NRSC REPORT

NATIONAL RADIO SYSTEMS COMMITTEE

NRSC-R203
Evaluation of the iBiquity Digital Corporation IBOC System – Part 1 – FM IBOC
November 29, 2001

Part II - Appendices

NAB NATIONAL ASSOCIATION OF BROADCASTERS

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FOREWORD

NRSC-R203, Evaluation of the iBiquity Digital Corporation IBOC System – Part 1 – FM IBOC, documents the NRSC's evaluation of the FM IBOC system which was subsequently selected by the FCC in October 2002 as the technology that will permit FM radio broadcasters to introduce digital operations. The DAB Subcommittee chairman at the time of adoption of NRSC-R203 was Milford Smith; the NRSC chairman at the time of adoption was Charles Morgan.

The NRSC is jointly sponsored by the Consumer Electronics Association and the National Association of Broadcasters. It serves as an industry-wide standards-setting body for technical aspects of terrestrial over-the-air radio broadcasting systems in the United States.

Appendix A –
DAB Subcommittee Goals & Objectives

NATIONAL
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DAB Subcommittee
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Part 1 – FM IBOC

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DAB Subcommittee

Goals & Objectives

(as adopted by the Subcommittee on May 14, 1998)

Objectives

(a) To study IBOC DAB systems and determine if they provide broadcasters and users with:
- A digital signal with significantly greater quality and durability than available from the AM and FM analog systems that presently exist in the United States;
- A digital service area that is at least equivalent to the host station's analog service area while simultaneously providing suitable protection in co-channel and adjacent channel situations;
- A smooth transition from analog to digital services.

(b) To provide broadcasters and receiver manufacturers with the information they need to make an informed decision on the future of digital audio broadcasting in the United States, and if appropriate to foster its implementation.

Goals

To meet its objectives, the Subcommittee will work towards achieving the following goals:

(a) To develop a technical record and, where applicable, draw conclusions that will be useful to the NRSC in the evaluation of IBOC systems;

(b) To provide a direct comparison between IBOC DAB and existing analog broadcasting systems, and between an IBOC signal and its host analog signal, over a wide variation of terrain and under adverse propagation conditions that could be expected to be found throughout the United States;

(c) To fully assess the impact of the IBOC DAB signal upon the existing analog broadcast signals with which they must co-exist;

(d) To develop a testing process and measurement criteria that will produce conclusive, believable and acceptable results, and be of a streamlined nature so as not to impede rapid development of this new technology;

(e) To work closely with IBOC system proponents in the development of their laboratory and field test plans, which will be used to provide the basis for the comparisons mentioned in Goals (a) and (b);

(f) To indirectly participate in the test process, by assisting in selection of (one or more) independent testing agencies, or by closely observing proponent-conducted tests, to insure that the testing as defined under Goal (e) is executed in a thorough, fair and impartial manner.

Appendix B –
IBOC laboratory test procedures – FM band

NATIONAL
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DAB Subcommittee
Evaluation of the iBiquity Digital
Corporation IBOC System

Part 1 – FM IBOC

IBOC LABORATORY TEST PROCEDURES – FM BAND
OVERALL COMMENTS

1. The test laboratory (ATTC) will provide a detailed certification of the test bed.
2. Appendix A is a list of the test results (resulting from these procedures) which must be included in the laboratory test record to be provided to the NRSC at the conclusion of testing. Note that this list is not meant to suggest the format in which those results are to be presented in that record, but is simply an enumeration of those results.
3. IBOC receiver point-of-blend is established by the "mode" signal which is supplied by the receiver. IBOC receiver block error rate (BLER) is also observable.
4. Unless otherwise specified, the audio selections to be used as source material for desired and interfering channels are specified in the NRSC audio test list, and, the source audio for analog reference recordings will be the same as that used for the corresponding IBOC digital audio recordings.
5. The following three RF composite signal levels are used in the FM laboratory tests:

DESIGNATION	DESCRIPTION	LEVEL (DBM)
M	Moderate	-62
S	Strong	-47
W	Weak	-77

6. Digital recordings of analog and IBOC digital audio indicated by these procedures are for archival and/or subjective evaluation purposes. All such recordings will be made in the following format: uncompressed linear 16-bit digital audio sampled at 44.1 kHz, and will be suitable for transfer to CD to facilitate further analysis.
7. Multipath scenarios used in these tests will be the same scenarios used in the EIA DAR laboratory tests conducted in 1995, utilizing nine desired signal paths (rays) and six undesired paths, as specified in Appendix E of the August 11, 1995 report ("VHF Rayleigh 9-path simulation").
8. The detailed procedure for RF noise measurements will be supplied. See Appendix S of the EIA DAR Laboratory Tests Report, August 11, 1995.
9. For tests involving use of the multipath simulator, the RF level will be characterized according to the procedure described in the ATTC report "The Measurement of Power as applied to IBOC DAB signals in the Presence of Multipath for the FM-band," Document #00-02 November 16, 2000.
10. Unless otherwise specified, IBOC transmitters will be used to generate undesired signals in co- and adjacent-channel interference tests.

IBOC LABORATORY TEST PROCEDURES – FM BAND
OVERALL COMMENTS (continued)

11. Unless otherwise specified, analog audio (as opposed to IBOC digital audio) signal power meas. will be made using the weighted quasi-peak ("WQP," CCIR weighting filter) measurement technique. Analog audio noise measurements will in addition use a 19 kHz lowpass pilot filter.
12. The host FM to digital power ratio used in the digital performance tests will also be used for the analog compatibility tests.
13. The following four subcarrier configurations are used in the FM laboratory analog compatibility tests (see test groups F, J):

		INJECTION LEVEL			
Description	Center frequency (kHz)	Config. #1	Config. #2	Config. #3	Config. #4
*Main channel audio	N/A	80%	85%	85%	80%
Stereo pilot	19.0	10%	10%	10%	10%
RDS digital subcarrier	57.0	3%	10%	-	-
"High speed" digital subcarrier (HSSC)	76.0	-	-	10%	-
**Analog audio subcarrier – FM modulated, ± 5 kHz peak deviation, 150 µsec pre-emphasis	67.0	8.5%	-	-	10%
**Analog audio subcarrier – FM modulated, ± 5 kHz peak deviation, 150 µsec pre-emphasis	92.0	8.5%	-	-	10%
TOTAL subcarrier injection		20%	10%	10%	20%
TOTAL injection (main channel and subcarriers)		110%	105%	105%	110%

* Main channel audio modulated with audio cuts from NRSC Audio Test List for subjective evaluations or 1 kHz tone for S/N measurements

**Analog subcarriers modulated with USASI noise except for subjective evaluations (TBD audio) or S/N measurements (400 Hz tone). When the same audio cuts are used for 67 and 92 kHz subcarriers, they will be offset in time by TBD sec (to de-correlate).

14. Unless otherwise indicated, interfering signals will not utilize any subcarriers other than the stereo pilot and L-R signal.
15. For tests involving multipath fading, point-of-blend will be determined utilizing the procedure described in the memo from G. Nease (iBiquity) to Andy Laird (TPWG chairman), dated November 28, 2000, and entitled "Method for the Determination of Point-of-Blend in Multipath Conditions."
16. NRSC analog test receivers specified on pg. 16 will undergo the following characterization tests: [list TBD]
17. [definition of clipped pink noise to be added here]

IBOC LABORATORY TEST PROCEDURES – FM BAND
CALIBRATION

Test Group	Test & Impairment	TEST DESCRIPTION Note: 1. One impairment audio cut will be selected from the NRSC Audio Test List for point of blend tests for calibration.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
A Calibration	1 Power	1. IBOC analog and digital average power will be measured separately (as needed). 2. The digital-only average and peak power will be measured at least once.	NA	Objective	Analog average power level Digital average and peak power levels
	2 Spectrum (each test day or as needed)	1. A spectrum analyzer plot of the system RF spectrum will be taken for each test day (or as needed). 2. The spectrum analyzer settings will be: RES BW 1 kHz, VBW 30 Hz, and sweep span of 500 kHz.	M	Objective	Spectrum plot
	3 Point of blend (as needed)	1. Gaussian noise will be added to the signal in 0.20 dB steps until point of blend is detected (using mode signal), or block error equivalent to point of blend is observed.	M	Objective	Noise level, BLER at point of blend
	4 Analog host proof-of-performance	1. During the analog compatibility tests, a proof of performance test will be conducted on the analog host portion of the IBOC system. A high quality demodulator will be used for this test.	Varying	Objective	Frequency response, L&R separation, audio SNR, and audio THD
	5 Monitor calibration (as needed)	1. The analog modulation monitors will be calibrated. Bessel null is the recommended method for calibration. Settings for the Belar Wizard modulation monitor will be: Hold 1.0 sec; Peak Mod 100.5%; Infinite off; Blank off; Resolution 0.1%; Time Mode past; Pk Weight 9 cyc; ppm duration 100 ms; ppm threshold 10.	NA	Objective	Calibration results
	6 Test bed calibration (prior to test)	1. All of the critical components in the test bed, including the multipath simulator, attenuators, combiners, filters, generators, and measuring instruments, will be certified by the testing laboratory prior to tests.	NA	Objective	Calibration results

IBOC LABORATORY TEST PROCEDURES – FM BAND
DIGITAL PERFORMANCE

Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		Notes: 1. For urban slow multipath tests, the desired multipath audio selections will be repeated as required to complete a full fading cycle on the MP simulator. 2. The audio will be restarted for each test. 3. The analog reference recordings specified in step B.2.5 will be made with the IBOC digital sidebands removed from the desired signals.			
B AWGN	1 Linear channel	1. The level of AWGN corresponding to system point of blend will be established. 2. The desired impairment audio segments will be recorded with the AWGN set at a level 2 dB below (i.e. before) the point of blend. 3. The BLER will be recorded with the AWGN set at a level 4 dB below (i.e. before) the point of blend, then with the AWGN level increased in 1 dB steps until at the point of blend, then at 2 dB and 4 dB above (i.e. after) the point of blend.	M	Objective	Cd/No, BLER for each measurement point (with point of blend identified)
				Subjective	Subjective impairment rating for recording made in step 2
	2 Multipath fading channel	1. This test will be conducted four times, each with a different Rayleigh multipath scenario. The multipath scenarios will be those specified on the "general comments" page of this procedure. Each cut will be recorded for subjective assessment. 2. For each multipath scenario, the level of AWGN corresponding to system point of blend will be established. 3. The desired impairment audio segments will be recorded with the AWGN set at a level 8 dB below (i.e. before) the point of blend. 4. The BLER will be recorded with the AWGN set at a level 8 dB below (i.e. before) the point of blend, then with the AWGN level increased in 2 dB steps until 6 dB above (i.e. after) the point of blend. 5. An analog reference recording will be made using NRSC analog test receivers #1 and #2 (automobile receivers) for each multipath scenario, at the measurement point of step 3.	M	Objective	Cd/No, BLER for each measurement point (with point of blend identified)
				Subjective	Subjective impairment rating for each multipath scenario and audio cut, for IBOC digital and analog reference recordings made in steps 2 and 5

IBOC LABORATORY TEST PROCEDURES – FM BAND DIGITAL PERFORMANCE					
Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. Desired audio cut used for these tests will be the desired impairment audio classical music selection; undesired audio cut will be the first adjacent impairment audio. 2. Each test will last no more than 30 seconds. 3. The audio will be restarted for each test. 4. The analog reference recordings specified in each step will be made with the IBOC digital sidebands removed from the desired and undesired signals. 5. For test C.1, only those sets of recordings corresponding to pulse frequencies of 120 Hz, and those closest to 500 Hz and 1500 Hz, will be subjectively evaluated.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
C IBOC with special impairments	1 Impulse noise	1. An RF pulse generator capable of RF pulses with a rise and decay time of at least 3 to 4 nanoseconds will be used for this test. The pulse generator output will be combined with the hybrid IBOC RF signal, and the RF pulse peak power level will be 30 dB above that of the unmodulated analog carrier. 2. IBOC digital audio will be recorded for one minute each, for six pulse rates between 100 Hz to 2000 Hz. 120 Hz pulse rate will be included in all the tests. The center frequency of the RF pulse should be the center frequency of the desired channel. 3. For each measurement point, the mode signal status will be recorded. 4. Steps 2 and 3 will be repeated using a random pulse repetition frequency (PRF) impulse noise source. 5. Steps 2-4 will be repeated using a single lower first adjacent undesired signal. The D/U ratio will be set for +6 dB. 6. An analog reference recording will be made using NRSC analog test receivers #1 and #2 (automobile receivers) for each impulse noise scenario described in steps 2-5.	M	Objective	Mode signal status for each measurement point
				Subjective	Subjective impairment rating for each pulse rate, amplitude and interference scenario for IBOC digital and analog reference recordings
	2 Airplane flutter (Doppler)	1. Tests will be conducted for three simulated aircraft speeds and MP delay scenarios: a. 400 Km/h, main signal attenuation 0 dB, reflection delay 27.5 µsec, attenuation 8 dB b. 200 Km/h, main signal attenuation 0 dB, reflection delay 18.7 µsec, attenuation 6 dB c. 100 Km/h, main signal attenuation 0 dB, reflection delay 6.8 µsec, attenuation 4 dB 2. A 30 second impairment recording will be made for each scenario. 3. For each measurement point, the mode signal status will be recorded. 4. Steps 1 and 2 will be repeated with a single lower first adjacent undesired signal. The D/U ratio will be set for +6 dB. 5. An analog reference recording will be made using NRSC analog test receivers #3 and #4 (non-automobile receivers) for each airplane flutter scenario described in steps 1-4.	M	Objective	Mode signal status for each measurement point
				Subjective	Subjective impairment rating for each airplane flutter scenario for IBOC digital and analog reference recordings

IBOC LABORATORY TEST PROCEDURES – FM BAND
DIGITAL PERFORMANCE

Test Group	Test and Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
		Notes: 1. All interferers are to be hybrid IBOC signals – refer to NRSC Audio Test List for information on interferer modulation. 2. The analog reference recordings specified in each step will be made with the IBOC digital sidebands removed from the desired and undesired signals. 3. For tests D.2 and D.3, analog reference recordings will be made with all relevant permutations of upper/lower adjacent channel interference. 4. The analog reference recordings specified in each step will be made with the IBOC digital sidebands removed from the desired and undesired signals.			
D IBOC ➜ IBOC	1 Co-channel	1. The co-channel D/U corresponding to system point of blend will be established. 2. The desired impairment audio segments will be recorded with the co-channel D/U set at a level 2 dB below (i.e. before) the point of blend. 3. For each measurement point, the mode signal status will be recorded. The BLER will be recorded with the co-channel D/U set at a level 2 dB below (i.e. before) the point of blend, then with the co-channel level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. 4. An analog reference recording will be made using NRSC analog test receivers #2 and #3 for the measurement point of step 2.	M	Objective	Co-channel D/U, BLER, mode signal for each measurement point
				Subjective	Subjective impairment rating for IBOC digital and analog reference recordings made in steps 2, 4
	2 Single and dual 1st adjacent	1. Using a lower 1st adjacent channel interferer, the D/U corresponding to system point of blend will be established. 2. The desired impairment audio segments will be recorded with the lower 1st adj. chan. D/U set at a level 2 dB below (i.e. before) the point of blend. 3. For each measurement point, the mode signal status will be recorded. The BLER will be recorded with the lower 1st adj. chan D/U set at a level 2 dB below (i.e. before) the point of blend, then with the 1st adj. chan. level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. 4. Steps 1-3 will be repeated with the addition of an upper 1st adj. chan. interferer at 6 dB D/U. 5. An analog reference recording will be made using all 4 NRSC analog test receivers for the measurement point 2 dB below (i.e. before) the point of blend.	M	Objective	1st adj. channel D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for IBOC digital and analog reference recordings made in steps 2, 4, and 5

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IBOC LABORATORY TEST PROCEDURES – FM BAND
DIGITAL PERFORMANCE

Test Group	Test and Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
		Notes: 1. All interferers are to be hybrid IBOC signals – refer to NRSC Audio Test List for information on interferer modulation. 2. The analog reference recordings specified in each step will be made with the IBOC digital sidebands removed from the desired and undesired signals. 3. For tests D.2 and D.3, analog reference recordings will be made with all relevant permutations of upper/lower adjacent channel interference. 4. The analog reference recordings specified in each step will be made with the IBOC digital sidebands removed from the desired and undesired signals.			
D IBOC ➜ IBOC	3 Single and dual 2nd adjacent, and simultaneous single 2nd and single 1st adjacent	1. Using a lower 2nd adjacent channel interferer, the D/U corresponding to system point of blend will be established. 2. The desired impairment audio segments will be recorded with the lower 2nd adj. chan. D/U set at a level 2 dB below (i.e. before) the point of blend. 3. For each measurement point, the mode signal status will be recorded. The BLER will be recorded with the lower 1st adj. chan D/U set at a level 2 dB below (i.e. before) the point of blend, then with the 1st adj. chan. level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. 4. Steps 1-3 will be repeated with the addition of an upper 1st adj. chan. interferer at 6 dB D/U. 5. Simultaneous upper and lower 2nd adj. chan. tests will be conducted using the D/U setting in step 2 for the lower interferer and with the upper interferer fixed at –20 dB D/U. 6. An analog reference recording will be made using NRSC analog test receivers #3 and #4 (non-automobile receivers) for the measurement point 2 dB below (i.e. before) the point of blend.	M	Objective	2nd adj. channel D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for IBOC digital and analog reference recordings made in steps 2, 4, 5, and 6

IBOC LABORATORY TEST PROCEDURES – FM BAND
DIGITAL PERFORMANCE

Test Group	Test and Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
		Notes: 1. Each undesired channel will be modulated with the multipath interference selection. When there are two undesired channels, the audio cuts and multipath conditions will be time shifted with respect to one another by TBD ms (for audio) and TBD ms (for multipath). 2. The audio in each channel (both desired and undesired) shall be synchronized in time with respect to its respective multipath simulator. 3. For tests E.2 and E.3, analog reference recordings will be made with all relevant permutations of upper/lower adjacent channel interference. 4. The analog reference recordings specified in each step will be made using NRSC analog test receivers #1 and #2 (automobile receivers), and with the IBOC digital sidebands removed from the desired and undesired signals.			
E IBOC ➜ IBOC with multipath	1 Co-channel	1. Test D.1 will be repeated using the four multipath scenarios, except that the desired impairment audio segments will be recorded with the co-channel D/U set at a level 8 dB below (i.e. before) the point of blend (instead of 2 dB).	M	Objective	Co-channel D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for IBOC digital and analog reference recordings made in steps 2, 4
	2 Single and dual 1st adjacent	1. Test D.2 will be repeated using the four multipath scenarios, except that the desired impairment audio segments will be recorded with the 1st adjacent channel D/U set at a level 8 dB below (i.e. before) the point of blend (instead of 2 dB).	M	Objective	1st adj. chan. D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for IBOC digital and analog reference recordings made in steps 2, 4, and 5
	3 Single and dual 2nd adjacent, and simultaneous single 2nd and single 1st adjacent	1. Test D.3 will be repeated using the four multipath scenarios, except that the desired impairment audio segments will be recorded with the 2nd adjacent channel D/U set at a level 8 dB below (i.e. before) the point of blend (instead of 2 dB). If the D/U level at a measurement point is greater than –20 dB, no multipath will be used on the undesired signal for that measurement.	M	Objective	2nd adj. chan. D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for IBOC digital and analog reference recordings made in steps 2, 4, 5, and 6

IBOC LABORATORY TEST PROCEDURES – FM BAND
ANALOG COMPATIBILITY (w/adjacent channel IBOC)

Test Group	Test & Impairment	DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		Notes: 1. These tests will compare hybrid IBOC-to-analog with analog-to-analog interference. The desired signal XMTR will be non-IBOC, and the undesired signal XMTR will be hybrid IBOC with the IBOC digital sidebands alternately turned on and off (see below). 2. The test will be conducted with no background RF noise and with RF AWGN equivalent to 30,000K. 3. The undesired analog will be modulated with the interference selection. 4. All NRSC analog test receivers will be used, however, subjective evaluations will only be made for the worst performing interferer (i.e. upper or lower) for each radio UNLESS the performance difference (as determined objectively) between interference cases is > 5 dB.			
F IBOC ➜ Analog (main channel audio) (interference to an analog receiver with no other impairments)	1 Single 1st adjacent	1. The desired signal will be modulated with 1 kHz tone and pilot (no other subcarriers). 2. Using a lower 1st-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, the desired main channel analog WQP S/N ratio will be measured for D/U settings of 16 dB, 6 dB, -4 dB, -14 dB, and –24 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer.	M (W for -14, -24 dB D/U cases)	Objective	Analog S/N ratio at specified D/Us with IBOC digital sidebands on and off (main channel audio)
	2 Single 2nd adjacent	1. The desired signal will be modulated with 1 kHz tone and pilot (no other subcarriers). 2. Using a lower 2nd-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, the desired analog WQP S/N ratio will be measured for D/U settings of –20, -25, -30, -35, and -40 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 2nd-adjacent channel IBOC interferer.			
	3 Single 1st adjacent	1. The desired signal will be modulated with the desired impairment audio selections (no other subcarriers). 2. Using a lower 1st-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, audio recordings of the desired signal main channel audio will be made for D/U settings of 16 dB, 6 dB, and –4 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer.	M	Subjective	Subjective impairment rating for each D/U setting for desired main channel analog audio signals with undesired IBOC digital sidebands on and off (for worst performing interferer for each radio only)
	4 Single 2nd adjacent	1. Same as test F.3, using 2nd adjacent instead of 1st adjacent channel interferers, at D/U settings of –20 dB and –40 dB.			

IBOC LABORATORY TEST PROCEDURES – FM BAND
ANALOG COMPATIBILITY (w/adjacent channel IBOC)

Test Group	Test & Impairment	DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		Notes: 1. These tests will compare hybrid IBOC-to-analog with analog-to-analog interference for FM subcarriers. The desired signal XMTR will be non-IBOC, and the undesired signal XMTR will be hybrid IBOC with the IBOC digital sidebands alternately turned on and off (see below). 2. The test will be conducted with no background RF noise and with RF AWGN equivalent to 30,000K. 3. The undesired analog will be modulated with the interference selection. 4. All NRSC analog subcarrier test receivers will be used, however, subj. evaluations will only be made for the worst performing interferer (i.e. upper or lower) for each radio UNLESS the performance difference (as determined objectively) between interference cases is > 5 dB.			
F/SC IBOC ➜ Analog (FM subcarriers) (interference to an analog receiver with no other impairments)	1 Single 1st adjacent – analog subcarriers	1. The desired signal will be modulated with CPN, and subcarrier config. #4. 2. Using a lower 1st-adj. chan. IBOC interferer, with the IBOC digital sidebands turned on, the 67 kHz, 92 kHz subcarrier audio WQP S/N ratio will be meas. for D/U settings of 16 dB, 6 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer.	M	Objective	Analog S/N ratio at specified D/Us with IBOC digital sidebands on and off (67 kHz subcarrier audio, 92 kHz subcarrier audio)
	2 Single 2nd adjacent – analog subcarriers	1. The desired signal will be modulated with CPN, and subcarrier configuration #4 (67 kHz and 92 kHz analog). 2. Using a lower 2nd-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, the 67 kHz and 92 kHz subcarrier audio WQP S/N ratio will be measured for D/U settings of 0, -10 dB, -20 dB, and -30 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 2nd-adjacent channel IBOC interferer.			
	3 Single 1st adjacent – digital subcarriers	1. The desired signal will be mod. with CPN, and subcarrier config. #2 (RDS). 2. Using a lower 1st-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, the subcarrier error rate will be measured for D/U settings of 26 dB, 16 dB and 6 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer. 5. Steps 2-4 will be repeated using subcarrier configuration #3 (HSSC).	M	Objective	Digital subcarrier error rate at specified D/Us with IBOC digital sidebands on and off (RDS, HSSC)

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IBOC LABORATORY TEST PROCEDURES – FM BAND ANALOG COMPATIBILITY (w/adjacent channel IBOC)					
Test Group	Test & Impairment	DESCRIPTION Notes: 1. These tests will compare hybrid IBOC-to-analog with analog-to-analog interference for FM subcarriers. The desired signal XMTR will be non-IBOC, and the undesired signal XMTR will be hybrid IBOC with the IBOC digital sidebands alternately turned on and off (see below). 2. The test will be conducted with no background RF noise and with RF AWGN equivalent to 30,000K. 3. The undesired analog will be modulated with the interference selection. 4. All NRSC analog subcarrier test receivers will be used, however, subj. evaluations will only be made for the worst performing interferer (i.e. upper or lower) for each radio UNLESS the performance difference (as determined objectively) between interference cases is > 5 dB.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
F/SC IBOC ➜ Analog (FM subcarriers) (interference to an analog receiver with no other impairments)	4 Single 2nd adjacent – digital subcarriers	1. The desired signal will be mod. with CPN, and subcarrier config. #2 (RDS). 2. Using a lower 2nd-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, the subcarrier error rate will be meas. for D/U settings of 0 dB, -10 dB, -20 dB, and -30 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 2nd-adjacent channel IBOC interferer. 5. Steps 2-4 will be repeated using subcarrier configuration #3 (HSSC).	M	Objective	Digital subcarrier error rate at specified D/Us with IBOC digital sidebands on and off (RDS, HSSC)
	5 Single 1st adjacent – analog subcarriers	1. The desired signal will be modulated with TBD audio (from audio cut list), and subcarrier configuration #4 (67 kHz and 92 kHz analog). 2. Using a lower 1st-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, audio recordings of the 67 kHz and 92 kHz subcarrier audio will be made for D/U settings of 16 dB, and 6 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer.	M	Subjective	Subjective impairment rating for each D/U setting for 67 kHz and 92 kHz subcarrier analog audio signals with undesired IBOC digital sidebands on and off (for worst performing interferer for each radio only)
	6 Single 2nd adjacent – analog subcarriers	1. The desired signal will be modulated with TBD audio (from audio cut list), and subcarrier configuration #4 (67 kHz and 92 kHz analog). 2. Using a lower 2nd-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, audio recordings of the 67 kHz and 92 kHz subcarrier audio will be made for D/U settings of -10 dB and -30 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 2nd-adjacent channel IBOC interferer.			

IBOC LABORATORY TEST PROCEDURES – FM BAND
ANALOG COMPATIBILITY (w/adjacent channel IBOC)

Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
		Notes: 1. These tests will compare hybrid IBOC-to-analog with analog-to-analog interference. The desired signal transmitter will be non-IBOC, and the undesired signal transmitter will be hybrid IBOC with the IBOC digital sidebands alternately turned on and off (according to the procedures below). 2. Both desired and undesired signals will be subject to multipath fading, using the urban slow and urban fast multipath scenarios. 3. The test will be conducted with no background RF noise and with RF AWGN equivalent to 30,000K. 4. The undesired channel will be modulated with the multipath interference selection. 5. The audio in each channel (both desired and undesired) shall be synchronized in time with respect to its respective multipath simulator. 6. NRSC analog test receivers #1 and #2 (automobile receivers) will be used for this test, however, subjective evaluations will only be made for the worst performing interferer (i.e. upper or lower) for each radio UNLESS the performance difference (as determined objectively) between interference cases is > 5 dB.			
G IBOC ➜ Analog (main channel audio) with multipath (interference to an analog receiver with multipath on the desired and undesired signals)	1 Single 1st Adjacent	1. The desired signal will be modulated with the desired impairment audio selections. 2. Using a lower 1st-adjacent channel IBOC interferer, with the IBOC digital sidebands turned on, audio recordings of the desired signal will be made for the urban slow and urban fast multipath scenarios, for a D/U setting of +6 dB. 3. Step 2 will be repeated with the IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer.	M	Subjective	Subjective impairment rating for desired analog signal with undesired IBOC digital sidebands on and off (for worst performing interferer for each radio only)

IBOC LABORATORY TEST PROCEDURES – FM BAND DIGITAL PERFORMANCE					
Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. The audio will be the classical music selection of the desired impairment audio. 2. Each acquisition recording will last one minute. 3. Each test will be repeated at least five times and the results recorded for further assessment.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
H IBOC acquisition	1 Acquisition with varying signal level	1. Using the strong signal level, the RF input will be disconnected from the receiver (as close to the receiver input connector as possible) for sixty seconds to assure loss of lock. 2. The signal will then be reconnected to the IBOC receiver. 3. The audio start will be synchronized with the signal reconnection. 4. The time to audio output will be measured in seconds using a digital oscilloscope (in storage mode). 5. Steps 1-4 will be repeated with the moderate signal level. 6. Steps 1-5 will be repeated with a +6 dB D/U lower first adjacent interferer.	S & M	Objective	Acquisition time at each noise level and audio recordings based upon laboratory observation (listening)

IBOC LABORATORY TEST PROCEDURES – FM BAND
DIGITAL QUALITY

Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
I IBOC quality	1 Quality transmission test	1. Tests will be conducted using the audio quality selections. 2. Each of the selections will be transmitted through the IBOC system without impairment and recorded for subjective evaluation. 3. For each measurement point, the mode signal status will be recorded.	S	Objective	Mode signal status of system during recording of audio selections
				Subjective	Subjective rating for each audio quality selection

IBOC LABORATORY TEST PROCEDURES – FM BAND ANALOG COMPATIBILITY (Host)					
Test Group	Test & Impairment	TEST PROCEDURE Note: 1. The test will be conducted with no background RF noise and with RF AWGN equivalent to 30,000K.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
J IBOC ➜ Host analog	1 IBOC to host analog	1. All 4 NRSC analog test receivers will be used for this test. 2. The host FM transmitter will be set for a total of 75 kHz deviation, modulated with a 1 kHz tone and pilot. 3. With the host IBOC digital sidebands turned on, the host analog WQP S/N ratio, and stereo separation will be measured. 4. Step 3 will be repeated with the host IBOC digital sidebands turned off.	S	Objective	Host analog S/N ratio, stereo separation, with IBOC digital sidebands on and off
	2 IBOC to host analog	1. All 4 NRSC analog test receivers will be used for this test. 2. The host FM transmitter will be set for a total of 75 kHz deviation, modulated with the desired impairment audio selections. 3. With the host IBOC digital sidebands turned on, audio recordings of the host analog the desired signal will be made. 4. Step 3 will be repeated with the host IBOC digital sidebands turned off.	S	Subjective	Subjective impairment rating of host analog audio with IBOC digital sidebands on and off
	3 IBOC to subcarriers – baseband spectral plots	1. The host FM transmitter will be set for a total of 75 kHz deviation, modulated with a 1 kHz tone and pilot. 2. With the host IBOC digital sidebands turned on , the received baseband noise floor (100 Hz to 300 kHz) will be plotted using a wideband precision demodulator. 3. Step 2 will be repeated with the host IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated with the 1 kHz program audio tone removed.	S & M	Objective	Baseband noise floor plots for various operating conditions
	4 IBOC to subcarriers – analog subcarrier performance	1. The FM host channel will be modulated with pilot, CPN on main channel audio, and subcarrier configuration #1 (RDS, 67 kHz analog, 92 kHz analog). 2. With the host IBOC digital sidebands turned on, the analog subcarrier S/N ratio will be measured on both 67 kHz and 92 kHz subcarriers. 3. Step 2 will be repeated with the host IBOC digital sidebands turned off. 4. With the host IBOC digital sidebands turned on, and the FM host channel main channel audio modulation changed from CPN to TBD (from audio cut list), audio recordings will be made of both the 67 kHz and 92 kHz subcarriers using TBD audio. 5. Step 4 will be repeated with the host IBOC digital sidebands turned off.	S & M	Objective Subjective	Analog subcarrier audio S/N ratio with IBOC digital sidebands on and off Subjective rating for each audio quality selection

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IBOC LABORATORY TEST PROCEDURES – FM BAND
ANALOG COMPATIBILITY (Host)

Test Group	Test & Impairment	TEST PROCEDURE Note: 1. These tests will be conducted with no background RF noise and with RF AWGN equivalent to 30,000K.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
J IBOC ➜ Host analog	5 IBOC to subcarriers – RDS subcarrier performance	1. The FM host channel will be modulated with pilot, CPN on main channel audio, and subcarrier configuration #1 (RDS at 3% injection). 2. With the host IBOC digital sidebands turned on, the RDS BLER will be measured. [RDS MEASUREMENT SOFTWARE TBD] 3. Step 2 will be repeated with the host IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated with the 1 kHz program audio tone removed. 5. Steps 2-4 will be repeated, substituting subcarrier configuration #1 with subcarrier configuration #2 (RDS at 10% injection).	S & M	Objective	RDS error rate for various operating conditions
	6 IBOC to subcarriers – “high speed” digital subcarrier (HSSC) performance	1. The FM host channel will be modulated with pilot, CPN on main channel audio, and subcarrier configuration #3 (HSSC). 2. With the host IBOC digital sidebands turned on, the high speed digital subcarrier (HSSC) BLER will be measured. 3. Step 2 will be repeated with the host IBOC digital sidebands turned off. 4. Steps 2 and 3 will be repeated with the 1 kHz program audio tone removed.	S & M	Objective	HSSC error rate for various operating conditions

NRSC Analog Test Receivers

Number	Make and Model	Type	Age in Years
1	Delphi Model: 09394139	Auto OEM	New
2	Pioneer Model: KEH-1900	Auto Aftermarket	New
3	Technics Model: SA-EX140	Home HiFi	New
4	Sony Model: CFD-S32	Table Combo	New

NRSC Analog Subcarrier Test Receivers

Number	Make and Model	Type	Age in Years
5	McMartin	67 kHz	
6	Norver	67 kHz Reading services	
7	CozmoCom	92 kHz	
8	ComPol SCA-BL	92 kHz	

Appendix C –
IBOC field test procedures – FM band

NATIONAL
RADIO
SYSTEMS
COMMITTEE

DAB Subcommittee
Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

IBOC FIELD TEST PROCEDURES – FM BAND
OVERALL COMMENTS

1. The independent engineering consultant (TBD) will provide a detailed certification of the mobile test vehicle including the stationary test platforms.
2. Appendix A is a table and set of maps which describe the test stations and test routes which this procedure is to be conducted for. Note that the test routes depicted therein represent the best possible estimate of the routes to be used, and that accommodations may be made during the actual test run due to road construction, etc. Maps of the actual routes taken will be provided in the field test record.
3. IBOC receiver point-of-blend is established by the "mode" signal which is supplied by the receiver. IBOC receiver block error rate (BLER) is also observable.
4. Unless otherwise specified, the audio selections to be used as source material for desired and interfering channels will be "audio of opportunity," and, the source audio for analog reference recordings will be the same as that used for the corresponding IBOC digital audio recordings.
5. Digital recordings of analog and IBOC digital audio indicated by these procedures are for archival and/or subjective evaluation purposes. All such recordings will be made in the following format: uncompressed linear 16-bit digital audio sampled at 44.1 kHz, and will be suitable for transfer to CD to facilitate further analysis.
6. The detailed procedure for RF noise measurements will be supplied.
7. The host FM to digital power ratio used in the digital performance tests will also be used for the analog compatibility tests.
8. Appendix A contains information on the stations and test routes to be used for these tests.
9. NRSC analog test receivers specified on pg. 5 will undergo the following characterization tests: [list TBD]
10. Test record will indicate direction of travel on all routes
11. All radial routes (this includes all field test locations except San Francisco) will be driven to the IBOC point of failure (POF), that is, until the IBOC signal is fully blended to analog.
12. "Strip chart" data plots will be included in the test record for all test routes [*e.g.*, a plot from USADR phase 1 submission will be included here].
13. NRSC will participate in selection of specific field test audio cuts to be submitted for subjective evaluation in a TBD fashion.

IBOC FIELD TEST PROCEDURES – FM BAND
CALIBRATION

Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. This calibration will be performed for each test station.	Type of Evaluation	Test Results Data to be Recorded
A Calibration	1 Power (as needed)	1. Analog power will be read by station's existing test equipment. 2. Digital power will be determined using a spectrum analyzer.	Objective	Analog average power level Digital average and peak power levels
	2 Spectrum (daily)	1. Spectrum analyzer plots of the system RF will be taken at the output of the transmission system. 2. The spectrum analyzer settings will be: (a) RES BW 1.0 kHz, VBW 30 Hz and sweep span 2.0 MHz, and (b) RES BW 1.0 kHz, VBW 30 Hz and sweep span 0.5 MHz (transmission line test). All plots will be made using digital averaging of at least 100 sweeps. 3. Four plots of the spectrum will be made: two at setting (a) with and without IBOC digital sidebands, and two at setting (b) with and without IBOC digital sidebands. 4. Test station modulation monitor readings will be recorded.	Objective	Daily power ratios and out-of-channel radiation monitored at combiner output
	3 Monitor (beginning of test period)	1. Test station occupied bandwidth characteristics will be established by the test crew using a spectrum analyzer in both “average” and “peak hold” modes.	Objective	Certification should be recorded in field test record
	4 Receiver antenna performance and data	1. A detailed description of the receiving antenna and RF distribution system will be included in the field test report. 2. If any active RF device is used, a full set of RF performance test results will be supplied with the report.	Objective	
	5 General	1. All test equipment will be certified to be in compliance with manufacturer's specifications and calibration schedules.	Objective	Calibration results

IBOC FIELD TEST PROCEDURES – FM BAND
DIGITAL PERFORMANCE

Test Group	Test & Impairment	TEST DESCRIPTION	Type of Evaluation	Test Results Data to be Recorded
		Notes: 1. Radials will be selected to demonstrate system performance under the following conditions: a) low interference and low multipath b) low interference and moderate/strong multipath c) single first adjacent interferer d) single second adjacent interferer e) simultaneous dual interferers, to the extent feasible f) terrain obstructions g) centrally-located urban antenna h) combined antenna i) strong single 1st adjacent interferer j) low power combiner/common amplification (otherwise high-power combiner assumed) k) class A FM facility l) 67 kHz analog subcarrier compatibility m) 92 kHz analog subcarrier compatibility n) RDS subcarrier compatibility o) DARC subcarrier compatibility 2. Radials will start within 1.0 mile of the transmitter (where possible) and extend beyond the edge of digital coverage. 3. Audio recordings in a digital format of both the analog and digital received audio will be made. 4. Recordings of the test route will be made including GPS data, derived signal strength and adjacent channel signal strength. 5. For all tests, stations will broadcast their regular programming. 6. NRSC analog test receiver #1 will be used for analog reception.		
B System performance	1 Low interference and low multipath	1. The undesired first adjacent analog signal should be at least 10 dB below the digital signal. 2. The undesired analog second adjacent D/U should not exceed a D/U of -20 dB in the test area.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)
	2 1st-adjacent interference	1. First adjacent interferer will be in an area where the interfering signal exceeds 6 dB below the desired signal.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)
	3 2nd-adjacent interference	1. Second adjacent interferer will be at least 20 dB above the desired signal.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)

IBOC FIELD TEST PROCEDURES – FM BAND
ANALOG COMPATIBILITY

Test Group	Test & Impairment	TEST DESCRIPTION	Type of Evaluation	Test Results Data to be Recorded
		Notes: 1. Tests C.1 and C.2 are host compatibility tests i.e. the analog receivers under test will be tuned to the host IBOC station. 2. Test C.3 is a non-host compatibility test i.e. the analog receiver under test will be tuned to a normal analog station which is 1st-adjacent to an IBOC station (as specified in note 5). 3. Host compatibility (main channel audio) tests (C.1) will be conducted at stations WETA and WPOC. 4. Host compatibility (analog and digital subcarriers) tests (C.2) will be conducted at stations TBD. 5. 1st-adjacent compatibility tests (C.3) will be conducted at WPOC and WNEW.		
C Compatibility	1 Host compatibility – main channel audio	1. Fixed compatibility tests will be conducted using all NRSC Test Receivers. 2. The digital signal should be switched on for 30 seconds and off for 30 seconds. This should be repeated twice. 3. Recordings will be made at 3 locations with strong desired signals, and as free as possible of other (undesired) strong signals, so as to maximize potential for host interference.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)
	2 Host compatibility – analog and digital subcarrier s	1. Fixed compatibility tests will be conducted using commercially available subcarrier receivers. 2. The digital signal should be switched on for 30 seconds and off for 30 seconds. This should be repeated twice. 3. Recordings will be made at 3 locations with strong desired signals, and as free as possible of other (undesired) strong signals, so as to maximize potential for host interference. 4. Tests of analog subcarriers will be conducted with 57, 67 and 92 kHz subcarriers with total injection of less than 20%. 5. Test of digital subcarrier will be conducted at 57 kHz and using a subcarrier at 76 kHz with a total injection of 10%. 6. BLER shall be recorded with DAB on and off for all relevant subcarriers.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)
	3 1st-adjacent compatibility	1. Fixed compatibility tests will be conducted using all test receivers. 2. Test will be conducted at a point where the first adjacent signal is on the order of 6 dB less than the desired analog signal. 3. Recordings will be made at 3 locations.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)

NRSC Analog Test Receivers			
Number	Make and Model	Type	Age in Years
1	Delphi Model: 09394139	Auto OEM	New
2	Pioneer Model: KEH-1900	Auto Aftermarket	New
3	Technics Model: SA-EX140	Home HiFi	New
4	Sony Model: CFD-S32	Table Combo	New

NRSC Analog Subcarrier Test Receivers			
Number	Make and Model	Type	Age in Years
5	McMartin	67 kHz	
6	Norver	67 kHz Reading services	
7	CozmoCom	92 kHz	
8	ComPol SCA-BL	92 kHz	

Table 1 – Test Condition Matrix (see notes on page 2)

					Test Condition(s)															
No	**Call Sign**	**Freq. (MHz)**	**Format**	**Location**	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	**Comments**
1	WETA	90.9	Talk and classical	Washington, D.C.	✔															• Coverage (8-radial test) • Host compatibility (no interferers – best station for host compatibility tests)
2	WPOC	93.1	Country	Baltimore, MD			✔													• Host compatibility • 2nd adjacent interferer to 93.5 MHz (WD2XAB) – used as 2nd adjacent undesired for compatibility testing with WD2XAB • 1st-adj. compatibility (0º radial) • 1st adj. compatibility and performance (180º radial) • 2nd-adj. performance (undesired)
3	WD2XAB	93.5	Test	Columbia, MD				✔												• Used as 2nd adjacent desired for compatibility testing with WPOC • 2nd-adj. performance (desired)
4	KLLC	97.3	"Alice"	San Francisco, CA		✔				✔										• Terrain obstructions • EIA/NRSC test routes used (from 1996 tests) – closed path, not radials
5	WHFS	99.1	Rock	Annapolis, MD					✔											2nd-adj. compatibility (270º radial)
6	KWNR	95.5	Country	Las Vegas, NV		✔				✔										• "Specular" multipath • Terrain obstructions
7	WNEW	102.7	Talk and rock (weekends)	New York, NY		✔					✔	✔	✔							• 1st-adj. compatibility • "Specular" multipath
8	WWIN	95.9	Urban (pop)	Baltimore, MD				✔						✔	✔					
				Number of stations with given test condition ➔	1	3	1	2	1	2	1	1	1	1	1					Subcarrier conditions (l-o) TBD
1R	WGRV	105.1	Urban oldies	Detroit, MI				✔												• Reserve – will only be used if problems prevent use of one or more of stations 1-8 • 2nd-adj. performance (180º radial)

<u>Notes for Table 1</u>:

1. Proponent will run at least 4 radials for each test station
2. Proponent will supply maps of the test radials plotted against predicted analog coverage and strip charts for each station
3. Select radials noted above will be extracted for further analysis and subjective evaluation
4. Multipath examples for subjective evaluation will be selected from recordings of multiple stations
5. Test conditions (see Field Test Procedure, Test B Notes):
   (a) low interference and low multipath
   (b) low interference and moderate/strong multipath
   (c) single first adjacent interferer
   (d) single second adjacent interferer
   (e) simultaneous dual interferers, to the extent feasible
   (f) terrain obstructions
   (g) centrally-located urban antenna
   (h) combined antenna
   (i) strong single 1st adjacent interferer
   (j) low power combiner/common amplification (otherwise high-power combiner assumed)
   (k) class A FM facility
   (l) 67 kHz analog subcarrier compatibility
   (m) 92 kHz analog subcarrier compatibility
   (n) RDS subcarrier compatibility
   (o) DARC subcarrier compatibility

Table 2. Station List for IBOC to Analog Compatibility Testing

Compatibility Type	Station of Interest Format Location	Freq. (MHz) Channel	Interfering Station Format Location	Freq. (MHz) Channel	Interferer location	Station Spacing
Host	WETA (IBOC) Classical/Talk Washington DC	90.9 215B				
Host	WPOC (IBOC) Country Baltimore, MD	93.1 226B				
First Adjacent	WMMR (FM) Rock Philadelphia, PA	93.3 227B	WPOC (IBOC) Country Baltimore, MD	93.1 226B	Upper	155 km
First Adjacent	WFLS (FM) Country Fredericksburg, VA	93.3 227B	WPOC (IBOC) Country Baltimore, MD	93.1 226B	Upper	123 km
First Adjacent	WMGK (FM) Classic Rock Philadelphia, PA	102.9 275B	WNEW (IBOC) Talk/Rock New York, NY	102.7 274B	Lower	132 km
Second Adjacent	WMZQ (FM) Country Washington DC	98.7 254B	WHFS (IBOC) Rock Annapolis, MD	99.1 256B	Upper	43 km
Second Adjacent	WJMO (FM) Jammin'Oldies Washington DC	99.5 258B	WHFS (IBOC) Rock Annapolis, MD	99.1 256B	Lower	39 km

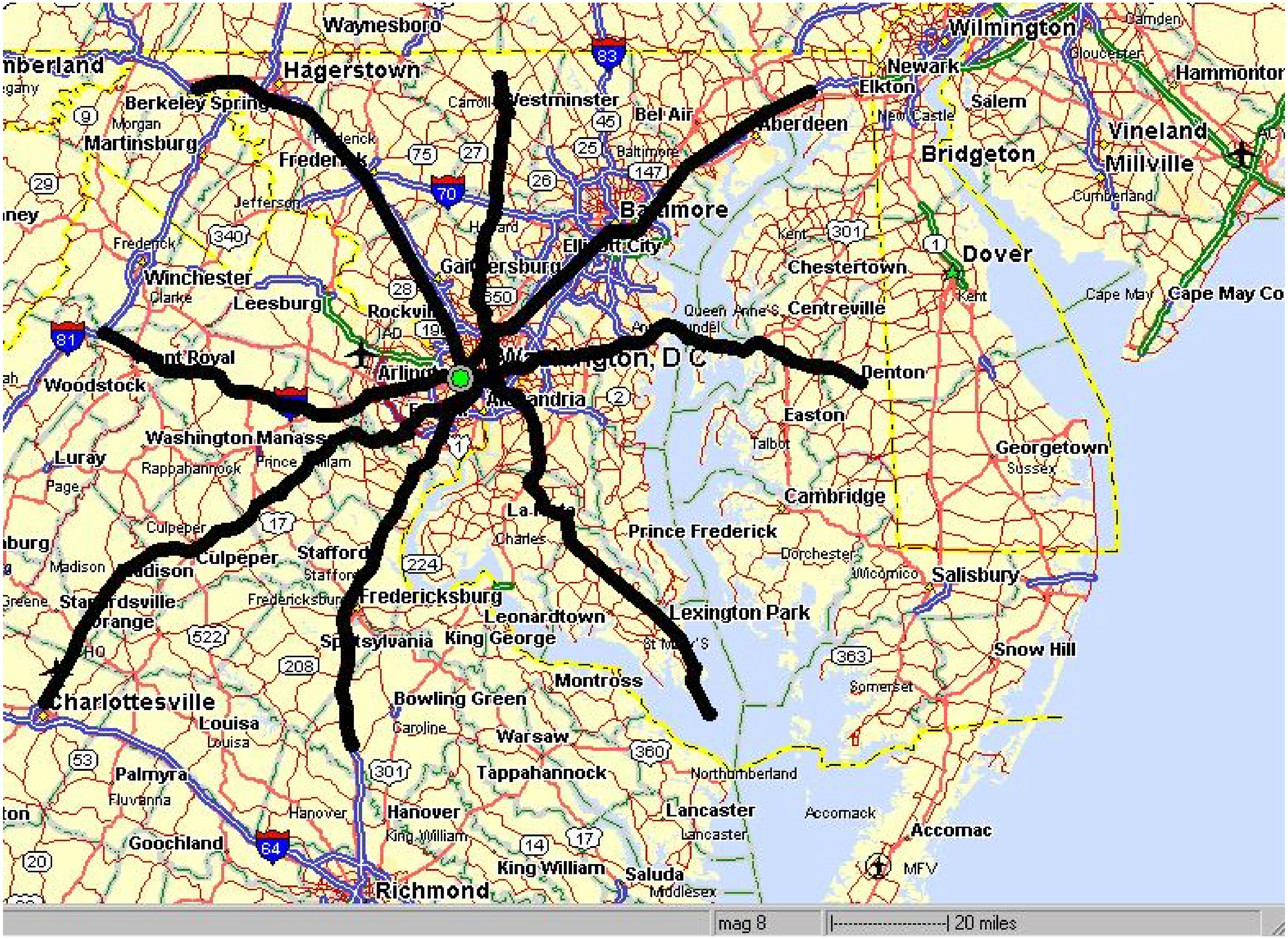
Table 3a. Station List for IBOC Performance Testing – Part 1 of 2

Test Station Format Location	Freq. (MHz) Channel	Subcarriers (TBD)	Propagation & Testing Features	Significant Interferers	Drive Routes
WETA Classical/Talk Washington DC	90.9 215B		Terrain Obstructed M/P; Urban performance of suburban TX site	Analog Co-channel WHYY in Philadelphia, Class B @ 207 km	Eight radials
WPOC Country Baltimore, MD	93.1 226B		Urban/suburban performance of suburban TX site	Analog 1st Adjacent WFLS in Fredericksburg, VA, 93.3 MHz, Class B @ 124 km	Five radials plus fork in southern radial toward WFLS
KLLC "Alice" San Francisco, CA	97.3 247B		Severe, Terrain Obstructed M/P		EIA loops as established in 1995 testing
WHFS Rock Annapolis, MD	99.1 256B			Analog 2nd Adjacents WMZQ in Wash. DC, 98.7 MHz, Class B @ 43 km WJMO in Wash. DC, 99.5 MHz, Class B @ 39 km	1 path from station toward area of 2nd adjacent stations
KWNR Country Henderson, NV	95.5 238C		Specula M/P, Class C station		Eight radials, including Las Vegas "Strip"

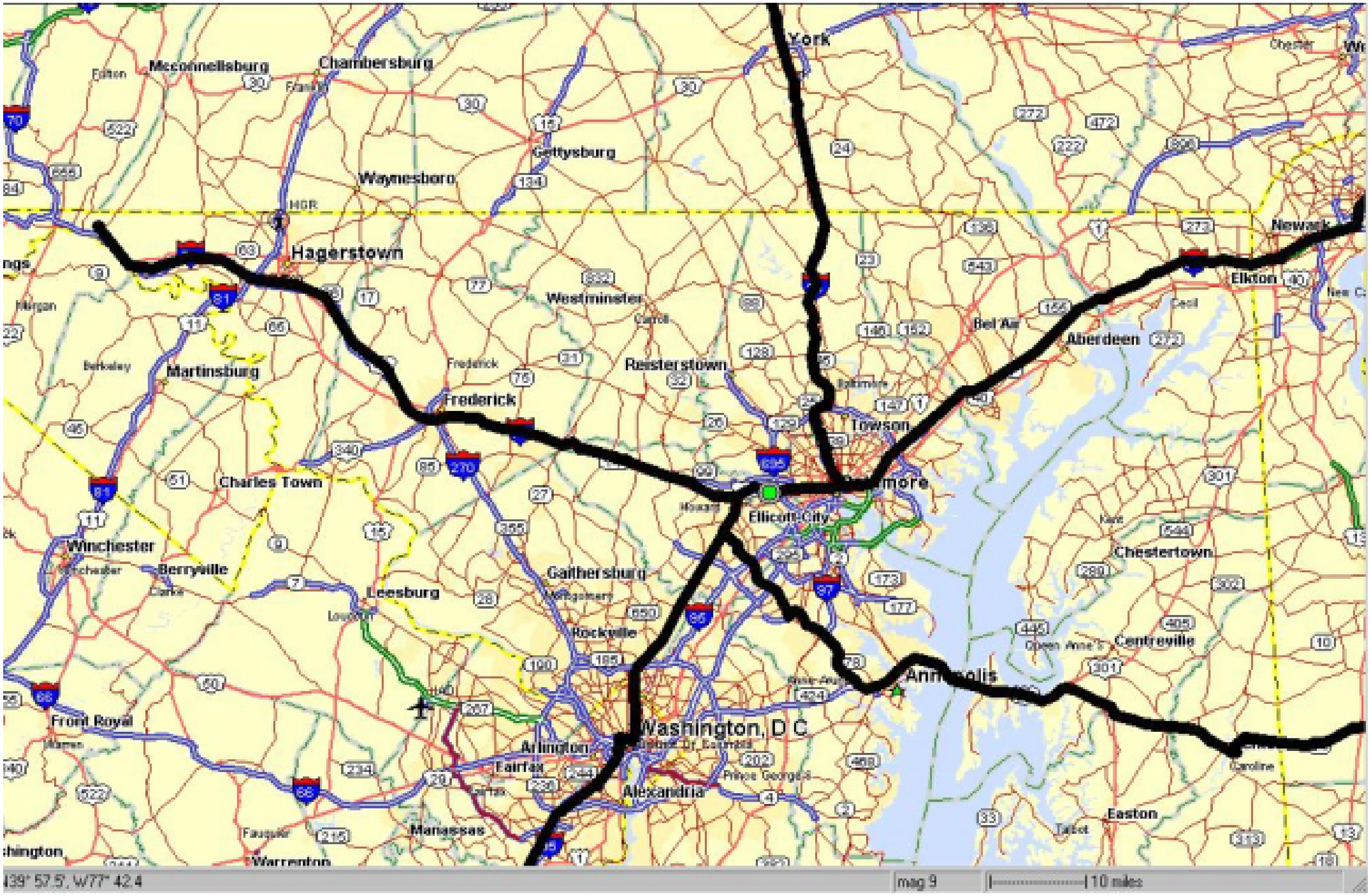
Table 3b. Station List for IBOC Performance Testing – Part 2 of 2

Test Station Format Location	Freq. (MHz) Channel	Subcarriers (TBD)	Propagation and Testing Features	Significant Interferers	Drive Routes
WNEW Talk/Rock New York, NY	102.7 274B		Urban and Terrain Obstructed M/P; Test of Urban and suburban coverage from central, urban TX site on master antenna system		Urban circles combined with four radials
WWIN Urban Pop Glen Burnie, MD	95.9 240A		Class A station with low power combining and common analog/IBOC amplification	Analog 2nd Adjacent WHUR in Wash. DC, 96.3 MHz, Class B @ 52 km	Four radials
WD2XAB, experimental Varied, as required Columbia, MD	93.5 228A		Suburban Class A station	IBOC 2nd Adjacent WPOC in Baltimore, 93.1 MHz Class B @ 12 km Analog 2nd Adjacent WKYS in Wash. DC, 93.9 MHz Class B @ 36 km	Four radials
WGRV Urban Oldies Farmington Hill, MI	105.1 286B		Reserve Test Station	TBD if required	TBD if required

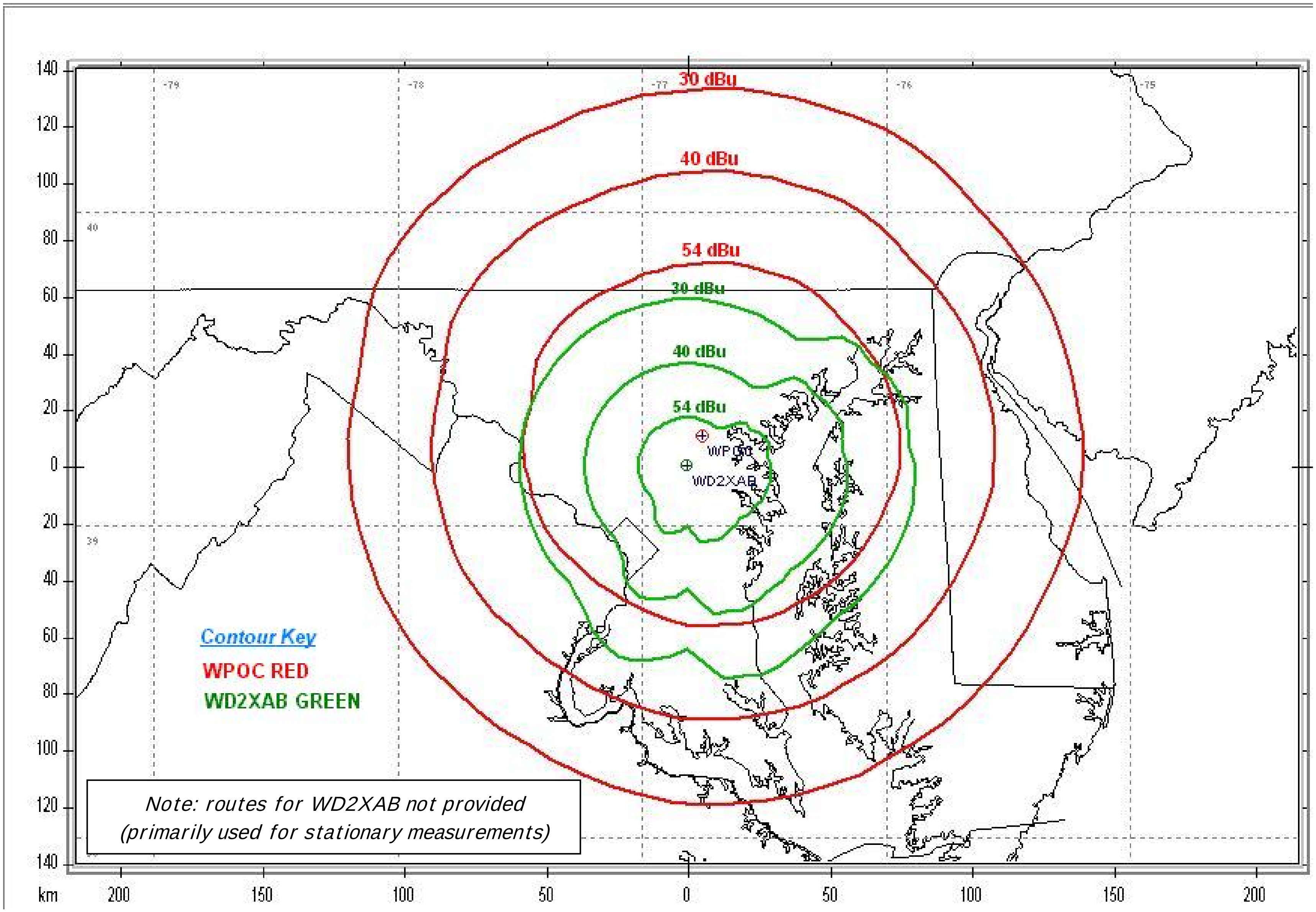
Field test route map – WETA-FM (wetamapR2.jpg)



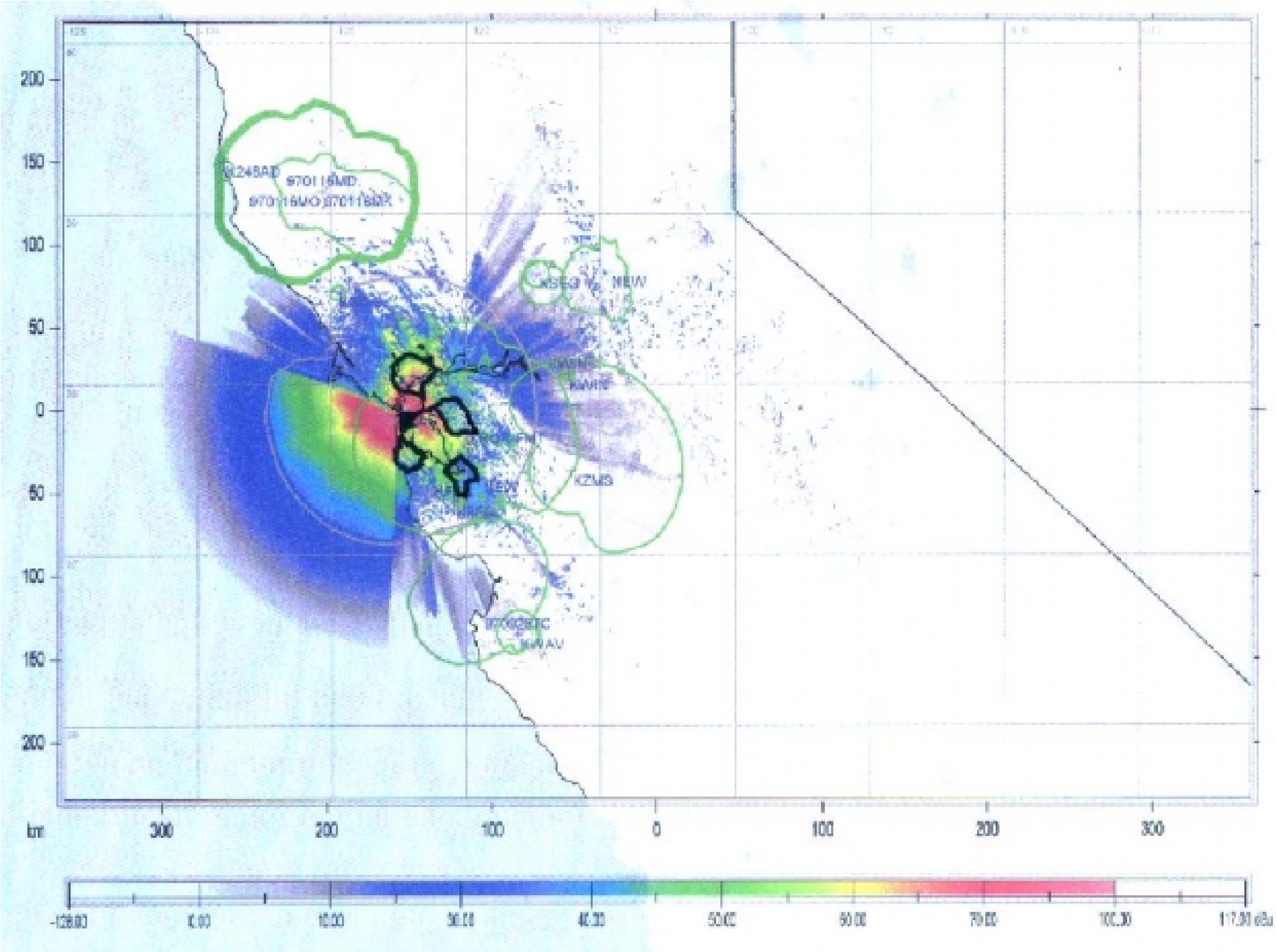
Field test route map – WPOC-FM (wpocmapR2.jpg)



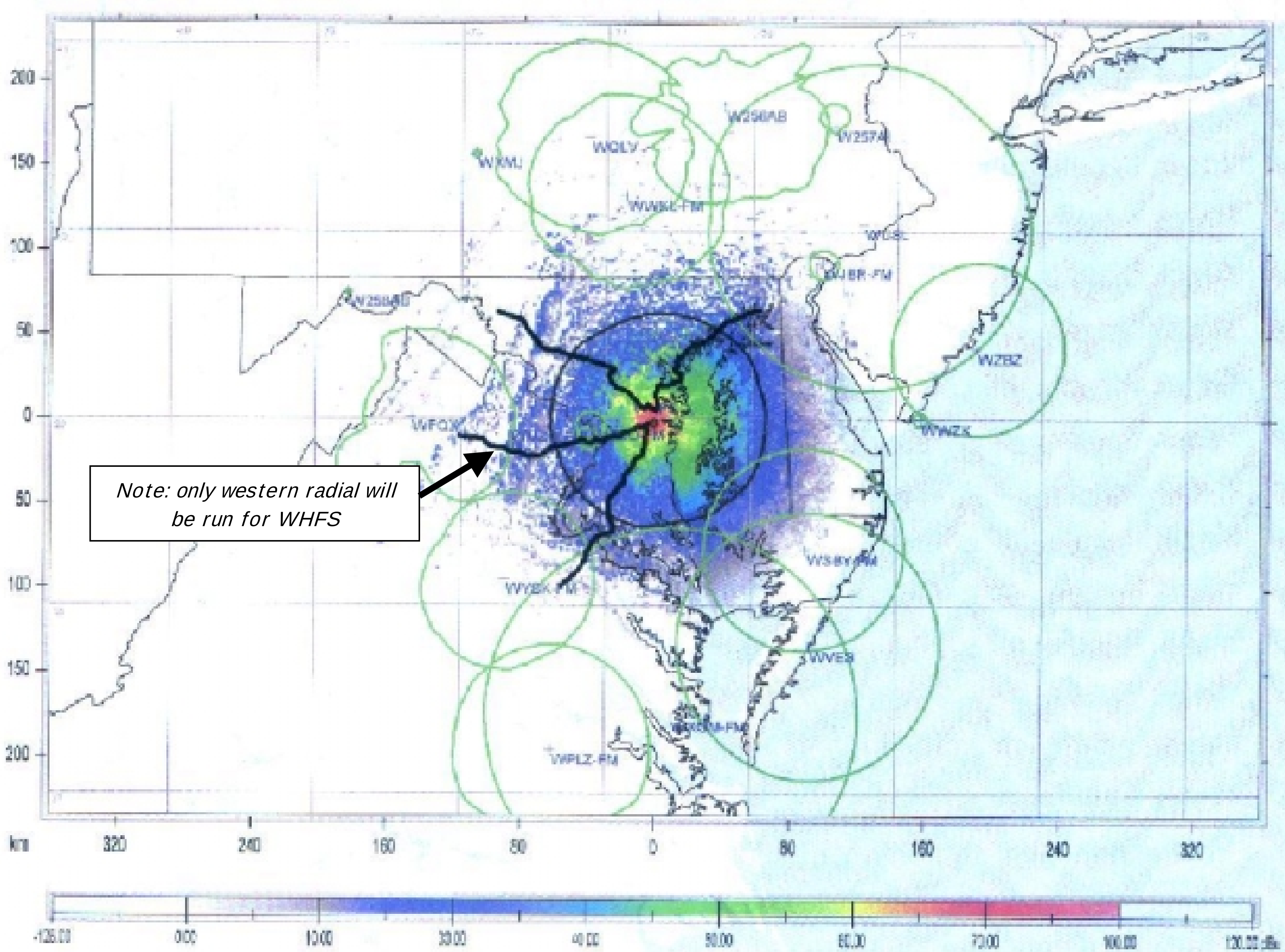
Field test route map – WD2XAB-FM (WPOC-WD2XAB contours.jpg)



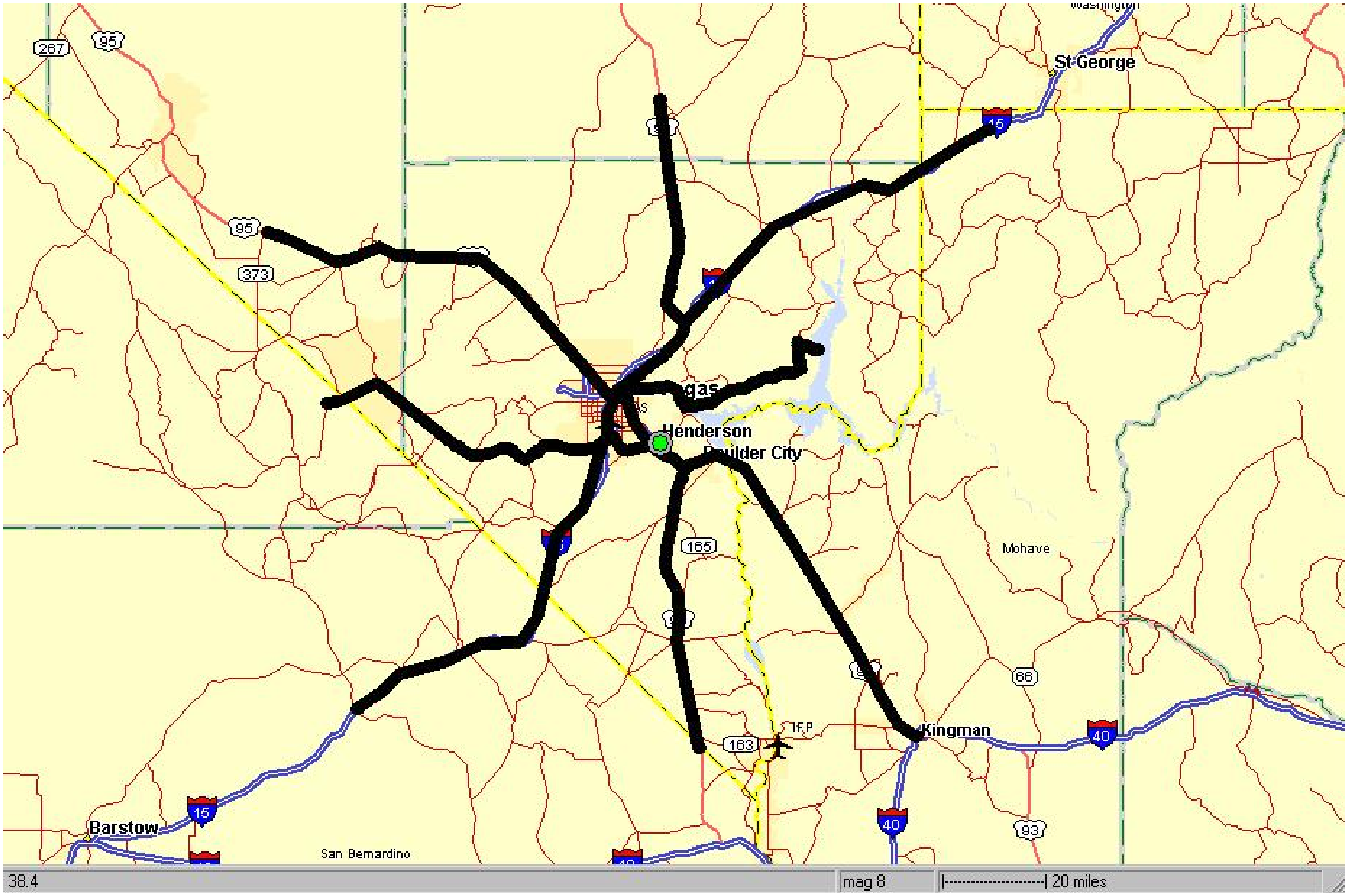
Field test route map – KLLC-FM (kllc.jpg)



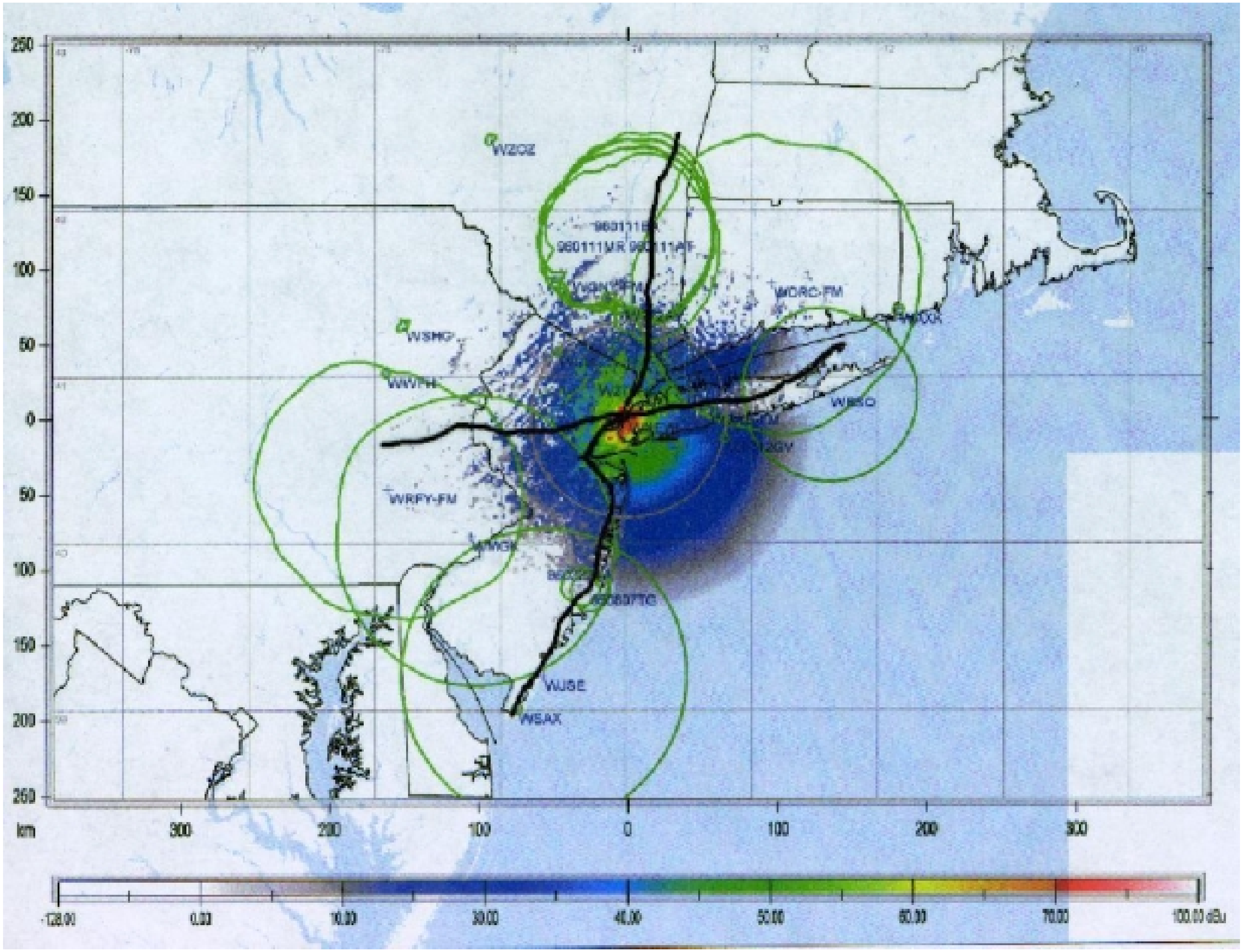
Field test route map – WHFS-FM (whfs1.jpg)



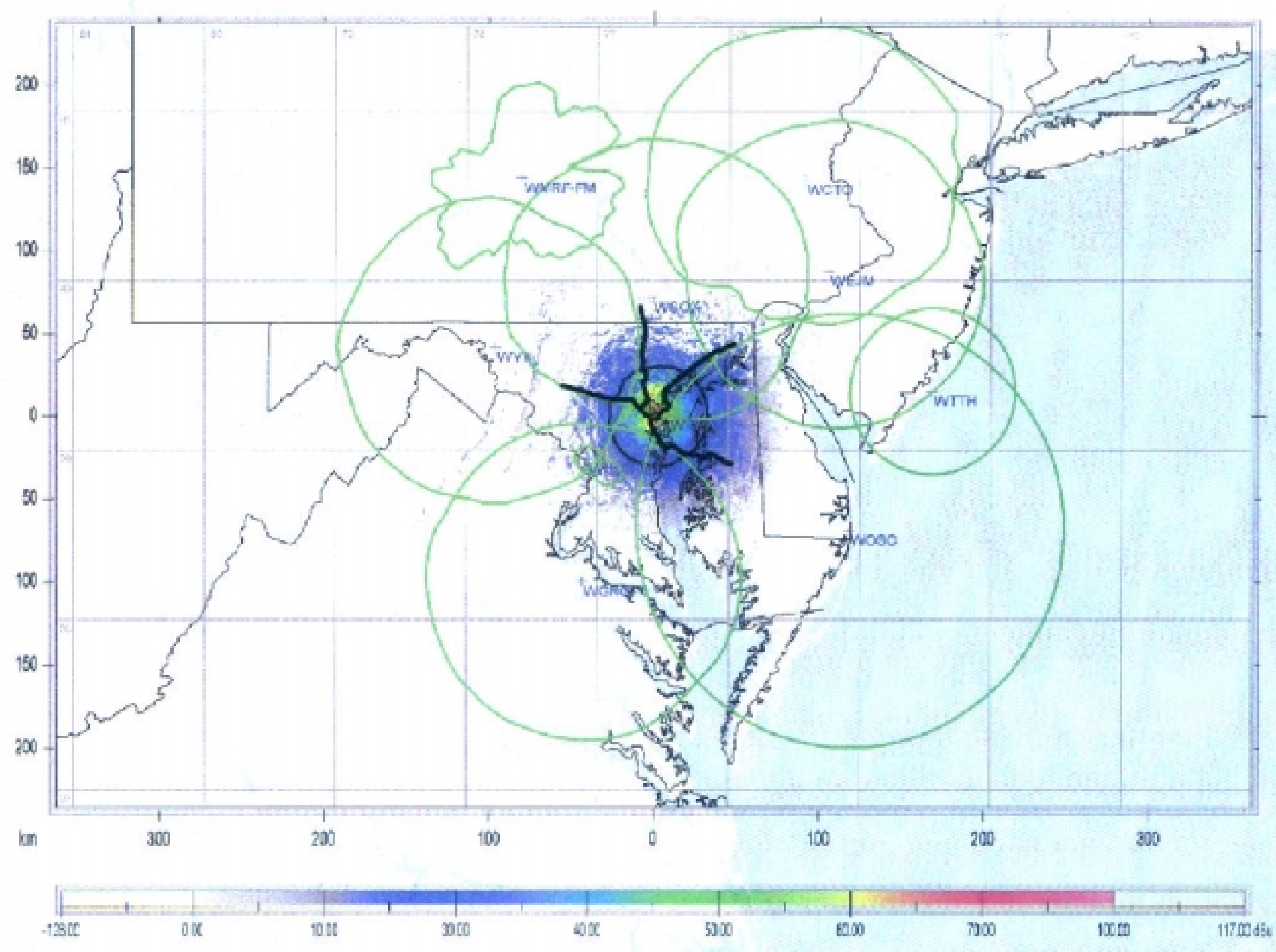
Field test route map – KWNR-FM (kwnrmapR2.jpg)



Field test route map – WNEW-FM (wnew.jpg)



Field test route map – WWIN-FM (wwin.jpg)



Appendix D –
NRSC analog receiver characterization

NATIONAL
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DAB Subcommittee
Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

The NRSC's FM IBOC compatibility and analog reference tests used four consumer FM stereo receiver models. These receivers were selected because their RF performance characteristics represent receivers used for FM stereo broadcast reception in the U.S. The table lists the receiver make, type, and IBOC test facility. The same model of each manufacture's receiver was used.

FM Receivers Used in the IBOC Laboratory and Field Tests				
Reference number	**Make**	**Type**	**Test**	**Characterization test size**
01	Delphi	Auto	Field west	Full
02	Delphi	Auto	ATTC laboratory	Full
03	Delphi	Auto	Field east	Short Form
05	Technics	Hi-fi	ATTC laboratory	Full
06	Technics	Hi-fi	Field compatibility	Full
10	Sony	Portable/Table	ATTC laboratory	Full
11	Sony	Portable/Table	Field compatibility	Short Form
17	Pioneer	Auto	Field west	Full
18	Pioneer	Auto	ATTC laboratory	Full
19	Pioneer	Auto	Field East	Short Form

Prior to the start of IBOC laboratory and field-testing an independent test laboratory characterized each receiver for RF sensitivity, RF selectivity, stereo separation, image rejection, IM, and sensitivity to narrow band noise. Over eighteen receivers were characterized of which the ten listed in the above table were used for the IBOC compatibility tests and digital performance tests.

The independent test laboratory conducted seventeen-characterization tests on seven of the ten receivers. Because of time restraints a limited number of characterization tests were conducted on the three remaining receivers. The short form receiver characterization tests consisted of distortion, RF level/SN, stereo separation, 1st adjacent selectivity, 2nd adjacent selectivity, IM, and narrowband noise sensitivity.

The following is a list of the characterization tests - those tests included in short form testing are noted (SF):

1) Local oscillator frequency
2) (SF) Distortion at standard output level
3) RF input overload
4) AM rejection
5) Image rejection
6) (SF) Curve tests – plots of RF level vs. signal-to-noise (mono, stereo); RF level vs. stereo separation
7) Capture ratio
8) Selectivity – 1st adjacent (for 30dB RMS S/N)
9) Selectivity – 2nd adjacent (for 30dB RMS S/N)
10) (SF) Selectivity – 1st adjacent (for 50dB RMS S/N)
11) (SF) Selectivity – 2nd adjacent (for 50dB RMS S/N)
12) Selectivity – 3rd adjacent (for 50dB RMS S/N)
13) 10.7 MHz rejection (not done)
14) 10.7 MHz intermodulation
15) Local oscillator interference
16) (SF) Intermodulation
17) (SF) Narrowband noise sensitivity

Included below are summary tables of the receiver characterization data collected for all ten receivers used for the NRSC lab and field IBOC compatibility and performance tests. The tables list the receiver make, test results, and the test facility (lab or field). The tables allow for the direct comparison of receiver basic performance parameters. Each table does not show all the parameters tested. Complete listings of all the test data are in the detailed receiver test reports.[1]

Attachment 1 to this Appendix includes block diagrams of each test mode; in Attachment 2, an example of a full receiver characterization report is given, for one of the Delphi receivers tested.

1) Local oscillator frequency

94.1 + 10.7 = 104.8 MHz

Receiver	LO Frequency MHz	Deviation MHz	Test
01 Delphi	104.801	+0.001	Field west
02 Delphi	104.801	+0.001	ATTC laboratory
03 Delphi	Short Form	-	Field east
05 Technics	104.750	-0.050	ATTC laboratory
06 Technics	104.748	-0.052	Field compatibility
10 Sony	104.801	+0.001	ATTC laboratory
11 Sony	Short Form	-	Field compatibility
17 Pioneer	104.799	-0.001	Field west
18 Pioneer	104.798	-0.002	ATTC laboratory
19 Pioneer	Short Form	-	Field East

[1] To be published by the NRSC.

2) (SF) Distortion at standard output level

1 kHz tone 75 kHz deviation, mono; test setup 2

Receiver	THD % Left	THD % Right	Test
01 Delphi	0.43	0.43	Field west
02 Delphi	0.48	0.35	ATTC laboratory
03 Delphi	0.40	0.40	Field east
05 Technics	0.15	0.18	ATTC laboratory
06 Technics	0.17	0.17	Field compatibility
10 Sony	0.28	0.28	ATTC laboratory
11 Sony	0.32	0.27	Field compatibility
17 Pioneer	0.38	0.39	Field west
18 Pioneer	0.36	0.38	ATTC laboratory
19 Pioneer	0.32	0.33	Field East

3) RF input overload

1 kHz tone, 75 kHz dev, mono; increase RF level until 5% THD at radio output, and record RF level; test setup 1

Receiver	RF level in dBm at 5% THD	Test
01 Delphi	22	Field west
02 Delphi	22	ATTC laboratory
03 Delphi	SF	Field east
05 Technics	22	ATTC laboratory
06 Technics	22	Field compatibility
10 Sony	20.2	ATTC laboratory
11 Sony	SF	Field compatibility
17 Pioneer	22	Field west
18 Pioneer	22	ATTC laboratory
19 Pioneer	SF	Field east

4) AM rejection

1 kHz tone 75 kHz deviation, mono; set radio audio to std. ref. level and record THD; set modulation mode to FM (75 kHz), AM (30%), record THD; test setup 2

Receiver	THD difference in dB	Test
01 Delphi	-0.10	Field west
02 Delphi	0.00	ATTC laboratory
03 Delphi	SF	Field east
05 Technics	-0.83	ATTC laboratory
06 Technics	-3.00	Field compatibility
10 Sony	0.00	ATTC laboratory
11 Sony	SF	Field compatibility
17 Pioneer	0.00	Field west
18 Pioneer	0.00	ATTC laboratory
19 Pioneer	SF	Field east

5) Image rejection

Set radio audio to std. ref. level; decrease RF level until S/N ratio = 30dB, record RF level 1; tune RF gen to desired freq. +/- 2X freq.; adjust RF level until S/N ratio= 30dB, record RF level 2; test setup 2

Receiver	Image Rejection in dB	Test
01 Delphi	-48	Field west
02 Delphi	-49	ATTC laboratory
03 Delphi	SF	Field east
05 Technics	-53	ATTC laboratory
06 Technics	-52	Field compatibility
10 Sony	-22	ATTC laboratory
11 Sony	SF	Field compatibility
17 Pioneer	-44	Field west
18 Pioneer	-44	ATTC laboratory
19 Pioneer	SF	Field east

6) (SF) RF level vs. S/N, separation

S/N WQP; signal, noise vs. RF level mono; signal, noise vs. RF level stereo; stereo separation vs. RF level; test setup 2

Receiver	Mono WQP S/N at –55dBm / -90dBm	Stereo WQP S/N at –55 dBm / –90 dBm	Separation at –55 dBm / –90 dBm
01 Delphi	64/45	56/45	29/0
02 Delphi	64/45	56/45	29/.5
03 Delphi	63/46	55/46	31/0
05 Technics	64/49	58/29	36/26
06 Technics	64/50	58/28	28/23
10 Sony	55/43	51/23	40/22
11 Sony	56/45	51/24	39/24
17 Pioneer	58/44	53/44	33/0
18 Pioneer	59/46	54/46	34/0
19 Pioneer	60/42	53/43	36/0

7) Capture ratio

D: -55dBm, 1kHz, 22.5 dev, Mono; U: -120dBm, CW; increase U audio drop 1dB, record RF level; increase U audio drop 30dB, record RF level (RF Lev. 1 – RF Lev. 2)/2; test setup 3

Receiver	Capture Ratio dB	Test
01 Delphi	-2.5	Field west
02 Delphi	-2.0	ATTC laboratory
03 Delphi	SF	Field east
05 Technics	-2.8	ATTC laboratory
06 Technics	-4.1	Field compatibility
10 Sony	1	ATTC laboratory
11 Sony	SF	Field compatibility
17 Pioneer	-4.0	Field west
18 Pioneer	6.5	ATTC laboratory
19 Pioneer	SF	Field east

8) Selectivity – 1st adjacent 30 dB RMS S/N

See TP; test setup 3

Receiver	Stereo Upper D/U dB	Stereo Lower D/U dB	Test
01 Delphi	-18	-19	Field west
02 Delphi	-22	-16	ATTC laboratory
03 Delphi	SF	SF	Field east
05 Technics	-11	-3	ATTC laboratory
06 Technics	-3	-4	Field compatibility
10 Sony	2	1	ATTC laboratory
11 Sony	SF	SF	Field compatibility
17 Pioneer	-17	-23	Field west
18 Pioneer	-24	-22	ATTC laboratory
19 Pioneer	SF	SF	Field east

9) Selectivity – 2nd adjacent 30 dB RMS S/N

See TP; test setup 3

Receiver	Stereo Upper D/U dB	Stereo Lower D/U dB	Test
01 Delphi	-55	-55	Field west
02 Delphi	-55	-55	ATTC laboratory
03 Delphi	SF	SF	Field east
05 Technics	-55	-55	ATTC laboratory
06 Technics	-55	-55	Field compatibility
10 Sony	-18	-20	ATTC laboratory
11 Sony	SF	SF	Field compatibility
17 Pioneer	-55	-55	Field west
18 Pioneer	-55	-55	ATTC laboratory
19 Pioneer	SF	SF	Field east

Note: A D/U of –55dB is the test bed limit.

10) (SF) Selectivity – 1st adjacent 50 dB RMS S/N

See TP; test setup 3

Receiver	Stereo Upper D/U dB	Stereo Lower D/U dB	Test
01 Delphi	-13	-18	Field west
02 Delphi	-18	-14	ATTC laboratory
03 Delphi	-21	-15	Field east
05 Technics	1	10	ATTC laboratory
06 Technics	10	9	Field compatibility
10 Sony	20	21	ATTC laboratory
11 Sony	18	23	Field compatibility
17 Pioneer	-12	-18	Field west
18 Pioneer	-19	-17	ATTC laboratory
19 Pioneer	-23	-11	Field east

11) (SF) Selectivity – 2nd adjacent 50 dB RMS S/N

See TP; test setup 3

Receiver	Stereo Upper D/U dB	Stereo Lower D/U dB	Test
01 Delphi	-55	-55	Field west
02 Delphi	-55	-55	ATTC laboratory
03 Delphi	SF	SF	Field east
05 Technics	-48	-45	ATTC laboratory
06 Technics	-43	-43	Field compatibility
10 Sony	-7	-11	ATTC laboratory
11 Sony	-9	-12	Field compatibility
17 Pioneer	-55	-55	Field west
18 Pioneer	-55	-55	ATTC laboratory
19 Pioneer	-55	-55	Field east

Note: A D/U of –55dB is the test bed limit.

12) Selectivity – 3rd adjacent 50 dB RMS S/N

See TP; test setup 3

Receiver	Stereo Upper D/U dB	Stereo Lower D/U dB	Test
01 Delphi	-55	-55	Field west
02 Delphi	-55	-55	ATTC laboratory
03 Delphi	SF	SF	Field east
05 Technics	-48	-45	ATTC laboratory
06 Technics	-45	-43	Field compatibility
10 Sony	-26	-22	ATTC laboratory
11 Sony	SF	SF	Field compatibility
17 Pioneer	-55	-55	Field west
18 Pioneer	-55	-55	ATTC laboratory
19 Pioneer	SF	SF	Field east

Note: A D/U of –55dB is the test bed limit.

13) 10.7 MHz rejection (no implications from IBOC)

14) 10.7 MHz intermodulation (FCC Taboo)

D -45 dBm; target S/N 50 dB RMS; see TP

Receiver	10.6 MHz D/U dB	10.7 MHz D/U dB	Test
01 Delphi	-55	-55	Field west
02 Delphi	-55	-55	ATTC laboratory
03 Delphi	SF	SF	Field east
05 Technics	-19	-19	ATTC laboratory
06 Technics	-19	-20	Field compatibility
10 Sony	-4	0	ATTC laboratory
11 Sony	SF	SF	Field compatibility
17 Pioneer	-39	-35	Field west
18 Pioneer	-40	-36	ATTC laboratory
19Pioneer	SF	SF	Field east

Note: A D/U of –55dB is the test bed limit.

15) Local oscillator interference

U 94.1MHz +10.6MHz or 10.7MHz; D Pilot only –45 dBm; target 50 dB S/N; see TP

Receiver	10.6 MHz D/U dB	10.7 MHz D/U dB	Test
01 Delphi	-55	-55	Field west
02 Delphi	-55	-55	ATTC laboratory
03Delphi	SF	SF	Field east
05 Technics	-16	-21	ATTC laboratory
06 Technics	-15	-21	Field compatibility
10 Sony	1	6	ATTC laboratory
11 Sony	1	4	Field compatibility
17 Pioneer	-36	-28	Field west
18 Pioneer	-37	-27	ATTC laboratory
19 Pioneer	-38	-30	Field east

Note: A D/U of –55dB is the test bed limit.

16) (SF) Intermodulation

Three tone receiver performance with IM signals at 800kHz and 1600kHz above desired.; see TP

D = -47 dBm:

Receiver	D only S/N WQP dB	-10 dB D/U S/N WQP dB	-20 dB D/U S/N WQP dB	-30 dB D/U S/N WQP dB	Test
01 Delphi	59	58	50	42	Field west
02 Delphi	59	58	51	43	ATTC laboratory
03 Delphi	57	57	52	47	Field east
05 Technics	59	41	13	2	ATTC laboratory
06 Technics	60	47	18	3	Field compatibility
10 Sony	52	10	1	0	ATTC laboratory
11 Sony	52	8	0	0	Field compatibility
17 Pioneer	55	54	52	44	Field west
18 Pioneer	56	55	53	45	ATTC laboratory
19 Pioneer	56	56	54	43	Field east

D = –62 dBm:

Receiver	D only S/N WQP dB	-10 dB D/U S/N WQP dB	-20 dB D/U S/N WQP dB	-30 dB D/U S/N WQP dB	Test
01 Delphi	52	51	49	43	Field west
02 Delphi	52	51	50	44	ATTC laboratory
03 Delphi	48	48	48	47	Field east
05 Technics	56	55	43	14	ATTC laboratory
06 Technics	55	54	46	17	Field compatibility
10 Sony	49	33	3	0	ATTC laboratory
11 Sony	49	30	2	0	Field compatibility
17 Pioneer	49	49	48	44	Field west
18 Pioneer	50	50	50	46	ATTC laboratory
19 Pioneer	49	49	49	47	Field east

17) (SF) Narrowband noise sensitivity

D/U at 45dB target S/N; receiver stereo; D –62dBm; see TP

Receiver	-190 kHz D/U dB	-114 kHz D/U dB	Center Channel D/U dB	+114 kHz D/U dB	+190 kHz D/U dB
01 Delphi	-20	-2	24	1	-19
02 Delphi	-20	4	22	3	-13
03 Delphi	-19	1	24	-2	-20
05 Technics	14	37	26	33	2
06 Technics	2	31	20	34	8
10 Sony	36	47	34	48	35
11 Sony	36	47	27	44	30
17 Pioneer	-15	4	27	4	-15
18 Pioneer	-18	2	26	1	-19
19 Pioneer	-16	6	25	-1	-19

Appendix E –
FM IBOC system evaluation criteria

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Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

EVALUATION CRITERIA - DIGITAL PERFORMANCE[1]:

Unimpaired audio quality – the fundamental audio quality of the IBOC system. This assessment is to be made with respect to the audio quality of the existing analog broadcasting service compared to the appropriate analog reference.

Service area – the geographical area surrounding the transmit station which can be expected to receive a listenable (usable) radio signal. The service area should take into account the impact of interference from co-channel, 1st-adjacent, and 2nd-adjacent channel signals.

Durability – characterized by an IBOC system design's ability to withstand impairments to the RF channel.

Acquisition performance – the characteristics of how a receiver "locks on" to a radio signal, primarily acquisition time (the elapsed time between tuning to a channel and when the audio on that channel is first heard).

Auxiliary data capacity[2] – characteristics of the data capacity supported by an IBOC system in excess of that needed to deliver the IBOC audio signal, including available throughput, nature of capacity (opportunistic versus continuously available), and transmission quality and durability through the channel (bit error rate and/or other relevant digital data transmission metrics as a function of impairments).

Behavior as signal degrades – how an IBOC system's blend function is able to prevent abrupt loss of the signal at the edge of coverage. Note that, due to the complexities of RF signal propagation, "edge of coverage" performance may be experienced throughout a station's service area and is not restricted simply to regions near or beyond the theoretical protected contour.

Stereo separation – the amount of stereo separation present in the IBOC audio signal, and how it varies as a function of channel and received signal conditions.

Flexibility[3] – represents the potential of an IBOC system to be adapted by broadcasters and manufacturers to meet the needs of listeners and consumers, both present and future.

EVALUATION CRITERIA - COMPATIBILITY:

Host analog signal impact – changes in performance of a host analog signal (main channel audio and any subcarriers) as a result of the presence of the IBOC digital signal energy associated with that host.

Non-host analog signal impact – changes in the performance of a (desired) analog signal (main channel audio and any subcarriers) as a result of the presence of interfering IBOC signals. Interfering signals of interest include co-channel, 1st, and 2nd adjacent channel signals, individually and in combinations.

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[1] All digital performance criteria should assess the relative audio quality of the digital system versus existing analog audio quality.
[2] Not currently being tested.
[3] Primarily addressed in system description portion of submission; test results not expected to provide direct evidence of system flexibility.

Appendix F –
FM IBOC system evaluation matrix

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Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

Notes:

- A checkmark ("✓ ") indicates that the results from a particular test are expected to apply to the indicated evaluation criteria.
- Test A (Calibration) provides a quality check on system testing as a whole and is not used directly for system evaluation.

<table>
<tr><th></th><th></th><th colspan="7">DIGITAL PERFORMANCE</th><th colspan="2">COMPATIBILITY</th></tr>
<tr><th>TEST</th><th>DESCRIPTION</th><th>UNIMPAIRED AUDIO QUALITY</th><th>SERVICE AREA</th><th>DURA-BILITY</th><th>ACQ. PERFORM.</th><th>AUX. DATA CAPACITY[4]</th><th>BEHAVIOR AS SIGNAL DEGRADES</th><th>STEREO SEP</th><th>HOST SIGNAL IMPACT</th><th>NON-HOST SIGNAL IMPACT</th></tr>
<tr><td>B</td><td>IBOC system performance with AWGN</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1)</td><td>Linear channel</td><td rowspan="2"></td><td rowspan="2">✓</td><td rowspan="2">✓</td><td rowspan="2"></td><td rowspan="2">✓</td><td rowspan="2">✓</td><td rowspan="2">✓</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>2)</td><td>Multipath fading channel</td></tr>
<tr><td>C</td><td>IBOC system performance with special impairments</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1)</td><td>Impulse noise</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4">✓</td><td rowspan="4"></td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>1.5)</td><td>Impulse noise, 1st-adjacent channel interference</td></tr>
<tr><td>2)</td><td>Airplane flutter (Doppler)</td></tr>
<tr><td>2.4)</td><td>Airplane flutter (Doppler), 1st-adjacent channel interference</td></tr>
<tr><td>D</td><td>IBOC ➜ IBOC digital performance</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1)</td><td>Co-channel interference</td><td rowspan="6"></td><td rowspan="6">✓</td><td rowspan="6">✓</td><td rowspan="6"></td><td rowspan="6">✓</td><td rowspan="6">✓</td><td rowspan="6">✓</td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>2)</td><td>Single 1st-adjacent channel interference</td></tr>
<tr><td>2.4)</td><td>Simultaneous upper and lower 1st-adjacent channel interference</td></tr>
<tr><td>3)</td><td>Single 2nd-adjacent channel interference</td></tr>
<tr><td>3.4)</td><td>Single 2nd-adjacent channel interference w/1st adj. channel interference</td></tr>
<tr><td>3.5)</td><td>Simultaneous upper and lower 2nd-adjacent channel interference</td></tr>
</table>

[4] See note 2.

		DIGITAL PERFORMANCE							COMPATIBILITY	
TEST	**DESCRIPTION**	**UNIMPAIRED AUDIO QUALITY**	**SERVICE AREA**	**DURA-BILITY**	**ACQ. PERFORM.**	**AUX. DATA CAPACITY[5]**	**BEHAVIOR AS SIGNAL DEGRADES**	**STEREO SEP**	**HOST SIGNAL IMPACT**	**NON-HOST SIGNAL IMPACT**
E	**IBOC ➜ IBOC digital performance in a multipath fading channel**									
1)	Co-channel interference									
2)	Single 1st-adjacent channel interference									
2.4)	Simultaneous upper and lower 1st-adjacent channel interference									
3)	Single 2nd-adjacent channel interference		✓	✓		✓	✓	✓		
3.4)	Single 2nd-adjacent channel interference w/1st adj. channel interference									
3.5)	Simultaneous upper and lower 2nd-adjacent channel interference									
F	**IBOC ➜ Analog compatibility performance**									
1), 3)	Single 1st-adjacent channel interference									✓
2), 4)	Single 2nd-adjacent channel interference									
F/SC	**IBOC ➜ Analog (FM subcarriers) compatibility performance**									
1), 5)	Single 1st-adjacent channel interference, analog subcarriers									
3)	Single 1st-adjacent channel interference, digital subcarriers									✓
2), 6)	Single 2nd-adjacent channel interference, analog subcarriers									
4)	Single 2nd-adjacent channel interference, digital subcarriers									
G	**IBOC ➜ Analog compatibility performance in a multipath fading channel**									
1)	Single 1st-adjacent channel interference									✓

[5] See note 2.

		DIGITAL PERFORMANCE							COMPATIBILITY	
TEST	**DESCRIPTION**	**UNIMPAIRED AUDIO QUALITY**	**SERVICE AREA**	**DURA-BILITY**	**ACQ. PERFORM.**	**AUX. DATA CAPACITY**[6]	**BEHAVIOR AS SIGNAL DEGRADES**	**STEREO SEP**	**HOST SIGNAL IMPACT**	**NON-HOST SIGNAL IMPACT**
H	**IBOC acquisition**									
1)	Acquisition with varying signal level				✓					
I	**IBOC quality**									
1)	Quality transmission test	✓								
J	**IBOC ➜ host Analog compatibility performance**									
1), 2)	Main channel audio performance versus presence or absence of IBOC digital signal energy								✓	
4)	Analog subcarrier performance versus presence or absence of IBOC digital signal energy									
5)	RDS subcarrier performance versus presence or absence of IBOC digital signal energy									
6)	HSSC performance versus presence or absence of IBOC digital signal energy									

[6] See note 2.

Notes:

- A checkmark ("✓ ") indicates that the results from a particular test are expected to apply to the indicated evaluation criteria.
- Test A (Calibration) provides a quality check on system testing as a whole and is not used directly for system evaluation.

		DIGITAL PERFORMANCE							COMPATIBILITY	
TEST	**DESCRIPTION**	**UNIMPAIRED AUDIO QUALITY**	**SERVICE AREA**	**DURA-BILITY**	**ACQ. PERFORM.**	**AUX. DATA CAPACITY[7]**	**BEHAVIOR AS SIGNAL DEGRADES**	**STEREO SEP**	**HOST SIGNAL IMPACT**	**NON-HOST SIGNAL IMPACT**
B	**System performance**									
1)	Low interference and low multipath		✓	✓		✓	✓	✓		
2)	1st-adjacent interference									
3)	2nd-adjacent interference									
C	**Compatibility**									
1)	Host compatibility – main channel audio								✓	
2)	Host compatibility – analog and digital subcarriers									
3)	1st-adjacent channel compatibility									✓

[7] See note 2.

Appendix G –
Discussion of stereo-mono blending in analog receivers

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FM stereo automobile radios use a circuit called blend to reduce the audible effects of multipath, adjacent channel interference, and stereo noise. Blending from stereo to mono accomplishes the noise reduction. The choice of blend characteristics is radio manufacturer dependent. Any or all of the following controls the amount of FM stereo blend: RF signal level, 1st adjacent interference, and 2nd through 20th adjacent channel interference. The effects of these blend controlling factors on stereo separations for the two automobile radios used in the IBOC laboratory and field tests are described in this report.

Signal Level Dependent Blend

Table 1 shows the results of stereo separation tests conducted by an independent laboratory with varying levels of RF power at the input of two automobile radios. These radios are the same model used for the IBOC field and laboratory tests. Assuming acceptable stereo to have a separation of 15 dB, the lowest signal level where acceptable stereo can be expected is at a RF power level of -67dBm for both radios. At RF signal levels of –70 dBm and lower, both radios are essentially mono.

Table 1. Signal Level/Stereo Separation
(bold text indicates blending transition region)

Automobile Radio Scenario			
Lab RF Power (dBm)	Field strength at 30ft above ground (dBu)	Separation (dB)	
		Delphi	Pioneer
-100	22	0	0
-95	27	0	0
-90	32	0	0
-85	37	0	0
-80	42	0	2
-75	47	3	4
-70	**52**	**7**	**12**
-65	**57**	**17**	**28**
-60	62	37	38
-55	67	31	39
-50	72	31	39

FM Stereo Separation with 1st Adjacent Analog Interferer

Table 2 shows the results of stereo separation tests conducted at four signal levels and four D/U ratios. The table lists the stereo separation for each receiver under varying interference conditions. At signal levels of –62 dBm or stronger and D/U of 6 dB or lower the stereo separation is 28 dB or larger. Only the Pioneer maintained separation at the –62 dBm or stronger signal levels with a D/U of –4 dB or higher. At the –72 dBm and lower signal levels the stereo separation ranged from 0.0 dB to 8.0 dB. Again, assuming acceptable stereo to have a separation of 15 dB or higher, the A-> A D/U ratio of no more than 6 dB and signal level of at least -62 dBm is necessary to produce stereo on the Delphi.

Table 2. FM stereo separation with 1st adjacent analog interference

LAB RF POWER (DBM)	FIELD STRENGTH AT 30FT. ABOVE GROUND (DBU)	STEREO SEPARATION			
		16 DB D/U	6 DB D/U	-4 DB D/U	-14 DB D/U
		SEPARATION DEL/PIO (DB)	SEPARATION DEL/PIO (DB)	SEPARATION DEL/PIO (DB)	SEPARATION DEL/PIO (DB)
-47	75	37/39	37/39	0/39	0/35
-62	60	28/38	28/38	0/38	0/32
-72	50	5/8	5/8	0/8	0/8
-82	40	0/0	0/0	0/0	0/0

FM Stereo Separation with 2nd Adjacent Single Analog Interferer

Table 3 shows the test results of 2nd adjacent stereo separation tests conducted at two signal levels. The Pioneer stereo separation was reduced to 10 dB at the -30 dB D/U at both signal levels. The Delphi lost stereo at the -40 dB D/U.

Table 3. FM stereo separation reduction caused by 2nd adjacent channel

DESIRE SIGNAL LEVEL	D/U –20DB DEL/PIO (DB)	D/U –30DB DEL/PIO (DB)	D/U –40DB DEL/PIO (DB)	D/U –50DB DEL/PIO (DB)
-47dBm	37/37	22/10	5/2	0/0
-62dBm	28/36	18/10	3/2	0/0

FM Stereo Separation with 5th through 20th Adjacent Channels

Table 4 and Table 5 show the results of 5th, 10th, and 20th adjacent A->A channel tests at two signal levels. At the -40 dB D/U the Delphi stereo separation was below 15 dB for 5 of the 6 tests and the Pioneer for 2 of 6 tests. For the -50 dB D/U the best separation was 7 dB for both receivers for all three adjacent channels tested and both signal levels.

Table 4. FM stereo separation controlled by adjacent channels (bold text indicates blending transition region)

5TH THROUGH 20TH -47 DBM				
ADJACENT CHANNEL	D/U –20DB DEL/PIO (DB)	D/U –30DB DEL/PIO (DB)	D/U –40DB DEL/PIO (DB)	D/U –50DB DEL/PIO (DB)
5th	37/41	29/34	**6/8**	0/2
10th	(not tested)	38/40	**10/19**	2/3
20th	(not tested)	37/40	**19/33**	4/7

Table 5. FM stereo separation controlled by adjacent channels (bold text indicates blending transition region)

5TH THROUGH 20TH -62 DBM				
ADJACENT CHANNEL	**D/U –20DB DEL/PIO (DB)**	**D/U –30DB DEL/PIO (DB)**	**D/U –40DB DEL/PIO (DB)**	**D/U –50DB DEL/PIO (DB)**
5th	28/36	20/36	**4/8**	0/1
10th	(not tested)	26/36	**6/20**	0/3
20th	(not tested)	27/36	**11/36**	2/7

Temporal Blend

During the laboratory characterization test it was found that the blend decay times for the two automobile radios used for the IBOC tests differed by several seconds. To measure this characteristic on a broader base two automobile radios, a Kenwood and Sony, were added to Delphi and Pioneer for the temporal blend tests. It was found that blend off-to-on time was less than one second for all four radios. The decay time for the Pioneer, Sony, and Kenwood radios was less than one second. The Delphi radio's blend decay time was four seconds long.

Conclusion

The threshold of blend to mono system in the automobile FM stereo radio is manufacturer dependent. The predominant controlling factors vary. The blend decay characteristic for one radio is much longer than the other three radios. The two automobile FM stereo radios selected for the IBOC tests represent a cross section of blend performance.

Appendix H –
Discussion of Differences Between Laboratory and Field Subjective Evaluation Results

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Part 1 – FM IBOC

The data from the NRSC's FM IBOC compatibility tests seems to indicate that listeners were more critical of interference at a particular D/U ratio when the results came from the laboratory than when they came from the field.[1] To investigate why this might be the case, additional laboratory tests were conducted by the NRSC subsequent to the release of the FM IBOC Test Data Report. These tests included an expanded number of automobile receivers (six), an expanded desired RF input signal range (-47, -62, -72 and -82 dBm), and the D/U ratios +16, +6, -4 and -14 dB. Objective data was collected to show stereo separation and audio signal-to-noise for each receiver at each desired signal level and D/U ratio combination.

iBiquity provided the NRSC with the RF signal levels that were measured at each of the host and first-adjacent field test fixed locations during the NRSC FM IBOC compatibility tests. This data was provided subsequent to the release of the FM IBOC test report, and thus is not found in the report. It, and the specific data points from the post-FM IBOC Test Data Report laboratory results that most closely match each D/U and desired receiver input signal level combination from the field, are summarized in Table H-1 and Table H-2 for the two automobile receivers that were tested in the field.

When the RF signal levels measured in the field are compared with the receiver characterization stereo separation vs. signal level test data (see Appendix D) it is apparent that both automobile receivers were operating in monophonic mode under most field test conditions. However, the laboratory data that was collected during the NRSC FM IBOC compatibility tests was collected at desired signal levels that were considerably higher than the signal levels found in the field, levels at which the receivers would be operating in stereo mode. For example, when the Delphi receiver was measured at the +6 dB D/U ratio in the laboratory during the NRSC FM IBOC compatibility testing, the desired receiver input level was -62 dBm. However, when the same receiver was measured at the same D/U ratio in the field the desired receiver input levels recorded were -61.5, -62.5, -65.5, -74.5, -82.0, -83.5, -85.0, -86.0 and -92.0 dBm. The stereo separation vs. signal level data from the characterization test for the Delphi receiver indicates that the stereo separation at these desired receiver input levels is 31, 31, 16, 3, 0, 0, 0, 0 and 0 dB, respectively. For all of the remaining first adjacent compatibility data points taken in the field with the Delphi receiver (*i.e.*, at D/U ratios that were lower, or more negative, than +6 dB) the stereo separation is predicted to exceed 7 dB at only one desired signal input level. The results for the Pioneer receiver are similar. Its receiver characterization data suggests that, generally speaking, it has slightly more stereo separation over the range of receiver input levels tested in the field, though it is essentially operating in mono at most of these levels.

Thus it appears that in the vast majority of field test locations the receivers were operating in monophonic mode. It also appears that under the +16 dB D/U and -62 dBm desired input signal condition, and under the +6 dB D/U and –62 dBm desired input signal condition (which together accounted for two-thirds of the no-multipath laboratory tests that were subjectively evaluated) both automobile receivers were operating in the stereophonic mode. It appears that the fact that the laboratory tests were generally conducted in stereo while the field tests were generally conducted in mono caused the subjective evaluators to rate the laboratory audio more critically than they rated the field audio. That is, all else being equal, listeners are more likely to detect a particular level of interference when the desired signal is stereo than when the desired signal is mono.

[1] For example, at the +6 dB D/U ratio in the field listeners rated a station's analog audio quality with speech programming on the Delphi receiver at 2.5 MOS ±0.28 when the undesired signal was a first adjacent channel IBOC signal. Under the same conditions in the laboratory, however, listeners rated the desired station's analog audio quality at 2.2 MOS ±0.25 (lower first adjacent interferer) and 2.2 MOS ±0.21 (upper first adjacent interferer). Similar situations are found throughout the test results. Some differences are more pronounced, and some are not. FM IBOC Test Data Report, Appendix I.

This data suggests that both results (those collected in the lab and those collected in the field) are accurate representations of how listeners will perceive interference at the specific D/U ratio and receiver input signal levels tested. Many of the data points taken in the field are actually providing information about a different reception condition than the corresponding data points taken in the laboratory for the same D/U ratio because of the difference in receiver input signal level. Thus, rather than using the laboratory and field tests to corroborate one another, it is more appropriate to use them to complement one another because, together, they provide information about more reception conditions than either of them do alone.

Table H-1. Delphi Automobile Radio First Adjacent Field and Laboratory Data

	Field Test Data						Stereo Separation at Field RF Level According to RX Characterization (dB)	Post FM IBOC Test Data Report Laboratory Test Data		Proximity of PFITDR Lab Data Point to Field	
Reference Number	1st Adj. D/U (dB)	Location Number	Station Call	Desired Frequency (MHz)	Format	RF Level @ RX Input (dBm)		Stereo Separation A->A / D[1]-A (dB)	Signal Level / 1st Adj. D/U	RF Level (Lab minus Field, dB)	D/U Ratio (Lab minus Field, dB)
1	6U	1	WMRA	90.7	Class/NPR	-61.5	31	28 / 28	-62 dBm / +6 dB	-0.5	0
2	6U	2	WMRA	90.7	Class	-65.5	16	28 / 28	-62 dBm / +6 dB	+3.5	0
3	6L	3	WHFC	91.1	Folk	-62.5	31	28 / 28	-62 dBm / +6 dB	+0.5	0
4	6L	1	WFLS	93.3	Country	-74.5	03	05 / 05	-72 dBm / +6 dB	+2.5	0
5	6L	2	WFLA	93.3	Country	-85.0	00	00 / 00	-82 dBm / +6 dB	+3.0	0
6	6U	3	WDSD	92.9	Country/Speech	-82.0	00	00 / 00	-82 dBm / +6 dB	0.0	0
7	6L	1	WMGK	102.9	Rock	-83.5	00	00 / 00	-82 dBm / +6 dB	+1.5	0
8	6L	2	WMGK	102.9	Country	-92.0	00	00 / 00	-82 dBm / +6 dB	+10.0	0
9	6L	3	WMGK	102.9	Rock	-86.0	00	00 / 00	-82 dBm / +6 dB	+4.0	0
10	-14L	1	WFLS	93.3	Country	-75.0	03	00 / 00	-72 dBm / -14 dB	+3.0	0
11	-11L	2	WFLS	93.3	Country	-72.5	04	00 / 00	-72 dBm / -14 dB	+0.5	-3
12	-10L	3	WFLS	93.3	Country	-70.5	07	00 / 00	-72 dBm / -14 dB	-1.5	-4
13	-8L	4	WFLS	93.3	Country	-70.0	07	00 / 00	-72 dBm / -4 dB	-2.0	+4
14	-6L	5	WFLS	93.3	Country	-71.0	07	00 / 00	-72 dBm / -4 dB	-1.0	+2
15	-4L	6	WFLS	93.3	Country	-69.5	07	00 / 00	-72 dBm / -4 dB	-2.5	0
16	-14L	7	WFLS	93.3	Country	-85.5	00	00 / 00	-82 dBm / -14 dB	+3.5	0
17	-13L	8	WFLS	93.3	Country	-77.5	01	00 / 00	-82 dBm / -14 dB	-4.5	-1
18	-18L	9	WFLS	93.3	Country	-75.5	02	00 / 00	-72 dBm / -14 dB	+3.5	+4
19	-8L	10	WFLS	93.3	Country	-74.5	03	00 / 00	-72 dBm / -4 dB	+2.5	+4
20	-6L	11	WFLS	93.3	Country	-74.5	03	00 / 00	-72 dBm / -4 dB	+2.5	+2
21	-4L	12	WFLS	93.3	Country	-74.0	02	00 / 00	-72 dBm / -4 dB	+2	0
22	-9U	1	WMRA	90.7	Class/NPR	-77.0	01	00 / 00	-72 dBm / -14 dB	+5	-5
23	-6U	2	WMRA	90.7	Class/NPR	-75.5	03	00 / 00	-72 dBm / -4 dB	+3.5	+2
24	-4U	3	WMRA	90.7	Class/NPR	-65.5	17	00 / 00	-62 dBm / -4 dB	+3.5	0

[1]For the Post FM IBOC Test Data Report Laboratory Tests, the FM IBOC signal was simulated with AWGN.

Level Dependent Blend:

1. Four desired RF test levels produced stereo separation of 16dB or higher.
2. Twenty desired RF test levels produced stereo separation 7dB or lower.

Interference and Level Dependent Blend:

1. With 1st adjacent analog interference three tests produced stereo separation of 15dB or more.
2. For these tests scenarios the IBOC did not change stereo separation.

Table H-2. Pioneer Automobile Radio First Adjacent Field and Laboratory Data

	Field Test Data						Stereo Separation at Field RF Level According to RX Characterization (dB)	Post FM IBOC Test Data Report Laboratory Test Data		Proximity of PFITDR Lab Data Point to Field	
Reference Number	1st Adj. D/U (dB)	Location Number	Station Call	Desired Frequency (MHz)	Format	RF Level @ RX Input (dBm)		Stereo Separation A->A / D[1]-A (dB)	Signal Level / 1st Adj. D/U	RF Level (Lab minus Field, dB)	D/U Ratio (Lab minus Field, dB)
1	6U	1	WMRA	90.7	Class/NPR	-61.5	35	38 / 37	-62 dBm / +6 dB	-0.5	0
2	6U	2	WMRA	90.7	Class	-65.5	27	38 / 37	-62 dBm / +6 dB	+3.5	0
3	6L	3	WHFC	91.1	Folk	-62.5	34	38 / 37	-62 dBm / +6 dB	+0.5	0
4	6L	1	WFLS	93.3	Country	-74.5	04	08 / 08	-72 dBm / +6 dB	+2.5	0
5	6L	2	WFLA	93.3	Country	-85.0	00	02 / 02	-82 dBm / +6 dB	+3.0	0
6	6U	3	WDSD	92.9	Country/Speech	-82.0	02	02 / 02	-82 dBm / +6 dB	0.0	0
7	6L	1	WMGK	102.9	Rock	-83.5	01	02 / 02	-82 dBm / +6 dB	+1.5	0
8	6L	2	WMGK	102.9	Country	-92.0	00	02 / 02	-82 dBm / +6 dB	+10.0	0
9	6L	3	WMGK	102.9	Rock	-86.0	00	02 / 02	-82 dBm / +6 dB	+4.0	0
10	-14L	1	WFLS	93.3	Country	-75.0	04	05 / 00	-72 dBm / -14 dB	+3.0	0
11	-11L	2	WFLS	93.3	Country	-72.5	10	05 / 00	-72 dBm / -14 dB	+0.5	-3
12	-10L	3	WFLS	93.3	Country	-70.5	12	05 / 00	-72 dBm / -14 dB	-1.5	-4
13	-8L	4	WFLS	93.3	Country	-70.0	12	08 / 08	-72 dBm / -4 dB	-2.0	+4
14	-6L	5	WFLS	93.3	Country	-71.0	11	08 / 08	-72 dBm / -4 dB	-1.0	+2
15	-4L	6	WFLS	93.3	Country	-69.5	12	08 / 08	-72 dBm / -4 dB	-2.5	0
16	-14L	7	WFLS	93.3	Country	-85.5	01	01 / 00	-82 dBm / -14 dB	+3.5	0
17	-13L	8	WFLS	93.3	Country	-77.5	03	01 / 00	-82 dBm / -14 dB	-4.5	-1
18	-18L	9	WFLS	93.3	Country	-75.5	04	05 / 00	-72 dBm / -14 dB	+3.5	+4
19	-8L	10	WFLS	93.3	Country	-74.5	04	05 / 00	-72 dBm / -4 dB	+2.5	+4
20	-6L	11	WFLS	93.3	Country	-74.5	04	08 / 08	-72 dBm / -4 dB	+2.5	+2
21	-4L	12	WFLS	93.3	Country	-74.0	04	08 / 08	-72 dBm / -4 dB	+2	0
22	-9U	1	WMRA	90.7	Class/NPR	-77.0	05	08 / 08	-72 dBm / -14 dB	+5	-5
23	-6U	2	WMRA	90.7	Class/NPR	-75.5	03	08 / 08	-72 dBm / -4 dB	+3.5	+2
24	-4U	3	WMRA	90.7	Class/NPR	-65.5	26	38 / 33	-62 dBm / -4 dB	+3.5	0

[1]For the Post FM IBOC Test Data Report Laboratory Tests, the FM IBOC signal was simulated with AWGN.

Level Dependent Blend:

1. Four desired RF levels produced stereo separation of 26dB or higher.
2. Twenty desired RF levels produced stereo separation of 12dB or lower.

Interference and Level Dependent Blend:

1. With 1st adjacent analog interference four tests produced stereo separation of 15dB or higher.
2. For these scenarios the IBOC made little change in stereo separation.

Appendix I –
NRSC 1st-adjacent channel study

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Part 1 – FM IBOC

This appendix is now a separate NRSC Report - see NRSC-R202, First Adjacent Channel IBOC Interference Demonstration

Appendix J –
FM IBOC Compatibility with Reception of Subcarrier Services

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Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

Introduction

As part of a thorough evaluation of FM IBOC, the TPWG prepared a test procedure with which the Subcommittee could attempt to determine the impact of FM IBOC on FM subcarrier services. After completing tests under this test plan, iBiquity submitted a report entitled "SCA Compatibility of the iBiquity Digital IBOC System in the FM Band." The report contains data on lab tests conducted by ATTC and the field tests conducted by iBiquity, for which all subjective testing was performed by Dynastat. Both the laboratory and field tests of subcarrier compatibility were monitored by NRSC representatives.

Summary of Findings

Host Compatibility with Analog Subcarrier Receivers

While objectively measured analog subcarrier reception can get noisier with FM IBOC signals present, and while the increased noise is often perceptible, the perceptual scores indicate that overall utility of the subcarrier is not particularly diminished with the addition of FM IBOC signals. As distance to the desired station is increased, the relative impact of the FM IBOC signal on subcarrier reception should decrease.

First Adjacent Channel Compatibility

The effect of first adjacent interference without FM IBOC signals present appears to be the controlling factor in subcarrier reception. The addition of FM IBOC signals to the first adjacent signal did not affect subcarrier reception at the desired-to-undesired ratios tested.

Second Adjacent Channel Compatibility

In general, subcarrier receivers are susceptible to all second adjacent FM signals at moderate interferer levels. As subcarrier receivers progress toward failure with increasing second adjacent analog-only signal levels, their failure is accelerated by the addition of FM IBOC on second adjacencies.

RBDS Subcarrier Reception Compatibility

There is no indication of any incompatibility between FM IBOC signals and the reception of RBDS. Reception of the RBDS data subcarrier at moderate signal levels is unaffected by the addition of FM IBOC signals to the host or to first or second adjacent signals.

DARC Subcarrier Reception Compatibility

FM IBOC signals are compatible with reception of DARC subcarrier data. Reception of the DARC data subcarrier at moderate signal levels is unaffected by the addition of FM IBOC signals to the host or to first or second adjacent signals.

Background on Subcarriers

FM subcarriers are signals that contain information and are "piggy-backed" onto FM signals. This "piggy-backing" is called "multiplexing," and involves combining the station's main channel audio, any additional stereo information signals, and one or more subcarriers prior to transmitting the radio signal. A typical analog receiver is able to recover the audio of the main channel program without appreciable degradation caused by the presence of any subcarriers. Special receivers are utilized to recover the information on a station's subcarrier. Popular uses of analog subcarriers include subscription (background) music services and free specialty audio programming targeting ethnic constituencies or providing reading services intended for persons who are print impaired. Digital subcarriers are utilized to deliver proprietary data for data subscription services, electrical load management, internal station communication and control, and the like.

With the advent of Radio Broadcast Data System (RBDS) in the USA (after 1993), some stations began sending station-related data to consumers listening to the stations' broadcasts. RBDS consists of a specialized slow-speed data subcarrier that delivers text based information and control symbols. Only those consumers who own an RBDS-enabled receiver can benefit from the additional features. This data can include a variety of information, but is largely utilized for presentation of station identifiers and music title and artist information.

Subcarrier Reception Testing

The NRSC test plan incorporated both laboratory and field testing to evaluate potential impact on subcarrier reception. Common subcarrier types were employed in the testing-- two analog audio services and two digital services. The analog subcarriers were operated on the traditional 67 and 92 kHz baseband frequencies. The digital services tested were an RBDS subcarrier (at two injection levels) and a DARC data subcarrier, employed by commercial data service providers.

Analog Subcarrier Receiver Testing

Receivers employed in the analog test were chosen to represent a range of common receivers and manufacturers. The manufacturers represented were McMartin, ComPol, CozmoCom, and Norver. Each of these companies manufacture(d) a variety of receiver models. Two of these manufacturers no longer exist but represent a large installed base of subcarrier receivers. With the assistance of the International Association of Audio Information Services, four representative receivers were selected and provided for testing. Two were operated on the 67 kHz subcarrier and two on the 92.

The analog subcarrier receiver test was determined to be an efficient way to obtain basic information on whether subcarrier users may receive perceptible interference under conditions that may be expected to challenge subcarrier receivers. Due to the nature of analog audio subcarrier reception, this sampling of receivers is not intended to provide a definitive scientific and statistically rigorous analysis of analog subcarrier reception and compatibility. The test, then, can be employed by people familiar with subcarrier performance to make reasonable inferences about the potential effects of adding FM IBOC signals to the FM spectrum.

Host FM IBOC Compatibility with Analog Subcarrier Reception

Objective Test Data

The subcarrier receivers demonstrated a wide variability in their behavior under the lab test conditions. Not only was there varying response to the presence of FM IBOC signals on the host station, but also there was varying response to changes in signal level from strong to moderate, without the presence of the FM IBOC signals (Table 1).

These measurements demonstrate that there is considerable variation in subcarrier receiver performance within the expected protected contour of a radio station. When subcarriers are transmitted on analog-only FM signals and are received under realistic noise conditions with injected AWGN, the quality of analog subcarrier reception is dependent on the received signal strength and the receiver. When signal strength is reduced from strong to moderate levels there are measurable increases in the noise reception of the tested FM subcarrier receivers.

The addition of FM IBOC signals on the host station presents challenges to subcarrier receivers similar in magnitude to the challenges presented by typical environmental radio frequency noise, as seen by comparing the summary data in Table 1 and Table 2 below.1 For reference, Table 3 contains a summary of the subcarrier same receiver tests as in Table 2, but conducted without injected radio frequency background noise.

The lab test data, as noted in the tables below, make it clear that the addition of FM IBOC signals to a station that operates an analog subcarrier will reduce the signal-to-noise performance of the received subcarrier when signal levels are strong to moderate. Hence, the greatest relative impact of FM IBOC on host subcarrier reception will be where the signal is strongest and cleanest. This information also reinforces the finding that with declining signal strength, noise increases, and the relative effects of the FM IBOC on analog subcarrier reception diminish. Because of the masking effect of reception noise outside the station's protected contour, the addition of FM IBOC signals to the desired host will have the least relative impact on subcarrier reception when the receiver is outside a station's protected contour.

[1] The data in these tables is obtained from Tables 11-14 in the laboratory test report, SCA Appendix A of iBiquity's SCA Compatibility report, pages 40 and 41.

Table 1

Lab test: Host: Without hybrid FM IBOC—
Change In Subcarrier Audio Signal-To-Noise
With Change From Strong To Moderate Received Signal Level

	Without Injected AWGN		**With Injected AWGN[2]**	
Subcarrier Receiver	**Audio Signal-to-Noise (S/N) with Strong Signal**	**Change in Audio S/N With Change to Moderate Signal Level**	**Audio Signal-to-Noise (dB WQP) with Strong Signal**	**Change in Audio S/N With Change to Moderate Signal Level**
McMartin 67 kHz	36.5 dB WQP	+1 dB*	36.2 dB WQP	-5 dB
Norver 67 kHz	31.7	0	31.2	-6
CozmoCom 92 kHz	28.9	0	28.8	-1
ComPol 92 kHz	27.9	0	27.0	-9

*A positive figure in the highlighted "Change" columns represents improvement in noise performance at the moderate signal strength with respect to the strong signal strength. A negative figure represents deterioration in noise performance at the moderate signal strength.

Table 2

Lab Test: Host: Injected RF background noise (AWGN)--
Change In Subcarrier Audio Signal-To-Noise Level
With The Addition of FM IBOC Signals

With Injected AWGN	Desired At Strong Signal Level		Desired At Moderate Signal Level	
Subcarrier Receiver	**Audio S/N without IBOC**	**Change in Audio S/N with FM IBOC Added**	**Audio S/N without FM IBOC**	**Change in Audio S/N with FM IBOC Added**
McMartin 67 kHz	36.2 dB WQP	-6 dB	31.2 dB WQP	-3 dB
Norver 67 kHz	31.2	-12	24.8	-6
CozmoCom 92 kHz	28.8	-7	27.4	-6
ComPol 92 kHz	27.0	-19	18.5	-10

[2] The injection of 30,000 K noise into the test bed has been determined by the Committee to be a realistic simulation of actual reception conditions. In contrast, the use of a test bed with no injected noise presents the test receivers with unrealistically pristine RF conditions. Such conditions fail to adequately represent typical background energy to which receivers are subjected in the field. However, tests without injected background noise are valuable tools for qualifying results of injected noise tests and for isolating other variables in tests to view their particular effects for diagnostic purposes. This subcarrier report refers to tests with AWGN injected unless otherwise indicated.

Table 3

Lab Test: Host: No Injected RF background noise (AWGN)--
Change In Subcarrier Audio Signal-To-Noise Level
With The Addition of FM IBOC Signals

Without Injected AWGN	Desired At Strong Signal Level		Desired At Moderate Signal Level	
Subcarrier Receiver	**Audio S/N without IBOC**	**Change in Audio S/N with FM IBOC Added**	**Audio S/N without FM IBOC**	**Change in Audio S/N with FM IBOC Added**
McMartin 67 kHz	36.5 dB WQP	-7 dB	37.6 dB WQP	-8 dB
Norver 67 kHz	31.7	-12	31.3	-12
CozmoCom 92 kHz	28.9	-7	29.3	-7
ComPol 92 kHz	27.9	-19	27.9	-17

Because field conditions on the whole have been determined to be best reflected in the lab by the presence of AWGN on the test bed3, the results with AWGN in the subcarrier testing deserve the closer scrutiny. Throughout this subcarrier report, the lab tests with injected AWGN are utilized unless otherwise indicated.

Subjective Test Data

While the lab test data illustrate the numerical change in signal to noise performance of a received analog subcarrier on a small sample of receivers, the data cannot indicate the perceived significance of a change in noise performance. To evaluate the perceived impact of host FM IBOC signal effects on reception of the host station's analog subcarriers, subjective testing was conducted with recordings from both lab and field tests.

Male and female voice selections were recorded on both the lab and field subcarrier tests. Musical selections were recorded on the lab tests, but not employed in the subjective analysis. The vocal selections are most representative of the content broadcast on reading services. Vocal content is also likely to be the most challenging under interference conditions because a single voice is not aurally dense enough to continuously mask noise, whereas processed music often is.

iBiquity submitted a table, "Lab Compatibility, SCA Host," (page 1 of its SCA Appendix C) that presents the average subjective MOS scores4 for each subcarrier receiver, with and without the FM IBOC signal

[3] See the NRSC FM IBOC Evaluation Report, section 4.2 for further discussion on the Committee's findings regarding the use of injected AWGN in laboratory tests. It has been the experience of the EWG in main channel tests that the use of injected AWGN in the lab best corresponds with field results.

[4] The Absolute Category Rating Mean Opinion Scores (ACR-MOS) are averages of integer scores given by test listeners using a scale in which 5, 4, 3, 2, and 1 represent Excellent, Good, Fair, Poor, and Bad, respectively. The subcarrier tests utilized the same "anchor" points of reference for quality as the main channel audio tests. Since subcarrier audio is inherently lower in quality than good main channel audio, subcarrier scores are less likely to score high, giving them less resolution on the remainder of the ACR scale.

activated. The table separates male and female audio cuts (and averages them with little change in result). It also separates tests with and without AWGN inserted under the test signal.

AWGN in Subjective Tests

On first blush, the inclusion of AWGN does not affect the MOS score of the CozmoCom receiver. Its male/female total remains at 2.1 with or without AWGN (and no FM IBOC). However, the EWG observed that the CozmoCom host compatibility recordings in this lab test were compromised by the presence of main channel crosstalk. Hence, the addition of AWGN does not appear to affect the perception of the receiver performance possibly because the quality is already poor. In field tests, there was no apparent crosstalk in the CozmoCom, which was tested on WD2XAB with classical music on the main channel. It is therefore not clear whether the receiver or the lab test configuration may have been the cause of the crosstalk.

In contrast, the other three receivers, without FM IBOC signals present, were diminished in performance with the addition of AWGN. Their starting values were higher than the CozmoCom's 2.1 MOS, showing 3.6, 3.3, and 4.0 for the ComPol, McMartin, and Norver. After AWGN was added, their performance slipped to 2.6, 3.0 and 3.0 respectively—still better than the CozmoCom at its best. These average scores starting between Good and better-than-Fair, shifted to being between Fair and better-than-Poor.

This response to AWGN (at moderate and strong signal levels) demonstrates the susceptibility of subcarrier receivers to outside influences within the host station's protected contours, even without the addition of FM IBOC signals.

Subjective Tests of Host Compatibility Lab Recordings

Under AWGN conditions, the addition of FM IBOC signals in the lab yielded FM IBOC Mean Opinion Scores of 2.6/1.4, 3.0/2.9, and 3.0/2.4 (without FM IBOC/with FM IBOC) among the latter three receivers. The CozmoCom, already compromised by crosstalk, changed from 2.1 to 1.7. Among the other three receivers, the McMartin showed on the average essentially no perceptible change. The Norver showed a change that just exceeds the confidence interval, suggesting the change was perceptible in some cases. The ComPol, which audibly seemed to pass higher frequencies (including noise) more readily than the others, produced the most dramatic change in MOS score with the addition of FM IBOC signals.

Subjective Tests of Host Compatibility Field Recordings

The field tests for Host Compatibility of subcarrier reception included two radio stations, each with two subcarriers and one receiver per subcarrier, received at three locations each.

The test signals on WPOC were corrupted by main channel crosstalk that did not appear to be related to multipath reception or individual receiver performance. The Norver receiver at 67 kHz and the ComPol at 92 kHz rated 1.9 MOS or less in each location, whether or not the FM IBOC signal was activated. Data from these two tests is not considered here. However, an experienced listener may glean some understanding of FM IBOC related noise mechanisms by listening to these sound cuts with the rest. For instance, even in the presence of distracting crosstalk, the variations in background hiss that occur with variations in signal level, AWGN, and analog/FM IBOC modes, appear to be consistent with other field and lab test recordings.

The data in iBiquity's "Field Host Compatibility" table shows the McMartin and CozmoCom receivers scoring quite well, both with and without the FM IBOC signals present. At three locations the

CozmoCom receiver, on 92 kHz, scored from 3.1 to 4.4 without FM IBOC. With FM IBOC added, the scores changed to between 2.9 and 3.5. Performance that was good-to-fair diminished to fair-and-better-than-fair.

The McMartin receiver on 67 kHz ranged from 3.8 MOS to 4.5 without FM IBOC. With FM IBOC, the scores stayed within overlapping confidence intervals of the original values, ranging from 3.6 to 4.4. The McMartin showed that it received no material change in performance with the addition of FM IBOC signals to the host.

Lab and Field Test Differences

The lab and field recordings for host subcarrier compatibility differ somewhat. The lab test recordings reveal more noise on the recordings with the FM IBOC present than the field recordings do. Mean Opinion Scores reflect this disparity as well. Mean Opinion Scores remain fairly high in both cases with the addition of FM IBOC signals.

The signal strengths used in the lab represent strong reception well within a station's protected contour and moderate reception comparable to strength at the contour. The field tests of the McMartin and CozmoCom on experimental station WD2XAB ranged from 53 to 75 dBu, which are comparable to the range of strong to moderate as approximated in the lab tests. There is no clear explanation for the clear, minor differences in the lab and field recordings. It has been the experience of the committee and in particular of several of its members involved in this type of testing that field conditions, with respect to RF noise and non-interfering out of band signals, can affect the way a receiver responds to the desired signal. The use of the 30,000 K AWGN in the lab is an important factor in simulating the impact of the radio frequency energy environment in the field, but may not duplicate it entirely.

Effect of Signal Strength

Signal strengths below the moderate level utilized in the tests represent subcarrier reception typically outside a station's protected signal coverage area. The impact of host FM IBOC signals can be inferred based on the observations available. The ATTC laboratory test summary contains spectrum analyzer plots of the demodulated baseband of various signals under test.5 Assuming that the commercial demodulator used to generate the analyzer plots behaves similarly to a typical receiver, the baseband plots reveal the relationship between signal strength, injected RF noise, host FM IBOC presence, and resulting composite baseband noise. In general, as the RF noise is increased, or the signal level is decreased, the noise in the subcarrier portion of the FM baseband increases. Lower signal levels and higher RF noise levels produce a masking effect that diminishes the impact of FM IBOC signals on the demodulated baseband. Consequently, it is reasonable to infer that as a subcarrier receiver is moved further from the host station, the received baseband noise will increase, and the noise of receiving the station will meet and exceed the noise generated in the receiver with the presence of FM IBOC signals.

Host Compatibility with Analog Subcarrier Receivers Conclusion

While objectively measured analog subcarrier reception may get noisier with FM IBOC signals present, and while the increased noise is often perceptible, the perceptual scores indicate that overall utility of the subcarrier is not particularly diminished with the addition of FM IBOC signals, because the field test subjective scores remain well above the listener "tune-out" threshold of approximately 2 MOS that was

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[5] SCA Compatibility Report, Appendix A, ATTC Document #01-16B, *SCA Compatibility of the iBiquity Digital IBOC System in the FM Band*, Oct 17, 2001, pp. 23-38

identified in Appendix J of the iBiquity main report. As distance to the desired station is increased, the relative impact of the FM IBOC signal on subcarrier reception should decrease.

First Adjacent Channel Compatibility with Subcarrier Reception

Laboratory tests were conducted on each of four subcarrier receivers, two on 67 kHz and two on 92 kHz subcarriers. Interferers on lower and upper adjacencies were tested separately. To obtain objective test data, test signals were utilized that permitted consistent measurement conditions. For recording subjective test audio samples, the test signals were replaced with program audio that permitted the main channels of the signals under test to have a "beat" component that is commonly found on radio stations and commonly heard when adjacent channel interference occurs.

First Adjacent Channel Compatibility Objective Tests

The objective tests for first adjacent channel interference to subcarrier reception were performed with the desired signal 6 dB and 16 dB above the undesired signal (+6 and +16 dB D/U). The 6 dB D/U ratio is the threshold utilized in protecting stations from interference at their protected contours. The 16 dB D/U value is less challenging to receivers.

The summary of results contained in the text below is derived from the iBiquity SCA Compatibility Report, Appendix A, Tables 3-6.

The McMartin receiver did not reveal any variation in Weighted Quasi Peak (WQP) noise between tests with and without FM IBOC signals on the first adjacent channel. Pairs of measured values were within 1 dB of each other.

The Norver receiver revealed no change at +16 dB D/U, with and without FM IBOC signals on first adjacent channel. However, its overall noise figures, around 15 dB WQP, were 9 to 12 dB worse than the McMartin. At 6 dB D/U, the Norver developed noise that measured in single digits, which may qualify as unlistenable. At 6 dB D/U, the Norver registered a 2 dB variation with the addition of FM IBOC on first adjacent channel. The Norver is clearly already compromised by first adjacent analog-only signals at these D/U ratios.

The CozmoCom receiver subjective lab recordings had what may have been the same main channel crosstalk that appeared in the lab tests for host compatibility, but the noise and interference components mostly masked the crosstalk. It is not clear whether the crosstalk also might have occurred during the objective tests with the different test audio signals employed. The CozmoCom receiver varied 0.3 dB or less with the addition of FM IBOC signals on first adjacent channel, with one exception. Without AWGN injected, the +16 D/U ratio revealed a 3.9 dB degradation on lower 1st adjacent channel and a1.6 dB change on upper. Like the Norver, 16 dB D/U measurements were in the teens of dB WQP, and in single digits at +6 dB D/U. The CozmoCom is clearly already compromised by first adjacent analog-only signals at these D/U ratios.

The signal to noise ratios for first adjacent interference in the ComPol receiver were all in the single digits and addition of FM IBOC signals on first adjacent channel did not vary the results more than 0.4 dB.

Overall, first adjacent channel interference exhibited by the tested subcarrier receivers in objective testing was challenging to the receivers whether or not the first adjacency had FM IBOC activated. The test results suggest that analog subcarrier reception is susceptible to first adjacent interference within the protected contour of a desired station.

First Adjacent Channel Compatibility Subjective Tests

Subjective testing of first adjacent channel compatibility of subcarrier reception with FM IBOC signals supports the results of the objective tests. With low figures of 1.1 MOS and a single high of 2.7, the subjective tests placed first adjacent performance without FM IBOC had a median of 1.8 MOS, slightly less than Poor. With FM IBOC the range was 1.1 to 2.6 MOS, with a median also of 1.8.

First Adjacent Channel Compatibility Conclusions

The effect of first adjacent interference without FM IBOC signals present appears to be the controlling factor in subcarrier reception. When the desired signal was sufficiently stronger than the undesired signal to meet FCC interference criteria, the subcarrier receivers delivered poor performance. The addition of FM IBOC signals to the first adjacent signal did not affect subcarrier reception at the desired-to-undesired ratios tested.

Second Adjacent Channel Compatibility with Subcarrier Reception

The subcarrier receiver tests utilized desired-to-undesired signal ratios that placed the undesired second adjacent analog signal equal to and greater than the desired signal in ten dB steps (from 0 to -30 dB D/U). The -30 dB desired-to-undesired signal ratio is not as severe as the endpoint of –40 dB D/U anticipated by FCC allocation methods. However, subcarrier receivers are generally not expected to perform at –40 dB D/U, as evidenced by their measured performance at –30. The -30 dB D/U ratio was a suitably challenging ratio for the purposes of this testing.

McMartin Receiver

Below is a graph (Figure 1) of the various tests performed on the McMartin receiver with a second adjacent signal. The X-axis contains the D/U ratio in dB. The Z-axis contains the variations in test conditions, grouped in two halves, with and without AWGN noise injected into the test bed. Each group contains two pairs-- one pair without FM IBOC signals on the adjacency and one pair with. Each pair consists of the test performed on the lower adjacency and the upper adjacency. The results are presented on the Y-axis as strips of weighted quasi peak signal to noise values. The lower the value, the poorer the signal quality.

The graph readily shows that the injection of AWGN into the test signal brings down the signal to noise ratio in comparison to those without 30,000 K AWGN. The Committee has determined that the injected noise more closely approximates the actual noise environment under field conditions.

In a noiseless environment, on the test bed, the introduction of FM IBOC signals to the second adjacent signal appear to have an impact on the McMartin reception quality at D/U ratios as low as –10 dB. With the noise masking that comes from the injected AWGN, the impact of the FM IBOC signals is less apparent, until the D/U ratio becomes more severe. At the –30 dB D/U ratio, the McMartin fails to produce discernable audio with FM IBOC signals on the second adjacency.

The McMartin retains respectable noise performance better than 29 dB WQP, in all conditions, from the zero through –20 dB D/U ratios. While there is better noise performance in the absence of AWGN, reception in the field is likely to contain energy more closely approximated by the 30,000 K AWGN.

Therefore, up through –20 dB D/U ratios, the impact of the second adjacent FM IBOC signals on the McMartin is likely to be negligible.

The subjective test data on the McMartin supports the lab data by showing that at –10 dB D/U the score is always 2.5 MOS or greater with AWGN and 3.6 or greater without AWGN. All MOS scores for analog only 2nd adjacent signals were matched within one-tenth dB by their corresponding FM IBOC test samples. Subjectively, second adjacent interference to the McMartin subcarrier receiver on 67 kHz is not discernable at this D/U ratio.

At the –20 D/U ratio the McMartin objective performance remains fairly stable without FM IBOC signals present. The addition of FM IBOC signals at –20 dB D/U shows a slight degradation that may or may not be perceptible.

Extended to –30 dB D/U, the analog-only adjacent signals appear to cause a slide in performance, but not steeply. The measured test signals with FM IBOC signals drive the receiver into very noisy performance at this ratio.

The subjective data at –30 dB D/U with FM IBOC present on second adjacent show the McMartin performing badly, which is consistent with the objective data. The 3.7 dB WQP signal to noise figures of the lower 2nd adjacent test correspond to Poor-to-Bad subjective results. On the upper adjacency the 0.3 dB signal to noise figures, essentially total failure, conform to the subjective audio which was not distinguishable enough to subjectively test.

Without FM IBOC, however, the upper second adjacent subjective audio was also not distinguishable or nearly so. Contrary to this subjective condition, the objective lab data show that upper second adjacency at –30 dB D/U should make a respectable showing of little noise degradation. This inconsistency could be caused by an error in the objective data collection or by a difference between the way the objective test signals were modulated versus the subjective test signals. The subjective test recordings were conducted under actual program audio modulation conditions rather than with test signals, and therefore are more likely to be reliable indicators of the McMartin performance.

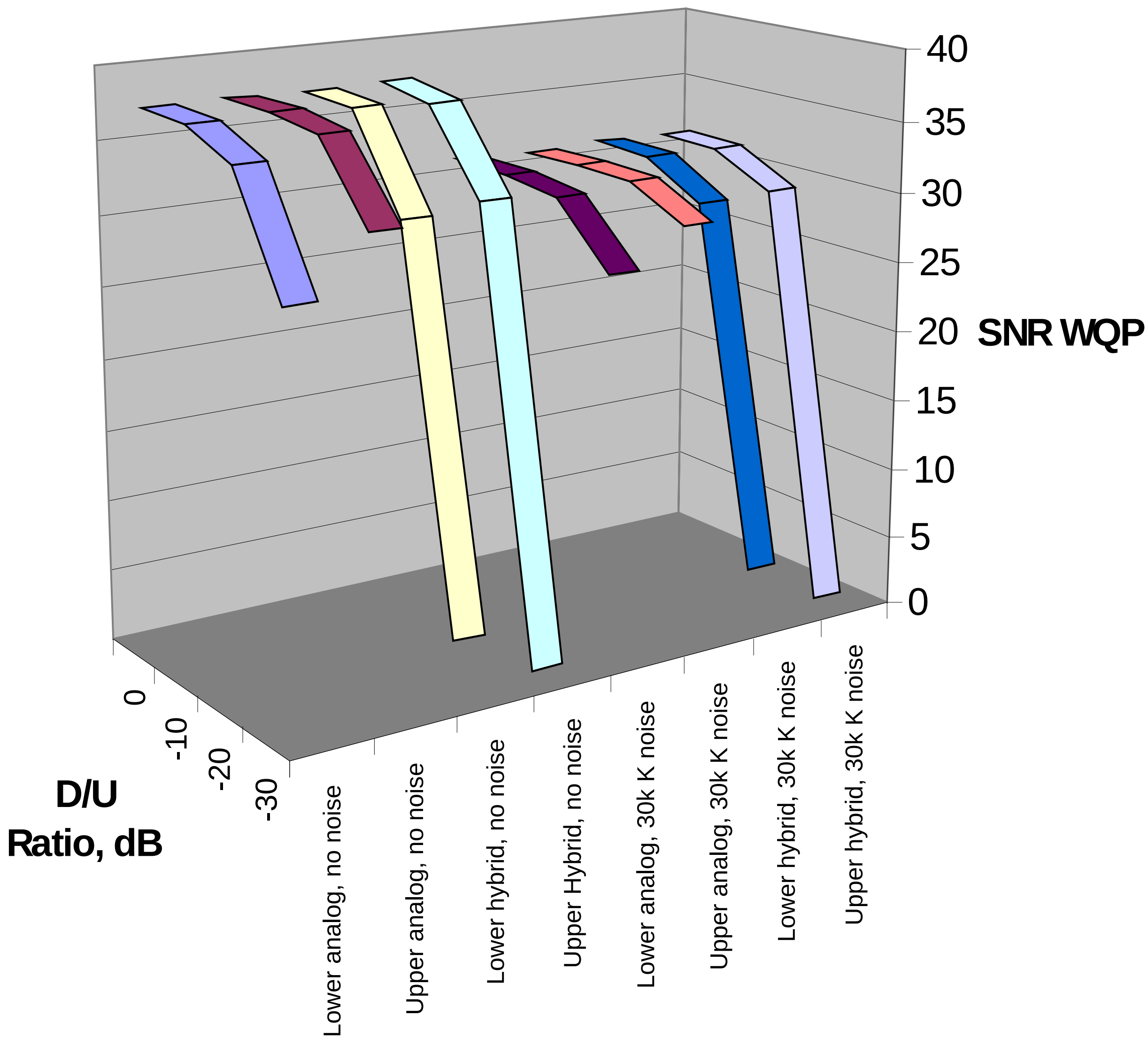
Norver Receiver

The Norver subcarrier receiver obtained poorer marks in objective testing than the McMartin. Its objective performance showed poor resistance to 2nd adjacent channel interference, regardless of the presence or absence of the FM IBOC signal. At –20 dB D/U, the Norver was already well on its way to failure without FM IBOC present. The addition of FM IBOC signals to the 2nd adjacencies accelerated the failure of the receiver, but not until it was well on its way already.

The subjective data for the Norver reinforce the objective results. At –10 dB D/U on 2nd adjacencies, the subjective scores hovered around 2.3 MOS (slightly above Poor) whether or not FM IBOC signals were present on a second adjacency. At –30 dB D/U the Norver was in failure, independent of the status of the FM IBOC signal. As with the McMartin, this, too, illustrates how the objective testing may understate the impact of the analog-only adjacency on the performance of the receiver. The Norver is simply susceptible to severe degradation in the presence of moderate to strong second adjacent analog interferers.

McMartin 2nd Adjacent Noise, 67 kHz

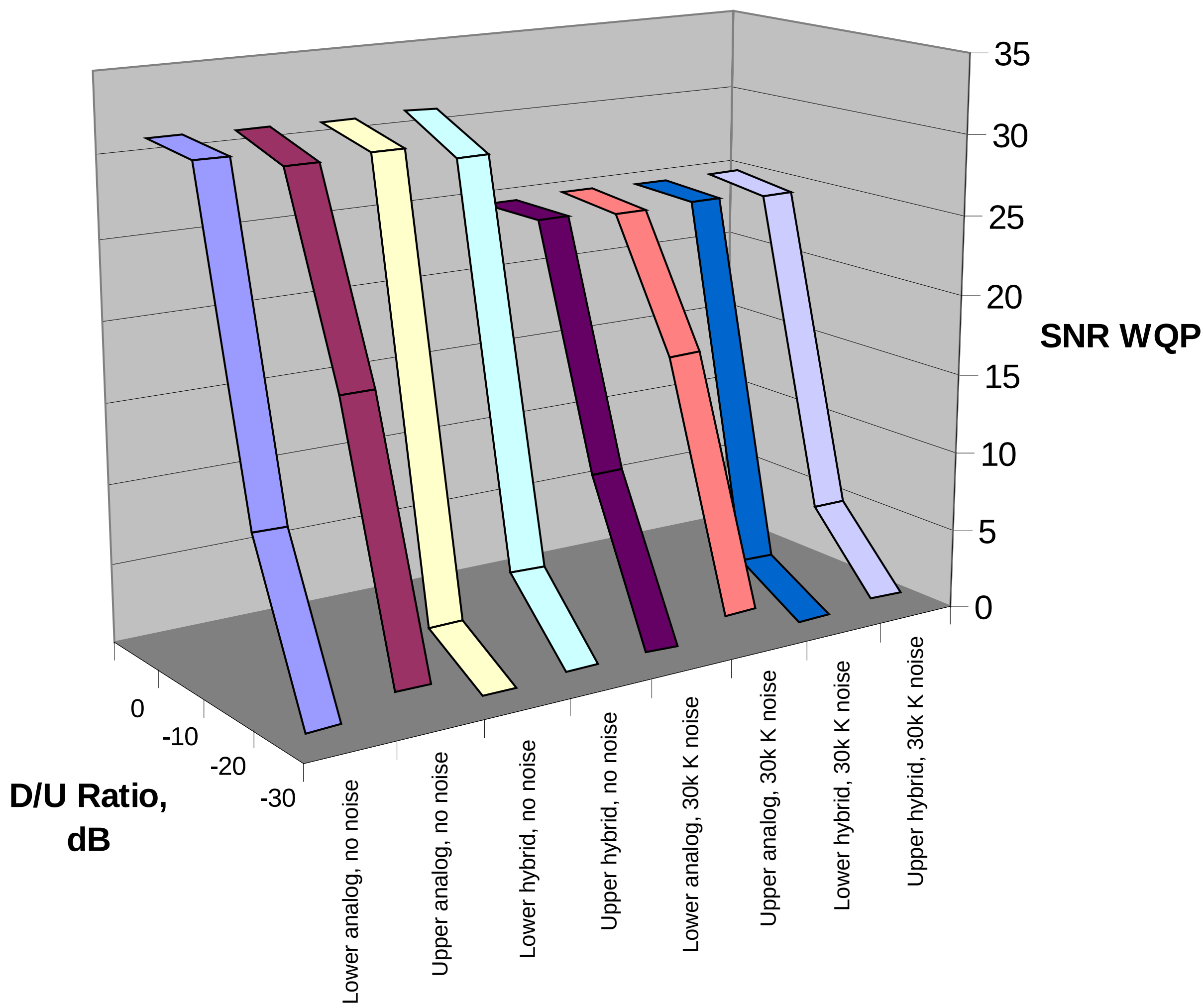
Figure 4
Data obtained from SCA Compatibility Report Appendix A, Table 3, pp. 10-11



	0	-10	-20	-30
Lower analog, no noise	37.5	37.3	35.7	28
Upper analog, no noise	37.5	37.5	37	31.8
Lower hybrid, no noise	37.4	37.2	30.7	3.7
Upper Hybrid, no noise	37.5	36.8	31.2	0.3
Lower analog, 30k K noise	31.3	31.2	30.7	26.6
Upper analog, 30k K noise	31.2	31.3	31.1	29.1
Lower hybrid, 30k K noise	31.3	31.2	28.8	3.7
Upper hybrid, 30k K noise	31.2	31.1	29	0.3

Norver 2nd Adjacent Noise, 67 kHz

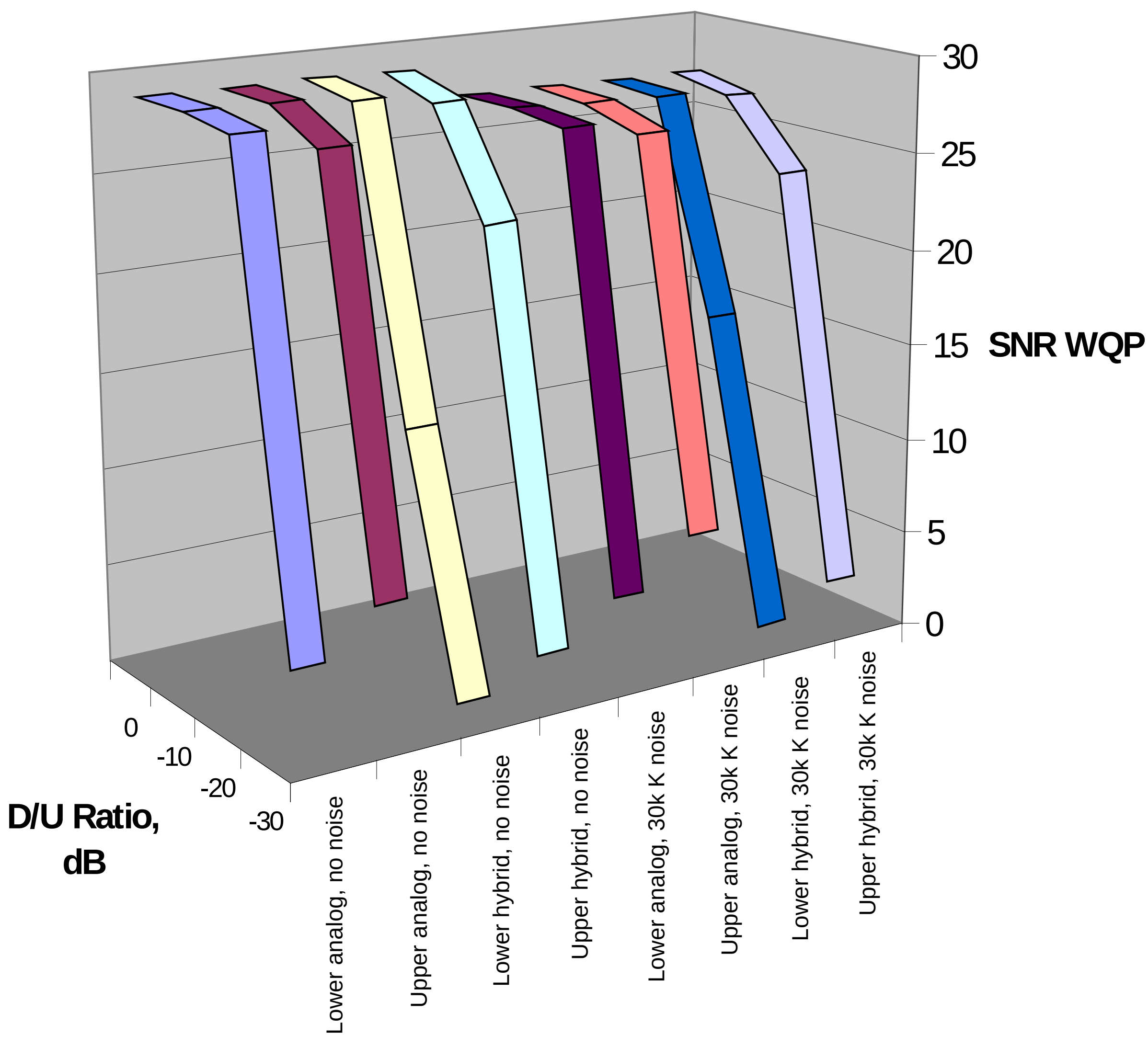
Figure 5
Data obtained from SCA Compatibility Report Appendix A, Table 4, pp. 12-13



	0	-10	-20	-30
Lower analog, no noise	31.2	30.8	10.5	0.4
Upper analog, no noise	31.2	29.9	17.6	1.6
Lower hybrid, no noise	31.1	30.1	2.6	0.1
Upper hybrid, no noise	31.2	29.2	4.9	0.4
Lower analog, 30k K noise	24.8	24.8	10	0.4
Upper analog, 30k K noise	24.9	24.5	16.6	1.6
Lower hybrid, 30k K noise	24.8	24.6	2.5	0.1
Upper hybrid, 30k K noise	24.9	24.3	5	0.5

CozmoCom 2nd Adjacent Noise, 92 kHz

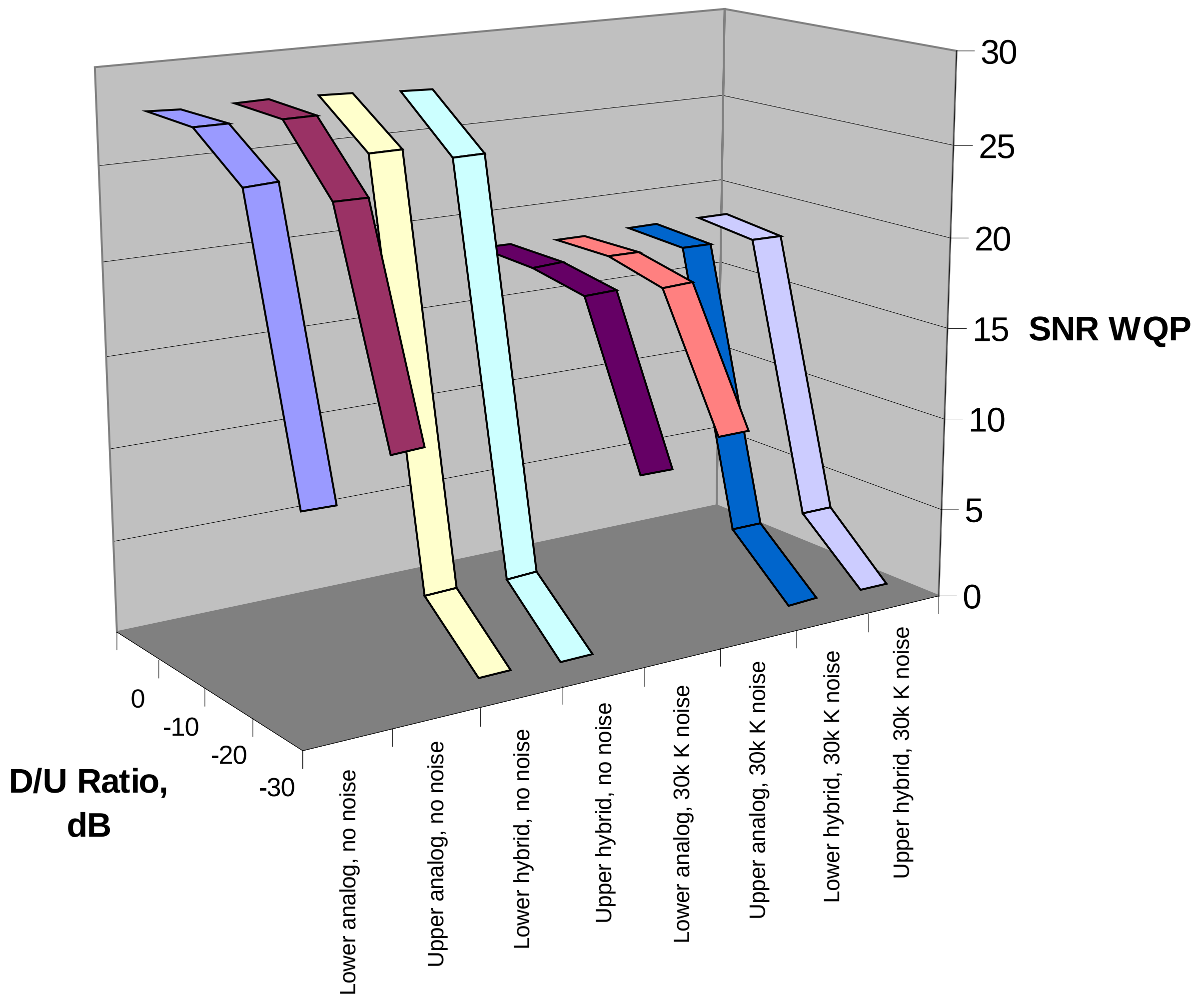
Figure 6
Data obtained from SCA Compatibility Report Appendix A, Table 5, pp. 14-15



	0	-10	-20	-30
Lower analog, no noise	29	29	28.6	4.3
Upper analog, no noise	29	28.9	27.4	6.5
Lower hybrid, no noise	29	28.6	13.2	0.6
Upper hybrid, no noise	28.9	28	22.7	2.1
Lower analog, 30k K noise	27.3	27.3	27	4.1
Upper analog, 30k K noise	27.3	27.1	26.2	6.5
Lower hybrid, 30k K noise	27.2	27	16.1	0.7
Upper hybrid, 30k K noise	27.2	26.6	23.2	2.2

ComPol 2nd Adjacent Noise, 92 kHz

Figure 7
Data obtained from SCA Compatibility Report Appendix A, Table 6, pp. 16-17



	0	-10	-20	-30
Lower analog, no noise	27.9	27.8	25.7	10.9
Upper analog, no noise	27.9	27.8	24.4	12.9
Lower hybrid, no noise	27.8	25.5	3.4	0.4
Upper hybrid, no noise	27.6	24.8	3.3	0.3
Lower analog, 30k K noise	18.5	18.4	17.8	9.3
Upper analog, 30k K noise	18.4	18.4	17.6	10.6
Lower hybrid, 30k K noise	18.5	18.2	3.3	0.4
Upper hybrid, 30k K noise	18.5	18.1	3.4	0.3

CozmoCom Receiver

The first of the two 92 kHz subcarrier receivers, the CozmoCom, was affected by second adjacent FM IBOC signals in objective tests but proved unaffected in the subjective tests.

At –20 dB D/U, upper second adjacent FM IBOC signals increased the measured noise by 3 dB, while on the lower adjacent it increased noise by 11 dB. At –30 dB D/U the measurements indicate the CozmoCom did not fail but performed poorly with noise measurements of 4 to 6.5 dB WQP.

The subjective testing was unaffected by the addition of an FM IBOC signal to the second adjacent channels with a –10 dB D/U ratio, showing only a couple of tenths of a dB difference in noise levels. At –30 dB D/U, the CozmoCom was in total failure with an analog-only second adjacent subjective test signal.

ComPol Receiver

The other 92 kHz subcarrier receiver, the ComPol, showed the most severe reduction in performance with second adjacent FM IBOC signals. The objective and subjective test results tracked fairly closely.

At –10 dB D/U there was no meaningful change in performance with both the objective and subjective tests in the presence of second adjacent FM IBOC. At –30 dB D/U, the objective tests begin with substantial noise (9-13 dB WQP) and go into failure when the FM IBOC signals are added to second adjacencies. Similarly, the subjective tests at –30 dB D/U go from nearly bad (1.1 to 1.6 MOS) to failure with FM IBOC on second adjacencies.

The –20 dB D/U point was only tested in the objective tests. The objective tests at –20 dB D/U show a significant increase in received noise with the addition of FM IBOC on second adjacencies, 14 dB. Because it falls between the unaffected –10 and the at-failure –30 dB D/U levels, the –20 test is in the midst of the ComPol receiver's transition to interference failure.

The ComPol receiver showed a measurable and significant reduction in performance only at the –20 dB D/U level when FM IBOC signals were added on second adjacencies. The performance with and without FM IBOC signals was essentially equalized at –30 dB D/U. The data suggest that the addition of FM IBOC on second adjacencies does accelerate the failure of the ComPol in the presence of second adjacent FM signals.

General Observations on Second Adjacent IBOC Compatibility with Subcarriers

In general, subcarrier receivers are susceptible to all second adjacent FM signals at moderate interferer levels (considering that –40 dB D/U is the FCC limit and that the subcarrier receivers typically failed between –10 and –30 dB D/U). Receiver failure is accelerated by the addition of FM IBOC on second adjacencies.

The resolution of the objective tests is at 10 dB D/U steps. The data suggest that FM IBOC induced degradation of subcarrier reception is likely to occur when the undesired signal is within 10 dB or less of the level at which an analog-only signal would cause the same conditions.

Limitations of Tests

The tests are extremely valuable and meaningful to the evaluation of FM IBOC compatibility with subcarrier reception. More detailed study in the future may help characterize the obvious variabilities in subcarrier receiver performance due to signal levels, in-band noise, upper-versus-lower adjacencies, and D/U ratios, as well as their responses to the addition of FM IBOC signals.

Simplifications and assumptions were made to streamline the testing process and obtain a battery of data that was readily processed. They include:

- Use of a limited sample of subcarrier receivers, two on 67 kHz and two on 92kHz;
- Laboratory objective tests utilizing standard, and modified standard, test signals rather than typical program audio;
- Injection of AWGN to approximate field reception conditions;
- Use of customary field practices for setting up main and subcarrier modulation and compression, limiting the precision and repeatability of the setups;
- Use of limited range and resolution of Desired-to-Undesired signal ratios;
- Limited characterization of receivers under test;
- Field tests with a simple vertical antenna was positioned in the judgment of the testers by ear without more rigorous characterization of the multipath environment;
- Field tests on WPOC and lab tests on the CozmoCom receiver in which there is apparent crosstalk on the recorded samples for which there was insufficient time and resources to verify causes and regenerate the tests;
- Subjective testing was conducted, for consistency, with headphones rather than speakers like those utilized in the subcarrier receivers;
- Subjective testing was conducted without limiting audio frequencies to the effective passbands of speakers utilized in subcarrier reception.

Data Subcarrier Compatibility

It stands to reason that just as an increase in composite baseband noise affects analog subcarrier reception, an increase in composite baseband noise may affect reception of digital subcarriers. Baseband noise is increased by the presence of insufficiently filtered adjacent channel signals, strong co-channel signals, and the general level of background noise.

The iBiquity subcarrier test report, Appendix A pp. 23-38, shows the spectral baseband components demodulated by a Belar monitor under a variety of noise and interference conditions. This series of graphs illustrates how variables such as signal level, injected noise, main channel modulation, and the presence of FM IBOC signals affect the noise level in the subcarrier portion of the demodulated FM baseband. Individual receivers, with the myriad tradeoffs in cost, filtering methods, demodulators, mixing and amplification, and other factors, will present varying results given the same reception conditions.

RBDS Compatibility

For the RBDS subcarrier test, a commercial analyzer, the Audemat, was utilized to measure Block Error Rates on the received RDS subcarrier in the presence of various test conditions. Consumer receivers may perform differently. However, the Audemat permitted accurate tabulation of data reception errors, and its results should prove to be a useful benchmark in the analysis of FM IBOC compatibility with RBDS reception.

Under strong and moderate signal levels in the laboratory, with 3% and 10% RBDS injection, with and without injected AWGN, with and without main channel modulation, RBDS reception exhibited no block errors (to a precision of 0.00%). Similarly, in first and second adjacent channel tests, with moderate signal levels, over a range of desired-to-undesired signal levels, with and without AWGN, there were no data errors.

Limited field tests were conducted on host RBDS reception to see whether they confirm the laboratory tests. Three locations were selected based on their approximate analog-only block error rates—0%, 1% and 10%. The injection of the RBDS subcarrier was 1 to 2%.

With the introduction of FM IBOC, the 0% location continued to deliver 0% errors over a 30-minute period.

At the 1% error location, the three three-minute analog-only samples ranged from 1.2 to 2.6% block errors. With FM IBOC on, three three-minute samples, which were alternated in time with the analog-only samples, yielded errors from 1.3% to 2.7 %. Clearly, at this level of resolution, the only variable in the error rate was a variation over time that resulted in the highest error rates being about double the lowest error rates. Perhaps with a much longer sample time, one could accumulate sufficient data to characterize the changes in error rates over time and determine if there are any subtle effects caused by the addition of FM IBOC signals to the host.

At the location yielding 10% errors, the analog-only rates ranged from 9.4 to 12.4% over three three-minute samples. With FM IBOC on, the rates ranged from 6.1 to 13.4%. As with the 1% test data, this data illustrates there is no obvious deterioration in error rates due to the addition of FM IBOC to the host station.

There is no indication of any incompatibility between FM IBOC signals and the reception of RBDS.

DARC Compatibility

Tests of the 76 kHz DARC digital subcarrier reception were performed with a commercially available DARC receiver. The received data stream was tested for errors both before and after the receiver's error correction stage.

Host Compatibility

Testing FM IBOC on the host signal, with moderate and strong signal levels, and with and without AWGN and main channel modulation, no block errors were detected prior to error correction.

In field tests, four locations with impaired reception were tested. One location was tested for a total of 30 minutes with host FM IBOC on, and 30 minutes with host analog only. The FM IBOC was turned on and off for ten-minute intervals over the period until each mode had accumulated thirty minutes of data. This represents nearly 100,000 blocks of data for each mode.

The raw received data in the thirty-minute tests, prior to error correction, indicated 0.00% error rate in analog-only mode, and 0.074% with FM IBOC. After error correction, the rates were zero.

At two locations the uncorrected error rates without FM IBOC were between 0.13 and 0.38% (plus an unusual value of 0.9%). With FM IBOC present, the uncorrected errors ranged from 0.15 to 0.37%. After error correction, all values were zero (except the unusually high analog-only measurement which resulted in a 0.232% post correction error rate). These tests included three three-minute samples of each mode at each location, for a total of 12 samples.

In the field tests with uncorrected error rates below 0.4% there is no apparent increase in errors due to the addition of FM IBOC to the host signal.

The remaining field test was run at a location with 6.2 to 9.9% uncorrected errors without FM IBOC. With FM IBOC, the uncorrected errors ranged from 7.7 to 10.8%. After error correction, the errors without FM IBOC ranged from 0.00% to 0.08%. With FM IBOC, the errors ranged from 0.02% to 0.1%. While these data may appear to hint at a slight increase in error rates with FM IBOC on, the apparent change is not statistically significant due to the limited number of samples (three three-minute samples each—FM IBOC on and off) and the large variations in errors over time.

The tests at approximately 10% uncorrected error rates do not indicate a significant change in error rates with the addition of FM IBOC to the host.

First Adjacent Compatibility

The first adjacent channel tests yielded significant block errors without FM IBOC present under certain conditions. At +16 dB D/U and in the absence of FM IBOC, block errors ranged about 1 to 2% prior to correction. These errors were fully corrected by the error correction scheme. At +6 dB D/U the pre-corrected block errors rose to 70-80%. Clearly, first adjacent signals at this ratio present a significant challenge to the DARC receiver. It is a testament to the robustness for the error corrector that these errors were reduced to a post-correction range of 1½ to 5%.

With the addition of FM IBOC on the first adjacent signal, no new errors were found in modes where errors had not previously occurred. The +16 dB D/U errors remained close to the analog-only errors, with the confidence intervals overlapping. These errors were fully corrected as were the analog-only errors in the same conditions.

At +6 dB D/U, the massive pre-correction errors increased by 1-2% with the addition of FM IBOC, still within overlapping confidence intervals of the analog-only results. Similarly, the corrected data at +6 dB D/U was very close to that of the analog-only tests, within the confidence intervals of the results.

There is a clear trend that shows a slight increase in errors with the presence of FM IBOC on first adjacent channels at +6 and +16 dB D/U, where there are already similar magnitude errors on the analog-only results. However, this trend is not statistically significant due to the overlapping confidence intervals of the results. More importantly, if this trend is indeed representative of the behavior of the DARC receiver in the presence of FM IBOC, it remains an extremely positive indication of compatibility. Small errors on both the analog-only and the FM IBOC signals are readily corrected under the same reception circumstances. Huge errors observed with analog-only first adjacent signals are incompletely corrected to the same magnitude of error as the huge errors that occur in the presence of analog with FM IBOC on first adjacent signals.

Second Adjacent Compatibility

Overall, the second adjacent compatibility data shows no impact of second adjacencies on the reception of DARC data. Error rates before correction were almost entirely zero with and without FM IBOC present. The –30 dB D/U ratio with the lower second adjacency produced fully correctable errors of less than 0.1% both with and without FM IBOC present.

Limitations of Testing

The most obvious variable observed in the field tests was that of reception quality over time. The data error rates obtained in the host field tests showed in some cases a 2 to 1 variation over only three three-minute samples. (One sample indicated a possible 4 to 1 variation). These tests do not provide the degree of resolution necessary to determine whether the addition of FM IBOC to the host signal causes any subtle but consistent variation in DARC reception.

First and second adjacent channel FM IBOC signals are not readily isolated as variables in field tests such that field-testing adjacent interference was not a part of this test plan. The laboratory tests show some consistently higher error rates for first adjacent channel reception with FM IBOC present. These differences in rates are statistically insignificant.

DARC Subcarrier Reception Compatibility Conclusion

FM IBOC signals are compatible with reception of DARC subcarrier data. Reception of the DARC data subcarrier at moderate signal levels is unaffected by the addition of FM IBOC signals to the host or to first or second adjacent signals.

Attachment 1 - Analog Subcarrier Receiver Characterization Tests

These tests were designed to insure that each receiver was meeting basic performance parameters prior to IBOC compatibility testing. The first column of the table below lists the characterization tests. The test procedure for these tests is on page 13 of the of the SC receiver characterization report which follows.

All tests were conducted with 10% subcarrier injection and 5 kHz deviation for both subcarrier frequencies (67 kHz and 92 kHz).

The RMS S/N was measured at five levels -85, -75, -65, -55, and -45 dBm. Only the -62 dBm S/N is listed in the Table. The S/N at the five levels is listed in the complete data report.

For the 1st adjacent tests the undesired transmitter was modulated with a 1kHz tone and deviated 75kHz. The tests were conducted on the upper and lower first adjacent channels at 16dB and 6dB D/U ratios. The results are WQP S/N.

Changes in 67 kHz subcarrier WQP S/N with and without 57kHz 3% RDS were measured at a signal level of -45 dBm.

Page 7 of the complete test data report lists the SC generator calibration data. Pages 8 through 12 show subcarrier calibration plots.

Summary of Analog Subcarrier Receiver Characterization Measurements

Make	CozmoCom	CozmoCom	Compol	McMartin	McMartin
Model	---	---	SCA-BL	TR-E5/55M	---
Serial Number	0073696	0073696	Sample 1001	286834	A0012461
SC Frequency	67 kHz	92 kHz	92 kHz	67 kHz	67 KHz
THD _45dBm 1kHz tone	1.0 V RMS 1.5% THD	1.0 V RMS 1.8% THD	0.5 V RMS 1.9% THD	0.175 V RMS 0.57% THD	1.0 V RMS 2.6% THD
S/N RMS at -65dBm (dB)	59	57	54	63	56
U 1st 16dB D/U WQP S/N (dB)	24	35	27	30	26
L 1st 16dB D/U WQP S/N (dB)	26	32	24	32	29
U 1st 6dB D/U WQP S/N (dB)	19	22	18	4	17
L 1st 6dB D/U WQP S/N (dB)	19	22	15	22	20
WQP S/N without and with 3% RDS (dB)	50/47	49/49	36/34	49/43	42/33

FM Receiver Test Laboratory

Date: 3/31/2001
Engineers: RMc
Project: SCA RX Characterization

Scope:

Basic SCA receiver tests to ensure that test radios are in good working condition for compatibility testing and to baseline receiver performance at a basic level. Further testing to be defined at a later date.

SCA receiver tests include:

1. Standard test audio output level (volume control calibration) and distortion
   SCA at 10% injection, 5kHz deviation, -45dBm RF level
   Audio measured RMS

2. Signal, noise curve at RF levels from -45dBm to -85dBm, 10dB resolution
   Audio measured RMS

3. First Adjacent selectivity using FM adjacent signal modulated 1kHz tone, 75kHz deviation at 16 and 6dB D/U
   Audio measured Weighted Quasi Peak (WQPK)

4. SCA receiver performance with and without 57kHz RBDS subcarrier
   Audio measured Weighted Quasi Peak (WQPK)

Receivers

1. CozmoCom FM portable radio with SCA audio for both 67kHz and 92kHz

2. Compol dedicated SCA receiver for 92kHz

3. McMartin dedicated SCA receiver for 67kHz

4. McMartin dedicated SCA receiver for 92kHz

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Portable
Radio Mfg.: CozmoCom
Model: FM Radio Receiver
Serial: 0073696

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 67 kHz
Injection: 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 1.00 Vrms

THD: 1.50 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	-0.50	-39.00
-75.00	0.00	-49.00
-65.00	0.00	-58.50
-55.00	0.00	-66.00
-45.00	0.00	-70.00

3 Selectivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

D/U (dB)		S/N	
	No Interference	50.00	dB
16	Upper	23.90	dB
	Lower	25.80	dB
6	Upper	19.20	dB
	Lower	18.50	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	50.00	dB
With 57kHz	48.50	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Portable
Radio Mfg.: CozmoCom
Model: FM Radio Receiver
Serial: 0073696

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 92 kHz
Injection: 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 1.00 Vrms

THD: 1.80 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	0.00	-37.25
-75.00	0.00	-47.00
-65.00	0.00	-57.00
-55.00	0.00	-65.00
-45.00	0.00	-69.00

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

		S/N	
No Interference		49.00	dB
D/U (dB)	Upper	34.50	dB
16	Lower	32.20	dB
D/U (dB)	Upper	22.00	dB
6	Lower	21.50	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	49.00	dB
With 57kHz	49.00	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Table
Radio Mfg.: ComPol
Model: SCA-BL
Serial: Sample 1001

Comments:
This receiver has a problem when tur
past a certain point the audio goes int
Therefore the audio output level was

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 92 kHz
Injection 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 0.50 Vrms

THD: 1.90 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	0.00	-37.50
-75.00	0.00	-47.00
-65.00	0.00	-54.25
-55.00	0.00	-57.25
-45.00	0.00	-57.50

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratic

		S/N	
No Interference		35.60	dB
D/U (dB)	Upper	27.00	dB
16	Lower	24.30	dB
D/U (dB)	Upper	17.80	dB
6	Lower	15.00	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratic

	S/N	
Without 57kHz	35.60	dB
With 57kHz	34.20	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Table
Radio Mfg.: McMartin
Model: TR-E5/55M
Serial: 286834

Comments:
Output at line level at jack on rear pa
Volume control does not affect audic
audio output jack on rear panel

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 67 kHz
Injection 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 0.175 Vrms

THD: 0.57 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	0.00	-42.00
-75.00	0.00	-52.25
-65.00	0.00	-62.00
-55.00	0.00	-63.00
-45.00	0.00	-64.00

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratic

		S/N	
No Interference		49.00	dB
D/U (dB)	Upper	30.30	dB
16	Lower	32.20	dB
D/U (dB)	Upper	4.16	dB
6	Lower	21.70	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratic

	S/N	
Without 57kHz	49.00	dB
With 57kHz	42.60	dB

FM Receiver Test Laboratory

Date: ######
Engineers: RMc
Project: SCA RX Characterization

Receiver Test No.:
Class: Table
Radio Mfg.: McMartin
Model: Unsure - Comm Center R9:
Serial: A0012461

Comments:
Audio output is headphone output on
(varies with volume control)

Antenna Network: None FM

RF Channel Frequency
RF: 97.90 MHz

Subcarrier Frequency

SCA: 67 kHz
Injection 10 %

1 Standard Audio Output
RF Lev.: -45 dBm

Level: 1.000 Vrms

THD: 2.60 %

2 Curve test

RF Level (dBm)	Signal (dBr)	Noise (dBr)
-85.00	-0.25	-39.50
-75.00	-0.25	-48.50
-65.00	0.00	-55.75
-55.00	0.00	-59.00
-45.00	0.00	-60.00

3 electivity 1st Adj
Desired: -45 dBm
Undesired: +/- 200kHz, 1kHz, 75kHz Dev
Measurement: WQPK Signal-to-Noise ratio

		S/N	
No Interference		42.60	dB
D/U (dB)	Upper	26.40	dB
16	Lower	29.30	dB
D/U (dB)	Upper	17.20	dB
6	Lower	20.00	dB

4 SC WQPK S/N With and Without 57kHz RBDS (3% / 2.25kHz)
Desired: -45 dBm
Undesired: None
Measurement: WQPK Signal-to-Noise ratio

	S/N	
Without 57kHz	42.40	dB
With 57kHz	33.30	dB

FM Receiver Test Laboratory

3/31/2001
RMc
SCA Generator Calibration Data
For 5kHz deviation

SCA Gen	**Mod Sci Sidekick**	
SCA Freq	67	kHz
Mod Freq	400	Hz
Input	1,2	Unbal
Input Lev	1.08	Vrms

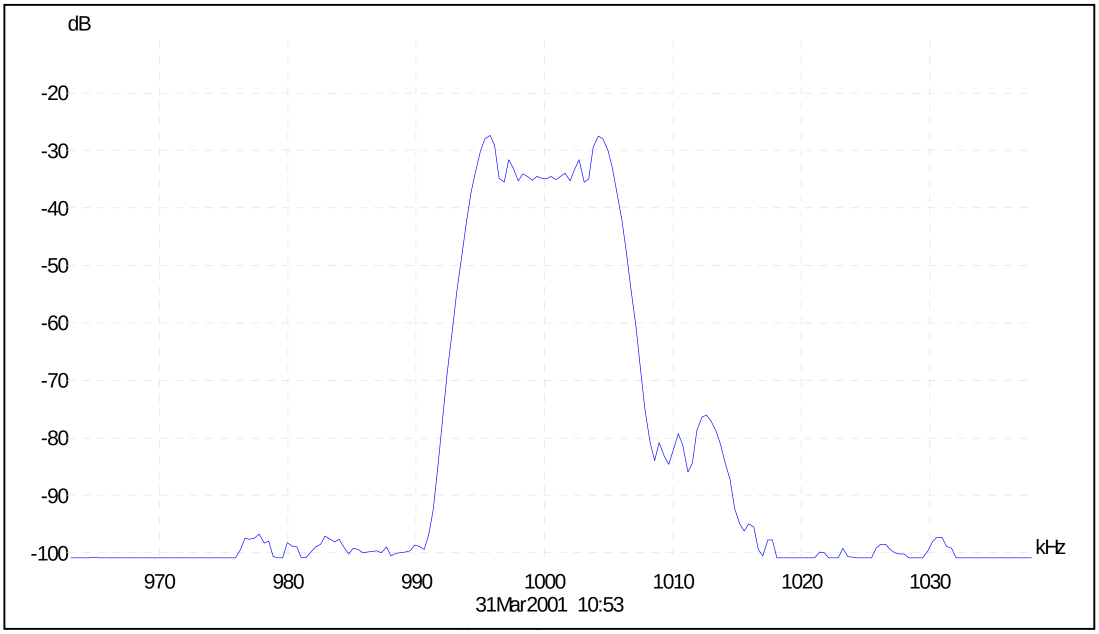
SCA Gen	**Mod Sci Sidekick**	
SCA Freq	92	kHz
Mod Freq	400	Hz
Input	1,2	Unbal
Input Lev	1.08	Vrms

RE533 RBDS Generator

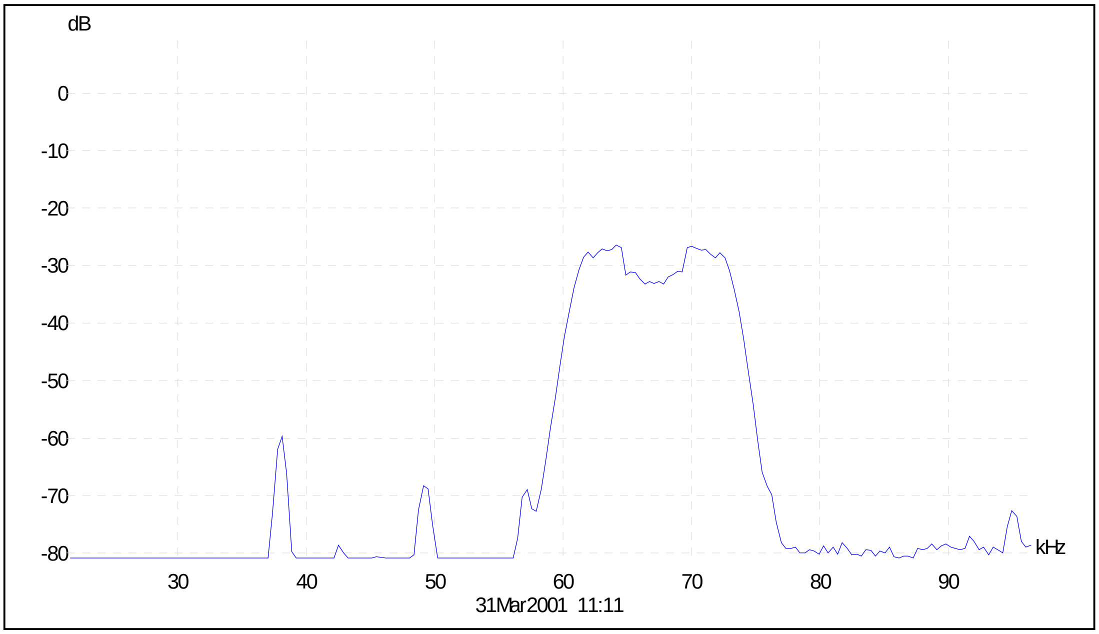
SCA Freq	57	kHz	
Phase Lock	19	kHz	(Pilot)

FM Receiver Test Laboratory

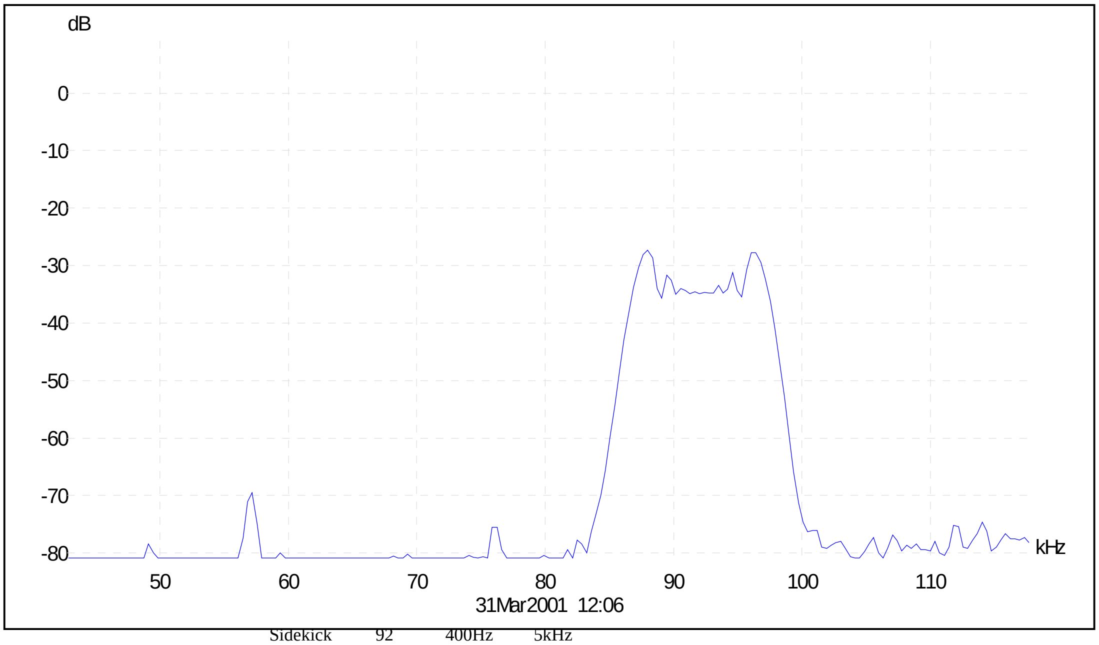
Initial plot of RE107 calibrated to Modulation analyzer establishes reference plot of spectrum analyzer.
Plot of Modulation Analyzer output



Plot of 67kHz SCA signal from Modulation Analyzer output

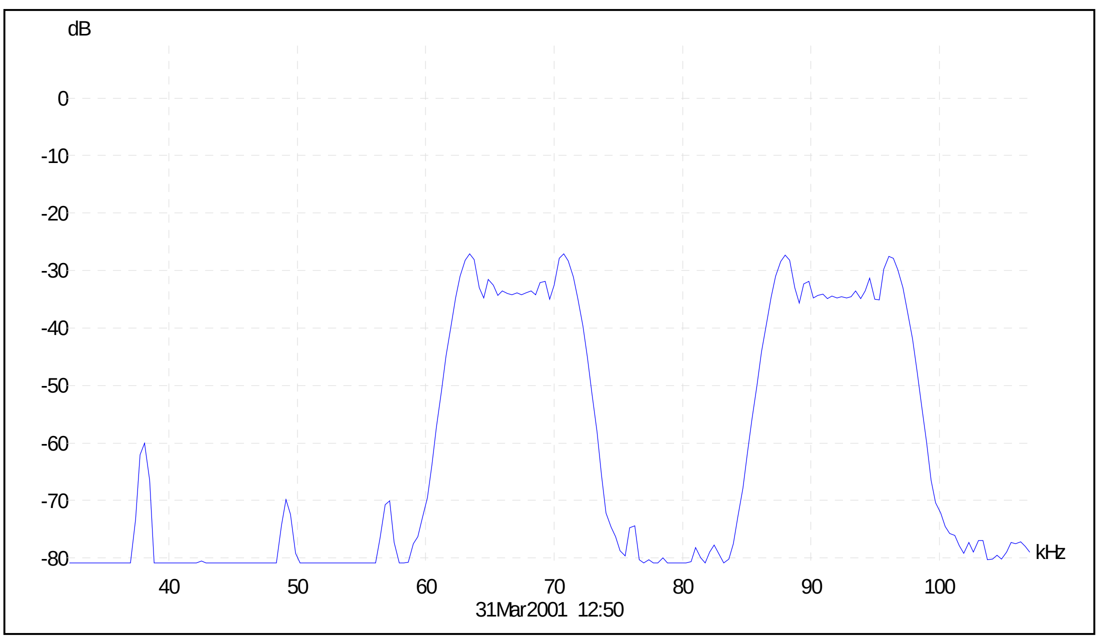


Plot of 92kHz SCA signal from Modulation Analyzer output

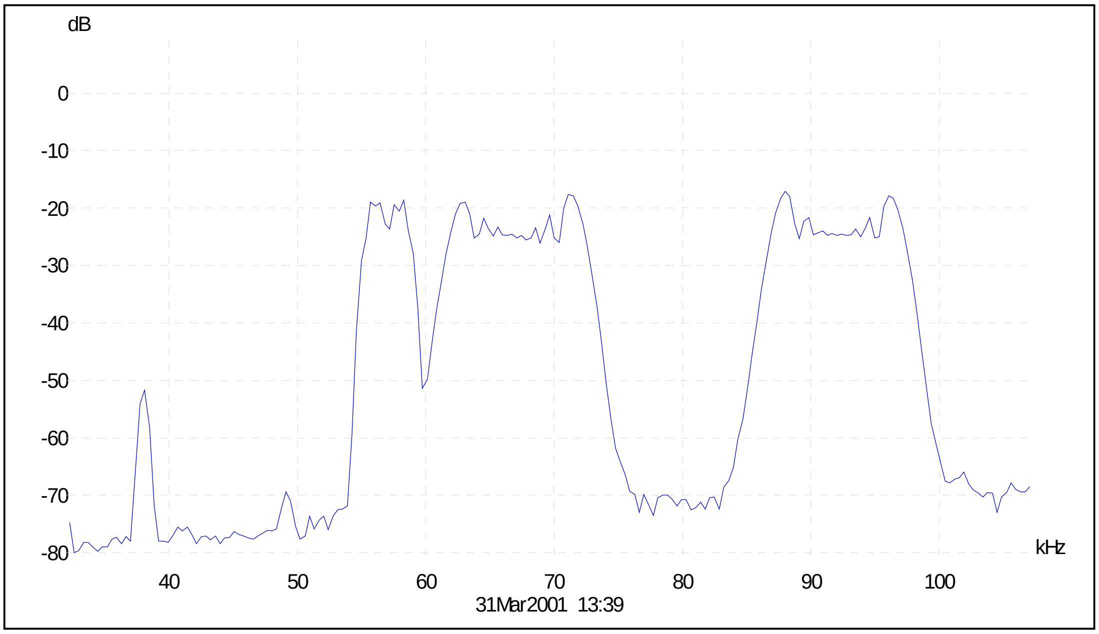


Sidekick 92 400Hz 5kHz

Plot of 67kHz and 92kHz SCA signals from Modulation Analyzer output



Plot of 57kHz, 67kHz and 92kHz SCA signals from Modulation Analyzer output



FM Receiver Test Laboratory

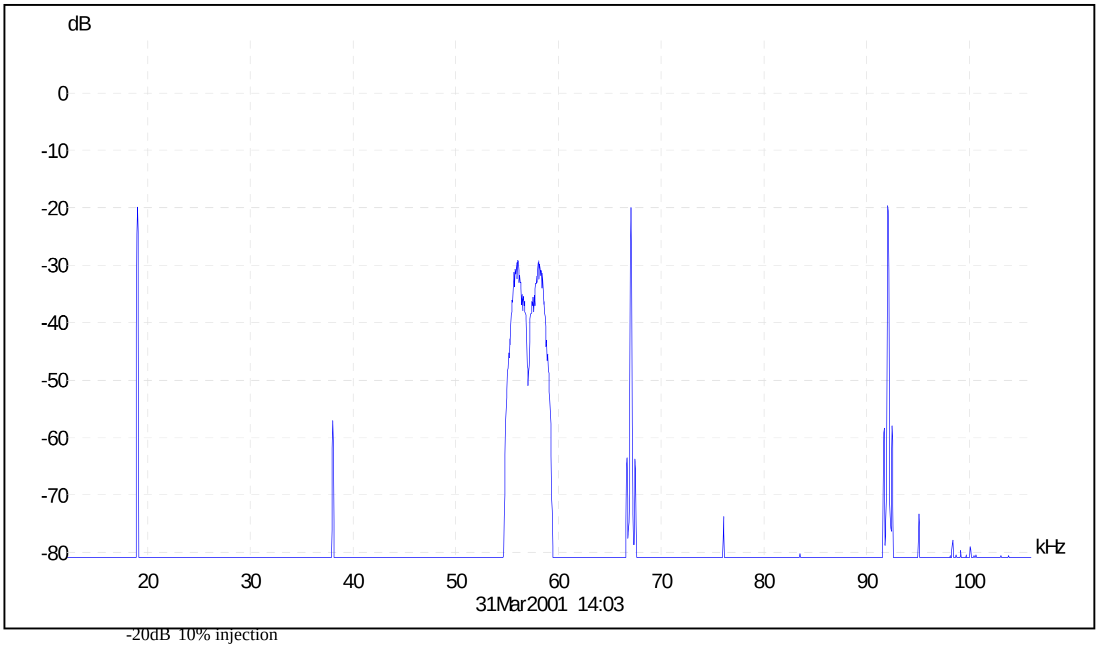
3/31/2001 RMc

Spectrum Analyzer

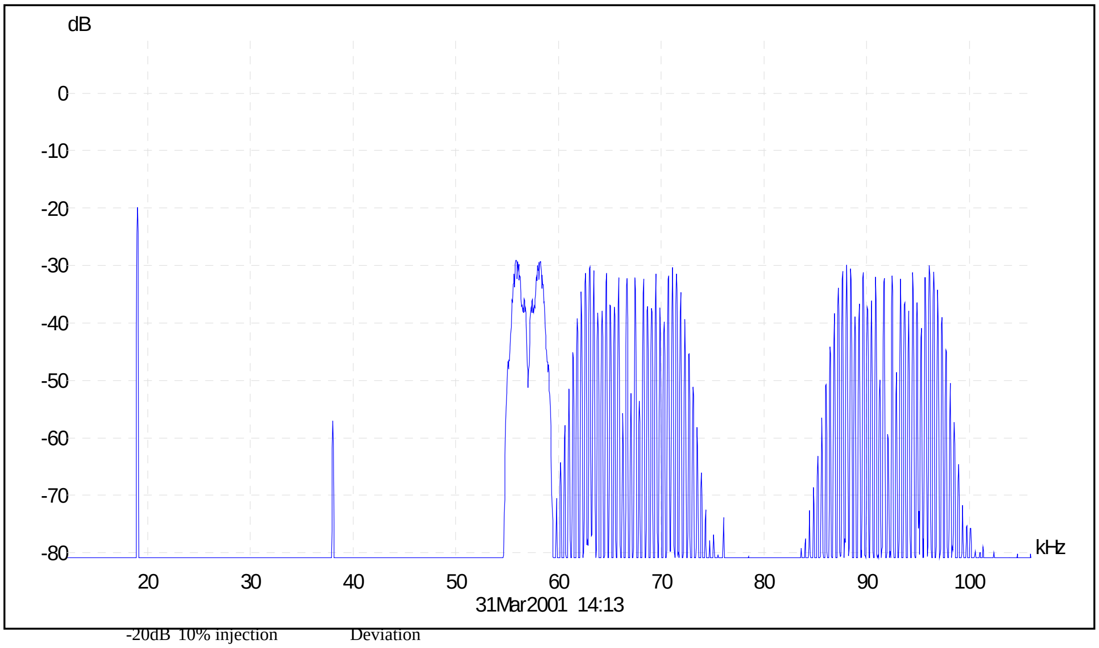
Type:	Pico ADC 212	
Input:	Fixed	
Level:	1	V
Timebase:	187	kHz
Mag:	2	X
Window:	Blackman	
No. of Bands:	4096	Bins
Disp. Mode:	Peak	

Source

Type:	AFM 2	
Meter range:	30	kHz
Filter Set:	200	kHz (wide)

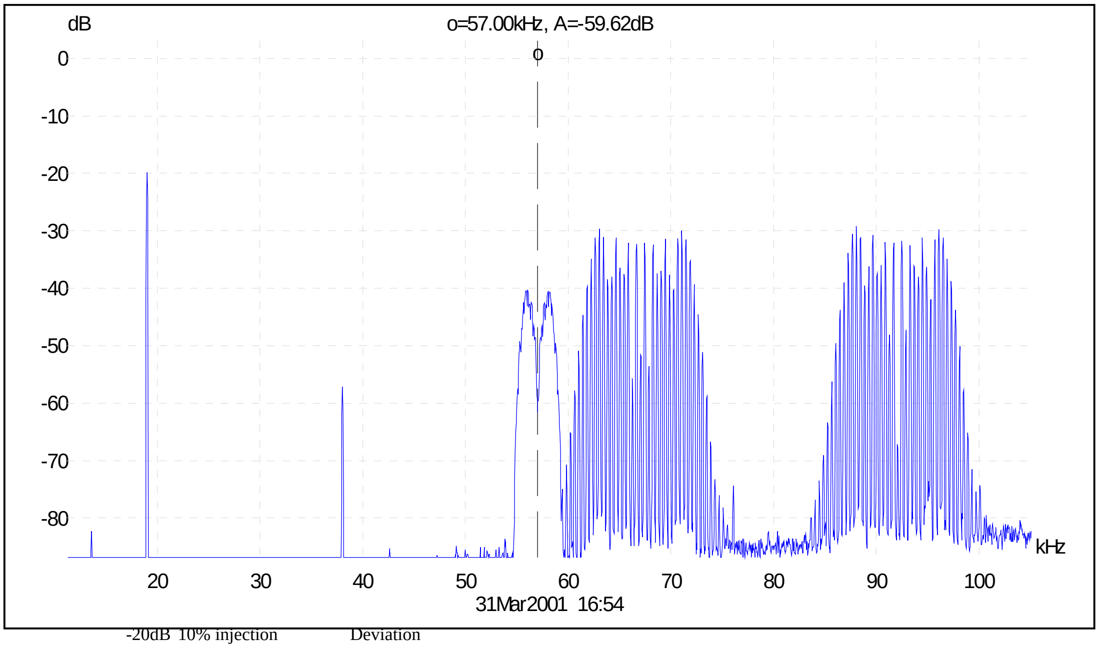


-20dB	10% injection
19 kHz	10%
57 kHz	10%
67 kHz	10%
92 kHz	10%



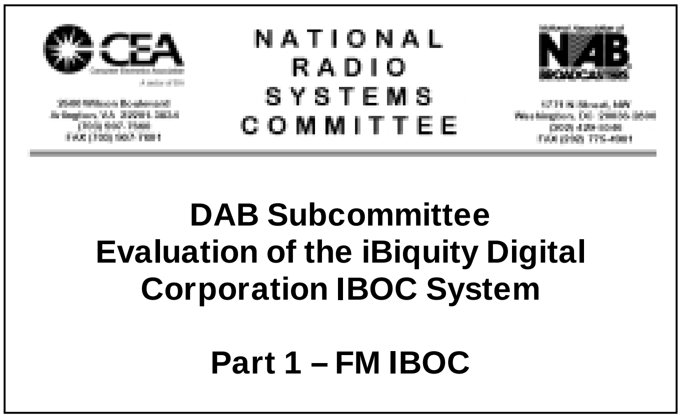
-20dB	10% injection	Deviation	
19 kHz	10%	NA	
57 kHz	10%	Std RDS	
67 kHz	10%	5	kHz
92 kHz	10%	5	kHz

Final Calibration



-20dB	10% injection	Deviation	
19 kHz	10%	NA	
57 kHz	3%	Std RDS	
67 kHz	10%	5	kHz
92 kHz	10%	5	kHz

Appendix K –
NRSC Industry Subjective Evaluation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DAB Subcommittee
Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

This appendix is now a separate NRSC Report - see NRSC-R201, FM Industry Evaluation

Appendix L –
FM IBOC Test Data Report
Table of Contents

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Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

The FM IBOC Test Data Report was submitted to the NRSC electronically, in 27 separate computer files, all in Adobe Acrobat (".pdf") format. Listed below is a description of each file, the number of pages (when printed), and the file size (in kbytes).

Description	# of pages	File size (kbytes)
Main report	56	6438
Appendix A - IBOC FM transmission specification	32	821
Appendix B - Lab test platform	2	65
Appendix C - Lab test procedures for the ATTC	113	558
Appendix D - ATTC summary of test results	65	331
Appendix E - FM field test procedures & notes	44	849
Appendix F.1 - Field test results - WETA	13	2618
Appendix F.2 - Field test results - WPOC	13	953
Appendix F.3 - Field test results - WHFS	17	1803
Appendix F.4 - Field test results - WNEW	16	3752
Appendix F.5 - Field test results - WWIN	12	2431
Appendix F.6 - Field test results - KWNR	14	6241
Appendix F.7 - Field test results - KLLC	28	7779
Appendix F.8 - Field test results - WD2XAB	12	2287
Appendix F.9 - Field test results - compatibility	8	2275
Appendix G - Subjective test program and platform	28	718
Appendix H - Dynastat - audio testing methods and procedures	25	374
Appendix I - FM subjective evaluation results	35	602
Appendix J - Summary of MOS interpretation test	2	472
Appendix K - Ticker test	12	563
Appendix L - Study of the present levels and instance of 1st adj. channel interference	7	595
Appendix M - Impact of national rollout of IBOC on analog radio listenership	13	930
Appendix N - On-air IBOC field trial record	10	651
SCA main report	12	177
Appendix SCA-A - ATTC summary of test results	60	1,858
Appendix SCA-B – Field test measurement locations	4	350
Appendix SCA-C - SCA subjective evaluation results	6	115
Appendix SCA-D – Digital subcarrier field test results	3	109

Appendix M –
Glossary of terms

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Evaluation of the iBiquity Digital Corporation IBOC System

Part 1 – FM IBOC

ACR-MOS – Absolute Category Rating Mean Opinion Score. A methodology for subjectively testing audio quality where participants are presented with sound samples, one at a time, and are asked to grade them on a 5 point scale. For the NRSC FM IBOC tests, the MOS scale used was 5=Excellent, 4=Good, 3=Fair, 2=Poor, 1=Bad.

After Market – A radio designed for purchase and installation some time after purchasing an automobile.

All-digital IBOC – The third of three modes in the iBiquity FM IBOC system that increases data capacity by adding additional digital carriers. All-digital IBOC uses four frequency partitions and no analog carrier. In this mode, digital audio data rate can range from 64 kbps to 96 kbps, and the corresponding ancillary data rate will range from 213 kbps for 64 kbps audio to 181 kbps for 96 kbps audio.

ATTC – The Advance Television Technology Center, the prime lab test contractor for the FM IBOC tests.

AWGN – Additive White Gaussian Noise, also known as white noise, which contains equal energy per frequency across the spectrum of the noise employed. In the context of the FM IBOC system tests, AWGN at radio frequencies was utilized in the laboratory tests to simulate the background noise present in the FM spectrum, which affects the quality of radio reception.

Blend to Analog – The point at which the BLER of an FM IBOC receiver falls below some predefined threshold and the digital audio is faded out while simultaneously the analog audio is faded in. This prevents the received audio from simply muting when the digital signal is lost. The receiver audio will also “blend to digital” upon re-acquisition of the digital signal.

Blend to Mono – The process of progressively attenuating the L-R component of a stereo decoded signal as the received RF signal decreases. The net result is a lowering of audible noise.

BLER – Block Error Rate. A ratio of the number of data blocks received with at least one un-correctable bit to the number of blocks received.

Compatibility – When one system has little to no negative impact on another system, it can generally be considered compatible. In the case of this report, compatibility testing has been performed to determine the extent to which the addition of an FM IBOC signal will impact current analog performance.

DAB – Digital Audio Broadcasting.

D/U – Ratio of Desired to Undesired signals (usually expressed in dB).

EWG – Evaluation Working Group of the NRSC DAB Subcommittee

Extended-hybrid IBOC – The second of three modes in the iBiquity FM IBOC system that increases data capacity by adding additional carriers closer to the analog host signal. Extended-hybrid IBOC mode adds two frequency partitions around the analog carrier. In this mode, digital audio data rate can range from 64 kbps to 96 kbps, and the corresponding ancillary data rate will range from 83 kbps for 64 kbps audio to 51 kbps for 96 kbps audio.

Hybrid IBOC – The first of three modes in the iBiquity FM IBOC system that increases data capacity by adding additional carriers closer to the analog host signal. Hybrid IBOC mode adds one frequency partition around the analog carrier and is characterized by the highest possible digital and analog audio quality with a limited amount of ancillary data available to the broadcaster. Digital audio data rate can range from 64 kbps to 96 kbps, and the corresponding ancillary data rate will range from 33 kbps for 64 kbps audio to 1 kbps for 96 kbps audio.

IBOC – In-Band/On-Channel system of digital radio where the digital signals are placed within the current AM and FM bands and within the FCC-assigned channel of a radio station.

Longley-Rice – A model used to predict the long-term median transmission loss over irregular terrain that is applied to predicting signal strength at one or more locations. Longley-Rice computations are employed both by the FCC allocations rules for FM stations to predict signal strength contours and by propagation modeling software to predict signal strengths in a two-dimensional grid on a map. The FCC implementation of Longley-Rice computations employs average terrain computations and an assumed 30-foot receive antenna height. The propagation modeling plots in this report implement Longley-Rice computations with actual terrain data and an assumed receive antenna height of 7 feet.

MPEG-2 AAC – Advanced Audio Coder, a high-quality, low bit rate perceptual audio coding system developed jointly by AT&T, Dolby Laboratories, Fraunhofer IIG, and Sony.

Multipath – An RF reception condition in which a radio signal arriving at a receiving antenna arrives by multiple paths due to reflections of the signal off of various surfaces in the environment. By traveling different distances to the receiver, the reflections arrive with different time delays and signal strengths. When multipath conditions are great enough, analog reception of FM radio broadcasts is affected in a variety of ways, including “stop-light fades,” “picket fencing,” and distortion of the received audio.

NRSC – National Radio Systems Committee, a technical standards setting body of the radio broadcasting industry, co-sponsored by the Consumer Electronics Association (CEA) and the National Association of Broadcasters (NAB).

Objective Testing – Using test equipment to directly measure the performance of a system under test. For example, the power output of a transmitter can be objectively measured using a wattmeter.

OEM – Original Equipment Manufacturer. Generally describes the “factory” radio installed in a car before purchase.

PAC – A flexible high-quality perceptual audio coding system originally developed by Lucent Technologies and later refined by iBiquity. The system can operate over a wide range of bit rates and is capable of supporting multichannel audio.

Perceptual Audio Coding – Also known as audio compression or audio bit rate reduction, this is the process of representing an audio signal with fewer bits while still preserving audio quality. The coding schemes are based on the perceptual characteristics of the human ear. Some examples of these coders are PAC, AAC, MPEG-2, and AC-3.

Protected Contour – A contour is a representation of the theoretical signal strength of a radio station that appears on a map as a closed polygon surrounding the station’s transmitter site. The FCC defines a particular signal strength contour, such as 60 dBuV/m for certain classes of station, as the Protected Contour. In allocating the facilities of other radio stations, the Protected Contour of an existing station may not be overlapped by certain interfering contours of the other stations. The Protected Contour coarsely represents the primary coverage area of a station, within which there is little likelihood that the signals of another station will cause interference with its reception.

RBDS – Radio Broadcast Data System, fully encapsulates the RDS system described below and adds additional features specific to North America such as Emergency Alert System (EAS) and Modified Mobile Broadcast Service (MMBS), a commercial nation-wide paging system.

RDS – Radio Data System, the RDS signal is a low bit rate data stream transmitted on the 57 kHz subcarrier of an FM radio signal. Radio listeners know RDS mostly through its ability to permit RDS radios to display call letters and search for stations based on their programming format. Special traffic announcements can be transmitted to RDS radios, as well as emergency alerts.

SDARS – Satellite Digital Audio Radio Service, describes satellite-delivered digital audio systems such as those from XM Radio and Sirius. The digital audio data rate in these systems is specified as being 64 kbps.

Subjective Testing – Using human subjects to judge the performance of a system. Subjective testing is especially useful when testing systems that include components such as perceptual audio coders. Traditional audio measurement techniques, such as signal-to-noise and distortion measurements, are often not compatible with way perceptual audio coders work and cannot characterize their performance in a manner that can be compared with other coders, or with traditional analog systems.

WQP – Weighted Quasi Peak,

NRSC Document Improvement Proposal

If in the review or use of this document a potential change appears needed for safety, health or technical reasons, please fill in the appropriate information below and email, mail or fax to:

National Radio Systems Committee
c/o Consumer Electronics Association
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FAX: 703-907-4190
Email: standards@ce.org

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