Television Field Strength[1] Prediction and Measurement

Introduction:

In the form of a 6th Report and Order, adopted April, 3 1997, the Federal Communications Commission (FCC) has issued channel assignments and determined maximum and minimum power levels for VHF and UHF Digital Television (DTV)[2] stations. The television industry has embraced this new technology with a fervor and financial commitment which is unmatched in the annals of broadcasting. New facilities are now under construction throughout the US. As of this writing, some 1693 new commercial and non-commercial stations are expected to be transmitting regularly scheduled digital television programming by 01 May 2003. Further, subject to the availability of suitable DTV reception equipment, the existing National Television System Committee (NTSC) analog television service is slated to terminate in the year 2006.

During the transition period DTV and NTSC service will coexist in the radio frequency (RF) spectrum which is currently allocated to NTSC television channels. Broadcast licensees' new DTV channel assignments are intended to replicate, to the extent practicable, existing NTSC broadcast coverage areas.

Before discussing the challenges of DTV field strength measurements, it may be worthwhile to briefly review certain VHF and UHF propagation concepts and an industry knowledge base that has evolved from 50 years of terrestrial analog television broadcasting.

PREDICTION

NTSC Predicted Coverage and Field Strength

An NTSC picture is most often evaluated on the basis of a "graceful degradation" due to an ever increasing video artifact which stems from random noise, RF interference, and other propagation anomalies as distance (from the TV transmitter) is increased. A subjective "impairment" rating consisting of five levels of picture quality is used to grade the NTSC picture. A perfect picture is a level 5 picture and a level 1 picture is considered non-viewable.

FCC Technical Standards imply an approximate relationship between picture quality and inverse

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[1] The National Institute of Standards and Technology (NIST) has determined that the term "field strength" relates specifically to the voltage component of field power which is, in turn, referred to as "field intensity."

[2] DTV refers to any technology that uses digital techniques to provide advanced television services such as High Definition TV (HDTV), multiple standard definition TV (SDTV), and other advanced features and services.

distance field strength (absent interference from other sources and assuming average terrain gradations) in the form of published propagation prediction curves derived through computer modeling. These same standards define the unit of measure for field strength as dBuV/M or dB above one microvolt per meter. These propagation curves are used to construct field strength contour maps that predict coverage over average terrain in the absence of interference from other television stations. Experience shows that, under actual conditions, the presence of trees, buildings, and terrain irregularities frequently result in large measured variations from location to location even within relatively small areas.

The following table depicts NTSC compliant median F (50,50) signal level contours as specified by FCC Technical Standards:

	City Grade		Grade A		Grade B	
	mV/M	dBuV/M	mV/M	dBuV/M	mV/M	dBuV/M
Channels 2 - 6	5.0	74.0	2.5	68.0	0.2	47.0
Channels 7 - 13	7.1	77.0	3.6	71.0	0.6	56.0
Channels 14 - 83	10.0	80.0	5.0	74.0	1.6	64.0

Table 1
NTSC requirements for City Grade, Grade A, and Grade B field strength contours

Coverage as set forth in Table 1 represents the minimum median value of field strength that would be imposed on a receiving antenna which is positioned at a height of 30 ft. above ground, at a specified distance from a NTSC transmitter. It is further assumed that the source transmitting antenna is positioned at a specific elevation above average terrain and that it is transmitting at a specific power level. (It is important to note that, although reasonably accurate field strength measurements may be obtained at receiving antenna elevations of less than 30 feet using appropriate antenna calibration factors, it is not possible to infer 30 ft. field strength values through interpolation of data obtained in that mode.)

Even though the FCC requires the use of its F (50,50) curves in predicting the distance to the field strength contours, it also cautions that the prediction curves are to be used with an appreciation of their limitations in estimating levels of field strength. Further, it should be clearly understood that the quality of NTSC service at any given location is a function not only of field strength it is also a function of receiver noise figure and sensitivity, receiving antenna gain and orientation, transmission line loss, and spurious RF emissions. However, for purposes of standardization and station authorization the F (50,50) charts have proven to be a valuable first approximation prediction tool.

The F (50,50) field strength curves are predicated upon statistical mean and standard deviation calculations which determine the mean field strength value that will be meet or exceeded at the best 50% of the locations for at least 50 % of the time. This methodology would imply that if one

were to attempt to prove (or disprove) the Grade B contour arc of a given station by measuring field strength with a horizontally polarized antenna positioned 30 feet above ground level, in one degree azimuthal increments, one would expect to see at least 180 locations (out of 360) exhibiting the predicted mean field strength at least 50% of the time. These prediction charts are based on an effective power of 1 kW radiated from a half-wave dipole in free space, which produces an unattenuated field strength at 1 mile of about 103 dB above 1 mV/M and they can be readily scaled to accommodate different power levels, depression angles, antenna gain, topography, etc.

In addition to the F (50,50) curves for Channels 2 - 6 (Low V), 7-13 (High V) and 14-83 (UHF) the FCC Technical Standards contain F (50,10) prediction curves (estimated field strength exceeded at 50% of potential receiver locations for at least 10% of the time) for each of the same 3 frequency bands. It follows then, that the coverage area which is bounded by the F (50,10) delimiters is greater than the area bounded by the F (50,50) delimiters. (The area beyond the Grade B contour is some-times referred to as the deep fringe area in the terrestrial broadcast industry.)

DTV Predicted Field Strength

Because of the, much discussed, Cliff Effect[3] of the 8-VSB[4] DTV platform it was determined that, for propagation planning purposes, the mean 8-VSB Threshold of Visibility (TOV)[5] field strength con-tours would be predicated upon the probability that the best 50% of receiving locations would receive a viewable signal for at least 90% of the time. The F (50,90) values are lower than the F (50,50) values) by the same amount that F (50,10) values are higher than the F (50,50) values as derived from the following formula: F(50, 90) = F(50, 50) - [F(50, 10) - F(50, 50)]. Of course, because of the nature of the digital modulation scheme, all receiving locations capable of attaining at least a TOV signal would be presumed to exhibit the same "studio quality" picture.

Table 2 illustrates the application of various planning factors that were included in the FCC

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[3] The phrase used to describe the point at which an abrupt total loss of picture and sound occurs and which exists when the combination of noise, interference and or propagation anomalies exceed a given receiver's ability to receive and decode the 8-VSB signal. (As in "Falling off a Cliff.")

[4] The vestigial sideband modulation format in which eight discrete levels of sideband amplitude are transformed into three bits of digital data per symbol period (92.9 nanoseconds).

[5] Defined as the Carrier to Noise + Interference ratio (currently 15.2 dB) which is required to pro-duce, at the input of the receiver's digital decoder, a digital bit stream of sufficient quality so as to be properly decoded and transformed into coherent program material output. Further empirically defined as 2.5 segment errors per second (SER) based upon the Advisory Committee on Advanced Television Service (ACATS) tests.

computer model and applied to Version 1.2.2 of the Longley-Rice propagation model to deter
mine DTV minimum field strength contour levels. The values shown were computed at the geometric
mean frequency of each band:

	Low VHF	High VHF	UHF
Assumed thermal noise floor in 6 MHz bandwidth	-106.2 dBm	-106.2 dBm	-106.2 dBm
Plus assumed minimum TOV carrier to noise ratio	15.0 dB	15.0 dB	15.0 dB
Plus assumed Noise figure of RF tuner	10.0 dB	10.0 dB	7.0 dB
Equals required field intensity at receiving antenna	-81.2 dBm	-81.2 dBm	-84.2 dBm
Plus dipole conversion factor (dBm to dBu)	111.8 dB	120.8 dB	130.8 dB
Equals required field strength at receiving antenna	30.6 dBu	39.6 dBu	46.6 dBu
Less assumed receive antenna gain	-4.0 dB	-6.0 dB	-10.0 dB
Plus assumed receive transmission line loss	1.0 dB	2.0 dB	4.0 dB
Equals minimum planning factor field strength	27.6 dBu	35.6 dBu	40.6 dBu

Table 2
DTV Computer Modeling Planning Factors

It is interesting to note that, in Table 2, if the Carrier to Noise numbers are all set to 35 dB and all
receiver noise figures are set to equal 10 dB, then the calculated minimum field strengths for each
frequency band falls to within 1 dB of the minimum values published for the F (50,50) NTSC Grade
B contours at those same frequencies as shown in Table 1.

For the DTV table of channel and power allotments set forth in Appendix B of Memorandum Opinion
and Order on Reconsideration of the Sixth Report and Order in MM Docket 87-286 adopted Febru-
ary 17, 1998, the Longley-Rice propagation prediction model was used to predict field strength
contours over a 360 degree arc from an assumed transmitter location.   The predicted field strength
values were derived using the DTV planning factors listed in Table 3.

First the distance to the Grade B contour for the existing NTSC facility was defined using data from
the FCC Engineering Data Base. Next, variables were established for average terrain data and direc-
tional antenna patterns also using data from appropriate FCC Engineering Data Bases. These vari-
ables were then included as part of an iterative calculation employing the noise-limited F (50,90)
coverage curves to derive corresponding values of ERP necessary to match the Grade B service
contour of the existing NTSC station with the assumption that the DTV station would operate from
the same geographic location and the same antenna height. Finally all DTV coverage contours were
truncated and scaled, if necessary, to restrict transmitted ERP to levels of not more than 1 megawatt
nor less than 50 kilowatts.

The Longley-Rice point-to-point propagation model used by the FCC allows for the coverage area to
be subdivided into a row and column type grid. Further, it allows for the selection of any point within
a given 4 square kilometer grid cell as the point of determination for reception threshold coverage

calculations. The point of coverage determination becomes the center of population density for cells with population. Otherwise, the FCC program defaults to a point representing the geographical center of a given cell to establish predicted coverage for that cell area. The initial determination point for each cell shall be deemed to be the cell reference point for subsequent calculations relating to coverage and / or interference.

MEASUREMENT

NTSC Measurements

Field strength measurements have been a fact of life in NTSC broadcasting from the beginning, as a means of propagation analysis, as a means of showing the level of service to a community, and as a means of showing interference levels. FCC Rules Sec. 73.686 (see Appendix A) sets out detailed requirements and procedures for these measurements, including the well-known "100-foot run" to show multipath and other propagation effects, at an antenna height of 30 feet. The field strength to be measured is that of the visual carrier, measured at its peak amplitude during the synchronizing signal. A tuneable, narrow-bandwidth voltmeter must be used; it must be tuneable and narrow-band to reject unwanted signals but wide enough in bandwidth to allow the synchronization pulse to reach peak amplitude. A baseband peak detector holds the peak amplitude long enough for measurement. Examples of such instruments are the Potomac Instruments FIM-71 Field Strength Meter for VHF and the FIM-72 for UHF. For the measuring antenna, the only FCC requirements are that it be for horizontal polarization and that it have calibration data. A half-wave dipole with direct NIST calibration, such as the Potomac ANT-71 (VHF) and ANT-72 (UHF), is usually used. A more directional, higher-gain antenna may be desirable for some measurements but obtaining accurate calibration data for it can be a formidable task.

DTV Measurements

Measurement of the received DTV signal needs to be done for at least two main purposes. The first and most urgent is to establish where and why a stations's transmission cannot be reliably received. The station needs to know this in order to consider remedial action and to advise its viewers on receiving antennas. The second, more long-term, is to compare actual coverage to predicted coverage with the hope of improving the propagation model. The question then arises, what sort of measurements can accomplish these purposes?

Measurements are now being done using well-equipped test vans such as those used at WHD in Washington, DC and at WRAL-HD in Raleigh, NC, based on the design used for ACATS testing at Charlotte, NC. The WRAL-HD Test Report describes the van design. These vans directly measure margin[6] for an antenna height of 30 feet based upon obtaining an acceptable segment

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[6] The unit of measure for the dB difference, at a given location, by which available signal level exceeds the minimum signal level for a veiwable picture (the Threshold of Visability or (TOV).

error rate for a period of ten minutes. They also measure field strength using the HP 89440 Vector Network Analyzer with its ability to measure the total received power in the channel. The severity of multipath propagation is evaluated by measuring the receiver equalizer tap energy. These measurements, thorough and valuable as they are, are time-consuming, taking perhaps 1/2 hour per point, and are by the very nature of spot measurements, not giving a complete picture of coverage. It is worth noting that, in the test van design used at WRAL, measurements could not be made at field strengths below +46.6 dBuV/M. Complete coverage measurements would have required measurements down to the minimum field strength given by the FCC planning factors for UHF. It is possible, however, that +41 dBuV/M, may when all is said and done, turn out to be unrealistically low.

Present owners of NTSC-based field strength meters such as the FIM-71 and FIM-72 may question their usefulness for DTV signal measurement. Another Potomac Instruments paper, attached as Appendix B, deals with this subject in detail. These meters can be used as long as care is exercised to deal with multipath propagation effects. The 100-foot run is useful here; at UHF, where path-length difference between direct and reflected signal paths may be several wavelengths. Under these conditions signal notches due to multipath are narrow in frequency, and observing field strength over distance at a fixed frequency gives amplitude variations similar to those seen when observing field strength over frequency (the channel width) at a fixed location. In DTV there is no carrier to measure comparable to the NTSC visual carrier, but the FIM can still measure a noise-like signal in its average detection mode. At low VHF frequencies the situation differs in that path-length differences may be a fraction of a wavelength, resulting in a slow variation of amplitude with distance or with frequency and a tilt in the channel frequency response.

For the next generation DTV field strength measuring system, one objective is to be able to make rapid, continuous measurements in a moving vehicle in order to collect a large amount of coverage data in a reasonable time. To measure coverage it is preferable to determine margin, rather than determining field strength alone, because it tells more about whether a picture can be received. Potomac Instruments, inc. hopes to devise an empirical scheme for doing this by combining field strength measurements with a measure of multipath severity and a measure of noise (including manmade noise and interference).

 A simple way to obtain a measure of multipath at UHF is to measure the DTV pilot carrier amplitude variation over distance. Because the pilot carrier is fixed in frequency and amplitude at the transmitter, it can be measured through a narrow bandwidth for noise rejection. The envelope of pilot variation observed in a moving vehicle is greater when larger reflected signals are received; the envelope amplitude is therefore a measure of multipath severity. Noise can be measured in a nearby empty channel, although an empty channel may be hard to find during the NTSC-DTV transition period. Field strength can be measured by directly measuring the total channel voltage through a filter which might have a 1 dB bandwidth of 5 MHz and be down 30 to 40 dB at the channel edges. It could also be measured by sweeping a narrow filter across the channel width while integrating the filter output, as in a spectrum analyzer.

A system incorporating these features would, of course, be controlled by a notebook computer which would also serve as the data storage device. The computer would also receive location data from a GPS receiver with DGPS capability for improved accuracy. The data file would consist of measured field strength and computed margin with latitude and longitude for each measurement, and measurements would be automatically executed at preset distance or time intervals. For analysis, the data could be imported into a map program to give a display of coverage. Coverage prediction data could be also be overlaid on to the same map, by the same program, for comparison.

A limitation of this proposed system is that for measurements in a moving vehicle the antenna height can be no more than 8-10 feet. The antenna would have to be automatically aimed at the transmitter at all times or would have to be omnidirectional. The field strength in its vicinity would be subject to influences not typical of adjacent home indoor or outdoor receiving antenna locations. Therefore, a method of relating such measurements to actual receiving experience would be needed. Nevertheless, such a system should be able to give large quantities of useful data on major coverage problems. The automatic features of the system would also facilitate making 100-foot runs at an antenna height of 30 feet.

If the purpose of measurements is to determine coverage, it is important to know what additional factors to add in order to account for changes in field strength with such variables as season of the year, time of day, and weather. A system like the one described which collects data automatically will be useful in accumulating the information needed to quantify these factors.

The measurement hardware should be portable and of modular construction so that field strength measurements at multiple frequencies and dissimilar modulation formats (employing multiple instrumentation packages) can be conducted simultaneously from a mobile platform by a single operator. The measurement system should also be capable of prolonged unattended stationary operation and remote interrogation.

Potomac Instruments' engineering department is currently developing a DTV / NTSC measuring system based on the approach discussed here. Measurements are being conducted to verify the feasibility of the proposed method of margin measurement, and it is planned to demonstrate the concept at NAB99.

Potomac Instruments, inc.   11-30-98

REFERENCES

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Appendix A

Part 73, § 73.686 of the FCC Rules and Regulations

§ 73.686 Field strength measurements.

   (a) Except as provided for in § 73.612, television broadcast stations shall not be protected from any type of interference or propagation effect. Persons desiring to submit testimony, evidence or data to the Commission for the purpose of showing that the technical standards contained in this subpart do not properly reflect the levels of any given type of interference or propagation effect may do so only in appropriate rulemaking proceedings concerning the amendment of such technical standards. Persons making field strength measurements for formal submission to the Commission in rulemaking proceedings, or making such measurements upon the request of the Commission, shall follow the procedure for making and reporting such measurements outlined in paragraph (b) of this section. In instances where a showing of the measured level of a signal prevailing over a specific community is appropriate, the procedure for making and reporting field strength measurements for this purpose is set forth in paragraph (c) of this section.

   (b) Collection of field strength data for propagation analysis.

   (1) *Preparation for measurements*.   (i) On large scale topographic maps, eight or more radials are drawn from the transmitter location to the maximum distance at which measurements are to be made, with the angles included between adjacent radials of approximately equal size. Radials should be oriented so as to traverse representative types of terrain. The specific number of radials and their orientation should be such as to accomplish this objective.

   (ii) At a point exactly 16.1 kilometers (10 miles) from the transmitter, each radial is marked, and at greater distances at successive 3.2 kilometer (2 mile) intervals. Where measurements are to be conducted at UHF, or over extremely rugged terrain, shorter intervals may be employed, but all such intervals shall be of equal length. Accessible roads intersecting each radial as nearly as possible at each 3.2 kilometer (2 mile) marker are selected. These intersections are the points on the radial at which measurements are to be made, and are referred to subsequently as measuring locations. The elevation of each measuring location should approach the elevation at the corresponding two mile marker as nearly as possible.

   (2) *Measurement procedure*. The field strength of the visual carrier shall be measured with a voltmeter capable of indicating accurately the peak amplitude of the synchronizing signal. All measurements shall be made utilizing a receiving antenna designed for reception of the horizontally polarized signal component, elevated 9.1 meters (30 feet) above the roadbed. At each measuring location, the following procedure shall be employed.

   (i) The instrument calibration is checked.

   (ii) The antenna is elevated to a height of 30 feet.

(iii) The receiving antenna is rotated to determine if the strongest signal is arriving from the direction of the transmitter.

(iv) The antenna is oriented so that the sector of its response pattern over which maximum gain is realized is in the direction of the transmitter.

(v) A mobile run of at least 30.5 meters (100 feet) is made, which is centered on the intersection of the radial and the road, and the measured field strength is continuously recorded on a chart recorder over the length of the run.

(vi) The actual measuring location is marked exactly on the topographic map, and a written record, keyed to the specific location, is made of all factors which may affect the recorded field, such as topography, height and types of vegetation, buildings, obstacles, weather, and other local features.

(vii) If, during the test conducted as described in paragraph (b) (2) (iii) of this section, the strongest signal is found to come from a direction other than from the transmitter, after the mobile run prescribed in paragraph (b) (2) (v) of this section is concluded, additional measurements shall he made in a "cluster" of at least five fixed points. At each such point, the field strengths with the antenna oriented toward the transmitter, and with the antenna oriented so as to receive the strongest field, are measured and recorded. Generally, all points should be within 61.0 meters (200 feet) of the center point of the mobile run.

(viii) If overhead obstacles preclude a mobile run of at least 30.5 meters (100 feet), a "cluster" of five spot measurements may be made in lieu of this run. The first measurement in the cluster is identified. Generally, the locations for other measurements shall be within 61.0 meters (200 feet) of the location of the first.

(3) *Method of reporting measurements*. A report of measurements to the Commission shall be submitted in affidavit form, in triplicate, and should contain the following information:

(i) Tables of field strength measurements, which, for each measuring location, set forth the following data:

(A) Distance from the transmitting antenna.
(B) Ground elevation at measuring location.
(C) Date, time of day, and weather
(D) Median field in dBu for 0 dBk, for mobile run or for cluster, as well as maximum and minimum measured field strengths.
(E) Notes describing each measuring location.

(ii) U.S. Geological Survey topographic maps, on which is shown the exact location at which each measurement was made. The original plots shall be made on maps of the largest available scale. Copies may be reduced in size for convenient submission to the Commission, but not to the extent

that important detail is lost. The original maps shall be made available, if requested. If a large number of maps is involved, an index map should be submitted.

(iii) All information necessary to determine the pertinent characteristics of the transmitting installation, including frequency, geographical coordinates of antenna site, rated and actual power output of transmitter, measured transmission line loss, antenna power gain, height of antenna above ground, above mean sea level, and above average terrain. The effective radiated power should be computed, and horizontal and vertical plane patterns of the transmitting antenna should be submitted.

(iv) A list of calibrated equipment used in the field strength survey, which, for each instrument, specifies its manufacturer, type, serial number and rated accuracy, and the date of its most recent calibration by the manufacturer, or by a laboratory. Complete details of any instrument not of standard manufacture shall be submitted.

(v) A detailed description of the calibration of the measuring equipment, including field strength meters, measuring antenna, and connecting cable.

(vi) Terrain profiles in each direction which measurements were made, drawn on curved earth paper for equivalent 4/3 earth radius, of the largest available scale.

(c) Collection of field strength data to determine television service in specific communities.

(1) *Preparation for measurement*. (i) The population (P) of the community, and its suburbs, if any, is determined by reference to an appropriate source, e.g., the 1970 U.S. Census tables of population of cities and urbanized areas.

(ii) The number of locations at which measurements are to be made shall be at least 15, and shall be approximately equal to 0.1 (P)l/2, if this product is a number greater than 15.

(iii) A rectangular grid, of such size and shape as to encompass the boundaries of the community is drawn on an accurate map of the community. The number of line intersections on the grid included within the boundaries of the community shall be at least equal to the required number of measuring locations. The position of each intersection on the community map determines the location at which a measurement shall be made.

(2) *Measurement procedure*. The field strength of the visual carrier shall be measured, with a voltmeter capable of indicating accurately the peak amplitude of the synchronizing signal. All measurements shall be made utilizing a receiving antenna designed for reception of the horizontally polarized signal component, elevated 9.1 meters (30 feet) above street level.

(i) Each measuring location shall be chosen as close as feasible to a point indicated on the map, as previously prepared, and at as nearly the same elevation as that point as possible.

(ii) At each measuring location, after equipment calibration and elevation of the antenna, a check is made to determine whether the strongest signal arrives from a direction other than from the transmitter.

(iii) At 20 percent or more of the measuring locations, mobile runs, as described in paragraph (b)(2) of this section shall be made, with no less than three such mobile runs in any case. The points at which such mobile measurements are made shall be well separated. Spot measurements may be made at other measuring points.

(iv) Each actual measuring location is marked exactly on the map of the community, and suitably keyed. A written record shall be maintained, describing, for each location, factors which may affect the recorded field, such as the approximate time of measurement, weather, topography, overhead wiring, heights and types of vegetation, buildings and other structures. The orientation, with respect to the measuring location shall be indicated of objects of such shape and size as to be capable of causing shadows or reflections. If the strongest signal received was found to arrive from a direction other than that of the transmitter, this fact shall be recorded.

(3) *Method of reporting measurements*. A report of measurements to the Commission shall be submitted in affidavit form, in triplicate, and should contain the following information:

(i) A map of the community showing each actual measuring location, specifically identifying the points at which mobile runs were made.

(ii) A table keyed to the above map, showing the field strength at each measuring point, reduced to dBu for the actual effective radiated power of the station. Weather, date, and time of each measurement shall be indicated.

(iii) Notes describing each measuring location.

(iv) A topographic map of the largest available scale on which are marked the community and the transmitter site of the station whose signals have been measured, which includes all areas on or near the direct path of signal propagation.

(v) Computations of the mean and standard deviation of all measured field strengths, or a graph on which the distribution of measured field strength values is plotted.

(vi) A list of calibrated equipment used for the measurements, which for each instrument, specifies its manufacturer, type, serial number and rated accuracy, and the date of its most recent calibration by the manufacturer, or by a laboratory. Complete details of any instrument not of standard manufacture shall be submitted.

(vii) A detailed description of the procedure employed in the calibration of the measuring equipment, including field strength meters measuring antenna, and connecting cable.

Appendix B

MEASURING DIGITAL TELEVISION FIELD STRENGTH
using the
POTOMAC INSTRUMENTS FIM-71 AND FIM-72 FIELD STRENGTH METERS

Cliff Hall, Chief Engineer, Potomac Instruments, Inc.; December 19, 1997

THE DTV SIGNAL AND THE FIMs:

8 VSB DTV transmissions complying with the ATSC Standard [1] are now on the air and many more are coming. For engineers who use the Potomac FIMs to measure NTSC TV field strength the question is, can these FIMs also measure 8 VSB DTV signals? The answer is yes, they can, thanks to these properties of the DTV signal:
 (1) The transmitted power, when averaged over the FIM meter response time (approx. 0.5 s), is distributed uniformly throughout the channel; the spectrum is flat over 4.76 MHz with half-power points 5.38 MHz apart [1, Sec. 4.1; 2, Sec. 9.4]. Because the power is uniformly distributed, the power passed by the FIM's 450 kHz - 3 dB bandwidth can be multiplied by the ratio [5380/450] to give the total channel power at the FIM's input as long as the received spectrum is flat.
 (2) The power passed by the FIM's bandwidth does not vary with picture, sound, or data content when averaged over the meter response time. The power is of course, subject to variations due to multipath, fading, and other propagation effects, and the same methods used to deal with these effects in NTSC VHF and UHF measurements, such as averaging continuous measurements over a 100-ft. distance, must be used for DTV measurements.
 (3) The DTV signal arriving at the FIM detector is noise-like. The FIMs in their average detection mode can correctly indicate the average received rms voltage of such a signal when corrections are applied as explained below. The signal peak-to-average ratio is 6.3 dB or less 99.9% of the time [2, Sec. 9.3]. This is within the FIM's "headroom" capability, so there is no inaccuracy due to peak clipping.

MEASUREMENT PROCEDURES:

Field strength measurements with the FIM-71 and FIM-72 are made as for NTSC TV by setting the switches, setting the frequency, calibrating, orienting the antenna, recording the reading, converting the reading to input voltage in dBu (dBuV across 50W), and adding cable loss and the antenna factor to the input voltage to obtain rms field strength in dBuV/M. DTV requires different switch and frequency settings and additional corrections to use when converting meter readings to input voltage in dBu.

Switch Settings for DTV:
(FIM-71) OSC: OFF   (FIM-72) MODE: REC
(Both) DEMOD: AM   DET: AVG   IF BW: TV   MTR: LIN or LOG

Frequency Setting for DTV:
Frequency is usually set to the channel center; high accuracy is not necessary because the spectrum is flat over more than 4 MHz, except for multipath effects. For the FIM-71, dial accuracy is good enough (with the cursor set using a known frequency) to simply set the dial. If in doubt, tune across the channel, noting the dial points at which the meter reading begins to drop rapidly at the channel edges, and set the dial halfway between these points. This procedure is especially useful for the FIM-72 with its limited dial accuracy. The FIM-72 can also be tuned by switching MODE to GEN OUT and connecting a frequency counter to the OSC OUT connector to read the tuned frequency with high precision and accuracy.

For either FIM, tuning across the band may reveal voltage peaks and valleys due to multipath propagation, and a tuning point giving an estimated average reading can be selected.

Calibrating:
Switch OSC (FIM-71) or MODE (FIM-72) to CAL; switch FULL SCALE to 100mV CAL; adjust GAIN for exactly 0 dB; the same as for NTSC TV.

Reading the Meter:
For easy conversion of readings to voltage values in dBu, record the dB scale reading with sign, and FULL SCALE setting; the same as for NTSC TV.

Converting Readings to Input Voltage:
FIM dB scale readings can be converted to input rms voltage in dBu by the following formulas. A calculation example is also given.

> DTV: FIM input rms voltage is: [(meter dB reading) + D - N + R + 100.0] dBu
> NTSC: [2]   [(meter dB reading) - N + R + 100.0] dBu

> where D is the DTV Correction, 11.7 dB or a user-calculated value (see discussion below);
> N is a noise correction used only for readings taken on the 10uV FULL SCALE range and is 0 for all other ranges (see MEASURING LOW FIELD STRENGTH below); and the FULL SCALE setting determines the value of R.

FULL SCALE	R	A calculation example:
10uV	-80	The FIM's measured -3 dB bandwidth is 478 kHz.
100uV	-60	The DTV Correction is therefore (see discussion below):
1mV	-40	D = 10log(5380/478) + 1.1 = 11.6 dB.
10mV	-20	A DTV signal reads -7.3 dB with FULL SCALE at 1mV.
100mV	0	The FIM input voltage is therefore:
1V	+20	V = [-7.3 + 11.6 - 0 + (-40) + 100.0] = 64.3 dBu.
10V	+40	

The DTV Correction:
The DTV Correction is the sum of three corrections which are all added to the indicated voltage to give the true DTV signal voltage at the FIM input.

One is needed because the DTV signal amplitude fluctuations are noise-like, while the FIM meter is calibrated for a CW signal. It has been determined by measurements that 0.8 dB must be added to readings to give the correct DTV rms voltage.

A second correction is for the power in the DTV pilot carrier, which is 0.31 MHz above the lower channel edge, out of the FIM's passband. It is 11.3 dB below average signal power [1, Sec. 4.3.2], so 0.34 dB must be added for the pilot, giving a rounded-off total of 1.1 dB for the first two corrections.

The third correction is for FIM bandwidth. Since the input power can be considered to be uniformly distributed over 5.38 MHz, while the FIM's nominal 3 dB bandwidth is 450 kHz, the input voltage (less that due to the pilot carrier) is obtained by adding to the reading in dBu the quantity [10log(5380/450)] = 10.8 dB. Adding 1.1 dB for the first two corrections, the overall DTV correction is 11.9 dB.

An error of up to 0.3 dB is possible in the bandwidth correction, however, because the actual -3dB bandwidth of a particular FIM may differ from the nominal value by up to ±30 kHz. To eliminate this error, measure the

FIM's actual -3 dB bandwidth (use a variable-frequency CW signal source having 1 kHz or smaller resolution; determine the frequency difference between the points at which the FIM meter reading drops to 3 dB below the maximum reading). Then calculate the quantity [10log(5380/BW)], where BW is the measured bandwidth in kHz, and add 1.1 dB to the result to obtain the overall correction. Use this figure for D, as shown in the example above, rather than 11.9 dB when converting readings.

The DTV Correction value has been verified by measurements on a DTV source at the experimental station WHD-TV operated by MSTV in Washington, D. C.

Converting Input Voltage to Field Strength:
Field strength in dBuV/M is given by E = V + L + F - A, where V is the FIM input voltage in dBu; L is the cable loss in dB from antenna output to FIM input; and A is the gain in dB of a low-noise RF preamplifier, if used (if not used, A = 0); and F is the antenna factor in dB; the same as for NTSC TV.

MEASURING LOW FIELD STRENGTH:

For DTV the FCC technical standards specify minimum field strength values to be used in defining coverage areas. When measuring such low fields using the ANT-71 or ANT 72 dipole antennas, errors due to FIM internal front-end noise can be appreciable. This can be dealt with in three ways: (1) apply noise correction factors (given below) to readings taken on the 10uV FULL SCALE range, which lowers the measurement threshold for low error approximately 8 dB; (2) use a higher-gain antenna; or (3) add a low-noise amplifier at the antenna terminal. How low can the FIMs measure? Here are calculated results for typical frequencies, with the FCC minimums for comparison.

For low VHF at 69 MHz the FCC minimum is 28 dBuV/M; the FIM-71 with ANT-71 and 34 ft. cable can measure down to 19 dBuV/M with noise corrections. For high VHF at 194 MHz the FCC minimum is 36 dBuV/M; the FIM-71, ANT-71, and cable can measure down to 31 dBuV/M with noise corrections. For UHF at 615 MHz, the FCC minimum is 41 dBuV/M; the FIM-72 with ANT-72 and 34 ft. cable can just measure down to this level with noise corrections; measuring any lower requires a higher-gain antenna or a low-noise amplifier.

Higher-Gain Antennas:
Various higher-gain TV receiving antennas are available which could be considered for field strength measurements, from narrow bandwidth yagi types to broadband log-periodic types.
The main problem in using them is that of calibration. A field calibration can be tried by comparing the antenna to be used against a calibrated dipole such as the ANT-71 or ANT-72, but the results typically vary from one receiving site to another because of differing site conditions and differences in directionality of the antennas being compared. The uncertainty of an antenna factor determined in this way may be 1-2 dB.

Low-Noise Amplifier:
To lower the measurement threshold at UHF, a low-noise RF amplifier can help when placed directly at the ANT-72 dipole output, ahead of the 34 ft. cable. The system noise figure at 650 MHz looking into the 34 ft. cable is approximately 9 dB, made up of the FIM-72's 5 dB noise figure plus cable loss of 4 dB. A low-noise amplifier placed ahead of the cable can lower the system noise figure to 3 dB for a threshold improvement of 6 dB. The gain added by the amplifier at the
measuring frequency must be accurately measured for use when calculating field strength; this can be done using the FIM-72 calibration generator output to measure the amplifier gain and cable loss together. The amplifier input VSWR should be low, 1.5:1 or less, to avoid errors due to poor matching to the ANT-72 antenna. The amplifier must be removed from the system to maintain accuracy when measuring signals large enough to cause amplifier gain compression.

Noise Correction Data:

These curves are for use with readings below -4 dB on the 10uV FULL SCALE range only. Locate the meter reading on the horizontal Meter Rdg axis, and determine the correction value from the curve for the channel measured. Use this value in the formula given above in Converting Readings to Input Voltage. The true value of the received signal is less than what the meter indicates by the amount of the correction (a smaller dBu number).

There are three curves because the FIM's noise figure is different in each frequency range.
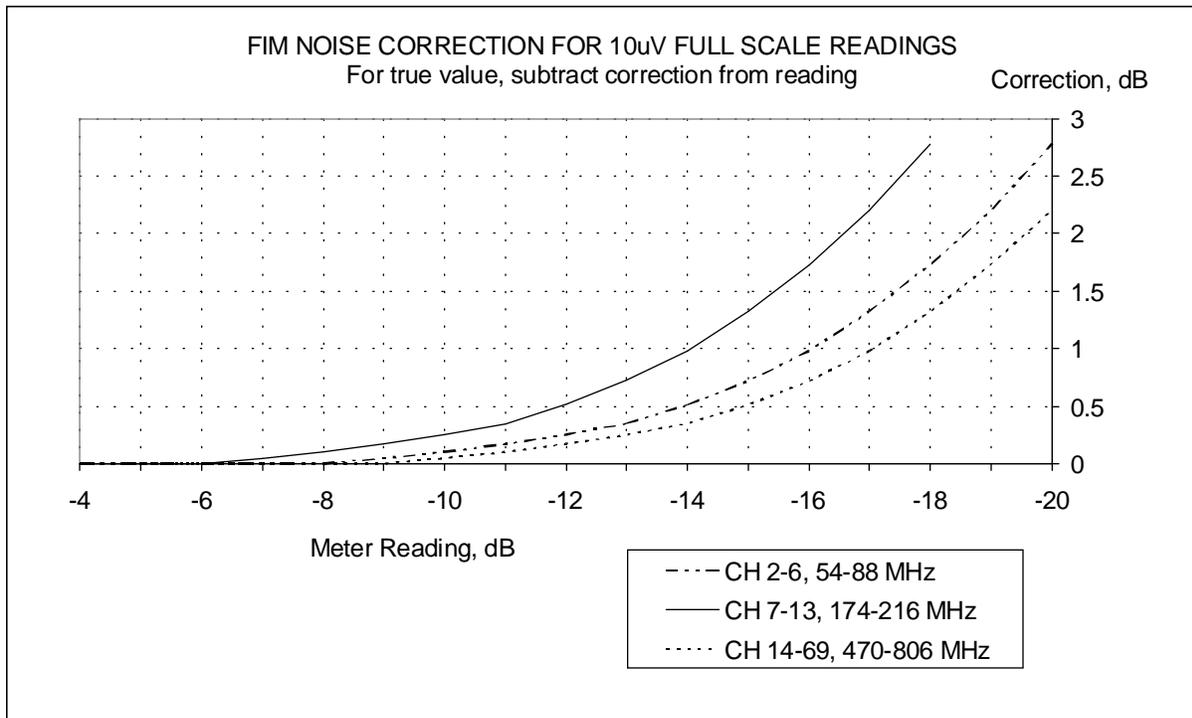
REFERENCES:

[1] ATSC Digital Television Standard, 16 Sep 95, Annex D.   Advanced Television Systems   Commitee; available at www.atsc.org.

[2] Guide to the Use of the ATSC Digital Television Standard, 4 Oct 95.   Advanced Television Systems Committee; available at www.atsc.org.