Report on:

DTV Channel 6 Interference to FM Band Reception

Laboratory Test Report

Section II

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1 INTRODUCTION

1.1 Abstract

The potential use of TV channel six for DTV requires protection criteria to ensure continued high quality FM reception by controlling DTV out-of-channel emissions into the 88.1 MHz to 92.0 MHz FM broadcast spectrum. This report presents Desired/Undesired (D/U) versus signal-to-noise laboratory measurement graphs for 6 FM and up to 3 subcarrier compatibility receivers, made while increasing the DTV undesired signal level in 5 dB steps. The graphs are repeated for five different (DTV) undesired transmitter out-of-channel emission masks, two-desired signal levels, and various desired (FM) signal frequencies. The receiver multipath noise is plotted for two multipath scenarios, three-desired FM frequencies and three out-of-channel emission types. The measurements contained in this report can be used to calculate protection ratios and predict interference to FM stereo reception based on the FCC DTV out-of-channel emissions mask and other emission masks.

1.2 General Description

1.2.1 DTV Channel 6 to FM Laboratory Tests

The channel six DTV to FM laboratory tests investigated potential interference to the reception of FM stereo stations operating at the lower frequency end of the FM band. Because TV channel six is adjacent to the low frequency end of the FM band (Ch 6, 82 MHz to 88 MHz and the FM band 88 MHz to 108 MHz), any DTV out-of-channel emission will fall into the low frequency end of the FM band. In the FCC DTV Sixth Report and Order released on February 23, 1998 the FCC has specified an emissions mask that is intended to control adjacent channel interference. The DTV test conducted in the laboratory used an 8-VSB exciter to generate the DTV signal operating on TV channel six. The DTV out-of-channel emissions were adjusted to simulate the FCC February 23, 1998 emissions mask and four other emission masks that will be described later. The tests objectively measured the interference to FM stereo transmissions operating on frequencies in the lower 2 MHz of the FM band caused by out-of-channel emission of a DTV transmitter operating on TV channel six.

Six representative consumer receivers were selected for the tests. Four of these receivers were used for the EIA In Band On Channel digital radio compatibility tests. Three analog subcarrier receivers were also tested. The interfering audio noise was measured using the CCIR weighting filter and quasi-peak detection (Psophometric). Multipath tests were also conducted using two of the scenarios developed for the EIA Digital Audio Radio tests.

The test results will show Desired/Undesired signal ratios for a fixed signal-to-noise ratio at selected frequencies, starting at 88.1 MHz and extending to 91.1 MHz. Because the FCC emission mask allows the most energy in the first 500 kHz of the FM band (Figure 18), more tests were conducted at the low frequency end of the FM band.

Tests were also conducted using 92 kHz and 67 kHz analog subcarriers systems. The majority of the tests were conducted using the 92 kHz subcarrier. The subcarrier receivers were as sensitive to interference as the stereo receivers were. Because the subcarrier channel is normally noisier than main program channel, a noise increase of 5 dB could render the analog subcarrier channel reception unusable.

1.2.2 Generation 8-VSB Signal and Out-of-Channel Emissions

The 8-VSB digital channel six transmitter consisted of an 8-VSB exciter, analog HPA corrector, RF mixer, and an RF signal generator which were supplied by Comark Communications of Southwick, MA. Without an input signal the Comark 8-VSB exciter automatically switched to a PN sequence generator that simulates the DTV signal (Figure 14). Prior to shipment the equipment was setup and calibrated at the Comark transmitter development laboratory in Southwick. The transmitter was then shipped to the Digital Radio Laboratory at NASA Lewis, Cleveland.

The transmitter corrector allowed for the precise adjustment of DTV out-of-channel emissions for FM channels at the lower end of the FM band. The method of measuring out-of-channel emissions power is described in Section 3.3.2 and 3.3.3 of this laboratory test report. These measurements followed the out-of-channel emissions measurement procedures specified by the ATSC DTV standard and the FCC.

1.2.3 DTV Emission Mask.

Five different emission masks were used for the laboratory tests. The high frequency side of a channel 6 DTV signal is graphed in Figure 18 (Section 4) to represent the out-of-channel emissions mask tested.

The mask, C1, simulated the FCC mask that was specified prior to February 23, 1998.

The second mask, C2, was set to be about 10 dB poorer than the old FCC mask. The C2 test is used to approximate the interference caused by a channel 6 DTV transmitter operating with a defective digital transmitter or defective out-of-channel emissions control system.

At the NAB Convention in April 1998, the transmitter manufacturer, Comark, demonstrated a digital adaptive transmitter pre-correction system that significantly reduces the out-of-channel emissions at the frequencies adjacent to the DTV signal. These emission are caused by high power amplifier distortions. With the FCC mask published on February 23, 1998, the out-of-band emissions at 88.5 MHz were reduced by only 1 dB. The tests conducted with the C3 mask are designed to simulate the interference reduction using new technology, which further reduces the emissions at the low end of the FM band. For the C3 mask the 500 kHz noise band at 88.25 MHz is 60 dB below the digital signal and 14 dB lower than the February 23, 1998 FCC emissions mask. The C3 mask is the noise floor for the laboratory channel six 8-VSB transmitter. C3 and C5 are the same at 88.1 MHz.

Tests using the C4 mask simulate the new FCC mask published on February 23rd. For this test the noise was set to match the FCC mask for each frequency tested. Because of the noise floor restrictions of the test transmitter, tests were not conducted beyond 90.1 MHz.

1.2.4 Compatibility Receiver Selection

Four of the five receivers used for the Digital Audio Radio (DAR) compatibility tests were used for the channel 6 DTV interference tests. A total of six receivers were used to represent the present receiver population. Receivers 1 through 4 were used for the EIA/CEMA DAR compatibility tests (Table 1). Receiver 5, a top-of-line high quality home Hi-Fi tuner, and receiver 6, an after-market audio radio, were added to the receiver matrix. The top of the line receiver (#5) represents the state-of-the-art in adjacent channel noise immunity using a Walsh function stereo decoder and phase compensated narrowband IF filters. Compatibility receiver #6 was added to represent an after-market auto radio.

Receiver Number	Receiver Model	Receiver Description
1	Denon TU-380 RD	Home Hi-Fi RBDS
2	Pioneer SX-201	Home Hi-Fi Competitive
3	Panasonic RX-FS430	Competitive Portable
4	Delco 16192463	Auto
5	Denon TU-680NAB	Home Hi-Fi Top of the Line
6	Audiovox AV 220 ETR	Auto after market

Table 1: Compatibility Receivers

1.2.5 Receiver Certification Tests

The six receivers were tested for S/N versus RF level, stereo separation versus RF level, audio distortion, sensitivity to co and adjacent channel interference, and sensitivity to narrow band noise on all the compatibility receivers. The DAR Laboratory Tests had previously certified receivers #1 through #4 for everything but the sensitivity to narrowband noise. The results of these tests are in Appendix A.

The sensitivity to narrow band noise tests were conducted using a Harris THE-1 FM exciter to generate the desired signal. A HP-8657B signal generator FM modulated with pink noise and deviated 5 kHz generated the narrow band undesired signal. The desired signal was modulated with pilot and RBDS. The tests were also conducted with the pilot turned off to test monophonic performance. The desired signal level used for these tests was –55 dBm. The receiver’s sensitivity to noise was measured by setting the undesired signal at multiples of 38 kHz, the stereo difference signal’s frequency. The measurements were made starting at a frequency 266 kHz below the channel center frequency, and continued to 266 kHz above the center frequency. The undesired signal was increased in level until a psophometric audio signal-to-noise ratio of 45 dB was measured at the test receiver’s output. At this point the D/U was recorded.

In Appendix A on page 10 of 13 is a frequency versus D/U graph for the Denon RDS receiver measured with a constant audio S/N for the narrow band noise stepped at 38 kHz steps across 532 kHz band. The desired channel’s center frequency was 88.5 MHz. for all of the narrow band noise tests. The upper plot designated with the diamonds is the stereo D/U at each frequency and the lower plot is monophonic D/U. It is clear that the sensitivity narrow band noise is greater at the stereo difference frequency than at the channel center frequency. It is also clear that in the monophonic mode the receiver is at least 20 dB less sensitive to narrow band noise. It can also be seen in the graph on page 10 that this receiver is sensitive to out-of-channel noise.

In Appendix A on page 11 of 13 is a plot of the test results for the Denon NAB receiver. This receiver incorporates technology that makes the receiver immune to out-of –channel noise. Comparing the two Denon receivers’ sensitivity to narrowband noise at 38 kHz above and below the center frequency, the sensitivity is about the same. The graph on page 10 shows that the Denon RDS receiver is sensitive to out-of-channel noise starting at 114 kHz from the carrier center frequency and that the Denon NAB receiver on page 11 is not. It can also be seen in the graph on page #9 that the Delco auto receiver has adjacent channel rejection characteristics that are similar to the Denon NAB receiver. The remaining four receivers are sensitive to out out-of-channel noise.

Comparing the stereo composite graph page 5 of 13, with the monophonic graph page 7 of 13, the average D/U at the carrier center frequency for the stereo is 26 dB and for monophonic mode the D/U is 25 dB. There is little difference in the sensitivity to noise at the FM channel center frequency. At the stereo difference channel frequency the average D/U is 44 dB better in the mono mode than in the stereo.

The composite stereo graph in Appendix A on page 5 of 13, shows that all six receivers exhibited nearly the same sensitivity to noise at the center channel. The graph also shows that at 38 kHz from the channel center frequency, all six receivers have nearly the same sensitivity to narrowband noise. It can also be seen that the adjacent channel performance varied significantly between receivers.

1.2.6 DTV to FM Interference Tests

The data in the Appendix J, K, L, M, and N are the results of the DTV to FM tests using the five-transmission masks and the six test receivers. The test data in Appendix M is the result of DTV to FM tests using the February 23, 1998 FCC transmission mask. The tests were conducted at five frequencies with two-desired signal levels of –56 dBm and –71 dBm. Except for noise floor there was little change in D/U for the two signal levels.

The test data in for the new mask is in Appendix M (FCC new), and test data for the original FCC mast is in Appendix J (FCC old). Comparing the test data for the two masks at 88.5 MHz and with a desired signal level –56 dBm, the D/U results are essentially identical. Comparing the test results at 89.9 MHz and above, a substantial reduction in interference is realized with the new FCC mask. The new mask has not assured the reduction in potential interference to stations operating in the low frequency end of the FM band.

All of the tests conducted at 88.1 MHz showed a wider D/U spread than the tests conducted at frequencies above 88.1 MHz. This agrees with the results of the narrow band noise tests graphed in Appendix A page 5 of 13.

1.2.7 Multipath Tests

The multipath tests were conducted using the urban slow and urban fast scenarios developed by the DAR Subcommittee. The FCC new and –60 dB masks and the Audiovox and Delco auto radios were used for these tests. The transmitter signal was pilot with no audio modulation. For the reference the audio output of the test receiver was plotted for 27 seconds with multipath and without the undesired signal. The second plot is with the undesired signal. Each test was conducted four times with different undesired signal levels. The D/U is listed at the bottom of each page. The multipath effected only the four lowest channels. The multipath test results are in Appendix O through T.

1.2.8 Test Results

The graphs in Figures 1 though 4 summarize DTV to FM test results for the 6 FM stereo receivers. The D/U represents a 55 dB RMS audio signal-to-noise ratio. The tick marks on the graph indicate the laboratory measured D/U at a specified frequency. The 55 dB RMS S/N is equal to the 45 dB psophometric S/N measurement.

Figure 1 tests were conducted using the FCC February 23, 1998 mask (FCC New). The out-of-channel emission was set for each frequency tested (see also Appendix W).

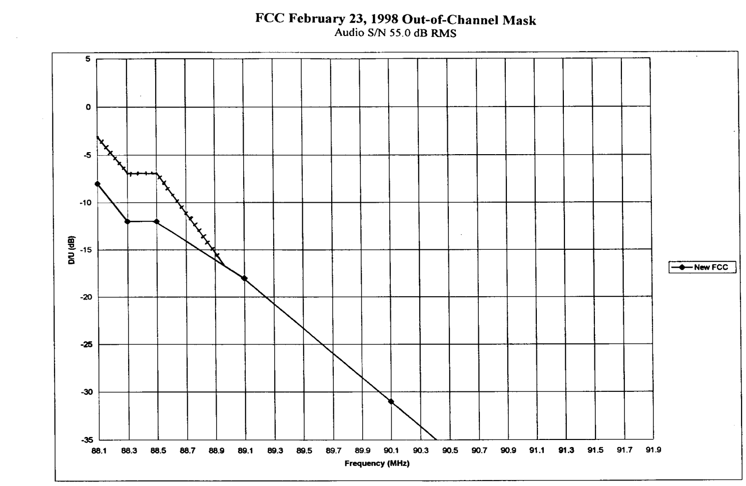

Figure 1.

The Figure 2. tests used the simulated new technology mask described previously. The interference is reduced at the low end of the FM band (see also Appendix X).

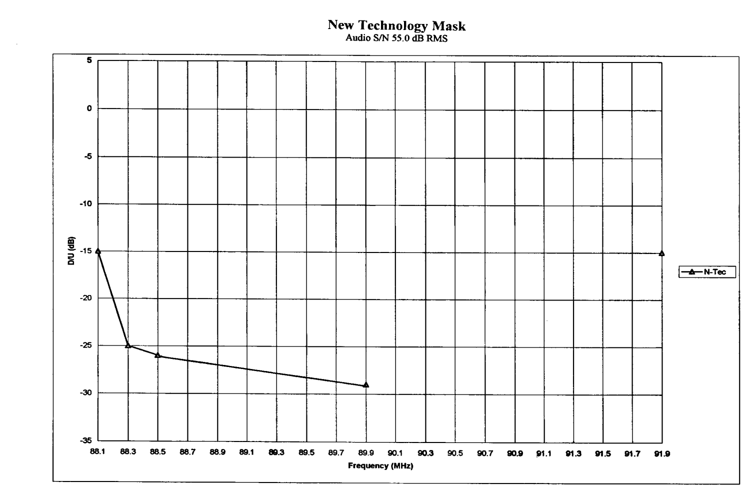

Figure 2.

Figure 3. shows the potential interference to FM stereo reception with a channel six DTV transmitter operating a defective transmitter (see also Appendix Y).

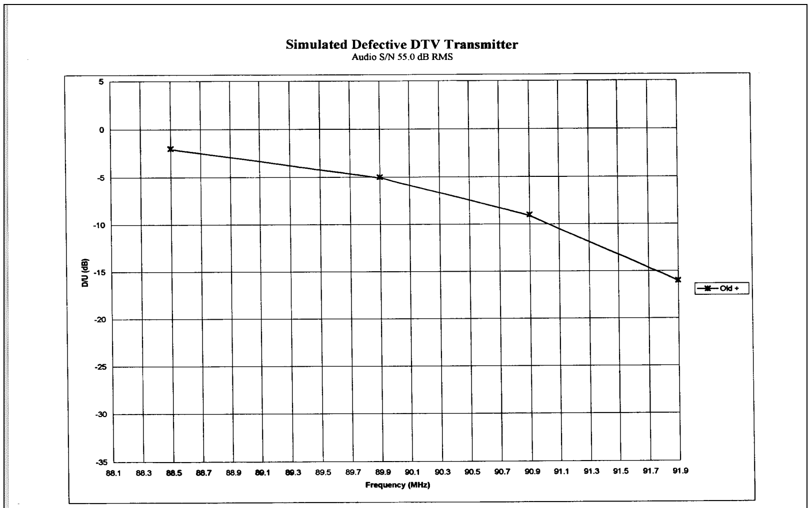

Figure 3.

Figure 4. shows the interference that would have existed with the FCC mask that was specified prior to February 23, 1998 (see also Appendix Z).

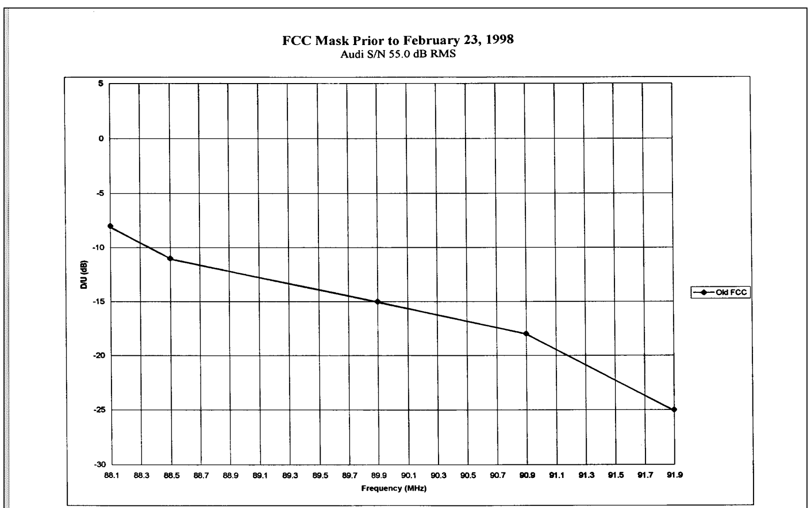

Figure 4.

2 RECEIVER CERTIFICATION

2.1 Sensitivity to Narrowband Noise

The 6 FM receivers in stereo and mono modes were characterized for susceptibility to narrow band noise. These tests involve stepping a 5 kHz deviated clipped pink noise (CPN) modulated FM signal in 38 kHz increments across the desired and adjacent channels. As this undesired signal is stepped across the band, the D/U is adjusted to produce a constant 45 dB S/N. Figure 5 and Figure 6 show the desired and undesired signals respectively.

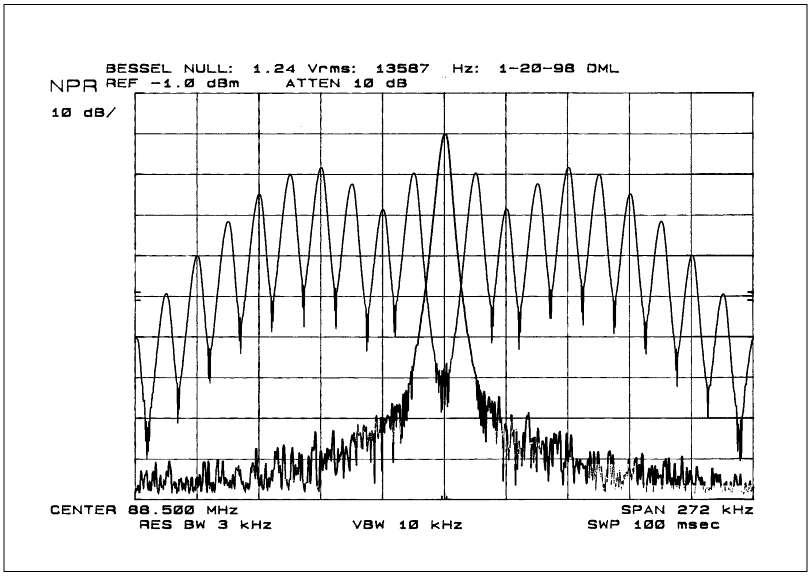

Figure 5:Desired Signal and Bessel Null of Desired Signal

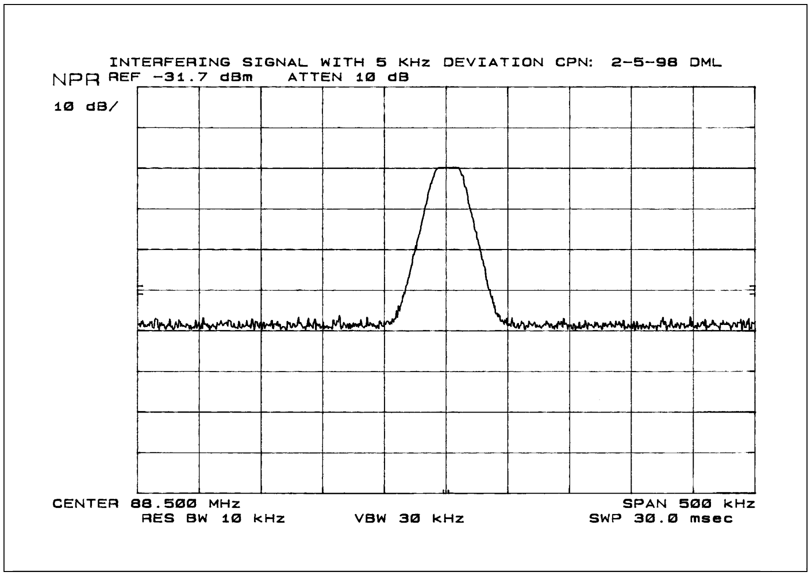

Figure 6: Undesired Signal Max Hold 30 second Integration

Figure 7 shows the relationship of the desired and undesired signal at the 38 kHz test point intervals. The desired signal is plotted on one trace, and the undesired signal is plotted on the other. A single sweep at each discrete test frequency of the undesired signal is made while the spectrum analyzer is in max hold mode.

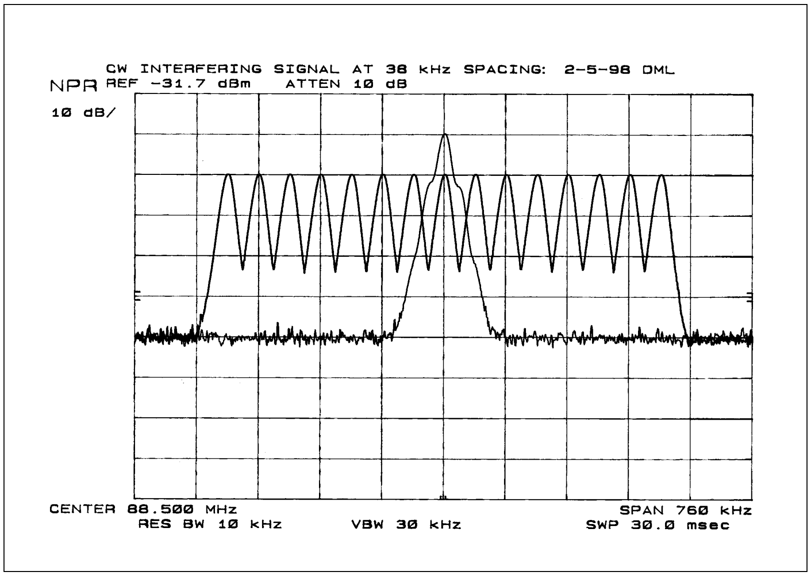

Figure 7: Desired and Undesired Signals

The results of the sensitivity tests can be found in Appendix A.

2.2 Receiver Characteristics

The first four receivers have been characterized previously. The results of these characterizations can be found in Volume 1 Appendix H of the DAR Laboratory Tests August 11, 1995.

2.2.1 Denon TU-380 RD

The Noise and Distortion Products plot is located in Appendix B.

2.2.2 Pioneer

The Noise and Distortion Products plot is located in Appendix C.

2.2.3 Panasonic

The Noise and Distortion Products plot is located in Appendix D.

2.2.4 Delco

The Noise and Distortion Products plot is located in Appendix E.

2.2.5 Denon TU-680 NAB

The additional certification tests for the NAB receiver can be found in Appendix F.

2.2.6 Audiovox

The additional certification tests for the Audiovox receiver can be found in Appendix G.

3 TEST BED CERTIFICATION AND CALIBRATION

3.1 Audio Signal to Noise Measurements

The measurements made on consumer FM receivers were made through 2 filters. These filters are a 15 kHz low pass filter and a CCIR weighting filter. The frequency response of the 15 kHz low pass and the CCIR filters can be found in Figure 8 and Figure 9 respectively.

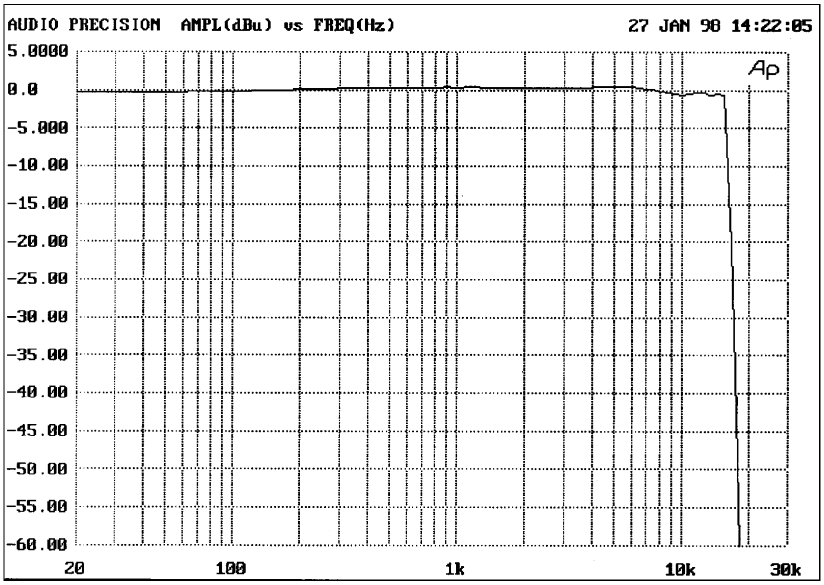

Figure 8: 15 kHz Low Pass Filter Frequency Response

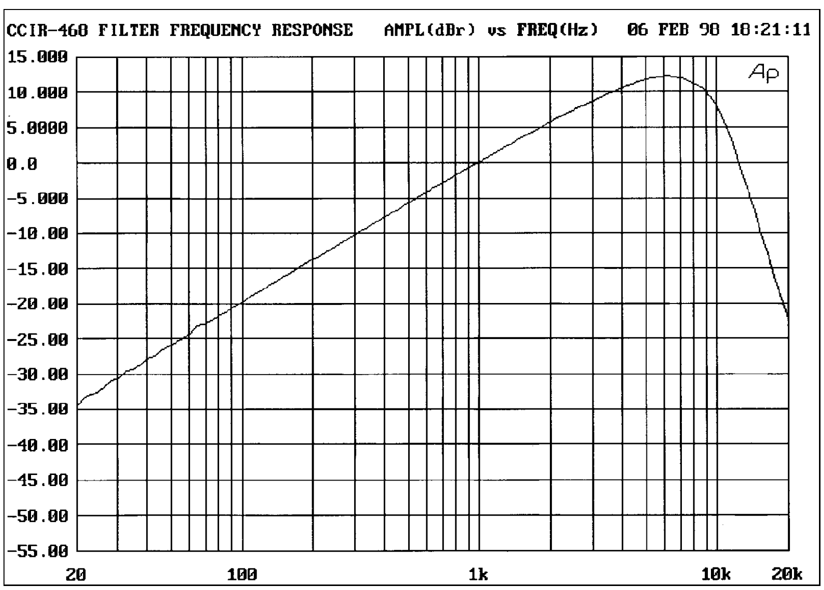

Figure 9: CCIR Weighting Filter Frequency Response

3.2 Laboratory Test Bed

3.2.1 RF Distribution

The RF distributions for multipath and non-multipath tests are found in Appendix H.

3.2.2 Audio Distribution

Documentation detailing the audio distribution and signal to noise measurements is located in Appendix I.

3.2.3 Calibration

The calibration of the desired and undesired signals can be found in other sections of this report.

3.2.3.1 92 kHz Subcarrier

The 10% injection level of the 92 kHz subcarrier is shown in Figure 10.

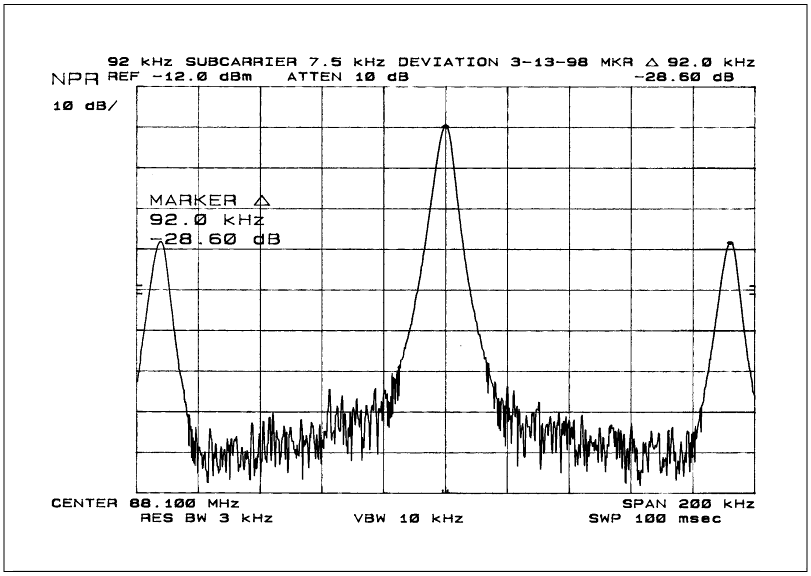

Figure 10: 92 kHz Subcarrier at 10% Injection

The 5.5 kHz of deviation of the 92 kHz subcarrier is shown in Figure 11.

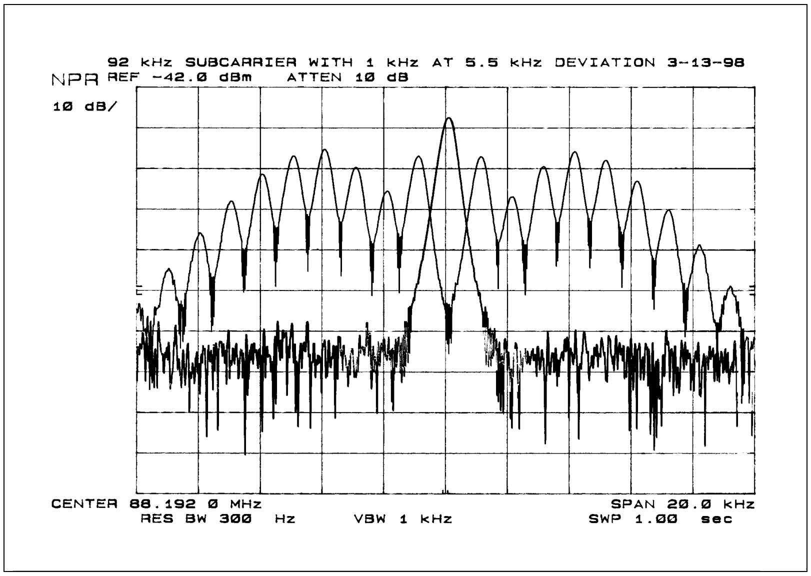

Figure 11: 92 kHz Subcarrier with 5.5 kHz of Deviation

3.2.3.2 67 kHz Subcarrier

The 10% injection level of the 67 kHz subcarrier is shown in Figure 12.

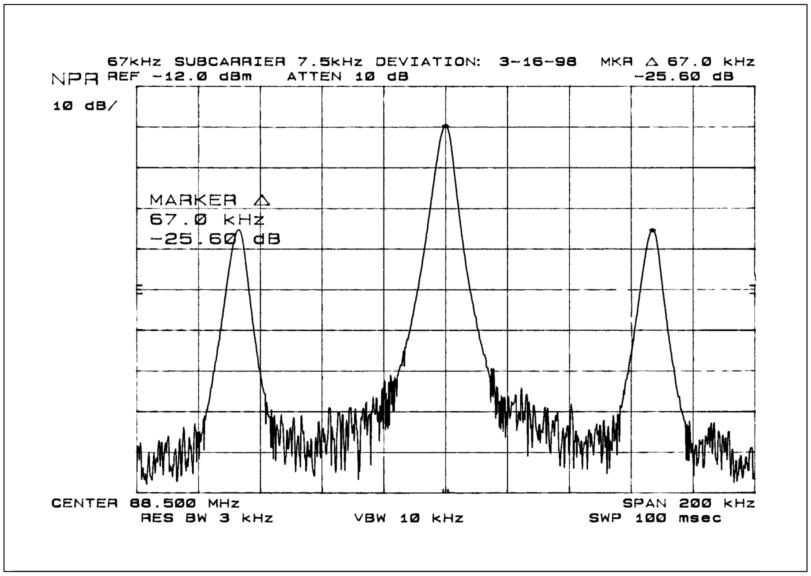

Figure 12: 67 kHz Subcarrier at 10% Injection

The 5.5 kHz of deviation of the 67 kHz subcarrier is shown in Figure 13.

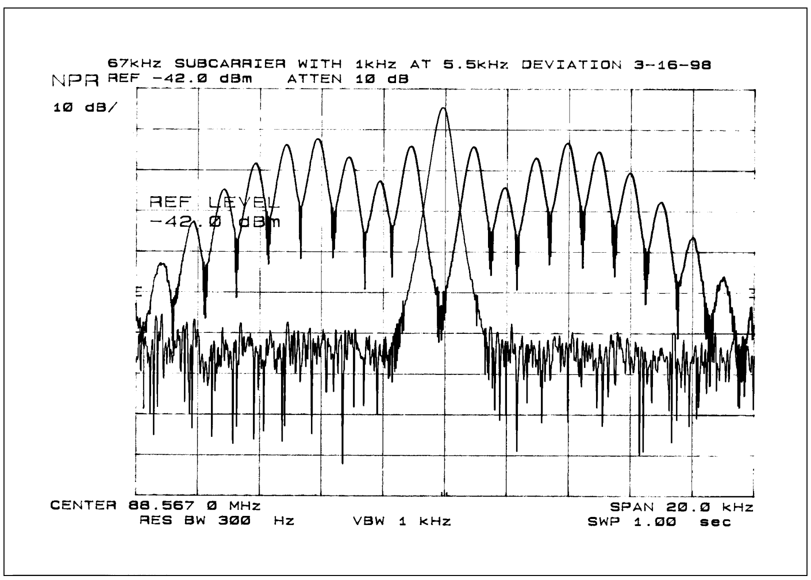

Figure 13: 67 kHz Subcarrier with 5.5 kHz of Deviation

3.3 Undesired Signal DTV Transmitter

3.3.1 RF Spectrum

The spectrum of the undesired signal is shown in Figure 14.

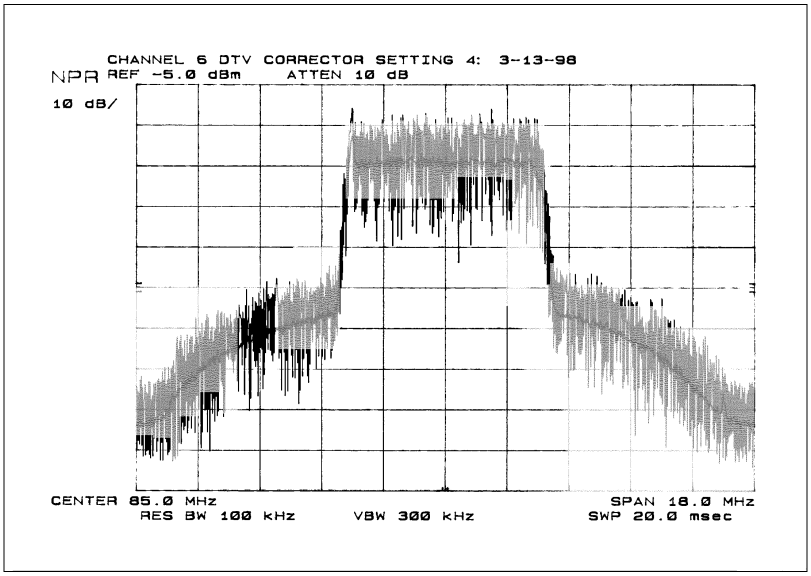

Figure 14: Undesired Signal Spectrum

3.3.2 Average Power Measurements

The average power of the desired FM signal was measured with an average power meter. The average power of the undesired signal was measured using a spectrum analyzer able to measure power in a one Hertz bandwidth. The spectrum analyzer was controlled via computer and IEEE-488. An algorithm stepped the analyzer across the undesired signal and out of band emission bands. Power measurements were made in one Hertz bandwidths and an average calculated. The bandwidth over which the measurements were made was factored into the calculation. Two bandwidths were considered. Six MHz bandwidth was used to calculate the total undesired signal average power and 500 kHz bandwidth was used to calculate power in the out of band emissions.

3.3.3 Spectrum Analyzer Settings

Spectrum analyzer settings greatly effect average power measurements and the spectral display of the undesired signal. The settings for resolution bandwidth and reference level were therefore chosen to show agreement between average power meter and spectrum analyzer algorithm and show correlation between the 8594E and 8566B spectrum analyzers in adjacent channel power measurement mode. Table 2 details the spectrum analyzer settings.

	Signal Bandwidth	
	6 MHz	500 kHz
Span	12 MHz	1 MHz
Resolution BW	1 MHz	10 kHz
Video BW	AUTO	AUTO
Reference Level	O dBm	-30 dBm

Table 2: Spectrum Analyzer Settings

3.4 Desired Signal FM Transmitter

3.4.1 Proof of Performance

3.4.1.1 Frequency Response

The frequency response of the desired signal at 88.5 MHz is shown in Figure 15.

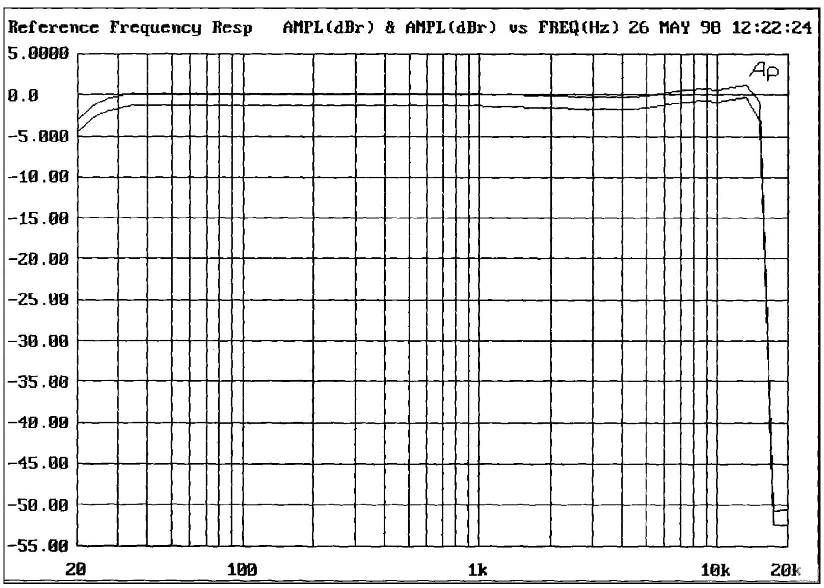

Figure 15: Desired Signal Frequency Response

3.4.1.2 Separation

The separation of the desired signal at 88.5 MHz is shown in Figure 16.

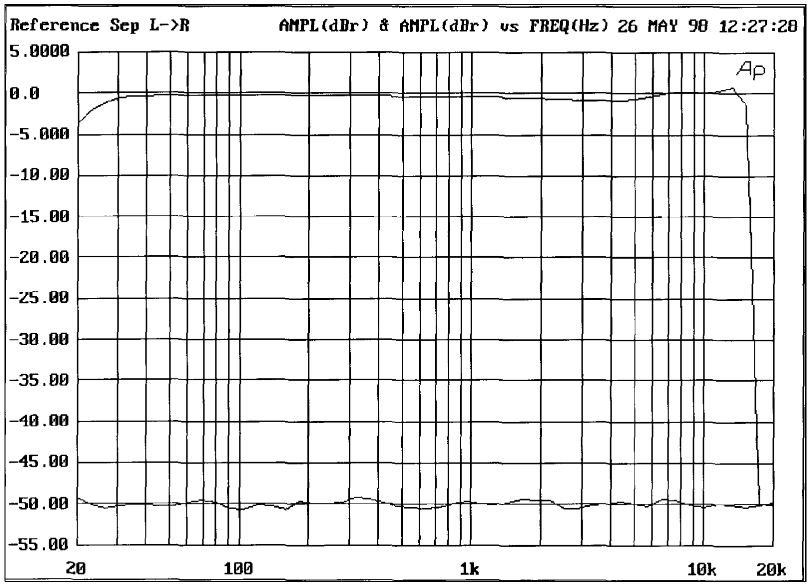

Figure 16: Separation of Desired Signal

3.4.1.3 Distortion + Noise

The distortion + noise of the desired signal at 88.5 MHz is shown in Figure 17.

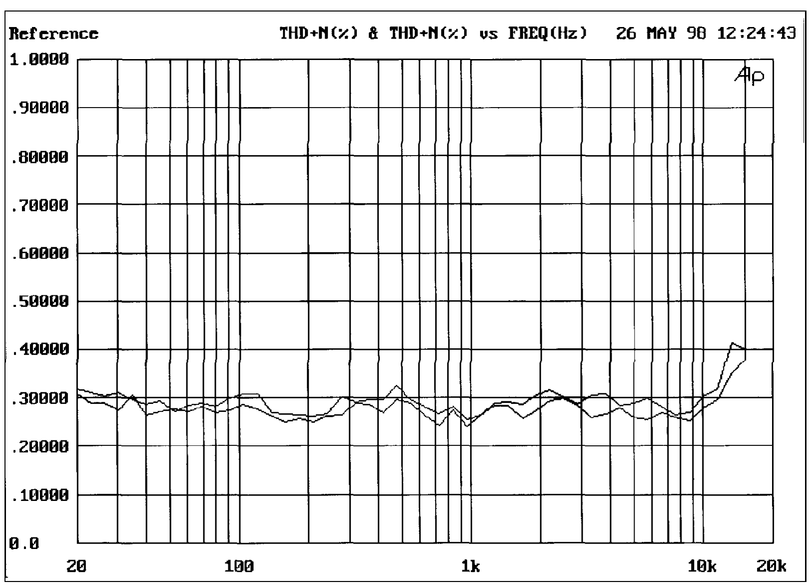

Figure 17: Desired Signal Distortion + Noise

4 CHANNEL 6 DTV TO FM TESTS

In these tests the independent variable (D/U) was stepped from +20 to -35 dB in -5 dB steps and the dependent variable (S/N) was measured and plotted for 6 consumer FM and up to 3 subcarrier receivers under various signal and undesired emission levels as described below.

The undesired signals out of channel emissions were controlled via an analog corrector unit. Figure 18 shows the emission levels of five different corrector settings (C1-C5) as compared to the Old FCC and New FCC masks.

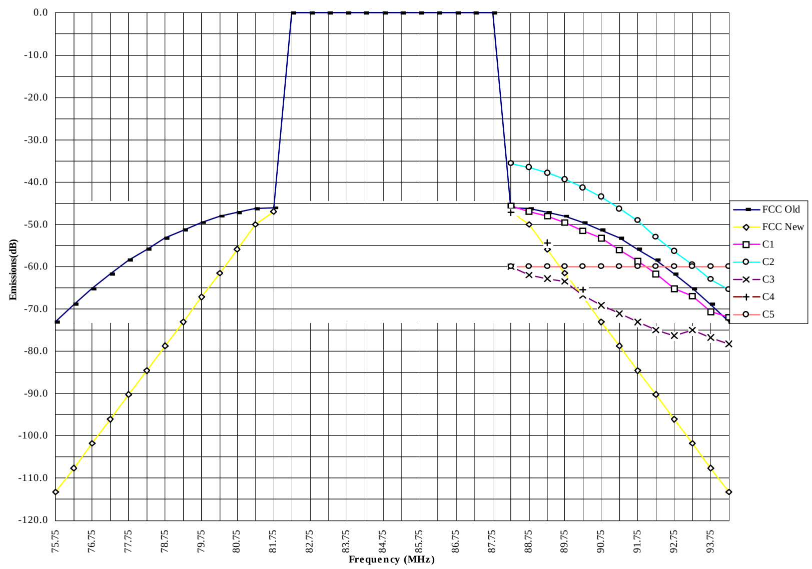

Figure 18: Undesired Signal Emission Levels

4.1 FCC Old C1

Tests to characterize performance based on Old FCC Specifications are located in Appendix J.

4.2 FCC Old + 10 C2

Tests to determine effects of DTV transmitter operating out of specification are located in Appendix K.

4.3 8VSB Noise Floor C3

Tests to determine performance based on minimum DTV equipment out of band emissions are located in Appendix L.

4.4 FCC New C4

Tests to determine performance based on new FCC Report and Order are located in Appendix M.

4.5 Proposed -60 dBm C5

Tests to determine performance based on proposed specifications are located in Appendix N.

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5 DTV TO FM TESTS WITH MULTIPATH

These tests are run with no interference (reference) and at interference D/U's of 0, -10, -20 and -30 dB. In all cases the RMS noise floor of the radios is measured, recorded and plotted for urban slow and urban fast multipath simulations. Details relating to the calibration of the RMS meter and supporting hardware can be found in Appendix V.

5.1 Tests at 88.5 MHz Corrector Setting C4

5.1.1 Audiovox

Audiovox data is located in Appendix O

5.1.2 Delco

Delco data is located in Appendix P.

5.2 Tests at 90.1 MHz Corrector Setting C4

5.2.1 Audiovox

Audiovox data is located in Appendix Q

5.2.2 Delco

Delco data is located in Appendix R.

5.3 Tests at 90.9 MHz Corrector Setting C5

5.3.1 Audiovox

Audiovox data is located in Appendix S

5.3.2 Delco

Delco data is located in Appendix T.

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