with a major field test, was a lesson in DTx system and hardware design as well as viability (i.e., feasibility). Positive small-scale prototype test results do *not* guarantee success in a massive deployment of such a system, as that depends on the specific network design that often includes a large number of factors beyond those that were tested in New York City. Further work on location and time variability would be beneficial when trying to extend these prototype results to larger metropolitan areas. However, these field test results indicate that DTx network *technology* is available today and it is viable when properly designed and implemented. Likewise, much has been learned from this field test that will guide future DTx network designs for highly urbanized metropolitan areas like New York City.

To briefly summarize the MTVA project:

1) The ATSC A/110B standard describes basic DTx synchronization theory, and has been shown to work in a major urban area, allowing multiple synchronized low-power gap fillers to improve DTV coverage (field strength) and service (reception).

2) Remote gap-filler transmitter site selection and site leasing in a major urban area are possible, although expensive.

3) System hardware design using the A/110B principles can be accomplished with current production equipment, although with additional hardware costs compared to single transmitter designs.

4) The main area of field testing (i.e., Brooklyn test "box") already had significant CH 33 *outdoor* DTV service and reasonable CH 33 *indoor* DTV service from ESB *without* DTx, thereby limiting the amount of possible service improvement due to DTx. However, when DTx was active, more substantial increases in margin (to overcome time variability) and range of antenna rotation (to allow easier antenna adjustment) were experienced. CH 12 had similar *outdoor* results, although not quite as good as CH 33. CH 12 *indoor* results were noticeably worse than that if UHF. This difference in performance between CH 12 and CH 33 is not entirely understood at this time.

5) Acceptable outdoor-to-indoor attenuation was obtained in the field test. However, it must be remembered that the outdoor-to-indoor attenuation was smaller (**6 dB**) than expected (**10 – 20 dB**) due to the test locations on upper floors (3rd floor and above) for many of the indoor test sites.

6) DTx did cause *some* self-induced interference in the overlapping regions, sometimes creating reduced service, margin, and range of antenna rotation, and in some cases a complete loss of service. However, the number of these loss-of-service occurrences was relatively small, and in the cases where it did not completely eliminate DTV service, it often still allowed acceptable receive parameters (margin > 10 dB and range of rotation > 90 degrees) for successful DTV reception. It is clear, however, that a carefully-designed DTx network can facilitate both outdoor and indoor DTV reception, and that its negative self-interference effects can be minimized with good DTx system design as well as good receive system design.

7) Automatically-adjusted *smart* antennas worked reasonably well with and without DTx, providing service comparable to the manually-adjusted antennas, although there is room for improvement regarding updating the parameters more often and in a quicker manner.

8) RF watermark technology for transmitter identification and for determining signal propagation distortion as well as relative levels and delays of distributed transmitter signals was proven useful and important in field testing the DTx system and in aiding with DTx network timing setup and verification.

9) The recent 5G (and the newer 6G) receivers are much improved over earlier generations, with the most improvement occurring in the VSB decoders and the RF tuners. However, while there are many models of 5G and 6G receivers, and they are all much improved, they will *not* all work identically in severe propagation situations.

SUMMARY

Distributed transmission for DTV signals has been proposed and standardized by the ATSC. The MTVA New York City field test has allowed the evaluation of the effectiveness of such a DTx system in a major urban area in both the UHF and high-VHF bands, and it has resulted in some much-needed information and experience. Knowledge and understanding of DTx fundamentals, as they apply to the ATSC transmission system, are essential for future DTx success. The MTVA small-scale prototype system in New York City optimized as many of the design parameters as possible, with the goal to ascertain the DTx system's effectiveness in providing this metropolitan area with acceptable outdoor and indoor DTV field strength levels, service, and margin, as well as ease of antenna adjustment. However, great care was taken to minimize any significant interference into existing analog or digital television signals. DTx networks in mountainous areas, while also important, do not have quite the same significant challenges that a major metropolitan area like New York City has, since urban areas potentially experience severe DTx-induced multipath (caused by multiple same-frequency synchronized transmitters) as well as considerable naturally-occurring multipath (caused by large buildings and other man-made structures).

While the main goal of the MTVA project was to study the performance of a scaled-down version of a widespread DTx design, an added benefit was the determination that the current commercial UHF CH 33 (WPIX) single source on ESB already provided reasonably good DTV *service* in the Brooklyn test "box." In other words, the actual measured *outdoor* and *indoor* DTV service numbers in the field test "box" from ESB alone (i.e., DTx *inactive*) were found to be good. Of course, this means that there could not be a significant increase in the number of sites serviced with DTx active. However, despite the modest service increases due to DTx, the increase in the margin and range of antenna rotation at many sites was *encouraging*. It should be noted that DTx did, in fact, cause loss of DTV service at a small percentage of sites. Nevertheless, there were many other sites where the DTx-induced degradation of margin or range of rotation still provided acceptable DTV reception conditions.

It must be remembered, however, that these DTx tests in New York City were *location* variability tests and not *time* variability tests. That is, the dynamic conditions that were encountered at many of the tests sites could become worse at certain times of the day (diurnal, such as with temperature changes that cause atmospheric inversion layers or with increased traffic flow at rush hour) and times of the year (seasonal, such as with and without foliage). Therefore, care must be taken when attempting to predict future widespread DTV service using short-term testing data on a small-scale prototype system. Long-term time-variability testing would certainly produce some of these answers.

A major outcome of the field test was the *experience* gained from designing, implementing, and testing a DTx system in a major metropolitan area. However, it is also important before deployment of any large communication network to determine the primary causes of DTV reception failure in order to better understand how to optimally design and construct a larger and improved *final* DTx network in New York City in time for the February 17, 2009 end of the *full-service* DTV transition. The resulting data from this field test will help future designers to achieve optimum DTx system designs.

Finally, consumer education regarding the retirement of the NTSC analog service is essential for the successful transition to over-the-air digital broadcast television. However, not only is it important to inform the public about the timing of the analog shutoff on February 17, 2009 and how to obtain NTIA converter coupons, but it is also vital to educate them about the "lost art" of over-the-air television reception. In addition to various DTV receivers, this includes the various types of receive support (accessory) equipment at their disposal, such as antennas, preamplifiers, coaxial cable, signal splitters, band splitters, attenuator pads, etc. It is likely that, even with DTx deployed in some form, successful DTV reception in New York City may depend on viewers having *reasonable* receive equipment properly installed in their homes. In order for broadcasters to successfully educate the public on DTV receive equipment and its proper use, they must first educate themselves regarding DTV reception in general (with or without DTx), and then familiarize themselves with high-quality consumer devices that are currently available.

TABLE OF CONTENTS

MTVA DISTRIBUTED TRANSMISSION FIELD TEST REPORT

INTRODUCTION

After the loss of the World Trade Center (**WTC**) on September 11, 2001, many of the New York City broadcasters had to scramble quickly to obtain a *temporary* transmission site in order to provide free, over-the-air (**OTA**) television signals to the region. Subsequently, many of these broadcasters ended up with facilities on the Empire State Building (**ESB**). However, with a crowded antenna structure, many of the digital television (**DTV**) television antennas were side-mounted and located at much lower heights above average terrain (**HAAT**) than their previous locations on the north tower of the WTC. In order to coordinate the recovery effort and develop broadcast facilities to replace those that were lost at the WTC, the commercial New York City television broadcasters, along with public station WNET, created the Metropolitan Television Alliance (**MTVA**).

At Empire, with a crowded antenna mast structure (originally designed as a mooring for dirigibles), many of the digital television antennas were side-mounted and located at lower elevations than their previous locations on the north tower of the WTC. Physical limitations on the mast, in terms of both real estate and loading capacity, required partially-obstructed antennas at ESB. The result is that some areas in the New York City metropolitan area have DTV television coverage (signal levels) and service (reception) inferior to that which was available from the former WTC site, and, in most cases, than is currently available from the analog facilities at ESB.

On March 22, 2007 the National Telecommunications and Information Administration (NTIA) approved the MTVA's application for a grant to support the design and deployment of a temporary digital television broadcast system for its member stations in the greater New York City region. The program was authorized as part of The Digital Television Transition and Public Safety Act of 2005 (Title III of the Deficit Reduction Act of 2005, Public Law 109-171).

One such alternative could be to utilize a Distributed Transmission System (**DTS**) in New York City. Distributed transmission (**DTx**) for DTV signals has been proposed and standardized by the Advanced Television Systems Committee (**ATSC**). If this approach were technically feasible, a system could be developed where a network of synchronized low-power “gap filler” transmitters could be installed to augment the coverage provided from the ESB. The MTVA membership is particularly interested in developing a system that would allow viewers currently utilizing *indoor* antennas for analog television reception to continue utilizing indoor antennas for digital television reception.

Since the DTS concept has never been deployed or even field tested in a dense urban environment such as the New York metropolitan area, the MTVA concluded that it was necessary that the technology be thoroughly field tested prior to making any decision regarding its applicability for the New York City market.

To determine if the DTS concept was feasible in this market, the MTVA has undertaken a project to deploy a small-scale (5 site) *prototype* implementation of a Distributed Transmission (**DTx**) system for DTV using both UHF (CH 33 and CH 65) and high-VHF (CH 12) bands in the New York City metropolitan area. Low-VHF is *not* of any interest to the MTVA since no *full-service* post-transition DTV channels have been allocated in this television band within the New York City market. It is anticipated that this small-scale prototype system project would enable MTVA to determine the *practicality* and *feasibility* for subsequent deployment of a large-scale system using distributed transmission in New York City by the February 2009 cessation of *full-service* analog television transmissions.

To assist in this undertaking, the MTVA retained the services of John F.X. Browne & Associates, P.C., to develop strategies to augment coverage as well as design the prototype DTx network. Axcera, LLC was selected to handle the detailed system design of the prototype network, and to implement and support the prototype network on a turnkey basis. The firm of Meintel, Sgrignoli, & Wallace (**MSW**) was retained to *characterize* the receive system aspect of the project (indoor antenna testing, receiver laboratory testing, and urban planning factors), *develop* a field test plan, and *perform* the actual field measurement (as described below).

As part of the overall DTS project, MTVA first commissioned **MSW** to do a detailed study and assessment of the availability and RF performance of current consumer *indoor antennas* and current consumer *DTV receivers* likely to be utilized by typical viewers for DTV reception in this area. **While *both* outdoor and indoor reception of DTV signals is vital to broadcasters, and is covered in this report, this project was specifically focused on *indoor* reception in the UHF and high-VHF television bands from multiple, synchronized DTS sources in the dense, urban New York City environment.** Subsequent to completion of both the consumer *indoor antennas* anechoic chamber testing and the *DTV receiver* laboratory testing, MTVA commissioned **MSW** to develop appropriate urban *planning factors* that may be used in predicting both indoor and outdoor DTV *coverage* and *service* of the New York City DTx system. After completion of the planning factors, MTVA then commissioned **MSW** to create a DTx *field test plan* that described test methodology for sophisticated and thorough field testing of the prototype DTx system within New York City. Using this test plan (dated **October 31, 2007**), per MTVA directive, **MSW** began the *DTV field test* on **January 15, 2008** and completed the field test on **May 9, 2008** Shortly after this, **MSW** completed the data analysis and documentation, which is the topic of this final report.

The *general* goal of the DTS field test was to use a small prototype DTx system in Brooklyn to determine the *capability* and *feasibility* of a large-scale DTx system in New York City built around the current DTV transmission at ESB. It was important to ascertain whether an increased percentage of viewers will be able to watch over-the-air DTV after February 17, 2009 when *full-service* analog NTSC television has been turned off. While *indoor* reception was ultimately the primary interest in these field tests, a majority of the New York City field testing was performed *outdoors* due to practical considerations (i.e., the difficulty in finding a large number of indoor test site volunteers living in specific neighborhoods within Brooklyn who were willing to make their homes available all day for “invading” engineers with test equipment). Nevertheless, some indoor test sites were visited and evaluated along with many outdoor test sites.

A list of the *specific* field test goals is shown below.

Determine DTV coverage, service areas, margins, and ease of reception (antenna adjustment) from ESB on CH 12 & CH 33 ***without*** an active DTx.

Determine DTV coverage, service areas, margins, and ease of reception (antenna adjustment) from ESB on CH 12 & CH 33 ***with*** an active DTx (with 4 low-power gap filler transmitters).

Compare DTV coverage and service areas from ESB on CH 12 & CH 33 to determine percentage increase or decrease from DTx implementation.

Determine DTV coverage and service performance of a DTx system on CH 65 with no ESB source.

Determine any RF *self*-interference effects caused by the DTx system.

The following material is meant to be a *detailed* description of the MTVA’s New York City prototype DTx system, the test plan and measurement equipment, and the test data results. It also includes some *general* information on the ATSC DTV system as well as distributed transmission. The DTS field test lasted *about* 4 months (mid January through early May). From this field test analysis and data results, **MTVA** can evaluate functionality and feasibility of a future *large*- scale DTx network in the New York City greater metropolitan area.

DTx PROTOTYPE SYSTEM DESIGN

OVERVIEW

The *general* DTS theory of operation described in **Appendix 1** is used as background information for the description of the *specific* MTVA prototype DTS design. This project was overseen on a daily basis by MTVA project leadership. Two *types* of field tests were performed in the New York City metropolitan area. **First**, two separate DTx tests (CH 33 and CH 12) were performed with a main transmitter operating on **ESB** and four (4) gap filler transmitters operating in the Brooklyn area on various buildings (although, the temporary CH 12 ESB transmitter radiated much lower power than the commercial CH 33 transmitter). **Second**, there was a distributed transmission test (CH 65) with no main centrally-located transmitter on ESB but instead with only four (4) Distributed Transmitters (**DTxT**s) operating from the *same* Brooklyn-area buildings as the others. (Despite the fact that the transmitters on CH 65 are *not* filling gaps in coverage from ESB, for consistency in the discussion, the four Brooklyn sites will be termed gap fillers regardless of which of the three test systems is under consideration.). The four lower power gap filler site locations were selected as part of the DTx network that was *designed* by **John F.X. Browne and Associates** and implemented by **Axcera, LLC**.

The system design included:

Selection of main DTx transmitter signal location and parameters (existing WPIX CH 33 and prototype CH 12)

Selection of four (4) remote gap filler DTx site locations in the Brooklyn area (forming corners of a “square box”)

Selection of low-power remote DTx gap filler transmitter site parameters:

Channel selection: CH 33, CH 12, and CH 65
Effective Radiated Power (**ERP**)
Antenna azimuth pattern
Antenna elevation pattern
Antenna height (**AGL**)

Gap filler transmitter relative timing adjustment

Based on the MTVA design described above, the system block diagram of the prototype DTx system that was implemented in New York City during the summer and fall of 2007 is shown in **Figure 1.**

MSW then developed a DTV *field test plan* based on this small-scale DTx prototype system design that was designed and implemented by MTVA.

The details found below regarding the system design (John Browne & Associates,) the subsystem design and hardware implementation (Axcera, Inc.), and the field test plan and field test equipment (MSW) have been reviewed and accepted by MTVA and these consultants. Further details are available upon request from the MTVA.

DTx MAIN SIGNAL SOURCE

The DTV source for all transmitters originated from the Tribune WPIX studios in New York City (**220 East 42nd Street 10017**), which is about **0.5** mile ("as the crow flies") from ESB. It consisted of an encoder with service multiplexer (**Tandberg 5780** encoder and **Harris DTP** Statistical Multiplexer), which is used for normal WPIX commercial DTV service. A pair of **Axcera** DTxA2B Distributed Transmission Adapter (**DTxA**) units, which acted as the DTS control center and its backup, received the MPEG-2 transport streams from the WPIX service multiplexer. One of these two DTxA units was the *active* main unit while the other was the *passive* reserve unit. A GPS receiver (**Trak 8821A-28**) provided 10 MHz and 1-pulse/second references to the DTxA for precision synchronization.

The 19.4 Mbps MPEG-2 transport data stream at the WPIX studios, which included the inserted DTxP synchronization and control packets (see **Appendix 1** for background material), was fed from the DTxA into a (**CWDM**) fiber transmitter (1470-1610 nm) for transmission to the main transmitters (CH 33 and CH 12) at ESB as well as three of the four remote gap filler sites in Brooklyn. The remaining gap filler site (Site #3), also in Brooklyn, was fed over a microwave link using 13 GHz equipment (Microwave Radio Corporation DRP127T10AH transmitter and DRP127R10A receiver).

The DTxA synchronization control parameters developed in the DTxA unit at WPIX studios as well as the gap filler transmitter RF parameters (ON or OFF, output power level, selected timing delays, output SNR, etc.) were all remotely controlled and monitored with a PC located at WPIX studios. This was accomplished using hardware and password-protected Axess software from Statmon Technologies Corporation. In all, six different sites could be controlled and monitored in this manner (DTxA at WPIX studios, the ESB transmitter in Manhattan, and the 4 gap-filler site transmitters in Brooklyn). Furthermore, this control hardware and software could be *remotely* accessed (e.g., from one of the field test vehicles) by wirelessly accessing the local PC at WPIX studios through the Internet. The Axess software allowed control and monitoring of various parameters as shown in **Table 1**.

Table 1 IP-Based Control and Monitor Parameters

Parameter	Monitor/Control	Comments
Tx ON/OFF	Control	ESB Tx and 4 gap filler transmitters
Tx TPO	Control	Within limits of full power to half power
SFN Timing	Control	ESB Tx and 4 gap filler transmitters
Tx On-Air Status	Monitor	ESB Tx and 4 gap filler transmitters
Tx TPO	Monitor	ESB Tx and 4 gap filler transmitters
Tx SNR	Monitor	ESB Tx and 4 gap filler transmitters

DTx MAIN TRANSMITTER AND REMOTE GAP FILLERS

The main transmitter site and the four gap filler sites are illustrated in **Figure 2**, as shown on a New York City map. Note that the locations of these remote low-power transmitter sites are all in the Brooklyn area, south and southeast of ESB, and essentially form a 3-mile "square", referred to as the Brooklyn "box." The *primary* area for field testing was inside this "box", although some test sites outside the "box" were visited as well.

At ESB, the main WPIX CH 33 DTV transmitter (**Harris Diamond**) fed a side-mounted broadband UHF panel antenna array (shared by a total of 6 UHF DTV stations) that was located only about a third of the way up the ESB tower, but above the "mooring mast" that includes the 102nd floor observatory. CH 33 was radiating a **137 kWatt** *average* effective radiated power (**ERP**) DTV signal. However, New York City broadcasters felt that field strength coverage *might* be compromised from ESB due to non-optimum mounting conditions with so many antennas situated on its roof-top structure, and due to this particular antenna being partially obstructed by the body of the supporting tower. Therefore, a helicopter antenna pattern test was commissioned and then performed, which showed a distorted pattern from this side-mounted panel antenna. The *assumption* was that this antenna had back scattering from the tower structure itself that caused the effective antenna pattern *not* to be omni-directional but rather highly scalloped, which then caused non-uniform field strength levels in the nearby urban areas. This was shown to be a problem for all stations using this broadband panel antenna. It was this situation that led to the consideration of a DTx network in the New York City area to overcome this problem.

For the MTVA field test program, the Diamond transmitter was temporarily equipped with the Axcera Axciter (in lieu of the Harris exciter) to process the DTxPs (synchronization and transmitter identification control packets) and provide the DTx synchronization functionality. The configuration was such that the DTx-equipped Axcera unit was used during the testing from 8:00 am in the morning to 6:00 pm at night, and the standard Harris exciter switched back in during the rest of the time, particularly during prime-time programming. In addition to CH 33, a *low*-power CH 12 transmitter and directional antenna (aimed southeast towards Brooklyn) were temporarily installed on ESB for this DTx field test, radiating (based on an STA from the FCC) a much lower power 1000 Watt average ERP high-VHF DTV signal. However, as expected, the received CH 12 ESB signal levels measured at the Brooklyn test sites were still fairly high level due to the height of ESB and the close proximity of Brooklyn to ESB. There was *no* CH 65 transmitter at ESB in accordance with the MTVA DTx network design.

Each remote gap filler site installation had *two* low-power UHF transmitters and *one* low-power high-VHF transmitter located within two self-contained 6' tall NEMA-rated 19" rack enclosures (including associated auxiliary equipment such as a UPS system, a 2.5-ton HVAC unit for heating and cooling requirements, and a smoke detector alarm system). These cabinets (***each*** with dimensions 86" x 35" x 30" and a weight of 1250 lbs) required 240 VAC single phase, 100 Amperes per cabinet (with earth ground), and were located either outdoors on the building roof or indoors in a room near the roof top of the building. The two UHF transmitters were each rated at 250 Watts of average transmitter power output (**TPO**) while the high-VHF transmitter was rated at 10 Watts of TPO. The two independent UHF transmitters were designed for CH 33 (584 – 590 MHz) and for CH 65 (776 - 782 MHz) while the high-VHF transmitter was designed for CH 12 (204 – 210 MHz). Each DTV transmitter was outfitted with an Axcera Axciter synchronized modulator that, along with the upconverter, was configured for DTS slave mode operation. The high power amplifier (**HPA**) contained an integrated emission mask filter.

All the low-power gap filler transmitters were controlled remotely, allowing adjustment of output power level, as well as ON/OFF control. As described above, this remote control capability was accomplished by use of a password-protected IP-based web interface that allowed a user to remotely access the controller via a URL on the Internet. Each gap filler site had a unique IP address that allowed authorized connection of all 4 remote transmitter sites. Therefore, RF parameters such as TPO/ERP and ON/OFF operation could be controlled remotely, and the status of each low-power transmitter could be monitored as well. See **Table 1** for a summary of available monitor and control parameters.

Each gap filler transmitter site also had a GPS receiver (**Trak 8821A-28**) that provided a stable and locked 10 MHz reference frequency signal and a 1 pulse/second timing signal for each synchronized VSB transmitter. The 10 MHz reference signal removed any frequency offsets between the various DTx transmitters, and the 1 pps reference signal allowed precise signal timing among all these slave DTx transmitters.

Table 2 contains the pertinent transmitter information for the DTx network.

Note that according to the FCC's special temporary authorization (**STA**), the gap filler antennas could be essentially omni-directional units and the gap filler transmitters could have *maximum* ERP values of 1 kW. However, as can be seen from **Table 2**, all of the CH 12 high-VHF antennas as well as the Site 3 UHF CH 33 and CH 65 UHF antennas had cardioid azimuth patterns. The installed UHF transmitters had only 250 W maximum TPO, with the antenna providing the necessary gain to reach the maximum ERP value. The actual TPO of each transmitter was capable of being adjusted downward during testing if the need had arisen, although this was *not* necessary during the testing.

Table 2 DTx Transmitter Information

Transmitter Status	Location Address	Location Latitude Longitude	Distance from Main ESB Tx (miles)	HAMSL (meters)	Pointing Angle (deg)	Antenna Model # Beam Tilt	CH #	Tx ERP (W)
Main (ESB)	350 Fifth Ave. New York, NY 10118	40-44-54 73-59-10	0.00	335.0	145	Scala Directional HDCA-5/URM 0 degrees	12	1,000
Main (ESB)	350 Fifth Ave. New York, NY 10118	40-44-54 73-59-10	0.00	410.0	Omni	***"Omni"*** Panel Harris Delta Star 0.75 degrees	33	137,000
Gap Filler 1	16 Court St. Brooklyn, NY	40-41-36.7 73-59-29.0	3.83	152.8	131	Scala Cardioid DRV-1/2HW (CH 12) Jampro Omni JL-SS-8-OM (CH 33) Scala Omni SL-8 Paraslot (CH 65) 0° (CH 12) /3.0° (CH 33/65)	12 33 65	100 1,000 1,000
Gap Filler 2	95 Evergreen Brooklyn, NY	40-41-59.3 73-55-57.7	4.37	43.3	221	Scala Cardioid DRV-1/2HW (CH 12) Scala Omni SL-8 Paraslot (CH 33/65) 0° (CH 12) /2.0° (CH 33/65)	12 33 65	100 1,000 1,000
Gap Filler 3	730 Linden Brooklyn, NY	40-39-12.7 73-55-54.1	7.15	33.1	311	Scala Cardioid DRV-1/2HW (CH 12) Scala Cardioid 4DR-8-3HC (CH 33/65) 0° (CH 12) / 0° (CH 33/65)	12 33 65	100 1,000 1,000
Gap Filler 4	Bishop Ford High School	40-39-20.7 73-58-56.16	6.39	69.1	40	Scala Cardioid DRV-1/2HW (CH 12) Scala Omni SL-8 Paraslot (CH 33/65) 0° (CH 12) /3.0° (CH 33/65)	12 33 65	100 1,000 1,000

Compliant with the ATSC DTx A/110B standard (**Ref A1-4**), each of the 5 distributed transmitters had a *unique* RF watermark transmitter identification (**TxID**) added to its output signal in the form of a binary spread-spectrum Kasami code sequence, as shown in **Appendix 2** and described in **Appendix 1**. This special sequence is transmitted 30 dB below the total *average* DTV signal power (in 6 MHz) and, therefore, it had negligible effect on consumer DTV receivers. This "bury ratio" is selectable in the exciter hardware, but 30 dB was deemed to be a reasonable value for the MTVA field test. This additional 2-VSB in-band RF watermark signal, which was clocked (in phase) at the 8-VSB symbol rate and synchronized with the 8-VSB field sync for robust and quick lockup, minimally affected (< 0.2 dB) the white noise thresholds of DTV receivers. These maximal-length *binary* sequences are repeated *approximately* 4 times for every one 8-VSB data field, but are *not* transmitted during the data field syncs. They are also referred to as buried spread spectrum (**BSS**) sequences since they are transmitted at power levels well below the host signal's average power level. These Kasami code sequences were selected since they exhibit excellent orthogonality (i.e., uniqueness) between all the various possible transmitter codes, and they have a code gain of more than 50 dB, which means that an RF watermark buried "only" 30 dB below the DTV signal can be "raised up" (using powerful correlation methods and averaging techniques) to about 20 dB above the DTV signal level, and therefore can accurately extracted for use as a relative *timing* and *power* indicator as well as a *channel impulse response* indicator. This means that, after signal processing an RF watermark signal that is buried 30 dB below the DTV signal, there remains a theoretical 20 dB measurement range for determining the levels of other synchronized transmitters, although a more practical limit would be around 12- 15 dB depending on the desired measurement accuracy that is required.

Relative DTx transmitter timing measurements in this field test were accomplished by using a *prototype* Hutech TxID RF Watermark receiver (one in *each* of the two field test trucks) that decoded the low-level RF watermark signals inserted "underneath" *each* synchronized 6 MHz DTV signal. These prototype receivers allowed reasonably precise relative signal *amplitude* and *timing* measurements among the transmitted ESB and gap filler signals for field test documentation. The relative timing measurement provided a means for initial timing adjustment of the DTx system as well as remote field test site documentation of the actual relative signal arrival times. An advantage of using the RF watermark receivers is that the timing relationship between the various DTx signals at a receive site could be measured while leaving the main signals from ESB active (i.e., without turning off either CH 33 or CH 12). Since the main WPIX CH 33 ESB signal could not be interrupted since it was an operating commercial DTV station, measurement of the relative signal levels and timing at every test site from each of the DTx network transmitters was reasonably determined from these RF watermark codes. Likewise, the TxID receiver was also able to determine the propagation effects of each transmitted signal (i.e., the propagation impulse response).

DTS SYNCHRONIZATION

In addition to the specifications for the DTxA that are both *explicit* and *implicit* in the ATSC A/110B standard, there are certain constraints as well as some flexibility that derive from the specific hardware implementation of the DTxA supplied by Axcera for this MTVA field test. The differences in requirements and operation from the A/110B standard are included in the discussion that follows. This discussion *assumes* the use of the GPS mode of operation by both the DTxA (at ESB) and all the remote DTx exciters (at the remote gap filler transmitter sites), as described in ATSC A/110B standard.

In the MTVA prototype DTx system, synchronization is required for 5 transmitters on CH 33 (one main and 4 gap fillers), five transmitters on CH 12 (one main and 4 gap fillers), and 4 transmitters on CH 65 (only four gap fillers since there was no existing transmitter on ESB for this particular field test). In order to maintain proper synchronization of symbol clock, trellis-coding, and signal delay among the main transmitter and all the gap fillers, an MPEG-transport link <u>must</u> exist among them as defined in the ATSC A/110B DTx standard (**Ref A1-4**). While there are various means to create such a link (fiber, microwave, satellite, etc.), the one originally selected for the MTVA DTx prototype system test was fiber service. This fiber link carried the DTV transport packets from the WPIX studios, where the DTxA controller and the baseband encoders (video and audio) with integrated service multiplexer resided, to the transmitters at ESB and the four gap filler sites. The following link requirements were necessary:

1) The frequency and drift specs of this link must meet the SMPTE 310M standard of ±2.8 ppm frequency tolerance and ±0.028 ppm frequency drift tolerance.
2) The total *delay* between the data leaving the DTxA and reaching the exciter's SMPTE 310M input must be less than 950 msecs (i.e., essentially less than one second).
3) Total end-to-end peak-to-peak delay variation (timing error) must not exceed 3.3 msecs, with a maximum rate of *change* dictated by the SMPTE 310M specification.
4) Unbuffered packet switched data networks, where the data stream is interrupted, will *not* meet the SMPTE 310M stream specs and are therefore to be avoided.

However, some potentially serious fiber installation schedule delays at Gap Filler Site 3 during the fall of 2008 forced the use of a 13 GHz (12900 – 12925 MHz) microwave MPEG transport link between ESB and that particular site.

In general, there are two requirements for synchronization precursor packets in the DTxA input stream from the service multiplexer, as described in detail in **Appendix 1**. One is for the insertion of a 188-byte "blank" or "precursor" Distributed Transmission Packet (**DTxP**) packet and the other is the insertion of an *occasional* null packet (for purposes of slight data clock frequency adjustment). The DTxP precursors are typically sent in the MPEG transport data stream from the DTV service multiplexer to the DTxA at least *once per second* in this particular DTx network design. They are ultimately replaced in the DTxA with the necessary information required to synchronize all the transmitters. This one-second repetition rate is reasonable as it occurs often enough to quickly resynchronize the system should a "glitch" knock the system out of sync yet not so often that it significantly reduces the net data throughput. According to the ATSC A/110B standard, each DTxP packet can update up to 16 slave transmitters.

The DTxP precursor, which is like any other MPEG transport packet in that it is 188 bytes long and starts with the usual 47hex sync byte, is followed by an ATSC-assigned PID of 0x1FFA. Therefore, the first 4 bytes of the precursor DTxP comprise a normal MPEG transport stream packet header with defined parameter values. Since the DTxP is a *version* of an ATSC-defined Operations &Maintenance packet (**OMP**), the header's fifth byte is 00h that indicates the <u>type</u> of OMP application. The rest of the packet data bytes from the service multiplexer are irrelevant, and are typically just set to 0x00 since the downstream DTxA hardware removes the zero bytes and inserts into the DTxP the proper synchronization and miscellaneous control data into the DTxP that is needed by the slave transmitters.

Table 3 contains the required byte definitions of the *precursor* DTxP transmitted from the service multiplexer to the Axcera DTxA during the MTVA DTx field test.

Table 3 Service Multiplexer DTxP Precursor Description: Byte Definitions

Packet Type	Byte #	Packet Data	Related Comments
Header	1	0x47	MPEG-2 Transport Stream Sync
Header	2	0x1F	Transport_Error_Indicator (1 bit) = 0b (no error) Payload_Unit_Start_Indicator (1 bit) = 0b ( ) Transport_Priority (1 bit) = 0b ( ) DTxP PID (upper 5 bits) = 11111b
Header	3	0xFA	DTxP PID (lower 8 bits) = 11111010bA
Header	4	0x10	Transport_Scrambling (2 bits) = 00b Adaption_Field_Control (2 bits) = 00b Continuity_Counter (4 bits) = 0001b
Payload	5	0x00	OMP_type = 0 (8 bits) = 00000000b (Tier 0 DTx)
Payload	6-188	0x00	Zero filler for remaining bytes (to be replaced in DTxA)
TOTAL	**188 bytes**	-----	**Standard MPEG-2 transport stream standard architecture**

Occasional *standard* null packets (packet ID of 0x1FFF) were inserted, on the order of approximately three every million packets or so (which is about two per minute), allowing the DTxA to remove any frequency difference in the transport stream between the service multiplexer and the DTxA by dropping null packets. Of course, the DTxA could have also *added* packets, if necessary, to the transport data stream when it was necessary to shift the data rate in the opposite direction.

DTV RECEIVERS

Two set-top boxes from well-known consumer manufacturers were selected as the DTV receivers to be used in the MTVA outdoor and indoor field tests, generically referred to as **Rx1** and **Rx2**. Both units were compliant with the mandated specifications set forth by the National Telecommunications & Information Administration (**NTIA**) for digital-to-analog (**D/A**) converter boxes to be sold under their federal coupon eligible converter box (**CECB**) program. Per NTIA certification requirements, these units were designed to receive ATSC RF signals on RF Channels 2 – 69, and perform VSB decoding (including equalization and error correction). Likewise, they also performed MPEG-2 video decoding and down-conversion to 480I standard definition video, Dolby AC-3 decoding and conversion to stereo. They also provided both CH 3/4 RF outputs and baseband composite video signals as well as line-level audio left/right outputs for connection to a legacy NTSC television set. These units came with remote control units for ON/OFF, channel change, menu selection, and other control and display functions.

These DTV receivers were characterized for RF performance during lab tests conducted previously at **MSW** facilities. Although not exactly identical in RF performance, these units were both shown to be at least 5th generation in nature and typical of what might be expected to exist in viewers' homes in the near future, and therefore were deemed appropriate for the MTVA DTx field test.

FIELD TEST EQUIPMENT SYSTEM DESIGN

OUTDOOR FIELD TEST EQUIPMENT SYSTEM DESIGN

Figure 3 illustrates the outside and inside of the two DTV field test vehicles (one belonging to **MSW** and the other to Univision) utilized in the MTVA New York City *outdoor* field test. Each truck had the ability to extend a hydraulic mast to 30' above ground level (**AGL**) and provided enough AC power from the on-board generator to operate all the test equipment.

Figure 4 contains a single block diagram of the equipment that was used in the two field test vehicles since *each* truck was essentially identical with regard to DTV signal measurement and reception capability. This truck design was based on the DTV Station Project field test vehicle design (**Ref 1**) from the late 1990s. However, it contained *updated* components and features. It was designed as a 50-Ohm *professional* installation for measurement purposes, and not a 75-Ohm *consumer* installation that would be found in typical home systems. Note that each field test truck utilized a broadband calibrated directional log periodic antenna, RG-214 double-shielded coaxial downlead cable, variable RF attenuator, robust amplifier distribution system, measurement instrumentation containing a spectrum analyzer with band-power measurement capability and RF Watermark transmitter identification (**TxID**) receiver/decoder, and two typical 5G DTV receivers (NTIA-approved D/A converter boxes).

Table 4 lists all of the pertinent equipment contained in each field test truck with its associated logistical information.

Table 4 Field Test Equipment Description

Item	Manufacturer	Part #	Item Description
Antenna (outdoor)	AH Systems	SAS-512-2	50 Ω, log periodic, VSWR<2.5; F/B>23 dB; 33L"x30"W
Antenna (indoor)	AH Systems	Model FCC-3	50 Ω,, calibrated VHF dipole, adjustable, ± 1 dB, (cal 3/11/08)
Antenna (indoor)	AH Systems	Model FCC-4	50 Ω,, calibrated UHF dipole, adjustable; ± 1 dB, (cal 3/11/08)
Antenna (indoor)	Zenith	Silver Sensor	Passive, UHF log periodic indoor antenna
Antenna (indoor)	Winegard	Sharpshooter	Active, VHF/UHF combination indoor antenna
Antenna (indoor)	Funai	DTA-5000	Active, smart UHF antenna, CEA 909 interface
Coaxial Cable (Truck #1 & #2)	Belden	RG-214	50 Ω, double-shielded, low-loss cable
Coaxial Cable (Indoor)	Belden	RG-58	50 Ω, single-shielded
Bandpass Filter #1	Microwave Filter	3160	CH 12 Bandpass filter, 50 Ω, 10 MHz 3-dB BW, N-connector
Bandpass Filter #2	Microwave Filter	3278 (4)	CH 33 Bandpass filter, 50 Ω, 10 MHz 3-dB BW, N-connector
Bandpass Filter #3	Microwave Filter	3278 (4)	CH 65 Bandpass filter, 50 Ω, 10 MHz 3-dB BW, N-connector
Variable Attenuator	JFW	50DR-001	50 Ω, 0-110 dB, 1-dB steps 1 W, BNC, VSWR≤1.4 @ 1 GHz
Fixed Attenuator Pad	Pasternack	PE-7001-3	3-dB pad for preamplifier input; 1 W, N-connectors
Preamplifier	Mini-Circuits	ZFL-1000VH	20 dB gain min, IP3=+38 dBm; NF=4.5 dB;P_{1dB}=+25 dBm
4-way Splitter	Mini-Circuits	ZFSC-4-1	Approx. 7 dB loss
DC Power Supply	Lambda	LND-2-152	Linear 15 Vdc supply; > 0.5 A
Spectrum Analyzer	Rohde & Schwarz	FSH-3	3 GHz, channel power markers, internal pre-amp, 5-dB steps
TxID RF Watermark Analyzer	Hutech	Prototype	Terrestrial watermark analyzer with companion PC software (x2)
DTV Receiver #1	-----	Prototype	NTIA prototype with remote control smart antenna interface
DTV Receiver #2	-----	Prototype	NTIA prototype with remote control smart antenna interface
Video Monitors (Truck #1)	Marshall Electronics	V-R102DP-HDA	*Dual,* 10.4" TFT flat-panel LCD monitors; multiple inputs
Video Monitors (Truck #2)	Sony Electronics	Trinitron	*Single*, 8" flat-panel CRT monitors (x2)
Video Monitors (Indoor #1)	Audiovox	PLV16081	8" LCD display, ATSC/NTSC tuner, internal speaker, headset jack
Video Monitors (Indoor #2)	Audiovox	PLV16081	8" LCD display, ATSC/NTSC tuner, internal speaker, headset jack
GPS Receivers	Garmin	GPS-76	Handheld integrated GPS receiver; Battery + ext power supply (x2)
External GPS Antenna	Garmin	GA-27C	Low profile External GPS Antenna
Laptop Computer (Truck #1)	Hewlett-Packard	NX9420	>1.2GHz processor; >256 MB RAM; >40 GB hard drive;
Laptop Computer (Truck #2)	Dell	Vostro 1500	>1.2GHz processor; >256 MB RAM; >40 GB hard drive;
USB Memory Drive	Memorex	Traveldrive	8 GB; for memory backup & archiving
Mast-mounted Compass	Raymarine	ST-40	Flux-gate compass; and electronic display; auto-correction
Operating System	Microsoft	Windows XP	Professional version;
Spreadsheet	Microsoft	Excel	Customized spreadsheet from **MSW**
US Map Program	Delorme	Street Atlas 2007	Standard map program
Spectrum Analyzer Software	Rohde & Schwartz	Flashview (FSHView)	FSH-3 control software

The *outdoor* receive antenna was a calibrated SAS-512-2 *professional* 50-Ohm log periodic antenna from A.H. Systems. This robust antenna was constructed of lightweight aluminum and manufactured to ensure maximum gain, low VSWR, and high power-handling capabilities, and had a 50-Ohm N connector. The antenna had a gain of approximately **5.5/6.5/7.2 dBi** (equivalent to **3.3/4.3/5.0 dBd**) at CH 12, CH 33, and CH 65, respectively.

The professional downlead coaxial cable was rugged RG-214, and was 50-Ohm, double-shielded, low-loss cable that was contained within a plastic Nycoil sheath for protection. The coaxial cable utilized 50-Ohm N-connectors at each end.

The truck system design utilized a professional *active* RF distribution system (i.e., not one that would be found in a consumer's home). The heart of this distribution system was the "works-in-a-drawer" (**WIAD**). **Figure 5** illustrates the WIAD's internal amplifier design, which provided variable input signal attenuation, signal amplification, and 4-way signal splitting. The truck's overall signal *sensitivity* was determined by the front-end amplifier's noise figure (along with the antenna gain and downlead loss) since there was enough system gain to overcome the noise floor of the following 5G DTV receivers, spectrum analyzer, and RF watermark receiver. This truck system gain not only determined the DTV reception sensitivity, but it also helped to provide absolute and relative signal strength measurement *accuracy* by reducing the effects of the noise floor of the spectrum analyzer and the RF watermark measurement devices. Such an arrangement allowed *simultaneous* signal level and RF watermark measurements as well as *simultaneous* DTV reception determination (i.e., service) of both DTV receivers. An *optional* bandpass filter (for CH 33, CH 65, or CH 12) was inserted (only when required) in front of the truck amplifier in situations where strong adjacent channel interference was limiting measurements and reception. **Figure 6** illustrates the magnitude response for each of these bandpass filters.

Note that the rotary RF attenuator was the *first* component in the distribution system unit, and was used to adjust the truck's amplifier *output* level (e.g., nominally adjusted for -50 dBm/6 MHz). This attenuator allowed the same truck amplifier to be used at *any* field location (close or far, line-of-sight or path-obstructed) regardless of the incoming signal level since it protected both the amplifier and the following measurement and reception devices from signal overload. The value of this attenuator was recorded in the data spreadsheet so that it was accounted for in the field strength calculation. If additional front-end overload protection was required, an *optional* bandpass filter (described above) was placed at the amplifier input. The RF amplifier was very robust (+34 dBm IP3) with ample gain to insure that the truck's noise floor was measurable above that of the spectrum analyzer and yet not be easily overloaded due to large undesired analog and digital television signals at its input. A fixed 3-dB pad on the input to the amplifier increased the 4-dB nominal amplifier noise figure to about 7 dB for the receive system, which is equal to the FCC planning factor for the UHF band (FCC planning factors assume a 10 dB noise figure value for VHF channels). A 4-way splitter inside the WIAD split the signal for simultaneous distribution to (1) the spectrum analyzer (signal *power* measurements), (2) the RF watermark receiver (DTx signal identification as well as relative *amplitude* and *timing* measurements), and (3) 5G DTV receiver Rx1 for its service measurement, and (4) 5G DTV receiver Rx2 for its *service* measurement. A shared control computer for the spectrum analyzer and the RF watermark receiver was utilized in the trucks.

Simultaneous signal measurement (for both spectrum and TxID analyzers) and DTV reception (for both 5G receivers) not only saved measurement time by allowing *parallel* operation, but it also allowed *real-time* observation of dynamic propagation conditions (signal level fading or dynamic multipath) that could not have been achieved if a *sequential* measurement process was performed. However, this type of active measurement philosophy did *not* account for typical mismatch conditions between receiving antenna and DTV tuner that might exist with an actual consumer implementation, nor did it account for the entire dynamic signal range of the two 5G receivers. Therefore, not every receiving condition was simulated in these field tests. Any concerns about receiver mismatches (with the antenna and downlead cable) and degraded sensitivities (due to increased noise figures from mismatched source impedances) must be accounted for by theoretically applying such conditions to the field test *results* in the form of reduced margins. While the use of an active antenna (or a passive antenna with an active distribution system, as used in the MTVA field test) can possibly improve the sensitivity over that of a pure passive antenna, the measured signal levels obtained during the DTS field test in New York City were not weak, but rather strong, and there typically was not a concern about sensitivity. In situations such as this in the future, passive antennas may be used, eliminating the possibility of amplifier overload that causes cross-modulation and intermodulation distortion. These passive antennas may supply enough signal strength for successful DTV reception, provided that any signal multipath can be handled by the DTV receiver's equalizer. As will be seen in a subsequent section, the *indoor* field test plan also called for an active distribution scheme for the tests.

Field strength (rms value over 6 MHz bandwidth) was *calculated* based on the total average power (in 6 MHz) that was measured by the spectrum analyzer (using band-power markers) in the truck. The wavelength at the DTV channel center frequency was used in the field strength calculations. The gain of the WIAD, the loss of the downlead coaxial cable, and the loss of the variable attenuator established the overall truck system gain. This truck system gain, coupled with the frequency-dependent dipole factor and antenna gain (certified by the antenna manufacturer), all played a role in the calculation of the DTV field strength at the antenna input (see **Figure 4** for the field strength equation). Calibration of the truck system gain was measured and recorded *each* day prior to the start of testing. Note that if the signal level at a field test site was varying, an estimated average value was recorded, along with a comment indicating the approximate amount of signal level variation.

INDOOR FIELD TEST EQUIPMENT SYSTEM DESIGN

The MTVA DTx indoor testing, like any other indoor field test, was a challenging task since it was desired to minimize the amount of test equipment that was needed to be carried into someone's home and yet maximize the amount of data that was capable of being gathered in a reasonably short period of time. Also, the ease and speed with which the equipment could be set up and torn down was crucial for minimum intrusion to the homeowner who provided personal living space for a considerable amount of time (approximately an entire weekday).

The equipment, shown in the pictures in **Figure 7**, was configured similarly to the outdoor truck system. The block diagram for the indoor test setup is similar to that used for the outdoor test setup in **Figure 5**. With the exception of the antenna and the dual video displays, the indoor test equipment was *identical* to that used in one of the trucks, except that it was removed from the truck's 19" rack system and mounted in two portable short 19" racks that were carried from the truck to inside the test home. Therefore, most of this equipment served double duty for *both* outdoor measurements and indoor measurements. The *primary* indoor receive antenna was a bi-directional ("figure-8" azimuth pattern) calibrated dipole antenna (one antenna for high-VHF and another antenna for UHF) and the two *secondary* antennas were a directional Sharpshooter for VHF and a directional Silver Sensor for UHF. These antennas were individually mounted on tripods to facilitate height and azimuth adjustment, as shown in **Figure 7**. Similar to the outdoor test setup, these antennas fed a portable amplifier/splitter unit (with variable input attenuation) that supplied the spectrum analyzer, the RF watermark test equipment, and the two 5G DTV receivers. Indoor field strength was calculated in the same manner as it was for outdoor measurements. Small video monitors (different ones than those used in the truck) for each receiver were also present in the portable rack in order to determine successful DTV reception, along with a shared control computer for the spectrum analyzer and the RF watermark receiver.

For the special case that used a smart UHF antenna system, a smart antenna was likewise mounted on a tripod (see **Figure 7**) and connected directly to one DTV receiver at a time since only one receiver can control a smart antenna. Field strengths at each test channel were *assumed* to be the same as that measured by the primary dipole antennas before the smart antenna receiver test was performed.

FIELD TEST PLAN DESIGN AND IMPLEMENTATION

MTVA retained **MSW** to create a field test plan based specifically on the MTVA DTS design described above, with input from and approval by the MTVA group and their other consultants. The fundamental goal of the DTx field test was to evaluate operation of the New York City *prototype* DTx network, primarily in the Brooklyn area. The details of the system design and the desired system test were originally recorded in the MTVA Field Test plan (dated **October 31, 2007**). No DTS design parameters were changed by **MSW**, but rather **MSW** conducted the New York City (Brooklyn) DTx field test using the original DTx system design. The field test plan called for at least **100** *outdoor* sites, of which at least **20** were to have corresponding *indoor* sites of varying conditions. This field test plan used elements of past DTV field test plans (**Ref 2, 3, 4, and 5**) from various industry groups (e.g., Grand Alliance, ACATS, DTV Station Project, and ATSC), with procedural modifications that accounted for the new features of a distributed transmission system.

For some readers of the report, the following definitions used in these MTVA field tests may be helpful:

Coverage:	field strength value (in dBμV/m) as *calculated* from measured total average power (in 6 MHz).
Service:	3 "hits" or fewer in the DTV *video* for 3 minutes are considered acceptable.
Dynamic signal conditions:	RF signal *varying* by more than ±3 dB (including due to traffic or airplanes).

OUTDOOR FIELD TEST OBJECTIVES

The primary *outdoor* field test objectives were:

Determine CH 33 *maximum field strengths* at 30' AGL and 15' AGL with ESB ON and all gap fillers **OFF** to ascertain coverage, service, and margin of ESB UHF transmitter by itself.

Determine CH 33 *maximum field strengths* at 30' AGL and 15' AGL with ESB ON and all gap fillers **ON** to ascertain coverage, service, and margin of a UHF DTx system.

Determine CH 12 *maximum field strengths* at 30' AGL and 15' AGL with ESB ON and all gap fillers **OFF** to ascertain coverage, service, and margin of ESB high-VHF transmitter by itself.

Determine CH 12 *maximum field strengths* at 30' AGL and 15' AGL with ESB ON and all gap fillers **ON** to ascertain coverage, service, and margin of a high-VHF DTx system.

Determine CH 65 *maximum field strengths* at 30' AGL and 15' AGL with all gap filler transmitters **ON** to ascertain coverage, service, and margin of a UHF "distributed transmitter" system (i.e., one in which there is no high-power main transmitter).

Determine CH 33 *range of antenna rotation service* at 30' AGL and 15' AGL from ESB with and without gap fillers to ascertain ease of adjustment and determine any cause of failure throughout the range of antenna rotation.

Determine CH 12 *range of antenna rotation service* at 30' AGL and 15' AGL from ESB with and without gap fillers to ascertain ease of adjustment and determine any cause of failure throughout the range of antenna rotation.

Determine CH 65 *range of antenna rotation service* at 30' AGL and 15' AGL with only gap filler transmitters to ascertain ease of adjustment and determine any cause of failure throughout the range of antenna rotation.

Note that each of these *outdoor* tests was performed on CH 12, CH 33, and CH 65 at two antenna heights above ground level (30' AGL and 15' AGL) using one broadband log periodic antenna that covers the entire high-VHF and UHF television bands.

INDOOR FIELD TEST OBJECTIVES

The primary *indoor* field test objectives, similar to the outdoor objectives, were:

Determine CH 33 *maximum field strengths* with a primary (dipole) antenna and a secondary antenna (directional) with ESB ON and all gap fillers **OFF** to ascertain coverage, service, and margin of ESB UHF transmitter by itself.

Determine CH 33 *maximum field strengths* with a primary (dipole) antenna and a secondary antenna (directional) with ESB ON and all gap fillers **ON** to ascertain coverage, service, and margin of a UHF DTx system.

Determine CH 12 *maximum field strengths* with a primary (dipole) antenna and a secondary antenna (directional) with ESB ON and all gap fillers **OFF** to ascertain coverage, service, and margin of ESB high-VHF transmitter by itself.

Determine CH 12 *maximum field strengths* with a primary (dipole) antenna and a secondary antenna (directional) with ESB ON and all gap fillers **ON** to ascertain coverage, service, and margin of a high-VHF DTx system.

Determine CH 65 *maximum field strengths* with a primary (dipole) antenna and a secondary antenna (directional) with all gap filler transmitters **ON** to ascertain coverage, service, and margin of a UHF “distributed transmitter” system (i.e., one in which there is no high-power main transmitter).

Determine CH 33 *range of antenna rotation service* with a primary (dipole) antenna and a secondary antenna (directional) from ESB with and without gap fillers to ascertain ease of adjustment and determine any cause of failure throughout the range of antenna rotation.

Determine CH 12 *range of antenna rotation service* with a primary (dipole) antenna and a secondary antenna (directional) from ESB with and without gap fillers to ascertain ease of adjustment and determine any cause of failure throughout the range of antenna rotation.

Determine CH 65 *range of antenna rotation service* with a primary (dipole) antenna and a secondary antenna (directional) with only gap filler transmitters to ascertain ease of adjustment and determine any cause of failure throughout the range of antenna rotation.

Determine CH 33 and CH 65 service for a smart antenna from ESB with and without DTx active.

DATA RECORDING AND DOCUMENTATION

The *outdoor* field test data was gathered and recorded in ***two*** detailed Excel spreadsheet files, one for each field test truck (crew), and was used for later data analysis and archiving. These two spreadsheets were identical to each other in format, with just the data entered from each truck being different. Within each spreadsheet, there were 10 worksheets representing 12 different sub-tests of the outdoor field test (2 antenna heights times 3 RF channels times 2 DTx ON/OFF modes):

30’ Peak Data	(outdoor antenna @ 30’ AGL rotated for maximum signal strength for <u>both</u> DTx inactive & active)
30’ Rx1 DTx OFF	(outdoor antenna @ 30’ AGL range of antenna rotation for DTV receiver #1 with DTx inactive)
30’ Rx2 DTx OFF	(outdoor antenna @ 30’ AGL range of antenna rotation for DTV receiver #2 with DTx inactive)
30’ Rx1 DTx ON	(outdoor antenna @ 30’ AGL range of antenna rotation for DTV receiver #1 with DTx active)
30’ Rx2 DTx ON	(outdoor antenna @ 30’ AGL range of antenna rotation for DTV receiver #2 with DTx active)
15’ Peak Data	(outdoor antenna @ 15’ AGL rotated for maximum signal strength for <u>both</u> DTx inactive & active)
15’ Rx1 DTx OFF	(outdoor antenna @ 15’ AGL range of antenna rotation for DTV receiver #1 with DTx inactive)
15’ Rx2 DTx OFF	(outdoor antenna @ 15’ AGL range of antenna rotation for DTV receiver #2 with DTx inactive)
15’ Rx1 DTx ON	(outdoor antenna @ 15’ AGL range of antenna rotation for DTV receiver #1 with DTx active)
15’ Rx2 DTx ON	(outdoor antenna @ 15’ AGL range of antenna rotation for DTV receiver #2 with DTx active)

Some *measured* data was entered into various columns, with each row pertaining to a particular test site and DTV RF channel while other data was *calculated* in the spreadsheet. Some of the various general types of data recorded and calculated are described below:

Site name and number (Grid, Interference, Driveway, Indoor, along with specific site number)

Site location & description (address, GPS latitude and longitude coordinates, distance & bearing to each transmitter)

Test conditions (CH #, CH frequency, antenna gain, date, time of day, weather)

Truck parameters (system gain, noise floor, spectrum analyzer noise floor, input attenuation, use of bandpass filter)

Signal power and antenna bearing (for maximum signal level and range of rotation)

Calculated field strength & SNR (for maximum signal level and range of rotation)

Plot filenames (spectrum and RF watermark)

DTV service for <u>*each*</u> receiver over 3-minute period (maximum signal level, range of rotation)

Reason for failure for <u>*each*</u> receiver (maximum signal level, range of rotation)

Margin for <u>*each*</u> receiver (maximum signal level)

Multipath energy SDR and relative DTx signal amplitude and delay (maximum signal level, range of rotation)

Calculated individual and total sector angles (range of rotation)

General test site comments (all aspects of the field testing)

In a similar manner, ***one*** separate spreadsheet file was created for the *indoor* data, which followed very closely to the outdoor field test described in the paragraphs above. However, instead of separate worksheets for 30' AGL and 15' AGL receive antennas, two worksheets were described as primary indoor antenna and secondary indoor antenna. The only extra data taken inside the home that was related to unique aspects of the indoor field test was: detailed descriptions of the indoor room location within the building where the testing was performed, and the results of the *smart antenna* testing.

Finally, ***one*** summary spreadsheet file was created to combine selected data into one reference file for quick and easy overview of pertinent data, and printout to hardcopy. A modified version of the summary data can be found in **Appendix 6** (outdoor results) and **Appendix 8** (indoor results).

All four Excel spreadsheet files along with this written report and the plot files (spectrum and RF Watermark analyzers) are available in electronic form from the MTVA.

FIELD TEST SITES

While *indoor* reception was the primary interest in these field tests, a majority of the testing was performed *outdoors* using a directional log periodic antenna situated either 30' AGL or 15 feet AGL due to logistical considerations. In order to obtain a statistically relevant dataset, it was desired to visit within Brooklyn at least a total of **100** *outdoor* ("grid" and "driveway") test sites and at least **20** indoor sites (each indoor site was to be co-sited with one of the outdoor "driveway" sites in order to determine building penetration loss). While more indoor test sites were desired, it was extremely challenging logistically to obtain indoor test volunteers who not only lived in the desired area of Brooklyn (i.e., "within the box" of gap filler transmitters), but who were willing and able to have engineers "invade" their homes with test equipment for an entire weekday. These outdoor and indoor test sites, along with some of their logistical descriptions, are listed in **Appendix 3**. It should be noted that the final set of field test sites visited were slightly different from the ones listed in the original **October 31, 2008** test plan due to various reasons, including, but not limited to, unavailability of access.

Table 5a indicates the number of actual tests performed for each of the 6 test scenarios: 3 RF channels (CH 33, CH 12, CH 65) at 2 antenna heights (30' AGL and 15' AGL) for outdoor testing and 3 RF channels (CH 33, CH 12, CH 65) with 2 antenna types (primary dipole antenna and a secondary directional antenna) for indoor testing. A smart antenna was also tested at each indoor test site. Due to the extremely large number of tests to be performed, each field test crew completed one test site per day. The total number of test sites visited was **132**, but not all tests were able to be performed at each test site due to various reasons such as inclement winter weather, transmitter shutdown, or lack of time at a site before the DTx transmitters and the RF Watermark were turned off at 6 pm. Nevertheless, enough data was taken for statistically relevant outdoor test results.

Table 5a Summary of *visited* MTVA DTx field test sites.

Test Channel #	OUTDOOR						INDOOR	
	Grid Sites (G1)		Interference Sites (IX)		Driveway Sites (HD)		Indoor Sites (HI)	
	30' AGL	15' AGL	30' AGL	15' AGL	30' AGL	15' AGL	Primary	Secondary
CH 33	80	80	6	6	23	23	23	23
CH 12	73	73	6	6	23	23	23	23
CH 65	77	77	6	6	23	23	23	23

It is also important to note that not all of the test sites were located within the main Brooklyn "box". **Table 5b** illustrates that breakdown of test site locations with respect to the "box" as well as by channel tests. It can be seen that a total of **90** *outdoor* test sites were within the "box" while **19** outdoor test sites were outside the "box". Likewise, the *indoor* test sites consisted of **10** inside the "box" and **13** outside the "box."

Table 5b Summary of *visited* MTVA DTx field test sites inside and outside the Brooklyn test "box."

Test CH #	OUTDOOR TEST SITES (109)				INDOOR TEST SITES (23)	
	Inside the "box" (90)		Outside the "box" (19)		Inside the "box" (10)	Outside the "box" (10)
	Grid	**Driveway**	**Interference**	**Driveway**	**Indoor**	**Indoor**
CH 33	80	10	6	13	10	13
CH 12	73	10	6	13	10	13
CH 65	77	10	6	13	10	13

In summary, the MTVA New York City DTS field test began on **January 15, 2008** after all parts of the system (transmit and receive) were installed and confirmed to be operational. The test was performed by two field test crews in two separate field test trucks (each equipped with hydraulic masts capable of 30' AGL extension of the receive antenna). Equipment from the first test vehicle was temporarily removed and used during the indoor testing phase of the project. The field test was completed on **May 9, 2008** after **132** test sites were visited.

OUTDOOR FIELD TEST DATA ANALYSIS

OUTDOOR FIELD TEST OVERIVEW

The purpose of this field test report is to provide the MTVA with the field test results of the New York City prototype Distributed Transmission System. The field test was performed by **MSW** during the months of January, February, March, April, and May of 2008.

The primary goal of the field test and subsequent analysis was to determine the overall success of the DTx network in providing improved urban DTV signal coverage and service to places in the greater metropolitan New York City area (primarily Brooklyn). As stated previously, the primary area of field testing was inside the **3-mile** square Brooklyn "box" formed by the location of the four remote low-power gap filler transmitters. Likewise, another goal of this report was to determine if the DTx network caused interference and no reception to places where the ESB transmitter alone could provide acceptable reception. The summary of the raw *outdoor* data is contained within **Appendix 6**.

General outdoor measurement results that are analyzed in this report include:

(1) DTV Field strength

(2) DTV service

(3) DTV margin

(4) Range of receive antenna rotation

OUTDOOR DTx FIELD STRENGTH EVALUATION

The first consideration in the performance evaluation of the DTx network is *peak* DTV field strength for the "inside the box" Brooklyn outdoor test sites. These sites consisted of all the Grid sites (which by definition are inside the "Box") and some of the Driveway sites (which were matched up with indoor sites, and only some were inside the "Box"). For *each* of the 6 individual tests (3 channels and 2 antenna heights), the antenna was first rotated to determine the azimuth angle at which the *maximum* DTV signal occurs at a given test site. Total *average* DTV signal power (in 6 MHz) was measured at the spectrum analyzer input in each field test truck, and the equivalent root-mean-square (**rms**) field strength (in dBμV/m) was *calculated* using the previously calibrated truck net gain (in dB) from antenna input to spectrum analyzer input. The net truck gain includes the downlead coaxial cable loss (in dB), the variable attenuator loss (in dB), and the preamplifier gain (in dB), plus the known antenna gain over dipole (in dBd) and the dipole conversion factor for each RF channel. Appropriate frequency-dependent parameter values were used for *each* test channel.

Table 6 shows the statistical results of field strength for both DTx OFF and DTx ON for each receive antenna height above ground and for each of the three RF test channels, as well as the amount of *increase* in signal field strength as a result of the DTx network being active. Since all the test sites in this particular analysis are located within the boundaries of the four DTx transmitters, signals from the ESB transmitter and one or more remote gap filler transmitters were expected to be available at each test site.

Note that with DTx *inactive* (i.e., only when the ESB signal was being radiated by itself), the CH 33 signal levels at 30' AGL antenna height averaged around **73 dBμV/m**, with an average increase of about **7 dB** to about **80 dBμV/m** observed when DTx was *active*. Similar test results were obtained at 15' AGL, except that all the values were about **3 dB** lower in value.

CH 12 likewise experienced a significant field strength *increase* when DTx was active, except that the increase was slightly higher (≈**11 dB**). However, the CH 12 average field strengths with DTx *inactive* (≈**59 dBµV/m**) and DTx *active* (≈**70 dBµV/m**) were lower values than its CH 33 UHF counterparts since relatively much less power was transmitted on CH 12 from ESB as well as from the low-power gap filler transmitters. Note that higher signal levels are not required for a VHF channel like they are for UHF channels due to the frequency-dependent dipole effect that more effectively converts field strength to output voltage in viewers' receive antennas.

CH 65, which is measured with only DTx-*active* since there was no CH 65 transmitter on ESB, had field strengths around **75 dBµV/m**, which were a few dB *less* that that observed on CH 33.

Also note that the difference in the *average* peak field strengths between the 30' AGL and 15' AGL receive antenna heights was only about **2 – 3 dB** on CH 33 and CH 12, with or without DTx.

Table 6 Inside the "box" *peaked* DTV field strength site statistics.

DTx Status	**CH 33**		**CH 12**		**CH 65**		**Units**
	30'	**15'**	**30'**	**15'**	**30'**	**15'**	
DTx OFF	72.7	69.9	58.9	56.7	N.A.	N.A.	dBµV/m (ave)
	73.7	70.3	58.0	56.7	N.A.	N.A.	dBµV/m (med)
	9.6	8.9	8.5	7.9	N.A.	N.A.	dBµV/m (std dev)
DTx ON	80.2	77.1	69.7	66.7	76.0	73.8	dBµV/m (ave)
	79.3	77.6	70.6	66.2	75.7	73.2	dBµV/m (med)
	7.8	7.6	8.7	8.8	8.9	8.2	dBµV/m (std dev)
Field Strength Increase	7.5	7.2	10.8	10.0	N.A.	N.A.	dBµV/m (ave)
	4.0	4.4	8.2	8.4	N.A.	N.A.	dBµV/m (med)
	9.0	8.5	10.2	10.0	N.A.	N.A.	dBµV/m (std dev)

The distribution of field strengths can be displayed graphically in a probability density function (**PDF**), sometimes referred to as a histogram, and its associated cumulative distribution (**CDF**). Such graphs were created and plotted for all the Brooklyn "box" measured field strength values obtained with the antenna "peaked" for maximum signal, and they are shown in **Figure A7-1** through **Figure A7-12** in **Appendix 7**. These plots visually describe the spread of the observed field strength levels measured at each test site both with and without DTx active. PDF and CDF plots were individually generated for CH 33, CH 12, and CH 65 (where applicable) at each of the two antenna heights. From these graphs, the statistical variations of field strength over all the test sites visited can be viewed, especially the comparison between DTx OFF and DTx ON for CH 33 and CH 12.

The break down of the site percentages by the amount of field strength *increase* created by the DTx network is shown in **Table 7**. Of course, CH 65 is not included in this analysis since there was no CH 65 transmitter on ESB with which to compare. It was expected that most Brooklyn "box" test sites would exhibit some increase in field strength when DTx was active. Note that CH 33 has at least some field strength increases (ΔFS > 0 dB) at over **80%** of the test sites compared to CH 12 at over **90 %** of the test sites. CH 12 has a larger increase due to the fact that the CH 33 ESB radiated signal is relatively larger (137 kWatt ERP) compared to its remote transmitters' radiated signals (1 kWatt ERP) than the CH 12 ESB radiated signal (1 kWatt ERP) compared to its remote transmitters' radiated signals (100 Watt ERP). Therefore, CH 12 signals would be expected to experience a larger increase with DTx active. Also note that over **30%** of the test sites experienced a 10 dB or greater increase in field strength due to the DTx system. The extra signal strength at these sites may aid with indoor DTV reception by helping to overcome the signal loss due to lower gain receive antennas at lower heights above ground level as well as building penetration loss.

Table 7 Inside the "box" DTx- increased *peaked* field strength site percentages

Field Strength Increase	CH 33		CH 12		CH 65		Units
	30'	15'	30'	15'	30'	15'	
ΔFS > 0 dB	72	78	78	78	N.A.	N.A.	sites
	90	90	83	83	N.A.	N.A.	sites, total
	80.0	86.7	94.0	94.0	N.A.	N.A.	%
ΔFS > 10 dB	29	28	38	33	N.A.	N.A.	sites
	90	90	83	83	N.A.	N.A.	sites, total
	32.2	31.1	45.8	39.8	N.A.	N.A.	%
ΔFS > 20 dB	10	7	17	12	N.A.	N.A.	sites
	90	90	83	83	N.A.	N.A.	sites, total
	11.1	7.8	20.5	14.5	N.A.	N.A.	%

Related to field strength is the signal-to-noise ratio (**SNR**) that is present at the input to the DTV receiver. It is this ratio of signal power to noise power (both measured in 6 MHz) that determines if the DTV signal is above the white noise threshold of visible (**TOV**) errors for the VSB transmission system, and whether it can be decoded error free. In this MTVA field test, the SNR was determined by the received signal strength and the truck's system noise floor. The noise floor in the truck (i.e., the WIAD) was determined by the low-noise preamplifier that was in the signal path for amplification and splitting of the received signal. The preamplifier itself effectively had a 4 dB noise figure, but when coupled with a 3-dB pad present at its front end, the total truck noise figure was the same as the 7 dB UHF noise figure found in the FCC planning factors (OET Bulletin 69).

The 8-VSB digital transmission system has a well-known *Gaussian* white noise SNR threshold of visible errors around 15 dB, assuming there is no interference or other impairments present. However, this 15 dB SNR threshold value may be degraded (i.e., increased) in *severe* propagation conditions experienced in the field (such as multipath) by as much as 5 - 8 dB. Therefore, knowledge about the SNR values statistically encountered at the field test sites is important. **Table 8** contains the site statistics while **Table 9** contains the site percentages.

Note that the average SNR values in **Table 8** were quite high (>**35 dB**) with DTx inactive and even higher (**7 – 10 dB**) when DTx was active due to the much larger received signal levels. Naturally, SNR was slightly lower for the 15' AGL antenna measurements due to the slightly lower field strengths at the lower receive antenna heights.

Table 8 Inside the "box" SNR site statistics.

DTx Status	CH 33		CH 12		CH 65		Units
	30'	15'	30'	15'	30'	15'	
DTx OFF	43.0	40.2	38.7	36.4	N.A.	N.A.	dBμV/m (ave)
	44.2	40.9	37.4	36.6	N.A.	N.A.	dBμV/m (med)
	9.8	9.0	8.7	8.0	N.A.	N.A.	dBμV/m (std dev)
DTx ON	50.5	47.4	49.4	46.4	42.6	40.4	dBμV/m (ave)
	50.3	47.5	49.8	46.1	41.9	39.6	dBμV/m (med)
	7.9	7.5	8.8	8.8	8.8	8.0	dBμV/m (std dev)
SNR Increase	7.5	7.2	10.8	10.0	N.A.	N.A.	dBμV/m (ave)
	4.0	4.4	8.2	8.4	N.A.	N.A.	dBμV/m (med)
	9.0	8.5	10.2	10.0	N.A.	N.A.	dBμV/m (std dev)

Of particular interest is the *distribution* of SNR values compared to the 15-dB white noise threshold. From **Table 9**, note that ***every*** test site with or without DTx active had a measured SNR value greater than 15 dB, and thus theoretically capable of successful DTV reception (in a white Gaussian propagation environment). There were very few sites (**< 7%**) that had SNR values between 15 and 23 dB with DTx inactive, but all the test sites had SNR > 23 dB with DTx active. However, two things must be remembered about this fact. First, these are outdoor measurements at 30' and 15' using a *directional* antenna that is adjusted for *maximum* signal level. One would expect a greater probability of large received signal levels and thus large SNR values. Second, these tests sites within the Brooklyn grid were typically less than 10 miles away from any one of the five transmitters (ESB and 4 remote gap filler transmitters), and quite often less than 5 miles away. Therefore, large SNR values would be expected during this testing, and they were, in fact, observed.

Another important issue is the fact that despite the relatively strong signals measured at each test site, limited DTV reception is still possible due to severe *naturally-occurring* multipath (DTx OFF or DTx ON) and/or due to severe *DTx-induced* multipath (DTx ON). That is, a minimum signal level that provides SNR values above 15 dB is a necessary, but not sufficient, condition for successful DTV reception. For outdoor measurements, the receive *antenna directivity* plays a vital role as does the *equalizer performance* of the DTV receiver. However, these are even more important for indoor reception. Nevertheless, this field test confirmed that there was ample signal level for outdoor reception where the antenna was pointed in the direction of maximum signal level.

Since equalizer white noise enhancement can occur in DTV receivers under severe propagation conditions (e.g., strong multipath), the breakdown in **Table 9** is helpful to see that almost all of the test sites (> **93%**) had more than 8 dB of excess SNR over the 15 dB white Gaussian noise threshold *without* DTx and all of them (**100%**) had at least 8 dB (and often more) of excess SNR *with* DTx active. However, it must be remembered that signal strengths measured in the field are a net total of *all* received signals from all the transmitters, and therefore, successful reception depends on the ability of the DTV receivers to remove the effects of the naturally-occurring multipath from the urban clutter or the self-induced multipath from multiple synchronized signals.

Table 9 Inside the "box" SNR site percentages

DTx Status	SNR Range	CH 33		CH 12		CH 65		Units
		30'	15'	30'	15'	30'	15'	
DTx OFF	SNR > 15 dB	90	90	83	83	N.A.	N.A.	sites
		90	90	83	83	N.A.	N.A.	sites, total
		100.0	100.0	100.0	100.0	N.A.	N.A.	%
DTx OFF	SNR > 23 dB	86	87	80	77	N.A.	N.A.	sites
		90	90	83	83	N.A.	N.A.	sites, total
		95.6	96.7	96.4	92.8	N.A.	N.A.	%
DTx OFF	SNR > 15 dB and SNR < 23 dB	4	3	3	6	N.A.	N.A.	sites
		90	90	83	83	N.A.	N.A.	sites, total
		4.4	3.3	3.6	7.2	N.A.	N.A.	%
DTx ON	SNR > 15 dB	90	90	83	83	87	87	sites
		90	90	83	83	87	87	sites, total
		100.0	100.0	100.0	100.0	100.0	100.0	%
DTx ON	SNR > 23 dB	90	90	83	83	87	87	sites
		90	90	83	83	87	87	sites, total
		100.0	100.0	100.0	100.0	100.0	100.0	%
DTx ON	SNR > 15 dB and SNR < 23 dB	0	0	0	0	0	0	sites
		90	90	83	83	87	87	sites, total
		0.0	0.0	0.0	0.0	0.0	0.0	%

Finally, in any DTx network consisting of two or more remote gap filler transmitters, the *largest* signal received at each test site in an overlapping coverage region is of interest to DTS designers. **Table 10** illustrates the percentages of sites for which each of the 5 transmitters (or 4, in the case of CH 65) was the largest signal when DTx was *active* and when the receive antenna was oriented for maximum total signal strength. It can be seen that Transmitter A at 16 Court Street is the predominant transmitter among the four remote low-power gap filler transmitters, most likely due to its higher elevation compared to the other gap filler transmitters.

On CH 33 at 30' AGL with DTx active, the ESB transmitter and gap-filler transmitter A (which was on the tallest building of the 4 remote transmitters) had a comparable number (≈**40%** each) of tests sites where each was the largest signal. However, for CH 33 at the lower receive antenna height of 15' AGL, the ESB signal was predominant over gap-filler transmitter A by about **10%**. This is most likely due to the much taller ESB transmit antenna playing a larger role at the lower receive antenna height given more urban obstacles (i.e., buildings) to attenuate the DTV signal. For CH 12, however, transmitter A was by far (**2-to-1** advantage over ESB at 30' AGL) the largest signal since the CH 12 ESB transmitter was not as relatively strong as its CH 33 counterpart. Transmitters B, C, and D had a negligible percentage (≈**10%** or less) of sites where they were the largest signal. However, it must again be pointed out that these results are taken from *outdoor* measurements at 30' AGL and 15' AGL while using a *directional* receive antenna pointed in the direction of maximum signal. Conditions inside a viewer's home were not identical (see the indoor field test results section).

Table 10 Inside the “box” largest field strength (DTx active) site percentages by transmitter

DTx Transmitter	CH 33		CH 12		CH 65		Units
	30’	15’	30’	15’	30’	15’	
A 16 Court Street Gap Filler Tx #1	36	30	43	40	50	51	sites
	89	89	83	83	86	87	sites, total
	40.4	33.7	51.8	48.2	58.1	58.6	%
B 95 Evergreen Gap Filler Tx #2	6	8	6	6.0	19	19	sites
	89	89	83	83	86	87	sites, total
	6.7	9.0	7.2	7.2	22.1	21.8	%
C 730 Linden Gap Filler Tx #3	7	6	7	6.0	9	10	sites
	89	89	83	83	86	87	sites, total
	7.9	6.7	8.4	7.2	10.5	11.5	%
D Bishop Ford High School Gap Filler Tx #4	5	6	8	9.0	8	7	sites
	89	89	83	83	86	87	sites, total
	5.6	6.7	9.6	10.8	9.3	8.0	%
E Empire State Building ESB Tx	35	39	19	22.0	N.A.	N.A.	sites
	89	89	83	83	N.A.	N.A.	sites, total
	39.3	43.8	22.9	26.5	N.A.	N.A.	%

OUTDOOR DTx SERVICE EVALUATION

This section deals with the evaluation of *outdoor* reception (“within the box”) via a directional receive antenna with DTx inactive or active at either 30’ AGL or 15’ AGL. Successful DTV reception (i.e., service), as described in the MTVA field test plan, is defined as 3 burst error “hits” or less in a 3-minute viewing window. Two 5G receivers (NTIA-compliant D/A converter boxes) from different manufacturers were used in the testing (generically referred to as **Rx1** and **Rx2**), and reception data for *each* receiver at every test site was measured and recorded since there is no guarantee that they will both perform identically in the field in all propagation environments.

Table 11 contains the results for outdoor DTV service site statistics. First, notice that with DTx *inactive* (i.e. DTx turned OFF), DTV service was observed to be very high already (**89% - 93%** on both CH 33 and CH 12) considering both DTV receivers and both receive antenna heights. In other words, there were very few outdoor test site reception failures. Of course, this is not surprising since the *peaked* signal field strengths reported in the last section were relatively large, and with the *directional* outdoor receive antenna at 30’ AGL and 15’ AGL, multipath is somewhat mitigated. Ultimately, the true test for New York City is indoor reception, which will be discussed later in this report.

A primary goal is to determine whether DTx technology *helps* DTV reception for a large percentage of test sites that either have weak signals or very poor quality signals (e.g., multipath) or both. However, another valid issue is to determine if DTx transmission *hinders* DTV reception in overlap regions where DTV service already exists without it.

With DTx *active* (i.e., DTx ON), the percentage of successful reception at 30’ AGL *increased* by only **9%** (Rx1 and Rx2) on CH 33. Similarly, successful DTV reception *increased* by only **6%** (Rx1 and Rx2) at 30’ AGL on CH 12. On one hand, these percentage increases are not very compelling, yet on the other hand they must be viewed in light of the fact that DTV service was already very good to start with *before* the DTx was activated.

An interesting phenomenon occurred at 15’ AGL testing. DTV service at the lower antenna height was slightly degraded compared to 30’ AGL, as one might expect. However, as the multipath became more severe at the *lower* antenna height above ground level, the differences in receiver performance became more apparent as Rx1 showed advantages over that of Rx2. For example, CH 33 service improved by almost **2.5%** for Rx1 but degraded by almost **3%** for Rx2. For CH 12, there was an improvement of more than **8%** for Rx1 but only an improvement of about **2%** for Rx2. The service differences between the two consumer receivers are obviously related to the level of equalizer performance in each 5G DTV receiver.

However, it should be noted that the absolute differences in DTV service among *all* of these various scenarios (DTx ON /OFF, 30’/15’, and CH 33/12/65) is relatively small, with service values in the very respectable range of **84% - 100%**. **Table 11** also shows the statistics regarding the number of sites that got better, stayed the same, and got worse. Note the largest percentage of sites (**85% - 92%** across all scenarios) represents DTV service that did *not* change with active DTx, which leads to the conclusion that a vast majority of the sites continued to have successful *outdoor* DTV reception in Brooklyn.

Therefore, a major observation from this data analysis is that the DTx network had very little effect (good or bad) on short-term DTV service for *outdoor* reception with peaked signals at both 30' AGL and 15' AGL. While this may not be surprising, it is a good result under the Brooklyn test conditions (which started out with good DTV service).

In the special case of CH 65 that had no "main" ESB transmitter, a high percentage of sites (**87% - 94%** at 30' AGL and **84% - 93%** at 15' AGL) had DTV reception with only four 1 kWatt low-power gap filler transmitters. This leads to the conclusion that DTV service on upper UHF channels (ultimately limited to CH 51 after the *full-service* DTV transition is complete) is *possible* with strategically-placed synchronized low-power transmitters and no single high-power DTV transmitter on ESB.

Table 11 Inside the "box" DTV service site percentages with antenna adjusted for *peak* signal strength.

DTx Status	CH 33				CH 12				CH 65				Units
	30'		15'		30'		15'		30'		15'		
	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF	82	81	83	80	77	76	74	74	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	91.1	90.0	92.2	88.9	92.8	91.6	89.2	89.2	N.A.	N.A.	N.A.	N.A.	%
DTx ON	90	85	85	77	80	77	81	76	82	76	81	73	sites
	90	90	90	90	83	83	83	83	87	87	87	87	sites, total
	100.0	94.4	94.4	85.6	96.4	92.8	97.6	91.6	94.3	87.4	93.1	83.9	%
Better Service	8	8	5	5	5	5	9	7	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	8.9	8.9	5.6	5.6	6.0	6.0	10.8	8.4	N.A.	N.A.	N.A.	N.A.	%
Same Service	82	78	82	77	76	74	72	71	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	91.1	86.7	91.1	85.6	91.6	89.2	86.7	85.5	N.A.	N.A.	N.A.	N.A.	%
Worse Service	0	4	3	8	2	4	2	5	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	0.0	4.4	3.3	8.9	2.4	4.8	2.4	6.0	N.A.	N.A.	N.A.	N.A.	%

Taking the analysis to the next level, not only is it important to measure DTV service, which often is described as either "all good" or "all bad" due to the digital *cliff effect*, it is important to determine how "close" to the digital cliff the service was at each test site. This is important since these field tests are considered *location* variability tests since a large statistically-relevant number of sites are visited for a short time period. Therefore, *time* variability is **<u>not</u>** being measured, and long-term signal variations (i.e., dynamics) are **<u>not</u>** being considered. One means of assessing reception reliability is to measure margin to the threshold of visible errors for *each receiver* at each test site. Margin is defined in the MTVA field test plan as the amount of attenuation prior to the truck preamplifier that can be inserted before DTV service is lost. This simulates signal fading, and indicates the amount of signal fading that can be tolerated before data errors occur that are displayed in the video (and heard in the audio). Note that this margin test does *not* indicate the effects of fading of the <u>desired</u> channel alone, as might be the case in practice. In reality, this test decreases, in a broadband manner, *all* of the incoming signals, including any potential adjacent RF channel interferors, thus keeping the relative interference D/U ratios constant. However, this margin test *does* bring the multipath-impaired desired DTV signal closer to the truck's noise floor (as determined by the truck's preamplifier) until threshold of errors is reached, and thus provides some measure of margin overhead at a given test site for a given set of propagation and reception conditions (i.e., CH 33, CH 12 or CH 65, 30' AGL or 15' AGL, DTx OFF or DTx ON).

Table 12 contains the margin site statistics and **Table 13** contains the margin site percentages. Note that *without* DTx, the average <u>margins</u> (not SNR values) at 30' AGL for both receivers was greater than **23 dB** (CH 33) and greater than **20 dB** (CH 12), while they were about **3 dB** lower at 15' where the signal levels were slightly lower and the multipath-induced noise enhancement may have been slightly worse. These are very respectable margin numbers, especially for DTx inactive. When DTx was activated, the average margins at 30' AGL increased by about **7 - 9 dB** (CH 33 and CH 12) and increased at 15'AGL by **4 – 9 dB** (CH 33 and CH 12), again presumably due to increased signal strength but also possibly by reduced naturally-induced multipath since a closer transmitter may have been the source of the largest signal to the directional receive antenna. Remember that the receive antenna is repositioned for the maximum signal level when the DTx system is activated, which may be at a different angle than when DTx is inactive. It is believed that outdoor reception margins greater than 25 dB may increase indoor DTV reception statistics, *possibly* accommodating lower gain receive antennas at lower levels above ground level and building penetration loss.

The CH 65 DTx network was only tested with DTx ON since no CH 65 transmitter existed on ESB. On the average, it typically provided **19-23 dB** of margin (for Rx1 and Rx2 at both 15’ AGL and 30’ AGL), indicating that any upper UHF channel may be useful for outdoor reception in Brooklyn, and that it might be useful for indoor reception with a DTx network containing only 1 kWatt low-power distributed transmitters and no large ESB transmitter.

Table 12 Inside the “box” DTV margin statistics with antenna adjusted for peak signal strength.

DTx Status	CH 33				CH 12				CH 65				Units
	30’		15’		30’		15’		30’		15’		
	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF	23.6	23.1	20.0	19.9	20.1	20.1	16.9	17.0	N.A.	N.A.	N.A.	N.A.	dB (ave)
	24.5	24.0	20.0	20.5	20.0	20.0	18.0	17.0	N.A.	N.A.	N.A.	N.A.	dB (med)
	11.8	12.5	10.5	11.3	10.0	10.2	9.6	9.6	N.A.	N.A.	N.A.	N.A.	dB (std dev)
DTx ON	30.9	30.3	25.8	24.3	29.7	28.9	26.4	25.1	22.5	21.6	19.7	18.8	dB (ave)
	32.0	31.5	26.5	26.0	32.0	32.0	26.0	26.0	23.0	22.0	20.0	20.0	dB (med)
	9.8	11.3	11.1	13.0	11.2	12.5	10.7	12.7	10.8	12.0	10.0	11.5	dB (std dev)
Change in Margin with DTx	7.3	7.2	5.8	4.4	9.6	8.8	9.5	8.1	N.A.	N.A.	N.A.	N.A.	dB (ave)
	2.5	3.0	2.0	0.0	8.0	8.0	8.0	7.0	N.A.	N.A.	N.A.	N.A.	dB (med)
	13.0	14.1	11.1	13.1	12.4	13.6	13.4	14.6	N.A.	N.A.	N.A.	N.A.	dB (std dev)

When evaluating DTV service, the well-known digital cliff effect can be very *helpful* (if you are *above* threshold) and it can provide the viewer with perfect picture and sound, or it can be very *harmful* (if you are *below* threshold) and provide the viewer with nothing but blue screen, silence, and frustration. Therefore, it is good to know the percentage of test sites that have at least 10 dB of margin (some amount of safety for outdoor reception in a severe multipath environment). A severe multipath condition can cause 5 dB to 8 dB of noise threshold degradation as well as some amount of flat spectral fading as well. Therefore, 10 dB is a reasonable number to use for a *minimum* desired margin for outdoor reception. Of course, additional margin would also be desired when indoor reception is of prime importance.

From **Table 13**, it can be seen that with DTx *inactive*, approximately **75% - 85%** of the sites (both 30’ AGL and 15’ AGL) had at *least* 10 dB of margin on CH 33 and CH 12. For all of the test scenarios with DTx *active* (CH 33 & CH 12, 30’ or 15’ AGL), the percentage of sites with greater than 10 dB of margin was greater than **83%**, as would be expected and desired. Between **50%** and **75%** of the sites experience some margin increase. Even CH 65 provided **80% – 86%** of the test sites with 10 dB of margin or better with the strategically place low-power gap filler transmitters.

Also demonstrated in **Table 13** is the fact that there are a majority of sites that had *improved* margins or *identical* margins with DTx active. However, there were definitely sites that had *reduced* margin when DTx was active, most likely due to the increased self-induced multipath from DTx. However, the resulting margin value often did not degrade significantly, and a vast majority of those sites where margins degraded still had margin values greater than 10 dB remaining, potentially still providing reliable DTV reception.

In **Table 11**, **Table 12** and **Table 13**, the overall performance advantage of **Rx1** over that of **Rx2** can be seen. While both DTV receivers utilize 5G VSB decoders, and both have passed the stringent NTIA-required RF performance specifications for certification, it should be noted that there still can be some performance differences among the various receivers on the market. **Table 11** reveals that Rx2 does not perform quite as well as Rx1 when DTx is active. Clearly, **Table 12** shows that while Rx1 and Rx2 sometimes provided comparable levels of margin over large numbers of test sites, Rx2 on the average had **1 – 2 dB** less margin than Rx1. Finally, **Table 13** demonstrates that Rx2 provided **5% - 10%** less sites that have at least 10 dB of margin. Despite these differences, Rx2 still had reasonable DTV reception in the field, and occasionally had **1 dB** or **2 dB** better margin than Rx1.

Therefore, while the DTx could not significantly improve outdoor DTV *service* at 30’ AGL and 15’ AGL since service was already so good, it indeed did improve site *margins*, and therefore provide for the potential of increased DTV service availability over time as conditions vary diurnally and seasonally.

Table 13 Inside the "box" DTV margin site percentages with antenna adjusted for peak signal strength.

DTx Status	CH 33				CH 12				CH 65				Units
	30'		15'		30'		15'		30'		15'		
	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF (M > 10 dB)	78	76	71	69	69	69	63	63	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	86.7	84.4	78.9	76.7	83.1	83.1	75.9	75.9	N.A.	N.A.	N.A.	N.A.	%
DTx ON (M > 10 dB)	88	85	81	75	79	77	79	73	75	71	73	69	sites
	90	90	90	90	83	83	83	83	87	87	87	87	sites, total
	97.8	94.4	90.0	83.3	95.2	92.8	95.2	88.0	86.2	81.6	83.9	79.3	%
Better Margin (Δ > 0 dB)	51	51	51	44	62	61	55	54	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	56.7	56.7	56.7	48.9	74.7	73.5	66.3	65.1	N.A.	N.A.	N.A.	N.A.	%
Same Margin (Δ = 0 dB)	8	10	12	16	10	7	7	4	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	8.9	11.1	13.3	17.8	12.0	8.4	8.4	4.8	N.A.	N.A.	N.A.	N.A.	%
Worse Margin (Δ < 0 dB)	31	29	27	30	11	15	21	25	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	34.4	32.2	30.0	33.3	13.3	18.1	25.3	30.1	N.A.	N.A.	N.A.	N.A.	%
Worse Margin but OK (Δ < 0 dB) (M > 10 dB)	30	26	22	20	10	11	19	17	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	33.3	28.9	24.4	22.2	12.0	13.3	22.9	20.5	N.A.	N.A.	N.A.	N.A.	%

OUTDOOR DTx RANGE OF ROTATION EVALUATION

The last major evaluation of the DTx system performance in the Brooklyn area is the range of antenna rotation that provides successful DTV reception. By measuring at every test site the number degrees of antenna azimuth rotation that provides DTV reception, referred to as range of rotation (**ROR**), an indication can be obtained as to how easy it might be for a viewer to manually adjust an outdoor antenna when it is installed or remotely adjust it (with the aid of a rooftop rotor) after installation.

Table 14 contains the statistical data for range of rotation for all the test sites. The average range of rotation with DTx *inactive* and using a *directional* antenna is between **200 degrees – 300 degrees** for both CH 33 and CH 12 at both 30' and 15' AGL antenna heights. This is a respectable range of rotation and it indicates that there is enough signal level to be received from the side and possibly back lobes of the antenna as well as there being possibly enough signal reflection off the local urban clutter (e.g., homes, apartments, stores, water towers, etc.) to provide a decodable DTV signal. With DTx *active*, there was an interesting "mixed bag" of test results. Rx1 exhibited significant increases in range of rotation (between **20 degrees – 100 degrees**) while Rx2 did not exhibit the same significant increases (between **-10 degrees** and **40 degrees**). The CH 65 DTx system provided an average range of rotation of at least **110 degrees**.

These antenna ranging results are very respectable, and allow for the *possibility* of reasonably easy and straightforward outdoor antenna adjustment. However, it must be pointed out that in some instances, it was difficult to measure the range of rotation due to *dynamic* signal conditions (e.g., nearby traffic flow, airplane flutter, etc.). Dynamics at some locations were significant and variable, which is a good reminder that this DTx field test is a *location* variability test and **NOT** a long-term *time* variability test.

Table 14 Inside the “box” DTV range of rotation statistics with antenna adjusted for *peak* signal strength.

DTx Status	CH 33				CH 12				CH 65				Units
	30’		15’		30’		15’		30’		15’		
	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF	300.4	256.4	290.0	240.5	266.4	254.2	242.6	228.3	N.A.	N.A.	N.A.	N.A.	deg (ave)
	360.0	307.5	360.0	296.0	305.0	273.0	270.0	236.0	N.A.	N.A.	N.A.	N.A.	deg (med)
	107.9	124.3	115.1	134.5	107.8	110.7	121.6	119.1	N.A.	N.A.	N.A.	N.A.	deg (std dev)
DTx ON	337.0	259.0	313.5	231.9	350.1	289.5	344.6	267.8	289.8	224.1	275.8	207.0	deg (ave)
	360.0	360.0	360.0	294.0	360.0	360.0	360.0	360.0	360.0	261.0	340.0	235.0	deg (med)
	65.3	130.5	104.9	139.9	49.1	109.7	54.1	122.8	109.4	138.4	112.7	142.7	deg (std dev)
Change in ROR with DTx	36.5	2.6	23.5	-8.5	83.7	35.3	102.0	39.5	N.A.	N.A.	N.A.	N.A.	deg (ave)
	0.0	0.0	0.0	0.0	41.0	17.0	72.0	8.0	N.A.	N.A.	N.A.	N.A.	deg (med)
	118.0	171.8	132.4	169.9	106.6	130.3	116.2	162.0	N.A.	N.A.	N.A.	N.A.	deg (std dev)

Finally, it is advantageous to know the percentage of sites that had what may be called reasonably “safe” minimal range of rotation for successful DTV reception. **Table 15** contains site percentages for range of rotation. Of course, the definition of a safe value can be considered a *subjective* assessment. Therefore, a couple of adjustment range values were considered in this analysis.

For example, a large percentage of test sites (**80% - 90%**) with DTx *inactive* had at least 90 degrees of range of rotation for successful DTV reception and an even higher percentage had a smaller range of 45 degrees. However, a 90-degree range of rotation should allow a typical viewer to easily adjust an *outdoor* antenna towards the general direction of a group of transmitter antennas in an antenna “farm” (which may be on top of a large urban building or two) or towards multiple station groups of transmitters that happen to be spaced around 90 degrees apart from each other relative to a given receive site. Remember that if two groups of antennas are 90 degrees apart, pointing the antenna half-way in-between the two groups will cause only a 45-degree error for the antenna. Most outdoor antennas have at least 60-degree 3-dB beamwidths, and coupled with the strong signal levels measured in the Brooklyn area, good *outdoor* reception seems possible.

Of course, with DTx active, one would expect the range of rotation to increase. From **Table 15**, approximately **1/3 to 2/3** of the test sites experience some range of rotation *improvement* (both CH 33 and CH 12 at both 30’ and 15’ AGL). A fair amount of sites remained the *same* with regard to range of rotation (many of these “same-range” sites had 360-degree values for *both* DTx OFF and DTx ON conditions). Naturally, one might expect that the extra DTx-induced multipath might cause the receivers to fail for certain angular sectors and thus reduce the range of rotation. This was, in fact, the case at a number of sites (**2% – 15%** for Rx1 and **25% - 40%** for Rx2). Obviously, the data clearly shows that Rx1 had better RF performance (probably with regard to multipath) than that of Rx2. One encouraging issue regarding these reduced range-of-rotation sites is that many of these sites still had 90 degrees or more of range of antenna rotation with DTx active, meaning that their range of rotation degradation still allowed for reasonable antenna adjustment by the viewer and thus potential for successful *outdoor* DTV reception.

Table 15 Inside the “box” DTV range of rotation site percentages with antenna adjusted for peak signal strength.

DTx Status	CH 33				CH 12				CH 65				Units
	30’		15’		30’		15’		30’		15’		
	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF (ROR >45 deg)	84	81	83	75	79	77	74	75	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	93.3	90.0	92.2	83.3	95.2	92.8	89.2	90.4	N.A.	N.A.	N.A.	N.A.	%
DTx OFF (ROR >90 deg)	82	76	81	72	75	75	72	72	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	91.1	84.4	90.0	80.0	90.4	90.4	86.7	86.7	N.A.	N.A.	N.A.	N.A.	%
DTx ON (ROR >45 deg)	90	82	85	77	82	78	82	76	83	74	82	68	sites
	90	90	90	90	83	83	83	83	87	87	87	87	sites, total
	100.0	91.1	94.4	85.6	98.8	94.0	98.8	91.6	95.4	85.1	94.3	78.2	%
DTx ON (ROR >90 deg)	88	77	81	68	82	75	82	72	79	64	79	61	sites
	90	90	90	90	83	83	83	83	87	87	87	87	sites, total
	97.8	85.6	90.0	75.6	98.8	90.4	98.8	86.7	90.8	73.6	90.8	70.1	%
Better ROR w/DTx (Δ > 0 deg)	30	34	27	28	49	43	51	43	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	33.3	37.8	30.0	31.1	59.0	51.8	61.4	51.8	N.A.	N.A.	N.A.	N.A.	%
Same ROR w/DTx (Δ = 0 deg)	52	24	49	26	32	19	30	14	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	57.8	26.7	54.4	28.9	38.6	22.9	36.1	16.9	N.A.	N.A.	N.A.	N.A.	%
Worse ROR (Δ < 0 deg)	8	32	14	36	2	21	2	26	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	8.9	35.6	15.6	40.0	2.4	25.3	2.4	31.3	N.A.	N.A.	N.A.	N.A.	%
Worse ROR but OK (Δ < 0 dB) (ROR >90 deg)	6	21	6	21	2	16	1	16	N.A.	N.A.	N.A.	N.A.	sites
	90	90	90	90	83	83	83	83	N.A.	N.A.	N.A.	N.A.	sites, total
	6.7	23.3	6.7	23.3	2.4	19.3	1.2	19.3	N.A.	N.A.	N.A.	N.A.	%

OUTDOOR INTERFERENCE SITES EVALUATION

The MTVA field test plan called for some small number of test sites outside the “Brooklyn box” that were predicted to possibly have self-interference. These sites were visited to evaluate any possible DTx self-interference effects since these receive areas were predicted to have relative amplitudes and delays (compared to the main ESB signal) from the multiple synchronized transmitted signals that might fall outside the cancellation delay range of a typical DTV receiver.

However, there were only **6** interference sites visited since the initial focus is “inside the box” for DTx performance. Therefore, with this small number of interference test sites, there is no statistically-relevant data to report. Nevertheless, the results from these **6** test sites generally indicated that there was no interference observed if they already had DTV reception without DTx active.

INDOOR FIELD TEST DATA ANALYSIS

INDOOR FIELD TEST OVERVIEW

While the primary interest of the MTVA field test was *indoor* reception, only **23** indoor sites were able to be visited during the field test as opposed to **109** outdoor sites. Indoor field testing has always been the most challenging type of field test to perform due to the required participation of willing volunteers opening their home to “invasion” by engineers with computers and other scientific equipment. Nevertheless, indoor testing was called for in the MTVA field test plan, and was accomplished, although on a much *smaller* scale than the outdoor testing due to practical considerations.

Since there is only a data set of **23** indoor test sites, with only **10** sites “inside the box” as desired, little meaningful statistically-relevant analysis can be performed, and widespread prediction of indoor performance is difficult at best.

However, *some* tabulation of the entire data set has been performed, while other anecdotal data analysis has been included in this report.

INDOOR FIELD STRENGTH EVALUATION

The first consideration in the performance evaluation of the DTx network is *peak* DTV field strength at each test site. The indoor antenna was first rotated to determine the angle at which the *maximum* DTV signal occurred at a given site. This was performed for each of the 6 individual test scenarios at each indoor test site. Total *average* DTV signal power (in 6 MHz) was measured at the spectrum analyzer input, and the equivalent root-mean-square (**rms**) field strength (in dBµV/m) was *calculated* using the previously calibrated indoor test system net gain (in dB) from antenna output to spectrum analyzer input. The net indoor test system gain includes the short coaxial feed-line cable loss (in dB), variable attenuator loss (in dB), and preamplifier gain (in dB), plus the known antenna gain over dipole (in dBd) and the dipole conversion factor for each RF channel. Appropriate frequency-dependent parameter values were used for *each* test channel.

Indoor field strength analysis, shown in **Table 16**, provides some insight into the ability of the DTV signal to penetrate buildings in the New York City area. Of particular interest is the DTx inactive statistics for all **23** sites where the average ESB signal strength (with the dipole antenna adjusted for maximum signal level) *inside the buildings* was very respectable (about **69 dBµV/m** on CH 33 and about **51 dBµV/m** on CH 12) using a dipole antenna. Of course, there is no result for CH 65 since there was no CH 65 transmitter at ESB (i.e., no DTV inactive condition).

Some observations can be made regarding these results. The average DTV field strength on CH 33 and CH 12 with DTx *inactive* was sufficiently above the required minimal level for successful DTV reception with typical indoor receive equipment. Since most of the indoor test sites (**13 out of 23**) were *outside* the box, the average *increase* in the indoor field strength with DTx active was only about **4 dB** (both CH 33 and CH 12).

However, when only the **10** Brooklyn "box" indoor sites are considered, the average field strength increase was noticeably greater (**7 dB** for CH 33 and about **9 dB** for CH 12), climbing from an average of **66 dBµV/m** to **73 dBµV/m** on CH 33 and from **51 dBµV/m** to **60 dBµV/m** on CH 12. The greater *increase* (i.e., change) in field strength with DTx active for these particular **10** test sites compared to the analysis with all **23** sites is due to the fact that these **10** sites were all inside the box and therefore they all benefited from the extra gap filler transmitter signals. Also, CH 12 exhibited a larger field strength increase than CH 33 with DTx *active* for the Brooklyn "box" test sites since the temporary ESB CH 12 transmitted signal is highly directional and relatively low power unlike the commercial omni-directional, high-power CH 33 transmitter signal, and can therefore benefit more from the extra "boost" that gap filler transmitters provide. Finally, the CH 65 received signal exhibited reasonable average indoor field strengths (**64 dBµV/m** with DTx active) at the **10** homes that were inside the box.

It should be noted that these results must be "taken with a grain of salt" for a couple of reasons. First, with only **23** total indoor test sites, and only **10** of them inside the box, statistical relevancy does not hold. Also, the indoor field strength values are also affected by the fact that the indoor test sites varied in height above ground level from **0' AGL** (ground level) to **60' AGL** (6th floor), i.e., they were located on a variety of different floors within the buildings where the testing was performed. Therefore, some of the indoor test sites were located *above* the outdoor 30' AGL height. To achieve relevant statistics for field strength in the region would require significantly more indoor test sites "inside the box."

Table 16 Indoor field strength statistics.

DTx Status	Primary Antenna			Secondary Antenna			Units
	CH 33	CH 12	CH 65	CH 33	CH 12	CH 65	
DTx OFF (all) (All **23 sites**)	68.8	51.4	N.A.	65.0	49.5	N.A.	dBµV/m (ave)
	67.7	50.2	N.A.	64.0	47.4	N.A.	dBµV/m (med)
	9.4	7.0	N.A.	9.4	7.4	N.A.	dBµV/m (std dev)
DTx ON (All **23 sites**)	72.4	56.0	61.6	68.7	53.9	57.8	dBµV/m (ave)
	70.4	55.5	58.4	66.7	52.5	53.8	dBµV/m (med)
	8.6	9.7	10.2	8.6	9.7	10.9	dBµV/m (std dev)
DTx OFF (Inside the Box) (**10 sites**)	66.2	51.1	N.A.	62.1	49.0	N.A.	dBµV/m (ave)
	66.6	49.7	N.A.	61.0	46.9	N.A.	dBµV/m (med)
	8.6	6.5	N.A.	7.5	6.5	N.A.	dBµV/m (std dev)
DTx ON (Inside the Box) (**10 sites**)	72.7	60.4	68.0	70.0	58.1	65.0	dBµV/m (ave)
	70.4	58.0	64.3	66.9	56.4	65.4	dBµV/m (med)
	7.5	10.2	7.7	7.0	9.7	7.5	dBµV/m (std dev)

An important aspect of the indoor field testing is the outdoor-to-indoor signal attenuation that is experienced in an urban area such as New York City. Therefore, at every indoor field test site, a companion outdoor test site measurement (referred to as a "driveway" measurement) was performed. This provided a reference outdoor set of data to match that gathered inside the home. The primary purpose of doing this was to determine not only the attenuation that the signal experiences as it travels from outside to inside (antenna height loss and building penetration loss), but to also ascertain what typical outside signal levels are required for acceptable indoor DTV reception with and without DTx.

The field test truck was parked as close as possible to the indoor test location, often on the street right in front of the building under test and typically within 50'. However, it is well understood that outdoor signal strength variations, sometimes large due to the presence of multipath, can occur over relatively short distances. Likewise, as mentioned above, the indoor test sites were located on different floors within the building, often *higher* above the ground level than the outside measurement (15' AGL and 30' AGL). For instance, **39%** (**9** out of **23**) sites were on floors 30' AGL or higher, and **74%** (**17** out of **23**) were on floors 15' AGL and higher. Understandably, some of the indoor test sites exhibited quite a bit *larger* field strengths inside than outside (e.g. some sites had indoor field strength levels **10 dB** – **16 dB** *higher* than the 15' AGL or 30' AGL outdoor field strength levels), thereby biasing the attenuation factors much *lower* than what would be expected for typical two-story single-family (residential) homes. Therefore, the following outdoor-to-indoor attenuation data, shown in **Table 17**, must be put into proper perspective when analyzing the results. With this biased test situation, the typical average attenuation values from outdoor at 30' AGL to indoor were about **6 dB** for CH 33, about **8.5 dB** for CH 12, and **5 dB** for CH 65.

Table 17 Outdoor-to-indoor field strength attenuation statistics.

DTx Status	30' AGL to Primary Antenna			15' AGL to Primary Antenna			Units
	CH 33	CH 12	CH 65	CH 33	CH 12	CH 65	
DTx OFF (All **23 sites**)	5.6	7.8	N.A.	5.0	5.5	N.A.	dB (ave)
	6.6	6.3	N.A.	5.8	5.0	N.A.	dB (med)
	6.5	10.4	N.A.	7.0	8.4	N.A.	dB (std dev)
DTx ON (All **23 sites**)	6.4	8.9	5.6	4.3	6.2	4.4	dB (ave)
	8.3	6.5	4.9	5.1	4.1	4.2	dB (med)
	8.8	10.0	10.3	7.9	8.7	9.2	dB (std dev)

Table 18 contains the corresponding statistical SNR values for these indoor sites. From this data, it is obvious that it is possible to provide reasonable SNR values inside the home to allow for the possibility of indoor reception without DTx. With DTx, the SNR values increase by **several dB or more**, even when including sites "outside the box," and they increase significantly for sites "inside the box" that benefit from the multiple synchronized DTx transmitters.

Table 18 Indoor SNR statistics.

DTx Status	Primary Antenna			Secondary Antenna			Units
	CH 33	CH 12	CH 65	CH 33	CH 12	CH 65	
DTx OFF (All Sites) (All **23 sites**)	37.6	30.3	N.A.	37.8	30.6	N.A.	dB (ave)
	36.9	29.0	N.A.	36.8	28.8	N.A.	dB (med)
	9.0	6.9	N.A.	8.9	7.1	N.A.	dB (std dev)
DTx ON (All Sites) (All **23 sites**)	41.3	34.8	28.6	41.5	34.9	30.3	dB (ave)
	39.4	34.4	25.6	39.9	33.9	26.7	dB (med)
	8.4	9.6	10.4	8.2	9.6	11.1	dB (std dev)
DTx OFF (Inside the Box) (Only **10 sites**)	35.2	30.2	N.A.	35.0	30.3	N.A.	dB (ave)
	35.5	28.7	N.A.	33.8	28.3	N.A.	dB (med)
	8.7	6.4	N.A.	7.6	6.5	N.A.	dB (std dev)
DTx ON (Inside the Box) (Only **10 sites**)	41.7	39.4	35.2	43.0	39.4	37.7	dB (ave)
	39.3	37.1	31.7	39.9	37.8	38.3	dB (med)
	7.6	10.3	7.7	7.2	9.7	7.5	dB (std dev)

INDOOR SERVICE EVALUATION

During the MTVA field test, only **10** of the **23** indoor test sites could be obtained *inside* the Brooklyn "box" (as defined by the location of the 4 low-power gap filter transmitters). Therefore, a majority of the test sites (**13**) did not experience full (or in some cases, not even partial) benefits from the DTx network signals, and were possibly even degraded by self-interference. Therefore, complete statistical DTx service analysis on all the visited test sites (**23**) was *not* warranted in this case (as it was in the outdoor field testing) as it would unfairly describe the DTx system performance since the major focus of the prototype design and field test was inside the Brooklyn "box". However, UHF CH 33 service directly from ESB (i.e., DTx *inactive*) was, in fact, analyzed and evaluated at all **23** indoor test sites since the transmitted commercial signal is operating at full power in all azimuth directions, although not with an optimum transmit antenna configuration due to the current overcrowding of antennas on the ESB mast. This specific statistical analysis provides some indication of current indoor DTV reception from ESB on a UHF channel without DTx. The CH 12 test results for the entire **23** indoor test sites were not completely evaluated statistically due to the CH 12 transmitter with its *lower effective radiated power* and *directional transmit antenna* on ESB, nor were the CH 65 results evaluated statistically for the entire **23** indoor test sites since there was not a CH 65 transmitter on ESB (i.e., there was no "DTX inactive signal to measure).

Using the primary UHF dipole receive antenna in each home, successful DTV reception was observed in **16** out of **23** homes (about **70%**) with Rx1 and **15** out of **23** (about **65%**) with Rx2, which are not bad results for using the existing single-source CH 33 ESB signal. This would indicate that, with a better transmit antenna facility on ESB, *perhaps* acceptable indoor DTV reception *might* be possible regionally.

For the *complete* evaluation of the DTx system, on the **10** Brooklyn "box" indoor test sites were considered. The results are shown in **Table 19** and **Table 20** for the primary and secondary receive antennas, respectively. While statistically not relevant due to the small number of test sites, the indoor test results do provide some indication of DTx performance benefits.

For the primary indoor receive antenna, CH 33 indoor DTV service with DTx *inactive* was reasonable (**70%**), and improved with DTx *active* (**90%**). CH 12 indoor DTV service with DTx *inactive* was very poor (**20%**), and only slightly increased with DTx *active* (**30%**). CH 65 with DTx *active* had very good indoor DTV service (**90%**), indicating that indoor service is possible with just four synchronized low-power gap filler transmitters.

Likewise, the indoor test results from these **10** indoor sites within the box show improvements in margin and range of antenna rotation on CH 33 and CH 12 with DTx active. Margins and range of rotation on CH 65 are also very encouraging. Also note that Rx1 once again exhibits slightly better indoor performance on the average than does Rx2.

Table 19 *Primary* antenna test results for the **10** "in-the-box" DTV indoor test sites

DTx Status	Test Parameter	CH 33		CH 12		CH 65		Units
		Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF (**10** sites)	DTV Service	70.0	60.0	20.0	10.0	N.A.	N.A.	%
	Margin	12.5	11.9	3.6	2.2	N.A.	N.A.	dB (ave)
	Range of Rotation	179.5	170.0	36.0	36.0	N.A.	N.A.	deg (ave)
DTx ON (**10** sites)	DTV Service	90.0	80.0	30.0	30.0	90.0	90.0	%
	Margin	18.2	16.6	9.0	8.8	16.6	16.4	dB (ave)
	Range of Rotation	288.0	261.0	92.0	92.0	251.5	233.5	deg (ave)

The secondary (directional) receive antenna also provided similar types of results (service, margin, and range of rotation), although not quite as good as the primary (dipole) receive antenna. Obviously, range of rotation could easily be better with the primary dipole antenna since the entire "back side" of its adjustment range is the same as its "front side" due to its "figure-8" azimuth pattern that provides no front-to-back attenuation ratio. On the other hand, one might have expected that service and margin would have been slightly better with the directional antennas (some multipath mitigation due to antenna directionality) unless the equalizer hardware and control algorithm makes good use of the "extra" echoes allowed by dipole antennas to help decode the DTV signal. Of course, the downside to dipole receive antennas is that they do not isolate certain sections of the viewing room as someone walks through and possibly disrupts the propagation path (which did occur occasionally during the MTVA indoor field tests). During these dynamic situations, a receiver with a dipole antenna must almost totally depend on its equalizer for error-free reception (except for the nulls in its azimuth pattern), which is a situation where receivers can differentiate themselves in performance from others. Nevertheless, there is encouragement that acceptable indoor service *may* be possible in New York City with appropriate optimizations in both transmitter system and receiver *system* design.

Table 20 *Secondary* antenna test results for the **10** "in-the-box" DTV indoor test sites

DTx Status	Test Parameter	CH 33		CH 12		CH 65		Units
		Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
DTx OFF (**10** sites)	DTV Service	60.0	50.0	20.0	20.0	N.A.	N.A.	%
	Margin	10.1	9.4	3.9	3.8	N.A.	N.A.	dB (ave)
	Range of Rotation	144.5	138.0	30.0	30.0	N.A.	N.A.	deg (ave)
DTx ON (**10** sites)	DTV Service	80.0	80.0	30.0	30.0	80.0	80.0	%
	Margin	18.6	18.3	8.6	8.1	16.1	15.8	dB (ave)
	Range of Rotation	208.5	208.5	58.0	54.0	265.5	265.5	deg (ave)

The comparison between DTx inactive and DTx active for indoor DTV reception is shown in **Table 21** for the **10** inside-the-box test sites. Each indoor test site was evaluated for DTV service, margin, and range of rotation with and without DTx, and then categorized as having either *better* performance, *same* performance, or *worse* performance with DTx. Once again, with only **10** Brooklyn "box" sites, there is not enough data to be statistically relevant, but the trends are very similar to those found from the outdoor field testing. Note that many of the sites had good DTV reception *without* DTx, and therefore no benefit was seen in DTV service. However, the margin and range of rotation was improved at a large percentage of sites, particularly for Rx1. These results also show that while the margin was sometimes reduced when DTx was active, some of these "degraded" sites still had more than 10 dB of margin (i.e., the "worse, but OK" description). It can also be seen from these results that DTx did not perform as well on CH 12 as it did on CH 33.

Table 21 Comparison test results for the **10** "inside the box" indoor test sites for CH 33 and CH 12.

Parameter	Comparison (**10** sites)	**Primary Antenna**				**Secondary Antenna**				Units
		CH 33		CH 12		CH 33		CH 12		
		Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	Rx1	Rx2	
Service	Better	30	40	20	20	30	40	20	20	%
Service	Same	60	40	70	80	60	50	70	70	%
Service	Worse	10	20	10	0	10	10	10	10	%
Margin	Better	60	50	20	20	60	60	30	20	%
Margin	Same	0	10	60	70	10	10	60	60	%
Margin	Worse	40	40	20	10	30	30	10	20	%
Margin	Worse, but OK	30	20	10	10	20	20	0	10	%
ROR	Better	50	50	20	20	40	40	20	20	%
ROR	Same	30	30	80	80	30	30	60	60	%
ROR	Worse	20	20	0	0	30	30	20	20	%
ROR	Worse, but OK	0	0	0	0	0	0	0	0	%

As part of the indoor DTV reception testing, a smart antenna was evaluated at *each* house, and for *each* receiver since this technology is expected to be available to consumers in the near future. The same smart antenna was used (sequentially) with each DTV receiver in order to minimize the number of test variables and thus keep the comparisons straightforward. The first step was to perform a channel scan with the receiver, letting it find as many DTV stations as it could, automatically optimizing the antenna for the best receive conditions. Once the scan was completed, which took noticeably *longer* than a normal scan without the smart antenna, and the received channels were stored in the receiver's channel memory, the tester sequentially selected the three desired DTV test channels to evaluate reception.

The smart antenna was found to generally work when the manually adjusted antennas succeeded, and it generally did not work when the manually-adjusted antennas failed. With all the scenarios (three RF channels, two types of receive antennas, and DTx active and inactive), the smart antenna mimicked the manually-adjusted antenna in terms of DTV service almost **90%** of the time. The other 10% of the time, the smart antenna split almost in half the number of times it was better than the manually-adjusted antenna and the times that it was worse.

While the smart antenna did *not* make much of an improvement, it essentially did not make matters worse, and it did provide *automatic* antenna adjustment (appreciated by most viewers, especially the "couch potatoes"), although at the cost of an increased channel scan time. It should be noted, however, that the smart antenna algorithms in these very early generation of smart controllers *apparently* do not constantly update the antenna optimization, nor is updating done when there is a channel change. Consequently, these primitive algorithms do not attempt to correct for quickly changing propagation effects (from dynamic conditions *outside* the home or movement of people *inside* the home) nor does it attempt to update its parameters for even slowly changing propagation effects (unless a manual scan is performed). Perhaps new algorithms may account for these types of changes in future products.

ANECDOTAL DTx OBSERVATIONS

During any type of field testing, there are often important observations made regarding the received signal and the conditions surrounding it, and these observations go a long way to help further understand RF propagation phenomenon in the real world. The MTVA New York City field test was no exception. The following material summarizes some of these observations, particularly with regard to DTV propagation in a major urban area and the effects of a DTx system. *Twelve* examples are briefly described, along with plots from a small number of the many (over 14,000) data files that were captured and archived as part of the MTVA DTx field test in New York City.

These examples are taken from a *variety* of test sites with varying propagation conditions, and include data from all three RF test channels (CH 33, CH 12, CH 65), both outdoor receive antenna height conditions (30' AGL and 15' AGL), and both indoor receive antenna types. All of these examples describe the system performance in field conditions that existed when the DTx network was *active* rather than inactive. Using the active DTx condition (rather than DTx inactive) simultaneously serves two purposes: (1) it shows the measurement results of two or more synchronized transmitters in a single frequency network, and (2) it still demonstrates the naturally-occurring multipath in a large urban area that each individual transmitter signal experiences. The primary purpose of these examples is to demonstrate some of the various propagation conditions that were encountered in the field, which will give broadcast engineers a better understanding of real-world conditions and their effect on urban DTV reception and distributed transmission.

Each of the examples described below refers to a *pair* of plots (contained in **Figure 8** through **Figure 19**), one showing the DTV signal spectrum at the time of the test and the other showing a TxID of the propagation channel impulse response (**CIR**) as measured using the RF watermark TxID test signal that was inserted 30 dB below the 6 MHz DTV signal. The spectrum analyzer plots display the desired DTV test channel on a 20 MHz span so that the first upper and lower adjacent channel is shown. The TxID analyzer plots are *not* the ones that were seen by the testers on site, but rather they are Excel plots that were created with a comma separated variable (CSV) file that was obtained from the TxID's control program. Each vertical line represents the relative *amplitude* and *delay* of an individual signal propagation path. Note that the horizontal linear time delay scale for these TxID plots varies from example to example in order to best illustrate the different field conditions that were encountered Also note that the vertical logarithmic scale has a maximum value of 0 dB (i.e., the largest received signal is defined as 0 dB and all the others are considered pre-echoes and post-echoes below this reference). The minimum value is -10 dB (which removes the sometimes-confusing noise-like data results from the RF watermark cross-correlation process). See Appendix 1 for more background information on the RF Watermark ID process.

The various curves on the TxID plots represent the different transmitter signals received at the give test site, and all have the same legend definitions:

Curve A = Gap Filler Transmitter #1 = **Blue** Diamond (16 Court Street)
Curve B = Gap Filler Transmitter #2 = **Lavender** Square (95 Evergreen)
Curve C = Gap Filler Transmitter #3 = **Orange** Triangle (730 Linden)
Curve D = Gap Filler Transmitter #4 = **Turquoise** "X" (Bishop Ford High School)
Curve E = ESB Transmitter = **Purple** Circle (Empire State Building)

It is important to remember that, while the spectrum analyzer and Tx ID analyzer plots are very helpful in determining ***static*** conditions at a given test site, ***dynamic*** conditions are not represented in these plots and these dynamic conditions may have significant effects on DTV reception. On-site expert observers often provide additional valuable information that may further help in assigning the cause of DTV reception problems in the field.

Each example in the text below describes the test site name and type as well as the base file name from which the spectrum and TxID plots were generated. The DTV signal attributes are also included (channel number, field strength, and SNR) as well as the signal multipath conditions. Note that the largest transmitter signal that was received is identified in the examples, and is called the main signal. All other transmitter signals are referred to as DTx-induced *multipath* since all the DTx transmitters are synchronized so that identical signals are transmitted from all the transmitters. However, each type of signal (main or otherwise) can have its own self-induced (i.e., naturally occurring) multipath, and they are identified as such. Remember that all of these echoes (pre- or post-, naturally-occurring or DTx-induced) act like static multipath to the DTV equalizer due to DTx synchronization. The description of the echo amplitude A_E (i.e., the strength) uses the following guidelines:

Very Strong: $-1\text{ dB} \leq A_E$
Strong: $-3\text{ dB} \leq A_E < -1\text{ dB}$
Moderate: $-7\text{ dB} \leq A_E < -3\text{ dB}$
Weak: $A_E < -7\text{ dB}$

The examples are numbered consecutively from 1 through 12.

Example 1: Reference Plot: **Figure 8**

Test Site: B54 File - 15-HD-011-T5-12 Driveway test site, 15' AGL

Signal attributes: CH 12 Field Strength = 41.1 dBµV/m SNR = 20.0 dB

Largest signal: Tx E (minimal multipath)

DTx signals: Tx A = -3.8 dB @ +20.8 µsecs (minimal multipath)

DTV reception: Rx1 service - No; Rx1 margin = 0 dB
Rx2 service - No; Rx2 margin = 0 dB

Comments: A strong, long, DTx-induced *post*-echo plus a relatively weak signal (SNR= 20 dB) probably caused lack of service. Flat amplitude spectrum occurred since the strong multipath echo is so long that multiple ripples fell within resolution bandwidth of the spectrum analyzer and are averaged out.

Example 2: Reference Plot **Figure 9**

Test Site: IN-7 File – S-HI-007-T5-33 Indoor test site, secondary antenna

Signal attributes: CH 33 Field Strength = 59.1 dBμV/m SNR = 32.1 dB

Largest signal: Tx E (strong, short post-echo)

DTx signals: Tx D = -0.6 dB @ -20.4 μsecs (minimal multipath)

Tx A = -9.8 dB @ - 7.8 μsecs (minimal multipath)

DTV reception: Rx1 service - No; Rx1 margin = 0 dB
Rx2 service - No; Rx2 margin = 0 dB

Comments: The very strong, long, DTx-induced *pre*-echo despite a relatively strong signal (SNR> 30 dB) probably caused lack of service. The short echo caused the 4-dB ripple across the 6 MHz DTV signal spectrum.

Example 3: Reference Plot **Figure 10**

Test Site: IN-7 File – S-HI-007-T5-12 Indoor test site, secondary antenna

Signal attributes: CH 12 Field Strength = 42.7 dBμV/m SNR = 24.0 dB

Largest signal: Tx D (2 moderate short post-echo & 1 moderate short pre-echo)

DTx signals: Tx E = -3.5 dB @ +15.8 μsecs (1strong, 1 moderate, & 1weak short pre-echoes)

Tx A = -3.7 dB @ +15.2 μsecs (1 strong short & 1 weak short pre-echoes)

DTV reception: Rx1 service - No; Rx1 margin = 0 dB
Rx2 service - No; Rx2 margin = 0 dB

Comments: The two very strong, long, DTx-induced *post*-echoes plus their own strong pre-echoes, despite a moderately strong signal (SNR> 32 dB), probably caused lack of service. The very short naturally-occurring post-echo caused the 2-dB upwards tilt across the 6 MHz DTV signal spectrum, while the strong DTx-induced echoes are so long that multiple ripples fell within resolution bandwidth of the spectrum analyzer and are averaged out.

Example 4: Reference Plot **Figure 11**

Test Site: A10 File – 30-G1-009-T5-33 Outdoor grid test site, 30’ AGL

Signal attributes: CH 33 Field Strength = 70.5 dBμV/m SNR = 41.9 dB

Largest signal: Tx E (minimal multipath)

DTx signals: Tx A = -3.3 dB @ -18.2 μsecs (many strong, pre- and post-echoes)

DTV reception: Rx1 service - Yes; Rx1 margin = 11 dB
Rx2 service - No; Rx2 margin = 0 dB

Comments: The strong, long, DTx-induced pre-echo plus its own multiple pre-and post echoes, despite a very strong signal (SNR> 40 dB), probably caused lack of service in Rx2. However, Rx1 was able to handle this condition, and demonstrates differing RF performance between various 5G VSB decoders. The strong DTx-induced pre-echoes are so long that multiple ripples fell within resolution bandwidth of the spectrum analyzer and are averaged out.

Example 5: Reference Plot **Figure 12**

Test Site: A33 File – 30-G1-061-T4-65 Outdoor grid test site, 30’ AGL

Signal attributes: CH 65 Field Strength = 64.5 dBμV/m SNR = 32.2 dB

Largest signal: Tx C (weak short post-echo)

DTx signals: Tx D = -2.7 dB @ -1.2 μsecs (moderate, short post-echo)

DTV reception: Rx1 service - Yes; Rx1 margin = 9 dB
Rx2 service - No; Rx2 margin = 0 dB

Comments: The strong, long, DTx-induced *pre*-echo plus its own pre-and post echoes, despite a very strong signal (SNR> 40 dB), probably caused a lack of service in Rx2. However, Rx1 was able to handle this condition, and demonstrates differing RF performance between various 5G VSB decoders. The strong (-2.7 dB), short (1.2 µsecs) DTx-induced echo caused the large (dominant) 10 -15 dB amplitude ripples on the DTV spectrum.

Example 6: Reference Plot **Figure 13**

Test Site: B8 File – 30-G1-051-T4-65 Outdoor grid test site, 30' AGL

Signal attributes: CH 65 Field Strength = 71.4 dBµV/m SNR = 37.3 dB

Largest signal: Tx A (1 moderate & 2 weak short post-echoes & 1 moderate short pre-echo)

DTx signals: Tx B = -3.1 dB @ +3.5 µsecs (minimal multipath)

DTV reception: Rx1 service - Yes; Rx1 margin = 14 dB
Rx2 service - No; Rx2 margin = 0 dB

Comments: The strong, DTx-induced *post*-echo, despite a very strong signal (SNR> 30 dB), probably caused a lack of service in Rx2. However, Rx1 was able to handle this condition, and demonstrates another example of differing RF performance between various 5G receivers. The short pre- and post-echoes of the main signal caused the combination of low-frequency ripple and downward tilt of the spectrum. The strong (-3.1 dB), longer (+3.5 µsecs), DTx-induced echo caused the higher frequency amplitude ripples on the DTV spectrum.

Example 7: Reference Plot **Figure 14**

Test Site: B8 File – 30-G1-051-T5-33 Outdoor grid test site, 30' AGL

Signal attributes: CH 33 Field Strength = 75.0 dBµV/m SNR = 45.2 dB

Largest signal: Tx E (1 very strong, short pre-echo)

DTx signals: Tx B = -1.3 dB @ -2.1 µsecs (minimal multipath)

Tx A = -4.0 dB @ -6.2 µsecs (1 very strong short pre-echo & 1 moderate short post-echo)

DTV reception: Rx1 service - Yes; Rx1 margin = 20 dB
Rx2 service - Yes; Rx2 margin = 17 dB

Comments: Despite the one very strong, DTx-induced short *pre*-echo and a strong self-induced, short *pre*-echo, both receivers were able to provide DTV service with good margins (although there was a 3 dB difference in the margins). The short naturally-occurring pre-echo caused the spectrum dip in the middle of the channel.

Example 8: Reference Plot **Figure 15**

Test Site: B8 File – 30-G1-051-T5-12 Outdoor grid test site, 30' AGL

Signal attributes: CH 12 Field Strength = 63.0 dBµV/m SNR = 41.8 dB

Largest signal: Tx A (1 very strong, short post-echo, 2 weak short pre-echoes)

DTx signals: Tx E = -0.2 dB @ -0.2 µsecs (1 strong post-echo, 1 weak short pre-echo)

Tx B = -7.9 dB @ -1.8 µsecs (2 very strong post-echoes)

DTV reception: Rx1 service - Yes; Rx1 margin = 14 dB
Rx2 service - Yes; Rx2 margin = 12 dB

Comments: Despite the one very strong (-0.2), DTx-induced, short *pre*-echo and a strong, naturally-occurring *post*-echo on the main signal, both receivers were able to provide DTV service with good margins. The very strong, DTx-induced, short pre-echo and the strong short, post-echo on the main signal caused the spectrum tilt at both ends of the RF channel.

Example 9: Reference Plot: **Figure 16**

Test Site: A5 File – 15-G1-023-T5-12 Outdoor grid test site, 15' AGL

Signal attributes: CH 12 Field Strength = 62.4 dBµV/m SNR = 48.7 dB

Largest signal: Tx A (1 weak short pre-echo)

DTx signals: Tx E = -0.5 dB @ -3.7 µsecs (1 moderate pre-echo)

DTV reception: Rx1 service - Yes; Rx1 margin = 20 dB
Rx2 service - Yes; Rx2 margin = 11 dB

Comments: Despite the one very strong (-0.5 dB), DTx-induced *pre*-echo, both receivers were able to provide DTV service with good margins (however, the RF performance difference between the two receivers is seen once again in the margins). With no strong very short echoes, the spectrum remained flat, with the long, strong, DTx-induced echo causing higher-frequency ripple in the spectrum.

Example 10: Reference Plot: **Figure 17**

Test Site: IN-21 File – P-HI-021-T5-33 Indoor test site, Primary antenna

Signal attributes: CH 33 Field Strength = 71.5 dBµV/m SNR = 39.9 dB

Largest signal: Tx E (1 weak short pre-echo, 1 moderate short post-echo)

DTx signals: Tx A = -2.7 dB @ -8.4 µsecs (minimal multipath)

DTV reception: Rx1 service - Yes; Rx1 margin = 19 dB
Rx2 service - Yes; Rx2 margin = 19 dB

Comments: Despite the one strong (-2.7 dB), DTx-induced *pre*-echo, both receivers were able to provide DTV service with good margins (and equivalent performance). The short pre- and post-echoes caused a slight spectrum “bowing” across the band, and the longer DTx-induced echo that causes higher-frequency ripple in the spectrum was averaged out by the spectrum analyzer’s RBW filter.

Example 11: Reference Plot: **Figure 18**

Test Site: A5 File – 15-G1-023-T5-33 Outdoor test site, 15’ AGL

Signal attributes: CH 33 Field Strength = 72.4 dBµV/m SNR = 44.0 dB

Largest signal: Tx E (1 weak pre-echo, 1 weak post-echo)

DTx signals: Tx A = -1.2 dB @ -4.1 µsecs (minimal multipath)

DTV reception: Rx1 service - Yes; Rx1 margin = 19 dB
Rx2 service - Yes; Rx2 margin = 20 dB

Comments: This is a relatively clean site in terms of naturally-occurring multipath. Despite the one very strong (-1.2 dB), DTx-induced *pre*-echo, both receivers were able to provide DTV service with good margins (and approximately equivalent performance). With no strong short echoes, the spectrum was reasonably flat, and the strong, long, DTx-induced pre-echo caused the higher-frequency ripple in the spectrum.

Example 12: Reference Plot: **Figure 19**

Test Site: A2 File – 30-G1-001-T5-12 Outdoor test site, 30’ AGL

Signal attributes: CH 12 Field Strength = 73.3 dBµV/m SNR = 54.3 dB

Largest signal: Tx E (1 weak short post-echo)

DTx signals: Tx A = -3.0 dB @ +3.3 µsecs (1 moderate short pre-echo, 3 moderate post-echoes)

DTV reception: Rx1 service - Yes; Rx1 margin = 32 dB
Rx2 service - Yes; Rx2 margin = 31 dB

Comments: Despite the one strong (-3.0 dB) DTx-induced post-echo, both receivers were able to provide DTV service with very good margins (and approximately equivalent performance). With no significant short echoes, the spectrum is reasonably flat, and the strong, long, DTx-induced echo caused the higher-frequency ripple in the spectrum.

SUMMARY

Distributed transmission for DTV signals has been proposed and standardized by the ATSC. The MTVA New York City field test has allowed the evaluation of the effectiveness of such a DTx system in a major urban area in both the UHF and high-VHF bands, and it has resulted in some much-needed information and experience. Knowledge and understanding of DTx fundamentals, as they apply to the ATSC transmission system, are essential for future DTx success. The MTVA small-scale prototype system in New York City optimized as many of the design parameters as possible, with the goal to ascertain the DTx system's effectiveness in providing this metropolitan area with acceptable outdoor and indoor DTV field strength levels, service, and margin, as well as ease of antenna adjustment. However, great care was taken to minimize any significant interference into existing analog or digital television signals. DTx networks in mountainous areas, while also important, do not have quite the same significant challenges that a major metropolitan area like New York City has, since urban areas potentially experience severe DTx-induced multipath (caused by multiple same-frequency synchronized transmitters) as well as considerable naturally-occurring multipath (caused by large buildings and other man-made structures).

The CH 33 *outdoor* field strength measurements at the **90** test sites within the Brooklyn "box" indicated that there were fairly consistent DTV field strength levels when the directional receive antenna angle was selected for *maximum* signal level at 30' AGL and 15' AGL. Throughout the Brooklyn "box," CH 33 DTV signals were found to be, on the average, in the range of **73 dBµV/m** (DTx OFF) to **80 dBµV/m** (DTx ON) for a 30' AGL receive antenna and they were about **3 dB** lower (DTx OFF and DTx ON) at 15'AGL. These CH 33 signal levels were not only large enough to produce SNR values (>**40 dB** for DTx OFF and >**47 dB** for DTx ON) at the receiver inputs that were above the required 15-dB white-noise threshold, but they also easily covered an additional 5 dB to 8 dB of possible noise threshold degradation due to the presence of naturally-occurring or DTx-induced multipath. The CH 33 outdoor DTV service numbers increased a modest amount from about **81%** (without DTx) to more than **85%** (with DTx). Also, significant margin and range of antenna rotation were observed at many test sites, providing *evidence* for successful long-term DTV service (i.e., accounting for signal level time variability) on CH 33.

Similarly, the CH 12 *outdoor* antenna-maximized field strength values were found to range between **59 dBµV/m** (DTx OFF) to **70 dBµV/m** (DTx ON) at 30' AGL, and they were about **2.5 dB** lower (DTx OFF and DTx ON) at 15' AGL, both producing a very high average SNR value. The CH 12 outdoor DTV service numbers increased a modest amount from about **75%** (DTx OFF) to **80%** (DTx ON), and significant margin and range of antenna rotation were likewise observed. This provided *evidence* for successful long-term DTV reception on CH 12.

Finally, the CH 65 *outdoor* results with DTx active (since there was no CH 65 ESB transmitter, this was the only mode possible to test) showed that the average field strength was a strong **76 dBµV/m** at 30' AGL and **2 dB** less at 15' AGL, and produced SNR values in excess of **40 dB**. The CH 65 DTV service was a significant **94%** (Rx) and **85%** (Rx2), with respectable margins around **20 dB**. This provided *evidence* for successful long-term DTV service on CH 65.

While the main goal of the MTVA project was to study the performance of a scaled-down version of a widespread DTx design, an added benefit was the determination that the current commercial UHF CH 33 (WPIX) single source on ESB already provided reasonably good DTV *service* in the Brooklyn test "box." In other words, the actual measured *outdoor* and *indoor* DTV service numbers in the field test "box" from ESB alone (i.e., DTx *inactive*) were found to be good. Of course, this means that there could not be a significant increase in the number of sites serviced with DTx active. However, despite the modest service increases due to DTx, the increase in the margin and range of antenna rotation at many sites was *encouraging*. It should be noted that DTx did, in fact, cause loss of DTV service at a small percentage of sites. Nevertheless, there were many other sites where the DTx-induced degradation of margin or range of rotation still provided acceptable DTV reception conditions.

Even though there were not enough *indoor* test sites within the DTx "box" for statistical relevancy, the **23** indoor test sites did provide field strength results on CH 33 that showed similar trends as the outdoor results. For the existing WPIX CH 33 commercial station operating at full allocated DTV power, with its partially-obstructed "omni-directional" antenna on ESB, the average indoor field strength value with DTx *inactive* for all **23** indoor test sites (including those *outside* the "box") was **69 dBµV/m**. This is a very respectable number for the average *indoor* field strength value in the New York City metropolitan area, providing an average SNR value of **38 dB** for CH 33. These **23** sites with DTx *inactive* exhibited good service (**70%** for Rx1 and **65%** for Rx2), with good margin and range of antenna rotation. Note that CH 12 and CH 65 were *not* analyzed with DTx inactive for indoor field strength using all **23** indoor test sites since (1) the CH 12 ESB transmit antenna was not omni-directional but rather directional, specifically pointing towards the Brooklyn "box," and (2) there was no CH 65 transmitter on ESB.

Analysis of all **23** indoor sites and their companion outdoor driveway sites showed that the signal attenuation experienced from outdoor to indoor averaged around **6 dB** for CH 33, which is much lower than the traditionally-presumed 10-dB to 20-dB values for two-story single-dwelling residences. However, this is partially explained by the fact that many of the **23** indoor test sites were *above* 15' AGL, and some were even above 30' AGL (i.e., test sites located on upper stories of buildings that were higher than the outdoor antenna heights used in the field test). Therefore, these attenuation results must be viewed under these special circumstances.

While all **23** indoor (and driveway) test sites were used in the CH 33 DTx-*inactive* analysis, DTx system evaluation was performed on *only* the **10** indoor test sites within the Brooklyn "box." The reason for this is that the other test sites (i.e., "outside-the-box") did *not* gain much benefit (and perhaps even experienced detrimental *self*-interference effects) from the DTx gap-filler transmitters. Any analysis that would have included the **13** "outside-the-box" test sites would have unfairly biased the results negatively for DTx evaluation since the DTx prototype test system was specifically designed to study its performance inside the Brooklyn "box."

For DTx inactive, the indoor field strengths at these **10** Brooklyn "box" test sites were approximately **66 dBμV/m** (CH 33) and **51 dBμV/m** (CH 12). These are very respectable field strength numbers for indoor DTV sites *without* benefit of DTx gap filler transmitters. Indoor DTV reception measurements resulted in about **65%** (CH 33) and **15%** (CH 12) service and *average* margins of **12 dB** (CH 33) and **3 dB** (CH 12).

For DTx active, the indoor field strengths at these **10** Brooklyn "box" test sites increased by about **7 dB** (CH 33) and **9 dB** (CH 12), meaning that these **10** sites exhibited average field strengths of about **73 dBμV/m** (CH 33) and **60 dBμV/m** (CH 12). Indoor DTV service increased to **85%** (CH 33) and **30%** (CH 12) of the test sites and the *average* margins were found to increase to approximately **17 dB** (CH 33) and **9 dB** (CH 12). As a comparison, the average CH 65 field strength with DTx active was about **65 dBμV/m**, with **90%** DTV service and an *average* margin of **16 dB**. The difference in performance between CH 33 and CH 12 is not entirely understood at this time.

An interesting side note is that the secondary *directional* indoor test antennas, which also performed well, did not do quite as well as the primary *dipole* indoor test antennas (with their figure-8 azimuth pattern). This indicates that *perhaps* the recent receiver equalizer innovations and updated algorithms now use the echoes of the signal (which typically occur more often with dipole antennas that have no front-to-back attenuation) for mitigating the multipath effect.

It is clear, however, that DTx can help DTV reception indoors, and that its negative self-interference effects can be minimized with good DTx system design as well as good receive system design.

The two 5G DTV receivers (Rx1 and Rx2) both did well in these field tests, and are significantly better than past generations. However, it was clear that Rx1 consistently did better than Rx2 in providing service, margin, and range of rotation. While both units were 5G, Rx1's multipath equalizer apparently is a little more robust, being able to handle slightly stronger and more dynamic multipath conditions than Rx2.

It must be remembered, however, that these DTx tests in New York City were *location* variability tests and not *time* variability tests. That is, the dynamic conditions that were encountered at many of the tests sites could become worse at certain times of the day (diurnal, such as with temperature changes that cause atmospheric inversion layers or with increased traffic flow at rush hour) and times of the year (seasonal, such as with and without foliage). Therefore, care must be taken when attempting to predict future widespread DTV service using short-term testing data on a small-scale prototype system. Long-term time-variability testing would certainly produce some of these answers.

A major outcome of the field test was the *experience* gained from designing, implementing, and testing a DTx system in a major metropolitan area. However, it is also important before deployment of any large communication network to determine the primary causes of DTV reception failure in order to better understand how to optimally design and construct a larger and improved *final* DTx network in New York City in time for the February 17, 2009 end of the *full-service* DTV transition. The resulting data from this field test will help future designers to achieve optimum DTx system designs.

Finally, consumer education regarding the retirement of the NTSC analog service is essential for the successful transition to over-the-air digital broadcast television. However, not only is it important to inform the public about the timing of the analog shutoff on February 17, 2009 and how to obtain NTIA converter coupons, but it is also vital to educate them about the "lost art" of over-the-air television reception. In addition to various DTV receivers, this includes the various types of receive support (accessory) equipment at their disposal, such as antennas, preamplifiers, coaxial cable, signal splitters, band splitters, attenuator pads, etc. It is likely that, even with DTx deployed in some form, successful DTV reception in New York City may depend on viewers having *reasonable* receive equipment properly installed in their homes. In order for broadcasters to successfully educate the public on DTV receive equipment and its proper use, they must first educate themselves regarding DTV reception in general (with or without DTx), and then familiarize themselves with high-quality consumer devices that are currently available.

REFERENCES

1 “**ATSC Field Test Vehicle Design Information**”, Gary Sgrignoli, DTV Station Project, RF Working Group, November 20, 2000.

2 “**Field Test Results of the Grand Alliance HDTV Transmission Subsystem**”, Charlotte Field Test Plan, submitted to SS/WP2 Field Testing Task Force of the Advisory Committee on Advanced Television Service of the Federal Communications Commission by the Association for Maximum Service Television, Inc., Cable Television Laboratories, Inc., and Public Broadcasting Service, September 16, 1994.

3 “**DTV Station Project General Field Test Plan for Digital Television Propagation**”, DTV Station Project, RF Working Group, November 20.

4 “**DTV Station Project Indoor Test Plan for Digital Television Propagation**”, DV Station Project, RF Working Group, November 20.

5 “**Developing DTV Field Test Plans**”, ATSC Recommended Practice A/75, July 26, 2001, www.atsc.org.

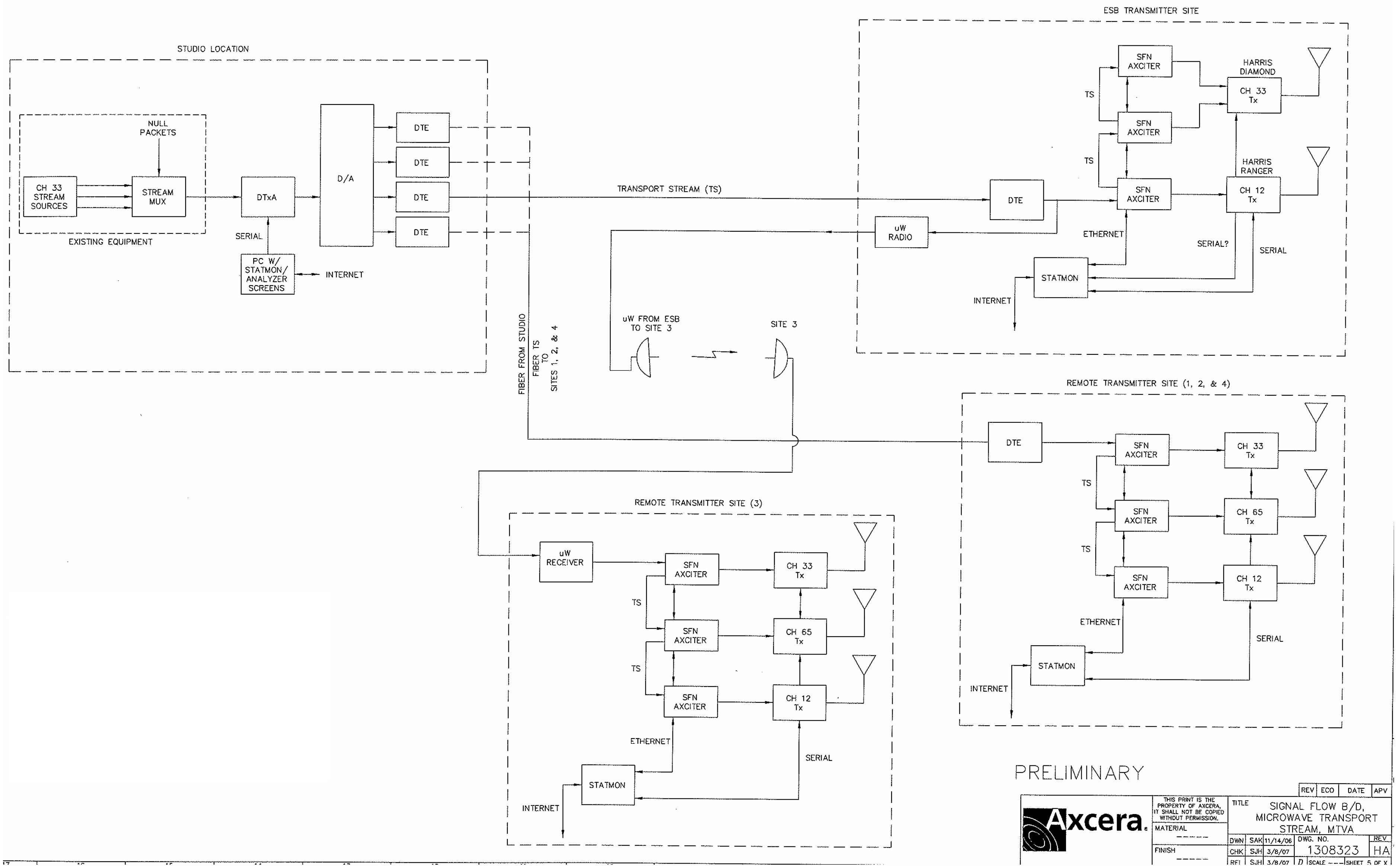


Figure 1 DTS Implementation block diagram (drawing from Axcera)

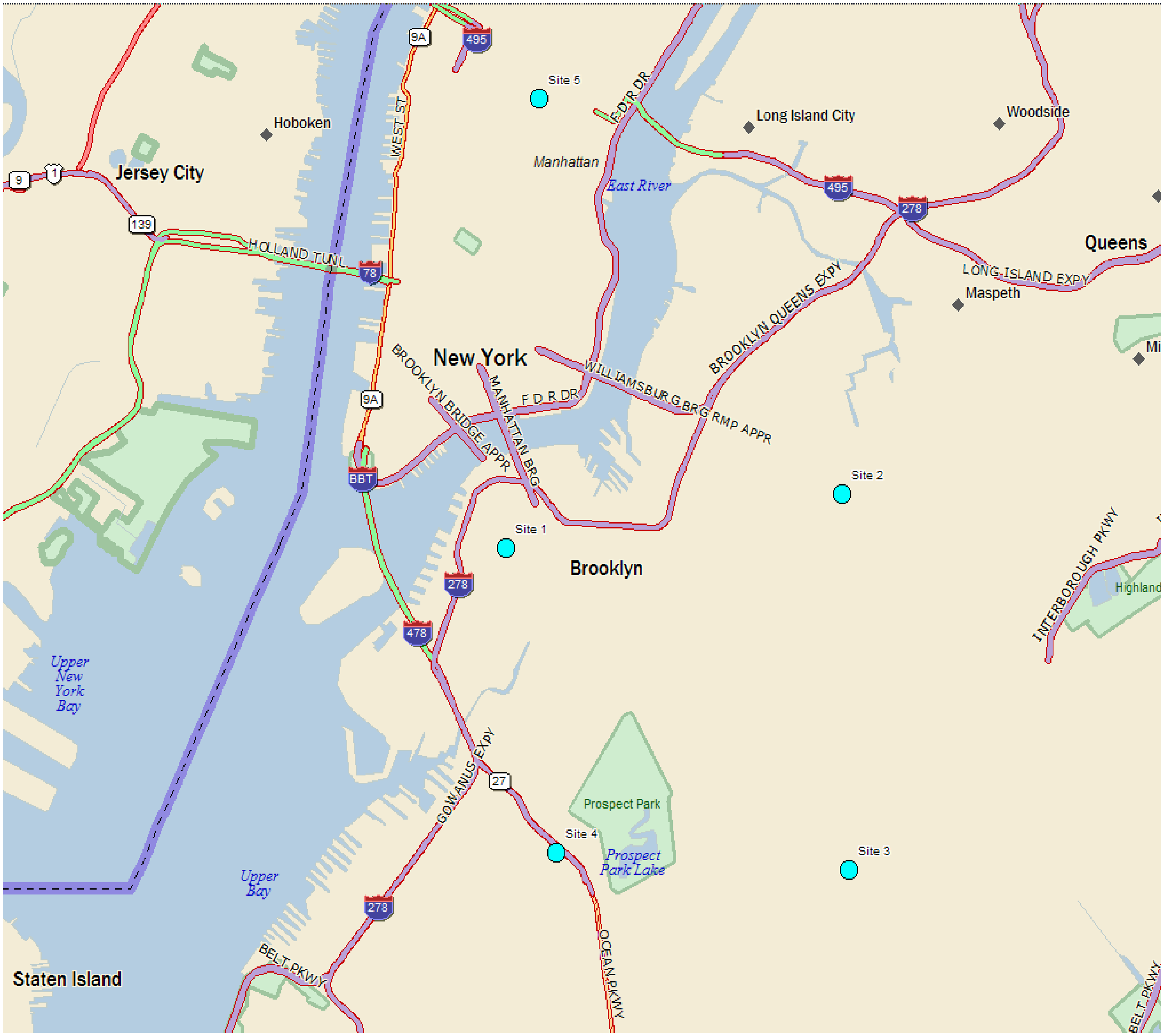


Figure 2 MTVA DTx transmitter sites (5 **BLUE** circles).

Figure 3a MSW Truck #1a *outside* view

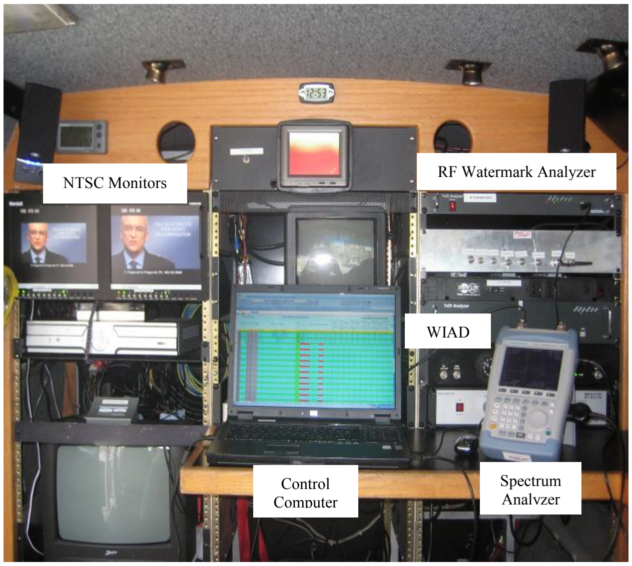


Figure 3b MSW Truck #1 *inside* view

Figure 3c Univision Truck #2 *outside* view

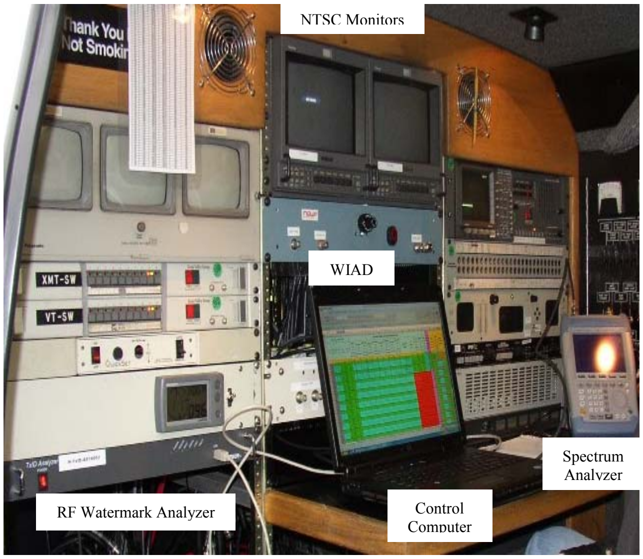


Figure 3d Univision Truck #2 *inside* view

$$\mathbf{FS\ (dB\mu V/m)} = \mathbf{S} - \mathbf{G_T} + \mathbf{A} + \mathbf{K} - \mathbf{G_A}$$

where: **K** = +130.5 dBµV/-dBm (CH 33)
K = +121.5 dBµV/-dBm (CH 12)
K = +133.0 dBµV/-dBm (CH 65)

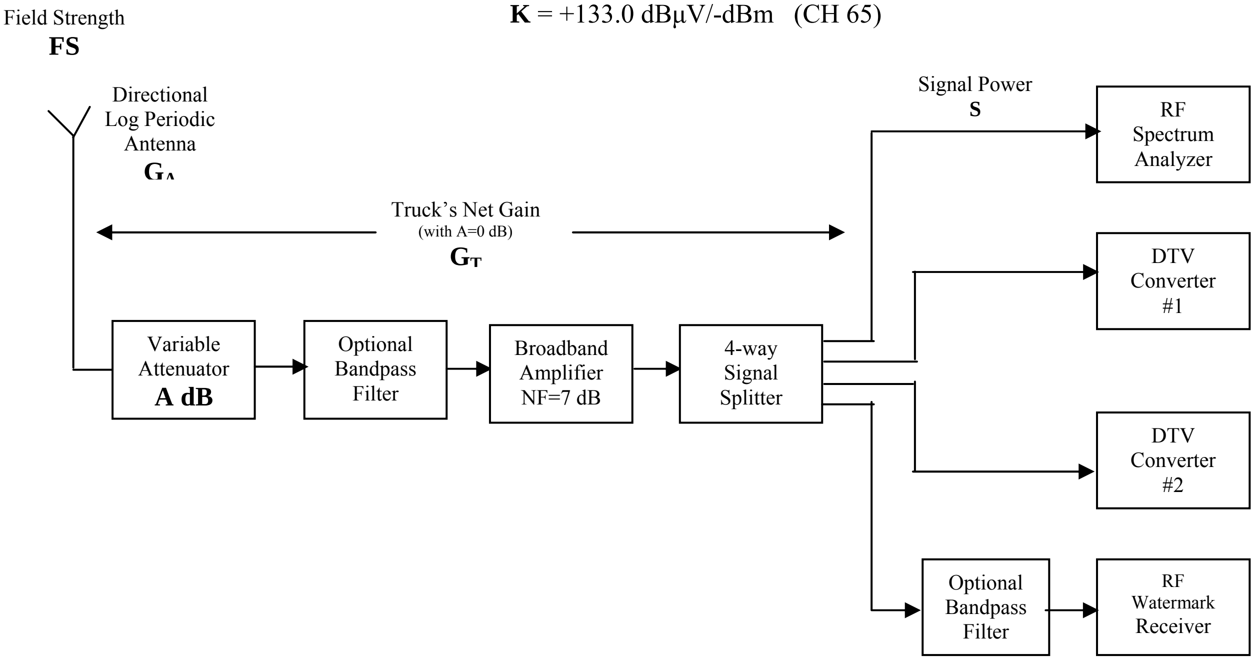


Figure 4 **MSW field test vehicle design**

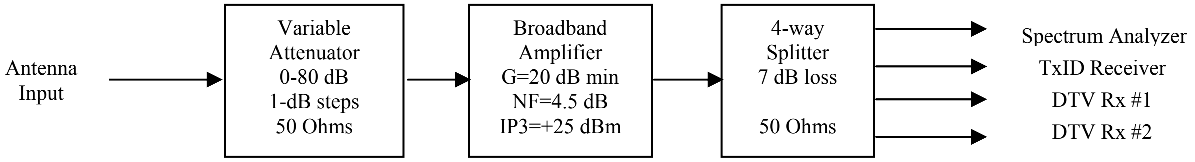


Figure 5 **MSW "Works-in-a-Drawer" (WIAD) RF preamplifier design**

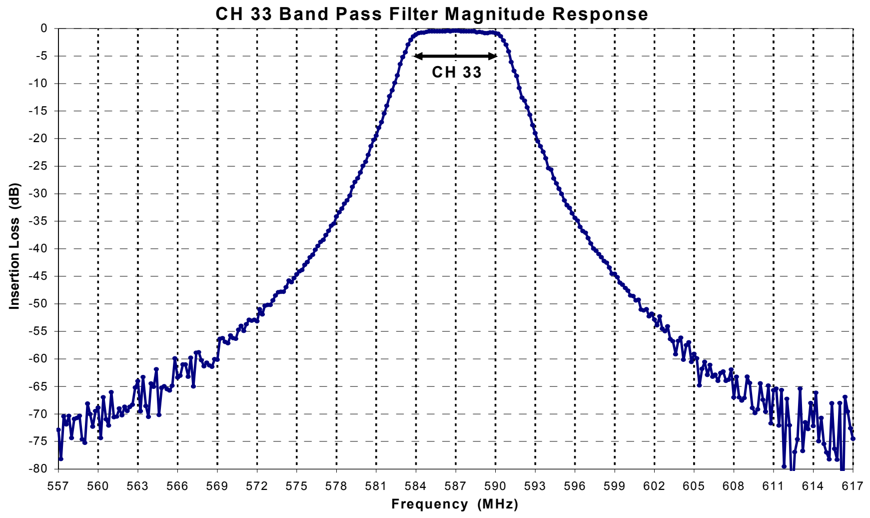


Figure 6a CH 33 (587 MHz) bandpass filter magnitude response

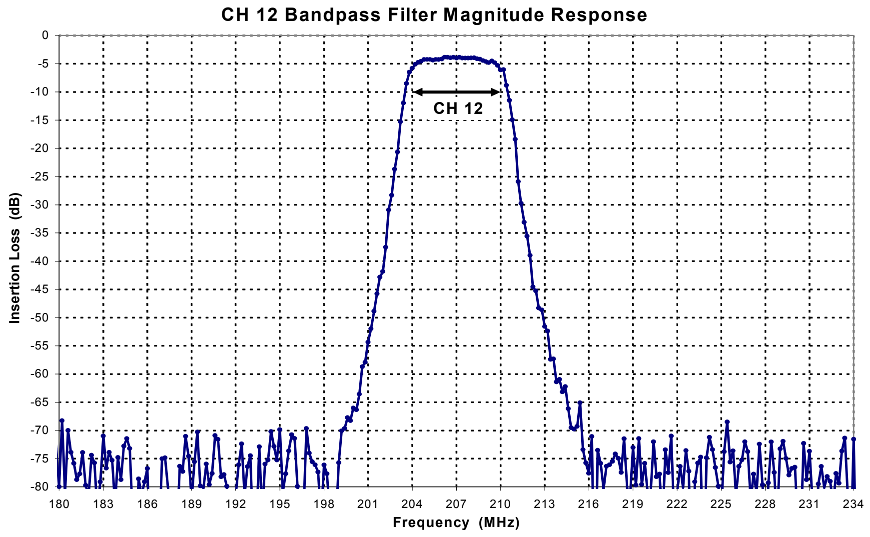


Figure 6b CH 12 (207 MHz) bandpass filter magnitude response

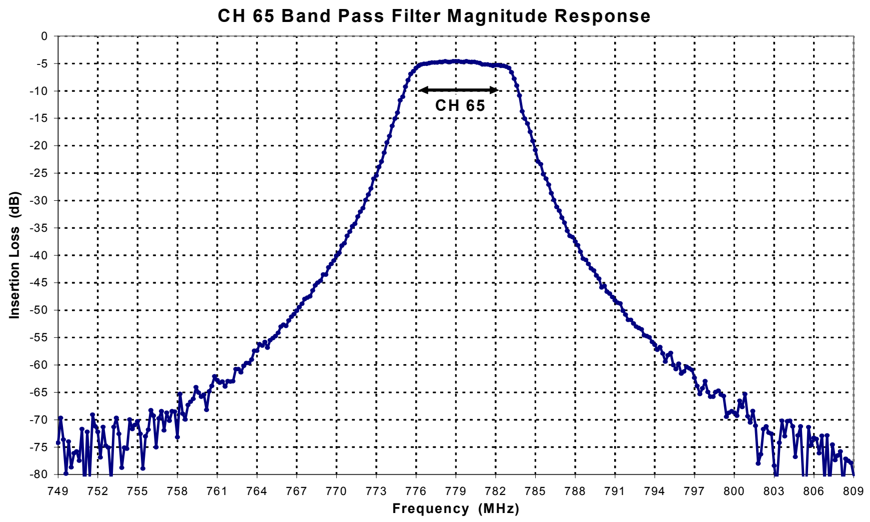


Figure 6c CH 65 (779 MHz) bandpass filter magnitude response

Figure 7a **Indoor rack system**

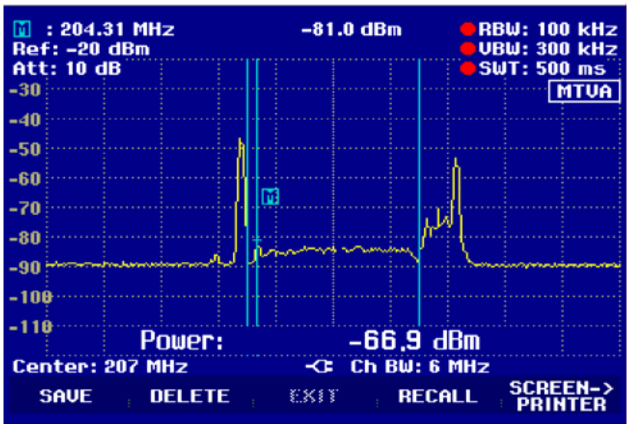
Figure 7b **Smart Antenna**

Figure 7c **Calibrated VHF dipole antenna**

Figure 7d **Calibrated UHF dipole antenna**

Figure 7e **Sharpshooter VHF antenna**

Figure 7f **Silver Sensor UHF antenna**



M : 204.31 MHz -81.0 dBm
Ref: -20 dBm
Att: 10 dB
RBW: 100 kHz
VBW: 300 kHz
SWT: 500 ms
Power: -66.9 dBm
Center: 207 MHz
Ch BW: 6 MHz

Figure 8a Example 1 spectrum analyzer plot

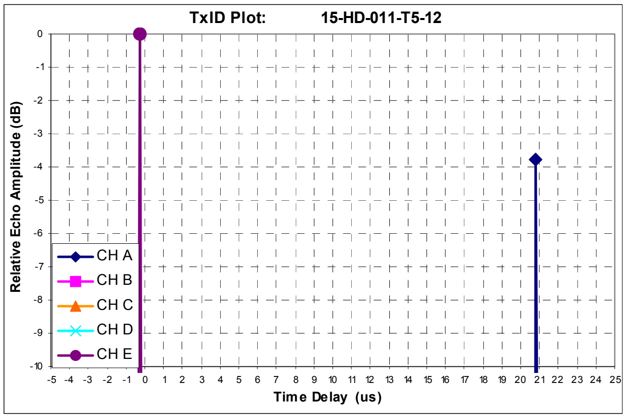
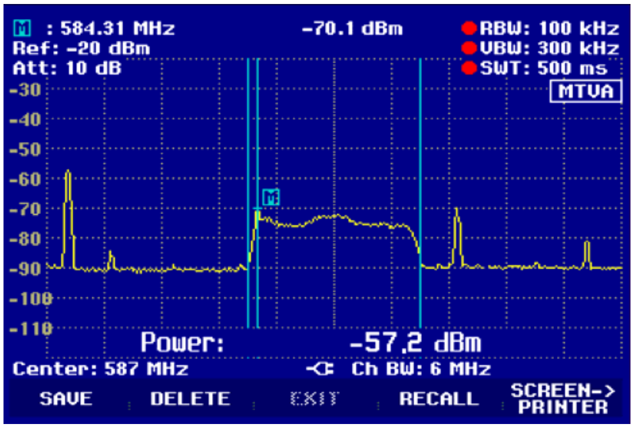


Figure 8b Example 1 TxID RF watermark analyzer plot



M : 584.31 MHz -70.1 dBm
Ref: -20 dBm
Att: 10 dB
RBW: 100 kHz
VBW: 300 kHz
SWT: 500 ms
Power: -57.2 dBm
Center: 587 MHz
Ch BW: 6 MHz

Figure 9a Example 2 spectrum analyzer plot

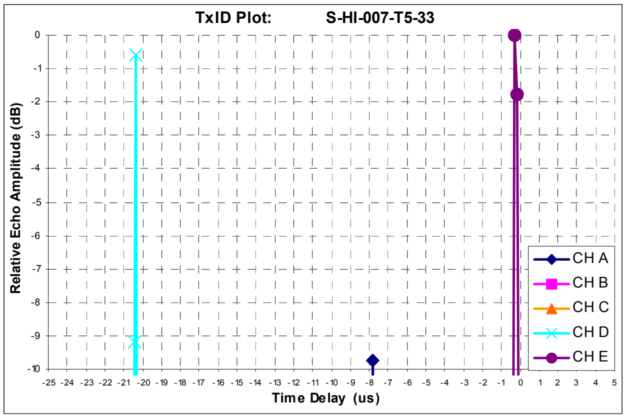
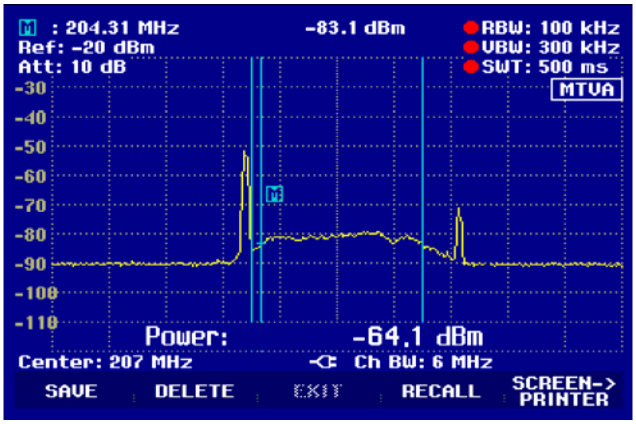


Figure 9b Example 2 TxID RF watermark analyzer plot



M : 204.31 MHz -83.1 dBm
Ref: -20 dBm
Att: 10 dB
RBW: 100 kHz
VBW: 300 kHz
SWT: 500 ms
Power: -64.1 dBm
Center: 207 MHz
Ch BW: 6 MHz

Figure 10a Example 3 spectrum analyzer plot

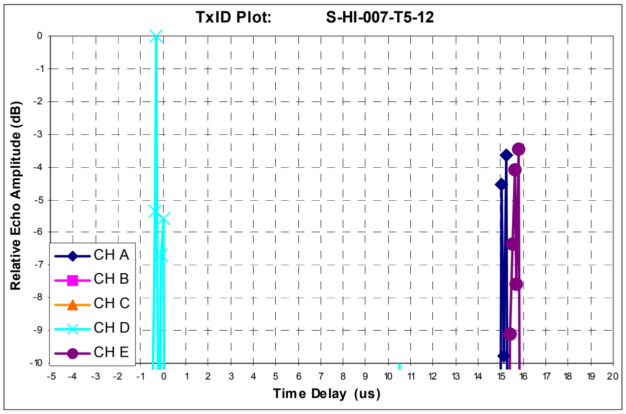


Figure 10b Example 3 TxID RF watermark analyzer plot

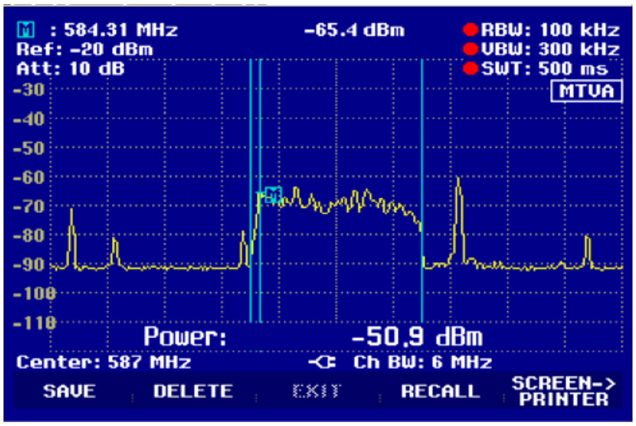


Figure 11a Example 4 spectrum analyzer plot

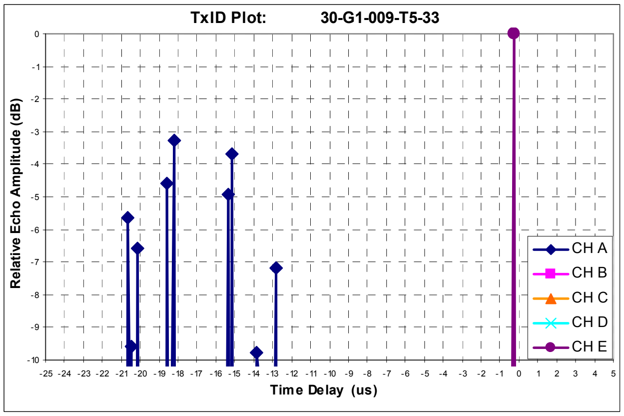


Figure 11b Example 4 TxID RF watermark analyzer plot

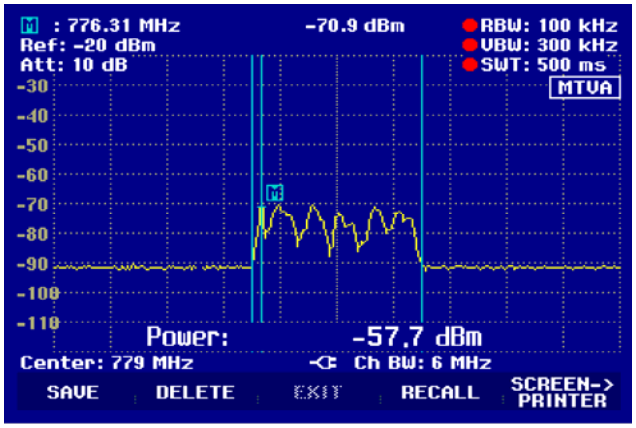


Figure 12a Example 5 spectrum analyzer plot

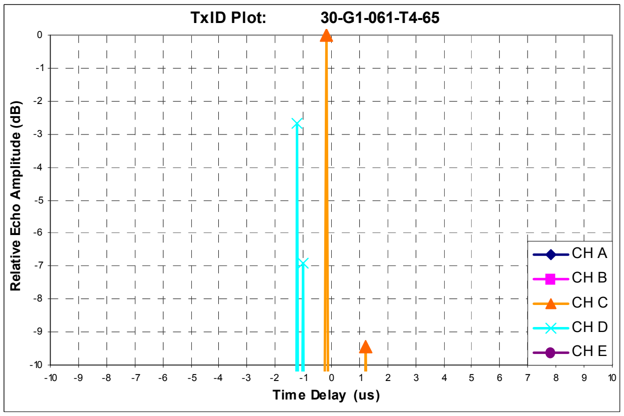


Figure12b Example 5 TxID RF watermark analyzer plot

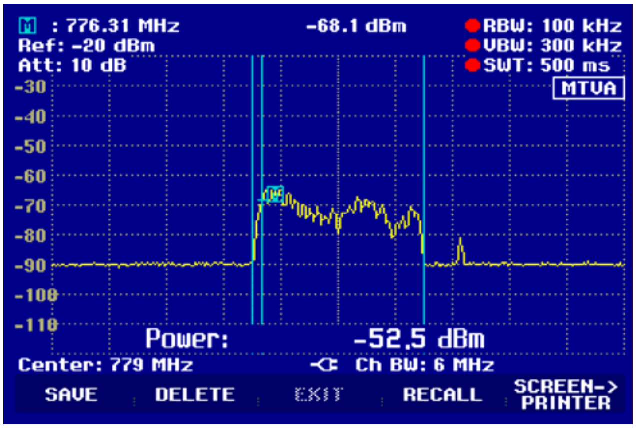


Figure 13a Example 6 spectrum analyzer plot

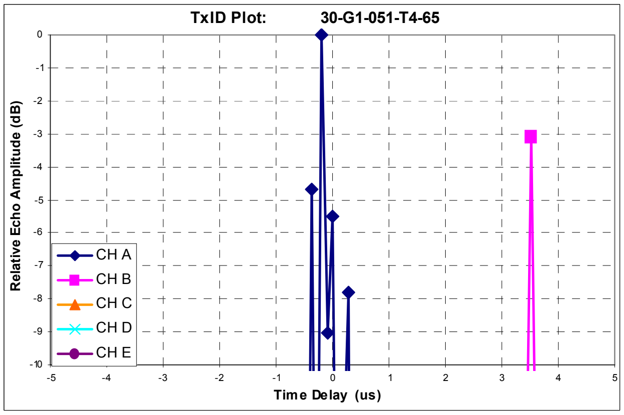


Figure 13b Example 6 TxID RF watermark analyzer plot

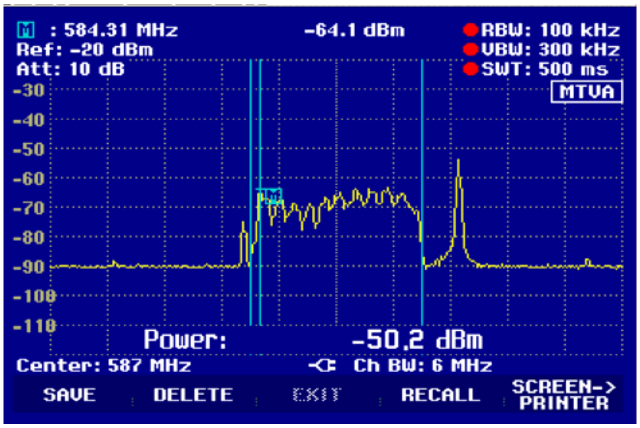

M : 584.31 MHz -64.1 dBm
RBW: 100 kHz
Ref: -20 dBm
VBW: 300 kHz
Att: 10 dB
SWT: 500 ms
Power: -50.2 dBm
Center: 587 MHz
Ch BW: 6 MHz

Figure 14a Example 7 spectrum analyzer plot

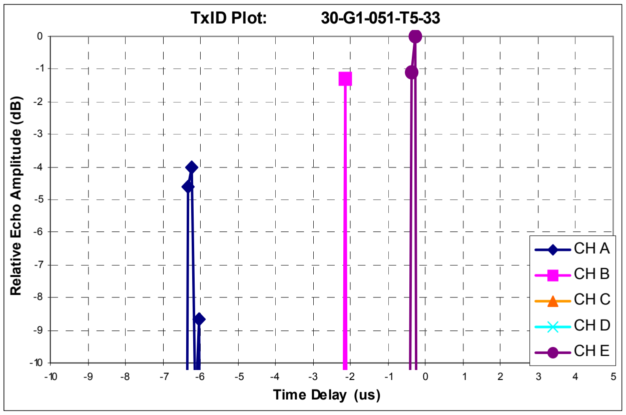


Figure 14b Example 7 TxID RF watermark analyzer plot

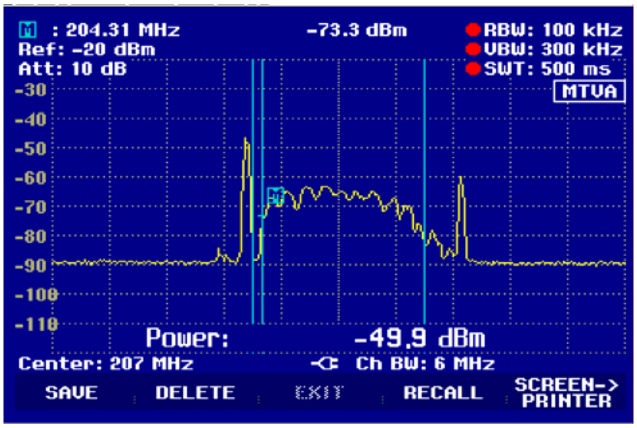

M : 204.31 MHz -73.3 dBm
RBW: 100 kHz
Ref: -20 dBm
VBW: 300 kHz
Att: 10 dB
SWT: 500 ms
Power: -49.9 dBm
Center: 207 MHz
Ch BW: 6 MHz

Figure 15a Example 8 spectrum analyzer plot

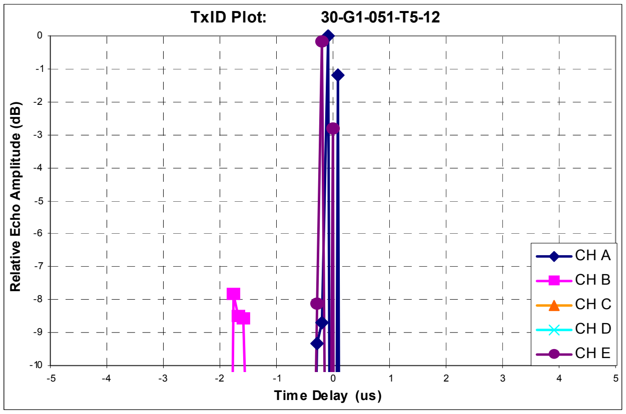


Figure 15b Example 8 TxID RF watermark analyzer plot

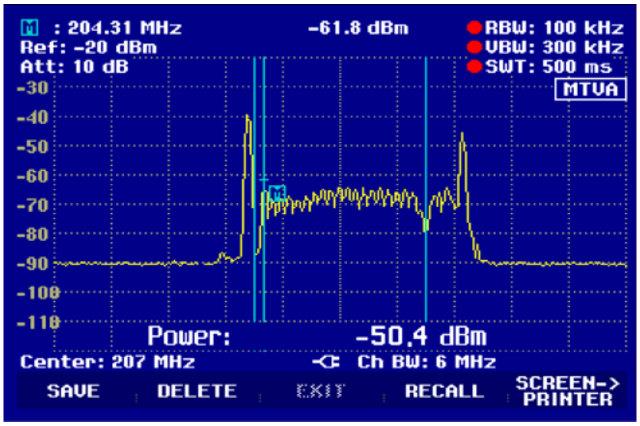

M : 204.31 MHz -61.8 dBm
RBW: 100 kHz
Ref: -20 dBm
VBW: 300 kHz
Att: 10 dB
SWT: 500 ms
Power: -50.4 dBm
Center: 207 MHz
Ch BW: 6 MHz

Figure 16a Example 9 spectrum analyzer plot

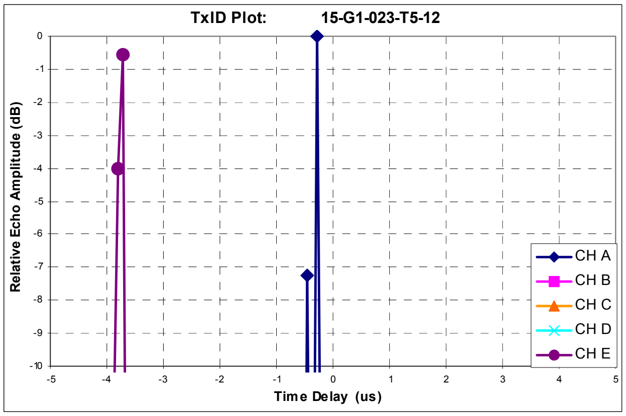


Figure 16b Example 9 TxID RF watermark analyzer plot

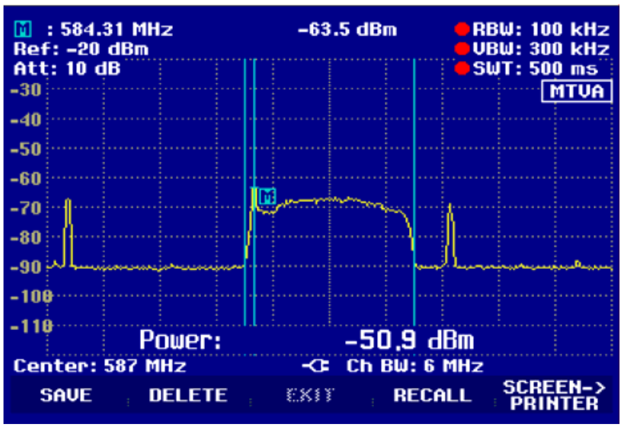


Figure 17a Example 10 spectrum analyzer plot

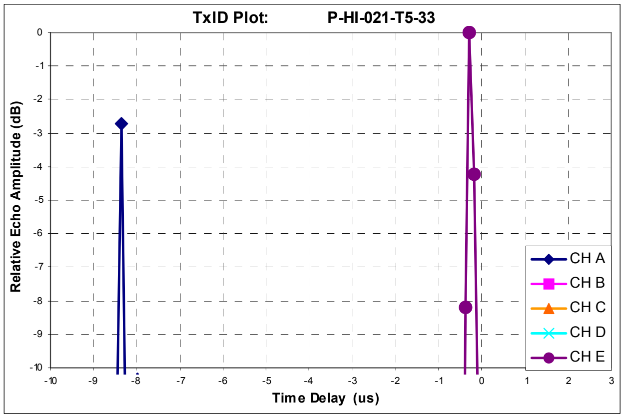


Figure 17b Example 10 TxID RF watermark analyzer plot

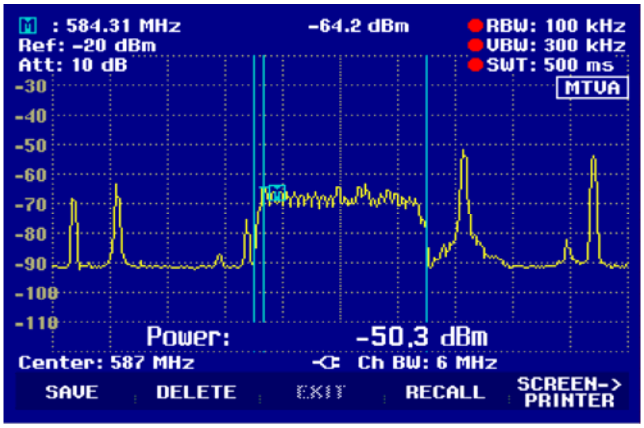


Figure 18a Example 11 spectrum analyzer plot

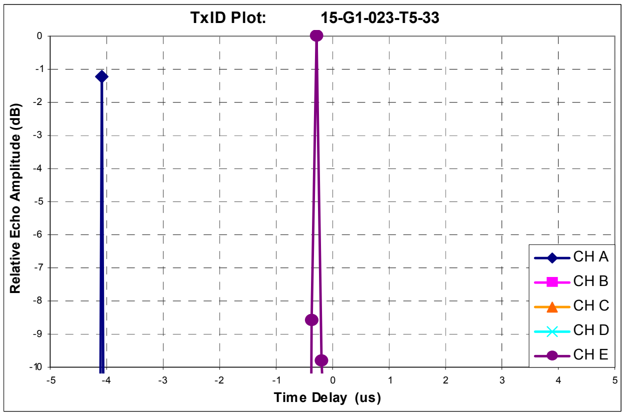


Figure 18b Example 11 TxID RF watermark analyzer plot

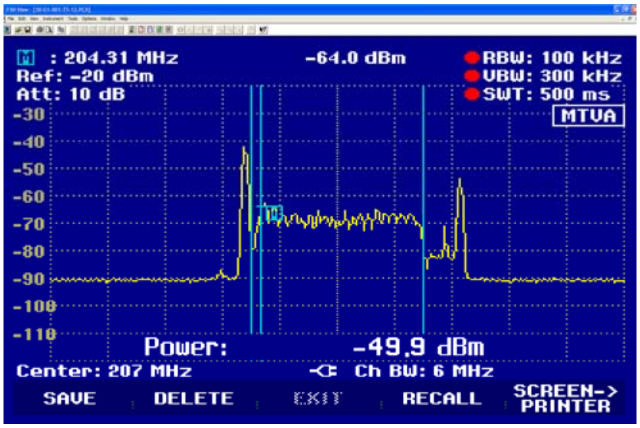


Figure 19a Example 12 spectrum analyzer plot

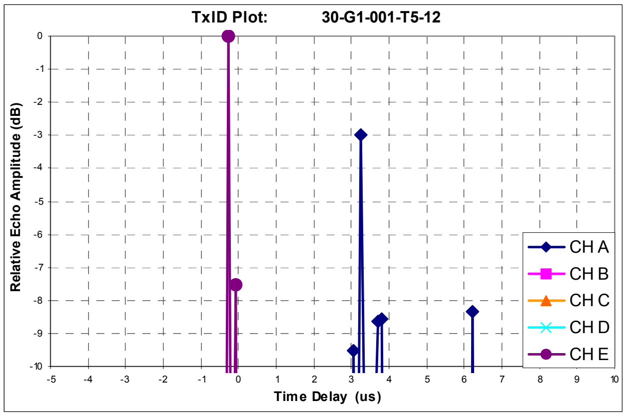


Figure 19b Example 12 TxID RF watermark analyzer plot

APPENDIX 1 DISTRIBUTED TRANSMISSION THEORY

Abbreviations and Definitions

CWDM	**Coarse Wavelength Division Multiplexing** is a term describing the use of different wavelengths of light to transmit different signals in parallel on a single fiber. Coarse WDM uses widely spaced wavelengths as compared to the spacing of wavelengths in Dense WDM (DWDM).
DOCR	**Digital On-Channel Repeater** is a term describing a system that receives digital signals over the air and retransmits them on the same channel on which they were received.
DTS[1]	**Distributed Transmission System** is a term that was adopted by the Federal Communications Commission to describe the type of transmission method that it was proposing to license on a routine basis in a Notice of Proposed Rulemaking (NPRM).
DTx	**Distributed Transmission** is a term describing a *form* of SFN that uses multiple transmitters fed over a Studio-to-Transmitter Link (STL). These transmitters separately generate the signals that they transmit in synchronization with one another and are controlled by data that they receive in common from a DTxA. The term DTx and all of its extensions were developed for and used in the ATSC standard (A/110B) and recommended practice (A/111) that describes operation of multiple-transmitter networks.
DTxA	**Distributed Transmission Adapter** is a term describing a device that provides synchronization and control of multiple transmitters in a network by developing and inserting into the MPEG-2 transport stream feeding those transmitters additional data to which the transmitters respond by operating synchronously with one another and by emitting their signals with controlled time relationships.
DTxN	**Distributed Transmission Network** is a term describing a form of SFN in which the transmitters are fed with signals from a DTxA over Studio-to-Transmitter Links (STLs), generate the radio frequency signals to be transmitted locally and emit them in synchronization and in time relationships with the signals from other transmitters in the SFN, under control of the data in the DTxPs from the DTxA.
DTxP	**Distributed Transmission Packet** is a term describing an MPEG-2 transport stream packet that is used to carry synchronization, timing, and control information from a DTxA to one or more DTxTs.
DTxR	**Distributed Translator** is a term describing a type of digital transmitter that receives signals *over the air*, converts them to a different channel, and retransmits them on that channel in synchronization with other DTxRs that share the output channel, all of which DTxRs respond to information in DTxPs directed to them.
DTxT	**Distributed Transmitter** is a term describing a digital transmitter that receives data over a Studio-to-Transmitter Link (STL) and modulates and emits that data in synchronization with and according to parameters and instructions that it receives from a DTxA via a DTxP.
E-DOCR	**Equalizing Digital On-Channel Repeater** is a term describing a form of DOCR that includes an adaptive equalizer in its receiver that has the purpose of minimizing effects of multipath in the channel from the source transmitter to the E-DOCR and of decoupling the receiving antenna from the E-DOCR transmitting antenna, thereby reducing the isolation required between those two antennas for a given radiated power.
Gap Filler	A **Gap Filler** is a transmitter that is used to fill in the service area of a larger transmitter that is obstructed by terrain, man-made objects, or deficiencies in its performance from an area that it could otherwise serve.
Repeater	A **Repeater** is a transmitter that receives signals from another transmitter and retransmits them. If it retransmits the signals on a different channel than the one on which they were received, it is termed a **Translator**. If it retransmits the signals on the same channel as the one on which they were received, it is termed an **On-Channel Repeater** (or, in the analog domain, a booster.)
SFN	Single-Frequency Network is a term describing a network of transmitters sharing a single channel and jointly providing service to a common area. In order to minimize interference with one another, the SFN

---

[1] It should be noted that in earlier documentation prepared by and for the MTVA, the term DTS was used somewhat ubiquitously to describe many of the techniques related to Distributed Transmission, as did the FCC in its NPRM on the subject. This document limits the use of the term DTS to those places where the words Distributed Transmission System are meant and uses other abbreviations for other concepts in order to more *precisely* express what is meant. This modified usage in no way changes the intent of the earlier documents to describe techniques involving multiple synchronized transmitters.

transmitters operate in synchronization and with specific time relationships between their output signals. Both DOCRs and DTxTs can be used to form an SFN, and when DTxRs are used, they form an SFN on their common output channel.

General Terrestrial DTV Background

The Advanced Television System Committee (**ATSC**) digital television (**DTV**) standard (**Ref A1-1**) has been in existence since November 28, 1995 when the FCC's Advisory Committee on Advanced Television Systems (**ACATS**) *recommended* it as the U.S. terrestrial television standard. The specific terrestrial *transmission* system selected for the *digital* ATSC system was eight-level vestigial sideband modulation (**8-VSB**), which carries a 19.393 Mbit/second data stream. The ATSC system was ultimately codified into rules (**Ref A1-2**) by the FCC on December 24, 1996. At that time, the primary focus of the new DTV standard was implementation by the traditional method of using a single high-power transmitter, which was employed for many decades prior to that for both the analog National Television Systems Committee (**NTSC**) black and white and color television systems.

However, these new terrestrial DTV signals, while carrying digital information, are inherently analog RF signals. This is due to their analog sinusoidal RF carriers and their random, noise-like data modulation envelope that is spectrally-shaped by a steep root-raised-cosine band-pass filter (i.e., a large amount of signal ringing occurs). This means that these DTV RF signals suffer from all the same propagation effects that analog RF signals do.

DTV signals also suffer from all the same high-power transmitter and low-level receiver hardware impairments such as linear and non-linear distortion as well as reflections during propagation. Likewise, they also experience RF interference effects from analog NTSC signals and other digital ATSC signals. To the extent that it is possible, it is always best to combat these effects in terms of the broadcast transmitter design (e.g., transmitter location, antenna height, antenna azimuth and elevation patterns, beam tilt, polarization selection, radiated power, etc.).

All DTV receivers have certain RF performance characteristics. They all have front-end tuners that provide proper tuning of desired channels (CH 2 – CH 69) and convert the incoming signal to an intermediate frequency (**IF**). These tuners also determine both the sensitivity (low-level) characteristics and the overload (high-level) performance characteristics of the DTV receiver.

Likewise, there is a *linear* adaptive equalizer present in *each* DTV receiver whose function is to remove any and all *linear* distortion from the signal, such as hardware-induced frequency magnitude and group delay distortion or propagation-induced multipath distortion. However, the amount of linear distortion (e.g., amplitude and group delay) that can be removed by the equalizer is always limited. Most modern day DTV equalizers can remove essentially 100% echo amplitudes if the delay is not too great (e.g., close-in echoes that are less than a few microseconds), and can now handle *single* echo delays (e.g., delay spread) from at *least* -25 µsecs to at *least* +45 µsecs. Many of the most recent DTV equalizers have variable-position center taps that can be intelligently moved by smart algorithms depending on the presence of pre-echoes and post-echoes. Also, they can handle fast *dynamic* multipath caused by Doppler effects from moving reflective objects. The importance of the cancellation delay range of both pre-cursor and post-cursor multipath can not be stressed enough, not only for severe multipath distortion experienced in major urban areas where typically no line-of-sight exists to the single transmitter, but also for Single Frequency Network (**SFN**) and Distributed Transmission (**DTx**) designs, as will be discussed below.

The most overarching characteristic of DTV reception is the digital "cliff effect" which is caused not only by the nature of the digital transmission system itself, but also by the extreme amounts of forward error correction (trellis-coded modulation and Reed-Solomon coding) that are included in the ATSC system. White Gaussian noise is present at the front end of every tuner, with the amount of noise (i.e., noise floor) dependent on the tuner noise figure (**NF**). As the incoming DTV signal decreases to a level that causes a signal-to-noise ratio (**SNR**) near 15 dB, the video and audio outputs of the DTV receiver change from error-free perfect pictures and sound to all-error frozen pictures without sound in a matter of less than 1 dB of signal change. This is a drastic occurrence, which is why it is called the digital "cliff effect" in DTV broadcasting.

After the digital television standard was selected in 1996, the FCC created a table of channel allotments in 1997 for the U.S., loaning every eligible *full-service* television station (about 1600 in the mid 1990s) a second 6 MHz RF channel with which to transmit DTV during the transition. However, not all stations were able to replicate their VHF NTSC coverage with a single high-power transmitter using their allocated UHF DTV channels, and some had local ordinances preventing them from putting up a tall transmitting tower that could have extended the optical and radio horizon and increased the number of line-of-sight receiving locations. Also, there was a growing expectation of improved outdoor *and* indoor television delivery systems for the 21st century as well as handheld and mobile systems. Therefore, other means of terrestrial television *distribution* were considered in order to provide improved over-the-air (**OTA**) television service.

Before describing various digital service extension strategies, a brief review of the traditional "single stick" transmission methodology is in order. The required large effective radiated power (**ERP**) used by single transmitter systems often has more than 30 dB of margin for line-of-sight conditions. However, *non*-line-of-sight conditions that occur at the edge of service (e.g., radio horizon), in rural areas with hilly terrain, or in urban areas with tall buildings require this extra 30 dB of transmitted power to overcome the greater attenuation and signal level variability (i.e., fading) in these propagation paths. With the digital cliff effect, a blank DTV picture 50% or 60% of the time is unacceptable. This is the reason that the FCC did *not* use its F(50, 50) statistical field strength prediction curves for DTV allocations which assume only 50% of the locations have acceptable field strength 50% of the time. They chose to use F(50, 90) prediction curves to get the 90% time variability that was desired for these new digital signals which exhibit cliff effect characteristics.

Additionally, RF propagation effects are even worse at UHF frequencies, which contain the largest number of DTV channel allocations, since UHF signals are "propagationally-challenged" in non-flat terrain due to their shorter wavelengths and their propensity to not bend as well as VHF signals. And when UHF signals do bend (due to refraction or diffraction), they can exhibit significant time variations that are dependent upon many different propagation path variables (e.g., temperature, weather, diurnal, seasonal, etc.). This condition, also called fading, requires a larger RF signal level in order to stay above a predetermined minimum field strength level that provides acceptable DTV service (i.e., for an acceptable percentage of time).

As stated above, this desired increased reliability for DTV service is important at both the noise-limited contour far from the transmitter and in highly urbanized areas that have very large structures close to the transmitter (e.g., urban clutter). In these cases, the signal path is either blocked or there are significant reflected signals present. To minimize these effects, transmitter height above average terrain (**HAAT**) is much more important to broadcasters than effective radiated power since increased height provides more line-of-sight (or near-line-of-sight) receiving locations while increased power can potentially cause interference into neighboring signals.

Therefore, a need exists to provide DTV reception in areas affected by the signal impairments discussed above. Some form of television service extension is often necessary to "fill in the gaps" where poor *coverage* and/or poor *service* exists. The primary purpose of these so-called "gap fillers" is to provide increased signal *levels* or improved signal *quality* to areas that are deficient. Care must always be exercised, however, to avoid increased co-channel or adjacent channel interference to neighboring analog or digital channels in the gap filler service areas.

Service Extension Techniques

Historically, a number of techniques have been applied by broadcasters and others to address problems with reception of *analog* NTSC broadcast signals in areas beyond the reliable service areas of single, high-power transmitters such as in areas where these signals are blocked by terrain or man-made objects. Analog service extension to these "propagationally-challenged" areas has involved both "translators" and "boosters."

Translators receive, amplify, and re-transmit the analog signals from a main transmitter (or from other cascaded translators earlier in a chain) on a different RF channel from the one received, as shown in **Figure A1-1**. **Boosters**, on the other hand, receive, amplify, and retransmit signals from a main transmitter (or from a translator) on the *same* RF channel from the one received, as illustrated in **Figure A1-2**. The FCC Rules provide for these two types of service extenders for use with NTSC signals. As a practical matter, boosters have been very difficult to implement, even on UHF channels, because of the difficulties of keeping transmitted signals from feeding back into receiver inputs. This unwanted feedback causes severe signal distortion, which limits the power that can be radiated, and can lead to oscillation of the booster systems when inadequate isolation is provided between transmitting and receiving antennas. Consequently, translators have been far more widely used to repeat analog NTSC signals than boosters. However, their application has been *somewhat* limited by the lack of availability of additional channels in which to operate them, primarily due to the NTSC taboo allocation requirements.

With the advent of digital television transmission, some new techniques have become available for the extension of service areas and the overcoming of propagation challenges. Since digital transmission actually involves radiating analog signals that carry digital information that can be recovered by DTV receivers, the same techniques that are used for analog service extensions remain available for use with DTV. ATSC digital receivers universally contain adaptive equalizers that overcome the effects of multipath caused by the natural environment that would normally prevent successful reception. Advantage can be taken of the adaptive equalizer technique to permit designing "**single-frequency networks**" that re-use the spectrum on the same channel. This can be accomplished either through "on-channel repeaters" (the digital equivalent of analog boosters) or through use of multiple, *synchronized* transmitters sharing the RF channel and producing signals that impact receivers in the *same* way as multipath. However, the simplest and most cost-effective form of service extension is the *unsynchronized* translator, which is also currently the most commonly implemented type of service extension. In the new digital environment, finding channels is easier than in the analog-only environment since the new DTV signals can safely use the analog taboo channels if certain conditions are met (**Ref A1-3**). However, in many situations, available RF channels are still not available to be allocated to interested broadcasters. Therefore, in these cases, the preferred method of service extension is an SFN, which will be the focus of the remaining background material.

General Single Frequency Network Background

SFNs can be constructed with two fundamental types of transmitters: off-air repeaters and separately-fed repeaters. Off-air repeaters receive RF signals, provide minimal processing, and then retransmit them, either on a different channel or on the same channel as the received signal. Separately-fed repeaters require some sort of studio-to-transmitter link (**STL**) to each transmitter, such as microwave, fiber, or satellite.

Two specific types of off-air digital repeaters are possible for use in SFNs. The first type is a translator repeater that heterodynes (either directly or via an intermediate frequency) the received off-air signal to a new RF channel for transmission to shielded areas. These are called Distributed Translators (**DTxR**s) when more than one shares an output channel and their outputs are synchronized with one another. The second type is a Digital On-Channel Repeater (**DOCR**), which amplifies and redirects the output signal on the same frequency used by the off-air input signal.

Digital *translators* (synchronized or unsynchronized) are by far the easiest to implement, assuming there are free channels available for use in the desired reception area, and they are the best and first choice of broadcasters. The use of a *different* channel frequency makes the repeater design and implementation relatively easy. The input and output antenna requirements are simple since there is no problem with self-interference from the translator's output signal feeding back to its input, which allows stable operation (i.e., no output-to-input feedback interference, distortion, or oscillation problems). Translator operation is not limited to terrain-shielded coverage areas since the output and input signals can "overlap" each other without causing co-channel interference. Implementation on VHF channels (input or output) is essentially as easy as on UHF channels (input or output). And the implementation cost is relatively low compared to more sophisticated approaches. The use of a separate channel frequency for the repeated DTV signal does not cause tuning problems for DTV receivers because PSIP data alleviates viewer channel selection confusion. To add to all of these benefits is the fact that *digital regeneration* (VSB demodulation to transport stream (**TS**) with multipath cancellation and forward error correction before VSB re-modulation) is relatively inexpensive and provides a pristine low-power DTV output signal for retransmission to shielded areas, assuming that the incoming DTV signal remains above the threshold of errors. **Figure A1-1** illustrates a simple translator system. Note that even first adjacent channel signals can be eliminated and not inadvertently re-transmitted by these digital regenerators. The only downside to translators is the requirement for frequency allocation planning, that is, finding an *available* RF television channel in the desired service area.

In many rural areas, extra channels are available for translator service, especially when co-located translator sites exist on mountain tops. Co-siting of translator sites allows relaxed taboo channel requirements (**Ref A1-3**). Even in some large urban areas, extra channels are available for use with low-power DTV signals and *directional* transmitting antennas since the same translator channel can be used at opposite ends of a large metropolitan area by having the low-power transmitters pointing away from each other through the use of highly directional transmit antennas. Important translator design aspects consist of finding an optimum translator site, determining the required input signal level and signal quality, specifying digital regeneration equipment, selecting an output emission mask filter (simple or stringent mask, per the FCC's low-power television (**LPTV**) and translator rules), and determining the minimum required radiated output power (to avoid causing interference to neighboring signals and yet provide the desired coverage and service). The use of translators (synchronized or unsynchronized) is the simplest and most cost-effective means to provide gap filling, and is the broadcaster's first choice. However, there are many areas that do not have extra spectrum available, thereby forcing broadcasters to consider complete on-channel techniques.

Digital *On Channel Repeaters* are an alternate means of repeating the signal on the *same* channel frequency when no extra spectrum is available for translators to use, such as in frequency-congested urban areas. This signal booster technique has been very carefully used in the past with analog NTSC signals. On-channel repeaters, like translators, take their input signals from off the air, but instead of translating them to a different RF channel, they repeat an amplified version of the signal on the same channel. Not only is this spectrum efficient, but it even may allow reduced main transmitter power since the main signal doesn't have to reach the specific, propagationally-challenged areas that the repeaters are servicing.

There are *five* basic configurations of on-channel repeaters, each comprising a similar overall system design of a receiving antenna, a signal processor, a power amplifier, and a transmitting antenna. The system design variation comes in the type of signal processing that is performed:

1) Simple on-channel LC band-pass filtering (*shortest* transit delay, fraction of a microsecond)
2) Frequency translation to and from an IF frequency (e.g., 44 MHz), with a simple IF LC band-pass filter (*short* transit delay of less than 1 μsec)
3) Frequency translation to and from an IF frequency, with a surface acoustic wave (**SAW**) filter (*longer* transit delay of 2 – 3 μsecs)

4) Frequency translation to and from an IF frequency, with SAW filtering and *equalization* of multipath effects on the receiver input, combined with level slicing of the symbols to restore them to accurate amplitudes, enabling transmitter pre-correction and use of an RF watermark (*longest practical* transit delay, on the order of 5 μsecs)

5) Complete VSB demodulation to the transport stream, complete with equalization and error correction before re-modulation back to a pristine VSB signal on the same RF channel (impractically *long* transit delay, in milliseconds)

It should be noted that a disadvantages of using DOCRs is that they can cause self-induced co-channel (or multipath if a synchronized digital regenerator is used) interference in coverage regions that are *overlapped* by both the main and repeated signals since the same frequency is used for both. In each of the five configurations described above, the time delay through the on-channel repeater increases with more sophisticated signal processing. The possibility of causing this multipath interference to consumer DTV receivers essentially limits the on-channel repeater design to be of an *analog* type or one with digital equalization and level slicing (i.e., *not* a full digital regenerator, as described in #5 above), except in the case of *significant* terrain-shielding between the main and repeated signals (i.e., minimal or no overlapped coverage regions where self-induced repeater multipath occurs). Minimal-delay repeaters are required since excessive processing delay, such as exist in full digital regenerators, would create echo delays in overlapping coverage regions that are longer than the cancellation ranges of practical consumer DTV equalizer hardware. The analog and equalizing digital repeaters typically have only a few microseconds or less of filter delay (the larger delay times are often from a SAW filter in the analog case and are from a combination of a SAW filter and the equalizer in the digital case), and therefore re-transmit the signal very quickly so that shorter self-induced echoes exist in overlapping coverage regions.

It is well known that *analog* repeaters always degrade the signals they carry (i.e., they never make them better) since there will be an *accumulation* of circuit and propagation noise and linear/nonlinear distortion along any cascaded system, which limits the quality of the repeated signal. The advantage of *digital regeneration*, which equalizes the signal and removes data errors (with forward error correction) before re-modulation and transmission, is *not* practical in off-air on-channel repeaters due to their unacceptably long processing delays (except in the special case where there is essentially complete terrain shielding between the main and repeated signals). The recently developed alternative listed in #4 above uses equalization of the received signals both to minimize the effects of multipath from the source transmitters to the repeaters and to counteract the effects of any feedback that occurs from the repeater transmitting antennas to their receiving antennas. The equalization is combined with level slicing to eliminate the noise from the earlier parts of a cascade, but noise effects large enough to cause slicing to the wrong levels will build errors into the transmitted signals, thereby limiting operation to areas with DTV input signals providing reasonably large (>25 dB) signal-to-noise (**SNR**) values at the receiver's tuner input. In all five fundamental designs, the delays through the repeaters are always *positive* values determined by the particular designs. That is, the output signals will always be transmitted at a *later* time with respect to the input signals. That is, there is no way in a practical (i.e., real world) implementations to achieve a "negative delay," as would be required to *reduce* the effective time delays between overlapping signals in target service areas.

Of course, the possibility of output-to-input feedback interference and distortion (or possibly oscillation) exists with these on-channel repeaters, which requires very careful antenna system design (selecting antenna patterns and determining physical mounting of the antennas). Antenna patterns may be required to have very narrow beamwidths or extreme front-to-back ratios, and transmitting-to-receiving antenna isolation levels of 80 dB to 100 dB. Antenna isolation in all three dimensions (x, y, and z) is often very necessary, along with additional shielding techniques. Thus, on-channel repeaters are only practical at relatively low power (a few hundred to a few thousand Watts of effective radiated power) and at the shorter-wavelength UHF frequencies (***not*** at VHF frequencies) where good antenna isolation is possible.

On-channel repeaters require careful network designs, even more so than for translators. Selection of the repeater *site* is important to take advantage of any terrain shielding (minimize overlapping coverage region for acceptable self-induced interference), antenna height (best controlled pattern possible), and radiated power (minimal output power for desired coverage and minimal interference). The critical network timing is dependent on the geometry of the locations of the main signal source location, the on-channel repeater site, and the receive site, with any timing calculations assuming the signals are traveling at the speed of light (3×10^8 m/sec or about one mile in 5.4 μsecs). The signal transit delay through the repeater hardware then must be added to this propagation delay value. Any additional delay in the repeater forces the delay spread in the wrong direction, thereby *not* helping the consumer DTV receiver equalizers to remove self-induced multipath. Also, the repeater output frequency must be identical (or at least *within* 0.5 Hz) with that of the input frequency to avoid any generation of self-induced *dynamic* multipath (e.g., if translation is to an IF frequency for filtering before heterodyning back again to the exact same RF channel). And the output emission mask filter is critical to once again avoid any interference to existing nearby adjacent channels. **Figure A1-2** illustrates a simple on-channel repeater system. Note that *adjacent* channel analog (or digital) signals at the on-channel repeater input are troublesome for an on-channel repeater since they cannot be fully removed with filtering without significant linear distortion of the desired DTV signal. Therefore, for all the reasons stated above, including power and timing limitations, on-channel DTV repeaters are often *not* desired for broadcasters.

However, the undesirability of off-air on-channel repeaters does *not* preclude all on-channel or SFN techniques. Distributed transmission, commonly referred to as DTx, can avoid some of the unacceptable characteristics of on-channel repeaters, although with increased complexity. By delivering the digital data that is to be transmitted by a means *other* than over-the-air broadcast and by synchronizing the output signals of all the digital transmitters, acceptable DTV reception can be possible with careful system design.

Distributed Transmission Overview

Distributed transmission (**DTx**) technology for digital television is a method of providing DTV signal coverage and service to an area using multiple *synchronized* low-power transmitters on the *same* channel frequency. This is in contrast to the *traditional* analog television method of using a single high-power transmitter on a tall tower to accomplish signal coverage and service. ATSC distributed transmission systems (**DTS**) apply single frequency network (**SFN**) technology to the ATSC system. The ATSC has developed a synchronization standard (**Ref A1-4**) and guidelines (**Ref A1-5**) for DTx transmission that provides means for transmitter synchronization in *carrier frequency* and *symbol emission* as well as proper timing adjustments to minimize *timing differences* between signals emanating from multiple transmitters. However, the DTx transmitter output signal format must be *identical* to that of the 8-VSB standard (**Ref A1-1**), and therefore be completely backwards compatible. Others have written descriptions regarding DTx systems and their design (**Ref A1-5, Ref A1-6**). The ATSC transmission system design has been shown to be very flexible, lending itself to both SFN and Enhanced VSB (**E-VSB**) technology.

DTx is a method where DTV signal coverage and service can be increased over that from a single transmitting antenna by strategically placing these multiple *low*-power transmitter sites *within* the original DTV service area, especially in areas where there is a lack of tall tower space (i.e., reduced vertical "real estate") for a single high-power transmitter, or in spectrally-congested areas where there may be a lack of available RF channels for DTV translators. DTx is different from on-channel repeaters in that each DTx transmitter receives its input signal from a studio-to-transmitter link (**STL**) signal that is different from the over-the-air signals delivered to viewers. This alternate *delivery* path that is separate from the terrestrial *transmission* path provides the necessary flexibility to easily adjust the timing and amplitudes for optimal DTS performance, which is limited primarily by the consumer DTV receiver performance.

In the traditional single transmitter system, the cost to the broadcaster of reaching the last mile of coverage with a single high-power transmitter is the most expensive. For instance, at 50 miles from a UHF transmit site and using a 1000' HAAT transmit antenna, it takes approximately 1 dB for every additional coverage mile, or 3 dB for every 3 miles of extended coverage (**Ref A1-6)**. That means the last 3 miles requires double the transmitter power output (**TPO**), which requires a significant initial hardware cost as well as on-going operational (electricity) cost. Likewise, RF interference to nearby analog and digital television signals is always an issue to consider. When using the FCC F(50, 10) field strength prediction curves for *interference* signals compared to the F(50, 90) curves for the *desired* service signal, a UHF DTV transmitter can cause interference at 3 times the radius of its service contour. This explains the large distance separations of high-power transmitters (**Ref A1-6)**. Furthermore, indoor DTV reception, expected to be used in urban and suburban areas within 20 to 30 miles of the transmitters, requires stronger signal levels outdoors by as much as 20 dB or more to overcome lower gain from indoor antennas and increased signal attenuation from antennas at lower antenna heights above ground level and building attenuation loss. Achieving strong signals inside the viewer's home is not difficult if the reception site is relatively close to the transmitter tower, but it requires large amounts of transmitted power when strong indoor signals are desired 30 miles away.

Many of the challenging *RF propagation problems* as well as *RF spectrum availability* issues can be addressed with SFN technology now that consumer DTV receiver implementations (tuners and equalizers) have improved significantly since they were originally introduced in late 1998. Since SFN technology creates absolutely synchronized multiple transmitted signals, the presence of multiple DTx signals will primarily appear as quasi-static multipath to DTV receivers. Sometimes the levels of multiple synchronized transmitter signals can be comparable to each other at some reception sites in overlapping coverage areas, which mean that severe self-induced multipath would be present at the DTV receiver's input. However, with proper SFN design, the modern DTV equalizers can often converge on a solution to cancel or significantly reduce the multipath effects and provide error-free reception. As the equalizers continue to improve, SFN self-interference requirements will relax.

A number of benefits exist when multiple synchronized low-power transmitters are employed to cover large areas. It is easier to maintain more uniform, higher field strength coverage since the area that each low-power transmitter covers is smaller than that of a single high-power transmitter. This reduced coverage distance also reduces signal level variability with time (i.e., fading), which requires less fade margin and therefore a lower radiated transmitter power and/or transmit antenna height. The lower radiated power has the *potential* for reduced interference, although it depends on where the neighboring transmitters are located and the relative level of their RF signals compared to the DTx signals near any of the DTx transmitter sites. Terrain limitations are easier to overcome with multiple transmitters since the low-power transmitters can be strategically placed to fill in the nearby shaded regions better than the one tall tower that resides far away. In many instances, the terrain limitations that are caused by obstructions such as mountains or large hills are, in fact, what may *facilitate* DTx network amplitude and delay design by minimizing overlapping coverage regions.

Another advantage of a distributed transmission network is that it provides a form of transmitter *diversity*. That is, the signal to any given DTV receiver can come from multiple transmitters from multiple directions over different terrain. This form of diversity reduces the chance of weak signal coverage areas or large propagationally-induced spectrum nulls due to multipath that might occur if only one high-power transmitter were used. As a matter of fact, inclusion of one high-power transmitter on the same channel along with all the low-power transmitters is *not* necessarily a requirement. Finally, when indoor reception is desired (either in urban or suburban areas), multiple transmitters may fill the houses with stronger and less time-varying (fading) signal levels, thus improving DTV reception reliability with simple receive antennas (**Ref A1-6).**

DTS methodology is also useful when signal coverage from a main transmitter may not be adequate to properly provide good enough signal *quality* across a large area. Reduced signal quality may be in the form of severe signal fading or significant multipath levels. Poor signal quality can certainly be caused by rough terrain (i.e., terrain shielding) out in rural areas, but it also can be caused by large buildings in a highly urbanized city like New York City or Chicago. The matter may be complicated if the main transmit site is located at a facility where the transmitting antennas cannot be placed in an optimum position, such as *some* of the DTV antennas on New York City's Empire State Building (**ESB**). In this particular situation, some of the transmitting antennas are currently side-mounted near the bottom of the tower structure that resides on top of ESB, and therefore they do not provide consistent coverage as was determined from fly-around and terrestrial field strength measurements.

Distributed transmission techniques can also be applied to *translator* systems, and these are called *distributed translator networks*. Traditional translator systems typically use many different channels, thus sometimes filling up the spectrum in a given region. In this scenario, there is no large main transmitter but rather only synchronized low-power distributed translators (**DTxRs**) all operating on the same channel. With multiple cascaded levels (tiers) of translators, only one *additional* channel is required (i.e., a total of two channels), where the signal is conveyed to each tier *not* through the traditional STL but rather through an over-the-air RF channel from the previous translator tier. One additional channel is required so that none of the distributed translators has to receive and transmit on the same channel, which would be a very challenging design as described in the previous section. Nevertheless, this is still a frequency efficient method to transmit digital signals over a wide area with challenging terrain. An interesting note is that the ATSC distributed transmission model did not originally support distributed translators, but that capability was added towards the end of the ATSC standardization process due to interest for rural area service (**Ref A1-7**). Many of the same DTx system requirements apply to this technology as well.

It is important to remember that distributed transmission technology is ***NOT*** on-channel repeater (booster) technology. The input to each transmitter is ***NOT*** taken off-the-air from the *same* channel on which it is re-transmitted, as described above for analog booster systems. Rather, a *separate* link is used to convey the data to the transmitter sites, which removes the tough requirement of antenna isolation that is required in order to prevent oscillation in booster applications. Even with the low processing delay time (less than a few microseconds due to RF and IF filtering) at each repeater site, it can be enough to prevent proper DTV receiver synchronization, and consequently degrade system performance significantly in overlapping coverage regions between the main and repeated signals. Rather, DTx uses a separate digital distribution channel to feed each transmitter site with the 19.393 Mb/sec MPEG transport stream. These separate feeder channels can be conventional microwave or fiber **STLs**, a satellite link, or they could be another television channel (e.g., distributed translators). Remember that when a main transmitter and some lower power transmitters (perhaps gap fillers) are used together in a network, the main transmitter is also a Distributed Transmitter because it receives, and is slaved to, the same signals over the STL just like all the other transmitters.

Therefore, a number of *low*-power distributed transmission transmitters (**DTxTs**) can be located in "cells" throughout a service area that can aid a main signal in providing DTV service to more viewers. Selection of the gap filler sites should be such that minimization of the overlap reception areas from the main and gap filler signals is achieved and yet DTV signal strength and quality to the largest area possible is realized. In a DTx network (DTxN) design, a few cells can each cover relatively large areas ("large cell" scheme) or a lot of cells can each cover a relatively small area ("small cell" scheme). In either case, while these cells may appear to be similar to a cellular telephone system, they are different in that all cells have the *exact* same signal on the *exact* same channel frequency.

From the information just presented, it should be obvious that DTx systems hold promise in those areas where both coverage and service need to be *extended* but no channels are available for simple translators. However, great care must be employed to design the system so that DTV receivers have the best chance for successful reception. This means accounting for both the DTS hardware parameter optimization, and considering also the impact that DTx might have upon consumer DTV receiver performance. Therefore, an important issue to consider all of the ***limitations*** in distributed transmission systems.

For example, the self-induced interference that occurs in the overlapping coverage areas from two or more DTx signals comes in the form of multipath since all the DTxTs are synchronized to transmit the exact same *symbol sequence* on exactly the same RF *carrier frequency*. Therefore, the ability of DTV receivers to handle potentially severe multipath is critical to the success of DTx systems, which means that certain DTV equalizer performance characteristics are an important consideration.

In a DTx environment, a DTV equalizer should have the ability to cancel one or more large amplitude (near 0 dB / 100%) *quasi*-static pre-echoes and post-echoes over a reasonable delay spread (e.g., at *least* ±5 µsecs). For smaller but still significant amplitude echoes, an even larger cancellation delay spread should be possible (e.g., at least ±20 µsecs if not ±30 µsecs). Equalizers should even be able to handle multipath conditions that *alternate* between large pre-echoes and post-echoes (called a "bobbing channel"), a very challenging condition. These conditions can commonly occur in rural areas behind hills, in urban "concrete canyons", or with indoor reception, and are the result of absolutely no line-of-sight between the receive and transmit antennas. Therefore, in DTV receivers, both the echo delay time cancellation window and the echo amplitude cancellation window are important, with a typical performance scenario of reduced echo amplitudes that can be cancelled with increasing delay. Such an echo-amplitude versus echo-delay profile curve exists in the ATSC recommended receiver practice (**Ref A1-8**), but this curve can change in time with future DTV equalizer performance improvements.

The equalizer noise-enhancement experienced in the presence of *severe* multipath should not degrade the DTV receiver's 15-dB white noise threshold by more than a reasonable amount (e.g., less than 7 or 8 dB). Finally, for small amplitude echoes, the equalizer's cancellation range should be at least ±40 µsecs.

These equalizer performance requirements are also necessary for normal, non-DTS *indoor* DTV reception in urban areas where no line-of-sight (i.e., Rayleigh propagation) conditions are often experienced due to either nearby buildings or just the lack of a window facing towards the transmitter. These conditions can lead to 0 dB echo amplitudes, where the signals can vary with time and even change from post-echoes to pre-echoes as mentioned above. While the design goals stated above were not met by early generations of DTV receivers in the late 1990s, they have already essentially been met by most 5th generation (**5G**) receivers, and certainly 6th generation (**6G**) receivers. Nevertheless, these DTV receiver performance levels still limit the DTxN design in terms of acceptable echo amplitudes and delays that are allowed in the overlapping coverage regions. These limitations, in turn, affect the individual DTx cell sizes that are allowed and thus determine the number of required DTxTs to cover a given area. However, as DTV receivers continue to improve and expand multipath cancellation capabilities, DTxN design limitations will be reduced and DTx network design will continue to get easier. In the mean time, careful DTS design is required in order to keep the self-induced multipath within the acceptable cancellation range (both amplitude and delay) of consumer DTV receivers.

For an optimized DTS design, it is desirable to transmit a repeated *pristine* RF signal (i.e., with minimal signal distortion) from each DTxT. To do this, *digital* regeneration is required in DTx systems. This means that both ATSC data and signal processing must be performed locally within each transmitter rather than just passing an amplified and filtered RF signal with all its inherent circuit and propagation distortions. However, just the *time delays* involved with VSB demodulation, equalization, trellis-decoding, de-interleaving, Reed-Solomon (**RS**) decoding, and de-randomization alone would be in excess of the equalization cancellation range of typical consumer DTV receivers located in the overlapping coverage regions if the DTxTs used an over-the-air input signal. When the processing delays in the 8-VSB encoding and re-modulation process of the digital regenerator are also considered, these digital regenerator delays are even longer, and make matters worse. Again, this is the reason that most on-channel repeaters are *not* acceptable for DTV operation. Rather, the data input to the digital exciter must be conveyed to each DTxT site by some other means than an over-the-air, on-channel RF signal in order to allow for proper synchronization and timing (delay or advancement) of the entire DTx system.

DTx network design includes consideration of DTxT locations and radiated power, cell sizes, transmitter antenna patterns, frequency offsets, amplitude differentials (e.g., Carrier-to-Interference ratios, or **C/I**), and timing delay differentials. Terrain shielding often makes the DTx system design easier since it reduces the number of overlapping coverage areas, and the isolation that it causes is often the reason for needing DTx systems in the first place. System optimization is always desired when designing these DTx systems. Of course, it is likely that there will be some overlapping RF coverage regions, and some of them may prove challenging for certain DTV receivers (particularly their equalizers). Viewers can use highly directional receive antennas to help mitigate the problem, but this is not always a possible solution. Certainly, DTx network design can also be optimized by placing these most difficult overlapping regions in areas with little or no population.

Flat terrain areas sometimes require DTx systems (e.g., lack of tall transmitter tower space), and they are obviously more challenging as there is no terrain shielding to reduce overlapping coverage regions. The DTS designer must work hard to limit desired-to-undesired (**D/U**) ratios in overlap regions as well as keeping the self-induced echo delays in critical overlapping coverage regions within reason. RF signals, in free space, travel one mile in about 5.4 µsecs, so echo delays change twice as fast as this (i.e., 10.4 µsecs/mile) as the reception area moves away from one DTx transmitter and towards another one. Design goals are to minimize the D/U ratios and echo delays in overlapping regions with significant population. Obviously, these goals do not need to be met in the middle of lakes or in wilderness areas where few humans will watch DTV signals. In many cases, directional transmitting antennas will help alleviate some of the overlapping coverage area problems, and they will be further aided if these areas (e.g., rural areas) typically have a significant number of viewers using directional outdoor antennas. These considerations, as well as the delay spread in the current generation of DTV receivers, will determine the cell size of an optimized DTx network.

As DTx networks become active and more commonplace, means must exist to easily measure and adjust the amplitudes and delays of the various transmitters at any field site installation. This system verification is critical, and therefore test methods and test equipment are required for field technicians to do this work. Preferably, this should be done while the DTx transmitters are all in service, without the need to shut them down individually. There is a method, however, to meet this requirement by use of an RF watermark signal that can be buried well below the DTV RF signal to avoid degradation of DTV receiver performance, yet allow accurate amplitude and delay measurements in the field (using power correlation methods to reduce the effects of the DTV signal) for both DTS network adjustment and verification. This topic is covered in a later section.

To summarize, the following are important considerations for DTxN design: DTxT site locations, DTxT antenna azimuth and elevation patterns, DTxT ERP, DTV receiver performance (e.g., VSB decoder IC generation), the physical location of a majority of people with DTV receivers, availability of outdoor receiving directional antennas, local terrain, and cell size. While early generations of DTV receivers, such as 1G through 3G (and even some 4G) had difficulties with large amplitude, self-induced DTS echoes, the excellent 5G (and later) designs have now permeated consumers' homes and allow reasonable DTxN performance. However, as larger percentages of deployed consumer DTV receivers in homes become 5G and later, DTS will play a larger role in many service areas that need additional help to be successful DTV regions.

Distributed Transmitter Synchronization

An important issue with a DTx design is the *requirement* for several VSB transmission parameters to be *synchronized* in all the DTx slave transmitters for the sake of DTV reception in coverage areas where the main and gap filler signals overlap one another. It is vital that the *exact* same symbol sequence (including the Data Field Synchronization (**DFS**) segments made up of both data field and data frame syncs) at the *exact* same symbol rate is modulated onto the *exact* same RF carrier frequency, and that these signals are transmitted from each transmitter at *very nearly* the same time. However, when two exciters are fed from the same SMPTE 310M MPEG transport data source, they will almost always generate different symbol sequences due to the *non*-deterministic (both repetitive and stochastic) ATSC *data* processing that relies on the exact location of the data field syncs with respect to the transport data packets as well as the initial conditions of the modulator's trellis-coding and pre-coding as well as its past data bit history. [*A stochastic process is one whose behavior is non-deterministic in that a state does not fully determine its next state, and is characterized by randomness - Wikipedia*]. Note that the ATSC *signal* processing that occurs in all VSB encoders does not alter the symbol *sequence*, but rather just alters signal characteristics like sync insertion, pilot insertion, root-raised cosine filtering, VSB modulation, and upconversion to the final RF channel. As long as the 10.762 Msymbol/sec, 8-level output of the ATSC data processor in each DTx transmitter is identical in sync timing and symbol sequence, the final RF outputs will all be identical as required.

When two DTx transmitters are *not* synchronized, they behave as co-channel DTV-into-DTV interferors rather than as echoes (i.e., replicas) of each other. Under this non-synchronized multiple transmitter condition, any DTV receiver in the overlapping coverage region can only have error-free reception with a D/U ratio of about 15 dB or more. However, if proper synchronization is accomplished so that each transmitter output has an identical symbol sequence modulated on the same frequency-locked RF carriers, D/U ratios near or at 0 dB (i.e., near or at 100% *echo* amplitudes) can be handled by the receiver if the time difference between the two signals is relatively small and well within the receiver's delay cancellation range. Therefore, synchronized distributed transmission systems potentially have a significant (about 15 dB) advantage over non-synchronized transmitter systems.

There are several issues to consider when discussing synchronization of an ATSC digital transmission signal. They are:

1) RF (pilot) carrier *frequency*
2) Data (symbol) clock *frequency*
3) *Symbol sequence*, which includes the exact MPEG transport data, the data field and data frame syncs locations with respect to the transport stream, and the special binary field sync bits that can carry mode of operation information
4) Relative *timing* of all the radiated signals

All of these factors play an important part in transmitter synchronization. *Frequency* and *timing* are fairly straightforward parameters to synchronize as well as the insertion of the field sync control data. The synchronization of an exact symbol sequence is a bit more complicated since normal ATSC data processing operations "free run," which means that they are not guaranteed to be identical in multiple transmitters unless some careful synchronization means is undertaken.

To provide further details, there are two primary areas of *non*-deterministic data processing in 8-VSB exciters, both of which are covered in the ATSC A/110B Synchronization Standard for Distributed Transmission (**Ref A1-4**).

> **First**, some of the VSB data processing methodology, as shown in **Figure A1-3**, is ***repetitive***, occurring at fixed intervals and synchronized to the VSB data frame and field syncs. Those data processing components synchronized to VSB *field* syncs are data byte randomization with a 16-bit maximum-length pseudo-random binary sequence, the 52-segment convolutional byte interleaver, and the 12-symbol intra-segment bit interleavers. All of these processes are *initialized* in the VSB modulator at the beginning of each VSB data field before any processing of the data begins, but without any pre-determined relationship to specific points in the incoming MPEG data stream. This is due to the fact that there are no data field syncs contained in the normal ATSC MPEG stream that is input to the VSB modulator. Rather, a standard VSB modulator *arbitrarily* selects a spot to insert the VSB frame sync in the data stream. Therefore, while normal ATSC data processing essentially "free runs", it is imperative that *each* DTx transmitter inserts the data field sync at the *same* point in the MPEG data stream. Otherwise, a different bit pattern and consequently a different symbol sequence will occur among the DTxTs. Since the data frame occurs every second data field with its non-inverted middle-63 pseudo-random binary sequence (**PRBS**), only the data *frame* sync needs to be synchronized among the various DTxTs while the data *field* sync can be easily derived from it.
>
> **Second**, part of the VSB data processing methodology, as shown in **Figure A1-3**, is VSB trellis-coded modulation, which includes trellis-coding of half the bits and pre-coding of the other half. It is a ***stochastic*** (non-deterministic) process whose result is dependent on the initial startup conditions as well as all the past data bits that have been processed. This process has no *fixed* relationship at all to the input data stream. The trellis-coding consists of a 4-state, linear Ungerboeck code (2 memory bits that together can have four different starting conditions) that is used to lower the error threshold in the receiver by means of soft Viterbi decoding. The pre-coding consists of a 2-state feedback process (1 memory bit that can have two different starting conditions) that is used to compensate for a comb filter in the receiver that reduces NTSC co-channel interference. The initial condition of these three bits affect the final bit (and ultimately symbol) sequence. To make matters more difficult, there is not just one trellis coder in the 8-VSB transmission system but rather 12 *independent* trellis coders in parallel that provide short symbol interleaving to complement the 12-symbol subtractive feed-forward comb filter in the receiver that reduces any NTSC co-channel interference that is present. None of the above memory bits is ever initialized or reset as part of the normal "free running" VSB data modulation process. That is, while the selection of *which* of the 12 parallel trellis/pre-coders is related to field sync (78 groups of 4 data segments is the trellis selection repetition rate that fits nicely into one 312-segment field), the trellis/pre-coding itself (*within* each of the 12 trellis/pre-coders) is *not* related to field sync at all or to any other element within the MPEG data stream since this coding process is "carried over" both data segment syncs and field syncs. Therefore this stochastic coding process must be synchronized in all DTxTs. This required data field sync carryover process for trellis/pre-coder processing is the reason that the last 12 symbols in the "binary" frame and field syncs are actually 8-levels, since they are a carry-over (i.e., a repeat) of the last 12 symbols in the last data segment that occurred just before the data frame and field syncs began.

This means that a total of 36 bits (i.e., 3 trellis/pre-coder bits times 12 trellis coders) have an arbitrary initial condition as does the exact placement of *frame* sync within any one of two groups of 312 data packets that occur between successive frame syncs. The odds of two transmitters, even with the required identical MPEG data stream at their inputs, having the *exact* same VSB symbol pattern at their outputs is 1 in 42 trillion (**Ref A1-7**). This means that there are 42 trillion different possible VSB symbol sequences for the same MPEG input data stream. Therefore, distributed transmission requires a means of synchronizing the *initial* VSB data processing conditions in the modulator and maintaining this synchronization over time.

Note that the effects of non-deterministic data processing or precise signal frequency and timing does not matter if a *single* transmitter is radiating a VSB signal to all DTV receivers in a given service area since any and all of the DTV receivers can decode this signal properly and provide valid pictures and sound. However, when *multiple* transmitters are required to be precisely synchronized to optimize DTV receiver performance in overlapping coverage areas, the non-deterministic data processing requires a method of synchronization that will make it deterministic for all slave transmitters.

Therefore, the following *four* items require consideration within a DTx system:

> **#1** The same VSB **carrier frequencies** of all distributed transmitters must be locked together so that the multiple DTV signals that are present at the input to any DTV receiver located within overlapping coverage areas will appear as *static* multipath rather than *dynamic* multipath, which is easier for the adaptive equalizer in a DTV receiver to handle.
>
> **#2** The same VSB **symbol clock frequency** must be used for all the transmitters in a DTx network in order to keep all the symbol sequences identical over time. In theory, if the ATSC standard is followed precisely, identical SMPTE 310M transport streams present at all exciter inputs would create identical symbol clock *frequencies* at the exciter outputs since the ATSC A/53E standard (**Ref A1-1**) requires fractional frequency locking of the VSB symbol clock and transport data stream clock. However, this ATSC system requirement is NOT followed strictly in many of

the deployed single DTV transmitter systems (i.e., without distributed transmission), and fancy data processing is often performed that involves adding or subtracting (if present) null packets from the MPEG stream and then re-stamping the PCR bytes. However, the danger exists that if there are not enough of existing null packets to delete from the MPEG stream (e.g., in the case of ultra-efficient opportunistic data or statistical multiplexing situations), loss of critical data can occur.

#3 The exact same **symbol modulation** must be transmitted from *each* transmitter. This requires not only the same MPEG data available at each of the modulator inputs, but also (a) the same placement of the VSB *frame sync* within the MPEG data stream, (b) the same field sync *control data*, and (c) and the same synchronization (initialization and tracking) of the *trellis-coders and pre-coders*.

#4 The **relative delay** between the various DTx network transmitter RF signals must be set so that a vast majority of receive locations in the overlapping coverage areas will *not* have large-amplitude DTS-induced echoes with *delays* greater than the echo cancellation range found in typical consumer DTV receivers. The time window that the earliest and the latest arriving echo signals fall within is called the delay spread (**DS**). For strong-signal multipath echo amplitudes greater than 18% (i.e., > -15 dB), the VSB data eyes will close and transmission errors will occur unless these correlated echoes fall within the DTV receiver's echo delay cancellation range.

The final DTx network design aspect is selecting the proper **radiated power value** and **antenna radiation pattern** for each of the transmitters so that there is enough signal strength for DTV reception in the desired areas but not so much that interference into nearby analog or digital signals is caused. This is a very delicate balance that complicates the DTS design.

Distributed Transmission System Implementation Techniques

Figure A1-4a illustrates a generic distributed *transmission* system that is based on the ATSC A/110B standard (**Ref A1-4**). Note that the "new" types of hardware that are required beyond that needed for normal DTV transmission are (1) the distributed transmission *adapter* (**DTxA**) and (2) distributed transmission slave *transmitters* (**DTxTs**). Understanding the operation of these new types of hardware is critical in understanding how the DTx system operates and how it should be optimized in the field. As a comparison, **Figure A1-4b** illustrates a generic distributed *translator* system, which has some additional system hardware requirements.

In order to properly synchronize the entire system, all the DTx transmitters are locked with respect to **RF carrier** and **symbol clock** *frequencies* (requirements #1 and #2 listed in the last section). From **FigureA1-4a**, it can be seen that the DTx system typically includes a Global Positioning System (**GPS**) satellite receiver for the DTxA as well as all the DTxT devices (LORAN-C can also be used as well). The purpose of the GPS receivers, which use reference signals from orbiting satellites, is to accurately provide both a common *frequency* (10 MHz) and a common *time* (1 pulse/second or 1 pps) reference to the DTxA and *each* slave transmitter.

The 10 MHz reference is used to generate precise IF modulator and RF upconverter local oscillator signals that will ultimately create precision RF carrier frequencies. The main source of frequency error is typically the IF modulator since the RF upconverter often will include straightforward phase-locked loop (PLL) synthesizers that can be locked to an external GPS 10 MHz reference source. An IF modulator that uses older, more traditional methods of *analog* IF modulation can do the same thing since the IF frequency is independent of the symbol clock. However, in modern VSB modulators that are often implemented digitally, the DSP clock is often locked to a multiple of the symbol clock frequency (e.g., x8), which is derived from the transport clock frequency (e.g., with a 313/564 ratio). The DSP clock is then used to create an IF signal. Therefore, transport clock frequency (and jitter) errors *may* affect the IF signal output frequency. However, IF frequency errors can be mitigated by carefully applying some form of frequency correction, thus making the IF frequency *independent* of the SMPTE 310M clock. One method is to make use of an accurate GPS 10 MHz reference for determining frequency errors in order to generate a correction. This frequency correction often is accomplished with low-frequency averaging methods that exhibits a correction lag time that may allow a small frequency error to occur if the SMPTE 310M clock frequency is slewing (**Ref A1-7**).

In addition to utilizing the GPS 10 MHz reference, the DTxA can provide some "frequency *smoothing*" to the SMPTE 310M signal through use of a *very* low bandwidth (i.e., "*very* slow") PLL. This allows different modulator designs to be used, and still maintain excellent DTxN performance. A desired goal is to keep the frequency error to less than 0.5 Hz of its nominal frequency so that all the DTxTs are within 1 Hz of each other, which minimizes the *apparent* Doppler shift among all of the DTx transmitter "echoes" that DTV receivers must handle.

The 1 pps GPS reference provides a precise time reference for accurately *determining* time delays and *creating* delay offsets. Common precision timing references at each transmitter are needed in order to accurately set the various timing delays from each DTxT so any existing multipath in the overlap coverage regions is well within the typical consumer DTV receiver echo delay cancellation range. When timing delays are compared to 1 second intervals, the 1 pps signal can be used in conjunction with the synchronous 10 MHz reference to create a 1-second tick signal for the DTxA and the DTxT units.

Therefore, both the GPS 10 MHz reference and the 1 pps timing pulses help with synchronization requirements #1, #2, and #4 listed in the previous section.

The ATSC A/110B standard also has *two* symbol frequency stability modes. In the distributed transmission packet (DTxP) that is used to carry timing and control information from the DTxA to the slave DTxTs, if the Stream_Locked_flag in the distributed transmission packet (**DTxP**) is set to a value of 1, the slave transmitters lock their symbol clock to the incoming transport stream to achieve compliance to the ATSC standard (**Ref A1-1**). However, the service multiplexer, which determines the transport stream frequency, should be accurate to within the recommended ± 2.8 ppm (**Ref A1-9**). While this is not be a difficult task since the ± 2.8 ppm frequency tolerance requirement is the same value used in the NTSC color television system from 1953, the service multiplexer can also use the GPS 10 MHz reference to create its output transport data stream, thus allowing all the downstream processing (DTxA and all the DTS slave transmitters) to be synchronized and therefore identical in their signal processing. Alternatively, if Stream_Locked_flag is set to a value of 0, then the GPS frequency reference system employed at all the transmitters is used to create the accurate data clock frequency. However, if the station's service multiplexer is not locked to the same external frequency reference (meaning that there is slight frequency difference between the service multiplexer and the DTxA transport clock rates), there is the possibility that null packets will have to be added to or subtracted by the DTxA from the transport stream (assuming there are enough of them available). The processing within the DTxA guarantees the output frequency stability to be within the required ATSC-recommended value of ± 2.8 ppm. More importantly, use of GPS locking of the transport stream data rate and of the slave transmitter data clocking becomes *necessary* when there are buffers in any of the STL paths that can result in reestablishing the data clock frequency. Even though buffer clocks might be within the SMPTE 301M standard permitted error, very large time delay differences can accumulate between transmitters from very small frequency differences occurring over a long time period.

The remaining synchronization tasks are initiated by the DTxA by processing the incoming MPEG transport stream from the encoder and inserting synchronization data before it passes the stream on to all the transmitters in the DTx system. The DTxA performs *four* functions in DTS synchronization:

1) Cadence sync insertion (for *frame* sync placement)
2) Side channel insertion (for *field* sync control data insertion)
3) ATSC channel coding (for synchronized data processing)
4) Distributed transmission packet insertion (to convey synchronization information to all transmitters)

In order to properly synchronize the data sequence in all the slave transmitters, some means is necessary to convey this synchronization or initialization information. Three methods are discussed below, and illustrated in **Figure A1-5**.

> ***First***, an IF version of the completely-modulated VSB signal can be conveyed to each DTS transmitter over an *analog* STL. Since no further data processing is required at the transmitter sites, all the transmitters will receive, and then pass along after RF upconversion to the same channel frequency, the exact same symbol stream. However, this requires a reasonably clean link (i.e., little noise or distortion) to all the transmitter sites since no further data processing (equalization or error-correction) is performed. It also requires GPS signals at all locations to create precise RF signals (within ±0.5 Hz) for quasi-static DTS-induced multipath in overlapping coverage areas as well as analog delay lines to adjust the relative system timing to minimize echo delays in these same areas. This method does *not* allow for exciter pre-correction to compensate for transmitter linear and nonlinear distortion.
>
> ***Second***, a *baseband* version of the completely-coded 8-level data stream can be conveyed to each DTS transmitter over an *analog* STL. Since no further data processing is required at the transmitter sites, all the transmitters will receive, and then pass along after modulation and RF upconversion to the same channel frequency, the exact same symbol stream. However, this again requires a reasonably clean link (i.e., little noise or distortion) to all the transmitter sites since no further data processing is performed. It also requires GPS signals at all locations to create precise IF and RF signals (within ±0.5 Hz) for quasi-static DTS-induced multipath as well as analog delay lines to adjust the relative system timing to minimize echo delays in the overlapping coverage areas. It also does *not* permit the use of exciter pre-correction of transmitter linear and nonlinear distortion. A similar method is to take this same signal, convert it into 3-bits for every symbol (2 data and 1 trellis), and then send it over a 32 Mbps STL (1.5 times the 21.5 Mbps VSB data rate) to all the transmitters, where it will then be converted back (with a digital-to-analog converter) into the same 8 levels for VSB modulation and RF upconversion. In this modified version, a digital delay line could be employed to set the delays for adjusting the relative system timing, and pre-correction of linear and transmitter nonlinear distortion would be possible.
>
> ***Third***, a normal MPEG-2 transport data stream at its typical 19.393 Mbps rate carrying some extra synchronization data within it can be conveyed to each DTS transmitter over a digital STL. Only a very small amount of the transport data bandwidth is used to convey this synchronization, timing, and control information to each DTS

transmitter, providing compatibility with the existing digital STL infrastructure and yet providing significant amounts of flexibility and control. It is this third method that the ATSC A/110B standard (**Ref A1-4**) describes.

The ATSC A/110B standard calls for ***three* mechanisms** to be added to the MPEG-2 transport stream that simultaneously transfers the appropriate synchronization information to all the transmitters, using the existing MPEG transport data stream that is sent from the service multiplexer to all the transmitters via the **SMPTE 310M** synchronous serial interface (**SSI**) standard that was designed specifically for DTV studio-to-transmitter links. However, no extra data bandwidth or error correction was added to this SMPTE 310M standard for this purpose. Therefore, to provide remote transmitters with the pre-coder and trellis synchronization, a very small amount of transport stream bandwidth must be allocated specifically for this purpose.

The **first** information transfer method is for the DTxA to insert a ***cadence sync*** (**CS**) signal into the MPEG transport data stream. Its purpose is to provide additional structure to the data stream that permits locking the *repetitive* transmission data processes (everything *except* trellis coding and pre-coding) in the DTxA and the DTx transmitters. The only purpose for this cadence sync insertion process is to remove the normally *arbitrary* selection of VSB data *frame* sync placement in a VSB signal by a transmitter (dependent upon when the modulator is first powered up). Therefore, the cadence sync defines a specific location within the transport stream for the insertion of the frame sync (requirement #3a listed in the last section) in all the DTxTs. Otherwise, all the transmitters would have arbitrary insertion of the VSB frame and field syncs into a VSB data stream, thus not providing identical symbol streams at a transmitter output.

Within the VSB transmission signal, there are binary data frame and data field syncs that are made up of pseudo-random *binary* sequences (511-bit PRBS and three repeated 63-bit PRBS) that can be used in DTV receivers to find the *location* of the data frame and data field syncs as well as serve as training signals for equalizers. However, every *other* data field sync has the middle 63-bit PRBS bit-inverted, which inherently creates a Data Frame structure composed of two Data Fields. Common ATSC nomenclature refers to the field sync with no inversion as the Data Frame Sync and the field sync with inversion as the Data Field Sync. Of course, there is a simple integer phase relationship between these two syncs: two Data Fields, *each* consisting of 313 data segments, occur in one Data Frame that has a total of 626 data segments (*inclusive* of the binary field and frame sync data segments). Therefore, if the Data Frame were synchronized in the VSB modulators, the Data Field sync would be automatically synchronized as well.

MPEG transport data streams *always* have a 47hex MPEG sync byte at the beginning of each packet, allowing proper synchronization within MPEG decoders due to its fixed 188-byte repetition rate. However, this DTx synchronization method periodically inserts a cadence sync by replacing this 47h sync byte with its *inverted* bitwise code (i.e., B8h) every 624 data packets so that it is easily recoverable. The reason that cadence sync is inserted every 624 MPEG packets (rather than every 626 or twice 313 as in the VSB signal) is due to the fact that no frame or field syncs exist in the **MPEG transport** world, only in the **VSB world**. Therefore, the DTxTs must insert a frame or field sync segment packet every 312 MPEG data packets, which means that in the DTS transmitters the VSB field *sync* repeats every 313 data segments and the VSB *frame* sync repeats every 626 data segments after the data stream is expanded by this sync insertion process.

The detection of a cadence sync (i.e., inverted MPEG sync byte) causes a slave transmitter to insert a Data *Frame* sync into the data stream that is defined as having ***no*** inversion of the middle PN-63 sequence (as opposed to the Data *Field* Sync which ***does*** have inversion of the middle PN-63 sequence). In DTxTs transmitters, a Data Frame sync is inserted into the stream immediately ***before*** the RF emission of the MPEG transport packet that contains the cadence sync. All MPEG sync bytes and cadence sync bytes are removed by the DTS transmitters and replaced with the 4-symbol (equivalent to one byte) VSB binary data segment sync before transmission, as expected by consumer DTV receivers. Note that, in the master timing control unit called the DTxA, the data frame cadence sync has arbitrary phase with respect to the MPEG transport data stream, but in all the DTx transmitters, it does *not* have arbitrary phase but rather it has the exact same relationship to the MPEG transport stream that exists in the DTxA. In other words, the DTxA synchronizes all the DTx transmitters via the cadence sync.

In addition to the cadence sync, the position of the Data Frame Sync can alternatively be determined from a 10-bit Packet Number that is part of the DTxP, as explained below. This 10-bit number designates the number of MPEG data packets that have passed since the last cadence sync (which represents Data Frame Sync), including the DTxP itself. The maximum value of the packet number is 624, which is covered by a 10-bit binary number (which has 1023 as its maximum value). The cadence sync is used in most DTx systems, but when distributed ***translators*** are employed that have multiple tiers (i.e., multiple cascaded levels), the cadence sync can *not* be transmitted through the RF system (since Data Segment Sync is used in the VSB domain instead of the MPEG 47hex sync). It would take a special VSB receiver to reinsert a cadence sync (which is certainly a possibility), but the redundant transmission of the Packet Number alleviates the need for a special VSB receiver.

With either approach, this first information transfer method allows for the ATSC data processing blocks to be synchronized to the VSB's frame sync.

The **second** information transfer method is for the DTxA to convey ***field sync control data*** for insertion into the VSB binary field sync at each DTx transmitter (requirement #3b listed in the last section). Besides the 24 bits that convey the VSB transmission *mode* (e.g., 2-VSB, 4-VSB, 8-VSB, 16-VSB, 8T-VSB), there are an additional 92 bits that immediately follow that are reserved for future use (e.g., future transmission modes). For example, some of these reserved information bits can be used for E-VSB which requires the dynamic robust channel map to be conveyed to any E-VSB transmitters once per field. Therefore, in addition to providing *control* of the transmitter mode in a DTx system, some of these DTxP bits are also used to *inform* DTV receivers out in the field which specific data mode that is being transmitted. Any changes in the actual transmitter mode starts upon the end of the first field *after* the bits are received (**Ref A1-4**). By transmitting all of the possible transmission mode bits (current and future) from the DTxA to all the slave transmitters, the possibility exists for additional processing to be performed at the MPEG source end that can add the necessary information bits to the DTxA for inclusion with the new enhanced data stream so that the same DTx transmitters can be used for a new service as well as for DTx networks. However, the mode data is *not* sent in the DTxP with the other data, but rather is conveyed in a *side channel* so that it can be updated quickly at a field rate rather than only occasionally at a slow DTxP rate (e.g., once per second).

This particular *Transmitter Mode Control Data* is formatted into 19 data bytes followed by 20 Reed-Solomon forward error correction bytes (total of 39 bytes, or 312 bits), which is sent using the MPEG transport data stream. The ATSC A/110B standard (**Ref A1-4**) refers to this path as the *Field Rate Side Channel*, and it is created by using the single MPEG "transport_error_indicator" bit within *each* individual MPEG packet. Therefore, 312 transmitter mode control bits are sent serially ***every*** field since there are 312 MPEG transport data packets transmitted within one VSB data field (exclusive of VSB frame or field sync). Two fields worth of side channel data occur in between two cadence signals. This control data is sent out constantly, and *not* in a bursted mode, and can update the VSB control data every VSB field, if needed. Note that *no* precious payload data is used in this method since the MPEG packet error indicator is not typically utilized in this particular path; however, this error indicator bit in each MPEG data packet is *restored* to its proper value of zero (indicating no error) in each of the DTS transmitters just prior to transmission over the air. This amount of data is enough to send the 24 VSB mode bits and the 92 reserved bits that are inserted into each binary VSB field sync, and still leave an additional 36 bits in reserve for some other future transmitter mode control use (although there is no more room to send any additional bits in the binary VSB field sync). However, it is critical that this side channel data path be very reliable, which is why the 19 data bytes are heavily protected by 20 Reed-Solomon error-correction bytes.

When either the VSB mode state or the DFS reserved bits change, the DTx transmitter inserts the bits into the *next* VSB data field or data frame sync that occurs. However, any transmitter *mode* or *characteristic* changes are delayed for one field after that and begin upon the occurrence of the data segment sync (first byte) of the *subsequent* data field sync.

If, by chance, there is no input to the DTxA, the DTxA creates a default Field Rate Side Channel using the MPEG "transport_error_indicator" bits in all of the null packets that it internally creates for transmission. The default pattern that it transmits for the Field Rate Side Channel is identical with those bits nominally specified by the ATSC A/53E standard (**Ref A1-4**).

The side channel is currently useful for E-VSB system operation that sends some of the packets with various levels of increased robustness over 8-VSB packets but with reduced data rate (½ -rate and ¼-rate). E-VSB operation *allows* for the possibility of changing E-VSB field sync data bits once per field, if required. The distributed transmission data packet described in the next paragraph can not be used to send this data since its repetition rate is too low to send this VSB field rate data. It is important to note that the DTx system synchronization standard was created in such a way that a distributed transmission slave transmitter is *already* E-VSB compatible. The only required change is the DTxA, which would require a new unit to properly combine the multiple data-rate streams before performing the required DTxA processing. This technique can easily be extended to *future* VSB-related transmission systems, such as the ones being developed for mobile and hand-held technology that also need to carefully place certain data packets at certain locations within the VSB data frame. **Table A-1** summarizes this transmitter mode control data format.

Table A1-1 Field Rate Side Channel Data Organization

Definition	# of Bits	Comments
VSB Mode Data Setting	24	Definition of 8T-VSB and 16-VSB Modes; **inserted** into field sync (see A/53E)
DTS Reserved Data	92	Reserved; Some bits are used for E-VSB; **inserted** into field sync (see A/53E)
Reserved	36	For future use; ***not*** for insertion into field sync (no room left in VSB frame sync)
Side Channel ECC	160	20 bytes of Reed-Solomon error correcting code; Protects 19 byes of Side Channel Data; ***not*** for insertion into field sync
TOTAL	312	Same number of data segments in a VSB field (exclusive of frame or field sync)

The **third** information transfer method is for the DTxA to synchronize all the slave transmitters with regard to ***data symbol emission*** and ***relative delay*** (requirements #3c and #4 listed in the last section). The data symbol emission synchronization process encompasses data randomization, Reed-Solomon (**RS**) encoding (t=10, 187, 207), convolutional byte interleaving (B=52, m=4, N=208, BxM=N), and trellis-coded/pre-coded processing complete with 12-symbol interleaving). Some of this *data* processing is related to *repetitive* processing that is synchronized to the VSB field sync and some of it is related to the *stochastic* process that is dependent on the modulator's initial conditions and past data history. This is the most sophisticated processing that the DTxA unit performs since it is a model of the *exact* same data processing that is performed in every VSB encoder/modulator as part of the normal ATSC transmission encoding (**Ref A1-1**).

However, to maintain data *symbol* emission synchronism in a DTx system, every transmitter within the network must perform its data processing on the *exact* same MPEG transport data stream that the DTxA unit uses, complete with proper identification of frame sync placement within the transport data packet stream. In order to achieve this goal, the DTxA must distribute synchronization information to all the DTxTs in a special synchronization packet (i.e., the DTxP) that allows "slaving" (i.e., synchronizing) the DTxTs transmitters to both the *repetitive* and *stochastic* processes described earlier. While the placement of the VSB frame and field syncs is accomplished with the cadence sync byte that synchronizes the repetitive processes in all the DTxTs transmitters, the remaining synchronization is accomplished by conveying the trellis/pre-coder stochastic *state* data to all slave transmitters and removing any initialization ambiguity.

The DTxA, which is the "brains" of the DTS synchronization process, is required to have an MPEG-transport stream input and output port as well as frequency (10 MHz) and timing (1 pps) reference input ports and transmitter control input ports (see **Figure A1-4a**). The transport data input port receives all the MPEG-2 transport packets from the DTV station's service multiplexer, which is the device that assembles (i.e., combines or multiplexes) the individual data packets from all the various video, audio, and data services. The most common interface in use today is the SMPTE 310M standard, although other interface standards can be used (e.g., Asynchronous Serial Interface, or **ASI**).

In order to guarantee meeting the requirement for identical data, the DTV station's service multiplexer must be programmed to add a reserved *placeholder* packet to the MPEG transport data stream with a special *Packet Identification* (**PID**) value of 0x1FFA at a pre-determined repetition rate that contains fixed (i.e., static) placeholder data. The pre-determined repetition rate is not critical, but is often selected by the DTS designer to be around 1 second. The special placeholder packet is ultimately modified in the DTxA unit by replacing the temporary data from the station's service multiplexer with actual synchronization data. The DTxA then conveys this synchronization information to all the slave transmitters. If the service multiplexer does not provide this special "pre-formatted" reserved packet, then the DTxA might possibly remove an active MPEG-2 transport data packet to insert the necessary synchronization data packet. This can possibly cause unacceptable video or audio errors if no null packets are available from the service multiplexer (e.g., if opportunistic data is being transmitted or statistical multiplexing is being performed that uses up all the available packets). This particular reserved packet is called the pre-processed *Distributed Transmission Packet* or **DTxP** and conforms to the MPEG-2 Transport Stream packet structure defined in ISO 13818-1 Systems (**Ref A1-4**). This means that this reserved packet has the usual 4-byte header that includes the 0x1FFA PID information and a 184-byte payload. These pre-formatted static placeholder packets in the service multiplexer will ultimately be converted into synchronization packets by the DTxA.

For synchronization purposes, the ATSC's A/110B standard (**Ref A1-4**) defines a specific form of the *Operations and Maintenance Packet* (**OMP**) structure that is part of the overall ATSC transport data structure. This OMP structure supports a variety of *operations* and *maintenance* functions in a DTV transmission system. The DTxP is the first such packet *type* defined in the ATSC's OMP structure, with other functions possibly to be defined in the future. The OMP contains a 184-byte payload, just like any other MPEG packet. However, there can be more than one *type* of OMP, which provides system flexibility. The various OMP types are defined by the first byte (**OM_type**) of the 184-byte payload, which for a DTxP can be any value between 0x00 (0 decimal) and 0x0F (15 decimal). Other values of OM_type are reserved for future standards. The value of the OM_type byte for DTxP use indicates the *tier* of a cascaded translator network to which the packet is addressed, where tiers are assigned in sequence proceeding *away* from the source and incrementing by one for each successive tier in the cascade (**Ref A1-4**). A maximum number of 16 different tiers are allowed in the ATSC standard (main

DTx system plus 15 levels of distributed translators). As shown in **Figure A1-4b**, multiple DTxAs can be cascaded to create multiple DTxPs in order to control multiple translator tiers within the network. Each group of DTxPs (one group for each translator tier) will be used only by the associated DTS transmitters in that tier since each group of DTxPs will have a unique OM_type byte. However, for normal DTx systems or distributed translators with *one* tier, this OM_type value is set to 0x00.

Therefore, not only must a fixed known data pattern be sent by the station multiplexer to the DTxA via the OMP (i.e., the *pre*-processed DTxP), this same fixed known pattern must also be *re-inserted* by every slave transmitter, replacing the trellis and pre-coding state synchronization data (as of the snapshot time) that was inserted at the *output* of the DTxA and transmitted on the STL. This is necessary since the trellis and pre-coding state data that is conveyed in the DTxP is not part of the actual MPEG data to be transmitted is not part of the data that went through the trellis and pre-coder coding process. Rather, this special data is a temporary snapshot of the 36 trellis and pre-coding memory states that are created in the replica of the ATSC data processing model (**Figure A1-3**) affected by the actual MPEG data. In other words, the DTxA and all the DTxTs must perform VSB data processing on the exact same data (and *only* that data) that will be transmitted as an RF signal over the air. **Therefore, the 36 bits of trellis and pre-coding state synchronization data exists only on the STL, and are *not* transmitted over the air nor are they ever manipulated by the ATSC data processing circuitry. Therefore, this fixed known "stuffing" data pattern must be pre-determined and used by both the DTxA and the DTxTs.**

In summary, after the service multiplexer sends out the 4-byte MPEG header and the OMP packet type data, the remaining 183 bytes of the OMP payload (OM_payload) contains fixed placeholder data, most of which is initially filler that will ultimately be replaced by actual synchronization and control data in the DTxA, thus turning the OMP into a DTxP. This OMP filler data created in the service multiplexer, which is reserved for synchronization and control, is filled with alternating bytes *after* the first payload byte (which is the OM_type), starting with 0x55 in the second payload packet and every subsequent even-number packet, and then 0xAA in the third payload packet and every subsequent odd-numbered packet. This means that the 184-byte payload data has one byte of OM_type, 92 bytes of 0x55, and 91 bytes of 0xAA. The definition of this form of OMP (also known as a DTxP *precursor* packet) is shown in **Table A1-2** below:

Table A1-2 Station Service Multiplexer Output: DTxP Precursor Operations and Maintenance Packet (OMP)

Data	# of Bits	Comments
MPEG Sync	8	MPEG Header: 47h sync byte
Transport_Error_Indicator	1	MPEG-Header: 0h
Payload Unit Start Indicator	1	MPEG-Header: 1h
Transport Priority	1	MPEG-Header: 1h
Packet Identification (PID)	13	MPEG-Header: 0x1FFA
Transport Scrambling	2	MPEG-Header: 00h
Adaptation Field Control	2	MPEG-Header: 01h
Continuity Counter	4	MPEG-Header (increments every OMP packet; from 0000 to 1111)
Operations & Maintenance Packet Type	8	OMP Type: 0x00 (DTx rather than DTxR, which can be 0x00 – 0x1F)
Fixed Data Pattern #1	736	Payload: 0x55 (92 bytes; only even-numbered payload packets)
Fixed Data Pattern #2	728	Payload: 0xAA (91 bytes; only odd-numbered payload packets)
TOTAL	1504	188 bytes = 4-byte header + 1 Type byte + 183 Data bytes

The OMP *pre*-processing in the station multiplexer readies the system for creation and distribution of the DTxP by the DTxA. The DTxA, which controls the DTS synchronization process described above, typically receives the SMPTE 310M signal from the station's service multiplexer, performs a *two*-step process that creates a DTxP (as described below), and then sends an MPEG transport stream with the inserted DTxP synchronization data over a SMPTE 310M link to all the slave transmitters. The following information briefly describes how the DTxA accomplishes all of these tasks and meets all the necessary DTS synchronization requirements.

Synchronization of multiple ATSC transmitters requires the exact same transport data at the inputs to the data processing sections of their VSB encoders in order to achieve emission symbol matching. However, even with this condition met at all the DTS transmitter inputs, there is still no guarantee that emission symbol synchronization will occur unless the DTxA sends further synchronization information (trellis and pre-coding *states*) to lock up the non-deterministic *stochastic* transmitter processing (i.e.., trellis coding which provides a lower receiver threshold SNR value and pre-coding which aids the receiver's NTSC rejection-comb filtering). This trellis and pre-coded data is *not* synchronized with the VSB frame or field syncs, but is dependent on a VSB modulator's startup state initialization and all the subsequent data history.

From the discussion above, it is clear that the OMP must have *some* of its placeholder bits replaced with the actual DTS synchronization data to form a DTxP. The DTxP data format and definitions are shown in **Table A1-3** below. In the first part of a two-part process, the timing and control data (to be described subsequently) that is inserted into the DTxP (replacing ***most*** of the placeholder bytes) is determined <u>apart</u> from the transport packet stream data itself. However, the following data is ***<u>not</u>*** inserted: (1) the trellis/pre-coder state data and (2) the Reed-Solomon FEC bytes that protect the 164 bytes of DTxP payload data. Since the trellis/pre-coder and Reed-Solomon information is dependent on the actual transport stream data sent from the service multiplexer, it is not known until *after* the OMP has been fully data processed within the DTxA just prior to sending it over the STL to all the transmitters. Therefore, *most* of the DTxP payload data is inserted into the OMP immediately upon its PID detection within the DTxA (prior to trellis and pre-coding processing). However, the special *stuffing* data bytes (0xAA and 0x55) which are temporary placeholders for the 12 bytes (7th through 18th) for trellis and pre-coder states as well as the 20 bytes (169th through 188th) for Reed-Solomon error correction code are left in the transport stream for *simulated* VSB data processing within the DTxA. For proper RF data symbol emission synchronization, these same stuffing data bytes must also be present in each of the DTS slave transmitters when the *actual* VSB data processing is subsequently repeated there just prior to transmission over the air.

This DTxP synchronization data (including the remaining 12 + 20 = 32 bytes of *<u>stuffing</u>* data) is processed in the DTxA through the *free-running* standard <u>VSB data processing</u> model (**Figure A1-3**) along with all the other transport stream data that has come before it. The data processing model establishes the various *timing relationships* (e.g., with respect to MPEG/segment sync and cadence/data frame sync) between the input transport stream and the several data processes that occur in a transmitter (**Ref A1-4**). This part of the DTxA processing can free run since the Distributed Transmission Adapter is the device that arbitrarily determines where frame sync will be placed and is the reference for all the transmitters.

Stochastic state synchronization is then accomplished by capturing a snapshot of the 36-bit trellis/pre-coder states (3 groups of 12 bits) at well-defined times that exist in the DTxA simulated VSB data processing model (i.e., at the end of *each* equivalent VSB data field or frame sync). The three groups represent the two trellis states and the one pre-coder state, and the 12 bits represent the twelve symbol intra-segment interleaver. Therefore, these 36 states represent the status of the trellis/pre-coder storage devices as they will exist <u>immediately</u> *following* the Data Field Sync at the start of the *next* Data Field after the appearance of the DTxP in the MPEG-2 transport stream (**Ref A1-4**), assuming that the proper stuffing data is appropriately inserted at the DTxTs. Before insertion into the DTxP, these 36 trellis/pre-coder state bits are extended to 96 bits by adding a 4th parity bit to each group of 3 bits and then appending to each 4-bit group an inverted second copy of the 4 bits for extra *robustness* for a total of 8 bits per trellis/pre-coder state (i.e., 8 bits x 12 groups = 96 bits). After the trellis and pre-coder states are known and inserted into the DTxP, the 20 Reed-Solomon error correction bytes are determined and then inserted at the end of the DTxP for transmission to the slave transmitters over the normal STL.

It is desired to send from the DTxA to the DTxTs the trellis/pre-coder states in a DTxP that occurs *before* the time these states actually exist in the trellis/pre-coders, thus allowing enough time for the DTxTs to properly process them and insert them accordingly into the final output stream. This requires the transport stream to be delayed by one data field in order to obey the physical laws of causality (in the real world). Therefore, the presence of a *data field delay* in the DTxA then allows for the state of the trellis/pre-coder at the *end* of a data field to be inserted into a DTxP that is transmitted *before* the end of that particular field. This facilitates the subsequent symbol synchronization in the slave transmitters.

Once again, it is very important to note that **all the DTxP data is passed through the VSB data processing algorithm *including* the 12 bytes of 0x55 and 0xAA <u>stuffing</u> data that are *placeholders* for the 96 trellis/pre-coding bits and the 160 Reed-Solomon bits (20 bytes), but *<u>not</u>* the actual trellis/pre-coding state data and Reed-Solomon data since they are a result of the data processing itself and are not known until *after* the data processing is complete at a well-defined snapshot time.**

In order to achieve DTS synchronization, the DTxP synchronization data is then sent to all the DTS transmitters. At each slave transmitter, the trellis/pre-coder state data and the Reed-Solomon error-correction data is immediately detected (robustly) and stripped from the DTxP and replaced with the exact same default filler data (multiple 0x55 and 0xAA bytes) that was present in the DTxA when the initial VSB data processing was performed. This step is critical in order for each slave transmitter to be able to produce an exact replica of the DTxA symbol sequence at its output and thus provide system synchronization for all the RF outputs. The remaining DTxP data is also stored in the slave transmitters for use in timing synchronization and other control functions, to be discussed below, but is also transmitted over the air with all the other MPEG transport stream data.

At the end of the next VSB field sync after a DTxP is detected in the DTx transmitters, each DTxT transmitter is slaved to the trellis/pre-coding states determined in the DTxA data processing model. After the first successful synchronization of all the slave transmitters has occurred, every subsequent processing of the DTxP data in the slave transmitters should track the DTxA data and only serve to *verify* synchronization. When the sync locations and the trellis/pre-coder states match, all the transmitters are running in “lock step.” Only if there is an error in the transport stream data to a transmitter or if some unusual event (e.g. a “glitch”) occurs in the operational timing of a slave transmitter will it be necessary to resynchronize a transmitter during normal operation. In this case, the DTxP data is actually used to “jam sync” the trellis/pre-coder memory storage devices during the VSB frame and field syncs and bring the offending transmitters(s) back into lock just *prior* to the beginning of the first data segment following the VSB frame or field sync.

Remember that since the DTxP replacement control and timing data that is inserted into the transport stream passes through the DTxA's VSB data processing, all of the slave transmitters must likewise process this same data and then transmit it *over the air* in order to achieve matching trellis code trajectories and keep the transmitters synchronized. This control and timing data can be received remotely and used by special test and measurement equipment in the field. The only data that is NOT transmitted over the air is the trellis/pre-coder states and the DTxP Reed-Solomon error correction codes used in the slave transmitters since they were not processed by the DTxA data processing (but were actually a *result* of that processing).

Table A1-3 DTxA Output: Complete Distributed Transmission Packet (DTxP) Organization

Data	# of Bits	Comments
MPEG Sync	8	MPEG Header: 47h sync byte
Transport_Error_Indicator	1	MPEG Header: 0h (unless Tx mode control data is being sent)
Payload Unit Start Indicator	1	MPEG Header: 1h
Transport Priority	1	MPEG Header: 1h
Packet Identification (PID)	13	MPEG Header: 0x1FFA
Transport Scrambling	2	MPEG Header: 00h
Adaptation Field Control	2	MPEG Header: 01h (no adaptation field, just payload data only)
Continuity Counter	4	MPEG Header: (increments every OMP packet; from 0000 to 1111)
Operations & Maintenance Packet Type	8	OMP Type: 00h (DTxTs rather than DTxRs)
Reserved	8	Payload: Reserved for future DTxP use
Trellis Code State (3-bit pre/trellis coder)	96	Payload: (3-bits+1 parity) x 2 copies x 12 parallel coders; data sync-ing
Synchronization Time Stamp	24	Payload: For time delay adjustment & optimization
Maximum Delay	24	Payload: Maximum time delay in DTxN (DTxA Output to Tx Output)
Network Identifier Pattern	12	Payload: Network Watermarking ID
Stream Locked Flag	1	Payload: Tx symbol clock lock requirement (internal TS=1 or external GPS=0)
Reserved	1	Payload: Reserved for future DTxP use
Packet Number	10	Payload: Supplements cadence sync for VSB frame sync location
Reserved	32	Payload: Reserved for future DTxP use
Tx Group Number	8	Payload: 1 byte; 1st 8-bits of Tx addresses (for Watermarking ID, *redundant*)
Tx Address (12-bits each)	192	Payload: Transmitter Watermarking ID (for up to 16 TXs)
Tx ID Level (3 bits each)	48	Payload: Amplitude level of Watermarking ID (for up to 16 TXs)
Tx Data Inhibit (1 bit each)	16	Payload: Watermarking *modulation* ON/OFF control (for up to 16 TXs)
Tx Time Offset (16 bits each)	256	Payload: Emission timing adjustment (for up to 16 TXs)
Tx Power (12 bits each)	192	Payload: TPO amplitude control (for up to 16 TXs)
Reserved (4 bits each)	64	Payload: Reserved (for up to 16 TXs)
Reserved	320	Payload: Reserved for future DTxP use
DTxP Forward Error Correction	160	FEC: Reed-Solomon (t=10, 164, 184); protects all bytes except header
TOTAL	1504	**DTxP**: 188 bytes = 4-byte header + 1 Type byte + 163 Data bytes + 20 RS

Once the emission symbol sequence is synchronized among all the slave transmitters, the next critical characteristic to optimize is the relative *timing* of each transmitter with respect to the others. DTV receivers in overlapping coverage regions must deal with these self-induced DTS multipath echoes. The goal is to minimize the areas in the overlapping region that have large echo amplitudes with echo delays greater than what typical consumer DTV receivers can handle. In order to do this, a *common time reference*, such as provided by a GPS receiver, is needed at all transmitter locations as well as the DTxA site, preferably a reference that is accurate within 50 nsec at all locations. Once this absolute time reference has been established (e.g., the *leading* edge of the GPS 1 pps signal), then individual transmitter timing offsets can be determined and controlled remotely from one location through the DTxP signal from the Distributed Transmission Adapter. The use of GPS receiver technology at each site provides both an accurate frequency (10 MHz) and timing (1 pps) relationship.

Adjusting the proper timing among all the slave transmitters deals with *two* separate issues. The first is to determine all the various delays within the DTS *distribution* network itself, including the STL. The second is to decide where to place the best-case and worst-case relative signal timings (including RF propagation delays) within the coverage areas. However, this second issue is a matter of system design optimization and is not a part of the system timing control's logical definition described here.

There are three time references values in the DTS synchronization scheme that are distributed over the DTx network via the Distributed Transmission Packet. Two of these references values are sent to *all* transmitters: the *Synchronization Time Stamp* (**STS**) and the *Maximum Delay* (**MD**). The third time reference value is an *Offset Delay* (**OD**) that is *individually* sent to specific transmitters to bring them into line for optimal and acceptable relative emission timing.

The first timing variable that is included in the DTxP is the **Synchronization Time Stamp**, which is the number of 10 MHz GPS clock periods (i.e., 100 nsec time intervals) between the *last* leading edge of the 1 pps GPS clock tick and the time that the first DTxP bit is sent out from the DTxA. This STS value is determined from the 1 pps GPS timing reference at the DTxA and then sent to every DTS transmitter over the STL. Since every transmitter *must* also be outfitted with a GPS receiver, this provides an absolute time reference for the entire system. All timing will be described with respect to the STS reference value.

The second timing variable that is included in the DTxP is the **Maximum Delay** value, which must be greater than the approximate worst-case time delay from the DTxA output to the RF output of the *latest* transmitter. This value, which is measured in 100 nsec time intervals (i.e., 10 MHz reference clock periods), should be selected *by the DTx network designer* based on the sum of the delays of the longest DTx distribution link and the longest transmitter processing. Its purpose is to guarantee that the RF signal output times of all transmitters in the network have enough delay to account for (i.e., match) the longest delay in the distribution path to any slave transmitter input plus the delay of the transmitter and antenna. This time relationship is what provides for the possibility of relative *advancement* of a given transmitter emission time without violating the physical laws of causality. The MD value must be in a reasonable range so that when the individual slave transmitter Offset Delay values (which can be either positive for delay or negative for advancement) are added to it, the final value will be positive and represent a *delay* between 0 and 1 second. *Absolute* advancement, which is negative time, is impossible due to the physical laws of causality (i.e., in real-world limits). If the calculated value is greater than 1 second, then a value of 1 second is subtracted from the calculated value to accurately reference the emission time to the most recent 1 pps clock tick.

The third timing variable that is included in the DTxP is the **Offset Delay** value, which is a value that is individually selected for *each* transmitter to provide optimum timing performance of the DTx network. It is measured in 100 nsec time intervals (10 MHz reference clock periods) and can be either a positive or negative value (-32,768 to +32,767 which is -3.2768 msecs to +3.2767 msecs) that is compensated within each exciter by its Transmitter and Antenna Delay (**TAD**) value that is stored in the transmitter's exciter for subsequent *calculations* of precise emission time.

TAD is officially defined as "the time from the entry of the first bit of a Cadence Sync word into the Data Randomizer (first block of Data Processing system) to the appearance at the antenna output of the leading edge (zero crossing of the +5 to -5 transition) of the segment sync of the corresponding Data Frame Sync data segment" (**Ref A1-4**). This technique provides a *constant* value of TAD that is independent of all the other *variable* delay processing that occurs within the exciter's data processing (e.g., convolutional byte interleaving does not provide constant data delay as some bytes are spread out longer than others). Then, the exciter delay value plus the delays of all the RF components (high power amplifier, harmonic filter, emission mask filter, any channel combiners in the path, transmission line, and antenna) yield the final value of TAD. This value of TAD, which can be provided by the equipment manufacturers, is then stored in *each* transmitter where it is simply subtracted from the OD value that is sent in the DTxP by the distributed transmission adapter.

The reference time T_{REF} for synchronizing the emission sequence timing is the synchronization time stamp plus the maximum delay (i.e. $T_{REF} = STS + MD$). Every transmitter can *calculate* this *reference emission time* if (1) a working GPS receiver is present with an available 1 pps signal, and (2) a working transport data stream receiver within the exciter is properly extracting the MD value from the DTxP. Then the individual Offset Delay for each transmitter is added to this reference emission time, minus the individual TAD value that is stored in each DTS transmitter. That is, the desired Transmitter Emission Time (**T_E**) is described by:

$$T_E = T_{REF} + OD - TAD = STS + MD + OD - TAD \qquad (1)$$

This emission time T_E is the desired time (relative to the last 1-second GPS clock tick) for *each* slave transmitter to begin radiating the VSB frame sync so that the required relative timing is met. However, once the desired emission time T_E is calculated for each transmitter, the amount of required transmitter delay (**Tx Delay**) must be determined by each transmitter in order for it to know how to adjust its internal variable data delay line so that the desired emission time is met.

Transmitter delay is achieved with a variable data delay line in each slave transmitter, which is the means for adjusting the timing of each transmitter's radiated output. It is defined as the delay between the leading edge of the arrival of the first bit of the MPEG sync byte of DTxP at the exciter input (**T_{IN}**) to the DTxP first bit of the MPEG sync byte at the Data Randomizer (**T_R**). The desired amount of variable transmitter delay (**T_D**), in 100 nsec steps, is found by:

$$T_D = T_R - T_{IN} = T_E - TAD - T_{IN}$$

where T_{IN} is *measured* by the transmitter, in 100 nsec time intervals, the time from the leading edge of the last 1 second clock tick to the first bit of the MPEG sync byte of the DTxP.

The relative timing variables are illustrated in **Figure A1-6**, which is taken from the ATSC A/110B document (**Ref A1-4**). If the calculated emission time exceeds 1 second (which is the 1 pps clock tick rate), then 1 second is mathematically subtracted from the total emission time value (i.e., $T'_E = T_E - 1$) so that the new emission time is determined relative to the *most recent* 1-second tick time reference.

As an aside, note that the maximum delay must be properly selected to be greater than the sum of the transport delay, transmitter exciter delay, and the TAD. Also, in **Figure A1-6**, the DTxP Arrival time denotes the arrival of the first bit of the MPEG sync byte of the DTxP to the transmitter's external SMPTE 310M input connector while the DTxP Modulation time signifies the arrival of the first bit of the MPEG sync byte of the DTxP to the VSB data randomizer input contained within the VSB exciter. The difference between these two times is called the Tx Delay, and the sum of the Tx Delay and the TAD together make up the total transmitter system delay.

In addition to all the timing synchronization aspects, the ATSC A/110B standard also allows individual control of the transmitter power. Transmitter power level control may be needed to obtain the desired DTx network design, providing proper D/U ratios in the critical areas.

Distributed *translators* are very similar to generic distributed transmission systems. However, a major difference exists when multiple DTxR transmitters are cascaded more than one level (i.e., tier) deep and they are receiving their transport stream from another RF transmitter (i.e., over the air). When this situation exists, the 2nd tier and beyond typically does not have access to the trellis/pre-coder states from transmitters in earlier tiers since this information is only carried in the STL signal and is *not* transmitted over the air. The exact solution will depend on the complexity of the translator system design.

If the DTxR system is a simple *single*-hop implementation, where the main transmitter is on one frequency and all the distributed translators that receive this RF signal (which is acting like an STL) are to be synchronized on the same channel, but different from the main transmitter's channel, the solution is straightforward. In this case, the main transmitter is receiving the transport packet stream from a DTxA. However, the main transmitter is ***not*** a distributed slave transmitter, but rather is an ordinary ATSC transmitter. That means that the DTxP is transmitted intact over the air like any other transport data stream packet, complete with trellis/pre-coder states (i.e., they are *not* stripped out by the main transmitter). Upon reception at each translator site by a VSB receiver, the slave transmitter performs its usual synchronization and timing processing as if the DTxP data came directly from an STL rather than over the air. Just as in normal DTx systems, the slave transmitters at the translator sites strip out the trellis/pre-coder states and the DTxP Reed-Solomon correction bytes. Thus, each of the slave transmitters in the second tier transmits synchronized signals on the same RF channel, but different from that used by the main transmitter. What makes this situation straightforward is that there is no on-channel synchronization required for the main transmitter, only the single tier remote translators. That is, the DTxA only controls the second tier translators, and the main transmitter free runs, operating autonomously (i.e., acting like an STL). The only issue that requires a slightly different processing scheme is that the cadence sync signal (bit-inversion of the MPEG 47h sync byte) is missing as the RF signal, which has data segment sync replacing the MPEG sync byte, is received by the translator site VSB receivers and typically no cadence sync is output indicating where the data frame sync had been inserted. However, this slight problem is mitigated by the fact that the position of the frame sync is sent redundantly in the DTxP as a pointer byte indicating the number of *packets* since the last cadence (i.e. VSB frame) sync. Obviously, the DTxRs will use these pointer bytes when the cadence sync is found to be missing from the transport stream. The only difference in operation is that when a cadence sync is used in a DTx situation, it comes once per frame, and when a DTxP is used in a distributed translator situation, it comes less often as determined by the system operator (e.g., typically once per second). Therefore, this scenario is reasonably similar to a typical DTx System, except that an RF signal from the main transmitter acts as the STL. Of course, this distributed translator system, like normal translator systems, will only work if the received signal at the translator input is above threshold and experiencing error-free DTV reception.

This simple technique is limited to a "one hop" translator system. The slightly more complicated translator scenario occurs when a 2nd tier (or more) is added to the system. But if synchronization is required only ***within*** each tier (and *not* between tiers), then a series of DTxAs can be placed at the source end so that *each* one is adjusted to control one tier. While they will all use the same OMP structure to create their individual DTxPs, each DTxA (one for each tier) can have its own unique OMP packet *type* (8-bits are allocated for this in the DTxP structure, with up to 32 DTS translator tiers defined by ATSC). At each translator tier, the associated DTxPs are interpreted and the embedded trellis/pre-coder state codes are removed along with the Reed-Solomon bytes before transmission via the antenna. However, since a *special* DTV receiver is necessary to pass along the Data Field Sync data segment information from the last tier to the current tier for subsequent transmission, the slave transmitters in each tier *after* the first generally will use the Packet Number information in the DTxP address to their tiers to establish the Data Field Sync location in the MPEG-2 transport packet stream. Therefore, DTxTs can be independently controlled to be synchronized within each tier. Remember that when complete terrain isolation exists between the various tiers of a translator system, there is no need to synchronize the system among the various tiers, just within each tier.

One last parameter to consider when discussing implementation of slave transmitter synchronization techniques is the insertion rate of the distributed transmission packet. There is no *minimum* DTxP insertion rate specified in the ATSC A/110B document (**Ref A1-4**). However, a minimum value can be considered that is a compromise between overhead data capacity and the recovery time for any transmitter that becomes unsynchronized due to a "glitch". For example, an insertion rate of one DTxP per second would use only 0.0078 percent of the overall data channel capacity. The *maximum* DTxP insertion rate is once every 312 data packets (i.e., once per VSB field), which is at a 41.3 Hz rate (24.2 msecs period). At this rate, 0.3% of the overall data channel capacity would be used. Since the DTxP carries data that is to be synchronized on a field rate, this synchronization data cannot show up at each transmitter more often than once per data field. The actual DTxP insertion rate is controlled by the station's service multiplexer since the DTxA only inserts synchronization packets when it sees the reserved OMP at its input with the appropriate PID value.

RF Watermarking Background

In a distributed transmission network, it is advantageous to be able to individually identify each on-channel synchronized signal present at a given receive site as well as any other conventional co-channel DTV signal *interferors*. This ability allows and facilitates DTx transmitter *in-service* amplitude level and timing delay adjustment and verification as well as provides a means to easily measure the propagation channel impulse response. However, this ability to distinguish each slave transmitter for both *identification* and *measurement* is not possible without turning them ON one at a time since each slave signal was intentionally made to be identical to all the others in the system so that they can be treated as quasi-static multipath echoes by DTV receiver equalizers.

One way to solve this identification problem is to assign specific, identifiable pseudo-random binary sequence (**PRBS**) codes to each *transmitter* and to the DTx *network* itself. These long, robust pseudo-random codes can be transmitted at a very low amplitude level "underneath" the VSB signal in the same RF channel due to their significant coding gain. They have negligible effect on DTV receivers, and provide diagnostic information to special receivers about the DTx transmitter (its *timing* and *amplitude* relative to the other transmitters) as well as the *channel estimation* of the signal propagation path from each transmitter. Additionally, interference identification and location finding can be accomplished with these techniques as well.

The unique network and transmitter identification codes are sent to each transmitter by the DTxA through the DTx network as part of the DTxP. Once received, these codes are used to create a *binary* symbol sequence that is modulated *synchronously* with the host 8-VSB symbols in such a way that ordinary DTV receivers are relatively unaffected by them. The "buried" transmitter and network identification signals are called RF "watermarks" (**WM**), they make use of spread-spectrum technology, which is why they are aptly called "buried spread spectrum" (**BSS**) signals (**Ref A1-4**). In this DTx context, spread-spectrum methodology is defined as very narrowband *baseband* data energy generated at the DTV carrier frequency that is distributed (i.e. spread) over a much larger frequency band. This is accomplished by use of long sequential noise-like pseudo-random codes that are subsequently buried underneath the desired DTV signal. At the special receiver, powerful *correlation* methods are used on the spread spectrum signal to retrieve the original narrowband specific codes.

In order to successfully use these RF watermarks, the binary codes must exhibit certain desirable attributes. For example, in order for them to be *uniquely* detected by special test equipment without causing interference to each other, these codes must be *orthogonal* to each other in order to have low *cross*-correlation values. This means that one transmitter code will be unlikely to be mistaken for another transmitter code. Another requirement for these *transmitter identifiers* (**TxID**) is that a large number of these orthogonal codes must exist from which to choose if a practical assignment is to be made by some regulating body to all transmitters on a region-wide or nation-wide basis. The other requirement is that they need to have large coding gain. This means that when an *auto*-correlation is performed, a very large value is obtained when the received code and stored code in the receiver line up, but when cross-correlation is performed with noise, other noise-like signals, or other codes present, the output is very low (i.e., they average close to zero). This is how these spread spectrum signals can reside far below the noise-like VSB signal and still be able to be decoded accurately.

The buried spread spectrum RF watermark signal can be created by using a 16-bit Kasami code sequence that is repeated almost 4 times (actually, 3.9 times since the 4th version is slightly truncated) throughout the ATSC data field, but ***NOT*** during the ATSC data frame or data field syncs. This sequence is created by *summing* three separate binary sequence generators, referred to as tiers, as shown in **Figure A1-7**. Each of the three generator groups (linear feedback shift registers) has a set pattern of "tap gains," and their outputs are summed together (modulo-2) before being modulated onto the RF carrier and buried beneath the VSB signal. These tap gains can be described by generator polynomials as follows:

Tier 1: $G_{(16)} = X^{16} + X^{12} + X^3 + X + 1$

Tier 2: $G_{(16)} = X^{16} + X^{12} + X^{11} + X^9 + X^8 + X^4 + X^3 + X^2 + 1$

Tier 3: $G_{(8)} = X^8 + X^7 + X^6 + X^3 + X^2 + X +1$

Out of the 40 total shift-register elements (i.e., 16 + 16 +8), 24 of them can be initialized with TxID data (Tier 2 and Tier 3). From **Table A1-3**, it is clear that, in the DTxP, each DTx network is identified by 12 bits (**Network Identifier Pattern**) and each DTx transmitter is identified by 12 bits (**Tx Address**). This provides over 16 million different sequences that are orthogonal to each other, making unique identification possible. **Table A1-4** shows the bitwise definitions of these shift registers.

Table A1-4 Kasami RF Watermark Code Sequence Generator Preloading Definitions

Shift Register	**Tier 1**	**Tier 2**	**Tier 3**
X^{16}	0	Tx bit 12	-----
X^{15}	0	Tx bit 11	-----
X^{14}	0	Tx bit 10	-----
X^{13}	0	Tx bit 9	-----
X^{12}	0	Tx bit 8	-----
X^{11}	0	Tx bit 7	-----
X^{10}	0	Tx bit 6	-----
X^9	0	Tx bit 5	-----
X^8	0	Tx bit 4	Net bit 8
X^7	0	Tx bit 3	Net bit 7
X^6	0	Tx bit 2	Net bit 6
X^5	0	Tx bit 1	Net bit 5
X^4	0	Net bit 12	Net bit 4
X^3	0	Net bit 11	Net bit 3
X^2	0	Net bit 10	Net bit 2
X^1	1	Net bit 9	Net bit 1

The RF watermark must be properly synchronized to the VSB signal. For instance, the shift register clock operates at the 10.762 MHz symbol clock rate of the host VSB signal and in phase with it so as to simplify watermark detection and to minimize VSB data eye closings. The PRBS sequences, which have no implicit framing structure themselves, are ***not*** transmitted during the VSB binary frame or field syncs and thus do not degrade VSB field synchronization at any relative RF watermark insertion level. The PRBS sequences are repeated approximately four times per VSB field, before being sent to the equivalent of a 2-VSB modulator that uses the same pilot carrier as the normal 8-VSB data. These sequences, just like the normal VSB data, are constrained by the same root-raised-cosine spectrum shaping filter. Therefore, the RF watermark signal fills the RF channel uniformly with a noise-like spectral characteristic and exhibits steep transition regions just like the 8-VSB signal. This requirement allows the test equipment that is to receive, process, and display the amplitude, timing, and channel impulse response to quickly lock up to the RF watermark signal by using the normal 8-VSB data field sync detection and clock synchronization methods. Since these two methods are very robust (operating down to 0 dB SNR), it is advantageous for the RF watermark test equipment to use the same methodology.

The RF watermark insertion *level* (or bury ratio) can be varied by changing its related variable in the DTxP (see **TxID Level** in **Table A1-3**) as shown in **Table A1-5**. There are 8 different level settings, including OFF. Bury ratio is defined as the ratio (in dB) between the total *average* power (in 6 MHz) of the primary 8-VSB signal and the total *average* power (in 6 MHz) of a buried spread spectrum signal (i.e., the RF watermark) that are sharing the same RF television channel. However, care must be taken when the largest RF watermark levels are used, not only for effects on the DTV receiver threshold degradation, but also for effects on the DTV transmitter's linear and non-linear feedback correction. The transmitter correction issue can be mitigated, however, by designing the exciter so that the known RF Watermark signal is accurately subtracted out from the incoming linear and non-linear feedback signals whenever the RF Watermark is active.

Table A1-5 Kasami RF Watermark Bury Ratio Definitions

Bit Value	Bury Ratio	Net Tx SNR w/30 dB Tx SNR	Rx Threshold
000	ID OFF	30.0 dB	15.04 dB
001	39 dB	29.5 dB	15.05 dB
010	36 dB	29.0 dB	15.07 dB
011	33 dB	28.2 dB	15.11 dB
100	30 dB	27.0 dB	15.18 dB
101	27 dB	25.2 dB	15.32 dB
110	24 dB	23.0 dB	15.63 dB
111	21 dB	20.5 dB	16.30 dB

Note: the 24-dB and 21-dB bury ratios should only be used in *off-line* testing

The RF watermark can also be modulated with slow speed data that is synchronous with the host 8-VSB data structure by inverting bit-by-bit the *entire* Kasami *sequence* to represent logic 1 and not inverting the entire *sequence* for logic 0. Since there are about 4 Kasami sequences per VSB data field, a total of 4 bits can be sent per VSB field, which is a 165.3 Hz bit rate (i.e., 4 x 41.327). If even more robustness is desired, “bits” (i.e., entire sequences) may be combined in pairs or in quads to gain 3 dB or 6 dB in exchange for ½ or ¼ the data rate, respectively.

Figure A1-8 illustrates the use of the RF watermark signal as it might be seen on a special piece of test equipment. Since DTxP information is transmitted over the air, with the exception of the trellis/pre-coder *states*, a piece of test equipment can find the DTxP, store the network and transmitters’ RF watermark codes, and then search for any or all of the DTx transmitters. Note that the relative DTS *timing* and *amplitude* can be easily observed and measured from such a display. Therefore, special test equipment can individually display the signals received from various DTx transmitters and allow straightforward adjustment and optimization of DTxT timing and radiated power.

Since the Kasami codes have over 50 dB of coding gain, the fact that they are often placed 30 dB below the 8-VSB signal does *not* cause a problem since the coding gain allows them to be detected by special test equipment (via powerful correlation techniques) at least 20 dB *above* the 8-VSB signal energy. If time is allowed for averaging, the coding gain increases. Since each DTx transmitters have its own unique orthogonal spread spectrum Kasami codes, they have very little effect on each other’s codes, which is the result of signal orthogonality. Each transmitter’s signal response can be color-coded on a color display on a customized piece of test equipment to make it easier to interpret. Note that an advantage exists with this methodology in that these results can be obtained with all the transmitters on-line, that is, while the 8-VSB transmitters are still transmitting RF data to all the viewers in their service areas. The buried spread spectrum Kasami signals in these photos (see **Figure A1-8**) are about 27 dB below the VSB signal, so there is less than 0.25 dB threshold degradation in consumer DTV receivers.

Note that relative transmitter amplitude and timing are not the only useful information that can be obtained from this display. Since these curves are the result of correlation of the incoming RF watermark with the known respective Kasami codes for each transmitter, it can be seen that any propagation-induced multipath echoes of each transmitted signal will also correlate and show up on the plots. Therefore, the individual plots can also serve as propagation channel impulse responses for each transmitter. This is due to the fact that the RF watermark signals have the same spectral characteristics as the VSB signal and traverse the same RF propagation path as the VSB signal. Again, due to the orthogonality of the various Kasami codes, each correlated signal will show the impulse response from one transmitter, allowing the user to evaluate the amount of naturally occurring multipath in addition to the DTS-induced multipath from all the transmitters. Both multipath *amplitude* and *delay* can be easily measured. It is clear that even for *single* transmitters that are not part of a DTx network, transmitting an RF watermark signal can be very helpful to determining multipath conditions in critical reception areas, or, if a nearby station has the watermark as well, the amount of co-channel interference can be easily measured as well.

The effects of the RF watermark on the normal 8-VSB signal depend on the insertion level of the RF watermark. For most applications, a level of -30 dB can be used with little effect on the DTV receivers in the service area. **Figure A1-9** illustrates an idea 8-VSB data eye diagram that has a -27 dB RF watermark present. Note the extra 8 small eyes that exist because of the synchronous binary Kasami codes riding “underneath” the VSB signal. **Figure A1-10** illustrates the same condition, but shows the constellation diagram. Instead of 8 vertical lines, each of the 8 lines has been “split” into two lines again due to the synchronous *binary* (2-level) Kasami signal that is present. Nevertheless, the 8-VSB eyes are still fairly wide open, with little effect on the threshold of DTV receivers.

The RF watermarking technique appears to be a great method of making *on-line* field measurements of DTx relative timing delays and amplitudes as well as propagation conditions for both DTx and non-DTx situations.

Appendix 1 References

A1-1 "**ATSC Digital Television Standard, Parts 1 - 6, 2007**", Document A/53, Part 2 2007, January 3, 2007, www.atsc.org.

A1-2 **FCC rules**, CFR 47, Subpart E, Section 73.601 – 73.699.

A1-3 "**Interference Analysis of Co-Sited DTV and NTSC Translators**", Gary Sgrignoli, IEEE Transactions of Co-Sited DTV and NTSC Translators, Vol. 51, No. 1, March 2005.

A1-4 "**A/110B: Synchronization Standard for Distributed Transmission, Revision B**," ATSC Standard, December 24, 2007, www.atsc.org.

A1-5 "**A/111: ATSC Recommended Practice: Design of Synchronized Multiple Transmitter Networks**", ATSC Recommended Practice, September 3, 2004, www.atsc.org.

A1-6 "**Distributed Transmission Systems — Overcoming the Limitations of DTV Transmission**", S. Merrill Weiss, NAB 2003, April 2003.

A1-7 "**The ATSC Distributed Transmission System and Applications to Translator Services,**" David L. Hershberger, NAB 2003 Broadcast Engineering Conference Proceedings, April 2003.

A1-8 **"Receiver Performance Guidelines, with Corrigendum No. 1 and Amendment No. 1",** ATSC Recommended Practice A/74, November 29, 2007, www.atsc.org.

A1-9 **"Transmission Measurement and Compliance for Digital Television, Rev. A**", Document A/64A, May 30, 2000, www.atsc.org.

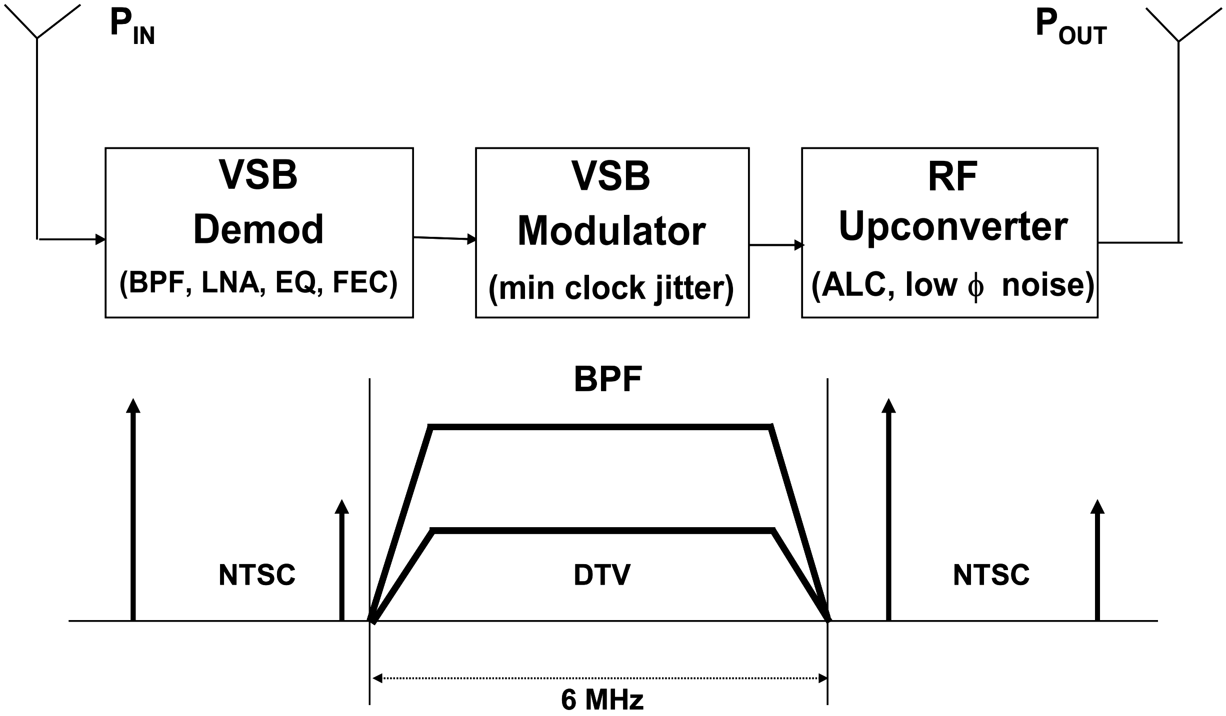


Figure A1-1 Translator block diagram

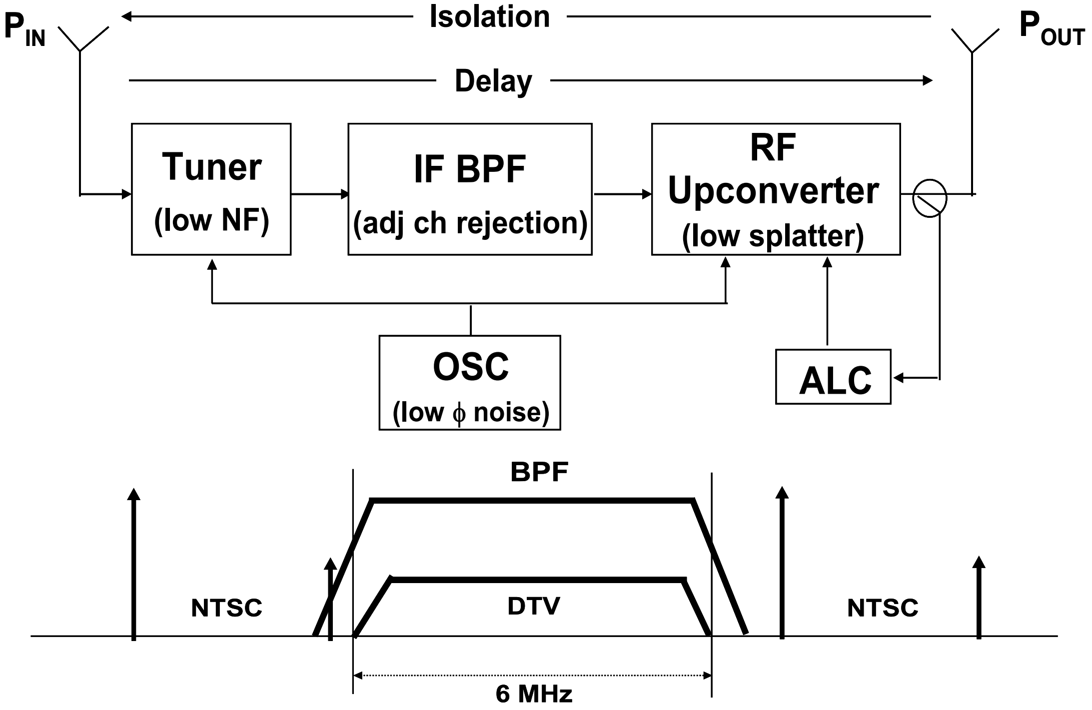


Figure A1-2 On-channel repeater block diagram

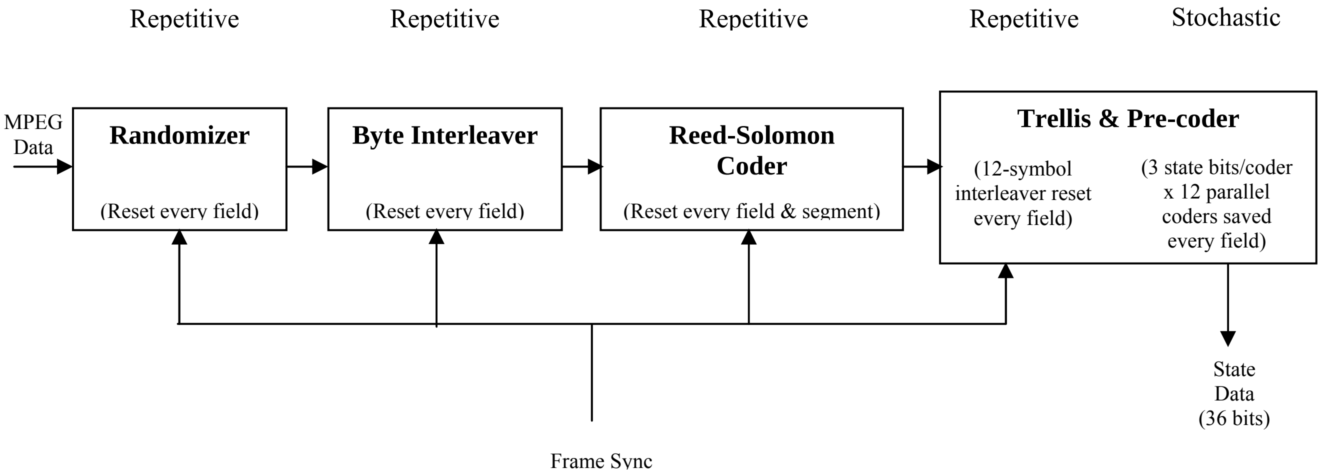


Figure A1-3 Generic VSB *Data* Processing Methodology (as defined in ATSC A/53/E)

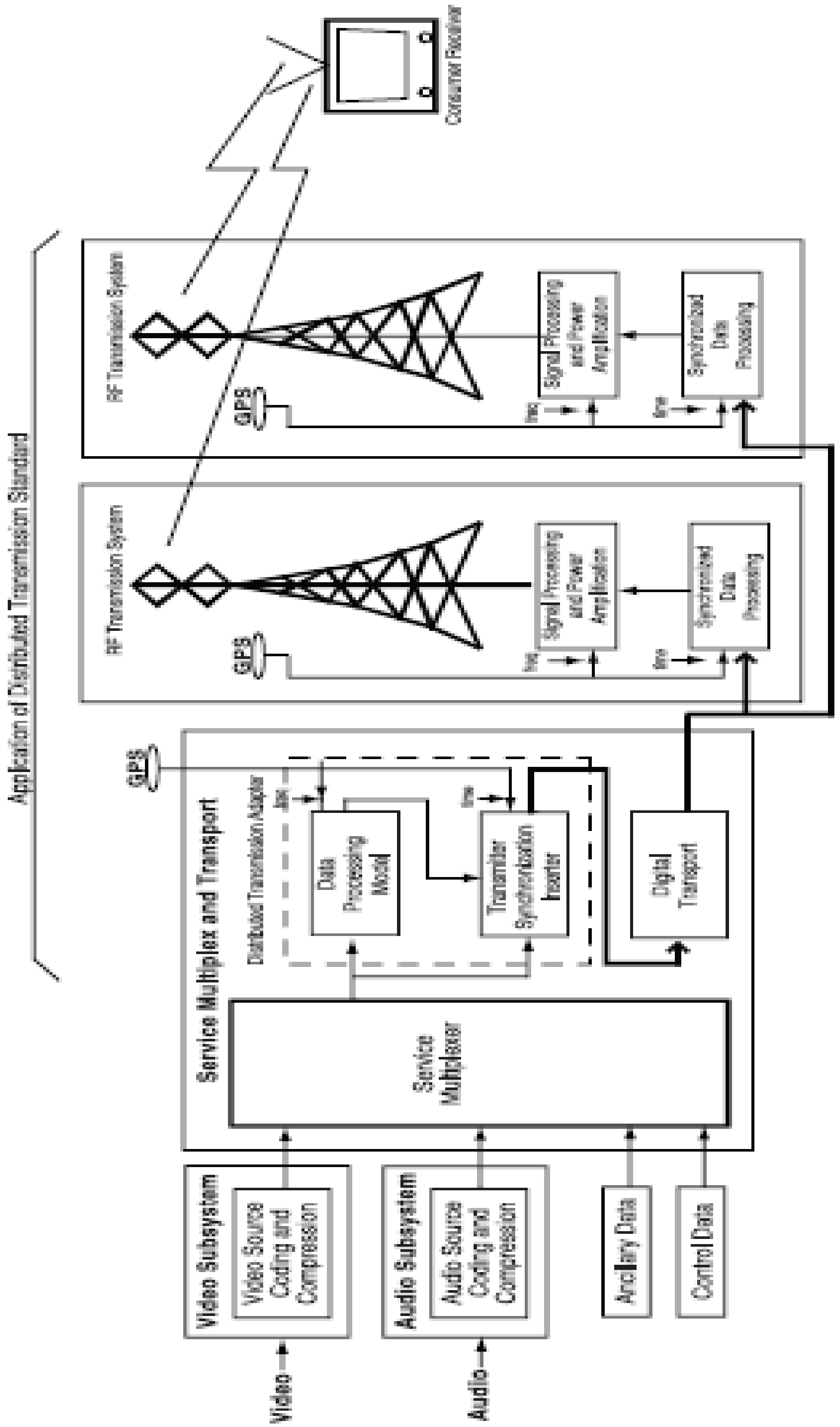


Figure A1-4a Synchronized distributed *transmission* system block diagram **(from A/110B Standard document)**

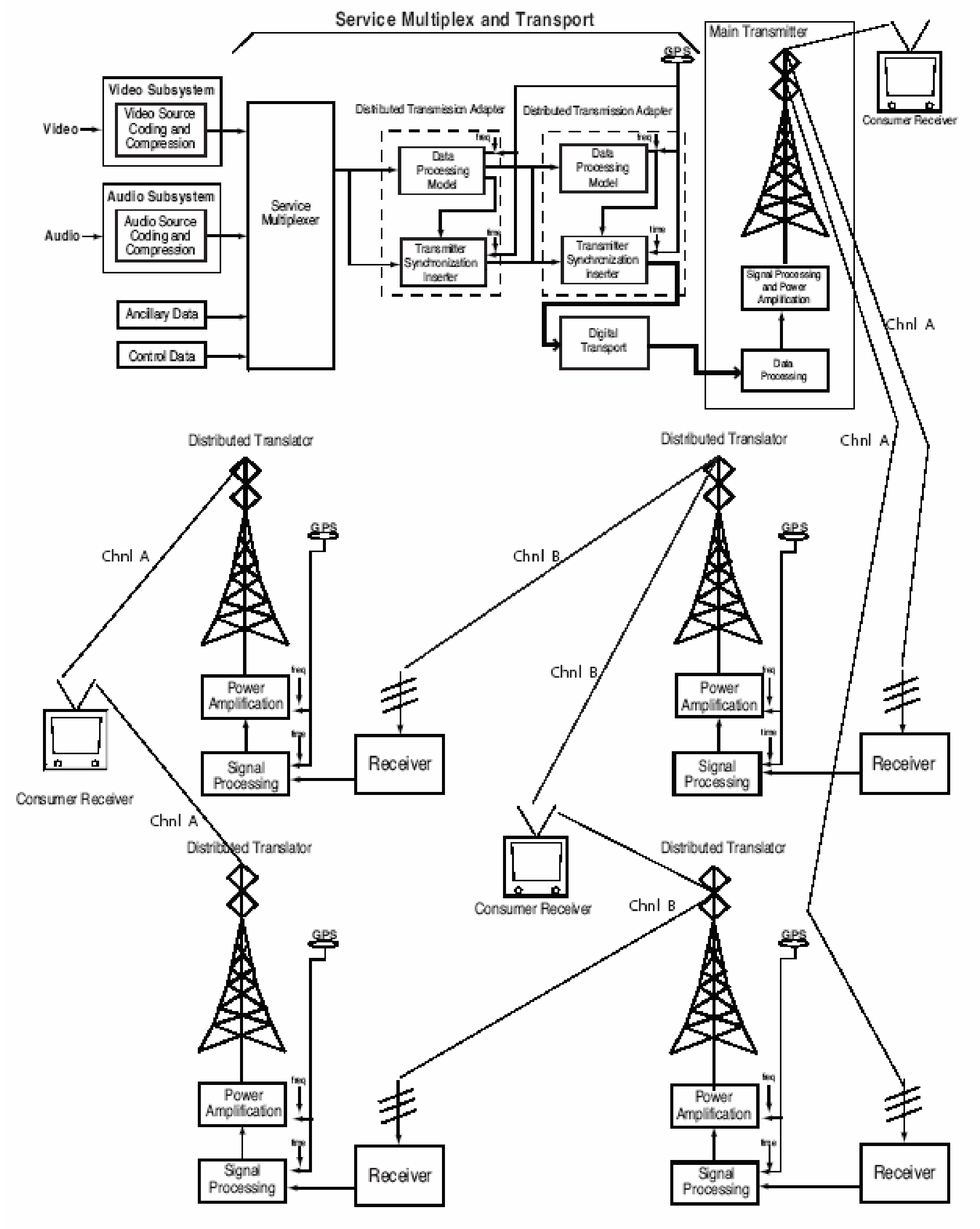


Figure A1-4b Synchronized *translator* system block diagram **(from A/110B Standard document)**

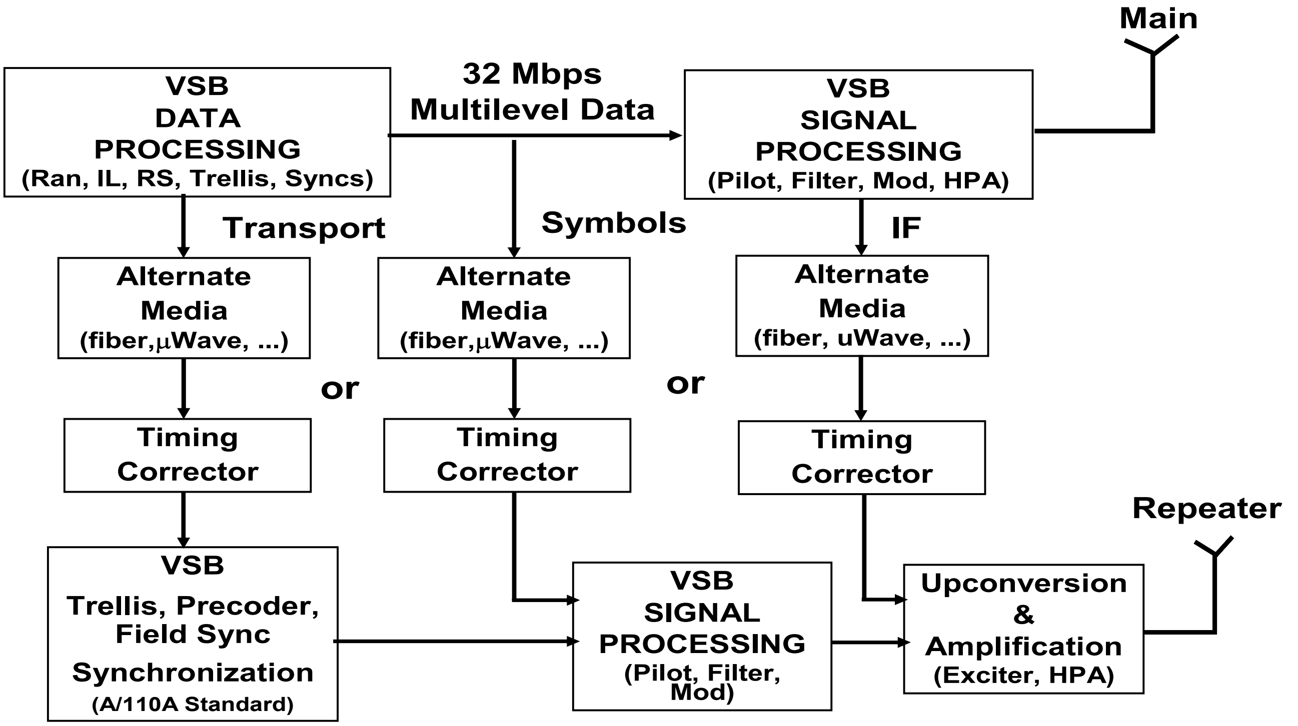


Figure A1-5 Alternate DTS Synchronization Methods

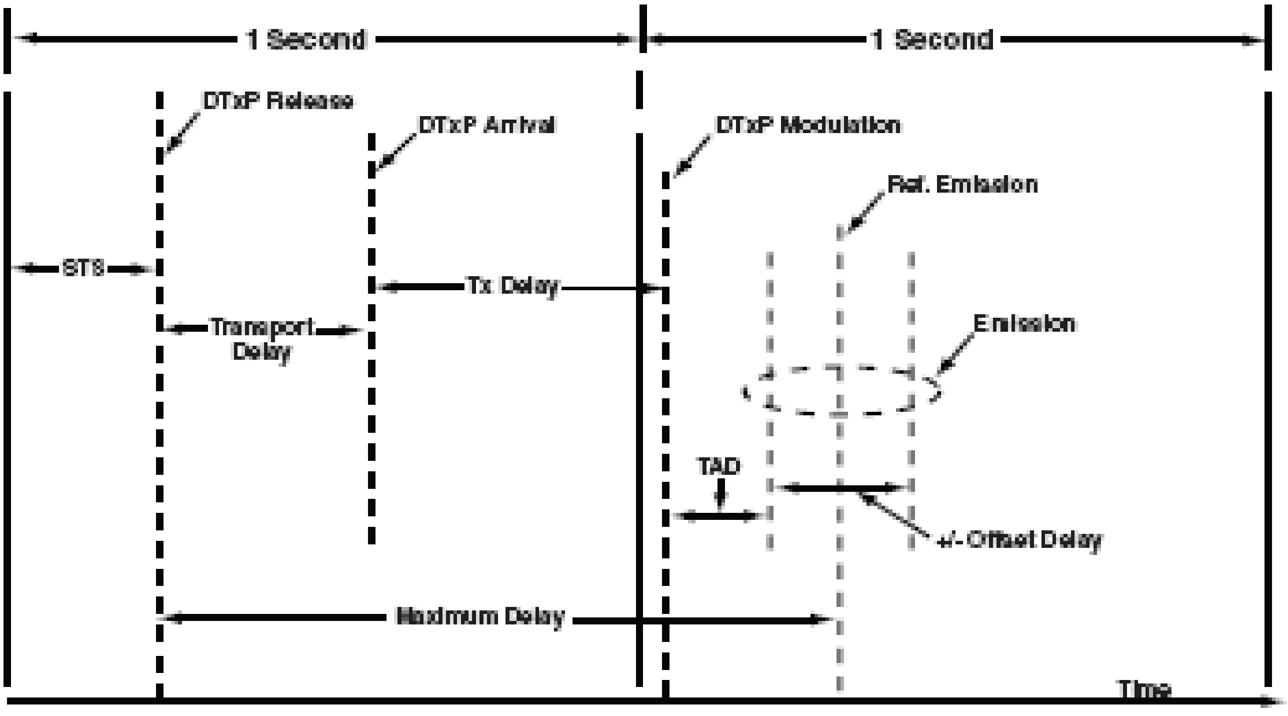


Figure A1-6 DTS Transmitter Timing Control Relationship **(from A/110B Standard document)**

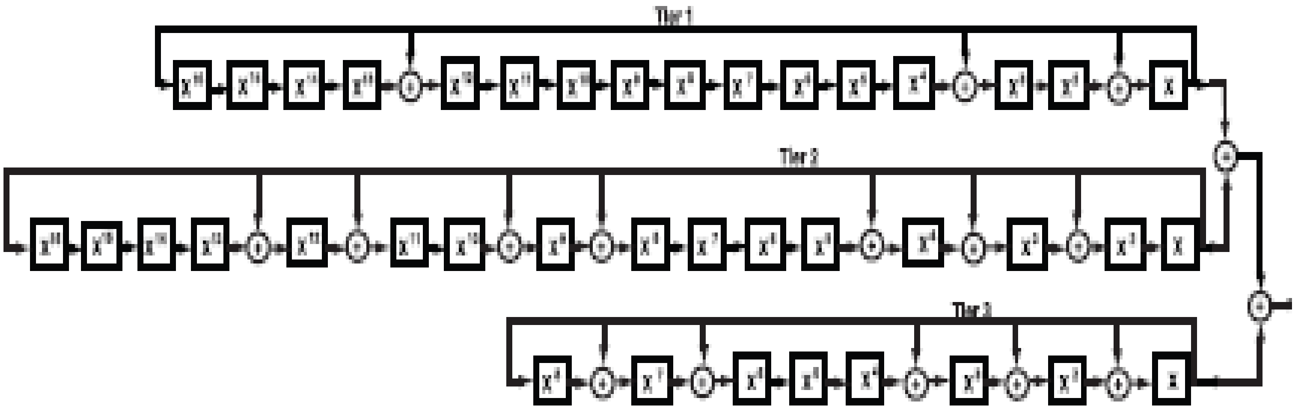


Figure A1-7 Kasami code sequence generator for RF watermarking (from ATSC A/110B Standard document)

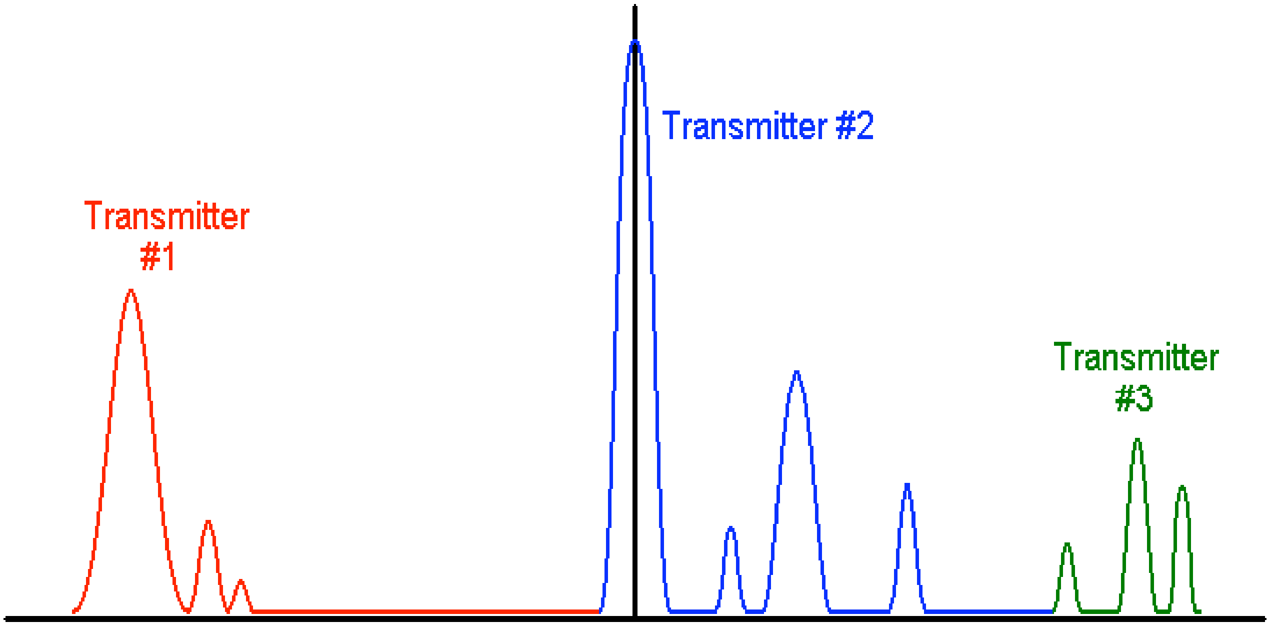


Figure A1-8 RF Watermark Test Equipment Display Example (from Ref 6)

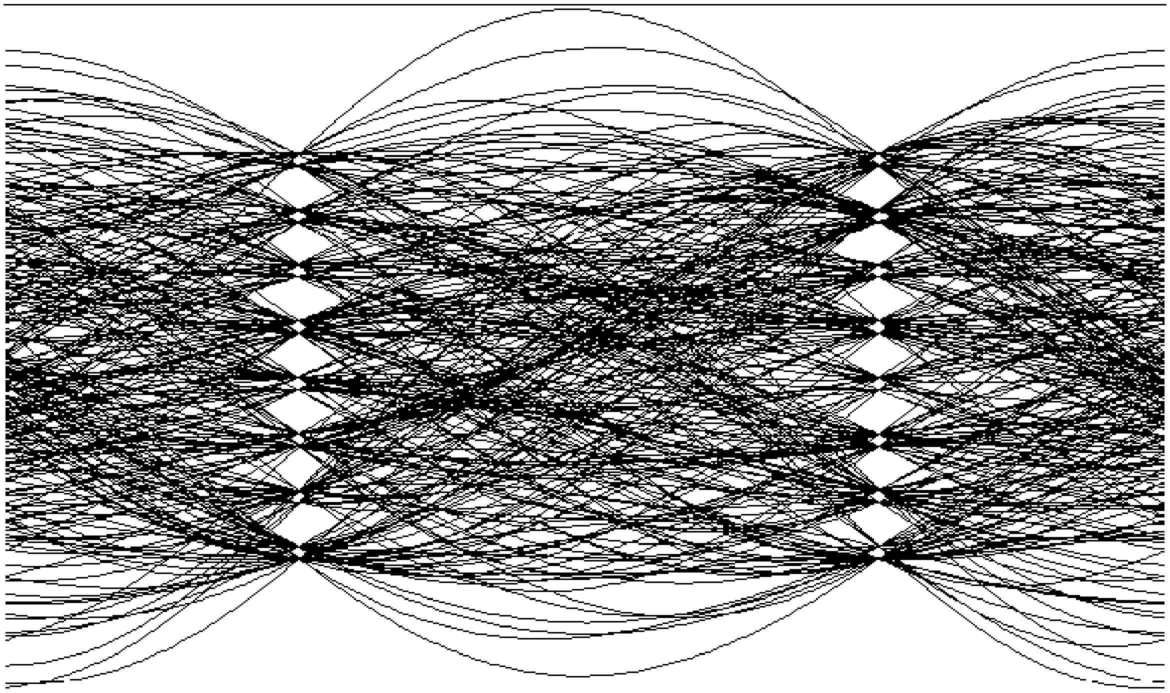


Figure A1-9 Software Simulation of Data Eyes with RF Watermark Signal Present @ -27 dB (from Ref 6)

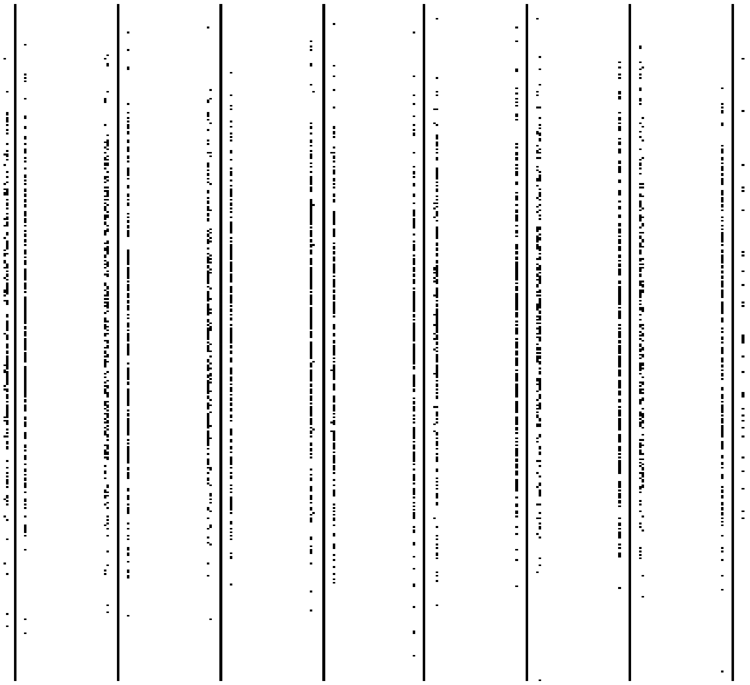


Figure A1-10 Software Simulation of Data Constellation with RF Watermark Signal Present @ -27 dB (from Ref 6)

APPENDIX 2 KASAMI CODE SEED ASIGNMENTS

This appendix describes Kasami codes for the RF Watermark Transmitter Identification (**TxID**) signals that were transmitted from the DTx transmitters during the MTVA Distributed Transmission test. Measurements using the RF Watermark method require *individual* identifiers to be uniquely assigned to each of the transmitters in the network. The required assignments utilized in the MTVA field test are given in **Table A2-1** below.

To implement the measurement regime using the Kasami code sequences specified in the A/110B standard, the values listed in the table were installed in the following locations:

Network ID	DTxA Network Identifier of 2165 (in DXP.INI file, Network section of the TxID control software)
Tx #	Transmitter Identifier (on Slave screen of corresponding Axciter)
Tier Binary Values	Kasami Seed (in Kasami window of TxID Analyzer software)

Table A2-1 Kasami Code Sequence Value Assignments

CH #	Tx Site	Network ID	Tx #	Binary Code Tier 1	Binary Code Tier 2	Binary Code Tier 3
12	BD1	2165	1	0000000000000001	0000000000011000	01110101
	BD2	2165	2	0000000000000001	0000000000101000	01110101
	BD3	2165	3	0000000000000001	0000000000111000	01110101
	BD4	2165	4	0000000000000001	0000000001001000	01110101
	ESB	2165	5	0000000000000001	0000000001011000	01110101
33	BD1	2165	6	0000000000000001	0000000001101000	01110101
	BD2	2165	7	0000000000000001	0000000001111000	01110101
	BD3	2165	8	0000000000000001	0000000010001000	01110101
	BD4	2165	9	0000000000000001	0000000010011000	01110101
	ESB	2165	10	0000000000000001	0000000010101000	01110101
65	BD1	2165	11	0000000000000001	0000000010111000	01110101
	BD2	2165	12	0000000000000001	0000000011001000	01110101
	BD3	2165	13	0000000000000001	0000000011011000	01110101
	BD4	2165	14	0000000000000001	0000000011101000	01110101

Note that:

Tier 1 was always 0001hex.

Tier 2 contains the 12-bit unique TxID code (bits b4 – b15) that was a number from 1 to 14 in the MTVA field test, and part of the network ID (bits b0 – b3) that was 8hex in the MTVA field test.

Tier 3 contains the network ID (bits 1-8) that was 75hex in the MTVA field test.

APPENDIX 3 FIELD TEST SITES

This appendix describes the **132** *actual* outdoor and indoor field test sites (i.e., grid, interference, driveway, and indoor) in the Brooklyn area that were visited by the MTVA DTS field test crews. Of these **132** test sites, **109** were outdoor test sites, with the remaining **23** indoor test sites (**10** of which were "inside the box"). A full-scale view of these test sites is illustrated in **Figure A3-1**, while an expanded view is shown in **Figure A3-2**. The four **BLUE DOTS** (labeled Site #1 through Site #4) represent the four remote low-power DTS transmitter sites. The **RED FLAGS** indicate the "inside the box" Grid test sites (denoted either as "G1-xx" in the tabular data). The **GREEN STARS** represent the driveway test sites (denoted as "HD-xx") that are co-sited with the indoor test sites (denoted as "HI"). Finally, the **RED Xs** are the "outside the box" interference test sites (denoted as either "IX-xx" for interference sites). Note that driveway and indoor sites, while desired to only be "inside the box", actually were located *both* "inside the box" and "outside the box" due to the availability of indoor test volunteers.

Table A3-1 contains the following information:

Site Number

Latitude & longitude

Bearing & Distance to *each* DTx transmitter

All Grid sites and HD sites with asterisks were "inside the "box" (as defined by the four Brooklyn DTx transmitters)

Note that in **Table A3-1** the indoor site (**HI**) location descriptions are always co-sited with the driveway locations (**HD**).

Table A3-2 contains the specific details regarding the indoor sites, such as room description, window locations, height (AGL), etc.

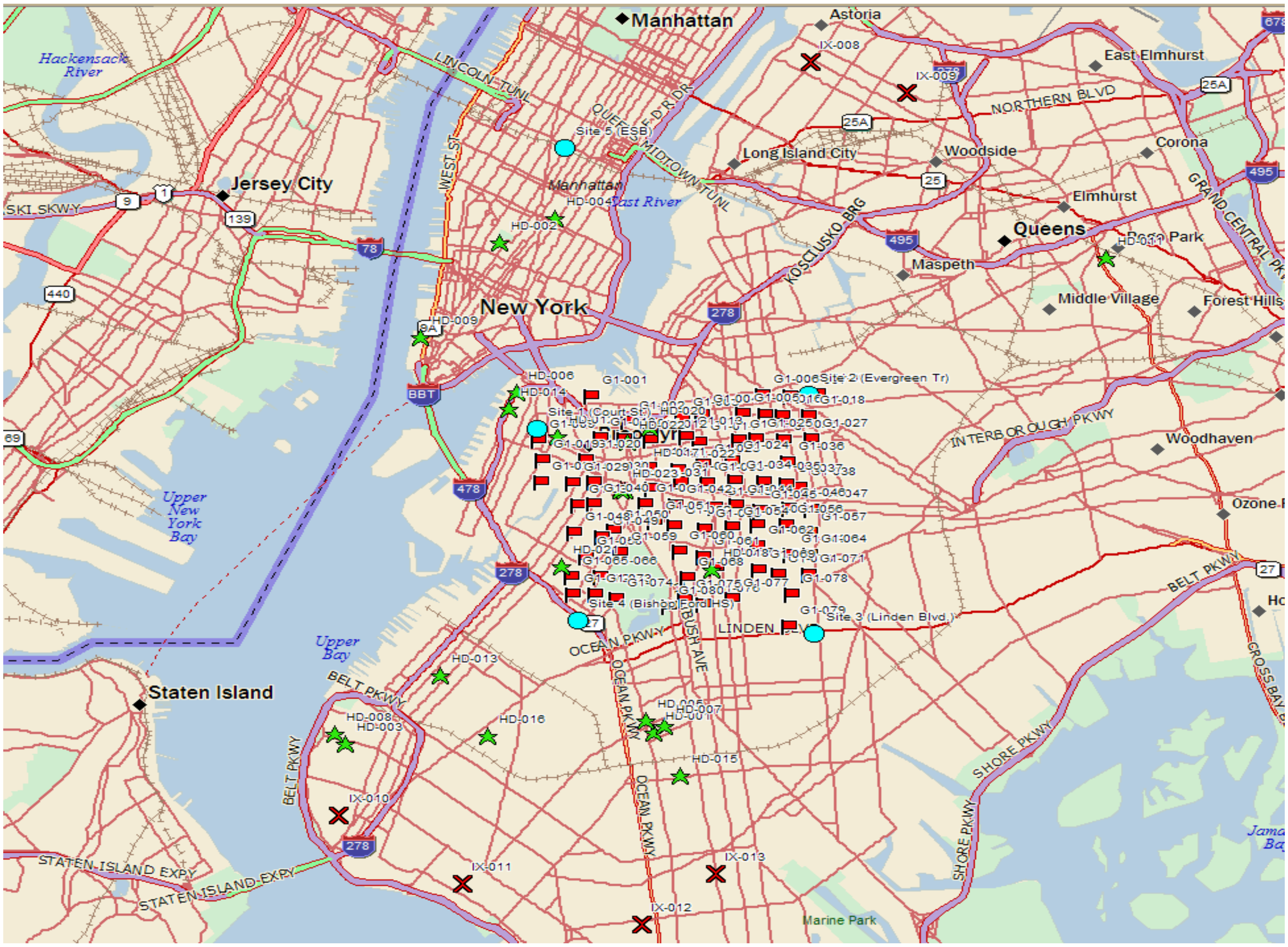


Figure A3-1 Full scale map of all visited remote field test sites (outdoor and indoor). **Blue dots** are DTx transmitters, **red flags** are sites "inside the box, **Red X** marks are interference sites, and **green stars** are indoor and driveway sites.

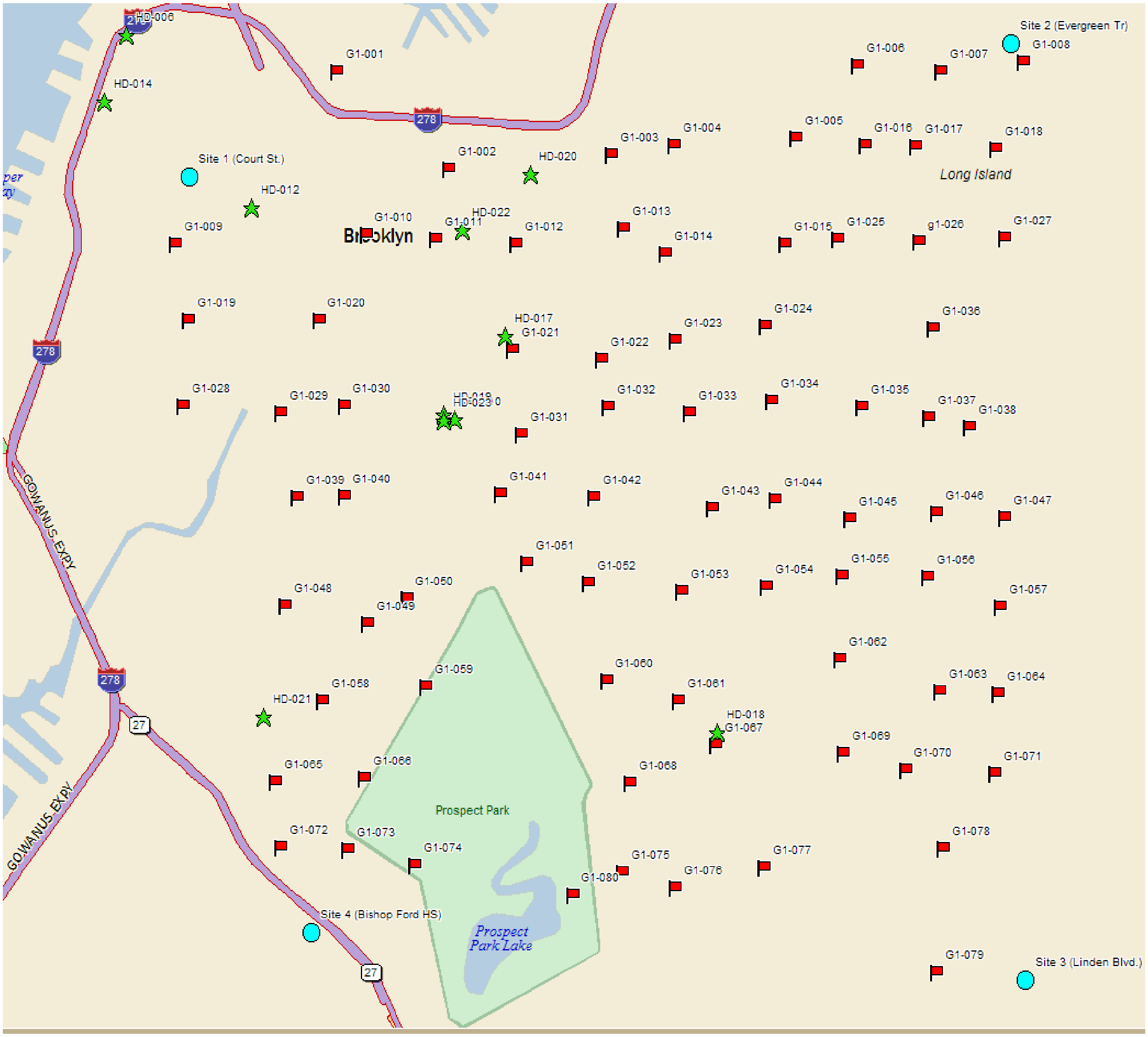


Figure A3-2 Expanded scale map of visited Brooklyn remote field test sites (outdoor and indoor). **Blue dots** are DTx transmitters, **red flags** are sites “inside the box, and **green stars** are indoor and driveway sites.

Table A3-1 MTVA DTx ***Outdoor*** Field Test Site Locations

Test Info		Site Info		Latitude			Longitude			ESB Tx		Tx A		Tx B		Tx C		Tx D		"Box"
Test #	Test Date	Site Name	Site Type	Lat (deg)	Lat (min)	Lat (sec)	Long (deg)	Long (min)	Long (sec)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	In/ Out
A1	1/15/08	G1	078	40	39	34	73	56	16	6.6	338	3.7	310	2.8	6	0.5	142	2.4	264	In
A2	1/16/08	G1	001	40	41	53	73	58	51	3.5	355	0.6	240	2.5	87	4.0	140	2.9	182	In
A3	1/17/08	G1	017	40	41	40	73	56	23	4.5	327	2.7	269	0.5	44	2.9	171	3.5	220	In
A4	1/18/08	G1	070	40	39	48	73	56	26	6.3	338	3.4	308	2.6	9	0.8	145	2.3	257	In
A5	1/21/08	G1	023	40	41	5	73	57	25	4.7	341	1.9	289	1.7	50	2.5	148	2.4	214	In
A6	1/22/08	G1	043	40	40	35	73	57	15	5.3	341	2.3	301	2.0	35	2.0	143	2.1	226	In
A7	1/23/08	IX	012	40	35	48	73	58	8	10.5	355	6.8	350	7.4	15	4.4	27	4.2	350	Out
A8	1/24/08	G1	050	40	40	19	73	58	33	5.3	354	1.7	331	3.0	50	2.7	119	1.2	197	In
A9	1/25/08	G1	063	40	40	2	73	56	17	6.1	336	3.3	303	2.3	7	1.0	161	2.5	251	In
A10	1/28/08	G1	009	40	41	22	73	59	32	4.1	4	0.3	9	3.2	77	4.0	128	2.4	167	In
A11	1/29/08	G1	020	40	41	8	73	58	56	4.4	357	0.7	319	2.8	69	3.5	130	2.1	181	In
A12	1/30/08	G1	066	40	39	47	73	58	44	5.9	356	2.2	343	3.5	43	2.6	105	0.5	201	In
A13	1/31/08	G1	049	40	40	14	73	58	44	5.4	356	1.7	337	3.2	50	2.8	116	1.0	190	In
A14	2/1/08	G1	069	40	39	51	73	56	42	6.2	340	3.2	310	2.5	15	1.0	137	2.1	253	In
A15	2/4/08	G1	003	40	41	37	73	57	41	4.0	341	1.6	270	1.6	1	3.2	151	2.8	203	In
A16	2/5/08	G1	014	40	41	19	73	57	27	4.4	340	1.8	281	1.5	59	2.8	151	2.6	210	In
A17	2/6/08	G1	011	40	41	23	73	58	26	4.1	351	1.0	286	2.3	72	3.4	139	2.4	191	In
A18	2/7/08	G1	015	40	41	22	73	56	56	4.5	334	2.2	277	1.1	50	2.7	160	2.9	217	In
A19	2/8/08	G1	047	40	40	33	73	56	2	5.7	331	3.3	292	1.7	2	1.6	176	2.9	241	In
A20	2/11/08	G1	028	40	40	53	73	59	30	4.6	4	0.8	2	3.4	1	3.7	122	1.8	164	In
A21	2/12/08	G1	052	40	40	22	73	57	47	5.4	347	2.1	314	2.5	40	2.1	129	1.6	221	In
A22	2/14/08	G1	058	40	40	0	73	58	56	5.6	358	1.9	345	3.5	49	2.8	109	0.8	181	In
A23	2/15/08	G1	057	40	40	17	73	56	4	6.0	333	3.3	297	1.9	3	1.3	173	2.8	246	In
A24	2/18/08	IX	010	40	37	4	74	2	1	9.4	15	5.7	23	7.8	43	5.9	65	3.8	46	Out
A25	2/19/08	G1	022	40	41	1	73	57	44	4.7	344	1.7	294	1.9	54	2.6	143	2.2	209	In
A26	2/20/08	G1	026	40	41	22	73	56	22	4.7	331	2.6	276	0.9	35	2.6	167	3.1	222	In
A27	2/21/08	IX	009	40	45	32	73	54	43	4.0	259	6.1	223	4.2	195	7.4	188	8.0	207	Out
A28	2/25/08	G1	072	40	39	34	73	59	6	6.2	359	2.4	352	3.9	44	2.8	98	0.3	151	In
A29	2/26/08	G1	032	40	40	53	73	57	42	4.8	344	1.8	298	2.0	50	2.5	141	2.1	212	In
A30	2/29/08	G1	038	40	40	49	73	56	10	5.4	331	3.0	287	1.4	8	1.9	173	3.0	235	In
A31	3/3/08	G1	039	40	40	38	73	59	1	4.9	359	1.2	340	3.1	60	3.2	121	1.5	177	In
A32	3/5/08	G1	076	40	39	28	73	57	26	6.5	346	3.1	324	3.2	24	1.4	102	1.3	265	In
A33	3/6/08	G1	061	40	40	1	73	57	25	5.8	345	2.6	316	2.6	29	1.6	125	1.5	240	In
A34	3/11/08	G1	055	40	40	22	73	56	42	5.7	338	2.8	301	2.0	19	1.5	152	2.3	239	In
A35	3/12/08	G1	062	40	40	8	73	56	44	5.9	339	3.0	305	2.3	17	1.3	145	2.1	245	In
A36	3/13/08	G1	041	40	40	37	73	58	10	5.0	350	1.5	315	2.5	51	2.6	129	1.6	205	In
A37	3/14/08	G1	008	40	41	55	73	55	56	4.5	321	3.1	264	0.1	346	3.1	179	4.0	222	In

Note 1: **G1** denotes Grid test sites; **IX** denotes Interference test sites; **HD** denotes Driveway test sites (which are the *same* as indoor test sites)

Table A3-1 (cont) MTVA DTx ***Outdoor*** Field Test Site Locations

Test Info		Site Info		Latitude Info			Longitude Info			ESB Tx		Tx A		Tx B		Tx C		Tx D		"Box"
Test #	Test Date	Site Name	Site Type	Lat (deg)	Lat (min)	Lat (sec)	Long (deg)	Long (min)	Long (sec)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	In/ Out
A38	3/17/08	G1	016	40	41	39	73	56	37	4.4	329	2.5	269	0.7	56	2.9	168	3.4	217	In
A39	4/21/08	G1	005	40	41	41	73	56	54	4.2	332	2.3	268	0.9	66	3.0	163	3.2	214	In
A40	4/22/08	G1	029	40	40	52	73	59	5	4.7	359	0.9	338	3.0	65	3.4	124	1.8	176	In
B1	4/21/08	G1	079	40	39	12	73	56	17	7.0	339	3.9	315	3.2	5	0.4	89	2.3	274	In
B2	1/16/08	G1	002	40	41	35	73	58	21	3.9	349	1.0	271	2.1	74	3.5	142	2.6	191	In
B3	1/17/08	G1	018	40	41	39	73	56	3	4.6	324	3.0	269	0.4	12	2.8	177	3.7	224	In
B4	1/18/08	G1	071	40	39	48	73	56	0	6.5	335	3.7	305	2.5	1	0.7	172	2.6	259	In
B5	1/21/08	G1	024	40	41	7	73	57	2	4.7	337	2.2	285	1.4	43	2.4	156	2.6	219	In
B6	1/22/08	G1	044	40	40	36	73	56	60	5.3	339	2.5	298	1.8	29	1.8	149	2.2	230	In
B7	1/23/08	IX	013	40	36	23	73	57	11	10.0	350	6.4	342	6.5	9	3.4	19	3.8	336	Out
B8	1/24/08	G1	051	40	40	25	73	58	2	5.3	349	1.9	317	2.6	45	2.3	127	1.5	213	In
B9	1/25/08	G1	064	40	40	2	73	56	2	6.2	334	3.5	301	2.3	2	1.0	172	2.7	253	In
B10	1/28/08	G1	010	40	41	24	73	58	43	4.1	355	0.7	291	2.5	74	3.5	136	2.4	185	In
B11	1/29/08	G1	019	40	41	9	73	59	29	4.3	4	0.0	1	3.2	72	3.8	126	2.1	168	In
B12	1/30/08	G1	065	40	39	46	73	59	7	5.9	0	2.2	351	3.8	47	2.9	103	0.5	164	In
B13	1/31/08	G1	048	40	40	17	73	59	4	5.3	359	1.6	347	3.4	54	3.0	114	1.1	174	In
B14	2/1/08	G1	068	40	39	45	73	57	36	6.1	347	2.7	322	2.9	29	1.6	113	1.3	248	In
B15	2/4/08	G1	004	40	41	40	73	57	25	4.0	338	1.8	268	1.3	74	3.1	155	3.0	207	In
B16	2/5/08	G1	013	40	41	25	73	57	38	4.2	342	1.6	278	1.6	66	3.0	149	2.7	206	In
B17	2/6/08	G1	012	40	41	22	73	58	5	4.2	347	1.3	283	2.0	69	3.2	142	2.4	198	In
B18	2/7/08	G1	025	40	41	23	73	56	43	4.6	332	2.4	276	1.0	43	2.6	164	3.1	220	In
B19	2/8/08	G1	046	40	40	34	73	56	18	5.6	333	3.0	293	1.7	10	1.6	167	2.7	239	In
B20	2/11/08	G1	030	40	40	53	73	58	49	4.6	356	1.0	325	2.8	63	3.2	127	1.8	183	In
B21	2/12/08	G1	053	40	40	20	73	57	23	5.5	343	2.4	309	2.3	33	1.8	135	1.8	230	In
B22	2/14/08	G1	059	40	40	3	73	58	28	5.6	354	2.0	334	3.1	45	2.5	114	0.9	207	In
B23	2/15/08	G1	056	40	40	23	73	56	20	5.8	335	3.1	297	1.9	10	1.4	164	2.6	242	In
B24	2/18/08	IX	011	40	36	16	74	0	25	10.0	6	6.2	8	7.7	31	5.2	49	3.8	20	Out
B25	2/19/08	G1	021	40	41	3	73	58	6	4.5	348	1.4	298	2.2	60	2.9	138	2.1	201	In
B26	2/20/08	G1	027	40	41	23	73	56	1	4.9	326	3.0	275	0.7	3	2.5	178	3.5	228	In
B27	2/21/08	IX	008	40	45	53	73	55	57	3.0	248	5.8	212	4.5	180	7.7	180	8.0	199	Out
B28	2/25/08	G1	073	40	39	34	73	58	48	6.2	357	2.4	346	3.7	42	2.6	99	0.3	206	In
B29	2/26/08	G1	033	40	40	52	73	57	21	5.0	342	2.1	97	1.8	42	2.3	145	2.2	219	In
B30	2/27/08	G1	074	40	39	31	73	58	31	6.2	355	2.6	341	3.6	38	2.3	99	0.4	243	In
B31	2/28/08	G1	075	40	39	30	73	57	38	6.4	348	2.9	327	3.2	27	1.6	103	1.2	261	In
B32	2/29/08	G1	037	40	40	51	73	56	20	5.3	332	2.9	288	1.4	14	1.9	168	2.9	233	In
B33	3/3/08	G1	040	40	40	37	73	58	49	5.0	356	1.3	333	3.0	58	3.0	123	1.5	185	In
B34	3/4/08	G1	067	40	39	54	73	57	14	6.0	344	2.8	315	2.7	25	1.4	124	1.6	247	In

Note 1: **G1** denotes Grid test sites; **IX** denotes Interference test sites; **HD** denotes Driveway test sites (which are the *same* as indoor test sites)

Table A3-1 (cont) MTVA DTx ***Outdoor*** Field Test Site Locations

Test Info		Site Info		Latitude			Longitude			ESB Tx		Tx A		Tx B		Tx C		Tx D		“Box”
Test #	Test Date	Site Name	Site Type	Lat (deg)	Lat (min)	Lat (sec)	Long (deg)	Long (min)	Long (sec)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	Distance (miles)	Bearing (deg)	In/ Out
B35	3/5/08	G1	077	40	39	31	73	57	1	6.5	343	3.2	318	3.0	18	1.1	110	1.7	264	In
B36	3/6/08	G1	060	40	40	4	73	57	42	5.7	347	2.4	319	2.7	34	1.9	122	1.4	233	In
B37	3/7/08	G1	036	40	41	7	73	56	19	5.0	330	2.8	281	1.0	17	2.3	170	3.1	228	In
B38	3/10/08	G1	042	40	40	37	73	57	45	5.1	346	1.9	307	2.2	45	2.3	135	1.8	216	In
B39	3/11/08	G1	054	40	40	21	73	57	2	5.6	340	2.6	304	2.1	26	1.6	143	2.0	235	In
B40	3/12/08	G1	045	40	40	33	73	56	40	5.5	337	2.7	296	1.8	21	1.7	156	2.4	235	In
B41	3/13/08	G1	031	40	40	48	73	58	4	4.8	348	1.6	307	2.3	54	2.7	134	1.9	204	In
B42	3/14/08	G1	007	40	41	53	73	56	17	4.3	324	2.8	264	0.3	65	3.1	174	3.7	219	In
B43	3/17/08	G1	006	40	41	55	73	56	38	4.1	327	2.5	262	0.6	82	3.2	168	3.6	214	In
B44	3/18/08	HD	001	40	38	2	73	57	57	8.0	352	4.3	342	4.9	21	2.3	53	1.7	330	Out
B45	3/19/08	HD	002	40	43	46	73	59	56	1.5	27	2.5	171	4.0	120	6.3	146	5.2	171	Out
B46	3/20/08	HD	003	40	37	55	74	1	55	8.4	17	4.8	26	7.0	48	5.5	74	3.1	57	Out
B47	3/21/08	HD	004	40	44	3	73	59	13	1.0	3	2.8	185	3.7	130	6.3	153	5.4	177	Out
B48	3/24/08	HD	005	40	38	11	73	58	3	7.8	353	4.1	342	4.7	23	2.2	58	1.6	330	Out
B49	3/25/08	HD	006	40	42	1	73	59	43	3.4	8	0.5	157	3.3	91	4.7	134	3.2	168	In
B50	3/26/08	HD	007	40	38	7	73	57	48	7.9	351	4.3	340	4.7	20	2.1	53	1.7	325	Out
B51	3/27/08	HD	008	40	38	1	74	2	3	8.3	18	4.7	28	7.0	49	5.6	76	3.1	61	Out
B52	3/28/08	HD	009	40	42	39	74	0	56	3.0	31	1.7	133	4.4	100	5.9	132	4.2	155	Out
B53	3/31/08	HD	010	40	40	52	73	58	19	4.7	351	1.3	310	2.4	58	2.9	132	1.8	198	In
B54	4/1/08	HD	011	40	43	35	73	52	7	6.4	284	6.8	251	3.8	241	6.1	213	7.7	231	Out
B55	4/2/08	HD	012	40	41	30	73	59	11	3.9	0	0.3	294	2.9	79	3.9	133	2.5	175	In
B56	4/3/08	HD	013	40	38	42	74	0	42	7.3	11	3.5	18	5.6	47	4.2	82	1.7	64	In
B57	4/4/08	G1	035	40	40	53	73	56	37	5.1	334	2.6	288	1.4	24	2.1	162	2.7	229	In
B58	4/22/08	G1	034	40	40	54	73	57	0	5.0	338	2.3	291	1.5	36	2.2	154	2.5	224	In
B59	4/23/08	HD	014	40	41	49.0	73	59	49.0	3.6	9	0.4	127	3.4	87	4.6	131	2.9	165	Out
B60	4/28/08	G1	080	40	39	26.0	73	57	50.0	6.4	350	2.9	330	3.4	29	1.7	99	1.0	265	In
B61	4/29/08	HD	015	40	37	41.0	73	57	36.0	8.4	351	4.8	340	5.2	16	2.3	40	2.3	329	Out
B62	4/30/08	HD	016	40	38	0.0	74	0	5.0	8.0	6	4.2	7	5.8	38	3.9	69	1.8	33	Out
B63	5/1/08	HD	017	40	41	7.0	73	58	6.0	4.5	348	1.3	295	2.1	62	2.9	139	2.2	200	In
B64	5/2/08	HD	018	40	39	56.0	73	57	12.0	6.0	343	2.8	314	2.6	25	1.4	126	1.7	246	In
B65	5/5/08	HD	019	40	40	53	73	58	22	4.7	351	1.3	311	2.5	59	2.9	132	1.8	196	In
B66	5/6/08	HD	020	40	41	36	73	58	0	3.9	345	1.3	270	1.8	76	3.3	146	2.7	198	In
B67	5/7/08	HD	021	40	39	59	73	59	7	5.7	0	1.9	350	3.6	50	3.0	108	0.8	169	In
B68	5/8/08	HD	022	40	41	26	73	58	17	4.1	349	1.1	281	2.1	73	3.3	141	2.5	193	In
B69	5/9/08	HD	023	40	40	52	73	58	22	4.7	351	1.3	311	2.5	59	2.9	132	1.8	196	In

Note 1: **G1** denotes Grid test sites; **IX** denotes Interference test sites; **HD** denotes Driveway test sites (which are the *same* as indoor test sites)

Table A3-2 MTVA DTx ***Indoor*** Test Site Descriptions

Test #	Test Date	Site Type	Site #	Room Location Floor #	Room Location Within Bldg	Room Location Height AGL	# Of Windows	Window Directions	Name Of Room	Building Structure & Material	“Box” In/ Out
IN-1	3/18/08	HI	001	6	Ext	60	2 Double	N, E	Living	Brick	Out
IN-2	3/19/08	HI	002	2	Ext	20	1 + French door	W	Living	Concrete	Out
IN-3	3/20/08	HI	003	1	Ext	10	19 individual	N,S,W	Sun	Stucco	Out
IN-4	3/21/08	HI	004	2	Ext	20	2	S	Living	Brick	Out
IN-5	3/24/08	HI	005	1	Ext	10	3	NE	Living	Wood	Out
IN-6	3/25/08	HI	006	4	Ext	40	2	NE	Living	Brick	In
IN-7	3/26/08	HI	007	2	Ext	20	1	N	Living	Concrete	Out
IN-8	3/27/08	HI	008	1	Ext	5	4	N	Living	Brick	Out
IN-9	3/28/08	HI	009	4	Ext	40	3	S	Living	Brick	Out
IN-10	3/31/08	HI	010	4	Ext	40	4	N	Loft	Plaster	In
IN-11	4/1/08	HI	011	1	Ext	10	11	E,N,W	Living	Brick	Out
IN-12	4/2/08	HI	012	4	Ext	40	2	W	Kitchenette	Brick	In
IN-13	4/3/08	HI	013	1	Ext	15	2	SW	Kitchenette	Brown Stone	Out
IN-14	4/23/08	HI	014	0	Ext	0	3	W	Living	Brick	Out
IN-15	4/29/08	HI	015	2	Ext	20	2	N	Living	Brick	Out
IN-16	4/30/08	HI	016	2	Ext	15	5	S & W	Living	Brick	Out
IN-17	5/1/08	HI	017	3	Ext	40	2	W	Living	Brick	In
IN-18	5/2/08	HI	018	4	Ext	40	2	S	Living	Brick	In
IN-19	5/5/08	HI	019	3	Ext	40	1	N	Living	Brick	In
IN-20	5/6/08	HI	020	2	Ext	25	2	S	Living	Brick	In
IN-21	5/7/08	HI	021	1	Ext	6	4	N & S	Living	Brick	In
IN-22	5/8/08	HI	022	3	Ext	40	2	E	Living	Siding & Brick	In
IN-23	5/9/08	HI	023	2	Ext	20	2	S	Loft	Plaster	In

Note 1: Indoor (“**HI**”) test site locations co-located with corresponding driveway (“**HD**”) test site (e.g., HD-001 is co-located with HI-001)

APPENDIX 4 STEP-BY-STEP *OUTDOOR* FIELD TEST PROCEDURES

The detailed outdoor field test procedures consist of a *morning calibration* and the actual remote *field test*. A companion customized Excel spreadsheet (available upon request from MTVA) allowed data entry by the field engineer directly into the computer and also served as a script that provided the engineers with a list of "cues" to follow for consistent measurement procedures. This was especially important in light of the fact that there were two teams of field test personnel that worked in parallel for these field measurements. Coordination between the two teams was very crucial with regard to transmitter control (i.e., ON/OFF switching). Detailed comments were also required to be entered by the field engineers, which described what was being observed at each test site. These comments were an important addition to the numerical results.

MORNING CALIBRATION PROCEDURE

1) Start generator and truck engine
    a. Verify operation (voltages, currents, mast pressure, etc.)
    b. Verify that fuel levels for the truck and generator are sufficient for the day's work
    c. Check tire air pressure
2) Warm-up test equipment on route to first test site (minimum of 20 minutes)
3) Verify rotor and compass operation
4) Measure & record truck system *gain* (dB) using spectrum analyzer with tracking generator (i.e., downlead cable input to spectrum analyzer input)
5) Measure & record truck's attenuator accuracy (10-dB steps and 1-dB steps)
6) Measure & record truck's *noise* floor power (dBm/6 MHz), with input attenuator at maximum attenuation
7) Verify GPS, computer operation, and digital camera (set correct date and time), including backup USB memory device
8) Verify all test equipment operation (set correct date and time)
9) Verify general operation of DTV Receivers:
    a. Channel tuning of CH 12, CH 33, CH 65 (proper video and audio outputs)
    b. Dynamic range (high and low) of CH 12, CH 33, CH 65
10) Verify that all transmitter sites are operational and calibrated.

OUTDOOR FIELD TEST SITE MEASUREMENT PROCEDURE

1) <u>Arrive at field test site</u>
    a. Park vehicle in any available location as *close as practical* to proposed field test site
        i. Exact test location is randomly selected at each test site
    b. Perform safety checks
        i. Place parking cones around the truck
        ii. Carefully secure antenna to hydraulic mast
        iii. Check for overhead obstructions ***before*** raising mast
    c. Raise mast to 30' AGL with high-VHF/UHF directional log periodic antenna attached
    d. Perform quick *on-site* self-calibration (at every field test site)
        i. With input attenuator *temporarily* at maximum value, measure & record truck system noise floor (in dBm/6 MHz) on all three RF test channels, verifying that it is within proper tolerance from that measured during morning calibration. Record noise floor (dBm/6 MHz).
        ii. Verify that computer, test equipment, and camera has correct date and time
    e. Document test site

    i. Record site number & name
    ii. Record specific street address plus a general area description
    iii. Record test date and time
    iv. Record GPS latitude & longitude coordinates (in degrees, minutes, & seconds) of test site
    v. Record *distance* from test site (in miles) to <u>*each*</u> DTS Tx as determined by GPS receiver
    vi. Record *bearing* from test site (in degrees with respect to true North) to <u>*each*</u> DTS Tx as determined by GPS receiver
    vii. Record basic description of weather (temperature, sunny, partly sunny, cloudy, rain, drizzle, fog, snow, windy, etc.)
    viii. Record description of any *unusual* structures in nearby surrounding areas
    ix. Document *outdoor* test site
        1. Take digital pictures showing test site and truck, with mast extended
        2. Note any significant obstructions (e.g., buildings, bridges, water towers, elevated train tracks, overpasses, etc.)

2) <u>CH 33 Measurements</u>
    a. CH 33 coverage @ 30' AGL with **ESB alone**
        i. Turn **OFF** <u>all</u> gap filler transmitters
        ii. Adjust directional *outdoor* antenna direction for *maximum* total *average* signal power as measured on spectrum analyzer
        iii. Document DTx system for *maximum* (peaked) signal level
            1. Record antenna bearing (in degrees with respect to true North)
                a. Calculate & record difference between maximum signal antenna bearing and bearing to ESB
                b. Note if antenna is pointed in a direction that is *significantly* different (> 45 degrees) from bearing to ESB
            2. Adjust input attenuator so that signal level is about –50 dBm/6 MHz at WIAD amplifier *output* or adjust attenuator to 0 dB if the largest available output signal is less than -50 dBm
            3. Record attenuator setting (in dB)
            4. Measure & record total *average* signal power (in dBm/6 MHz)
            5. Calculate & record outdoor **FIELD STRENGTH** (in dBμV/m) using truck system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
            6. Calculate & record **SNR** (in dB) of received signal using the measured signal level, input attenuator value, and truck's noise floor (anything less than 15 dB can *not* be received error free)
            7. Record and save spectrum plot (20 MHz span, 10 dB/div, TIF)
                a. Note any significantly larger NTSC or ATSC signals within ±4.5 channels (i.e. within ±30 MHz of desired channels center frequency) that could possibly cause interference to the DTx signals
                b. Record levels of any of these signals that are greater than 20 dB above the desired DTV signal's total *average* power level (in 6 MHz)
                c. Record additional spectrum plot (60 MHz span, 10 dB/div, TIF), *if necessary*
            8. Record & save RF Watermark data (RPT) for ESB signal
            9. Measure & record ESB's *naturally* occurring multipath
                a. Document SDR value (in dB), which is total *integrated* energy in the channel impulse response *other* than main impulse energy

b. Note any significant large pre-echo and post-echo amplitudes and delays in the comments

10. Determine & record **SERVICE** for *each* DTV receiver
    a. Watch video for 3 minutes
    b. Count and record # of burst errors or "hits" (acceptable reception defined as ≤ 3 "hits" in 3 minutes)
        i. Enter total # of burst errors (0 – 18)
        ii. If partial picture viewable, but very bad (>18 errors), enter 555
        iii. If absolutely no picture viewable, enter 999
    c. Record *failure mode* code and enter comments about cause of failure in site comments.
        i. No failure (code 0)
        ii. Signal level (code 1)
        iii. Multipath, natural (code 2)
        iv. Multipath, DTx-induced (code 3)
        v. Interference (code 4)
        vi. Signal level and multipath (code 5)
        vii. Signal level and interference (code 6)
        viii. Multipath plus interference (code 7)
        ix. Other, with specific explanation in comments section (code 8)
11. Increase attenuation to lower signal down to threshold (**TOV**) for *each* DTV receiver, and document attenuator setting (in dB) for *each* DTV receiver, which is the reception **MARGIN** (in dB) relative to the truck's noise floor.
12. Return attenuator to original setting

iv. Document DTx system for antenna ***range of rotation*** (ease of consumer adjustment)

1. Set attenuator level, if possible, so that signal level around entire 360 degrees azimuth range falls between -30 dBm and -70 dBm, and record value
2. Slowly rotate directional *outdoor* antenna, recording angular sectors (in degrees) where DTV service exists
    a. Maximum of 6 sectors is considered (practical limitation due to time), with a sector requiring to be at least 30 degrees for consideration)
    b. More sectors than this, and adjustment is deemed unacceptable for typical consumer (make note in Comments section regarding sectors and total degrees)
3. At *each* antenna bearing *transition* from good to bad DTV reception or vice versa:
    a. Record antenna bearing (in degrees, with respect to true North)
    b. Record total *average* signal power (dBm/6 MHz)
    c. Calculate & record *outdoor* **FIELD STRENGTH** (in dBμV/m) using truck system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
    d. Calculate & record **SNR** (in dB) using the measured signal level, input attenuator value, and truck's noise floor (anything less than 15 dB can <u>not</u> possibly be received error free)
    e. Record and save spectrum data (20 MHz span, 10 dB/div, TIF)
    f. Record & save RF Watermark data (RPT) for ESB signal
    g. Measure & record ESB *naturally*-occurring multipath information
        i. Document **SDR** value (in dB), which is total energy in channel impulse response other than main impulse energy

            ii. Note any significant large pre-echo and post-echo amplitudes and delays

        h. Record *failure mode* code for *each* sector and enter comments about any *unique* causes of failure in site comments section for each failed sector.

            i. No failure (code 0)
            ii. Signal level (code 1)
            iii. Multipath, natural (code 2)
            iv. Multipath, DTx-induced (code 3)
            v. Interference (code 4)
            vi. Signal level and multipath (code 5)
            vii. Signal level and interference (code 6)
            viii. Multipath plus interference (code 7)
            ix. Other, with specific explanation in comments section (code 8)

    4. After rotating antenna through entire 360 degrees, record *total* degrees of reception (in degrees)

b. CH 33 coverage @ 30' AGL *with* **ESB** and **4 gap fillers ON**

    i. Turn **ON** all gap filler transmitters
    ii. Adjust directional *outdoor* antenna direction for *maximum* total *average* signal power as measured on spectrum analyzer
    iii. Document DTx system with maximum (peaked) signal level
        1. Record antenna bearing (in degrees with respect to true North)
            a. Calculate & record difference between maximum signal antenna bearing and bearing to ESB
            b. Note if antenna is pointed in a direction that is *significantly* different (> 45 degrees) from bearing to ESB
        2. Adjust input attenuator so that signal level is about –50 dBm/6 MHz at WIAD amplifier *output* or adjust attenuator to 0 dB if the largest available output signal is less than -50 dBm
            a. Note difference from attenuator setting between DTx active and DTx inactive
        3. Record attenuator setting (in dB)
        4. Measure & record total *average* signal power (in dBm/6 MHz)
        5. Calculate & record outdoor **FIELD STRENGTH** (in dBμV/m) using truck system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
            a. Note and record any difference between DTx active and DTx inactive
        6. Calculate & record **SNR** (in dB) of received signal using the measured signal level, input attenuator value, and truck's noise floor (anything less than 15 dB can not be received error free)
        7. Record and save spectrum plot (20 MHz span, 10 dB/div, TIF)
            a. Note any significantly larger NTSC or ATSC signals within ±4.5 channels (i.e. within ±30 MHz of desired channels center frequency) that could possibly cause interference to the DTx signals
            b. Record levels of any of these signals that are greater than 20 dB above the desired DTV signal's total average power level
            c. Record additional spectrum plot (60 MHz span, 10 dB/div, TIF), *if necessary*
        8. Record and save RF Watermark data (RPT) for all DTx signals
        9. Measure & record DTx-induced multipath

a. Document echo amplitude values (in dB) & delay values(in µsecs) from all DTx transmitters

b. Note any significant large pre-echo and post-echo amplitudes and delays in the comments

10. Determine & record **SERVICE** for *each* DTV receiver

a. Watch video for 3 minutes

b. Count and record # of burst errors or "hits" (acceptable reception defined as ≤ 3 "hits" in 3 minutes)

i. Enter total # of burst errors (0 – 18)

ii. If partial picture viewable, but very bad (>18 errors), enter 555

iii. If absolutely no picture viewable, enter 999

c. Record *failure mode* code and enter comments about cause of failure in site comments.

i. No failure (code 0)

ii. Signal level (code 1)

iii. Multipath, natural (code 2)

iv. Multipath, DTx-induced (code 3)

v. Interference (code 4)

vi. Signal level and multipath (code 5)

vii. Signal level and interference (code 6)

viii. Multipath plus interference (code 7)

ix. Other, with specific explanation in comments section (code 8)

11. Increase attenuation to lower signal down to threshold (**TOV**) for *each* DTV receiver, and document attenuator setting (in dB) for *each* DTV receiver, which is the reception **MARGIN** (in dB) relative to the truck's noise floor

a. Note and record any difference, if any, between DTx active and DTx inactive

12. Return attenuator to original setting

iv. Document DTx system for antenna ***range of rotation*** (ease of consumer adjustment)

1. Set attenuator level, if possible, so that signal level around entire 360 degrees azimuth range falls between -30 dBm and -70 dBm, and record value

2. Slowly rotate directional *outdoor* antenna, recording angular sections (in degrees) where DTV service is present

a. Maximum of 6 sectors is considered (practical limitation for time), with a sector requiring to be at least 30 degrees for consideration)

b. More sectors than this, and adjustment is deemed unacceptable for average consumer (make note in Comments section regarding sectors and total degrees)

3. At *each* antenna bearing *transition* from good to bad DTV reception or vice versa:

a. Record antenna bearing (in degrees, with respect to true North)

b. Record total *average* signal power (dBm/6 MHz)

c. Calculate & record *outdoor* **FIELD STRENGTH** (dBµV/m) using truck system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain

d. Calculate & record **SNR** (in dB) using the measured signal level, input attenuator value, and truck's noise floor (anything less than 15 dB can <u>not</u> be received error free)

e. Record and save spectrum data (20 MHz span, 10 dB/div, TIF)

f. Record and save RF Watermark data (RPT) for all DTx signals

            g. Measure & record DTS-induced multipath information
                i. Document echo amplitude values (in dB) & delay values(in µsecs) from all DTx transmitters
                ii. Note any significant large pre-echo and post-echo amplitudes and delays in the comments
            h. Record *failure mode* code for each sector and enter comments about unique causes of failure in site comments section for each failed sector.
                i. No failure (code 0)
                ii. Signal level (code 1)
                iii. Multipath, natural (code 2)
                iv. Multipath, DTx-induced (code 3)
                v. Interference (code 4)
                vi. Signal level and multipath (code 5)
                vii. Signal level and interference (code 6)
                viii. Multipath plus interference (code 7)
                ix. Other, with specific explanation in comments section (code 8)
        4. After rotating through entire 360 degrees, record *total* degrees of reception (in degrees)
            a. Note any difference in range of rotation between DTx active and DTx inactive
    c. Repeat field test procedure for antenna @ 15' AGL

3) <u>CH 12 Measurements</u>
    a. Repeat field test procedure used for CH 33

4) <u>CH 65 Measurements</u>
    a. Repeat field test procedure used for CH 33
    b. Except for ESB measurements (no ESB CH 65 transmitter, which means there is no DTx OFF test)

5) Record any final comments that describe conditions at the test site

6) Backup all electronic files created at test site *before* departing
    a. Data Spreadsheet (XLS)
    b. Spectrum analyzer files (TIF)
    c. RF Watermark files (RPT)
    d. Digital Pictures (JPG)

7) Prepare to leave test site
    a. Lower mast
    b. Remove antenna from hydraulic mast, and secure in truck
    c. Gather parking cones, and secure in truck

8) Leave test site

APPENDIX 5 STEP-BY-STEP *INDOOR* FIELD TEST PROCEDURES

The detailed outdoor field test procedures consist of a *morning calibration* and the actual remote *field test*. A companion customized Excel spreadsheet (available upon request from MTVA) allowed data entry by the field engineer directly into the computer and also served as a script that provided the engineers with a list of "cues" to follow for consistent measurement procedures. This was especially important in light of the fact that there were two teams of field test personnel that worked in parallel for these field measurements. Coordination between the two teams was very crucial with regard to transmitter control (i.e., ON/OFF switching). Detailed comments were also required to be entered by the field engineers, which described what was being observed at each test site. These comments were an important addition to the numerical results.

The indoor DTS field test was conducted similarly to the outdoor field test, first with the ESB transmitter ON alone (except for CH 65) and then with all the DTx transmitters active. The companion *outdoor* field test site, referred to as the "driveway" test site, was evaluated simultaneously (i.e., in parallel) with the indoor field test site using the second truck and crew, making use of the same DTx transmitter switching and documenting simultaneous RF propagation conditions. The outdoor field test truck was required to be parked reasonably close (as possible) to the location of the indoor test site (within 50').

Each test home's resident was contacted by MSW prior to the day of the visit to confirm availability and arrival time. The same morning calibration procedure was used for both the outdoor and indoor field test equipment in the previous section.

Note that both the primary *dipole* antenna (with "figure-8" azimuth pattern) and a secondary directional antenna were employed in the indoor testing. In this case, a *passive* directional Silver Sensor was used for the CH 33 and CH 65 UHF stations with the active WIAD distribution system (i.e., amplifier and splitter) while an *active* directional Winegard Sharpshooter antenna was used for the CH 12 high-VHF station with the same external WIAD distribution system. While the use of an active antenna (or a passive antenna with an active distribution system) possibly improves the sensitivity and thus weak-signal DTV reception over that of a purely passive antenna, the DTx field test signal levels in New York City were not generally expected to be weak, but rather strong. In situations such as this, passive antennas may supply DTV signals with sufficient strength to allow successful DTV reception, providing the multipath can be handled by receiver's equalizer. Also, at every indoor test site, a smart antenna was connected to one of the 5G DTV receivers (Rx2) for determination of successful reception with automatic antenna adjustment.

This indoor field test has provided further information about requirements for successful indoor DTV reception in the greater New York City region with and without DTx.

INDOOR FIELD TEST SITE MEASUREMENT PROCEDURE

1) <u>Arrive at field test site</u>
    a. All indoor test sites will have a corresponding outdoor "driveway" test site.
        i. Park vehicle for "driveway" measurements as close as possible to indoor test location
        ii. Perform safety checks (same as in outdoor test plan)
        iii. Driveway measurements will be made with the same outdoor directional antenna at both 30' AGL and 15' AGL
        iv. Driveway measurements will be made simultaneously with the indoor measurements
    b. Transport test equipment into home (with permission of homeowner)
    c. Set up equipment so that antenna can be placed on a tripod in a *typical* and *reasonable* location within the room of choice, preferably near an existing television set. Otherwise, select a reasonable location where a television set might reside.
        i. Primary antennas
            1. For CH 33 and CH 65, *passive* adjustable UHF dipole with active WIAD distribution system
            2. For CH 12, *passive* adjustable VHF dipole with active WIAD distribution system
        ii. Secondary antennas
            1. For CH 33 and CH 65, *passive* UHF Silver Sensor with active WIAD distribution system
            2. For CH 12, *active* VHF Sharpshooter with active WIAD distribution system
    d. Perform quick on-site self-calibration

- i. With input attenuator *temporarily* at maximum value, measure & record the indoor system noise floor (in dBm/6 MHz) on all 3 RF channels, verifying that it is within proper tolerance from that measured in morning calibration
- ii. Verify computer, test equipment, and camera have correct date and time

e. Document test site

- i. Record site number & name (that can be easily matched with its corresponding outdoor test site number)
- ii. Record specific street address and general area description
- iii. Record test date and time
- iv. Record GPS latitude & longitude coordinates (in degrees, minutes, & seconds) of test site
- v. Record *distance* from test site (in miles) to *each* DTS Tx as determined by GPS receiver
- vi. Record *bearing* from test site (degrees with respect to true north) to <u>*each*</u> DTS Tx as determined by GPS receiver
- vii. Record basic description of weather (temperature, sunny, partly sunny, cloudy, rain, drizzle, fog, snow, windy, etc.)
- viii. Record description of any *unusual* structures in nearby surrounding areas
- ix. Document *indoor* test site
    1. Take digital pictures of the test site room, whenever possible
    2. Note significant nearby obstructions within the home such as adjacent rooms, large metal objects (e.g., piano, refrigerator, washing machines, etc.), plastered walls with metal lathe, etc. or outside the home (e.g., buildings, bridges, water towers, elevated train tracks, overpasses, etc.)
    3. Record room location within building
        - a. Floor number (0 for ground floor, -1 for basement, 2 or second floor, etc.)
        - b. Position in building (exterior, interior)
        - c. Estimate of height of floor above ground level (in feet, AGL)
        - d. # of windows(s), direction(s), size of windows
    4. Describe building structure and materials
        - a. Construction materials (e.g., frame, brick, stucco, etc.)
        - b. Wall construction and insulation materials (e.g., plasterboard, plaster walls with metal lathe, foil-backed insulation, etc.)
        - c. Windows in room where testing is to occur (size, type of glass, direction facing, type of frame material, etc.)

2) <u>CH 33 Measurements</u>

a. CH 33 coverage with *primary* antenna with **ESB alone**

- i. Turn **OFF** <u>all</u> gap filler transmitters
- ii. Adjust *primary* indoor antenna direction for *maximum* total *average* signal power as measured on spectrum analyzer
- iii. Document DTx system with *maximum* (peaked) signal level
    1. Record antenna bearing (in degrees with respect to true North)
        - a. Calculate & record difference between maximum signal antenna bearing and bearing to ESB
        - b. Note if antenna is pointed in a direction *significantly* different (> 45 degrees) from bearing to ESB

2. Adjust input attenuator so that signal level is about –50 dBm/6 MHz at WIAD amplifier *output* or adjust to 0 dB if the largest available output signal is less than -50 dBm
3. Record attenuator setting (in dB)
4. Measure & record total *average* signal power (in dBm/6 MHz)
5. Calculate & record indoor **FIELD STRENGTH** (in dBμV/m) using portable amplifier system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
6. Calculate & record **SNR** (in dB) of received signal using the measured signal level, input attenuator value, and portable amplifier's noise floor (anything less than 15 dB can not be received error free)
7. Record and save spectrum plot (20 MHz span, 10 dB/div, TIF)
    a. Note any significantly larger NTSC or ATSC signals within ±4.5 channels (i.e. within ±30 MHz of desired channels center frequency) that could possibly cause interference to the DTx signal
    b. Record levels of any of these signals that are greater than 20 dB above the desired DTV signal's total average power level (in 6 MHz)
    c. Record additional spectrum plot (60 MHz span, 10 dB/div, TIF), *if necessary*
8. Record & save RF Watermark data (RPT) for ESB signal
9. Measure & record ESB *naturally* occurring echo amplitudes & delays
    a. Document SDR value (in dB), which is total integrated energy in the channel impulse response *other* than main impulse energy
    b. Note any significant large pre-echo and post-echo amplitudes and delays in the comments
10. Determine & record **SERVICE** for *each* DTV receiver.
    a. Watch video for 3 minutes
    b. Count and record # of burst errors or "hits" (acceptable reception defined as ≤ 3 "hits" in 3 minutes)
        i. Enter total # of burst errors (0 – 18)
        ii. If partial picture viewable, but very bad (>18 errors), enter 555
        iii. If absolutely no picture viewable, enter 999
    c. Record *failure mode* code and enter comments about cause of failure in site comments.
        i. No failure (code 0)
        ii. Signal level (code 1)
        iii. Multipath, natural (code 2)
        iv. Multipath, DTx-induced (code 3)
        v. Interference (code 4)
        vi. Signal level and multipath (code 5)
        vii. Signal level and interference (code 6)
        viii. Multipath plus interference (code 7)
        ix. Other, with specific explanation in comments section (code 8)
    d. Note reception sensitivity to any personnel movement in vicinity of antenna
11. Increase attenuation to lower signal down to threshold (**TOV**) for *each* DTV receiver, and document attenuator setting (in dB) for each *receiver*, which is the reception **MARGIN** (in dB) relative to the portable amplifier's noise floor.
12. Return attenuator to original setting

iv. Document DTx system for antenna ***range of rotation*** (ease of consumer adjustment)

  1. Set attenuator level, if possible, so that signal level around entire 360 degrees azimuth range falls between -30 dBm and -70 dBm, and record value
  2. Slowly rotate primary *indoor* antenna, recording angular sectors (in degrees) where DTV service exists
     a. Maximum of 6 sectors will be considered (practical limitation for time)
     b. More sectors than this, and adjustment is deemed unacceptable for typical consumer (make note in Comments section regarding sectors and total degrees)
  3. At *each* antenna bearing *transition* from good to bad DTV reception and vice versa:
     a. Record antenna bearing (in degrees) with respect to *maximum* signal strength bearing
     b. Record total *average* signal power (dBm/6 MHz)
     c. Calculate & record *indoor* **FIELD STRENGTH** (in dBμV/m) using portable amplifier system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
     d. Calculate & record **SNR** (in dB) using the measured signal level, input attenuator value, and portable amplifier's noise floor (anything less than 15 dB can not be received error free)
     e. Record and save spectrum plot (20 MHz span, 10 dB/div, TIF)
     f. Record & save RF Watermark data (RPT) for ESB signal
     g. Measure & record ESB *naturally*-occurring multipath information
        i. Document **SDR** value (in dB), which is total energy in channel impulse response other than main impulse energy
        ii. Note any significant large pre-echo and post-echo amplitudes and delays
     h. Record *failure mode* code for *each* sector and enter comments about any *unique* causes of failure in site comments
        i. No failure (code 0)
        ii. Signal level (code 1)
        iii. Multipath, natural (code 2)
        iv. Multipath, DTx-induced (code 3)
        v. Interference (code 4)
        vi. Signal level and multipath (code 5)
        vii. Signal level and interference (code 6)
        viii. Multipath plus interference (code 7)
        ix. Other, with specific explanation in comments section (code 8)
  4. After rotating antenna through entire 360 degrees, record total degrees of reception (in degrees)

b. CH 33 coverage <u>*with*</u> **ESB** and **4 g**ap fillers **ON**

  i. Turn **ON** <u>all</u> gap filler transmitters
  ii. Adjust primary *indoor* antenna direction for *maximum* total *average* signal power as measured on spectrum analyzer
  iii. Document DTx system with maximum (peaked) signal level
     1. Record antenna bearing (in degrees with respect to true North)
        a. Calculate & record difference between maximum signal antenna bearing and bearing to ESB

  b. Note if antenna is pointed in a direction significantly different (> 45 degrees) from bearing to ESB

2. Adjust input attenuator so that signal level is about –50 dBm/6 MHz at WIAD amplifier *output* or adjust to 0 dB if the largest available output signal is less than -50 dBm
    a. Note difference from attenuator setting between DTx active and DTx inactive
3. Record attenuator setting (in dB)
4. Measure & record total *average* signal power (in dBm/6 MHz)
5. Calculate & record indoor **FIELD STRENGTH** (in dBμV/m) using portable amplifier system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
    a. Note any difference from between DTx active and DTx inactive
6. Calculate & record **SNR** (in dB) of received signal using the measured signal level, input attenuator value, and portable amplifier's noise floor (anything less than 15 dB can not be received error free)
7. Record and save spectrum plot (20 MHz span, 10 dB/div, TIF)
    a. Note any significantly larger NTSC or ATSC signals within ±4.5 channels (i.e. within ±30 MHz of desired channels center frequency) that could possibly cause interference to the DTx signals
    b. Record levels of any of these signals that are greater than 20 dB above the desired DTV signal's total average power level
    c. Record additional spectrum plot (60 MHz span, 10 dB/div, TIF), *if necessary*
8. Record and save RF Watermark data (RPT) for all DTx signals
9. Measure & record DTx-induced multipath
    a. Document echo amplitude values (in dB) and delay values (in μsecs) from all DTx transmitters
    b. Note any significant large pre-echo and post-echo amplitudes and delays in the comments
10. Determine & record **SERVICE** for *each* DTV receiver.
    a. Watch video for 3 minutes
    b. Count and record # of burst errors or "hits" (acceptable reception defined as ≤ 3 "hits" in 3 minutes)
        i. Enter total # of burst errors (0 – 18)
        ii. If partial picture viewable, but very bad (>18 errors), enter 555
        iii. If absolutely no picture viewable, enter 999
    c. Record *failure mode* code and enter comments about cause of failure in site comments.
        i. No failure (code 0)
        ii. Signal level (code 1)
        iii. Multipath, natural (code 2)
        iv. Multipath, DTx-induced (code 3)
        v. Interference (code 4)
        vi. Signal level and multipath (code 5)
        vii. Signal level and interference (code 6)
        viii. Multipath plus interference (code 7)
        ix. Other, with specific explanation in comments section (code 8)
    d. Note reception sensitivity to any personnel movement in vicinity of antenna

11. Increase attenuation to lower signal down to threshold (**TOV**) for *each* DTV receiver, and document attenuator setting (in dB) for *each* DTV receiver, which is the reception **MARGIN** (in dB) relative to the portable amplifier's noise floor.
    a. Note and record any difference, if any, between DTx active and DTx inactive
12. Return attenuator to original setting

iv. Document DTx system for antenna ***range of rotation*** (ease of consumer adjustment)

1. Set attenuator level, if possible, so that signal level around entire 360 degrees azimuth range falls between -30 dBm and -70 dBm, and record value
2. Slowly rotate primary *indoor* antenna, recording angular sections (in degrees) where DTV service is present
    a. Maximum of 6 sectors is considered (practical limitation for time)
    b. More sectors than this, and adjustment is deemed unacceptable for average consumer (make note in Comments section regarding sectors and total degrees)
3. At *each* antenna bearing *transition* from good to bad reception and vice versa:
    a. Record antenna bearing (in degrees, with respect to true North)
    b. Record total *average* signal power (dBm/6 MHz)
    c. Calculate & record *indoor* **FIELD STRENGTH** (dBμV/m) using portable amplifier system gain, attenuator value, channel-dependent dipole factor, and channel-dependent antenna gain
    d. Calculate & record **SNR** (dB) using the measured signal level, input attenuator value, and truck's noise floor (anything less than 15 dB can not be received error free)
    e. Record and save spectrum plot (20 MHz span, 10 dB/div, TIF)
    f. Record and save RF Watermark data (RPT) for all DTx signals
    g. Measure & record ESB *naturally*-occurring and DTS-induced echo amplitudes & delays
        i. Document echo amplitude values (in dB) & delay values(in μsecs) from all DTx transmitters
        ii. Note any significant large pre-echo and post-echo amplitudes and delays in the comments
    h. Record *failure mode* code and enter comments about cause of failure in site comments section for each failed sector
        i. No failure (code 0)
        ii. Signal level (code 1)
        iii. Multipath, natural (code 2)
        iv. Multipath, DTx-induced (code 3)
        v. Interference (code 4)
        vi. Signal level and multipath (code 5)
        vii. Signal level and interference (code 6)
        viii. Multipath plus interference (code 7)
        ix. Other, with specific explanation in comments section (code 8)
4. After rotating through entire 360 degrees, record *total* degrees of reception (in degrees)
    a. Note any difference in range of rotation between DTx active and DTx inactive
5. If very poor or no DTV reception is available for the range of rotation test, then repeat with Silver Sensor directional UHF antenna

   c. Repeat CH 33 test with secondary directional antennas (*passive* Silver Sensor directional UHF antenna):
   d. Determine if *smart* UHF antenna system can provide DTV service

3) <u>CH 12 Measurements</u>
   a. Repeat field test procedure used for CH 33,
   b. Except use a active Sharpshooter high-VHF antenna as the secondary antenna
   c. There is no smart antenna available for CH 12
4) <u>CH 65 Measurements</u>
   a. Repeat field test procedure used for CH 33
   b. Except use Silver Sensor UHF antenna as the secondary antenna
   c. Except for ESB measurements (no ESB CH 65 transmitter, which means there is no DTx OFF test)
5) Record any final comments that describe conditions at the test site
6) Backup all electronic files created at test site *before* departing
   a. Data Spreadsheet (XLS)
   b. Spectrum analyzer files (TIF)
   c. RF Watermark files (RPT)
   d. Digital Pictures (JPG)
7) Prepare to leave test site
   a. Pack up all equipment
   b. Carry equipment to truck and secure in truck
8) Leave test site

Appendix 6 *OUTDOOR* RAW DATA SUMMARY TABLES

Table A6-1 Summary of **30'** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
A1	1/15/08	33	G1	078	61.6	32.5	0	0	8	8	319	104	87.8	58.7	C	0	0	42	42	360	360
A1	1/15/08	12	G1	078	44.1	24.0	0	555	3	0	52	0	80.7	60.6	C	0	0	44	44	360	360
A1	1/15/08	65	G1	078									78.3	45.5	C	0	0	28	28	360	360
A2	1/16/08	33	G1	001	83.2	54.5	0	0	47	48	360	360	82.2	53.5	E	0	0	36	37	360	360
A2	1/16/08	12	G1	001	69.5	50.5	0	0	32	32	360	360	73.3	54.3	E	0	0	32	31	360	360
A2	1/16/08	65	G1	001									69.4	36.9	A	555	555	0	0	189	183
A3	1/17/08	33	G1	017	63.4	34.9	0	0	12	12	215	86	81.1	52.6	A	0	0	34	34	360	360
A3	1/17/08	12	G1	017	50.7	32.0	0	0	13	14	228	117	68.5	49.8	A	0	0	32	32	230	110
A3	1/17/08	65	G1	017									76.7	44.3	A	0	0	25	25	360	74
A4	1/18/08	33	G1	070	74.6	45.8	0	0	29	28	360	360	72.0	43.2	E	0	0	24	25	71	182
A4	1/18/08	12	G1	070	54.9	35.9	0	0	14	14	181	150	62.2	43.2	C	0	0	22	22	330	107
A4	1/18/08	65	G1	070									74.9	42.4	C	0	0	24	25	238	61
A5	1/21/08	33	G1	023	68.6	40.2	0	0	19	19	360	360	79.0	50.6	A	0	0	33	34	360	360
A5	1/21/08	12	G1	023	55.7	42.0	0	0	18	19	233	176	65.3	51.6	A	0	0	28	29	322	254
A5	1/21/08	65	G1	023									69.7	37.8	A	0	0	20	21	360	192
A6	1/22/08	33	G1	043	73.6	45.2	0	0	27	28	61	281	73.7	45.3	E	0	0	25	25	290	360
A6	1/22/08	12	G1	043	60.2	41.3	0	0	24	25	105	114	61.7	42.8	E	0	0	18	18	360	360
A6	1/22/08	65	G1	043									67.6	36.4	A	0	0	13	14	360	360
A7 *	1/23/08	33	IX	012	74.5	45.6	0	0	28	28	349	351	73.6	44.7	E	0	0	27	28	296	314
A7 *	1/23/08	12	IX	012	56.8	37.6	0	0	20	21	161	157	57.7	38.5	E	0	0	19	20	192	137
A7 *	1/23/08	65	IX	012									57.1	24.9		999	999	0	0	0	0
A8	1/24/08	33	G1	050	76.2	47.7	0	0	30	31	303	293	81.1	52.6	A	0	0	33	33	312	133
A8	1/24/08	12	G1	050	56.2	37.2	0	0	19	20	274	268	67.2	48.2	A	0	0	30	31	333	278
A8	1/24/08	65	G1	050									79.1	47.6	A	0	0	29	30	293	274
A9	1/25/08	33	G1	063	60.0	31.2	0	0	13	13	87	128	72.4	43.6	A	0	0	25	25	189	73
A9	1/25/08	12	G1	063	58.3	39.4	0	0	21	21	247	205	61.7	42.8	A	0	0	22	11	122	43
A9	1/25/08	65	G1	063									68.6	36.8	A	0	0	18	14	324	237
A10	1/28/08	33	G1	009	64.4	35.8	0	555	14	0	107	27	70.5	41.9	E	0	999	11	0	185	0
A10	1/28/08	12	G1	009	43.2	24.2	999	999	0	0	0	0	67.6	48.6	A	0	555	28	21	360	48
A10	1/28/08	65	G1	009									70.7	38.4	A	555	999	0	0	0	0
A11	1/29/08	33	G1	020	80.0	51.1	0	555	33	0	292	67	83.9	55.0	A	0	0	33	34	360	360
A11	1/29/08	12	G1	020	56.9	38.0	0	0	19	20	334	262	77.0	58.1	A	0	0	42	41	360	360
A11	1/29/08	65	G1	020									80.8	48.4	A	0	0	30	32	360	58
A12	1/30/08	33	G1	066	80.0	51.0	0	0	35	35	360	360	79.0	50.0	E	0	0	26	26	88	113
A12	1/30/08	12	G1	066	51.4	32.3	0	0	16	16	157	140	62.8	43.7	A	0	0	26	26	360	262
A12	1/30/08	65	G1	066									72.0	39.1	D	1	1	16	16	75	50
A13	1/31/08	33	G1	049	77.4	48.6	0	0	30	31	360	214	87.1	58.3	A	0	0	41	42	360	360
A13	1/31/08	12	G1	049	63.9	44.9	0	0	27	27	241	275	74.1	55.1	A	0	0	39	39	360	360
A13	1/31/08	65	G1	049									81.3	48.9	A	0	0	33	33	360	360
A14	2/1/08	33	G1	069	79.3	50.6	0	0	33	34	237	154	79.1	50.4	E	0	0	32	33	109	219
A14	2/1/08	12	G1	069																	
A14	2/1/08	65	G1	069									71.7	38.9	C	3	999	13	0	260	211

* denotes test site "***outside*** the box"

Table A6-1 (cont) Summary of **30’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
A15	2/4/08	33	G1	003	88.8	60.0	0	0	42	42	360	323	88.4	59.6	E	0	0	42	42	360	171
A15	2/4/08	12	G1	003	78.4	59.2	0	0	42	42	360	360	78.5	59.3	E	0	0	40	40	360	360
A15	2/4/08	65	G1	003									73.7	41.0	A	0	0	20	20	360	293
A16	2/5/08	33	G1	014	87.0	58.8	0	0	41	42	360	360	86.8	58.6	E	0	0	40	41	360	360
A16	2/5/08	12	G1	014	72.8	56.5	0	0	36	37	322	327	72.6	56.3	E	0	0	36	36	360	360
A16	2/5/08	65	G1	014									77.6	45.3	B	0	0	27	27	360	199
A17	2/6/08	33	G1	011	75.0	46.6	0	0	28	31	360	360	82.6	54.2	A	0	0	36	37	360	360
A17	2/6/08	12	G1	011	69.8	51.0	0	0	34	34	360	360	75.2	56.4	A	0	0	38	38	360	360
A17	2/6/08	65	G1	011									80.9	49.0	A	0	0	31	32	360	360
A18	2/7/08	33	G1	015	79.1	50.6	0	0	33	34	360	360	79.4	50.9	E	0	0	33	34	360	360
A18	2/7/08	12	G1	015	74.1	55.1	0	0	38	38	360	360	73.4	54.4	E	0	0	37	37	360	360
A18	2/7/08	65	G1	015									63.4	31.1	B	0	0	11	13	215	50
A19	2/8/08	33	G1	047	89.0	60.5	0	0	43	43	360	360	89.4	60.9	E	0	0	43	43	360	360
A19	2/8/08	12	G1	047	68.9	49.8	0	0	32	33	360	360	69.4	50.3	E	0	0	32	32	360	360
A19	2/8/08	65	G1	047									71.8	39.8	B	0	0	19	21	360	360
A20	2/11/08	33	G1	028	67.1	39.0	0	0	18	18	360	268	75.8	47.7	A	0	0	27	27	360	360
A20	2/11/08	12	G1	028	52.7	33.8	0	0	16	16	228	215	71.9	53.0	A	0	0	35	35	360	360
A20	2/11/08	65	G1	028									73.7	41.7	A	0	0	22	22	360	279
A21	2/12/08	33	G1	052	73.9	45.7	0	0	25	25	279	267	74.5	46.3	E	0	0	19	19	360	145
A21	2/12/08	12	G1	052																	
A21	2/12/08	65	G1	052																	
A22	2/14/08	33	G1	058	77.2	48.8	0	0	30	31	360	268	83.5	55.1	A	0	0	35	36	360	360
A22	2/14/08	12	G1	058																	
A22	2/14/08	65	G1	058									81.4	49.3	A	0	0	31	32	299	296
A23	2/15/08	33	G1	057	82.1	53.7	0	0	37	38	360	360	79.8	51.4	E	0	0	31	32	360	360
A23	2/15/08	12	G1	057	65.4	46.3	0	0	29	29	360	360	65.5	46.4	E	0	0	28	30	360	284
A23	2/15/08	65	G1	057									68.8	36.4	B	0	0	18	19	360	42
A24 *	2/18/08	33	IX	010	89.9	61.3	0	0	43	45	360	360	91.5	62.9	E	0	0	44	44	360	360
A24 *	2/18/08	12	IX	010	66.8	47.6	0	0	30	30	317	277	67.5	48.3	E	0	0	31	31	309	237
A24 *	2/18/08	65	IX	010									58.0	25.7	A	0	0	7	8	50	49
A25	2/19/08	33	G1	022	68.3	39.7	0	0	22	23	276	267	75.5	46.9	A	0	0	27	27	360	360
A25	2/19/08	12	G1	022	61.7	42.7	0	0	25	26	332	314	65.0	46.0	A	0	0	27	27	360	360
A25	2/19/08	65	G1	022									72.8	41.9	A	0	0	23	23	360	360
A26	2/20/08	33	G1	026	78.8	50.5	0	0	33	33	360	360	77.2	48.9	E	0	0	25	25	360	360
A26	2/20/08	12	G1	026	57.8	39.0	0	0	21	21	283	263	62.3	43.5	A	0	0	22	22	360	280
A26	2/20/08	65	G1	026									70.9	39.1	B	0	0	20	20	360	360
A27 *	2/21/08	33	IX	009	95.8	67.4	0	0	50	50	360	360	95.5	67.1	E	0	0	49	51	360	360
A27 *	2/21/08	12	IX	009	56.6	40.1	4	555	0	0	0	0	56.3	39.8		555	555	0	0	0	0
A27 *	2/21/08	65	IX	009									52.3	20.1	A	999	999	0	0	0	0
A28	2/25/08	33	G1	072	84.7	55.8	0	0	39	40	360	360	84.2	55.3	D	0	0	35	36	346	334
A28	2/25/08	12	G1	072	63.0	44.0	0	0	26	26	219	202	72.7	53.7	D	0	0	36	36	360	360
A28	2/25/08	65	G1	072									81.4	49.3	D	0	0	31	31	360	360

* denotes test site “***outside*** the box”

Table A6-1 (cont) Summary of **30’** AGL raw outdoor data

Test Site Name & Date					**DTx OFF**								**DTx ON**									
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
A29	2/26/08	33	G1	032	60.7	32.2	0	0	10	12	360	360	87.6	59.1	A	0	0	40	43	360	360
A29	2/26/08	12	G1	032	60.3	41.3	0	0	24	24	360	313	74.4	55.4	A	0	0	38	38	360	360
A29	2/26/08	65	G1	032									81.3	49.3	A	0	0	31	31	360	360
A30	2/29/08	33	G1	038	86.6	58.5	0	0	41	42	360	360	86.4	58.3	E	0	0	40	41	360	102
A30	2/29/08	12	G1	038	67.5	48.9	0	0	31	31	360	360	67.4	48.8	E	0	0	31	31	360	360
A30	2/29/08	65	G1	038									71.8	40.2	B	0	0	15	15	0	0
A31	3/3/08	33	G1	039	77.4	49.2	555	3	0	0	318	226	97.5	69.3	A	0	0	52	52	360	360
A31	3/3/08	12	G1	039																	
A31	3/3/08	65	G1	039																	
A32	3/5/08	33	G1	076	60.7	32.0	0	0	12	12	105	108	64.7	36.0	A	0	999	11	0	326	0
A32	3/5/08	12	G1	076	54.6	35.7	0	0	18	18	156	157	59.4	40.5	A	0	0	20	20	360	360
A32	3/5/08	65	G1	076									65.3	32.9	D	0	0	13	13	81	48
A33	3/6/08	33	G1	061	69.1	40.7	0	0	22	22	360	360	70.8	42.4	C	0	555	16	0	111	0
A33	3/6/08	12	G1	061	54.8	35.7	0	0	15	16	219	211	61.1	42.0	D	0	555	19	0	360	0
A33	3/6/08	65	G1	061									64.5	32.2	C	0	555	9	0	360	0
A34	3/11/08	33	G1	055	70.4	41.6	0	0	22	20	360	360	72.4	43.6	B	0	0	25	26	360	237
A34	3/11/08	12	G1	055	53.5	34.3	0	0	10	10	360	360	60.1	40.9	B	0	0	21	22	360	360
A34	3/11/08	65	G1	055									67.0	34.4	B	0	0	16	16	87	39
A35	3/12/08	33	G1	062	72.6	43.9	0	0	24	24	360	360	75.0	46.3	E	0	0	19	15	360	360
A35	3/12/08	12	G1	062	56.3	37.5	0	0	18	19	307	199	60.1	41.3	C	0	0	22	23	360	360
A35	3/12/08	65	G1	062									69.2	37.0	B	0	0	16	14	360	360
A36	3/13/08	33	G1	041	89.7	61.0	0	0	43	45	360	360	92.1	63.4	E	0	0	43	45	360	360
A36	3/13/08	12	G1	041	64.2	45.2	0	0	28	28	360	360	78.2	59.2	A	0	0	41	42	360	360
A36	3/13/08	65	G1	041									88.5	56.4	A	0	0	38	40	360	360
A37	3/14/08	33	G1	008	63.7	35.2	0	0	11	9	143	64	98.1	69.6	B	0	0	41	41	360	360
A37	3/14/08	12	G1	008	55.4	36.4	0	0	18	19	275	270	110.7	91.7	B	0	0	74	74	360	360
A37	3/14/08	65	G1	008									103.5	71.4	B	0	0	53	44	360	360
A38	3/17/08	33	G1	016	62.9	34.4	555	555	0	0	0	0	75.5	47.0	A	0	0	26	25	360	0
A38	3/17/08	12	G1	016	54.2	35.4	555	555	0	0	0	0	64.8	46.0	A	555	555	0	0	0	0
A38	3/17/08	65	G1	016									70.5	38.9	B	0	0	18	19	360	360
A39	4/21/08	33	G1	005	86.6	57.8	0	0	41	41	360	360	86.8	58.0	E	0	0	41	41	360	360
A39	4/21/08	12	G1	005	60.9	42.0	0	0	25	25	360	360	73.1	54.2	A	0	0	37	36	360	360
A39	4/21/08	65	G1	005									76.9	44.8	A	0	0	26	26	360	360
A40	4/22/08	33	G1	029	73.8	45.0	0	0	24	25	360	0	82.8	54.0	A	0	0	37	37	360	360
A40	4/22/08	12	G1	029	54.4	35.4	0	0	18	16	303	303	75.9	56.9	A	0	0	39	39	360	360
A40	4/22/08	65	G1	029									80.5	48.4	A	0	0	30	30	360	360
B1	4/21/08	33	G1	079	83.1	52.6	0	0	36	36	360	360	96.1	65.6	C	0	0	47	47	127	127
B1	4/21/08	12	G1	079	65.1	43.7	0	0	27	27	291	291	89.0	67.6	C	0	0	49	50	360	360
B1	4/21/08	65	G1	079									79.7	45.3	C	0	0	25	25	146	146
B2	1/16/08	33	G1	002	74.9	44.4	0	0	26	24	360	360	91.2	60.7	A	0	0	44	42	360	360
B2	1/16/08	12	G1	002	58.8	37.2	0	0	21	20	360	360	78.9	57.3	A	0	0	40	40	360	285
B2	1/16/08	65	G1	002									91.7	57.9	A	0	0	41	39	360	360

* denotes test site “***outside*** the box”

Table A6-1 (cont) Summary of **30’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B3	1/17/08	33	G1	018	68.2	36.9	0	0	21	19	360	290	98.2	66.9	B	0	0	54	53	360	360
B3	1/17/08	12	G1	018	57.7	35.6	0	0	21	20	160	160	77.2	55.1	B	0	0	40	40	360	360
B3	1/17/08	65	G1	018									97.5	62.4	B	0	0	47	47	360	360
B4	1/18/08	33	G1	071	60.0	29.0	0	0	9	8	210	110	79.5	48.5	C	0	0	34	31	360	260
B4	1/18/08	12	G1	071	51.5	29.7	0	0	14	13	205	205	73.1	51.3	C	0	0	35	33	360	271
B4	1/18/08	65	G1	071									81.9	46.7	C	0	0	30	20	360	250
B5	1/21/08	33	G1	024	69.4	40.9	0	0	16	18	360	360	82.4	53.9	A	0	0	34	34	360	123
B5	1/21/08	12	G1	024	55.6	35.9	0	0	18	16	360	360	61.3	41.6	A	0	0	21	21	360	162
B5	1/21/08	65	G1	024									76.3	43.3	A	0	0	22	22	360	360
B6	1/22/08	33	G1	044	75.7	45.2	0	0	28	28	360	360	72.6	42.1	E	0	0	19	20	360	360
B6	1/22/08	12	G1	044	58.0	36.6	0	0	17	18	360	360	59.0	37.6	E	0	0	16	16	360	360
B6	1/22/08	65	G1	044									60.4	26.0	A	555	555	0	0	135	149
B7 *	1/23/08	33	IX	013	72.8	42.3	0	0	32	34	287	190	72.1	41.6	E	0	0	22	22	174	162
B7 *	1/23/08	12	IX	013	65.4	44.2	0	0	28	28	322	234	66.0	44.8	E	0	0	27	26	221	154
B7 *	1/23/08	65	IX	013									64.4	29.9	A	0	0	10	10	84	75
B8	1/24/08	33	G1	051	73.3	43.5	0	0	24	24	360	360	75.0	45.2	E	0	0	20	17	360	0
B8	1/24/08	12	G1	051	59.8	38.6	0	0	20	19	319	270	63.0	41.8	A	0	0	14	12	360	40
B8	1/24/08	65	G1	051									71.4	37.3	A	0	9	14	0	266	0
B9	1/25/08	33	G1	064	65.5	36.2	0	0	16	14	286	212	78.4	49.1	B	0	0	30	30	360	101
B9	1/25/08	12	G1	064	55.8	34.8	0	0	17	17	222	238	64.8	43.8	B	0	0	25	24	360	302
B9	1/25/08	65	G1	064									80.3	46.0	B	0	0	28	28	360	261
B10	1/28/08	33	G1	010	75.3	44.8	0	0	28	28	161	236	79.0	48.5	E	0	0	26	25	360	360
B10	1/28/08	12	G1	010	75.6	54.1	0	0	37	38	143	208	79.0	57.5	A	0	0	39	39	360	352
B10	1/28/08	65	G1	010									79.9	45.2	A	0	0	28	28	275	103
B11	1/29/08	33	G1	019	68.1	37.1	0	0	19	19	360	162	81.2	50.2	A	0	0	32	31	360	360
B11	1/29/08	12	G1	019	58.1	36.9	0	0	20	20	109	115	82.7	61.5	A	0	0	44	44	360	360
B11	1/29/08	65	G1	019									95.1	60.7	A	0	0	42	42	360	360
B12	1/30/08	33	G1	065	87.7	57.2	0	0	40	40	360	255	85.9	55.4	E	0	0	36	36	360	26
B12	1/30/08	12	G1	065	67.3	46.0	0	0	28	28	305	360	69.4	48.1	B	0	555	23	0	360	62
B12	1/30/08	65	G1	065									76.2	41.5	A	0	0	23	23	262	73
B13	1/31/08	33	G1	048	80.5	50.0	0	0	13	12	360	317	84.4	53.9	E	0	0	35	35	360	360
B13	1/31/08	12	G1	048	56.5	35.6	0	0	17	16	222	204	64.7	43.8	A	0	0	25	25	360	360
B13	1/31/08	65	G1	048									74.8	40.4	A	0	0	22	21	360	218
B14	2/1/08	33	G1	068	55.4	25.1	555	999	0	0	0	0	78.6	48.3	A	0	0	30	30	360	153
B14	2/1/08	12	G1	068																	
B14	2/1/08	65	G1	068									73.8	39.9	A	0	0	20	20	328	111
B15	2/4/08	33	G1	004	81.8	51.7	0	0	30	28	276	202	85.0	54.9	A	0	0	37	37	360	360
B15	2/4/08	12	G1	004	66.1	44.8	0	0	27	27	250	222	61.4	40.1	A	0	0	32	32	360	141
B15	2/4/08	65	G1	004									83.5	49.5	A	0	0	30	30	196	79
B16	2/5/08	33	G1	013	90.5	59.8	0	0	43	43	360	360	89.5	58.8	E	0	0	42	42	360	360
B16	2/5/08	12	G1	013	75.3	54.1	0	0	37	37	360	360	76.0	54.8	E	0	0	37	37	360	360
B16	2/5/08	65	G1	013									77.6	43.3	A	0	0	24	24	179	51

* denotes test site “***outside*** the box”

Table A6-1 (cont) Summary of **30'** AGL raw outdoor data

Test Site Name & Date					**DTx OFF**								**DTx ON**								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B17	2/6/08	33	G1	012	62.7	31.8	999	999	0	0	167	3	92.7	61.8	A	0	0	45	45	360	331
B17	2/6/08	12	G1	012	64.1	42.5	0	0	26	25	360	218	72.2	50.6	A	0	0	32	32	360	344
B17	2/6/08	65	G1	012									86.4	51.8	A	0	0	33	34	360	360
B18	2/7/08	33	G1	025	82.0	51.1	0	0	35	35	360	360	83.6	52.7	E	0	0	35	35	360	125
B18	2/7/08	12	G1	025	64.9	43.5	0	0	27	27	360	360	76.1	54.7	A	0	0	37	37	360	300
B18	2/7/08	65	G1	025									81.1	46.8	A	0	0	28	28	360	184
B19	2/8/08	33	G1	046	75.7	45.4	0	0	29	29	360	360	78.8	48.5	B	0	0	30	30	360	360
B19	2/8/08	12	G1	046	61.0	39.6	0	0	23	23	360	360	61.5	40.1	A	0	0	13	13	360	259
B19	2/8/08	65	G1	046									78.6	44.4	B	0	0	26	26	360	360
B20	2/11/08	33	G1	030	73.5	43.3	0	0	28	25	360	65	89.8	59.6	A	0	0	44	43	360	360
B20	2/11/08	12	G1	030	58.0	37.1	0	0	19	18	360	360	82.7	61.8	A	0	0	45	44	360	360
B20	2/11/08	65	G1	030									88.0	53.9	A	0	0	35	41	360	360
B21	2/12/08	33	G1	053	62.6	32.2	0	0	15	14	285	80	67.3	36.9	A	0	0	20	18	360	360
B21	2/12/08	12	G1	053																	
B21	2/12/08	65	G1	053																	
B22	2/14/08	33	G1	059	71.7	40.5	0	0	23	22	360	340	74.9	43.7	A	0	0	24	23	360	110
B22	2/14/08	12	G1	059																	
B22	2/14/08	65	G1	059									75.7	40.7		0	0	25	25	360	360
B23	2/15/08	33	G1	056	71.8	41.3	0	0	26	26	360	267	74.5	44.0	E	3	1	24	20	360	260
B23	2/15/08	12	G1	056	61.5	40.1	0	0	25	25	305	290	65.1	43.7	E	0	0	26	26	360	260
B23	2/15/08	65	G1	056									74.9	40.3	B	0	0	22	21	360	258
B24 *	2/18/08	33	IX	011	83.2	53.4	0	0	38	38	360	360	84.3	54.5	E	0	0	37	37	360	360
B24 *	2/18/08	12	IX	011	61.8	41.1	0	0	25	24	245	220	63.6	42.9	E	0	0	26	26	275	210
B24 *	2/18/08	65	IX	011									68.7	34.8	A	0	0	17	17	150	140
B25	2/19/08	33	G1	021	76.4	46.2	0	0	31	31	360	220	72.3	42.1	E	3	0	28	25	360	55
B25	2/19/08	12	G1	021	54.4	33.2	0	0	15	15	360	215	61.9	40.7	A	0	0	26	25	360	360
B25	2/19/08	65	G1	021									73.9	39.8	A	0	0	23	22	360	360
B26	2/20/08	33	G1	027	52.6	22.6	0	0	9	8	195	130	78.6	48.6	A	0	0	40	39	360	360
B26	2/20/08	12	G1	027	45.3	24.5	0	0	15	14	250	260	73.8	53.0	A	0	0	37	36	360	360
B26	2/20/08	65	G1	027									78.7	45.2	A	0	0	35	35	360	325
B27 *	2/21/08	33	IX	008	77.0	46.5	0	0	27	27	360	360	77.8	47.3	E	0	0	30	30	360	360
B27 *	2/21/08	12	IX	008	49.3	27.8	999	999	0	0	0	0	57.5	36.0	A	0	999	16	0	35	5
B27 *	2/21/08	65	IX	008									72.2	37.7		0	0	10	10	75	60
B28	2/25/08	33	G1	073	86.2	55.5	0	0	37	37	360	360	93.5	62.8	D	0	0	46	46	307	360
B28	2/25/08	12	G1	073	62.2	40.7	0	0	24	24	337	360	74.7	53.2	D	0	0	35	35	360	160
B28	2/25/08	65	G1	073									97.3	63.8	D	0	0	45	45	360	360
B29	2/26/08	33	G1	033	70.4	40.0	0	0	23	23	360	360	85.8	55.4	A	0	0	38	38	360	360
B29	2/26/08	12	G1	033	58.7	37.2	0	0	19	20	323	319	71.3	49.8	A	0	0	32	32	360	360
B29	2/26/08	65	G1	033									83.0	48.7	A	0	0	30	31	360	360
B30	2/27/08	33	G1	074	70.6	40.2	0	0	23	23	230	206	82.8	52.4	D	0	0	34	35	360	360
B30	2/27/08	12	G1	074	48.5	27.0	0	0	7	7	172	146	71.2	49.7	D	0	0	32	32	360	360
B30	2/27/08	65	G1	074									79.7	45.3	D	0	555	18	0	360	0

* denotes test site "***outside*** the box"

Table A6-1 (cont) Summary of **30’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B31	2/28/08	33	G1	075	48.3	17.8	999	999	0	0	0	0	67.9	37.4	D	0	0	20	20	236	151
B31	2/28/08	12	G1	075	39.1	17.9	999	999	0	0	0	0	73.0	51.8	D	0	0	34	34	360	205
B31	2/28/08	65	G1	075									67.3	33.0	D	0	0	14	14	155	145
B32	2/29/08	33	G1	037	71.1	40.8	0	0	23	23	360	360	72.5	42.2	E	0	0	23	23	360	65
B32	2/29/08	12	G1	037	55.2	34.3	0	0	15	15	360	360	62.6	41.7	A	0	0	22	22	360	360
B32	2/29/08	65	G1	037									68.3	34.2	B	0	0	15	15	146	50
B33	3/3/08	33	G1	040	77.3	47.4	0	0	28	28	360	360	78.7	48.8	A	0	0	27	28	360	360
B33	3/3/08	12	G1	040	54.4	33.2	0	0	9	9	360	319	71.8	50.6	A	0	0	32	32	360	292
B33	3/3/08	65	G1	040									73.2	39.2	A	0	0	20	21	360	316
B34	3/4/08	33	G1	067	53.5	23.2	555	999	0	0	0	0	62.9	32.6	C	0	0	10	10	323	63
B34	3/4/08	12	G1	067	43.5	22.3	0	0	4	4	51	50	54.1	32.9	D	0	0	10	8	360	84
B34	3/4/08	65	G1	067									65.4	30.9	C	0	555	9	0	100	0
B35	3/5/08	33	G1	077	65.4	35.1	0	0	18	18	360	360	70.8	40.5	C	0	0	20	19	306	142
B35	3/5/08	12	G1	077	55.1	33.7	0	0	17	17	236	209	62.5	41.1	C	0	0	20	20	360	311
B35	3/5/08	65	G1	077									66.3	32.1	D	0	0	6	4	119	106
B36	3/6/08	33	G1	060	50.0	19.5	999	999	0	0	0	0	69.9	39.4	C	0	0	20	20	360	124
B36	3/6/08	12	G1	060	44.8	23.6	555	555	0	0	65	0	55.7	34.5	D	0	0	14	14	360	360
B36	3/6/08	65	G1	060									57.3	23.2	C	0	0	13	13	155	43
B37	3/7/08	33	G1	036	74.5	44.0	0	0	26	26	360	360	72.7	42.2	E	0	555	8	0	360	0
B37	3/7/08	12	G1	036	51.4	30.2	0	0	5	5	360	360	55.5	34.3	E	0	555	10	0	360	0
B37	3/7/08	65	G1	036									67.5	33.4	B	0	0	11	11	146	115
B38	3/10/08	33	G1	042	66.0	35.8	0	0	20	18	345	344	70.7	40.5	A	0	1	19	17	360	70
B38	3/10/08	12	G1	042	52.5	31.3	0	2	8	8	360	360	59.6	38.4	A	5	0	14	13	360	360
B38	3/10/08	65	G1	042									69.5	36.2	A	0	999	11	0	0	0
B39	3/11/08	33	G1	054	66.6	36.4	0	0	16	17	360	360	66.8	36.6	E	2	2	12	11	360	0
B39	3/11/08	12	G1	054	57.7	36.5	0	0	20	20	79	75	58.7	37.5	E	2	2	16	16	360	185
B39	3/11/08	65	G1	054									63.3	29.0	B	0	0	10	8	70	30
B40	3/12/08	33	G1	045	67.9	37.6	0	0	18	18	360	360	67.6	37.3	E	0	4	14	14	360	360
B40	3/12/08	12	G1	045	58.8	37.4	0	0	21	21	360	360	60.1	38.7	E	0	0	21	21	360	305
B40	3/12/08	65	G1	045									63.2	29.1	A	0	0	10	8	177	100
B41	3/13/08	33	G1	031	65.6	35.4	0	0	14	13	360	175	78.6	48.4	A	0	0	29	28	360	360
B41	3/13/08	12	G1	031	54.5	33.5	0	0	14	13	250	270	68.9	47.9	A	0	0	29	29	360	360
B41	3/13/08	65	G1	031									79.0	44.7	A	0	0	29	29	360	360
B42	3/14/08	33	G1	007	74.5	44.3	0	0	29	29	360	360	82.8	52.6	B	0	0	40	40	360	297
B42	3/14/08	12	G1	007	56.3	35.1	0	0	18	16	360	360	72.7	51.5	B	0	0	33	33	360	325
B42	3/14/08	65	G1	007									87.0	52.1	B	0	0	33	33	360	360
B43	3/17/08	33	G1	006	83.6	53.4	0	0	36	36	329	273	84.4	54.2	A	0	0	32	31	360	95
B43	3/17/08	12	G1	006	72.2	51.0	0	0	34	34	360	290	75.1	53.9	A	999	999	0	0	358	92
B43	3/17/08	65	G1	006									86.6	52.2	A	0	0	33	33	360	249
B44 *	3/18/08	33	HD	001	77.9	47.7	0	0	31	31	360	246	78.2	48.0	E	0	0	29	29	302	134
B44 *	3/18/08	12	HD	001	53.5	32.6	0	0	15	15	208	208	59.0	38.1	A	0	0	19	19	168	118
B44 *	3/18/08	65	HD	001									66.6	32.2	A	0	0	5	4	77	80

* denotes test site “***outside*** the box”

Table A6-1 (cont) Summary of **30’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B45 *	3/19/08	33	HD	002	95.6	65.2	0	0	47	47	360	360	94.7	64.3	E	0	0	47	47	360	360
B45 *	3/19/08	12	HD	002	82.7	61.4	0	0	44	44	360	360	82.6	61.3	E	0	0	44	44	360	360
B45 *	3/19/08	65	HD	002									52.3	18.2		999	999	0	0	0	0
B46 *	3/20/08	33	HD	003	68.0	37.6	0	0	16	17	292	92	66.2	35.8	E	0	0	15	14	230	42
B46 *	3/20/08	12	HD	003	45.7	24.4	0	0	5	4	57	55	41.2	19.9	A	555	999	0	0	0	0
B46 *	3/20/08	65	HD	003									58.5	24.2	A	0	0	5	6	87	87
B47 *	3/21/08	33	HD	004	75.7	45.4	0	555	20	0	360	0	78.3	48.0		0	555	20	0	283	0
B47 *	3/21/08	12	HD	004	71.9	50.7	0	0	30	30	360	360	71.0	49.8	E	0	0	29	29	360	360
B47 *	3/21/08	65	HD	004									53.5	19.4	A	0	0	3	3	29	29
B48 *	3/24/08	33	HD	005	82.9	52.3	0	0	22	22	247	229	82.9	52.3	E	0	0	34	34	315	158
B48 *	3/24/08	12	HD	005	68.3	47.1	0	0	20	20	245	249	59.4	38.2		0	0	19	19	285	110
B48 *	3/24/08	65	HD	005									67.2	32.9	D	0	0	13	14	0	73
B49	3/25/08	33	HD	006	81.1	50.9	0	0	31	30	360	163	78.7	48.5	E	0	0	30	27	360	153
B49	3/25/08	12	HD	006	77.9	56.9	0	0	40	39	360	360	75.3	54.3	E	0	0	39	39	360	305
B49	3/25/08	65	HD	006									80.1	45.9	A	0	0	25	24	360	0
B50 *	3/26/08	33	HD	007	74.0	43.2	0	0	27	27	360	360	76.8	46.0	E	0	0	24	23	360	275
B50 *	3/26/08	12	HD	007	63.9	42.6	0	0	26	26	245	260	64.9	43.6	E	0	0	21	21	255	140
B50 *	3/26/08	65	HD	007									67.0	33.5	A	0	0	12	11	95	35
B51 *	3/27/08	33	HD	008	83.9	53.2	0	0	35	35	360	360	84.9	54.2	E	0	0	37	37	360	360
B51 *	3/27/08	12	HD	008	65.8	44.4	0	0	27	27	360	360	76.0	54.6	E	0	0	27	27	360	360
B51 *	3/27/08	65	HD	008									58.3	23.8	A	0	0	3	4	20	20
B52 *	3/28/08	33	HD	009	80.2	49.3	2	0	26	21	360	250	70.3	39.4	E	0	0	28	28	360	0
B52 *	3/28/08	12	HD	009	55.5	33.7	1	555	10	0	240	0	45.2	23.4	E	1	999	10	0	360	0
B52 *	3/28/08	65	HD	009									55.4	21.8	A	999	999	0	0	0	0
B53	3/31/08	33	HD	010	68.9	39.1	0	0	21	21	360	160	80.7	50.9	A	0	0	31	32	360	310
B53	3/31/08	12	HD	010	51.0	30.2	0	0	12	12	237	237	73.2	52.4	A	0	0	34	35	360	360
B53	3/31/08	65	HD	010									79.9	46.1	A	0	0	27	28	360	360
B54 *	4/1/08	33	HD	011	83.3	52.8	0	0	35	35	360	360	84.7	54.2	E	0	0	36	37	360	360
B54 *	4/1/08	12	HD	011	36.3	15.2	555	555	0	0	0	0	47.0	25.9		999	999	0	0	0	0
B54 *	4/1/08	65	HD	011									53.4	18.9	A	999	999	0	0	0	0
B55	4/2/08	33	HD	012	75.7	45.6	0	0	27	27	360	298	77.0	46.9	A	0	0	32	33	360	360
B55	4/2/08	12	HD	012	65.5	43.8	0	0	25	26	158	158	85.9	64.2	A	0	0	47	48	360	360
B55	4/2/08	65	HD	012									75.9	41.9	A	0	0	27	28	360	223
B56 *	4/3/08	33	HD	013	82.1	52.0	0	0	34	33	360	360	84.5	54.4	E	0	0	36	34	360	360
B56 *	4/3/08	12	HD	013	54.2	33.1	0	0	14	14	331	331	55.5	34.4	E	0	0	13	13	331	331
B56 *	4/3/08	65	HD	013									62.6	28.4	A	0	0	9	10	66	66
B57	4/4/08	33	G1	035	80.5	50.1	0	0	32	33	360	360	77.8	47.4	E	0	0	29	29	360	360
B57	4/4/08	12	G1	035	70.6	48.9	0	0	32	33	360	360	71.9	50.2	E	0	0	32	33	360	360
B57	4/4/08	65	G1	035									73.8	39.5	A	0	0	20	21	264	264
B58	4/22/08	33	G1	034	80.5	50.1	0	0	32	32	326	326	81.1	50.7	E	0	0	33	34	360	360
B58	4/22/08	12	G1	034	62.2	41.0	0	0	23	24	307	307	63.7	42.5	E	0	0	24	25	360	360
B58	4/22/08	65	G1	034									68.9	34.7	B	0	0	10	10	325	325

* denotes test site “***outside*** the box”

Table A6-1 (cont) Summary of **30'** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B59 *	4/23/08	33	HD	014	74.4	44.0	0	0	20	21	360	360	76.8	46.4	E	0	0	25	26	360	360
B59 *	4/23/08	12	HD	014	66.8	45.5	0	0	28	29	360	360	67.5	46.2	E	0	0	28	29	360	360
B59 *	4/23/08	65	HD	014									65.7	31.4	A	0	0	9	9	203	0
B60	4/28/08	33	G1	080	75.8	44.8	0	0	28	29	360	360	77.9	46.9	D	0	0	29	29	360	305
B60	4/28/08	12	G1	080	59.3	37.7	0	0	21	21	137	135	72.7	51.1	D	0	0	33	34	360	360
B60	4/28/08	65	G1	080									71.1	37.4	D	0	0	17	18	360	330
B61 *	4/29/08	33	HD	015	60.8	29.9	0	0	13	14	315	320	63.0	32.1	E	10	999	4	0	160	0
B61 *	4/29/08	12	HD	015	49.1	27.3	0	0	10	10	170	175	50.5	28.7	E	8	999	4	0	95	0
B61 *	4/29/08	65	HD	015									59.5	24.5	D	10	3	1	1	0	0
B62 *	4/30/08	33	HD	016	66.9	36.3	0	0	19	20	285	275	68.5	37.9	E	0	0	21	21	295	295
B62 *	4/30/08	12	HD	016	46.8	25.2	0	0	8	8	90	90	48.5	26.9	E	0	0	6	6	75	75
B62 *	4/30/08	65	HD	016									53.3	18.7	A	999	999	0	0	0	0
B63	5/1/08	33	HD	017	63.7	32.3	0	0	12	12	245	235	70.6	39.2	A	0	0	20	20	360	360
B63	5/1/08	12	HD	017	72.3	50.4	0	0	33	34	360	360	72.7	50.8	E	0	0	33	34	360	360
B63	5/1/08	65	HD	017									66.2	31.9	A	5	0	3	3	360	360
B64	5/2/08	33	HD	018	48.3	17.7	999	999	0	0	0	0	69.8	39.2		0	0	17	17	360	360
B64	5/2/08	12	HD	018	41.4	19.6	999	999	0	0	0	0	58.0	36.2	C	0	0	17	17	360	105
B64	5/2/08	65	HD	018									67.3	32.6	C	0	555	10	10	270	165
B65	5/5/08	33	HD	019	67.6	36.9	0	0	14	14	360	166	81.5	50.8	A	0	0	30	31	360	360
B65	5/5/08	12	HD	019	46.0	24.8	999	999	0	0	141	146	68.2	47.0	A	0	0	28	29	360	360
B65	5/5/08	65	HD	019									78.1	43.6	A	0	0	24	25	360	360
B66	5/6/08	33	HD	020	69.5	38.8	0	0	21	22	360	298	91.8	61.1	A	0	0	43	43	360	222
B66	5/6/08	12	HD	020	61.9	40.6	0	0	23	24	360	360	76.5	55.2	A	0	0	37	38	360	360
B66	5/6/08	65	HD	020									89.6	55.0	A	0	0	35	36	360	360
B67	5/7/08	33	HD	021	80.3	49.4	0	0	32	33	360	360	82.8	51.9	E	0	0	31	31	360	360
B67	5/7/08	12	HD	021	62.3	40.7	0	0	23	24	360	360	68.6	47.0	A	0	0	29	29	360	360
B67	5/7/08	65	HD	021									79.2	44.4	A	0	0	25	26	360	360
B68	5/8/08	33	HD	022	79.1	48.3	0	0	30	31	360	360	79.2	48.4	E	0	0	32	33	360	360
B68	5/8/08	12	HD	022	69.8	48.3	0	0	31	31	348	348	70.6	49.1	E	0	0	31	32	360	299
B68	5/8/08	65	HD	022									61.7	27.1	A	555	555	0	0	0	0
B69	5/9/08	33	HD	023	71.9	41.1	0	0	13	13	360	360	91.1	60.3	A	0	0	42	43	360	297
B69	5/9/08	12	HD	023	52.3	30.7	0	0	9	10	273	273	76.2	54.6	A	0	0	36	37	360	360
B69	5/9/08	65	HD	023									93.0	58.4	A	0	0	40	41	360	360

* denotes test site "***outside*** the box"

Table A6-2 Summary of **15'** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
A1	1/15/08	33	G1	078	52.4	23.3	555	555	0	0	0	0	79.3	50.2	C	0	0	18	20	360	293
A1	1/15/08	12	G1	078	39.9	19.8	555	555	0	0	0	0	62.9	42.8	C	0	0	24	24	360	283
A1	1/15/08	65	G1	078									78.0	45.2	C	0	0	27	28	360	152
A2	1/16/08	33	G1	001	78.0	49.3	0	0	31	33	360	360	77.7	49.0	E	0	0	29	30	353	78
A2	1/16/08	12	G1	001	68.5	49.5	0	0	32	32	360	360	70.8	51.8	E	3	3	26	25	360	360
A2	1/16/08	65	G1	001									71.4	38.9	A	3	5	9	0	118	250
A3	1/17/08	33	G1	017	59.2	30.7	0	0	8	7	316	0	75.5	47.0	A	1	555	0	0	360	288
A3	1/17/08	12	G1	017	46.5	27.8	3	555	0	0	0	0	72.7	54.0	A	0	0	37	36	232	205
A3	1/17/08	65	G1	017									76.5	44.1	A	0	0	20	19	360	61
A4	1/18/08	33	G1	070	66.2	37.4	0	0	15	16	360	360	68.8	40.0	C	555	555	0	0	69	0
A4	1/18/08	12	G1	070	56.7	37.7	0	0	17	17	156	173	68.3	49.3	C	0	0	31	32	360	201
A4	1/18/08	65	G1	070									73.9	41.4	C	0	0	23	23	360	156
A5	1/21/08	33	G1	023	69.4	41.0	0	0	21	23	360	360	72.4	44.0	E	0	0	19	20	360	360
A5	1/21/08	12	G1	023	60.2	46.5	0	0	24	25	157	170	62.4	48.7	A	0	0	20	11	360	95
A5	1/21/08	65	G1	023									70.5	38.6	A	0	0	20	20	0	0
A6	1/22/08	33	G1	043	66.9	38.5	0	0	20	21	360	240	71.7	43.3	A	0	0	19	20	48	111
A6	1/22/08	12	G1	043	45.4	26.5	0	0	6	6	62	121	57.8	38.9	A	0	0	20	20	168	71
A6	1/22/08	65	G1	043									64.5	33.3	A	0	0	14	14	256	164
A7 *	1/23/08	33	IX	012	60.8	31.9	0	0	12	13	343	205	66.2	37.3	E	0	0	11	11	324	133
A7 *	1/23/08	12	IX	012	52.5	33.3	0	0	16	16	143	157	56.1	36.9	E	0	0	17	18	133	94
A7 *	1/23/08	65	IX	012									51.3	19.1		999	999	0	0	0	0
A8	1/24/08	33	G1	050	74.5	46.0	0	0	17	19	190	132	77.8	49.3	E	0	0	25	26	360	301
A8	1/24/08	12	G1	050	55.0	36.0	0	0	16	17	253	177	64.7	45.7	A	0	0	25	26	360	276
A8	1/24/08	65	G1	050									68.2	36.7	A	0	0	19	20	316	247
A9	1/25/08	33	G1	063	56.3	27.5	0	0	9	10	97	116	64.0	35.2	A	0	555	10	0	94	0
A9	1/25/08	12	G1	063	51.0	32.1	0	0	13	14	182	258	53.7	34.8	E	0	0	11	8	128	23
A9	1/25/08	65	G1	063									63.5	31.7	B	0	0	12	13	131	172
A10	1/28/08	33	G1	009	58.3	29.7	555	555	0	0	75	0	66.0	37.4	E	555	999	0	0	0	0
A10	1/28/08	12	G1	009	42.8	23.8	999	999	0	0	0	0	66.2	47.2	A	0	0	27	26	360	261
A10	1/28/08	65	G1	009									70.0	37.7	A	555	555	0	0	136	0
A11	1/29/08	33	G1	020	79.7	50.8	0	0	31	32	264	228	83.3	54.4	E	0	0	35	34	360	180
A11	1/29/08	12	G1	020	55.9	37.0	0	0	18	19	360	224	72.6	53.7	A	0	0	37	37	360	360
A11	1/29/08	65	G1	020									74.5	42.1	A	0	3	22	23	360	360
A12	1/30/08	33	G1	066	80.2	51.2	0	0	35	36	360	360	80.3	51.3	E	0	0	33	34	68	61
A12	1/30/08	12	G1	066	53.7	34.6	0	0	19	19	185	100	61.4	42.3	D	0	0	22	23	360	156
A12	1/30/08	65	G1	066									70.8	37.9	D	0	0	19	20	128	11
A13	1/31/08	33	G1	049	76.0	47.2	0	0	26	27	203	83	87.4	58.6	A	0	0	42	43	360	360
A13	1/31/08	12	G1	049	61.7	42.7	0	0	24	24	222	215	67.9	48.9	A	0	0	33	33	360	40
A13	1/31/08	65	G1	049									82.9	50.5	A	0	0	34	35	360	77
A14	2/1/08	33	G1	069	70.3	41.6	0	0	23	24	304	191	69.0	40.3	E	0	2	23	24	30	35
A14	2/1/08	12	G1	069																	
A14	2/1/08	65	G1	069									67.5	34.7	C	0	0	16	15	180	43

* denotes test site "***outside*** the box"

Table A6-2 (cont) Summary of **15’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
A15	2/4/08	33	G1	003	86.2	57.4	0	0	39	42	360	360	87.1	58.3	E	0	0	39	39	360	360
A15	2/4/08	12	G1	003	76.9	57.7	0	0	41	41	360	360	75.7	56.5	E	0	0	38	39	360	360
A15	2/4/08	65	G1	003									70.6	37.9	A	0	0	19	19	360	360
A16	2/5/08	33	G1	014	79.0	50.8	0	0	30	33	360	360	80.2	52.0	E	0	0	32	33	360	191
A16	2/5/08	12	G1	014	67.1	50.8	0	0	31	31	360	332	67.5	51.2	E	0	0	31	32	360	360
A16	2/5/08	65	G1	014									70.2	37.9	B	0	0	18	19	324	290
A17	2/6/08	33	G1	011	78.7	50.3	0	0	33	33	360	360	81.6	53.2	A	0	0	35	35	360	360
A17	2/6/08	12	G1	011	62.7	43.9	0	0	25	25	360	360	72.3	53.5	A	0	0	34	34	360	360
A17	2/6/08	65	G1	011									82.4	50.5	A	0	0	32	32	360	360
A18	2/7/08	33	G1	015	69.4	40.9	0	0	23	23	360	360	68.8	40.3	E	0	0	21	21	360	360
A18	2/7/08	12	G1	015	65.1	46.1	0	0	29	29	360	360	65.9	46.9	E	0	0	29	30	360	360
A18	2/7/08	65	G1	015									59.9	27.6	B	555	555	0	0	71	0
A19	2/8/08	33	G1	047	84.2	55.7	0	0	38	39	360	360	84.0	55.5	E	0	0	37	38	360	360
A19	2/8/08	12	G1	047	59.6	40.5	0	0	24	24	360	360	61.2	42.1	E	0	0	23	25	360	199
A19	2/8/08	65	G1	047									75.0	43.0	B	0	0	25	25	323	320
A20	2/11/08	33	G1	028	67.8	39.7	0	0	20	21	150	113	80.5	52.4	A	0	0	33	34	360	360
A20	2/11/08	12	G1	028	47.6	28.7	0	0	8	10	144	132	66.3	47.4	A	0	0	28	29	360	360
A20	2/11/08	65	G1	028									71.9	39.9	A	0	0	21	21	360	360
A21	2/12/08	33	G1	052	67.8	39.6	0	0	17	17	360	158	70.8	42.6	E	0	0	17	17	360	118
A21	2/12/08	12	G1	052																	
A21	2/12/08	65	G1	052																	
A22	2/14/08	33	G1	058	71.4	43.0	0	0	20	21	331	298	71.8	43.4	A	0	0	25	26	360	142
A22	2/14/08	12	G1	058																	
A22	2/14/08	65	G1	058									67.3	35.2	A	0	0	14	14	303	318
A23	2/15/08	33	G1	057	73.0	44.6	0	0	27	27	360	360	72.6	44.2	E	0	0	25	23	360	205
A23	2/15/08	12	G1	057	56.7	37.6	0	0	19	20	360	360	58.8	39.7	E	0	0	18	18	360	94
A23	2/15/08	65	G1	057									68.3	35.9	B	0	0	15	15	360	52
A24 *	2/18/08	33	IX	010	82.9	54.3	0	0	34	36	360	360	83.1	54.5	E	0	0	32	34	360	360
A24 *	2/18/08	12	IX	010	60.4	41.2	0	0	23	23	220	216	58.1	38.9	E	0	0	23	24	235	215
A24 *	2/18/08	65	IX	010									52.2	19.9	A	999	999	0	0	0	0
A25	2/19/08	33	G1	022	65.6	37.0	0	0	19	20	277	259	72.2	43.6	A	0	0	23	24	286	122
A25	2/19/08	12	G1	022	61.8	42.8	0	0	25	26	282	284	61.8	42.8	E	0	0	25	25	360	360
A25	2/19/08	65	G1	022									69.3	38.4	A	0	0	20	20	360	234
A26	2/20/08	33	G1	026	70.0	41.7	0	0	20	20	360	360	71.8	43.5	E	0	0	20	20	360	347
A26	2/20/08	12	G1	026	59.2	40.4	0	0	22	23	360	360	67.3	48.5	A	0	0	30	30	360	360
A26	2/20/08	65	G1	026									66.2	34.4	B	0	0	14	15	360	108
A27 *	2/21/08	33	IX	009	83.5	55.1	0	0	32	35	360	360	83.0	54.6	E	0	0	30	34	360	360
A27 *	2/21/08	12	IX	009	45.2	28.7	555	999	0	0	0	0	49.7	33.2		999	999	0	0	0	0
A27 *	2/21/08	65	IX	009									52.7	20.5	A	555	555	0	0	0	0
A28	2/25/08	33	G1	072	75.3	46.4	0	0	26	26	360	360	81.0	52.1	D	0	0	26	26	360	360
A28	2/25/08	12	G1	072	57.0	38.0	0	0	16	16	360	360	67.6	48.6	D	0	0	29	29	360	360
A28	2/25/08	65	G1	072									79.4	47.3	D	0	0	21	21	360	220

* denotes test site “***outside*** the box”

Table A6-2 (cont) Summary of **15'** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
A29	2/26/08	33	G1	032	65.1	36.6	0	0	19	20	318	265	77.9	49.4	A	0	0	27	29	360	360
A29	2/26/08	12	G1	032	59.5	40.5	0	0	23	23	323	325	67.9	48.9	A	0	0	30	30	360	360
A29	2/26/08	65	G1	032									78.0	46.0	A	0	0	28	28	360	262
A30	2/29/08	33	G1	038	76.4	48.3	0	0	30	32	360	360	76.9	48.8	E	0	0	31	32	360	22
A30	2/29/08	12	G1	038	61.0	42.4	0	0	25	25	360	360	61.2	42.6	E	0	0	23	23	360	110
A30	2/29/08	65	G1	038									67.6	36.0	B	0	0	12	12	319	0
A31	3/3/08	33	G1	039	73.8	45.6	0	0	20	20	250	107	82.5	54.3	A	0	0	23	23	360	360
A31	3/3/08	12	G1	039																	
A31	3/3/08	65	G1	039																	
A32	3/5/08	33	G1	076	57.5	28.8	555	555	0	0	0	0	62.0	33.3	E	555	555	0	0	0	0
A32	3/5/08	12	G1	076	57.0	38.1	0	0	20	20	166	150	58.3	39.4	E	0	0	19	19	360	360
A32	3/5/08	65	G1	076									62.3	29.9	D	555	555	0	0	0	0
A33	3/6/08	33	G1	061	67.6	39.2	0	999	11	0	274	0	68.4	40.0	E	555	999	0	0	89	0
A33	3/6/08	12	G1	061	54.2	35.1	0	0	14	14	222	204	60.0	40.9	C	0	0	18	18	360	212
A33	3/6/08	65	G1	061									72.5	40.2	C	0	0	16	16	21	56
A34	3/11/08	33	G1	055	66.6	37.8	0	0	16	16	360	360	69.4	40.6	E	0	0	18	16	360	360
A34	3/11/08	12	G1	055	50.4	31.2	0	0	10	10	328	332	62.1	42.9	B	0	0	23	23	360	122
A34	3/11/08	65	G1	055									66.5	33.9	B	0	0	16	16	121	129
A35	3/12/08	33	G1	062	70.7	42.0	0	0	24	24	360	292	72.6	43.9	E	0	0	20	20	360	360
A35	3/12/08	12	G1	062	54.3	35.5	0	0	11	12	251	158	57.1	38.3	A	0	555	14	0	360	0
A35	3/12/08	65	G1	062									63.9	31.7	A	0	555	9	0	133	0
A36	3/13/08	33	G1	041	78.6	49.9	0	0	31	32	360	360	82.5	53.8	E	0	0	29	29	360	360
A36	3/13/08	12	G1	041	58.9	39.9	0	0	22	22	219	175	69.0	50.0	A	0	0	31	31	360	360
A36	3/13/08	65	G1	041									82.0	49.9	A	0	0	32	33	360	360
A37	3/14/08	33	G1	008	57.3	28.8	0	0	3	3	50	42	100.0	71.5	B	0	0	47	47	360	360
A37	3/14/08	12	G1	008	55.1	36.1	0	0	14	16	281	299	116.6	97.6	B	0	0	80	80	360	360
A37	3/14/08	65	G1	008									98.7	66.6	B	0	0	49	50	360	360
A38	3/17/08	33	G1	016	63.2	34.7	0	555	8	0	254	0	70.9	42.4	B	0	555	19	0	360	0
A38	3/17/08	12	G1	016	56.9	38.1	0	0	17	17	114	108	62.6	43.8	A	555	555	0	0	0	0
A38	3/17/08	65	G1	016									67.6	36.0	B	0	555	11	0	360	0
A39	4/21/08	33	G1	005	81.2	52.4	0	0	35	36	360	360	81.6	52.8	E	0	0	26	27	360	360
A39	4/21/08	12	G1	005	55.6	36.7	0	0	16	16	360	360	59.5	40.6	A	0	0	17	11	360	0
A39	4/21/08	65	G1	005									76.2	44.1	A	0	0	26	27	360	360
A40	4/22/08	33	G1	029	70.3	41.5	0	0	24	24	360	360	79.3	50.5	A	0	0	28	28	360	360
A40	4/22/08	12	G1	029	44.8	25.8	555	555	0	0	0	0	64.3	45.3	A	0	0	26	26	360	360
A40	4/22/08	65	G1	029									77.2	45.1	A	0	0	26	26	360	360
B1	4/21/08	33	G1	079	80.9	50.4	0	0	33	33	360	360	87.7	57.2		0	0	38	39	265	265
B1	4/21/08	12	G1	079	60.9	39.5	555	555	0	0	0	0	84.8	63.4	C	0	0	46	46	295	295
B1	4/21/08	65	G1	079									75.2	40.8	C	0	0	21	21	156	156
B2	1/16/08	33	G1	002	69.9	39.4	0	0	17	16	360	318	87.9	57.4	A	0	0	43	42	360	360
B2	1/16/08	12	G1	002	61.0	39.4	0	0	22	21	360	360	77.0	55.4	A	0	0	38	38	360	360
B2	1/16/08	65	G1	002									91.7	57.9	A	0	0	42	41	360	360

* denotes test site "***outside*** the box"

Table A6-2 (cont) Summary of **15'** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B3	1/17/08	33	G1	018	67.7	36.4	0	0	21	19	360	294	94.2	62.9	B	0	0	47	46	360	360
B3	1/17/08	12	G1	018	44.2	22.1	0	0	16	15	180	155	75.7	53.6	B	0	0	38	37	360	360
B3	1/17/08	65	G1	018									90.0	54.9	B	0	0	39	40	360	360
B4	1/18/08	33	G1	071	55.3	24.3	0	0	7	5	104	79	78.0	47.0	C	0	0	29	29	360	360
B4	1/18/08	12	G1	071	48.1	26.3	0	0	10	9	147	146	68.6	46.8	C	0	0	34	32	360	360
B4	1/18/08	65	G1	071									81.9	46.7	C	0	0	31	30	360	360
B5	1/21/08	33	G1	024	67.2	38.7	0	0	18	19	360	360	77.3	48.8	A	0	0	30	29	360	97
B5	1/21/08	12	G1	024	53.3	33.6	0	0	18	17	167	119	63.1	43.4	A	0	0	24	23	360	360
B5	1/21/08	65	G1	024									74.6	41.6	A	0	0	22	21	360	321
B6	1/22/08	33	G1	044	71.1	40.6	0	0	23	23	360	360	74.5	44.0	E	0	0	26	26	360	360
B6	1/22/08	12	G1	044	59.1	37.7	0	0	20	20	360	360	59.3	37.9	A	0	0	21	21	360	66
B6	1/22/08	65	G1	044									60.0	25.6	A	555	555	0	0	0	0
B7 *	1/23/08	33	IX	013	77.1	46.6	0	0	31	31	230	206	74.4	43.9	E	0	0	27	27	134	124
B7 *	1/23/08	12	IX	013	63.1	41.9	0	0	25	26	360	263	63.8	42.6	E	0	0	26	26	81	64
B7 *	1/23/08	65	IX	013									63.0	28.5	A	0	0	10	10	47	17
B8	1/24/08	33	G1	051	74.0	44.2	0	0	25	27	360	360	73.6	43.8	E	0	0	18	19	360	360
B8	1/24/08	12	G1	051	60.8	39.6	0	0	23	23	360	360	64.8	43.6	A	0	555	19	0	360	167
B8	1/24/08	65	G1	051									72.6	38.6	B	0	555	16	0	288	32
B9	1/25/08	33	G1	064	62.0	32.7	0	0	14	10	168	177	77.8	48.5	B	0	0	30	30	206	226
B9	1/25/08	12	G1	064	54.5	33.5	0	0	16	16	163	199	60.3	39.3	B	0	0	16	18	294	82
B9	1/25/08	65	G1	064									73.9	39.6	B	0	0	22	22	236	163
B10	1/28/08	33	G1	010	76.7	46.2	0	0	29	30	360	217	85.3	54.8	A	0	0	35	35	182	77
B10	1/28/08	12	G1	010	74.4	52.9	0	0	36	36	360	335	76.2	54.7	A	0	0	34	35	360	360
B10	1/28/08	65	G1	010									85.8	51.1	A	0	0	33	33	184	166
B11	1/29/08	33	G1	019	65.9	34.9	0	0	14	11	165	41	79.3	48.3	A	0	0	30	30	360	360
B11	1/29/08	12	G1	019	53.5	32.3	0	0	16	14	203	196	80.2	59.0	A	0	0	41	41	360	360
B11	1/29/08	65	G1	019									88.8	54.4	A	0	0	35	35	360	360
B12	1/30/08	33	G1	065	82.5	52.0	0	0	35	35	340	284	76.9	46.4	E	0	0	28	26	327	208
B12	1/30/08	12	G1	065	65.8	44.5	0	0	27	27	360	169	61.9	40.6	E	0	0	17	10	360	58
B12	1/30/08	65	G1	065									75.0	40.3	A	0	0	21	21	331	263
B13	1/31/08	33	G1	048	78.5	48.0	0	0	31	31	360	360	82.7	52.2	E	0	0	35	35	360	330
B13	1/31/08	12	G1	048	56.9	36.0	0	0	19	18	141	133	63.0	42.1	A	0	0	20	20	360	360
B13	1/31/08	65	G1	048									78.2	43.8	A	0	0	22	22	303	235
B14	2/1/08	33	G1	068	57.7	27.4	0	0	2	2	15	18	74.5	44.2	A	0	0	25	25	360	360
B14	2/1/08	12	G1	068																	
B14	2/1/08	65	G1	068									71.4	37.5	A	0	0	19	19	282	157
B15	2/4/08	33	G1	004	80.5	50.4	0	0	30	31	360	360	78.6	48.5	A	0	0	28	25	360	360
B15	2/4/08	12	G1	004	64.1	42.8	0	0	25	25	299	162	71.7	50.4	A	0	0	33	33	360	360
B15	2/4/08	65	G1	004									80.1	46.1	A	0	0	26	26	230	91
B16	2/5/08	33	G1	013	87.5	56.8	0	0	40	40	360	360	76.8	46.1	E	0	0	38	38	360	360
B16	2/5/08	12	G1	013	73.3	52.1	0	0	35	35	360	360	73.5	52.3	E	0	0	35	35	360	360
B16	2/5/08	65	G1	013									73.2	38.9	A	0	0	18	19	183	26

* denotes test site "***outside*** the box"

Table A6-2 (cont) Summary of **15'** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON									
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B17	2/6/08	33	G1	012	63.6	32.7	0	0	8	8	103	12	91.5	60.6	A	0	0	44	43	360	360
B17	2/6/08	12	G1	012	63.2	41.6	0	0	23	23	360	175	65.8	44.2	A	0	0	22	22	360	360
B17	2/6/08	65	G1	012									85.7	51.1	A	0	0	31	31	360	360
B18	2/7/08	33	G1	025	84.5	53.6	0	0	37	37	360	360	85.1	54.2	E	0	0	35	35	360	360
B18	2/7/08	12	G1	025	61.5	40.1	0	0	22	22	360	283	70.6	49.2	A	0	0	32	32	360	360
B18	2/7/08	65	G1	025									77.4	43.1	A	0	0	24	24	312	360
B19	2/8/08	33	G1	046	72.3	42.0	0	0	23	23	360	301	74.9	44.6	B	0	999	22	0	360	119
B19	2/8/08	12	G1	046	58.5	37.1	0	0	20	20	318	330	62.2	40.8	A	0	0	22	22	360	283
B19	2/8/08	65	G1	046									72.7	38.5	B	0	0	18	18	360	245
B20	2/11/08	33	G1	030	74.8	44.6	0	0	24	21	360	360	88.1	57.9	A	0	0	42	41	360	360
B20	2/11/08	12	G1	030	55.7	34.8	0	0	19	18	260	242	77.7	56.8	A	0	0	41	40	360	360
B20	2/11/08	65	G1	030									88.5	54.4	A	0	0	36	41	360	360
B21	2/12/08	33	G1	053	55.8	25.4	0	0	6	4	150	0	61.8	31.4	B	555	555	0	0	0	0
B21	2/12/08	12	G1	053																	
B21	2/12/08	65	G1	053																	
B22	2/14/08	33	G1	059	65.9	34.7	0	0	19	18	360	360	69.9	38.7	E	3	999	19	0	360	295
B22	2/14/08	12	G1	059																	
B22	2/14/08	65	G1	059									73.2	38.2	A	0	0	22	17	360	360
B23	2/15/08	33	G1	056	64.5	34.0	0	0	18	17	360	242	70.8	40.3	A	0	0	22	19	360	49
B23	2/15/08	12	G1	056	59.2	37.8	0	0	22	21	288	295	60.7	39.3	E	0	0	19	19	360	300
B23	2/15/08	65	G1	056									67.6	33.0	B	0	999	12	0	360	0
B24 *	2/18/08	33	IX	011	81.7	51.9	0	0	36	36	360	360	81.3	51.5	E	0	0	20	19	330	313
B24 *	2/18/08	12	IX	011	53.7	33.0	0	0	17	17	292	280	53.2	32.5	E	0	0	16	16	325	155
B24 *	2/18/08	65	IX	011									63.5	29.6	A	0	0	11	11	150	150
B25	2/19/08	33	G1	021	65.8	35.6	0	0	20	19	360	143	76.3	46.1	A	0	0	26	24	360	110
B25	2/19/08	12	G1	021	56.5	35.3	0	0	19	19	320	300	60.4	39.2	E	0	555	20	0	360	290
B25	2/19/08	65	G1	021									68.6	34.5	A	0	0	14	13	315	305
B26	2/20/08	33	G1	027	63.0	33.0	0	0	9	7	190	180	77.8	47.8	B	0	0	38	37	360	360
B26	2/20/08	12	G1	027	47.3	26.5	0	0	5	5	135	90	67.8	47.0	B	0	0	31	29	295	255
B26	2/20/08	65	G1	027									81.1	47.6	A	0	0	31	30	360	360
B27 *	2/21/08	33	IX	008	77.8	47.3	0	0	28	27	360	360	77.8	47.3	E	0	0	30	30	360	360
B27 *	2/21/08	12	IX	008	44.7	23.2	999	999	0	0	0	0	53.4	31.9		1	999	9	0	0	0
B27 *	2/21/08	65	IX	008									57.4	22.9		0	0	5	5	40	35
B28	2/25/08	33	G1	073	81.1	50.4	0	0	33	33	360	360	91.8	61.1	D	0	0	44	44	294	222
B28	2/25/08	12	G1	073	61.3	39.8	0	0	23	23	360	360	68.8	47.3	D	0	0	29	29	360	140
B28	2/25/08	65	G1	073									85.8	52.3	D	0	0	32	32	360	360
B29	2/26/08	33	G1	033	68.3	37.9	0	0	14	15	360	331	84.6	54.2	A	0	0	37	37	360	360
B29	2/26/08	12	G1	033	58.1	36.6	0	0	16	17	360	360	69.2	47.7	A	0	0	31	31	360	330
B29	2/26/08	65	G1	033									77.4	43.1	A	0	0	24	24	360	360
B30	2/27/08	33	G1	074	67.0	36.6	0	0	17	16	267	220	84.6	54.2	D	0	0	37	37	360	281
B30	2/27/08	12	G1	074	54.8	33.3	0	0	16	16	194	199	68.6	47.1	D	0	0	28	27	360	306
B30	2/27/08	65	G1	074									80.2	45.8	D	0	555	12	0	360	166

* denotes test site "***outside*** the box"

Table A6-2 (cont) Summary of **15’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON									
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B31	2/28/08	33	G1	075	48.7	18.2	999	999	0	0	0	0	65.2	34.7	D	0	0	17	17	295	150
B31	2/28/08	12	G1	075	39.1	17.9	999	999	0	0	0	0	67.3	46.1	D	0	0	29	29	360	360
B31	2/28/08	65	G1	075									63.3	29.0	D	0	0	10	12	145	137
B32	2/29/08	33	G1	037	73.5	43.2	0	0	25	25	360	360	73.4	43.1	E	0	0	21	5	360	50
B32	2/29/08	12	G1	037	51.1	30.2	0	0	10	11	319	319	61.4	40.5	A	0	0	22	22	360	360
B32	2/29/08	65	G1	037									63.5	29.4	B	0	0	10	10	239	341
B33	3/3/08	33	G1	040	76.1	46.2	0	0	27	27	360	229	78.5	48.6	A	0	0	27	27	360	360
B33	3/3/08	12	G1	040	52.0	30.8	0	0	10	10	360	261	67.0	45.8	A	0	0	23	23	360	360
B33	3/3/08	65	G1	040									74.9	40.9	A	0	0	22	22	360	360
B34	3/4/08	33	G1	067	53.3	23.0	555	999	0	0	0	0	58.0	27.7	D	2	999	4	0	147	0
B34	3/4/08	12	G1	067	43.3	22.1	0	0	3	3	68	56	56.9	35.7	D	0	0	14	11	360	360
B34	3/4/08	65	G1	067									63.5	29.0	C	0	0	5	2	127	0
B35	3/5/08	33	G1	077	59.9	29.6	0	0	13	13	360	178	65.0	34.7	C	0	0	2	1	0	0
B35	3/5/08	12	G1	077	51.6	30.2	0	0	13	13	104	95	59.6	38.2	D	0	0	12	7	360	360
B35	3/5/08	65	G1	077									69.1	34.9	C	0	0	13	13	346	34
B36	3/6/08	33	G1	060	50.0	19.5	999	999	0	0	0	0	70.2	39.7	C	0	0	21	20	262	81
B36	3/6/08	12	G1	060	43.8	22.6	999	999	0	0	0	0	53.6	32.4	D	0	555	6	0	360	0
B36	3/6/08	65	G1	060									64.4	30.3	C	0	0	11	10	104	28
B37	3/7/08	33	G1	036	70.3	39.8	0	0	10	10	360	360	71.1	40.6	E	0	555	13	0	360	46
B37	3/7/08	12	G1	036	54.0	32.8	0	0	15	15	262	259	55.3	34.1	E	0	0	13	12	292	98
B37	3/7/08	65	G1	036									66.7	32.6	B	0	555	7	0	187	0
B38	3/10/08	33	G1	042	64.3	34.1	0	0	15	13	360	335	69.0	38.8	E	1	0	17	14	360	0
B38	3/10/08	12	G1	042	55.3	34.1	0	0	15	14	270	275	63.8	42.6	A	2	0	23	23	360	360
B38	3/10/08	65	G1	042									68.6	35.3	A	25	0	13	11	360	360
B39	3/11/08	33	G1	054	74.4	44.2	0	0	16	14	225	200	74.7	44.5	E	0	0	28	29	360	360
B39	3/11/08	12	G1	054	50.5	29.3	2	0	11	10	154	160	50.9	29.7	E	5	555	10	0	360	110
B39	3/11/08	65	G1	054									58.1	23.8	A	555	999	0	0	15	0
B40	3/12/08	33	G1	045	64.6	34.3	0	0	17	17	360	360	68.4	38.1	E	0	0	15	12	360	360
B40	3/12/08	12	G1	045	56.8	35.4	0	0	18	17	360	360	56.6	35.2	E	0	0	16	15	360	360
B40	3/12/08	65	G1	045									66.0	31.9	A	0	0	13	14	169	50
B41	3/13/08	33	G1	031	60.2	30.0	2	999	4	0	280	75	75.8	45.6	A	0	0	27	26	360	261
B41	3/13/08	12	G1	031	53.2	32.2	0	0	11	12	155	71	65.9	44.9	A	0	0	27	27	360	360
B41	3/13/08	65	G1	031									81.8	47.5	A	0	0	30	30	360	360
B42	3/14/08	33	G1	007	71.8	41.6	0	0	23	22	360	360	85.4	55.2	B	0	0	38	37	360	330
B42	3/14/08	12	G1	007	56.1	34.9	0	1	18	17	360	360	74.8	53.6	B	0	0	34	35	360	360
B42	3/14/08	65	G1	007									83.3	48.4	B	0	0	32	32	360	360
B43	3/17/08	33	G1	006	80.7	50.5	0	0	32	32	360	240	84.5	54.3	A	0	999	30	0	360	0
B43	3/17/08	12	G1	006	68.2	47.0	0	0	30	30	360	337	77.0	55.8	A	0	0	32	32	360	214
B43	3/17/08	65	G1	006									86.0	51.6	A	0	0	32	31	322	323
B44 *	3/18/08	33	HD	001	72.1	41.9	0	0	24	24	360	360	74.2	44.0	E	0	0	23	21	360	103
B44 *	3/18/08	12	HD	001	52.9	32.0	0	0	15	15	178	178	57.3	36.4	A	555	555	0	0	0	0
B44 *	3/18/08	65	HD	001									63.3	28.9	D	999	999	0	0	0	0

* denotes test site “***outside*** the box”

Table A6-2 (cont) Summary of **15’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B45 *	3/19/08	33	HD	002	99.3	68.9	0	0	52	52	360	360	99.8	69.4	E	0	0	52	52	360	360
B45 *	3/19/08	12	HD	002	80.7	59.4	0	0	43	43	360	280	81.0	59.7	E	0	0	42	42	360	360
B45 *	3/19/08	65	HD	002									52.0	17.9		999	999	0	0	0	0
B46 *	3/20/08	33	HD	003	63.7	33.3	0	0	9	10	108	108	51.7	21.3	E	0	555	10	0	111	0
B46 *	3/20/08	12	HD	003	42.8	21.5	999	999	0	0	0	0	41.4	20.1	A	999	999	0	0	0	0
B46 *	3/20/08	65	HD	003									61.2	26.9	A	0	0	7	8	61	61
B47 *	3/21/08	33	HD	004	75.7	45.4	0	0	19	16	360	69	74.0	43.7	E	0	555	19	0	360	112
B47 *	3/21/08	12	HD	004	74.6	53.4	0	0	35	35	360	360	72.8	51.6	E	0	0	33	33	360	360
B47 *	3/21/08	65	HD	004									59.8	25.7	A	555	555	0	0	0	0
B48 *	3/24/08	33	HD	005	81.7	51.1	0	0	22	22	220	215	81.4	50.8	E	0	0	34	34	325	165
B48 *	3/24/08	12	HD	005	56.5	35.3	0	0	18	19	165	170	57.9	36.7	E	0	0	12	11	175	0
B48 *	3/24/08	65	HD	005									66.6	32.3	D	999	3	0	2	1	0
B49	3/25/08	33	HD	006	81.8	51.6	0	0	32	32	360	225	80.7	50.5	E	0	0	30	30	360	85
B49	3/25/08	12	HD	006	72.9	51.9	0	0	33	34	360	360	72.9	51.9	E	0	0	33	33	360	280
B49	3/25/08	65	HD	006									78.1	43.9	A	0	0	22	21	340	180
B50 *	3/26/08	33	HD	007	76.0	45.2	0	0	29	29	360	360	76.7	45.9	E	0	0	28	28	360	150
B50 *	3/26/08	12	HD	007	59.2	37.9	0	0	21	20	210	225	61.2	39.9	E	0	0	15	15	255	175
B50 *	3/26/08	65	HD	007									69.9	36.4	A	0	0	16	17	110	70
B51 *	3/27/08	33	HD	008	80.2	49.5	0	0	30	30	360	360	82.6	51.9	E	0	0	31	31	360	360
B51 *	3/27/08	12	HD	008	59.4	38.0	0	0	20	20	360	360	60.1	38.7	E	0	0	21	21	360	360
B51 *	3/27/08	65	HD	008									58.0	23.5	A	0	0	3	3	20	25
B52 *	3/28/08	33	HD	009	82.0	51.1	0	0	30	30	360	0	81.4	50.5	E	0	0	29	28	360	0
B52 *	3/28/08	12	HD	009	55.5	33.7	0	3	10	10	360	75	55.9	34.1		0	555	6	0	230	0
B52 *	3/28/08	65	HD	009									54.2	20.6	A	999	999	0	0	0	0
B53	3/31/08	33	HD	010	66.8	37.0	0	0	17	18	360	194	81.8	52.0	A	0	0	33	34	360	360
B53	3/31/08	12	HD	010	51.0	30.2	0	0	11	12	236	236	68.5	47.7	A	0	0	29	30	360	360
B53	3/31/08	65	HD	010									78.7	44.9	A	0	0	26	27	360	360
B54 *	4/1/08	33	HD	011	78.8	48.3	0	0	30	32	360	360	77.8	47.3	E	0	0	30	30	360	360
B54 *	4/1/08	12	HD	011	40.4	19.3	999	999	0	0	0	0	41.1	20.0	E	999	999	0	0	0	0
B54 *	4/1/08	65	HD	011									52.0	17.5		999	999	0	0	0	0
B55	4/2/08	33	HD	012	77.5	47.4	0	0	28	29	360	150	79.4	49.3	A	0	0	30	31	360	108
B55	4/2/08	12	HD	012	64.2	42.5	999	0	0	2	0	139	81.0	59.3	A	0	0	44	45	360	360
B55	4/2/08	65	HD	012									83.1	49.1	A	0	0	22	22	360	360
B56 *	4/3/08	33	HD	013	79.8	49.7	0	0	31	31	360	325	79.8	49.7	E	0	0	31	32	360	360
B56 *	4/3/08	12	HD	013	56.6	35.5	0	0	14	14	360	340	57.4	36.3		0	0	14	15	360	360
B56 *	4/3/08	65	HD	013									57.6	23.4	A	0	0	1	1	56	56
B57	4/4/08	33	G1	035	73.8	43.4	0	0	25	26	316	316	73.8	43.4	E	0	0	23	24	360	316
B57	4/4/08	12	G1	035	68.0	46.3	0	0	29	29	360	360	69.1	47.4	E	0	0	26	27	360	325
B57	4/4/08	65	G1	035									68.1	33.8	A	0	0	13	14	141	141
B58	4/22/08	33	G1	034	79.9	49.5	0	0	31	32	360	360	81.0	50.6	E	0	0	31	32	360	72
B58	4/22/08	12	G1	034	53.1	31.9	555	555	0	0	135	135	56.0	34.8	E	0	555	10	0	326	0
B58	4/22/08	65	G1	034									67.6	33.4	B	0	0	13	14	335	252

* denotes test site “***outside*** the box”

Table A6-2 (cont) Summary of **15’** AGL raw outdoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
B59 *	4/23/08	33	HD	014	78.4	48.0	0	0	30	29	360	360	80.2	49.8	E	0	0	31	32	360	227
B59 *	4/23/08	12	HD	014	59.7	38.4	0	0	17	17	360	360	59.8	38.5	E	0	0	15	14	360	360
B59 *	4/23/08	65	HD	014									62.7	28.4	A	0	0	4	4	93	21
B60	4/28/08	33	G1	080	74.7	43.7	0	0	26	26	360	360	78.1	47.1	D	0	0	28	29	360	235
B60	4/28/08	12	G1	080	63.6	42.0	0	0	23	24	225	210	73.6	52.0	D	0	0	34	35	360	360
B60	4/28/08	65	G1	080									69.5	35.8	D	0	0	16	16	360	360
B61 *	4/29/08	33	HD	015	64.2	33.3	0	0	12	12	325	225	61.5	30.6	A	0	0	10	10	85	30
B61 *	4/29/08	12	HD	015	46.3	24.5	10	10	2	2	130	115	47.0	25.2	D	0	999	2	0	65	0
B61 *	4/29/08	65	HD	015									56.8	21.8	A	999	999	0	0	0	0
B62 *	4/30/08	33	HD	016	59.4	28.8	0	0	8	8	200	220	59.2	28.6	E	0	0	8	7	80	75
B62 *	4/30/08	12	HD	016	43.6	22.0	0	555	3	1	50	40	45.2	23.6	E	999	999	0	0	0	0
B62 *	4/30/08	65	HD	016									51.9	17.3		999	999	0	0	0	0
B63	5/1/08	33	HD	017	69.2	37.8	0	0	20	20	360	360	70.2	38.8	E	0	0	20	20	360	360
B63	5/1/08	12	HD	017	66.6	44.7	0	0	28	28	330	360	66.8	44.9	E	0	0	27	27	360	360
B63	5/1/08	65	HD	017									64.3	30.0	A	0	0	10	10	90	60
B64	5/2/08	33	HD	018	48.6	18.0	999	999	0	0	0	0	70.5	39.9	C	0	0	21	21	360	360
B64	5/2/08	12	HD	018	43.4	21.6	999	999	0	0	0	0	55.1	33.3	C	0	0	15	15	295	230
B64	5/2/08	65	HD	018									66.3	31.6	C	0	555	9	0	220	60
B65	5/5/08	33	HD	019	70.6	39.9	0	0	19	20	360	360	77.4	46.7	A	0	0	25	26	360	326
B65	5/5/08	12	HD	019	49.3	28.1	0	0	5	4	202	132	65.9	44.7	A	0	0	25	26	360	360
B65	5/5/08	65	HD	019									76.1	41.6	A	0	0	22	23	360	360
B66	5/6/08	33	HD	020	64.0	33.3	0	3	8	8	264	119	83.6	52.9	A	0	0	34	35	360	203
B66	5/6/08	12	HD	020	57.7	36.4	0	0	16	16	360	360	74.5	53.2	A	0	0	35	36	360	360
B66	5/6/08	65	HD	020									85.6	51.0	A	0	0	31	32	360	360
B67	5/7/08	33	HD	021	78.9	48.0	0	0	30	31	360	360	81.0	50.1	E	0	0	22	23	360	360
B67	5/7/08	12	HD	021	58.5	36.9	0	0	18	19	360	360	64.7	43.1	A	0	0	16	17	360	360
B67	5/7/08	65	HD	021									75.3	40.5	A	0	0	21	22	360	360
B68	5/8/08	33	HD	022	72.9	42.1	0	0	25	26	360	360	73.7	42.9	E	0	0	25	26	360	159
B68	5/8/08	12	HD	022	68.0	46.5	0	0	28	29	288	288	68.2	46.7	E	0	0	28	29	360	210
B68	5/8/08	65	HD	022									62.7	28.1	A	0	999	2	0	82	0
B69	5/9/08	33	HD	023	75.3	44.5	0	0	22	23	360	322	85.7	54.9	A	0	0	37	37	360	360
B69	5/9/08	12	HD	023	49.4	27.8	0	0	9	9	229	229	74.9	53.3	A	0	0	36	36	360	360
B69	5/9/08	65	HD	023									80.3	45.7	A	0	0	26	27	314	314

* denotes test site “***outside*** the box”

APPENDIX 7 *OUTDOOR* FIELD STRENGTH STATISTICAL PLOTS

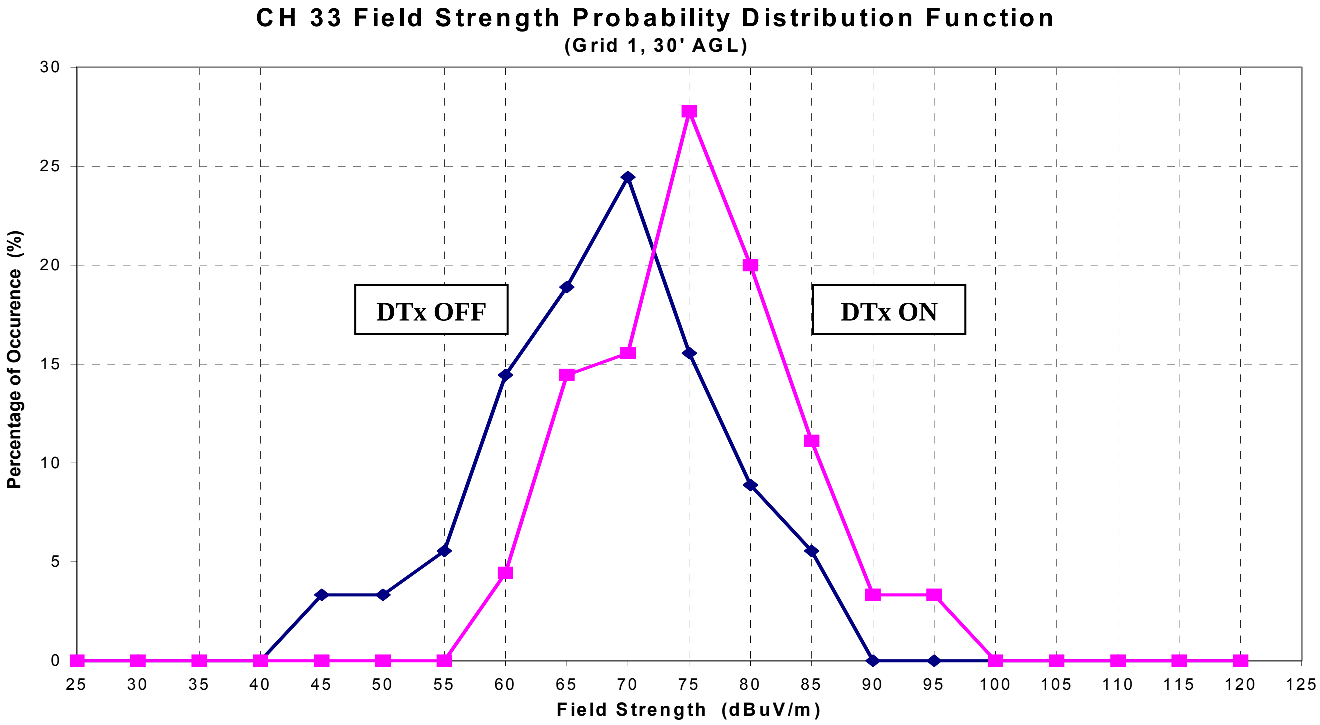


Figure A7-1a PDF of CH 33 outdoor field strength values at 30’ AGL

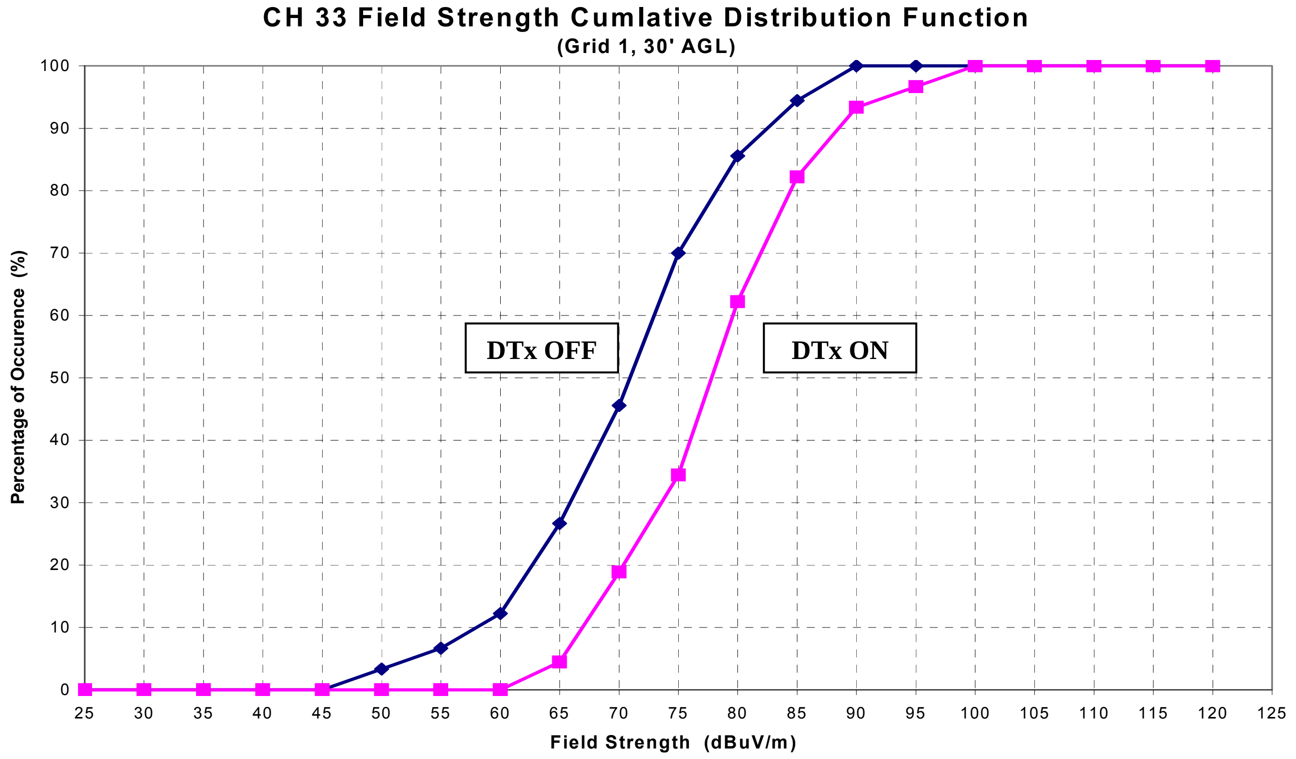


Figure A7-1b CDF of CH 33 outdoor field strength values at 30’ AGL.

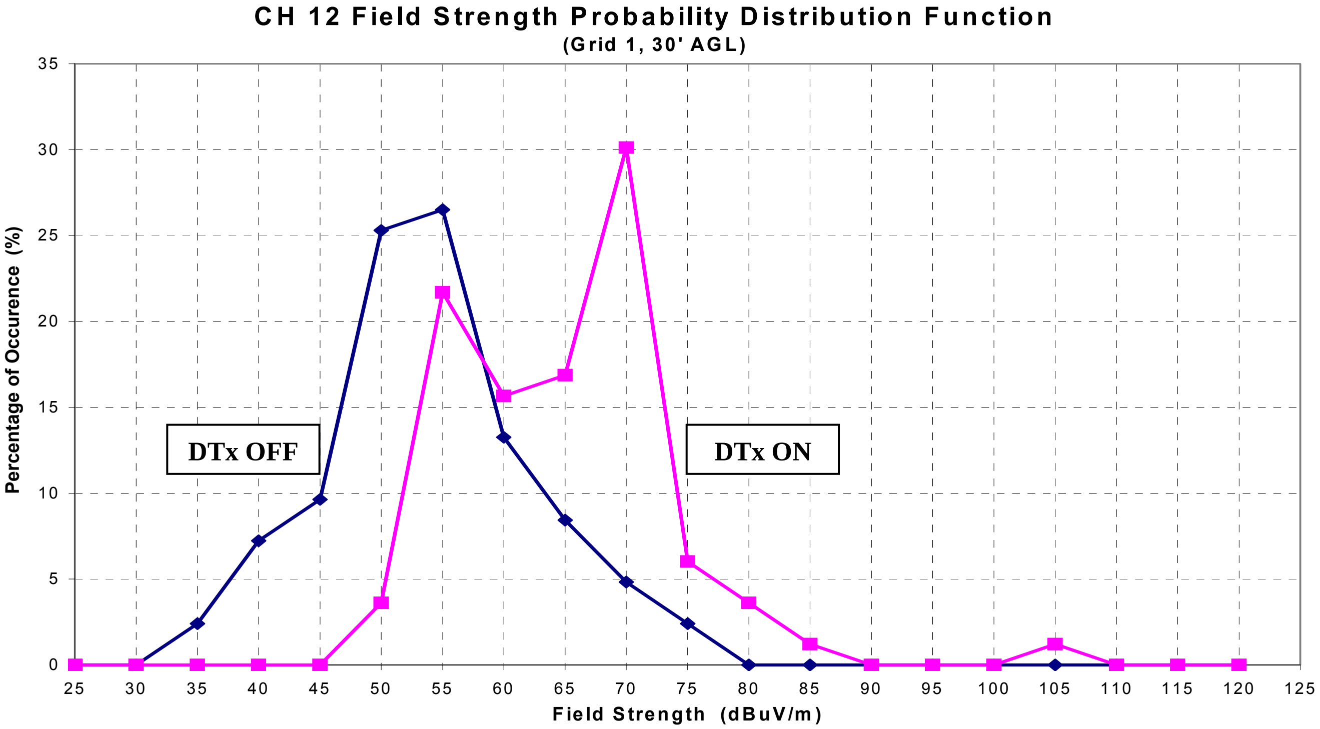


Figure A7-2a PDF of CH 12 outdoor field strength values at 30’ AGL

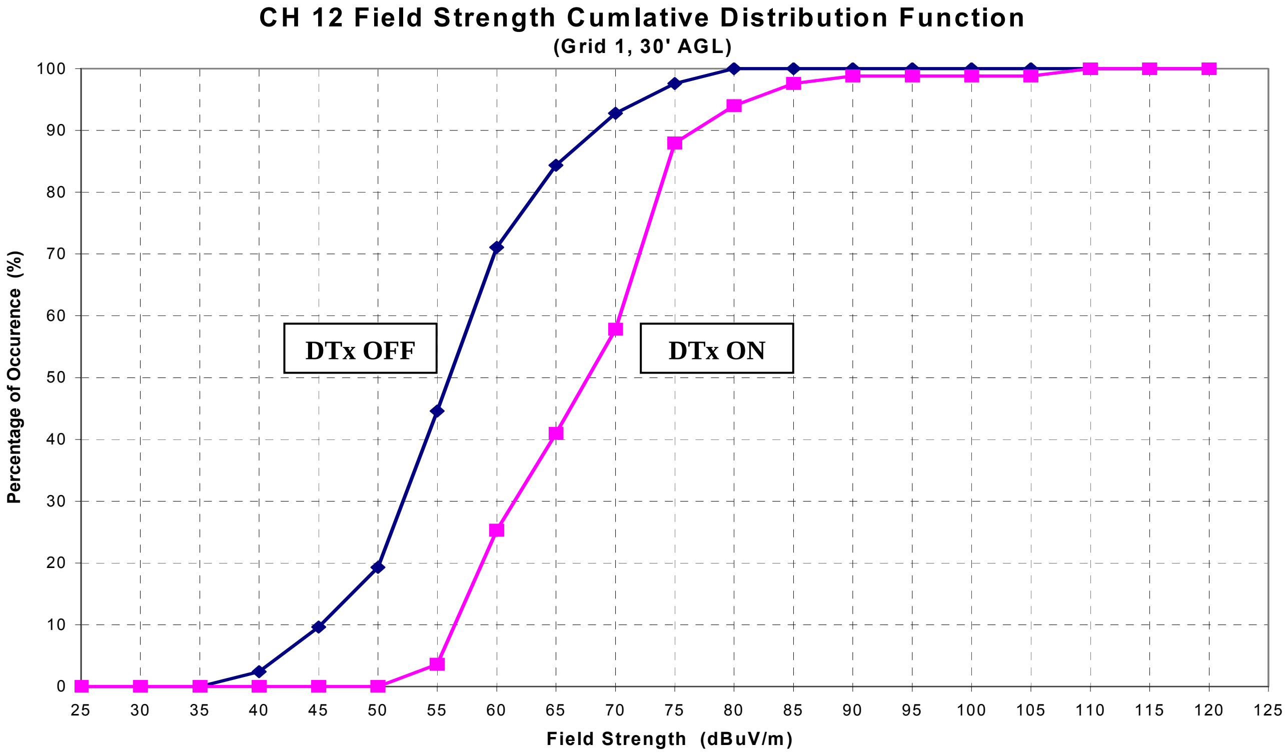


Figure A7-2b CDF of CH 12 outdoor field strength values at 30’ AGL.

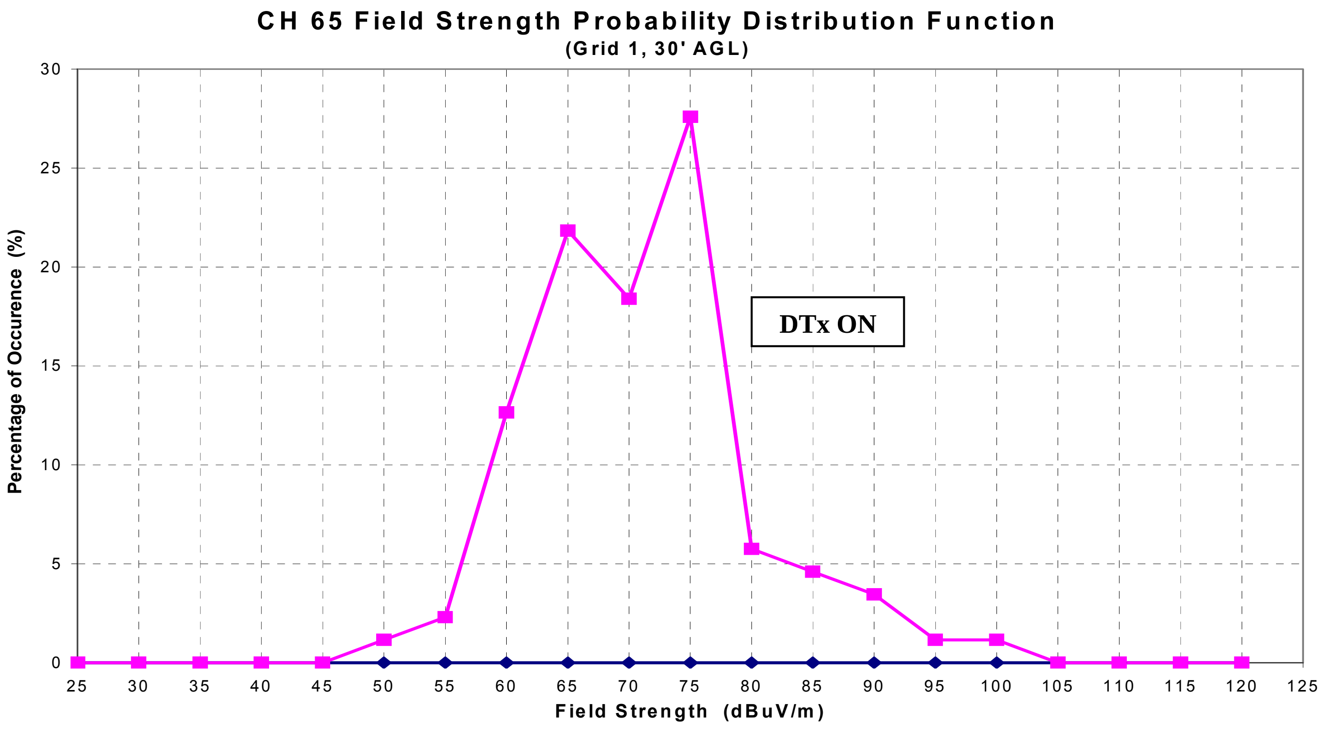


Figure A7-3a PDF of CH 65 outdoor field strength values at 30' AGL

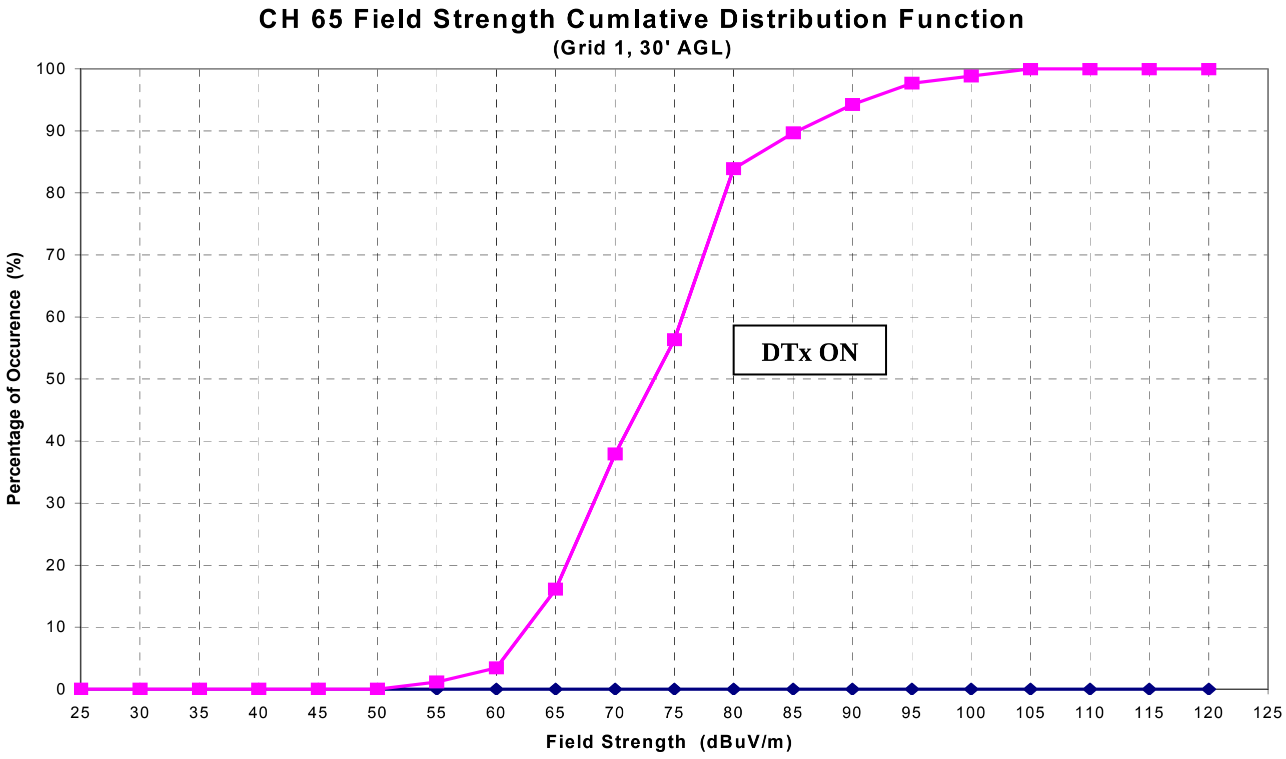


Figure A7-3b CDF of CH 65 outdoor field strength values at 30' AGL.

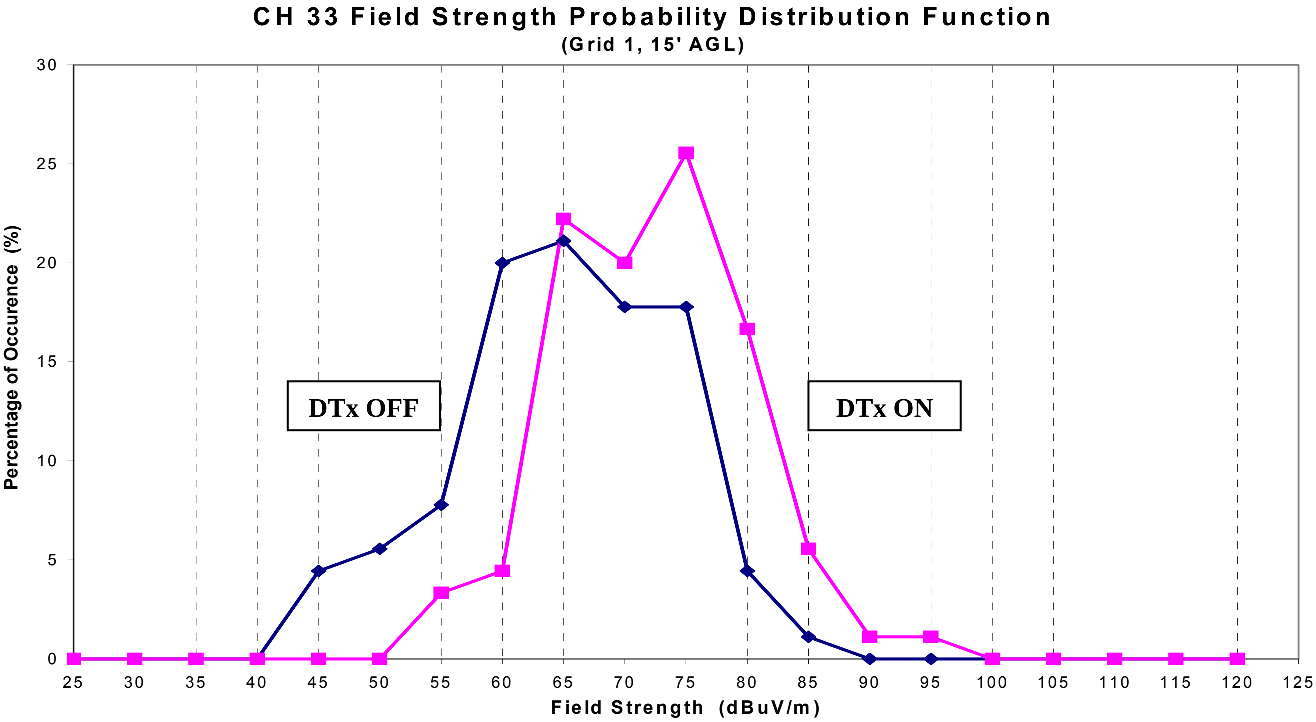


Figure A7-4a PDF of CH 33 outdoor field strength values at 150' AGL

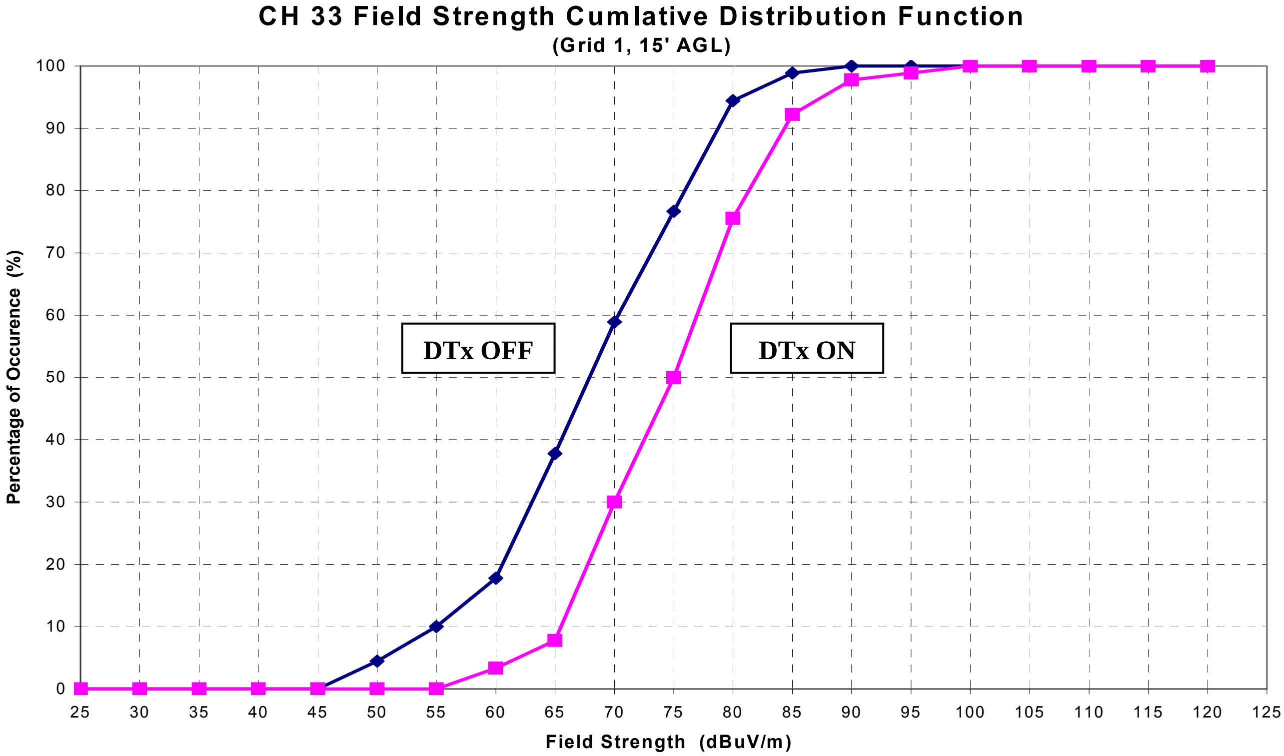


Figure A7-4b CDF of CH 33 outdoor field strength values at 15' AGL.

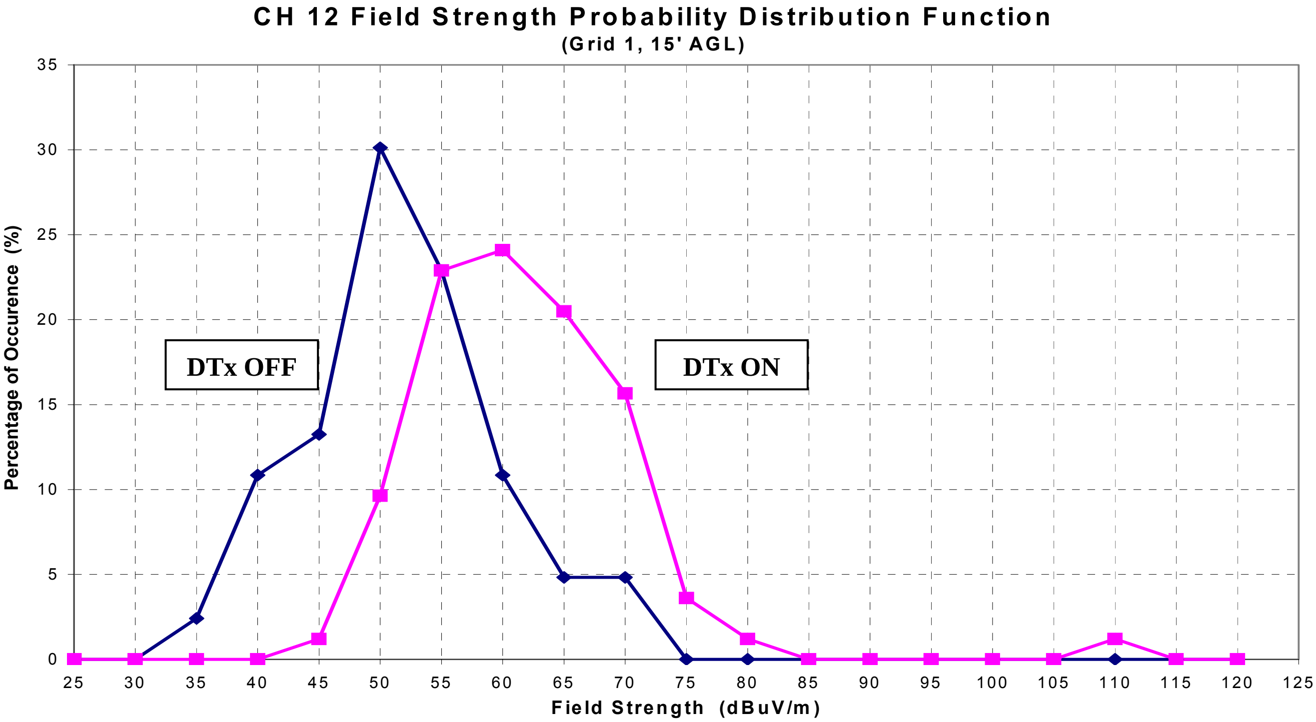


Figure A7-5a PDF of CH 12 outdoor field strength values at 15' AGL

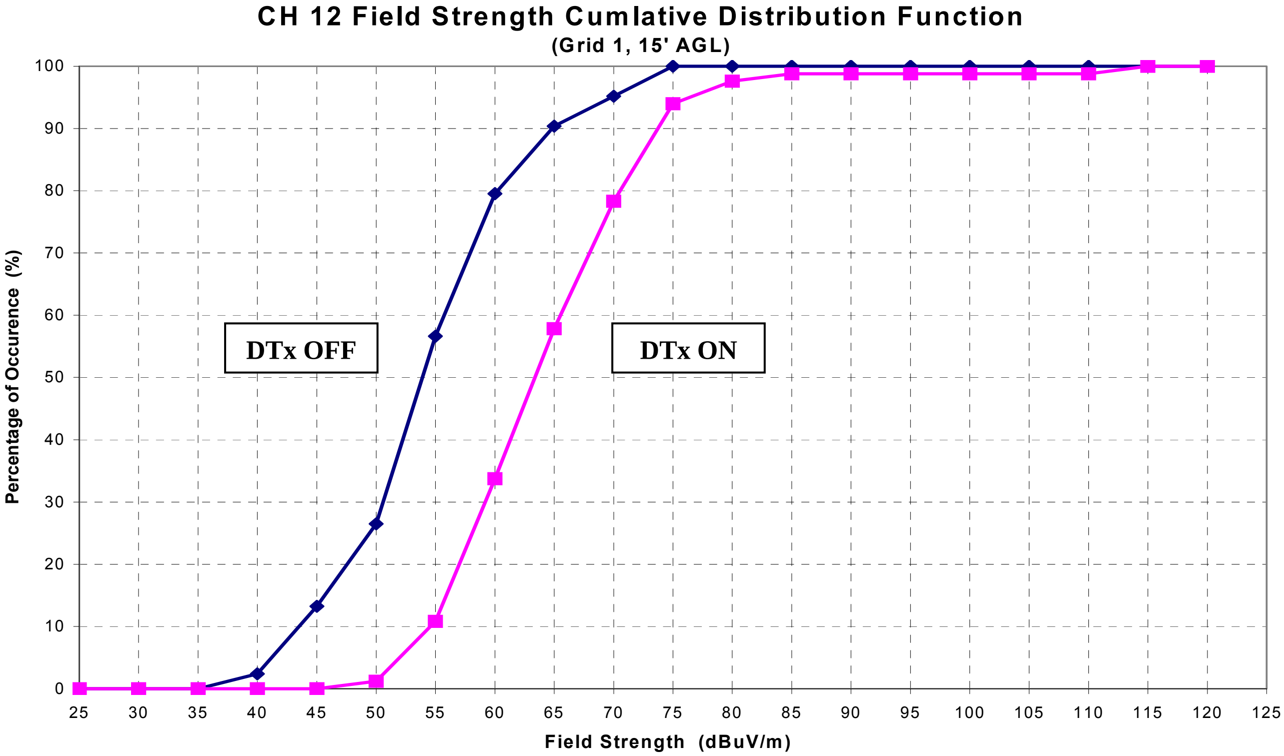


Figure A7-5b CDF of CH 12 outdoor field strength values at 15' AGL.

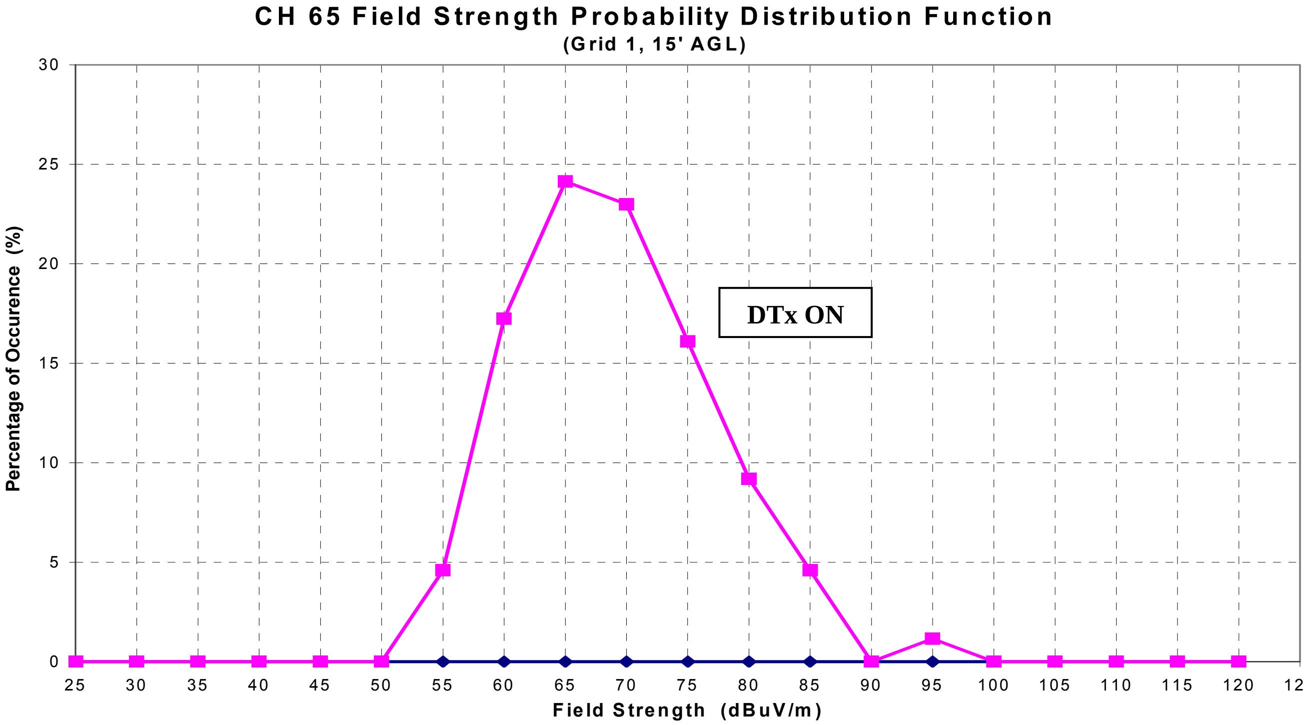


Figure A7-6a PDF of CH 65 outdoor field strength values at 15’ AGL

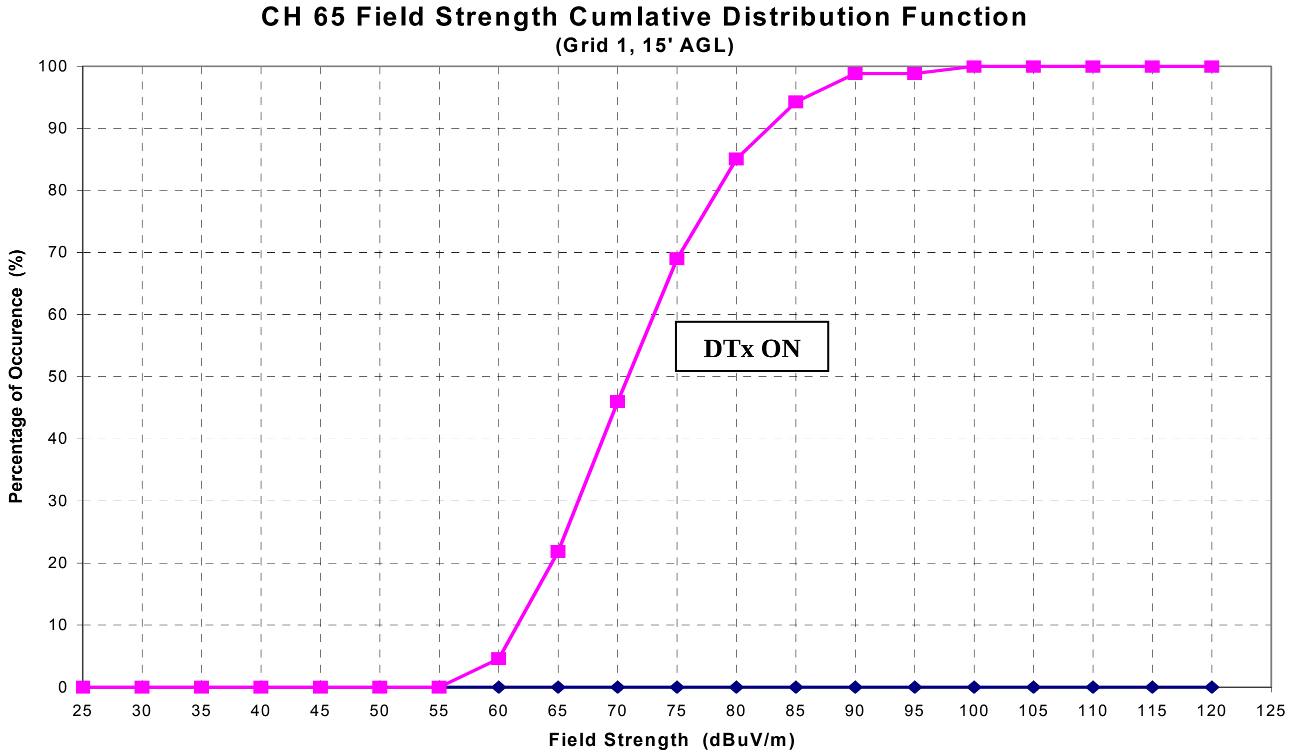


Figure A7-6b CDF of CH 65 outdoor field strength values at 15’ AGL.

APPENDIX 8 *INDOOR* RAW DATA SUMMARY TABLES

Table A8-1 Summary of ***primary antenna*** raw indoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
IN-1 *	3/18/08	33	HI	001	70.5	39.6	0	0	17	19	360	360	82.0	51.1	A	0	0	30	30	360	360
IN-1 *	3/18/08	12	HI	001	53.3	32.3	555	555	0	0	0	0	60.4	39.4	A	0	0	18	19	85	40
IN-1 *	3/18/08	65	HI	001									79.6	46.6	A	0	0	28	29	360	360
IN-2 *	3/19/08	33	HI	002	89.9	54.4	0	0	35	35	360	360	87.4	51.9	E	0	0	24	26	360	360
IN-2 *	3/19/08	12	HI	002	57.9	32.4	999	999	0	0	0	0	62.2	36.7	E	999	999	0	0	0	0
IN-2 *	3/19/08	65	HI	002									55.1	17.3		999	999	0	0	0	0
IN-3 *	3/20/08	33	HI	003	65.9	35.3	555	555	0	0	0	0	66.2	35.6	E	555	555	0	0	0	0
IN-3 *	3/20/08	12	HI	003	44.4	23.4	999	999	0	0	0	0	47.1	26.1		999	999	0	0	0	0
IN-3 *	3/20/08	65	HI	003									50.8	17.9	A	999	999	0	0	0	0
IN-4 *	3/21/08	33	HI	004	70.9	40.1	0	0	18	18	240	190	72.4	41.6	E	0	0	21	21	305	305
IN-4 *	3/21/08	12	HI	004	70.3	49.5	0	0	32	32	290	290	69.2	48.4	E	0	0	31	31	245	245
IN-4 *	3/21/08	65	HI	004									51.0	18.4	A	999	999	0	0	0	0
IN-5 *	3/24/08	33	HI	005	67.6	36.9	0	0	18	19	320	320	68.2	37.5	E	0	0	16	16	200	200
IN-5 *	3/24/08	12	HI	005	47.5	26.6	999	999	0	0	0	0	47.1	26.2	E	999	999	0	0	0	0
IN-5 *	3/24/08	65	HI	005									56.5	23.7	D	555	555	0	0	0	0
IN-6	3/25/08	33	HI	006	72.0	41.2	0	0	19	19	360	360	70.4	39.6	A	0	0	17	15	360	360
IN-6	3/25/08	12	HI	006	60.5	39.6	0	555	14	0	0	0	60.1	39.2	E	555	555	0	0	0	0
IN-6	3/25/08	65	HI	006									73.2	40.9	A	0	0	19	18	360	360
IN-7 *	3/26/08	33	HI	007	66.5	35.5	0	0	15	15	170	170	66.5	35.5	E	0	0	14	14	120	120
IN-7 *	3/26/08	12	HI	007	47.5	26.6	999	999	0	0	0	0	47.8	26.9	A	999	999	0	0	0	0
IN-7 *	3/26/08	65	HI	007									53.3	20.2	D	999	999	0	0	0	0
IN-8 *	3/27/08	33	HI	008	77.3	46.4	0	0	29	29	360	360	76.4	45.5	E	0	0	28	28	360	360
IN-8 *	3/27/08	12	HI	008	49.2	28.4	999	999	0	0	0	0	48.3	27.5	E	999	999	0	0	0	0
IN-8 *	3/27/08	65	HI	008									52.4	19.6	A	999	999	0	0	0	0
IN-9 *	3/28/08	33	HI	009	77.8	46.8	555	999	0	0	0	0	79.4	48.4	E	0	999	19	0	0	0
IN-9 *	3/28/08	12	HI	009	52.2	31.4	999	999	0	0	0	0	52.5	31.7	E	999	999	0	0	0	0
IN-9 *	3/28/08	65	HI	009									56.8	24.2	A	999	999	0	0	0	0
IN-10	3/31/08	33	HI	010	83.1	52.7	0	0	33	34	360	360	86.1	55.7	E	0	0	34	34	360	360
IN-10	3/31/08	12	HI	010	63.6	42.4	0	0	22	22	360	360	64.4	43.2	E	0	0	19	17	360	360
IN-10	3/31/08	65	HI	010									75.0	42.3	A	0	0	20	19	360	360
IN-11 *	4/1/08	33	HI	011	69.5	38.5	0	0	19	19	360	360	69.8	38.8	E	0	0	21	21	360	360
IN-11 *	4/1/08	12	HI	011	42.1	21.1	999	999	0	0	0	0	42.5	21.5		999	999	0	0	0	0
IN-11 *	4/1/08	65	HI	011									49.3	16.6		999	999	0	0	0	0
IN-12	4/2/08	33	HI	012	65.9	35.1	555	555	0	0	0	0	86.8	56.0	A	0	0	36	36	360	360
IN-12	4/2/08	12	HI	012	48.3	27.5	999	999	0	0	0	0	86.0	65.2	A	0	0	48	48	360	360
IN-12	4/2/08	65	HI	012									82.6	49.9	A	0	0	39	39	360	360
IN-13 *	4/3/08	33	HI	013	77.1	46.2	0	0	26	26	360	340	79.3	48.4	E	0	0	29	29	360	320
IN-13 *	4/3/08	12	HI	013	51.5	30.6	999	999	0	0	0	0	52.6	31.7	E	555	555	0	0	0	0
IN-13 *	4/3/08	65	HI	013									54.9	22.2	A	555	555	0	0	0	0
IN-14 *	4/23/08	33	HI	014	78.5	47.4	0	0	29	29	360	360	79.0	47.9	E	0	0	26	20	360	360
IN-14 *	4/23/08	12	HI	014	60.5	39.2	999	999	0	0	0	0	61.0	39.7	E	555	999	0	0	0	0
IN-14 *	4/23/08	65	HI	014									73.6	40.9	A	0	0	19	19	360	360

* denotes test site "***outside*** the box"

Table A8-1 (cont) Summary of ***primary antenna*** raw indoor data

Test Site Name & Date					DTx OFF								DTx ON									
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
IN-15 *	4/29/08	33	HI	015	51.4	20.6	999	999	0	0	0	0	52.5	21.7	E	999	999	0	0	0	0
IN-15 *	4/29/08	12	HI	015	50.2	29.0	999	999	0	0	0	0	47.8	26.6		999	999	0	0	0	0
IN-15 *	4/29/08	65	HI	015									52.6	20.0		999	999	0	0	0	0
IN-16 *	4/30/08	33	HI	016	57.8	26.8	999	999	0	0	0	0	59.2	28.2	E	999	999	0	0	0	0
IN-16 *	4/30/08	12	HI	016	44.6	24.0	999	999	0	0	0	0	45.7	25.1		999	999	0	0	0	0
IN-16 *	4/30/08	65	HI	016									50.1	17.2		999	999	0	0	0	0
IN-17	5/1/08	33	HI	017	59.2	28.3	0	555	7	0	95	0	70.3	39.4	A	0	0	21	21	360	360
IN-17	5/1/08	12	HI	017	45.7	25.0	999	999	0	0	0	0	56.3	35.6	A	999	999	0	0	0	0
IN-17	5/1/08	65	HI	017									73.9	40.9	A	0	0	24	24	360	360
IN-18	5/2/08	33	HI	018	50.4	19.4	999	999	0	0	0	0	65.4	34.4	C	0	0	12	12	360	90
IN-18	5/2/08	12	HI	018	44.6	23.8	999	999	0	0	0	0	57.2	36.4	C	555	555	0	0	0	0
IN-18	5/2/08	65	HI	018									63.2	30.1	C	0	0	10	10	360	180
IN-19	5/5/08	33	HI	019	60.9	30.0	555	555	0	0	0	0	69.2	38.3	A	0	0	13	13	360	360
IN-19	5/5/08	12	HI	019	49.0	28.0	999	999	0	0	0	0	63.2	42.2	A	0	0	23	23	200	200
IN-19	5/5/08	65	HI	019									64.8	32.0	A	0	0	13	14	210	210
IN-20	5/6/08	33	HI	020	69.3	38.1	0	0	20	20	305	305	69.5	38.3	E	0	555	14	0	0	0
IN-20	5/6/08	12	HI	020	50.4	29.4	999	999	0	0	0	0	55.4	34.4	A	999	999	0	0	0	0
IN-20	5/6/08	65	HI	020									62.1	29.7	A	0	0	5	5	0	0
IN-21	5/7/08	33	HI	021	67.7	36.1	0	0	20	20	360	360	71.5	39.9	E	0	0	19	19	360	360
IN-21	5/7/08	12	HI	021	51.1	30.0	999	999	0	0	0	0	55.5	34.4	A	999	999	0	0	0	0
IN-21	5/7/08	65	HI	021									62.9	29.5	A	0	0	11	11	145	145
IN-22	5/8/08	33	HI	022	67.1	35.9	0	0	14	14	140	140	70.4	39.2	E	0	0	16	16	360	360
IN-22	5/8/08	12	HI	022	53.8	32.8	999	999	0	0	0	0	58.8	37.8	A	999	999	0	0	0	0
IN-22	5/8/08	65	HI	022									58.4	25.6	A	555	555			0	0
IN-23	5/9/08	33	HI	023	66.1	34.8	0	0	12	12	175	175	67.4	36.1	E	555	999	0	0	0	0
IN-23	5/9/08	12	HI	023	44.4	23.2	999	999	0	0	0	0	46.9	25.7		999	999	0	0	0	0
IN-23	5/9/08	65	HI	023									63.8	31.3	A	0	0	8	8	360	360

* denotes test site "***outside*** the box"

Table A8-2 Summary of ***secondary antenna*** raw indoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
IN-1 *	3/18/08	33	HI	001	63.7	36.8	0	0	18	20	0	360	74.7	47.8	A	0	0	28	28	360	360
IN-1 *	3/18/08	12	HI	001	51.8	33.0	555	999	0	0	2	0	61.5	42.7	A	555	999	0	0	0	0
IN-1 *	3/18/08	65	HI	001									76.6	49.1	A	0	0	31	33	360	360
IN-2 *	3/19/08	33	HI	002	89.5	58.0	0	0	35	36	0	360	88.8	57.3	E	0	0	32	36	360	360
IN-2 *	3/19/08	12	HI	002	60.3	37.0	999	999	0	0	2	0	59.4	36.1	E	999	999	0	0	0	0
IN-2 *	3/19/08	65	HI	002									51.3	19.0		999	999	0	0	0	0
IN-3 *	3/20/08	33	HI	003	64.9	38.3	555	555	0	0	2	0	62.7	36.1	E	555	555	0	0	0	0
IN-3 *	3/20/08	12	HI	003	44.1	25.3	999	999	0	0	2	0	41.5	22.7		999	999	0	0	0	0
IN-3 *	3/20/08	65	HI	003									45.6	18.2	A	999	999	0	0	0	0
IN-4 *	3/21/08	33	HI	004	65.9	39.1	0	0	16	16	0	225	65.7	38.9	E	0	0	16	14	360	360
IN-4 *	3/21/08	12	HI	004	66.1	47.5	0	0	22	20	0	85	65.9	47.3	E	0	0	19	17	50	50
IN-4 *	3/21/08	65	HI	004									46.3	19.2	A	999	999	0	0	0	0
IN-5 *	3/24/08	33	HI	005	60.3	33.6	0	0	15	15	0	210	62.5	35.8	E	999	999	0	0	0	0
IN-5 *	3/24/08	12	HI	005	42.9	24.2	999	999	0	0	2	0	43.7	25.0	A	999	999	0	0	0	0
IN-5 *	3/24/08	65	HI	005									53.7	26.4	D	0	0	3	3	45	45
IN-6	3/25/08	33	HI	006	64.6	37.8	0	0	16	11	0	360	66.7	39.9	A	0	0	17	15	360	360
IN-6	3/25/08	12	HI	006	58.0	39.3	0	0	15	14	0	45	58.6	39.9	E	0	0	17	13	40	0
IN-6	3/25/08	65	HI	006									68.1	41.3	A	0	0	19	12	360	360
IN-7 *	3/26/08	33	HI	007	56.1	29.1	999	999	0	0	2	0	59.1	32.1	E	999	999	0	0	0	0
IN-7 *	3/26/08	12	HI	007	44.6	25.9	999	999	0	0	2	0	42.7	24.0	D	999	999	0	0	0	0
IN-7 *	3/26/08	65	HI	007									49.5	21.9	A	999	999	0	0	0	0
IN-8 *	3/27/08	33	HI	008	73.8	46.9	0	0	29	29	0	360	67.4	40.5	E	0	0	20	20	360	360
IN-8 *	3/27/08	12	HI	008	53.1	34.5	555	999	0	0	2	0	52.5	33.9	E	999	999	0	0	0	0
IN-8 *	3/27/08	65	HI	008									45.5	18.2	A	999	999	0	0	0	0
IN-9 *	3/28/08	33	HI	009	76.7	49.7	555	999	0	0	2	0	76.8	49.8	E	555	999	0	0	0	0
IN-9 *	3/28/08	12	HI	009	48.2	29.6	999	999	0	0	2	0	48.5	29.9	E	999	999	0	0	0	0
IN-9 *	3/28/08	65	HI	009									53.8	26.7	A	555	999	0	0	0	0
IN-10	3/31/08	33	HI	010	77.3	50.9	0	0	31	32	0	360	81.6	55.2	A	0	0	30	30	360	360
IN-10	3/31/08	12	HI	010	62.9	43.9	0	0	24	24	0	255	62.9	43.9	A	555	555	0	0	0	0
IN-10	3/31/08	65	HI	010									74.2	47.0	A	0	0	25	29	360	360
IN-11 *	4/1/08	33	HI	011	66.2	39.2	0	0	20	20	0	360	66.5	39.5	E	0	0	18	18	360	360
IN-11 *	4/1/08	12	HI	011	38.9	20.1	999	999	0	0	5	0	42.4	23.6		999	999	0	0	0	0
IN-11 *	4/1/08	65	HI	011									43.6	16.4		999	999	0	0	0	0
IN-12	4/2/08	33	HI	012	60.4	33.6	555	555	0	0	2	0	83.9	57.1	A	0	0	37	37	360	360
IN-12	4/2/08	12	HI	012	47.4	28.8	999	999	0	0	2	0	81.3	62.7	A	0	0	48	48	360	360
IN-12	4/2/08	65	HI	012									76.2	49.0	A	0	0	28	28	360	360
IN-13 *	4/3/08	33	HI	013	75.1	48.2	0	0	25	26	0	360	73.9	47.0	E	0	0	24	24	360	310
IN-13 *	4/3/08	12	HI	013	51.6	32.9	999	999	0	0	2	0	51.6	32.9	E	999	999	0	0	0	0
IN-13 *	4/3/08	65	HI	013									52.9	25.7	A	555	555	0	0	0	0
IN-14 *	4/23/08	33	HI	014	73.0	45.9	0	555	24	0	2	360	74.5	47.4	E	0	0	24	24	360	180
IN-14 *	4/23/08	12	HI	014	60.5	41.4	0	0	22	22	0	70	60.7	41.6	E	0	0	19	19	90	90
IN-14 *	4/23/08	65	HI	014									69.0	41.8	A	0	0	20	20	360	360

* denotes test site "***outside*** the box"

Table A8-2 (cont) Summary of ***secondary antenna*** raw indoor data

Test Site Name & Date					DTx OFF								DTx ON								
Test #	Test Date	CH #	Site Type	Site #	Field Strength (dBuV/m)	SNR Value (dB)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)	Field Strength (dBuV/m)	SNR Value (dB)	Largest Signal (*)	Rx #1 Errors	Rx #2 Errors	Rx #1 Margin (dB)	Rx #2 Margin (dB)	Rx #1 ROR (deg)	Rx #2 ROR (deg)
IN-15 *	4/29/08	33	HI	015	51.7	24.9	999	999	0	0	2	0	53.7	26.9		999	999	0	0	0	0
IN-15 *	4/29/08	12	HI	015	45.4	26.4	999	999	0	0	2	0	45.2	26.2		999	999	0	0	0	0
IN-15 *	4/29/08	65	HI	015									46.2	19.1		999	999	0	0	0	0
IN-16 *	4/30/08	33	HI	016	56.4	29.4	999	999	0	0	2	0	54.1	27.1	E	999	999	0	0	0	0
IN-16 *	4/30/08	12	HI	016	41.8	23.4	999	999	0	0	2	0	41.9	23.5		999	999	0	0	0	0
IN-16 *	4/30/08	65	HI	016									44.5	17.1		999	999	0	0	0	0
IN-17	5/1/08	33	HI	017	57.5	30.6	0	999	3	0	2	65	67.8	40.9	A	0	0	19	16	360	360
IN-17	5/1/08	12	HI	017	44.4	25.9	999	999	0	0	2	0	50.7	32.2	A	999	999	0	0	0	0
IN-17	5/1/08	65	HI	017									69.9	42.4	A	0	0	25	25	360	360
IN-18	5/2/08	33	HI	018	47.7	20.7	999	999	0	0	5	0	64.4	37.4	C	0	0	19	21	180	180
IN-18	5/2/08	12	HI	018	44.2	25.6	999	999	0	0	2	0	54.3	35.7	C	999	999	0	0	0	0
IN-18	5/2/08	65	HI	018									60.1	32.5	C	0	0	12	12	270	270
IN-19	5/5/08	33	HI	019	60.0	33.1	555	555	0	0	2	0	71.2	44.3	A	0	0	26	26	360	360
IN-19	5/5/08	12	HI	019	46.5	27.7	999	999	0	0	2	0	62.2	43.4	A	0	0	21	20	180	180
IN-19	5/5/08	65	HI	019									67.7	40.4	A	0	0	24	24	360	360
IN-20	5/6/08	33	HI	020	67.2	40.0	0	0	22	22	0	145	67.1	39.9	E	0	0	21	21	40	40
IN-20	5/6/08	12	HI	020	49.8	31.0	999	999	0	0	2	0	53.0	34.2	A	999	999	0	0	0	0
IN-20	5/6/08	65	HI	020									57.0	30.1	A	555	555	0	0	150	150
IN-21	5/7/08	33	HI	021	61.5	33.9	0	0	13	13	0	360	65.6	38.0	E	555	555	0	0	0	0
IN-21	5/7/08	12	HI	021	48.7	29.8	999	999	0	0	2	0	51.9	33.0	A	999	999	0	0	0	0
IN-21	5/7/08	65	HI	021									60.7	32.8	A	0	0	14	14	290	290
IN-22	5/8/08	33	HI	022	64.0	36.8	0	0	16	16	0	155	65.5	38.3	E	0	0	17	17	65	65
IN-22	5/8/08	12	HI	022	46.5	27.7	999	999	0	0	2	0	59.7	40.9	A	555	555	0	0	0	0
IN-22	5/8/08	65	HI	022									53.1	25.8	A	555	555	0	0	0	0
IN-23	5/9/08	33	HI	023	60.4	33.1	555	555	0	0	2	0	65.9	38.6	A	555	555	0	0	0	0
IN-23	5/9/08	12	HI	023	42.1	23.1	999	999	0	0	2	0	46.8	27.8		999	999	0	0	0	0
IN-23	5/9/08	65	HI	023									63.1	36.1	A	0	0	14	14	145	145

* denotes test site "***outside*** the box"