OET BULLETIN No. 69

Longley-Rice Methodology

for

Evaluating TV Coverage and Interference

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I. INTRODUCTION

This Bulletin provides guidance on the implementation and use of Longley-Rice methodology for evaluating TV service coverage and interference in accordance with Sections 73.622, 73.623 and 74.704 of the FCC rules, 47 C.F.R. §§ 73.622, .623, and 74.704. Bulletin No. 69 explains technical details of the *Sixth Report and Order* in MM Docket No. 87-268, FCC 97-115, adopted April 3, 1997. The Longley-Rice radio propagation model is used to make predictions of radio field strength at specific geographic points based on the elevation profile of terrain between the transmitter and each specific reception point. A computer is needed to make these predictions because of the large number of reception points that must be individually examined. Computer code for the Longley-Rice point-to-point radio propagation model is published in an appendix of NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. Some modifications to the code were described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985. With these modifications, the code is referred to as Version 1.2.2 of the Longley-Rice model. This version is used by the FCC for its evaluations.

The Bulletin is divided into three parts. Part 1 provides information on evaluating TV service area or coverage. Part 2 provides information on evaluating interference to the service areas of both analog NTSC and digital television (DTV) stations. Part 3 provides information on implementation of the FCC's Longley-Rice Computer program.

The present document updates the previous version that was published on July 2,1977. Internet references point to currently available FCC web pages. Certain adjacent-channel D/U ratios have been corrected as indicated in Table 5A. Otherwise, the changes are of an editorial nature, and the program parameters given here are exactly those used by the Media Bureau in processing applications for new or modified stations.

II. PART 1: EVALUATION OF SERVICE

The Area Subject to Calculation

Under the FCC's rules, computation of a TV station's service area or coverage using the Longley-Rice methodology is limited to the areas within certain specific geographic contours.

For analog TV, computations are made inside the conventional Grade B contour defined in Section 73.683 of the FCC rules, 47 C.F.R. § 73.683, with the exception that the defining field for UHF channels is modified by subtracting a dipole factor equal to 20 log[615/(channel mid-frequency in MHz)]. Thus the area subject to calculation for analog TV consists of the geographic points at which the field strength predicted for 50% of locations and 50% of time by FCC curves is at least as great as the values given in Table 1 below. The relevant curves for predicting these fields are the F(50, 50) curves found in Section 73.699 of FCC rules, 47 C.F.R. § 73.699.

Table 1

Field Strengths Defining the Area Subject to Calculation for Analog Stations

Channels	Defining Field Strength, dBu, to be predicted using F(50, 50) curves
2 - 6	47
7 - 13	56
14 - 69	64 - 20 log[615/(channel mid-frequency in MHz)]

For digital television stations, service is evaluated inside contours determined by DTV planning factors in combination with field strength curves derived for 50% of locations and 90% of the time from curves which are also found in Section 73.699 of FCC rules. The family of FCC propagation curves for predicting field strength at 50% of locations 90% of the time is found by the formula F(50, 90) = F(50, 50) - [F(50, 10) - F(50, 50)]. That is, the F(50, 90) value is lower than F(50, 50) by the same amount that F(50, 10) exceeds F(50, 50).

The defining field strengths for DTV service are shown in Table 2. They are determined from the DTV planning factors identified in Table 3. They are used first to determine the area subject to calculation using FCC curves, and subsequently to determine whether service is present at particular points within this area using Longley-Rice terrain-dependent prediction.

Table 2

Field Strengths Defining the Area subject to Calculation for DTV Stations

Channels	Defining Field Strength, dBu, to be predicted for 50% of locations, 90% of time
2 - 6	28
7 - 13	36
14 - 69	41 - 20 log[615/(channel mid-frequency in MHz)]

For digital TV three different situations arise:

1) For DTV stations of the initial allotment plan located at the initial reference coordinates, the area subject to calculation extends in each direction to the distance at which the field strength predicted by FCC curves falls to the value identified in Table 2. The bounding contour is identical, in most cases, to that of the analog station with which the initial allotment is paired. The initial allotment plan and reference coordinates are set forth in Appendix B of the *Sixth Report and Order* in MM

Docket No. 87-268 concerning Digital Television Allotments, adopted April 3, 1997, 12 FCC Rcd 14588 (1997).

2) For new DTV stations, the area subject to calculation extends from the transmitter site to the distance at which the field strength predicted by FCC curves falls to the value identified in Table 2.

3) In the case where a DTV station of the initial allotment has moved, the area subject to calculation is the combination (logical union) of the area determined for the initial allotment and the area inside the contour which would apply in the case of a new DTV station.

Planning Factors

The planning factors shown in Table 3 lead to the values of field strength given above in Table 2 to define the area subject to calculation for DTV stations. These planning factors are assumed to characterize the equipment, including antenna systems, used for home reception. They determine the minimum field strength for DTV reception as a function of frequency band and as a function of channel number in the UHF band.

Table 3

Planning Factors for DTV Reception

Planning Factor	Symbol	Low VHF	High VHF	UHF
Geometric mean frequency (MHz)	F	69	194	615
Dipole factor (dBm-dBu)	K_d	-111.8	-120.8	-130.8
Dipole factor adjustment	K_a	none	none	see text
Thermal noise (dBm)	N_t	-106.2	-106.2	-106.2
Antenna Gain (dBd)	G	4	6	10
Downlead line loss (dB)	L	1	2	4
System noise figure (dB)	N_s	10	10	7
Required Carrier to Noise ratio (dB)	C/N	15	15	15

The adjustment, $K_a = 20 \log[615/(\text{channel mid-frequency in MHz})]$, is added to K_d to account for the fact that field strength requirements are greater for UHF channels above the geometric mean frequency of the UHF band and smaller for UHF channels below that frequency. The geometric mean frequency, 615 MHz, is approximately the mid-frequency of channel 38.

The modified Grade B contour of analog UHF stations is determined by applying this same adjustment factor to the Grade B field strength given in Section 73.683 of the rules. With this

dipole factor modification, the field strength defining the Grade B of UHF channels becomes 64 - 20 log[615/(channel mid-frequency in MHz)] dBu, in place of simply 64. Thus the modified Grade B contour for channel 14 is determined by a median field strength of 61.7 dBu, and the value for channel 51 is 66.3 dBu. This modified Grade B contour bounds the area subject to Longley-Rice calculations for analog stations.

The values appearing in Table 2 follow from the planning factors. They are found from Table 3 by solving the equation: Field + K_d + K_a + G - L - N_t - N_s = C/N.

For a new DTV station with a particular authorized set of facilities, the values given in Table 2 will determine the contour within which the FCC will make all subsequent calculations of service and interference.

Reference Value of ERP for DTV Operation

The initial allotment plan, set forth in Appendix B of the *Sixth Report and Order*, establishes a reference value for the effective radiated power (ERP) of DTV stations. This ERP is the maximum of the values needed to match the service contour of the paired analog station in each direction supposing that the new station operates at the same location with the same antenna height. The reference ERP was calculated using the following methodology:

The distance to the existing analog grade B contour was determined in each of 360 uniformly spaced compass directions starting from true north using linear interpolation of available data as necessary. This determination was made using information in the FCC engineering database of April 3, 1997, including directional antenna data, and from terrain elevation data at points separated by 3 arc-seconds of longitude and latitude. FCC curves (Section 73.699 of FCC rules) were applied in the usual way, as described in Section 73.684 of the rules, 47 C.F.R. § 73.684, to find this grade B contour distance, with the exception that dipole factor considerations were applied to the field strength contour for UHF.

Height above average terrain was determined every 45 degrees from terrain elevation data in combination with the height of the transmitter radiation center above mean sea level, and by linear interpolation for compass directions in between. In cases where the Media Bureau Consolidated Database System (CDBS) indicates that a directional antenna is employed, the ERP in each specific direction was determined through linear interpolation of the relative field values describing the directional pattern. (The directional pattern stored in the CDBS provides relative field values at 10 degree intervals and may include additional values in special directions. The result of linear interpolation of these relative field values is squared and multiplied by the overall maximum ERP listed for the station in the CDBS to find the ERP in a specific direction.)

The corresponding values of ERP for DTV in each direction were then calculated by a further application of FCC curves, with noise-limited DTV coverage defined as the presence of the field strengths identified in Table 2 at 50% of locations and 90% of the time. These ERP values were computed for all 360 azimuths using the same radial-specific height above average terrain as for the analog TV case, but now in conjunction with F(50, 90) curves.

Finally, the ERP for DTV was modified so that it does not exceed 1 megawatt and is not less than 50 kilowatts. This was been done by scaling the azimuthal power pattern rather than by truncation. Thus if replication by FCC curves as described above requires an ERP of 2 megawatts, the power pattern is reduced by a factor of 2 in all directions. The resulting ERP is the reference value cited in Section 73.622 of the rules.

DTV Transmitting Antenna Patterns

In general, these computations of DTV power to match the distance to the grade B contour of an analog station result in ERP values which vary with azimuth. For example, the azimuthal ERP pattern which replicates in UHF the grade B contour of an omnidirectional VHF operation will be somewhat distorted because terrain has a different effect on propagation in the two bands. In addition, the 90% time variability allowance for DTV has an effect on the DTV pattern. Thus the procedure described above effectively derives a new directional antenna pattern wherever necessary for a precise match according to FCC curves.

These DTV azimuthal patterns may be calculated using the procedure outlined above. In addition, these patterns are retained in the CDBS. They are available for downloading at http://www.fcc.gov/mb/databases/cdbs, and searches can be made for particular antennas at http://www.fcc.gov/mb/video. The format for describing DTV transmitting antenna patterns is identical to the historical format for analog stations. Relative field values are given at intervals of 10 degrees, and supplemental values are given at special azimuths. For DTV patterns, special azimuths are included where the pattern factor is unity but both bracketing factors at 10-degree azimuths are less.

Application of the Longley-Rice Methodology

The area subject to calculation is divided into rectangular cells, and the Longley-Rice point-to-point propagation model Version 1.2.2 is applied to a point in each cell to determine whether the predicted field strength is above the value found in Table 1 or Table 2, as appropriate. The values identified in those tables are considered to be thresholds for reception in the absence of interference. For cells with population, the point chosen by the FCC computer program is the population centroid; otherwise it is the geometric center; and the point so determined represents the cell in all subsequent service and interference calculations. The station's directional transmitting antenna pattern, if any, is taken into account in determining the ERP in the direction of each cell. Cells 2 kilometers on a side were used to produce the service and interference data appearing in Appendix B of the *Sixth Report and Order*.

Those desiring to implement the Longley-Rice model in their own computer program to make these calculations should consult NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. The report may be obtained from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, by requesting Accession No. PB 82-217977.

Parameter values set in the Longley-Rice Fortran code as implemented by the FCC are given in Table 4. In addition to these parameters, execution of the code requires a specification of the percent of time and locations at which the predicted fields will be realized or exceeded, and a third percentage identifying the degree of confidence desired in the results. To predict DTV service at cells of the area subject to calculation, the FCC sets the location variability at 50% and the time variability at 90%. The percent confidence is set at 50% indicating that we are interested in median situations. All of these values are the same as the ones used in the computer program developed in the years 1996-1997 by an industry group, the Broadcasters' Caucus, to evaluate various DTV allotment tables.

Table 4

Parameter Values Used in FCC Implementation of the Longley-Rice Fortran Code

Parameter	Value	Meaning/Comment
EPS	15.0	Relative permittivity of ground.
SGM	0.005	Ground conductivity, Siemens per meter.
ZSYS	0.0	Coordinated with setting of EN0. See page 72 of NTIA Report.
EN0	301.0	Surface refractivity in N-units (parts per million).
IPOL	0	Denotes horizontal polarization.
MDVAR	3	Code 3 sets broadcast mode of variability calculations.
KLIM	5	Climate code 5 for continental temperate.
HG(1)	see text	Height of the radiation center above ground.
HG(2)	10 m	Height of TV receiving antenna above ground.

HG(1) in Table 4 is the height of the radiation center above ground. It is determined by subtracting the ground elevation above mean sea level (AMSL) at the transmitter location from the height of the radiation center AMSL. The latter is found in the CDBS while the former is retrieved from the terrain elevation database as a function of the transmitter site coordinates also found in the CDBS. If the coordinates are wrong, the antenna may be seen as under ground. This shouldn't happen, but if it does the FCC computer program replaces the radiation center height AMSL with the ground elevation at the given coordinates plus the height above average terrain found for the station in the CDBS.

Finally, terrain elevation data at uniformly spaced points the between transmitter and receiver must be provided. The FCC computer program is linked to a terrain elevation database with values every 3 arc-seconds of latitude and longitude. The program retrieves elevations from this database at regular intervals with a spacing increment which is chosen at the time the program is compiled; the

computer runs that evaluated service and interference for the *Sixth Report and Order* used a spacing increment of 1 kilometer. The elevation of a point of interest is determined by linear interpolation of the values retrieved for the corners of the coordinate rectangle in which the point of interest lies.

Evaluations of service coverage and interference using finer spacing increments are expected to be consistent with those using 1 kilometer. Evaluations using cells smaller than 2 km on a side are also expected to be consistent with the evaluations given in Appendix B of *Sixth Report and Order*.

III. PART 2: EVALUATION OF INTERFERENCE

The presence or absence of interference in each grid cell of the area subject to calculation is determined by further application of Longley-Rice. Radio paths between undesired TV transmitters and the point representing each cell are examined. The undesired transmitters included in the analysis of each cell are those which are possible sources of interference at that cell, considering their distance from the cell and channel offset relationships. For each such radio path, the Longley-Rice procedure is applied for median situations (that is, confidence 50%), and for 50% of locations, 10% of the time.

The interference analysis examines only those cells that have already been determined to have a desired field above the threshold for reception given in Table 1 for analog stations and Table 2 for DTV stations. A cell being examined is counted as having interference if the ratio of the desired field to that of any one of the possible interference sources is less than a certain critical minimum value. The comparison is made after applying the discrimination effect of the receiving antenna. The critical value is a function of the channel offset relationship.

Cells of the area subject to calculation for an analog station are examined first as to whether the desired signal is above the threshold for reception, second with regard to whether there is interference from another analog station, and finally as to whether there is interference from DTV stations. Thus a DTV station does not cause interference to analog stations in places where there is no service because of a weak desired signal, or in places where interference from other analogue stations already exists.

D/U Ratios

Criteria for the ratio of desired to undesired field strength are specified in Section 73.623 of FCC rules for interference involving DTV stations as desired or undesired. These criteria are summarized in Tables 5A, 5B, and 5C.

Tables 5A, 5B, and 5C also include the criteria for interference between analog stations used in preparing the service and interference evaluation in Appendix B of the *Sixth Report and Order*. The FCC continues to apply an analog-into-analog interference analysis using these criteria for consistency with the *Sixth Report and Order*. DTV stations are therefore allowed to modify their facilities without consideration of possible interference to analog stations where interference from other analog stations already exists.

Table 5A

Interference Criteria for Co- and Adjacent Channels[1]

Channel Offset	D/U Ratio, dB			
	Analog into Analog	DTV into Analog	Analog into DTV	DTV into DTV
-1 (lower adjacent)	-3	-14	-48	-28
0 (co-channel)	+28	+34	+2	+15
+1 (upper adjacent)	-13	-17	-49	-26

The evaluation of service and interference in Appendix B of the *Sixth Report and Order* considered taboo channel relationships for interference into DTV. However, the D/U ratios (approximately -60 dB) were such that they rarely if ever had an effect on the results, and the FCC rules adopted in the *Sixth Report and Order* do not require attention to UHF taboo interference to DTV stations.

The D/U ratios for co-channel interference to DTV service in Table 5A are only valid at locations where the signal-to-noise ratio is 28 dB or greater for interference from DTV and 25 dB or greater for interference from analog TV service. At the edge of the noise-limited service area, where the signal-to-noise (S/N) ratio is 16 dB, the co-channel D/U ratios are 21 dB and 23 dB for interference from analog TV and DTV, respectively. At locations where the S/N ratio is greater than 16 dB but less than 28 dB, D/U values for co-channel interference to DTV are as follows:

To protect DTV reception from DTV co-channel interference, minimum D/U ratios are computed from the following formula:

$$D/U = 15 + 10\log_{10}[1.0/(1.0-10^{-x/10})], \qquad \text{where } x = S/N - 15.19 \text{ dB}.$$

The quantity x is the amount by which the actual desired S/N exceeds the minimum required for DTV reception.

To protect DTV reception from analog co-channel interference, minimum D/U ratios are found from Table 5B. Use linear interpolation for S/N values between those given in the table.

[1] The adjacent-channel D/U ratios given in this table for interference from DTV transmissions are corrections of those published with the July 1997 version of this bulletin. The values given here agree with those used in the *Sixth Report and Order* and with the computer program now used by the Media Bureau to evaluate applications for new and modified stations as well as predecessors of that program.

Table 5B

Minimum Co-channel D/U Ratios for Analog Interference to DTV

DTV Signal-to-Noise Ratio (S/N) in the Absence of Interference, dB	Desired-to-Undesired Ratio to Protect DTV reception from Co-channel Analog Transmissions, dB
16.00	21.00
16.35	19.94
17.35	17.69
18.35	16.44
19.35	7.19
20.35	4.69
21.35	3.69
22.35	2.94
23.35	2.44
25.00	2.00

Receiving Antenna Pattern

The receiving antenna is assumed to have a directional gain pattern which tends to discriminate against off-axis undesired stations. This pattern is a planning factor affecting interference. The specific form of this pattern was chosen by a working group of the FCC Advisory Committee for Advanced Television Service. It is built into the service and interference computer program developed by the Broadcasters' Caucus and also used in the FCC program.

The discrimination, in relative volts, provided by the assumed receiving pattern is a fourth-power cosine function of the angle between the lines joining the desired and undesired stations to the reception point. One of these lines goes directly to the desired station, the other goes to the undesired station. The discrimination is calculated as the fourth power of the cosine of the angle between these lines but never more than represented by the front-to-back ratios identified in Table 6. When both desired and undesired stations are dead ahead, the angle is 0.0 giving a cosine of unity so that there is no discrimination. When the undesired station is somewhat off-axis, the cosine will be less than unity bringing discrimination into play; and when the undesired station is far off axis, the maximum discrimination given by the front-to-back ratio is attained.

Table 5C

Interference Criteria for UHF Taboo Channels

(NC means Not Considered)

Channel Offset Relative to Desired Channel N	D/U Ratio, dB			
	Analog into Analog	DTV into Analog	Analog into DTV	DTV into DTV
N - 8	-32	-32	NC	NC
N - 7	-30	-35	NC	NC
N - 4	NC	-34	NC	NC
N - 3	-33	-30	NC	NC
N - 2	-26	-24	NC	NC
N + 2	-29	-28	NC	NC
N + 3	-34	-34	NC	NC
N + 4	-23	-25	NC	NC
N + 7	-33	-43	NC	NC
N + 8	-41	-43	NC	NC
N + 14	-25	-33	NC	NC
N + 15	-9	-31	NC	NC

Table 6

Front-to-Back Ratios Assumed for Receiving Antennas

TV Service	Front-to-Back Ratios, dB		
	Low VHF	High VHF	UHF
Analog	6	6	6
DTV	10	12	14

IV. PART 3: THE FCC LONGLEY-RICE COMPUTER PROGRAM

The FCC computer program is available as Fortran code. It is complex, and many of its options are available only by recompilation for each case of interest. The individual installing it should have computer programming skills and experience as a system administrator of the computer system on which it is to be installed because linking the data files, which occupy 1.6 gigabytes of disk space, will be a site-specific task. The FCC compiles and runs the program on Sun Microsystem Enterprise 3500 and UltraSPARC computers. The Fortran code currently used by the Media

Bureau to evaluate new proposals is available for downloading from the FCC internet site at http://www.fcc.gov/oet/dtv, and the code used to produce the information presented in Appendix B of the *Sixth Report and Order* is also available there.

Outline of Evaluation Procedure

The examination of each station proceeds as follows:

1) The area subject to calculation is boxed in latitude and longitude. This is performed by proceeding around the compass and finding the latitude and longitude of points at 5 degree azimuth increments on the bounding contour. The maxima and minima of the resulting list of latitudes and longitudes determine a coordinate box.

2) The coordinate box is divided into square cells of a chosen size which should be 2 km on a side or smaller, adjusting the coordinate box to be slightly larger if necessary to accommodate an integer number of cells. The cells must be an integer number of latitude seconds high and an integer number of longitude seconds wide.

3) The coordinates of census blocks falling inside each cell are retrieved along with the population of each block. From this information the total population and the coordinates of the cell centroid are determined for each cell.

4) The Longley-Rice propagation model is then applied as in Part 1, Evaluation of Service, and Part 2, Evaluation of Interference. The output information is organized as shown in Figure 1.

Longley-Rice Parameters

See Table 4 and accompanying text.

Identification of Potentially Interfering Stations

Stations that may be a source of interference are identified as a function of distance and channel relationships. This is performed independently for each cell. Only those stations whose distance from the cell of interest is less than the value given in Table 7 are considered as potential sources of interference.

Figure 1

Form of FCC Longley-Rice Program Output

```
  Analysis of Analog Station IL SOME CITY, Channel 9
                                POPULATION   AREA (sq km)
within Noise Limited Contour      610288      14667.4
not affected by terrain losses    604312      14165.4
lost to NTSC IX                        0          0.0
lost to additional IX by DTV           0          4.0
lost to all IX                         0          4.0

  Analysis of DTV Station IL SOME CITY, Channel 32
                                POPULATION   AREA (sq km)
within Noise Limited Contour      610288      14667.4
not affected by terrain losses    606241      14378.2
lost to NTSC IX                     1347         84.3
lost to additional IX by DTV         425         44.2
lost to DTV IX only                  425         44.2
lost to all IX                      1772        128.5
```

Table 7

Culling of Undesired Stations

(NC means Not Considered; it is presumed that stations at the indicated offset do not cause interference even though they may be close in distance to the cell of interest.)

Offset Relative to Desired Channel N	Undesired Channel	Maximum Distance from Cell to Undesired Stations, km			
		Analog Into Analog	Digital into Analog	Analog into Digital	Digital into Digital
-8	N - 8	35.0	35.0	NC	NC
-7	N - 7	100.0	35.0	NC	NC
-4	N - 4	NC	35.0	NC	NC
-3	N - 3	35.0	35.0	NC	NC
-2	N - 2	35.0	35.0	NC	NC
-1	N - 1	100.0	100.0	100.0	100.0
0	N	300.0	300.0	300.0	300.0
+1	N + 1	100.0	100.0	100.0	100.0
+2	N + 2	35.0	35.0	NC	NC
+3	N + 3	35.0	35.0	NC	NC
+4	N + 4	35.0	35.0	NC	NC
+7	N + 7	100.0	35.0	NC	NC
+8	N + 8	35.0	35.0	NC	NC
+14	N + 14	100.0	35.0	NC	NC
+15	N + 15	125.0	35.0	NC	NC

Transmitting Antenna Patterns

The vertical patterns used in the FCC computer program are shown in Table 8. They represent typical patterns. These patterns were used in computing the evaluation of service and interference in Appendix B of the *Sixth Report and Order* and continue to be used in the Media Bureau computer program for evaluating applications for new and modified stations.

Table 8

Vertical Pattern Assumed for Transmitting Antennas

ANGLE, Degrees	Gain in Vertical Plane (expressed as relative field strength)				
	Low VHF Analog and DTV	High VHF		UHF	
		Analog	DTV	Analog	DTV
0.75	1.000	1.000	1.000	1.000	1.000
1.50	1.000	0.950	0.970	0.740	0.880
2.00	0.990	0.860	0.940	0.520	0.690
2.50	0.980	0.730	0.890	0.330	0.460
3.00	0.970	0.600	0.820	0.220	0.260
3.50	0.950	0.470	0.730	0.170	0.235
4.00	0.930	0.370	0.650	0.150	0.210
5.00	0.880	0.370	0.470	0.130	0.200
6.00	0.820	0.370	0.330	0.110	0.150
7.00	0.740	0.370	0.280	0.110	0.150
8.00	0.637	0.310	0.280	0.110	0.150
9.00	0.570	0.220	0.280	0.110	0.150
10.00	0.480	0.170	0.250	0.110	0.150