Communications-Applied Technology ICRI-4TG Technical Evaluation

The Office for Interoperability and Compatibility
Department of Homeland Security

Homeland Security

Test Procedures and Results

TE-08-0004
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Homeland Security

THE OFFICE FOR INTEROPERABILITY AND COMPATIBILITY

Defining the Problem

Emergency responders—police officers, fire personnel, emergency medical services—need to share vital voice and data information across disciplines and jurisdictions to successfully respond to day-to-day incidents and large-scale emergencies. Unfortunately, for decades, inadequate and unreliable communications have compromised their ability to perform mission-critical duties. Responders often have difficulty communicating when adjacent agencies are assigned to different radio bands, use incompatible proprietary systems and infrastructure, and lack adequate standard operating procedures and effective multi-jurisdictional, multi-disciplinary governance structures.

OIC Background

The Department of Homeland Security (DHS) established the Office for Interoperability and Compatibility (OIC) in 2004 to strengthen and integrate interoperability and compatibility efforts in order to improve local, tribal, state, and Federal emergency response and preparedness. Managed by the Science and Technology Directorate, OIC is assisting in the coordination of interoperability efforts across DHS. OIC programs and initiatives address critical interoperability and compatibility issues. Priority areas include communications, equipment, and training.

OIC Programs

OIC's communications portfolio is currently comprised of the SAFECOM and Disaster Management (DM) programs. SAFECOM is creating the capacity for increased levels of interoperability by developing tools, best practices, and methodologies that emergency response agencies can put into effect, based on feedback from emergency response practitioners. DM is improving incident response and recovery by developing tools and messaging standards that help emergency responders manage incidents and exchange information in real time.

Practitioner-Driven Approach

OIC is committed to working in partnership with local, tribal, state, and Federal officials in order to serve critical emergency response needs. OIC's programs are unique in that they advocate a "bottom-up" approach. The programs' practitioner-driven governance structures gain from the valuable input of the emergency response community and from local, tribal, state, and Federal policy makers and leaders.

Long-Term Goals

- Strengthen and integrate homeland security activities related to research and development, testing and evaluation, standards, technical assistance, training, and grant funding that pertain to interoperability.
- Provide a single resource for information about, and assistance with, interoperability and compatibility issues.
- Reduce unnecessary duplication in emergency response programs and unneeded spending on interoperability issues.
- Identify and promote interoperability and compatibility best practices in the emergency response arena.

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Department of Homeland Security (DHS)

Science and Technology Directorate (S&T)

Office for Interoperability and Compatibility (OIC)

TECHNOLOGY EVALUATION PROJECT

Technical Evaluation of the

INCIDENT COMMAND RADIO INTERFACE (ICRI-4TG)

Manufactured by Communications-Applied Technology

Test Procedures and Results

Document No. TE-08-0004

January 2008

Prepared by

National Institute of Standards and Technology (NIST) Office of Law Enforcement Standards (OLES) via

National Telecommunications and Information Administration (NTIA)/Institute for Telecommunication Sciences (ITS)

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Homeland Security

Publication Notice

Abstract

This report describes the test procedures and results of the product evaluation for the ICRI-4TG (Incident Command Radio Interface for four talk groups). The ICRI-4TG is an audio gateway device manufactured by Communications-Applied Technology. An audio gateway device (also called an audio matrix or a cross-band switch) links disparate radio systems to support communications interoperability between dissimilar wireless systems. Such a device simply passes baseband (audio) signals from the receiver portion of one radio to the transmitter portion of a dissimilar radio system.

Disclaimer

The U.S. Department of Homeland Security's Science and Technology Directorate serves as the primary research and development arm of the Department, using our Nation's scientific and technological resources to provide local, state, and Federal officials with the technology and capabilities to protect the homeland. Managed by the Science and Technology Directorate, the Office for Interoperability and Compatibility (OIC) is assisting in the coordination of interoperability efforts across the Nation.

Certain commercial equipment, materials, and software are sometimes identified to specify technical aspects of the reported procedures and results. In no case does such identification imply recommendations or endorsement by the U.S. Government, its departments, or its agencies; nor does it imply that the equipment, materials, and software identified are the best available for this purpose.

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Executive Summary

Working on behalf of the National Institute of Standards and Technology (NIST)/Office of Law Enforcement Standards (OLES), the National Telecommunications and Information Administration's Institute for Telecommunication Sciences (ITS) conducted a series of tests to evaluate the functionality of the ICRI-4TG (Incident Command Radio Interface for four talk groups). The ICRI-4TG is manufactured by Communications-Applied Technology (http://www.c-at.com/). It is part of a collection of bridge, or audio gateway, technology products offered by various manufacturers.

An audio gateway device (also called an audio matrix or a cross-band switch) links disparate radio systems to support communications interoperability between dissimilar wireless systems. Such a device simply passes baseband (audio) signals from the receiver portion of one radio to the transmitter portion of a dissimilar radio system.

The ICRI-4TG is designed to enable one user to simultaneously broadcast to five radios, one satellite phone, one phone line or cell phone, and one direct audio channel, each of which can be set for one of four available talk groups

To demonstrate the functionality of the ICRI-4TG, ITS developed a series of focused test procedures to evaluate:

- Balanced Input Audio Impedance
- Balanced Output Audio Impedance
- Input Audio Level
- Output Audio Level
- Frequency Response
- VOX[1] Input Threshold
- VOX Attack Time, and Throughput Delay
- Audio Distortion – Signal + Noise + Distortion to Noise + Distortion (SINAD) and Total Harmonic Distortion plus Noise (THD+N)
- Crosstalk

In general, the ICRI-4TG performed as advertised, and the test results in this document bear that out. The system is very easy to set up and configure with the front panel controls. It can be easily reconfigured for changing conditions.

Document Scope and Intended Audience

This report presents the procedures employed in the technical evaluation testing for the ICRI, and also summarizes the results. The ICRI falls under the category of cross-band technology devices that public safety organizations may use to perform wireless communications interoperability between dissimilar wireless systems. By necessity, this document is quite technical in nature.

[1] VOX means voice operated transmit.

1 Introduction

Public safety operations require effective command, control, coordination, communication, and sharing of information with numerous criminal justice and public safety agencies. Thousands of incidents that require mutual aid and coordinated response happen every day. High-profile incidents, such as bombings or plane crashes, test the ability of public safety service organizations to mount well-coordinated responses. In an era where technology can bring news, current events, and entertainment to the farthest reaches of the world, many police officers, firefighters, and emergency medical service (EMS) personnel cannot communicate with each other during major emergencies, as evidenced by September 11, 2001, and Hurricanes Katrina and Rita, or even during routine traffic accidents or fire operations.

1.1 Bridging Communications Gaps

There are more than 18,000 state and local law enforcement agencies in the United States. Approximately 95 percent of these agencies employ fewer than 100 sworn officers. Additionally, more than 32,000 fire and EMS agencies exist across the Nation. Due to the fragmented nature of this community, most public safety communications systems are stovepiped, i.e., individual systems do not communicate with one another or help bring about interoperability. Just as the public safety community is fragmented, so is radio spectrum. Public safety radio frequencies are distributed across isolated frequency bands from very high frequency (VHF) (25 to 50 megahertz (MHz)) to 800 MHz (806 to 869 MHz), and now 4.9 gigahertz (GHz).

The convergence of information and communication technologies requires a coordinated approach to bridge the gaps in interoperability. By focusing on enabling technologies and open standards for interoperability, the Department of Homeland Security's (DHS) Office for Interoperability and Compatibility (OIC)Technology Evaluation Project provides this needed link.

1.2 The OIC Technology Evaluation Project

The OIC Technology Evaluation Project is focused on assessing the applicability of currently available and evolving products and services to the interoperability requirements of users in public safety agencies. To accomplish this, products and services are evaluated to determine if they are both cost-efficient and effective for users. They also are evaluated consistent with the tenets of the long-term standardization approach developed by OIC for nationwide interoperability.

Evaluation comprises classic techniques, including observation, analysis, demonstration, and testing. In many cases, products or services may be comprehensively evaluated within an independent laboratory or other closed environment. For other products or services, however, a more extensive approach may be necessary to determine the ramifications of placing those products or services in an agency conducting actual job functions. To help with the demonstrations and testing of selected products or services of this type, operational test beds (OTBs) may be established. This aim is to assess the operational impacts of technologies that assist interoperability. In addition, focused "pilot projects" are also used to evaluate solutions to specific operational requirements.

While evaluation processes conducted at independent laboratories may take weeks to complete (for example, 4 to 8 weeks), evaluations within the OTB may take months (for example, 6 to 12 months). This is because such evaluations carefully characterize the impact of the new product or service on existing operations. In addition, they project how future operations may change with a permanent application of the technology.

2 Background

A fundamental interoperability challenge today is wireless voice communications among agencies that have different radio systems operating on various radio frequencies. OIC will ultimately address this issue through promotion of interoperability standards, including standardized methods of bridging between systems operating in different frequency bands.

While interoperability standards are being developed, however, other mechanisms are needed that can address interoperability requirements. One such mechanism is the audio gateway device (also called an audio matrix or a cross-band switch) that links the disparate radio systems. Not unlike a dispatcher's patch panel, such a device simply passes baseband (audio) signals from the receiver portion of one radio to the transmitter portion of a dissimilar radio system. For example, audio from the receiver function of a very high frequency (VHF) transceiver is passed to the transmitter circuitry of an ultra high frequency (UHF) transceiver.

2.1 Audio Gateway Advantages

An audio gateway has several advantages over the dispatcher's patch panel. One big advantage is that an audio gateway requires no manual intervention once it is configured. The device automatically routes voice calls from one radio system to another via control signals (e.g., dual-tone multi-frequency (DTMF) signals) input by a radio user. Audio gateways also support connections between radios, telephone lines, and cellular phones. In addition, an audio gateway offers mobile versatility over dispatchers' patch panels. For example, an audio gateway can be configured for a van or sport utility vehicle (SUV) to become part of an incident commander's command post. This way, the audio gateway becomes a mobile repeater, allowing the disparate radio systems to communicate in a wide geographical radius around the incident.[2]

2.2 Overview of the Communications-Applied Technology ICRI-4TG

The Communications-Applied Technology ICRI-4TG is an audio gateway device. It is designed to enable interoperability between wireless and wireline communication systems by multiplexing audio input signals to the audio input ports of several radios. The ICRI-4TG serves to connect radios that operate within different radio frequency (RF) bands and use analog or digital modulation. This is accomplished by fanning out a single audio input source (for example, a radio) to multiple radio audio inputs.

One user can simultaneously broadcast on several radios using the ICRI-4TG. It can connect to a total of five land mobile radios (LMRs), one satellite (Sat) phone, one phone line or cell phone, and one direct audio channel. Each can be set for one of four available talk groups. Note that there is a minimum of two radios per talk group.

Figure 1 shows the four module chassis of the ICRI-4TG, which supports:

- Up to 4 talk groups
- A satellite phone

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[2] The ability to configure and operate an audio gateway device in the field is a powerful feature. However, proper training is crucial to operating an audio gateway. Field personnel, not properly trained in the technical operation of the device or relevant agency policies, can create connections that cause unforeseen problems. It is incumbent on the operating agency to ensure that appropriate policies and procedures are used for any audio gateway device in its possession.

- Line I/O or cell phone
- A handset
- An Ethernet port

Figure 1: ICRI-4TG

The ICRI-4TG chassis is metal with metal face plates. No configuration of the device is necessary. The ICRI-4TG comes with a handset.

For all tests, setup and operation of the unit was conducted according to manufacturer documentation. This report refers to the Revision C, 7/23/2006 version of *ICRI Setup and Operating Procedures* as “the ICRI user’s manual.” The unit was conformance-tested in accord with vendor-supplied product specifications detailed on the Communications-Applied Technology Web site (http://www.c-at.com/).

3 General Evaluation Approach: Laboratory Testing

The first phase of evaluation involves laboratory testing and analysis. The aim is to answer two basic questions:

- Does the product operate and perform “as advertised” and successfully address the interoperability problems that it was designed to confront?
- Did issues arise during the testing that might affect the use of the product for the purposes advertised?

ITS conducted a series of tests to confirm that the device operates in conformance with published specifications. Furthermore, ancillary tests, of significant interest to the users and agencies in general, were performed to provide a means to benchmark or compare this device to others in its class.

The next sections outline the types of tests and analysis performed. Section 4 lists detailed test and analysis procedures for the ICRI-4TG.

3.1 Specifications Testing

Specifications testing determines how well the unit performs relative to the manufacturer's specifications. This report evaluates the following ICRI-4TG specification parameters:

- Input audio impedance
- Output audio impedance
- Input audio level
- Output audio level
- Audio response
- VOX input threshold
- VOX attack time and throughput delay

3.2 Performance Testing

Performance testing quantifies the performance of the ICRI-4TG gateway device by evaluating the degradation (if any) it inflicts on end-to-end (radio system-to-radio system) operation. Although not specified by the manufacturer, such testing is considered important for this evaluation and will be assessed. The following performance parameters are evaluated:

- Audio Distortion – SINAD and THD+N
- Crosstalk

3.3 Observations

Section 5 details the procedures for measuring RF emissions and the results observed for the ICRI-4TG.

4 ICRI-4TG Evaluation

This section refers to the ICRI-4TG's five LMR ports as LMR Ports 1 to 5. The ICRI-4TG accepts both audio input and output (I/O) signals at its interface ports.

Figure 2 shows how connections to the audio input and output signals at these radio ports were made using audio input or output (I/O) cables. ITS engineers custom-made the cables that mate with the LMR interface ports. Each cable provides connections to the ICRI-4TG interface ports using a pigtail with XLR connectors on each end: one for audio input and one for audio output. Connector pin-out information can be found in the ICRI-4TG user's manual.

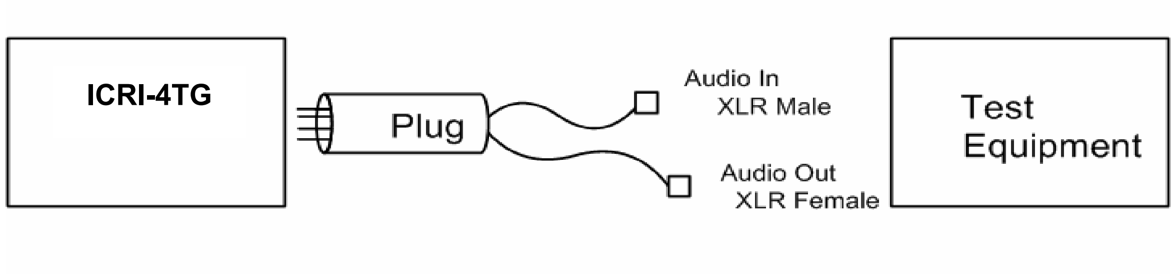

Figure 2: Audio I/O Cable

The following test equipment was used to conduct these tests:

- Tektronix TDS 3012B Digital Phosphor Oscilloscope
- Audio Precision ATS-1 Dual Domain Audio Test System Audio Analyzer
- IET Labs Precision Resistance Substituter (model number RS-201)
- Agilent E4443A PSA Series Spectrum Analyzer

In this report, the Tektronix TDS 3012B Digital Phosphor Oscilloscope is referred to as *DPO*. The Audio Precision ATS-1 Dual Domain Audio Test System Audio Analyzer is referred to as *ATS*.

4.1 Conformance to Manufacturer's Specifications

The following tests measure the ICRI-4TG's conformance to published specifications, and summarize the results obtained. Each test comprises the following components:

- Datasheet specification
- Test Procedures
- Test Case Results and Summary

4.1.1 Input Audio Impedance

Impedance refers to the amount of resistance to an electrical current. Input impedance provides information on the types of electrical signals that can be input into the device. If this parameter is out of specification, potential effects include increased noise in the audio signal.

Datasheet Specification

- o Unbalanced 80 ohms nominal

Test Procedures

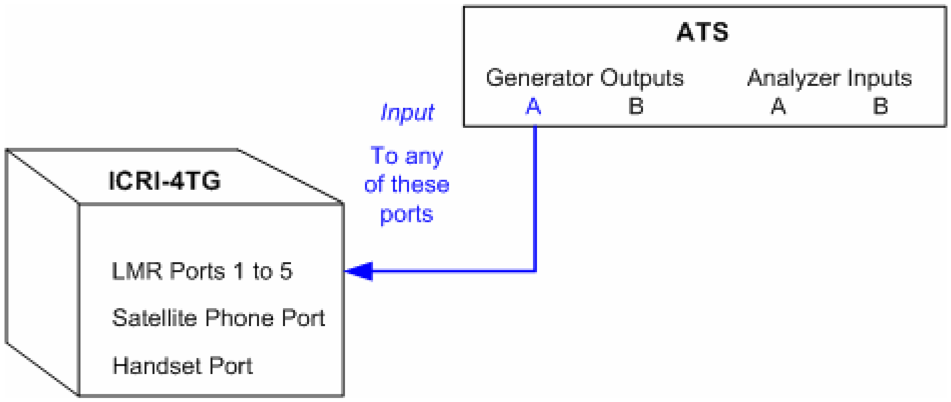

Figure 3: Input Audio Impedance

1. For each radio port, connect the ICRI-4TG audio input to the Generator Output A port of the ATS.
2. Configure a 1 kilohertz (kHz) sine wave as the input signal to the ICRI-4TG from the Generator Output A port of the ATS.
3. From the ATS front panel, select the Gen Load softkey. This will automatically measure the input impedance of the radio port under test.
4. Record the input impedance measurement from the front panel display of the ATS.

Test Case Results and Summary

Table 1: Input Impedance

Interface	Measured Impedance in (Ω)
Port 1	87
Port 2	87
Port 3	87
Port 4	87
Port 5	87
Sat Phone	6600
Handset	6300

Operationally, for typical usage the difference between the specified 80 ohm impedance and the measured values is insignificant.

4.1.2 Output Audio Impedance

Output impedance provides information on the electrical signal that can be provided to other devices. When output audio impedance is greater than the specified value, potential effects include increased noise in the audio signal.

Datasheet Specification

- Unbalanced, 1000 ohms nominal

Test Procedures

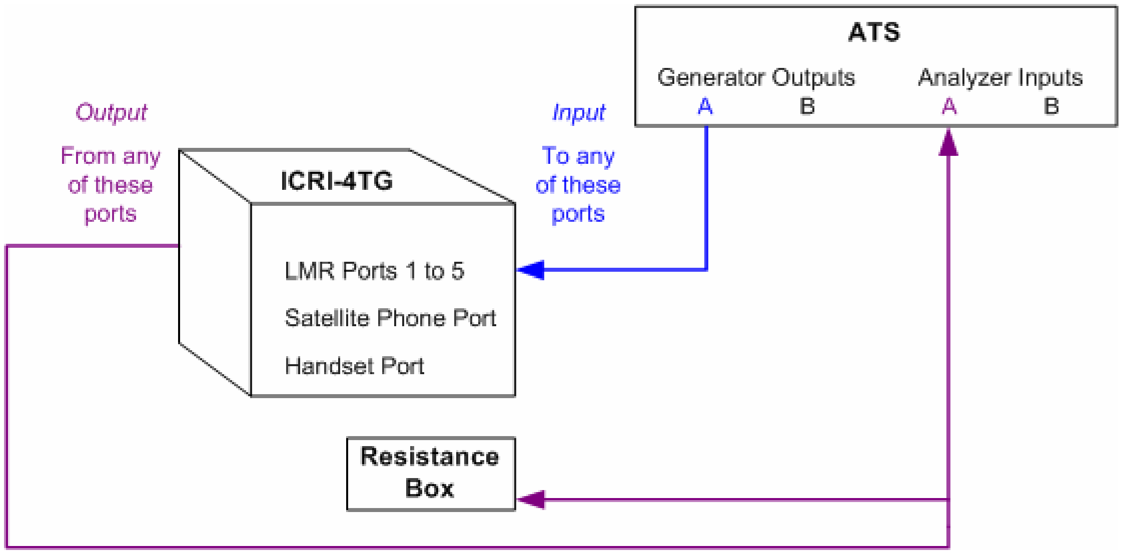

Figure 4: Output Audio Impedance

1. For each radio port, assign the radio port under test to net 1 (*net* means network).
2. Assign one of the other radio ports to net 1, to which the input signal will be applied. Ensure that no other radio ports are assigned to net 1.
3. Connect the ATS I/O cables to the radio port under test and the input radio port.
4. At the input radio port, connect the audio cable's input pigtail to the Generator Output A port of the ATS.
5. At the radio port under test, connect the audio cable's output pigtail to an adjustable resistance box. Split the signal to connect the Analyzer Input A port of the ATS in parallel with the resistance box.
6. Configure the ATS to provide a 1 kHz sine wave at a value of 287 mVp (peak level in millivolts).
7. Record the non-terminated voltage reading from the ATS. Calculate the value for a 50 percent reduction in voltage.
8. Connect the resistance box on the output radio port. Adjust its load resistance until the 50 percent reduction in voltage is measured at the ATS. The value of the resistance box, when connected in parallel with the output radio port that yields a 50 percent reduction in the output voltage, should equal the output impedance of the radio port.
9. Record the output impedance value.

Test Case Results and Summary

Table 2: Output Impedance

Input Port	Output Port	Original V	Output Impedance Level in Ω to Result in Half of Original V
1	2	35.05	490
1	3	36.86	520
1	4	35.30	510
1	5	34.88	488

Input Port	Output Port	Original V	Output Impedance Level in Ω to Result in Half of Original V
5	1	37.26	524
5	2	34.96	490
1	Handset	555	59

Operationally, the difference between the specified 1000 ohm impedance and the measured values is insignificant for typical usage.

4.1.3 Input Audio Level

Input audio level shows the range of acceptable input signal levels to achieve an acceptable output signal level. Having a wide range of acceptable input levels means that the device should provide a good quality signal without extensive calibration of the levels provided from external devices. One example is that the output volume from a handheld radio is not calibrated. The ability to accept a wide variety of signal levels means that a technician does not have to spend time to ensure volume levels have been set precisely. Instead, volume can just be set by ear to a reasonable level.

Datasheet Specification

- -32 dBm to +12 dBm (20 mV to 2 V), no adjustment required

Test Procedures

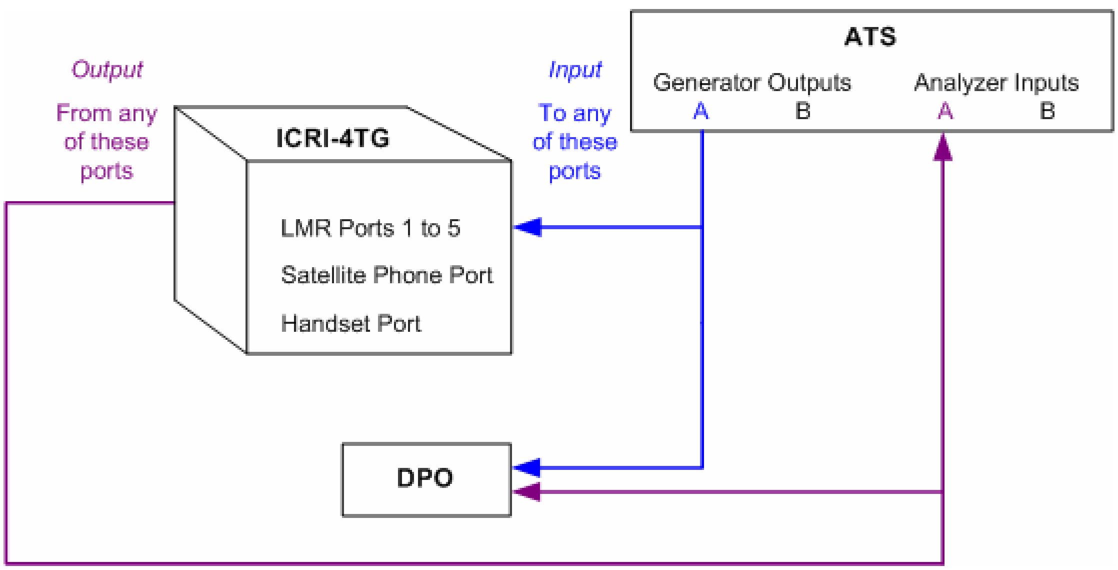

Figure 5: Input Audio Level

1. Assign the radio port to be tested to net 1. This will be the input interface.
2. Assign the output radio port to net 1. Ensure that no other radio ports are assigned to net 1.
3. At the input radio port, connect the audio cable's input pigtail to the Generator Output A port of the ATS in parallel with the DPO.
4. At the output radio port, connect the audio adaptor's output pigtail to the Analyzer Input A port of the ATS in parallel with the DPO.

5. Set the ATS output level for the 1 kHz sine wave to the desired input level measured at the DPO.
6. Measure the level and THD+N at the output port at varying input levels.

Test Results and Summary

Table 3: Input Audio Level

ATS Output mVp	ICRI-4TG Input Port 1 V Peak to Peak	ICRI-4TG Output Port 2 mV Peak to Peak	ATS THD+N %
51	.076	54	.575
75	.108	65	.416
100	.145	75	.377
125	.180	82	.349
150	.212	91	.321
175	.247	94	.301
200	.288	97	.299
225	.318	101	.302
250	.352	104	.314
275	.388	107	.309
300	.420	111	.312
350	.488	114	.307
400	.572	119	.309
450	.640	120	.299
500	.712	122	.309
550	.780	124	.305
600	.844	127	.283
650	.912	127	.311
700	.976	130	.298
750	1.04	131	.290
800	1.12	132	.296
850	1.18	132	.299
900	1.29	133	.254
950	1.35	135	.270
1000	1.42	135	.255
1100	1.56	135	.240
1200	1.70	137	.260
1300	1.83	138	.246
1400	1.98	138	.240

ATS Output mVp	ICRI-4TG Input Port 1 V Peak to Peak	ICRI-4TG Output Port 2 mV Peak to Peak	ATS THD+N %
1500	2.09	139	.220
2103	3	144	.211
2847	4	146	.204
3576	5	148	.191
4333	6	149	.195
4936	7	150	.191
5702	8	152	.194
6447	9	153	.199

The results show that distortion is fairly low across the full range of input levels, but it is higher at the lower levels. This is typical for electronic equipment.

4.1.4 Output Audio Level

Output audio level shows the range of available output signal levels that would be available to another device. Having a wide range of acceptable output levels means that the device can provide an appropriate signal to a variety of devices.

Datasheet Specification

- -40 dBm to -18 dBm, adjustable (preset: -25 dBm)

Test Procedures

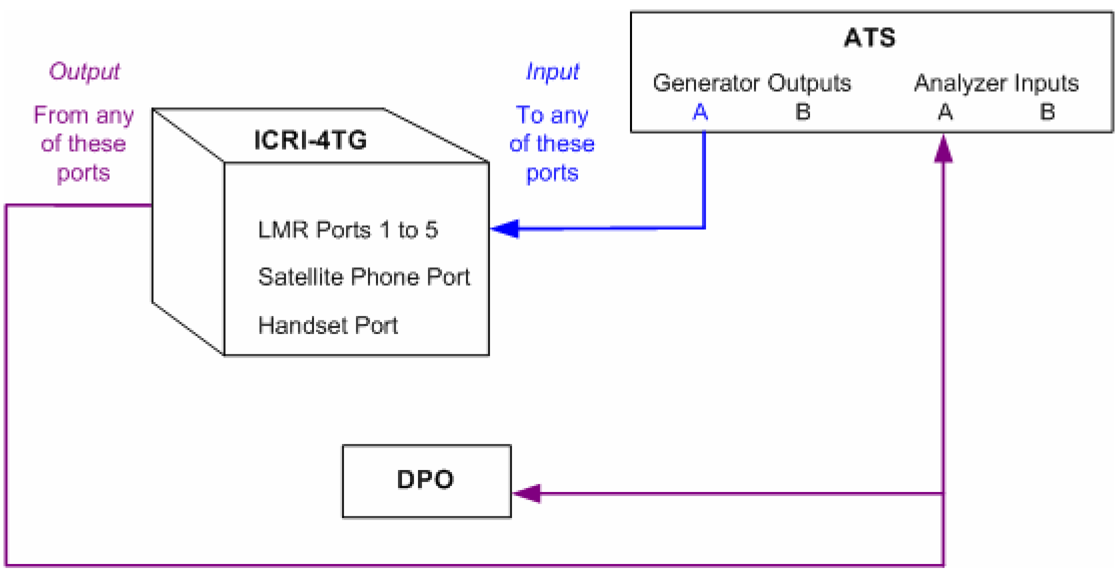

Figure 6: Output Audio Level

1. Connect the Generator Output A port of the ATS to the desired ICRI-4TG input port.
2. Connect the output port under test to the Analyzer Input A port of the ATS.
3. Set the ATS to generate a 1 kHz sine wave at 1 Vpp (peak-to-peak voltage).
4. Select the Level softkey on the ATS.

5. Record the output level from the ATS display.
6. Repeat the preceding steps for all ports.

Test Case Results and Summary

Table 4: Output Audio Level

Interface	Output Level dBm
Port 1	-25.6
Port 2	-26.2
Port 3	-25.7
Port 4	-26.1
Port 5	-26.2
Satellite phone/LMR	-66.4
Handset	6.95

The results are consistent with the specifications.

4.1.5 Audio Frequency Response

Audio frequency response indicates how accurately the device outputs a speech signal from a given input signal. The frequency band that the telephone industry has used for decades is 300 Hertz (Hz) to 3.5 kHz. It is generally accepted that accurate reproduction across this band will allow for good speaker recognition and speaker voice characteristic (e.g., emotional state) recognition.

Datasheet Specification

- 280 Hz to 3.4 kHz

Test Procedures

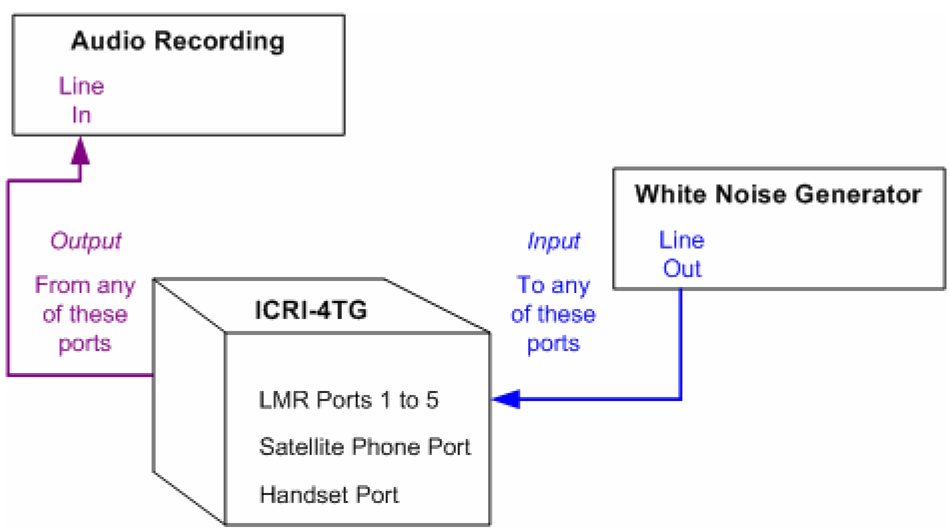

Figure 7: Frequency Response

This test is performed non-invasively by combining the input and output frequency response tests.

1. For each output radio port to be tested, assign a single input by making the appropriate net selection.
2. Inject white noise into the port.
3. Record the audio output.
4. Calculate the Fast Fourier Transform (FFT) of the audio output response.
5. Plot the device frequency response.

Test Case Results and Summary

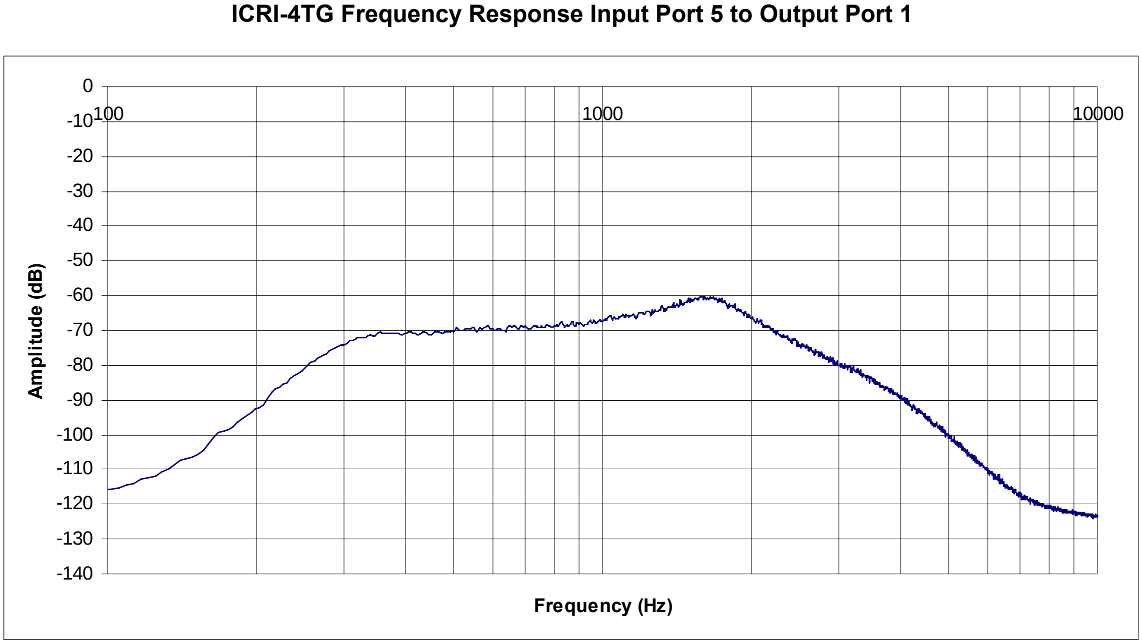

Figure 8: Frequency Response

The frequency response measurements are in concord with the ICRI-4TG audio response specification.

4.1.6 VOX Input Threshold

The VOX input threshold is the level of signal at which the device switches open the channel to allow a transmission to happen. It is an audio signal equivalent to a radio squelch control, helping the device to distinguish a valid signal from background noise. How the threshold is set may affect how the device reacts to quiet sounds, such as someone whispering over a radio channel or someone who talks very quietly.

Datasheet Specification

- Adjustable -32 to -6 dBm (preset: -30 dBm)

Test Procedures

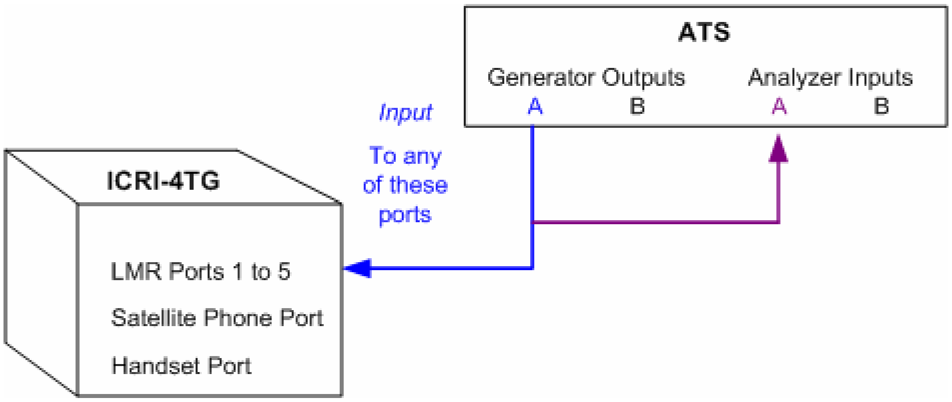

Figure 9: VOX Input Threshold

1. Insert a 1 kHz sine wave at a level below VOX threshold into the port being tested.
2. Adjust the input level until the VOX activates.
3. Record the output amplitude from the ATS and the VOX level on the ICRI-4TG.

Test Case Results and Summary

Table 5: VOX Input Threshold

Input Port	Input Level (dBm)	Generator Output (mVp)
1	-32.09	48.94
2	-31.79	50.69
3	-32.70	45.58
4	-32.18	48.44
5	-31.98	49.55
Sat Phone	-33.70	40.70

The measured VOX threshold is consistent with the minimum specifications given.

4.1.7 Throughput Delay and Transmit Delay

Throughput delay is the amount of time it takes the device to reproduce an audio signal presented at the input port onto the output port. It is separate, but often related to, VOX attack time. VOX attack time is the time interval between when a valid audio signal is received by the device, and when the device recognizes that the signal is valid and actually starts allowing the audio signal to be reproduced at the output.

The VOX transmit delay is an additional programmable delay to allow time for transmitters to ramp up before the audio signal starts. This helps to avoid the loss of words or syllables in transmission.

Datasheet Specification

- Each net, individually adjustable; 0, 50, 100, 150, 200, 250, 300, 350, 400, and 500 ms (preset: 250 ms).

Test Procedures

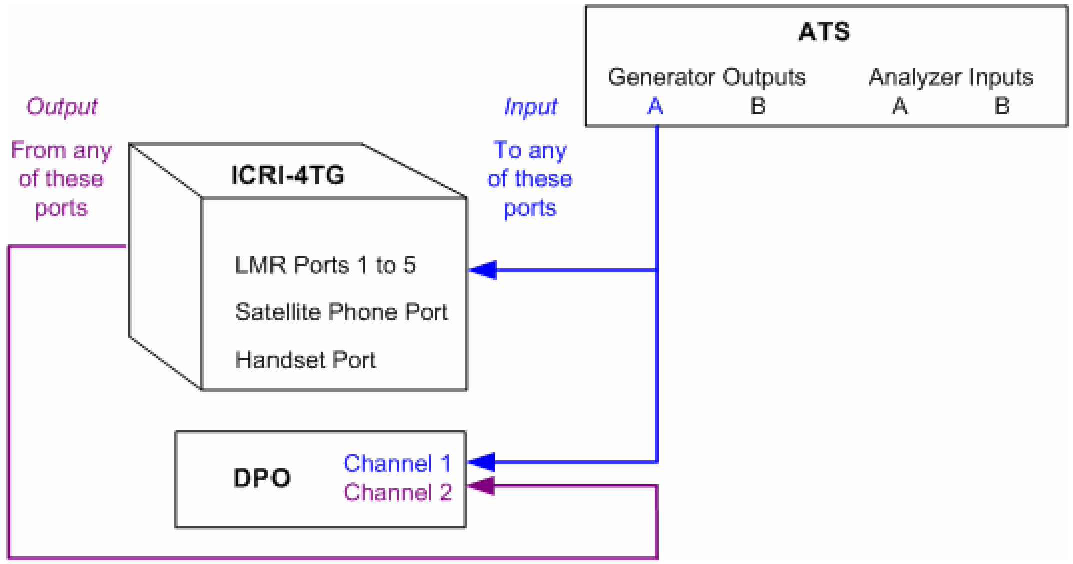

Figure 10: VOX Attack Time and Throughput Delay

1. Connect the output of an input source, such as the ATS, to the ICRI input port under test and to the DPO.
2. Configure the ATS to give a 20 millisecond (ms) 1 kHz burst with a 0.8 second duty cycle.
3. Set the DPO to single sweep mode, externally triggered from the ATS.
4. Connect the output radio port to the DPO.
5. Adjust the DPO as appropriate.
6. Each time the signal is initiated, it will simultaneously trigger the DPO and the voice activation feature of the ICRI-4TG radio port. Record the time difference from the input signal to the output signal.

Test Case Results and Summary

Table 6: Audio Delay

Input Port	Output Port	Delay in (ms)
1	5	250
1	3	250

The measured transmit delay is precise as set by the manufacturer.

4.2 Characteristics Not Specified by the Manufacturer

The next sections discuss measurements for performance parameters not specified by the manufacturer, namely: audio distortion and crosstalk.

4.2.1 Audio Distortion – SINAD and THD+N

SINAD is the ratio of Signal + Noise + Distortion to Noise + Distortion. SINAD is a rough, commonly used estimation of audio quality. Radio thresholds are commonly set at the point where SINAD equals 10, 12, or 20 dB. As long as the device does not approach these values (i.e., has a significantly higher value), this is not a source of concern.

Total Harmonic Distortion + Noise (THD+N) is a measurement of how changed the audio signal is as it passes through a device. A THD+N higher than 0.3 percent is generally considered slight audible distortion. A THD+N higher than 3.0 percent is generally considered audible distortion. Exceeding that threshold may cause difficulty in speaker recognition or in the identification of the emotional state of a speaker.

Test Procedures

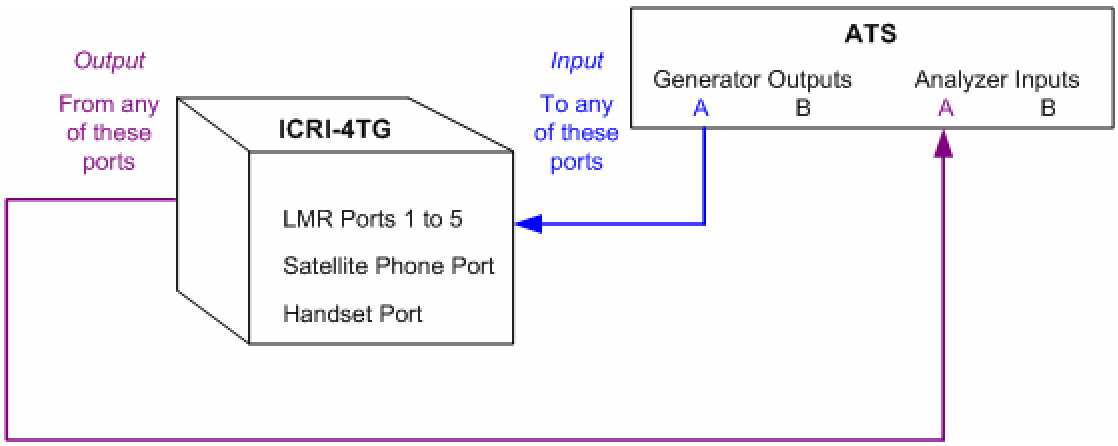

Figure 11: Audio Distortion - THD+N

1. Configure the ATS to measure THD+N using the front panel softkeys.
2. Connect the input radio port to the ATS, and apply a 1 kHz sine wave at an amplitude of 1 Vp (peak level in volts).
3. Record the ATS THD+N and SINAD.

Test Results and Summary

Table 7: Audio Distortion

GEN A 1 volt peak, 1 kHz sine, 22 Hz to 22 kHz

Input Port	Output Port	THD+N in Percent	SINAD in dB
1	2	.282	50.8
1	3	.283	51.0
1	4	.280	51.1
1	5	.284	51.2
1	Satellite phone/LMR	.290	50.5
1	Handset	1.02	39.7

The THD+N and SINAD are consistent over all ports tested.

4.2.2 Crosstalk

Crosstalk occurs when the content of a signal on one path through a system bleeds over into other parts of the system. Being significantly out of specification could cause conversations of different groups to be confused or unintelligible. For example, a conversation from one net could be heard on a net for which it was unintended.

Test Procedures

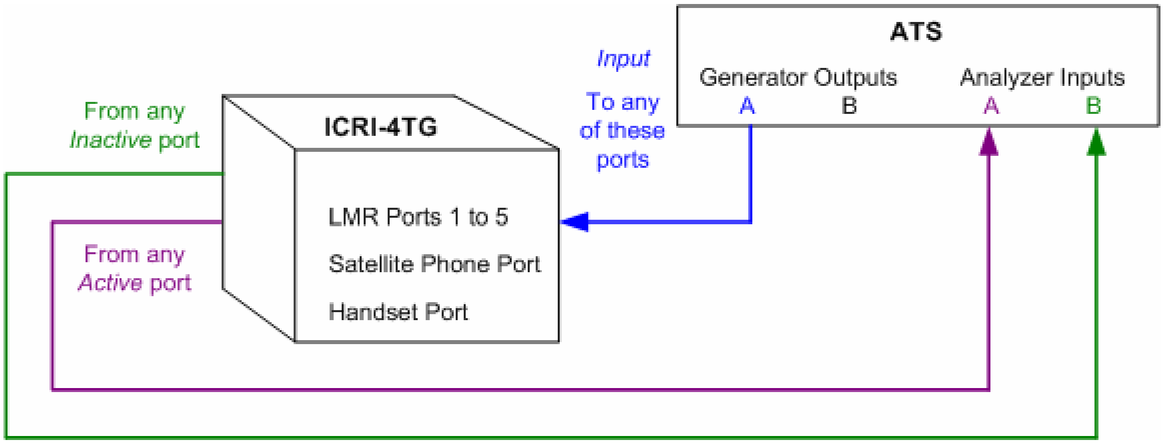

Figure 12: Crosstalk Measurement

1. Configure the ATS to measure crosstalk using the front panel softkeys.
2. Connect the input radio port to the ATS and apply a 1 kHz sine wave with an amplitude of 2 Vp to trigger the input filter on the ATS.
3. Using the ATS measurement, determine the crosstalk in dBV.[3]
4. Repeat step 3 for all output radio ports.

Test Results and Summary

Table 8: Crosstalk

Input Port	Driven Port	Measured Port	Crosstalk, dBV
1	2	3	-114.1
1	2	4	-115.8
1	2	5	-115.2
1	2	Satellite Phone/LMR	-109.6
1	2	Handset	-84.4
5	4	1	-109.3
5	4	2	-110.4
5	4	3	-119.2
5	4	Satellite Phone/LMR	-113.9
5	4	Handset	-84.3

Crosstalk values indicate that crosstalk should not be a significant concern with this device.

[3] dBV is a decibel relative to 1 volt peak-to-peak.

5 Observations of RF Emissions

Gateway devices like the ICRI-4TG must operate in environments with other RF equipment. Therefore, an informal RF emissions scan was made in the 20 MHz to 500 MHz range, with no transmitters attached or active. This section details those measurement procedures and results.

Test Procedures

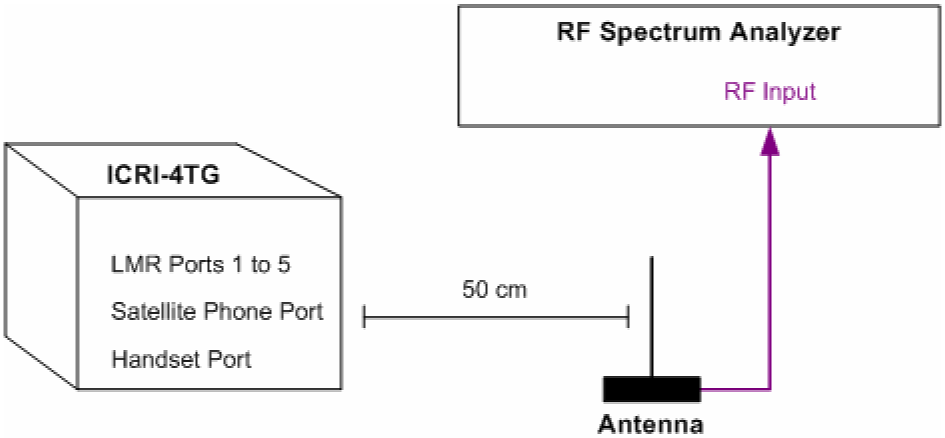

Figure 13: RF Emission Measurement

1. Configure the RF Spectrum Analyzer to measure RF energy from 20 MHz to 500 MHz, which encompasses the VHF and UHF band.
2. Position the antenna probe at 50 centimeters (cm) from the device under test.
3. Using the spectrum analyzer, record the RF energy across the frequency band of interest with the device under test powered off.
4. Repeat step 3 with the device under test powered on.

Test Results and Summary

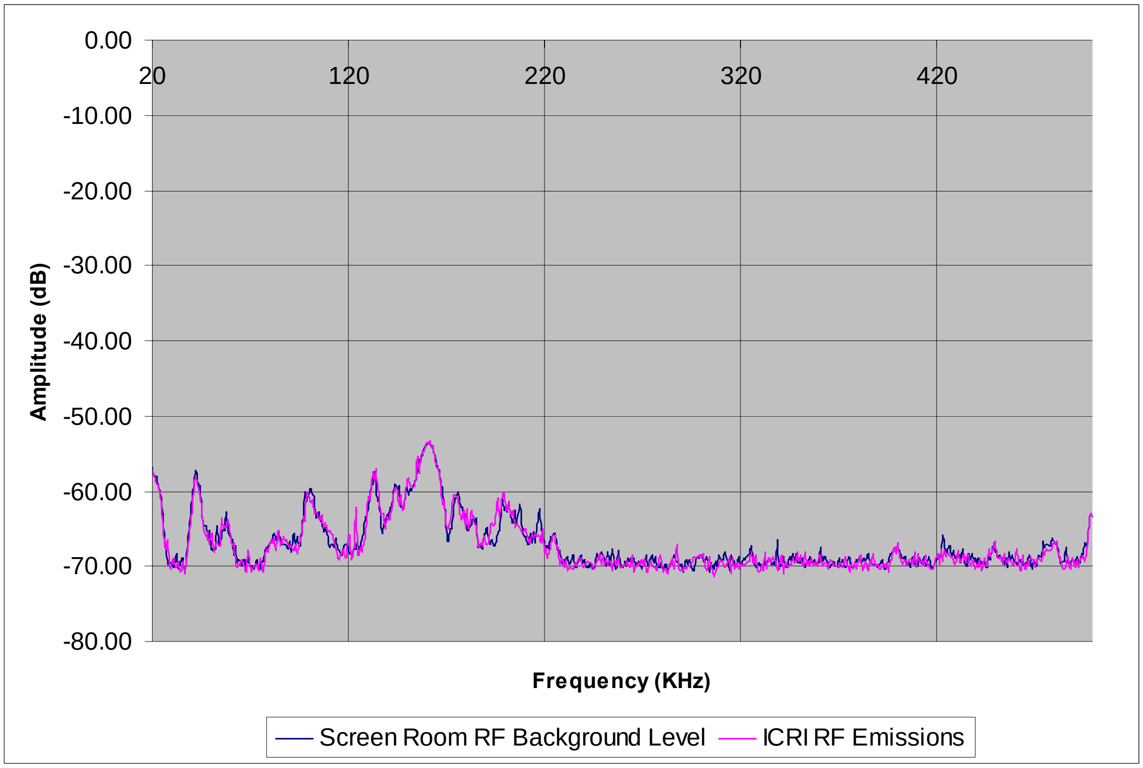

Figure 14: RF Emissions from 20 MHz to 500 MHz

There were no noticeable RF emissions from the ICRI-4TG.

Appendix: Glossary of Terms and Acronyms

AGC (Automatic Gain Control) – A process or means by which a signal level is adjusted in a specified manner. AGC attempts to keep a consistent output signal level regardless of the level of the input signal.

Crosstalk – Undesired coupling or bleeding of a signal in one portion of an electronic circuit or channel into another, causing undesired effects if the crosstalk is too great

dBV – Decibels relative to 1 volt peak to peak

DHS – U.S. Department of Homeland Security

DPO – Digital Phosphor Oscilloscope, for the tests in this document, the Tektronix TDS 3012B

DTMF (Dual-tone multi-frequency) – A method of coding the numbers on a telephone touch pad into combinations of frequencies that machines can interpret

FFT (Fast Fourier Transform) A computationally efficient means of computing the frequency content of a waveform

Hang Time – Indicates the duration that a channel is open following the most recent audio signal to exceed the VOX (voice operated transmit) level setting.

ICRI-4TG – An interoperability communications controller manufactured by Communications-Applied Technology

I/O – Input/Output

LMR (Land Mobile Radio) – A common descriptor of the type of radio communication system frequently used by public safety practitioners

ms – Milliseconds

OIC – The Office of Interoperability and Compatibility within the DHS Science and Technology (S&T) Directorate

RF (Radio Frequency) – Of, or pertaining to, any frequency within the electromagnetic spectrum normally associated with radio wave propagation

RX – Received or Receiver

S&T – Science and Technology Directorate of DHS

SINAD – The ratio of Signal + Noise + Distortion to Noise + Distortion

THD+N – The sum of the Total Harmonic Distortion plus Noise. THD is the ratio of the power of all harmonic frequencies introduced by a system to the power of the fundamental frequency to which they are added.

Throughput Delay – The time from when a specific signal is introduced into the system being tested until that signal appears on an output port of the device being tested

Transmit Delay – A delay intentionally introduced into an audio signal path to enable a transmitter to ramp up to appropriate power levels before the audio signal is presented to the transmitter. This is to avoid temporal clipping (for example, words or syllables being chopped off) at the beginning of a transmission.

TX – Transmitted or Transmitter

UHF (Ultra High Frequency) – Frequencies from 300 MHz to 3,000 MHz

VHF (Very High Frequency) – Frequencies from 30 MHz to 300 MHz

VOX (Voice Operated Transmit) – A device that transmits a signal only when an active audio signal (that is, voice) above detection of a defined threshold

VOX Attack Time – The amount of time it takes a voice detection circuit to recognize that an audio signal is above the defined threshold and to begin transmitting that audio signal

Vp – Peak voltage

Vpp – Peak-to-peak voltage