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

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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 50Ω), 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: 〃 [(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
10uV	-80
100uV	-60
1mV	-40
10mV	-20
100mV	0
1V	+20
10V	+40

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

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.

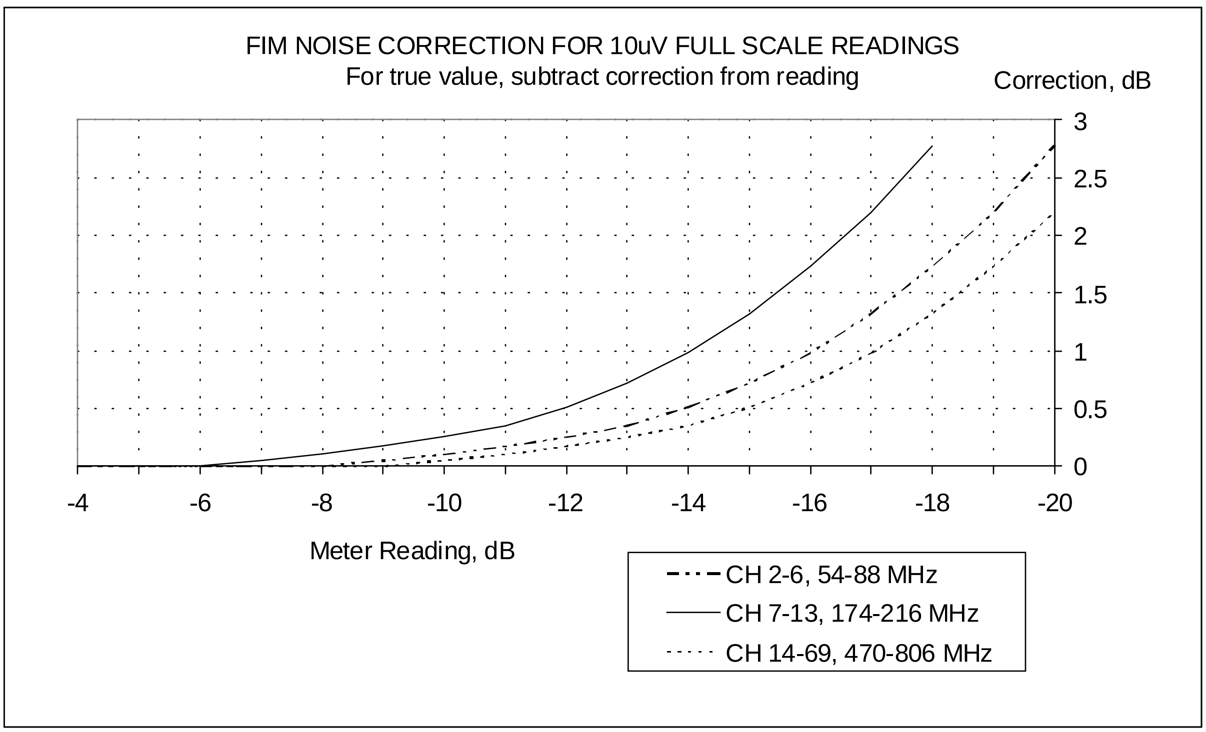
Higher-Gain Antennas:
Various higher-gain TV receiving antennas are available which could be considered for field strength measurements, from narrow bandwidth yagi types to broadband log-periodic types.
The main problem in using them is that of calibration. A field calibration can be tried by comparing 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.