

*NRSC
REPORT*

NATIONAL RADIO SYSTEMS COMMITTEE

**NRSC-R204
Evaluation of the iBiquity Digital
Corporation IBOC System –
Part 2 – AM IBOC
April 26, 2002**

Part II - Appendices



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NRSC-R204

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NRSC-R204

FOREWORD

NRSC-R204, Evaluation of the iBiquity Digital Corporation IBOC System – Part 2 – AM IBOC, documents the NRSC's evaluation of the AM IBOC system which was subsequently selected by the FCC in October 2002 as the technology that will permit AM radio broadcasters to introduce digital operations. The DAB Subcommittee chairman at the time of adoption of NRSC-R204 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.



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D A B S u b c o m m i t t e e

**EVALUATION OF THE iBiquity DIGITAL
CORPORATION IBOC SYSTEM**

Part 2 – AM IBOC

Appendix A

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.



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D A B S u b c o m m i t t e e

**EVALUATION OF THE iBiquity DIGITAL
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Part 2 – AM IBOC

Appendix B

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IBOC LABORATORY TEST PROCEDURES – AM 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 loss of enhanced audio” and “point-of-blend” are 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 AM laboratory tests:

DESIGNATION	DESCRIPTION	LEVEL (MV/M)	COMMENTS
M	Moderate	5.0	Current FCC “city grade” coverage value
S	Strong	25.0	Previous FCC “city grade” coverage value
W	Weak	0.5	Extent of service

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. The detailed procedure for RF noise measurements will be supplied. See Appendix S of the EIA DAR Laboratory Tests Report, August 11, 1995.
8. Unless otherwise specified, IBOC transmitters will be used to generate undesired signals in co- and adjacent-channel interference tests.
9. Unless otherwise specified, analog audio (as opposed to IBOC digital audio) signal power measurements will be made using the weighted quasi-peak (“WQP,” CCIR weighting filter) measurement technique.
10. The host AM to digital power ratio used in the digital performance tests will also be used for the analog compatibility tests.
11. NRSC analog test receivers specified on pg. 12 will undergo the following characterization tests: [list TBD]
12. Modulation of non-IBOC interferers, and modulation of signals used for analog reference recordings, will conform to the NRSC standard AM mask (i.e. 10 kHz nominal audio bandwidth).
13. Analog modulation level shall be established using a 400 Hz tone and with the audio processor in bypass mode.

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<p align="center">IBOC LABORATORY TEST PROCEDURES – AM BAND CALIBRATION</p>					
Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		Note: 1. Pulsed USASI noise will be used as the modulation source material for all calibration tests.			
A Calibration	1 Power	1. IBOC analog and digital average power will be measured by first measuring the signal power with the analog signal only, then the digital carriers will be added and the signal power will be measured again.	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. Spectral occupancy will be measured using a spectrum analyzer with a peak hold of 10 minutes, video bandwidth greater than 10 kHz, RBW 300 Hz, and sweep span of 100 kHz (derived from 47 CFR §73.44).	M	Objective	Spectrum plot
	3 Point of loss of enhanced audio/blend (as needed)	1. Gaussian noise will be added to the signal in 0.20 dB steps until both the point of loss of enhanced audio and point of blend are detected (using mode signal), or block error equivalent to these points is observed.	M	Objective	Noise level, BLER at point of loss of enhanced audio, 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, audio SNR, and audio THD
	5 Monitor calibration (as needed)	1. The analog modulation monitors will be calibrated with 100% modulation by observing the resulting trapezoid pattern in the modulated envelope waveform, using an oscilloscope.	NA	Objective	Calibration results
	6 Test bed calibration (prior to test)	1. All of the critical components in the test bed, including the transmission path simulator, attenuators, combiners, filters, generators, and measuring instruments, will be certified by the testing laboratory prior to tests.	NA	Objective	Calibration results

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IBOC LABORATORY TEST PROCEDURES – AM BAND DIGITAL PERFORMANCE					
Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		Notes: 1. The audio will be restarted for each test.			
B Characterization of signal failure with AWGN	1 AWGN	1. The level of AWGN corresponding to system point of loss of enhanced audio will be established. 2. 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 2 dB below (i.e. before) the point of loss of enhanced audio. 4. 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. 5. The BLER will be recorded with the AWGN set at a level 2 dB below (i.e. before) the point of loss of enhanced audio, 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 loss of enhanced audio, point of blend identified)
				Subjective	Subjective impairment rating for each level of Cd/No for recordings made in steps 3 and 4

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<p align="center">IBOC LABORATORY TEST PROCEDURES – AM BAND</p> <p align="center">DIGITAL PERFORMANCE</p>					
Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		<p>Notes:</p> <ol style="list-style-type: none"> 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. Each test will last no more than 30 seconds. The audio will be restarted for each test. The analog reference recordings specified will be made with the IBOC digital sidebands removed from the desired signal and analog modulation conforming to the NRSC standard AM mask. 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. 			
C IBOC with special impairment	1 Impulse noise	<ol style="list-style-type: none"> 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. 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. For each measurement point, the mode signal status will be recorded. Steps 2 and 3 will be repeated using a random pulse repetition frequency (PRF) impulse noise source. Steps 2-4 will be repeated using a single lower first adjacent undesired signal. The D/U ratio will be set for +6 dB. Analog reference recordings will be made using NRSC analog test receivers #1 and #4 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

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<p align="center">IBOC LABORATORY TEST PROCEDURES – AM BAND</p> <p align="center">DIGITAL PERFORMANCE</p>						
Test Group	Test and Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded	
		<p>Notes:</p> <ol style="list-style-type: none"> All interferers are to be hybrid IBOC signals – refer to NRSC Audio Test List for mod. info. For tests D.2, D.3, and D.4, analog reference recordings will be made with all relevant permutations of upper/lower adjacent channel interference. The analog reference recordings specified in each step will be made with the IBOC digital sidebands removed from the desired and undesired signals and analog modulation conforming to the NRSC standard AM mask. 				
<p>D</p> <p>IBOC → IBOC</p>	<p>1</p> <p>Co-channel</p>	<ol style="list-style-type: none"> The co-channel D/U corr. to system point of loss of enhanced audio will be established. The co-channel D/U corresponding to system point of blend will be established. The desired impairment audio segments will be recorded with the co-chan. D/U set at a level 2 dB below (i.e. before) the point of loss of enhanced audio. 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. 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 loss of enhanced audio, then with the co-channel level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. Analog reference recordings will be made using NRSC analog test receivers #2 and #3 for each measurement point in steps 3 and 4. 	<p>M</p>	<p>Objective</p>	<p>Co-channel D/U, BLER, mode signal for each measurement point</p>	
				<p>Subjective</p>	<p>Subjective impairment rating for each D/U setting for IBOC digital and analog reference recordings made in steps 3, 4, and 6</p>	
	<p>2</p> <p>Single and dual 1st adjacent</p>		<ol style="list-style-type: none"> Using a lower 1st adjacent channel interferer, the D/U corresponding to system point of loss of enhanced audio will be established. Using a lower 1st adjacent channel interferer, the D/U corresponding to system point of blend will be established. 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 loss of enhanced audio. 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. 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 loss of enhanced audio, then with the 1st adj. chan. level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. Steps 1-5 will be repeated with the addition of an upper 1st adj. chan. interferer at 6 dB D/U. Analog reference recordings will be made using all 4 NRSC analog test receivers for each of the measurement points in steps 3, 4, and 6. 	<p>M</p>	<p>Objective</p>	<p>1st adj. channel D/U, BLER, mode signal status for each measurement point</p>
					<p>Subjective</p>	<p>Subjective impairment rating for each D/U setting for IBOC digital and analog reference recordings made in steps 3, 4, 6, and 7</p>

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<p align="center">IBOC LABORATORY TEST PROCEDURES – AM BAND DIGITAL PERFORMANCE</p>					
Test Group	Test and Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
D IBOC → IBOC	3 Single and dual 2nd adjacent, and simultaneous single 2nd and single 1st adjacent	<p>Notes: SEE NOTES ON PREVIOUS PAGE</p> <ol style="list-style-type: none"> Using a lower 2nd adjacent channel interferer, the D/U corresponding to system point of loss of enhanced audio will be established. Using a lower 2nd adjacent channel interferer, the D/U corresponding to system point of blend will be established. 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 loss of enhanced audio. 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. For each measurement point, the mode signal status will be recorded. The BLER will be recorded with the lower 2nd adj. chan D/U set at a level 2 dB below (i.e. before) the point of loss of enhanced audio, then with the 2nd adj. chan. level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. Steps 1-5 will be repeated with the addition of an upper 1st adj. chan. interferer fixed at 6 dB D/U. Steps 1-5 will be repeated with the addition of an upper 2nd adj. chan. interferer fixed at – 20 dB D/U. Analog reference recordings will be made using NRSC analog test receivers #3 and #4 (non-automobile receivers) for each of the measurement points (at which recordings were made) in steps 3, 4, 6, and 7. 	M	Objective	2nd adj. channel D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for each D/U setting for IBOC digital and analog reference recordings made in steps 3, 4, 6, 7, and 8
	4 Single 3rd adjacent	<ol style="list-style-type: none"> Using a lower 3rd adjacent channel interferer, the D/U corresponding to system point of loss of enhanced audio will be established. Using a lower 3rd adjacent channel interferer, the D/U corresponding to system point of blend will be established. The desired impairment audio segments will be recorded with the lower 3rd adj. chan. D/U set at a level 2 dB below (i.e. before) the point of loss of enhanced audio. The desired impairment audio segments will be recorded with the lower 3rd adj. chan. D/U set at a level 2 dB below (i.e. before) the point of blend. For each measurement point, the mode signal status will be recorded. The BLER will be recorded with the lower 3rd adj. chan D/U set at a level 2 dB below (i.e. before) the point of loss of enhanced audio, then with the 3rd adj. chan. level increased in 1 dB steps until 1 dB above (i.e. after) the point of blend. Analog reference recordings will be made using NRSC analog test receivers #3 and #4 (non-automobile receivers) for each measurement point in steps 3 and 4. 	M	Objective	3rd adj. channel D/U, BLER, mode signal status for each measurement point
				Subjective	Subjective impairment rating for each D/U setting for IBOC digital and analog reference recordings made in steps 3, 4, and 6

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IBOC LABORATORY TEST PROCEDURES – AM 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 (modulated in accordance with the NRSC standard AM mask), and the undesired signal XMTR will alternately be hybrid IBOC with the IBOC digital sidebands turned on, and non-IBOC (modulated in accordance with the NRSC standard AM mask). 2. The test will be conducted with no background RF noise. 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.			
E 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 400 Hz tone. 2. Using a lower 1st-adjacent channel hybrid 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 +30 dB, +15 dB, and 0 dB. 3. Step 2 will be repeated with the hybrid IBOC interferer replaced with a non-IBOC interferer (with 10 kHz nom. modulation). 4. Steps 2 and 3 will be repeated using an upper 1st-adjacent channel IBOC interferer.	M	Objective	Analog WQP S/N ratio at specified D/Us with hybrid IBOC interferer and non-IBOC interferer (main channel audio)
	2 Single 2nd adjacent	1. The desired signal will be modulated with 400 Hz tone. 2. Using a lower 2nd-adjacent channel hybrid IBOC interferer, with the IBOC digital sidebands turned on, the desired analog WQP S/N ratio will be measured for D/U settings of +30 dB, +15 dB, and 0 dB. 3. Step 2 will be repeated with the hybrid IBOC interferer replaced with a non-IBOC interferer (with 10 kHz nom. modulation). 4. Steps 2 and 3 will be repeated using an upper 2nd-adjacent channel IBOC interferer.			
	3 Single 3rd adjacent	1. The desired signal will be modulated with 400 Hz tone. 2. Using a lower 3rd-adjacent channel IBOC interferer, with the hybrid IBOC digital sidebands turned on, the desired analog WQP S/N ratio will be measured for D/U settings of +20 dB, +5 dB, and -10 dB. 3. Step 2 will be repeated with the hybrid IBOC interferer replaced with a non-IBOC interferer (with 10 kHz nom. modulation). 4. Steps 2 and 3 will be repeated using an upper 3rd-adjacent channel IBOC interferer.			

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IBOC LABORATORY TEST PROCEDURES – AM 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: SEE NOTES ON PREVIOUS PAGE			
E IBOC→ Analog (main channel audio) (interference to an analog receiver with no other impairments)	4 Single 1st adjacent	1. The desired signal will be modulated with the desired impairment audio selections. 2. Using a lower 1st-adjacent channel hybrid 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 +30 dB, +15 dB, and 0 dB. 3. Step 2 will be repeated with the hybrid IBOC interferer replaced with a non-IBOC interferer (with 10 kHz nom. modulation). 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 hybrid IBOC interferer and non-IBOC interferer (for worst performing interferer for each radio only – see note 4)
	5 Single 2nd adjacent	1. Same as test E.4, using 2nd adjacent instead of 1st adjacent channel interferers, at D/U settings of +30 dB, +15 dB, and 0 dB.			

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<p align="center">IBOC LABORATORY TEST PROCEDURES – AM BAND DIGITAL PERFORMANCE</p>					
Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		<p>Notes:</p> <ol style="list-style-type: none"> 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. 			
F IBOC acquisition	1 Acquisition with varying signal level	<ol style="list-style-type: none"> 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. 	M	Objective	Acquisition time at each noise level and audio recordings based upon laboratory observation (listening)

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<p align="center">IBOC LABORATORY TEST PROCEDURES – AM BAND DIGITAL QUALITY</p>					
Test Group	Test & Impairment	TEST DESCRIPTION	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
		<p>Note:</p> <ol style="list-style-type: none"> 1. Analog reference recordings will be obtained using an exciter which conforms to the NRSC standard AM mask (i.e. 10 kHz nominal audio bandwidth). 2. Audio processors will be used in both IBOC and analog signal paths (settings for analog and digital signal paths will vary based upon audio selection and may be different from one another). 			
G IBOC quality	1 Quality transmission test	<ol style="list-style-type: none"> 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. 4. An analog reference recording will be made using all four NRSC analog test receivers for each audio quality selection. 5. A recording of each selection will also be made through an FM signal chain using the home hi-fi NRSC analog test receiver (and appropriate audio processing). 	S	Objective	Mode signal status of system during recording of audio selections
				Subjective	Subjective rating for each audio quality selection recorded (using IBOC, all four analog receivers) as well as for FM recordings

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IBOC LABORATORY TEST PROCEDURES – AM BAND ANALOG COMPATIBILITY (Host)					
Test Group	Test & Impairment	TEST PROCEDURE	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
		Note: 1. The test will be conducted with no background RF noise.			
H IBOC → Host analog	1 IBOC to host analog	1. All 4 NRSC analog test receivers will be used for this test. 2. The host AM transmitter will be set for 100% modulation, modulated with a 400 Hz tone. 3. With the host IBOC digital sidebands turned on, the host analog WQP S/N ratio will be measured. 4. Step 3 will be repeated with the host IBOC digital sidebands turned off.	M	Objective	Host analog S/N ratio 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 AM transmitter will be set for 100% modulation, modulated with the desired impairment audio selections. 3. With the host IBOC digital sidebands turned on, audio recordings of the host analog signal will be made. 4. Step 3 will be repeated with the host IBOC digital sidebands turned off. 5. Using an AM carrier modulated according to the NRSC standard AM mask, audio recordings of the analog signal will be made.	M	Subjective	Subjective impairment rating of host analog audio with IBOC digital sidebands on and off, and using normal AM signal

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

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NRSC Document Improvement Proposal

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