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

NAB: 1771 N Street, N.W.
Washington, DC 20036
Tel: (202) 429-5356 Fax: (202) 775-4981

CEA: 1919 South Eads Street
Arlington, VA 22202
Tel: (703) 907-7660 Fax: (703) 907-8113

Co-sponsored by the Consumer Electronics Association and the National Association of Broadcasters
http://www.nrscstandards.org

NOTICE

NRSC Standards, Guidelines, Reports and other technical publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards, Guidelines, Reports and other technical publications shall not in any respect preclude any member or nonmember of the Consumer Electronics Association (CEA) or the National Association of Broadcasters (NAB) from manufacturing or selling products not conforming to such Standards, Guidelines, Reports and other technical publications, nor shall the existence of such Standards, Guidelines, Reports and other technical publications preclude their voluntary use by those other than CEA or NAB members, whether to be used either domestically or internationally.

Standards, Guidelines, Reports and other technical publications are adopted by the NRSC in accordance with the NRSC patent policy. By such action, CEA and NAB do not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Standard, Guideline, Report or other technical publication.

This Guideline does not purport to address all safety problems associated with its use or all applicable regulatory requirements. It is the responsibility of the user of this Guideline to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before its use.

Published by
CONSUMER ELECTRONICS ASSOCIATION
Technology & Standards Department
1919 S. Eads St.
Arlington, VA 22202

NATIONAL ASSOCIATION OF BROADCASTERS
Science and Technology Department
1771 N Street, NW
Washington, DC 20036

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.

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

N A T I O N A L R A D I O S Y S T E M S C O M M I T T E E

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

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.

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix B

Revision #6d (Final) February 6, 2002

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.

IBOC LABORATORY TEST PROCEDURES – AM BAND
CALIBRATION

Test Group	Test & Impairment	TEST DESCRIPTION Note: 1. Pulsed USASI noise will be used as the modulation source material for all calibration tests.	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 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

Revision #6d (Final) February 6, 2002

IBOC LABORATORY TEST PROCEDURES – AM BAND
DIGITAL PERFORMANCE

Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. The audio will be restarted for each test.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
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

Revision #6d (Final) February 6, 2002

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. 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 will be made with the IBOC digital sidebands removed from the desired signal and analog modulation conforming to the NRSC standard AM mask. 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.			
C IBOC with special impairment	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. 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

IBOC LABORATORY TEST PROCEDURES – AM BAND
DIGITAL PERFORMANCE

Test Group	Test and Impairment	TEST DESCRIPTION Notes: 1. All interferers are to be hybrid IBOC signals – refer to NRSC Audio Test List for mod. info. 2. 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. 3. 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.	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
D IBOC → IBOC	1 Co-channel	1. The co-channel D/U corr. to system point of loss of enhanced audio will be established. 2. The co-channel D/U corresponding to system point of blend will be established. 3. 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. 4. 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. 5. 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. 6. Analog reference recordings will be made using NRSC analog test receivers #2 and #3 for each measurement point in steps 3 and 4.	M	Objective	Co-channel D/U, BLER, mode signal 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
	2 Single and dual 1st adjacent	1. Using a lower 1st adjacent channel interferer, the D/U corresponding to system point of loss of enhanced audio will be established. 2. Using a lower 1st adjacent channel interferer, the D/U corresponding to system point of blend will be established. 3. 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. 4. 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. 5. 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. 6. Steps 1-5 will be repeated with the addition of an upper 1st adj. chan. interferer at 6 dB D/U. 7. 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.	M	Objective	1st 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, and 7

(continued on next page)

(continued from last page)

IBOC LABORATORY TEST PROCEDURES – AM BAND
DIGITAL PERFORMANCE

Test Group	Test and Impairment	TEST DESCRIPTION Notes: SEE NOTES ON PREVIOUS PAGE	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	1. Using a lower 2nd adjacent channel interferer, the D/U corresponding to system point of loss of enhanced audio will be established. 2. Using a lower 2nd adjacent channel interferer, the D/U corresponding to system point of blend will be established. 3. 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. 4. 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. 5. 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. 6. Steps 1-5 will be repeated with the addition of an upper 1st adj. chan. interferer fixed at 6 dB D/U. 7. Steps 1-5 will be repeated with the addition of an upper 2nd adj. chan. interferer fixed at –20 dB D/U. 8. 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	1. Using a lower 3rd adjacent channel interferer, the D/U corresponding to system point of loss of enhanced audio will be established. 2. Using a lower 3rd adjacent channel interferer, the D/U corresponding to system point of blend will be established. 3. 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. 4. 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. 5. 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. 6. 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

IBOC LABORATORY TEST PROCEDURES – AM 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. 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.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
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.			

(continued on next page)

Revision #6d (Final) February 6, 2002

(continued from last page)

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

Test Group	Test & Impairment	DESCRIPTION Notes: SEE NOTES ON PREVIOUS PAGE	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
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.			

IBOC LABORATORY TEST PROCEDURES – AM 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
F 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.	M	Objective	Acquisition time at each noise level and audio recordings based upon laboratory observation (listening)

Revision #6d (Final) February 6, 2002

IBOC LABORATORY TEST PROCEDURES – AM BAND DIGITAL QUALITY					
Test Group	Test & Impairment	TEST DESCRIPTION Note: 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).	Desired Signal Level	Type of Evaluation	Test Results & Data to be Recorded
G 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. 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

IBOC LABORATORY TEST PROCEDURES – AM BAND ANALOG COMPATIBILITY (Host)					
Test Group	Test & Impairment	TEST PROCEDURE Note: 1. The test will be conducted with no background RF noise.	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
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

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

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix C

Revision #6c (Final) April 12, 2001

IBOC FIELD TEST PROCEDURES – AM 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 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 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 host AM to digital power ratio used in the digital performance tests will also be used for the analog compatibility tests.
7. NRSC analog test receivers specified on pg. 5 will undergo the following characterization tests: [list TBD]
8. Test record will indicate direction of travel on all routes.
9. All radial routes will be driven to the IBOC point of failure (POF), that is, until the IBOC signal is fully blended to analog.
10. All radial routes will be run at day (between 2 hrs. after sunrise and 2 hrs. before sunset) and at night (between 2 hrs. after sunset and 2 hrs. before sunrise).
11. "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].
12. 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 – AM 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 with a peak hold of 10 minutes, video bandwidth greater than 10 kHz, RBW 300 Hz, and sweep span of 100 kHz in accordance with CFR 47§73.44. 3. Two plots of the spectrum will be made: one with and one 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 – AM 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 no grounded conductive structures b) low interference and grounded conductive structures c) single first adjacent interferer d) single second adjacent interferer e) high-tension power lines parallel to radial; ideally, power lines will pass within 1-2 miles of transmitter site f) power lines (not high-tension) overhead in urban areas 2. Radials will start within 2.0 miles of the transmitter (where possible) and extend beyond the edge of digital coverage. 3. Audio recordings 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 20 dB below the digital signal. 2. The undesired analog second adjacent D/U should not exceed a D/U of 0 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. 1st-adjacent interferer tests will be conducted in an area where the interfering signal is not greater than 15 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. 2nd-adjacent interferer tests will be conducted in an area where the interfering signal is not greater than 0 dB below the desired signal.	Objective	Mode signal, various RF signal levels [see example plot]
			Subjective	Analog recordings (to be subjectively evaluated)

IBOC FIELD TEST PROCEDURES – AM BAND
ANALOG COMPATIBILITY

Test Group	Test & Impairment	TEST DESCRIPTION Notes: 1. Host compatibility tests (C.1) will be conducted at stations TBD. 2. 1st-adjacent compatibility tests (C.2) will be conducted at stations TBD.	Type of Evaluation	Test Results Data to be Recorded
C Compatibility	1 Host compatibility	1. Fixed compatibility tests will be conducted using all NRSC Test Receivers. 2. The IBOC digital sidebands 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 1st-adjacent compatibility	1. Fixed compatibility tests will be conducted using all test receivers. 2. Modulation of desired analog signal will conform to the NRSC standard AM mask (i.e. 10 kHz nominal audio bandwidth). 3. Test will be conducted at a point where the first adjacent signal is not greater than 15 dB below the desired analog signal. 3. Recordings will be made at 3 locations. At each location, the IBOC digital sidebands should be switched on for 30 seconds and off for 30 seconds. This should be repeated twice. If practical, the bandwidth of the analog portion of the interfering signal should be increase to ±10 kHz during the 30 second intervals when the digital sidebands are turned off.	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	Aftermarket	New
3	Sony Model: CFD-S32	Table Combo	New
4	Technics Model: SA-EX140	Home HiFi	New

Revision #6c (Final) April 12, 2001

NRSC IBOC DAB Evaluation - AM Field Test Stations

APPENDIX A

Table 1 – Test Condition Matrix (see notes below)

No.	Call Sign	Freq. (kHz)	Format	Location	Test Condition(s) (a)	(b)	(c)	(d)	(e)	(f)				Comments
1	WD2XAM	1660	Test	Cincinnati, OH	✔	✔				✔				
2	WWJ	950	News/talk	Detroit, MI	✔	✔	✔	✔		✔				
3	WTOP	1500	News/talk	Washington, DC	✔	✔	✔	✔	✔	✔				
4	KABL	960	Oldies ("MOL")	Oakland, CA	✔	✔	✔			✔				
				Number of stations with given test condition ➜	4	4	3	2	1	4				

Notes for Table 1:

1. Proponent will run at least 4 radials for each test station; radials will be run at day (between 2 hrs. after sunrise and 2 hrs. before sunset) and at night (between 2 hrs. after sunset and 2 hrs. before sunrise).
2. Proponent will supply maps of the test radials (with blend information) plotted against predicted analog coverage and strip charts for each station
3. Select radials will be extracted for further analysis and subjective evaluation (selection to be done by proponent in conjunction with independent testing facility and NRSC observer)
4. Test conditions (see Field Test Procedure, Test B Notes):
   a) low interference and no grounded conductive structures
   b) low interference and grounded conductive structures
   c) single first adjacent interferer
   d) single second adjacent interferer
   e) high-tension power lines parallel to radial; ideally, power lines will pass within 1-2 miles of transmitter site
   f) power lines (not high-tension) overhead in urban areas

Table 2. Station List for IBOC-to-analog Compatibility Testing

Compatibility Type	Station of Interest Format Location	Freq. (kHz) Channel	Interfering Station Format Location	Freq. (kHz) Channel	Interferer location	Station Spacing
Host	KABL	960				
Host	WTOP	1500				
First Adjacent	WTOP	1500	WNNN	1510		
First Adjacent	WTOP	1500	WWSM	1510		
First Adjacent	KABL	960	KANM	970		
Second Adjacent	WTOP	1500	WTRI	1520		
Second Adjacent	WTOP	1500	WPWC	1480		

Table 3. Station List for IBOC Performance Testing

Test Station Format Location	Freq. (kHz) Channel	Propagation & Testing Features	Significant Interferers†	Drive Routes
WD2XAM Test station Cincinnati, OH	1660	10.0 kW, 1 tower Daytime only (experimental)		
WWJ News/talk Detroit, MI	950	6 kW (day), 6 kW (night) DA2 5 towers		
WTOP News/talk Washington, DC	1500	50 kW (day/night) DA2 3 towers	Co-Channel Interference	
KABL Oldies ("MOL") Oakland, CA	960	5 kW (day/night) DA1 3 towers	1st Adjacent Interference	

†Due to limitations on station coverage, it is likely that interference will not be tested except during nighttime testing

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix D

Analog Receiver Characterization

Overview

In addition to the four AM receiver models used in the AM IBOC testing, five other AM receiver models were characterized. The nine radios tested included three OEM automobile radios, two aftermarket automobile radios, two portable radios, and two home hi fi receivers. The receivers, and their respective ages, are listed in Table D.1. The receivers that were not actually used in the AM IBOC testing were characterized to confirm that the receivers that were used in the testing adequately represented the performance of AM receivers in general.

The receiver characterization tests were performed by Robert McCutcheon, a consultant in North Olmsted, Ohio.

Table D.1: AM Receivers Characterized

	Delphi Auto[1]	Pioneer Auto[1]	Technics HiFi[1]	Sony Portable[1]	Visteon Auto	Koss Auto	Panasonic Portable	Ford Auto	Pioneer HiFi
Age	New	New	New	New	2 yrs.	2 yrs.	7 yrs.	7 yrs.	7 yrs.

[1]Receivers selected for the AM compatibility tests.

The characterization test data for the nine receivers is summarized in Table D.2, Table D.3, Table D.4 and Table D.5. It shows that the frequency response and selectivity of the four receivers used in the AM IBOC compatibility testing were representative of the frequency response and selectivity of the two-year-old and seven-year-old receivers that were also tested.

Characterization Test Description

The tone control of each radio under test was set to the flat frequency response position. The loudness control was set to the off position, or the volume control set for no loudness compensation. The stereo balance control was set at mid position. The volume control was set to produce a standard output (2.0 volts, 4 ohms) on the automobile radios. The measurements were made at the speaker output for the auto radios, the line output for the HiFi, and the headphone output for the portable. The left channel was used for the measurements. The noise and selectivity measurements were RMS and weighted quasi peak (WQP). Each automobile radio was characterized using a 50 ohm load to match the signal generator to the receiver RF input. Unless otherwise indicated, the desired RF level was -50 dBm. The RF frequency used for the desired signal under test was 1,000.0 kHz. The first adjacent signals were 1010.0 kHz and 990.0 kHz. Distortion was measured at 1 kHz.

Test Results

Table D.2 shows distortion at standard output level for each receiver. Table D.3 shows the WQP signal-to-noise ratio for each receiver at two RF input levels 80 dBm and -60 dBm. Table D.4 shows the audio frequency response at 100 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz for each receiver. (The reference audio frequency used for the desired signal in the other characterization tests was a 1 kHz tone.)

Table D.5 shows the upper and lower first adjacent selectivity at fixed D/U ratios of -10 dB, -20 dB, and -30 dB. The undesired modulation was 400 Hz at 80%.

Table D.2: Distortion at Standard Output Level

RF input level: -50 dBm Modulation: 1 kHz, 80%									
	Delphi Auto	Pioneer Auto	Technics HiFi	Sony Portable	Visteon Auto	Koss Auto	Panasonic Portable	Ford Auto	Pioneer HiFi
THD	0.32%	0.9 %	1.4%	0.56%	1.5%	0.6%	0.8%	0.7%	0.5%
Output Level (V_{rms})	1.85	1.68	0.32	0.95	1.7	0.5	1.0	1.85	0.49

Table D.3: WQP S/N at -80 dBm and -60 dBm RF Input Levels

	Delphi Auto	Pioneer Auto	Technics HiFi	Sony Portable	Visteon Auto	Koss Auto	Panasonic Portable	Ford Auto	Pioneer HiFi
S/N (dB WQP) at -80 dBm	24	23	30	22	17	11	2	17	28
S/N (dB WQP) at -60 dBm	42	44	48	41	36	30	27	38	47

Table D.4: Audio Frequency Response at -50 dBm RF input

	Delphi Auto (dB)	Pioneer Auto (dB)	Technics HiFi (dB)	Sony Portable (dB)	Visteon Auto (dB)	Koss Auto (dB)	Panasonic Portable (dB)	Ford Auto (dB)	Pioneer HiFi (dB)
100 Hz	-1	-8	-7	-1	-1	-3	-8	0	-7
250 Hz	1	-1	-1	1	1	-1	-2	1	0
500 Hz	1	1	1	1	1	0	1	1	1
1 kHz	0	0	0	0	0	0	0	0	0
2 kHz	-4.0	-4.0	-4	-3.5	-3	-1	-4	-2	-5
4 kHz	-18	-15	-17	-11	-13	-9	-14	-12	-18
8 kHz	-66	-67	-50	-27	-46	-37	-32	-40	-41

Table D.5: First Adjacent Selectivity

Desired: -50 dBm Undesired: AM, 400Hz, 80% S/N is WQP									
	Delphi Auto S/N (dB)	Pioneer Auto S/N (dB)	Technics HiFi S/N (dB)	Sony Portable S/N (dB)	Visteon Auto S/N (dB)	Koss Auto S/N (dB)	Panasonic Portable S/N (dB)	Ford Auto S/N (dB)	Pioneer HiFi S/N (dB)
-10 dB D/U Upper	53	50	15	5	44	38	23	45	24
-10 dB D/U Lower	53	50	14	14	44	17	16	42	21
-20 dB D/U Upper	51	40	5	2	37	25	11	42	7
-20 dB D/U Lower	51	39	5	6	38	7	7	35	7
-30 dB D/U Upper	45	31	5	2	28	15	6	33	3
-30 dB D/U Lower	44	31	4	3	30	2	7	25	7

As noted above, the receivers that were used in the AM IBOC testing were the Delphi OEM automobile receiver, the Pioneer aftermarket automobile receiver, the Sony portable receiver, and the Technics home hi fi receiver. To enable the testing process to move as quickly as possible, and to ensure that backups were available if one of the analog receivers were to fail for some reason, multiple units of the same model were used in the testing. To confirm that there was no significant difference in the performance of a particular receiver model across different serial numbers, multiple units of the same model were characterized. The multiple receivers tested, and the laboratory in which they were used, are listed in Table D.6. Additional units of the same model numbers as those that were characterized were also used in the testing process. Although these additional units were not characterized, it is expected that their performance is similar to the units that were characterized.

The test data in Table D.7, Table D.8, Table D.9 and Table D.10 show that for the three different receiver models where multiple units were characterized, the characteristics of the multiple units were similar. Each receiver was characterized for distortion, audio signal-to-noise at a varying RF input level, audio frequency response, and selectivity.

Table D.6: AM Receivers Used in AM IBOC Tests

Make	Model	Type	Serial No:	Laboratory where used
Delphi	09394139	Auto	89DDSTM103490265	ATTC
Delphi	09394139	Auto	89DDSTM103490268	Xetron
Pioneer	KEH-1900	Auto	UHHIO86599UC	ATTC
Pioneer	KEH-1900	Auto	UHHIO86960UC	Spare
Technics	SA-EX110	Hi-fi	GY8JA84758	ATTC
Technics	SA-EX110	Hi-fi	GY8JA38798	Xetron
Sony	CFD-S22	Portable	0005122	ATTC

Table D.7: Distortion at Standard Output Level

RF input level: -50 dBm Modulation: 1 kHz, 80 %				
Make	Serial No:	THD (left channel)	RMS Volts	Laboratory where used
Delphi	89DDSTM103490265	0.39 %	1.918	ATTC
Delphi	89DDSTM103490268	0.32 %	1.850	Xetron
Pioneer	UHHIO86599UC	0.23 %	1.935	ATTC
Pioneer	UHHIO86960UC	0.95 %	1.680	Spare
Technics	GY8JA84758	1.40 %	0.320	ATTC
Technics	GY8JA38798	1.18 %	0.317	Xetron
Sony	0005122	0.56 %	0.950	ATTC

Table D.8: WQP S/N at -80 dBm and -60 dBm RF Input Levels

Make	Serial No:	S/N (dB, WQP/RMS) at -60 dBm RF input	S/N (dB, WQP/RMS) at -80 dBm RF input	Laboratory where used
Delphi	89DDSTM103490265	53/46	34/27	ATTC
Delphi	89DDSTM103490268	50/43	30/24	Xetron
Pioneer	UHHIO86599UC	51/44	31/24	ATTC
Pioneer	UHHIO86960UC	52/44	32/23	Spare
Technics	GY8JA84758	58/48	40/30	ATTC
Technics	GY8JA38798	54/45	35/26	Xetron
Sony	0005122	49/41	30/22	ATTC

Table D.9: Audio Frequency Response at -50 dBm RF Input

Make	Serial No:	250 Hz (dB)	500 Hz (dB)	1 kHz (dB)	2 kHz (dB)	4 kHz (dB)	8 kHz (dB)	Laboratory
Delphi	89DDSTM103490265	0.75	1	0	-4	-19	-65	ATTC
Delphi	89DDSTM103490268	0.75	1.25	0	-4	-18	-66	Xetron
Pioneer	UHHIO86599UC	-0.5	1	0	-4	-15	-63	ATTC
Pioneer	UHHIO86960UC	-1.0	0.75	0	-4	-15	-67	Spare
Technics	GY8JA84758	-1.07	0.65	0	-4	-17	-50	ATTC
Technics	GY8JA38798	-1.0	0.75	0	-3	-17	-52	Xetron
Sony	0005122	0.75	1.0	0	-4	-11	-27	ATTC

Table D.10: First Adjacent Selectivity

Desired: -50 dBm 1,000 kHz
Undesired: AM, Upper first adjacent (1,010 kHz), 400 Hz modulation at 80%
Data points are dB S/N (WQP)

Make	Serial No:	D/U -10 dB		D/U -20 dB		D/U -30 dB		Laboratory
		Upper	Lower	Upper	Lower	Upper	Lower	
Delphi	89DDSTM103490265	53	53	53	53	52	51	ATTC
Delphi	89DDSTM103490268	53	53	51	51	45	44	Xetron
Pioneer	UHHIO86599UC	53	53	42	44	35	38	ATTC
Pioneer	UHHIO86960UC	50	50	40	39	31	31	Spare
Technics	GY8JA84758	15	14	5	5	5	4	ATTC
Technics	GY8JA38798	17	13	6	4	3	4	Xetron
Sony	0005122	5	14	2	6	2	3	ATTC

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix E

NRSC DAB SUBCOMMITTEE – IBOC EVALUATION CRITERIA DESCRIPTIONS

5/29/01

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.

[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

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix F

AM IBOC System Evaluation Matrix – Field Tests – rev. 1/02

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	BEHAVIOR AS SIGNAL DEGRADES	STEREO SEP	HOST SIGNAL IMPACT	NON-HOST SIGNAL IMPACT
B	**Characterization of signal failure with AWGN**									
1)	Linear channel, no interferers		✔	✔		✔	✔	✔		
C	**IBOC with special impairment**									
1)	Impulse noise		✔	✔		✔	✔	✔		
D	**IBOC ➜ IBOC digital performance**									
1)	Co-channel									
2)	Single and dual 1st adjacent									
3)	Single and dual 2nd adjacent, and simultaneous single 2nd and single 1st adjacent		✔	✔		✔	✔	✔		
4)	Single 3rd adjacent									
E	**IBOC ➜ Analog (main channel audio)**									
1), 4)	Single 1st adjacent									
2), 5)	Single 2nd adjacent									✔
3)	Single 3rd adjacent									
F	**IBOC acquisition**									
1)	Acquisition with varying signal level				✔					
G	**IBOC quality**									
1)	Quality transmission test	✔								
H	**IBOC ➜ Host analog**									
1), 2)	Main channel audio performance versus presence or absence of IBOC digital signal energy								✔	

AM IBOC System Evaluation Matrix – Field Tests – rev. 1/02

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**	**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								✔	
2)	1st adjacent compatibility									✔

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix G

iBiquity/ATTC/Xetron Test Data Report
Table of Contents

The iBiquity/ATTC/Xetron Test Data Report was submitted to the NRSC electronically, in 17 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).

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix H

Additional AM 1st Adjacent Compatibility Analysis and Tests

Undesired Modulation Model

The undesired signal for the 1st adjacent analog-to-analog objective reference tests conducted at Xetron used an analog AM NRSC pre-emphasized exciter, modulated with 10 kHz LP filtered processed pink noise. For the laboratory subjective recordings the undesired signal path was the same as the objective with the undesired channel modulated with the processed "Shania" audio cut. The modulation of the undesired channel for both the objective and subjective tests was in accordance with the NRSC test procedures. Table 1 shows the S/N performance of the two test groups with widely different undesired modulating signals. Test group #1 shows the 0 dB D/U Xetron test results using a pre-emphasized pink noise 10 kHz LP filtered signal for the undesired modulation. The S/N ranged from 14dB to 16dB for the four receivers. Test group #2 shows the results for the characterization tests that used a 400 Hz tone for the undesired modulation. The S/N for the two narrow bandwidth automobile radios measured 53 dB, the portable 5 dB, and hi fi 17 dB. It is clear that the selectivity of the radios has little to do with performance when the 1st adjacent undesired signal is modulated with wideband noise, and selectivity has a definite affect when the undesired modulation is narrow band.

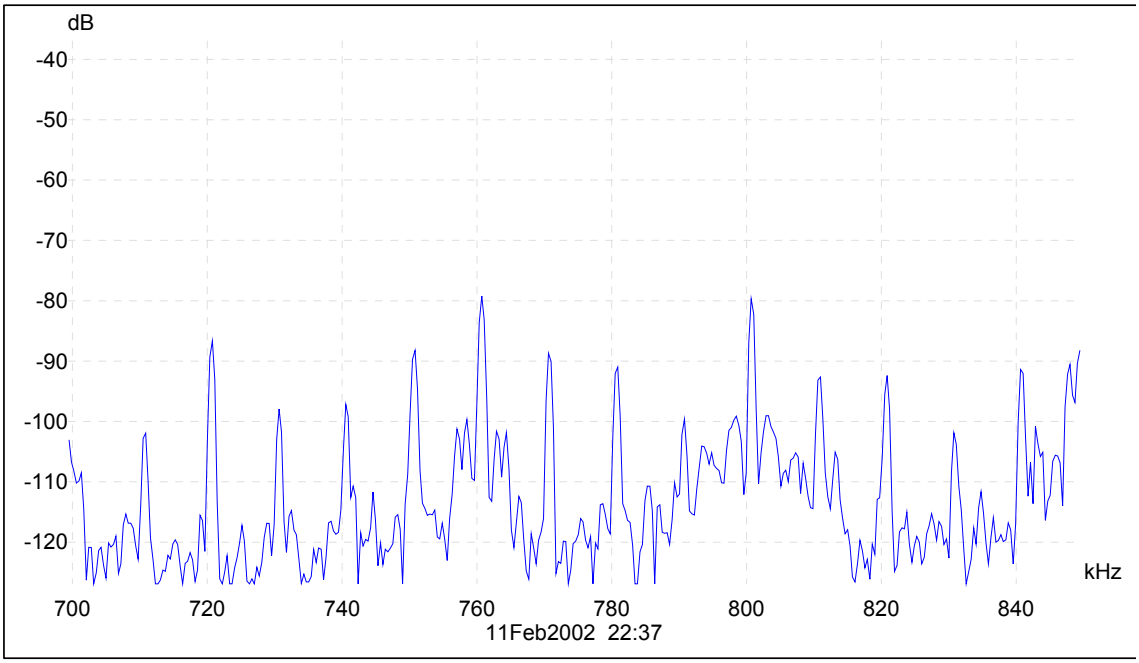
Table 1: 1st Adjacent Analog-to-Analog Interference as a Function of Undesired Modulation – Laboratory Results

Illustrates S/N difference with modulating bandwidth WQP S/N		
	Test Group #1 Xetron D/U = 0 dB Undesired modulation 10 kHz Noise (S/N)	Test Group #2 RMc D/U = -10 dB Undesired modulation 400 Hz Tone (S/N)
Delphi	15 dB	53 dB
Pioneer	14 dB	53 dB
Sony	16 dB	5 dB
Technics	15 dB	17 dB
Test group #1 is the result of compatibility tests conducted at Xetron for the NRSC. The undesired modulation was 10 kHz low-pass filtered, processed, and pre-emphasized pink noise. Test group #2 is the result of receiver characterization tests performed at the McCutcheon Laboratory for iBiquity. The undesired modulation is 400 Hz.		

The objective of the compatibility test program is to measure differences found with the introduction of the digital signal. The undesired modulation models used for the objective and subjective tests were based on fully processed wideband music, a program format that does not fit the majority of contemporary nighttime AM broadcast stations. Assuming that the 10 kHz LP filtered audio is representative of contemporary music interference, the objective and subjective test data in the iBiquity report is representative of the A to A interference from analog stations with a music format. To make the laboratory tests represent real world interference, the test should have been conducted with talk and music interferers.

Supplemental off-air Listening Tests (First adjacent off-air quality)

Because of the limitations of the laboratory undesired analog model and the limitations of the field tests, first adjacent listening tests were conducted at the McCutcheon laboratory in North Olmsted, Ohio, a western suburb of Cleveland. The test objective was to assess the quality of AM reception with 1st adjacent analog interference. The spectrum analyzer plot in Figure 1 shows the relative levels of four first adjacent stations: WSB, WJR, WABC, and WBBM spaced at 10 kHz intervals. The test was conducted around 10 PM EST on February 11, 2002. The receiver used for this evaluation test was a seven-year-old Ford auto radio Model F3FX-19B165-DA connected to a HiFi sound system used for evaluating AM audio quality. The receiving antenna was a short probe mounted above the structure. Reference audio was from a strong local 50 kW talk station (WTAM, 1100 kHz). All four stations broadcast talk formats. The WJR signal was 10 dB (760 kHz) stronger than WSB (750 kHz), WSB received a slight increase in noise. With WABC (770 kHz) 10 dB below WJR (760 kHz) and WBBM (780 kHz) 3 dB weaker than WABC, WABC received with slight adjacent channel interference. The listening tests were conducted by Mr. Robert McCutcheon and were not as sophisticated as those conducted by iBiquity at Dynastat. The off air monitoring shows that good AM audio is being received in the presence of 0 dB D/U 1st adjacent signals.



Freq.	Call	Location	M/S	Audio
750 kHz	WSB	Atlanta	Mono	Clear
760 kHz	WJR	Detroit	Stereo	Clear
770 kHz	WABC	New York	Mono	Minor Interference
780 kHz	WBBM	Chicago	Mono	Clear

Radio: Ford Auto F3FX-19B165-DA 1994

Figure 1: Spectrum Analyzer Plot

Extended Laboratory Tests

The laboratory compatibility tests conducted by iBiquity for the NRSC used only three D/U ratios, 0 dB, 15 dB, and 30 dB. An additional objective compatibility test conducted by Xetron is reported in the Clark engineering study done for iBiquity. The interference for these tests was advanced in 3 dB steps for 23 levels for both upper and lower 1st adjacent and extended from -24 dB to +45 dB D/U. Two (Delphi auto and Sony portable) of the four NRSC radios were used for this test. The test results show that with the interference reduced 9 dB (D/U 9 dB), the WQP S/N for both receivers improved by 9 dB. At +15 dB D/U all four receivers are in the 28 dB WQP S/N range (NRSC tests).

Conclusions

Using the Delphi receiver's D to A extended test data from the Clark report and the off air D/U ratios measured in the Cleveland area, the S/N for each station can be predicted. Using this data the following S/N predictions are made. If WJR went on the air with digital, WSB and WABC signal to noise ratio at this Ohio site would be 5 dB. If WABC went on the air with digital, WBBM S/N would be 10.5 dB.

2500 Wilson Boulevard
Arlington, VA 22201-3834
(703) 907-7660
FAX (703) 907-7601

NATIONAL RADIO SYSTEMS COMMITTEE

1771 N Street, NW
Washington, DC 20036-2800
(202) 429-5346
FAX (202) 775-4981

DAB Subcommittee

EVALUATION OF THE iBiquity DIGITAL CORPORATION IBOC SYSTEM

Part 2 – AM IBOC

Appendix I

Glossary

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.

Aftermarket receiver – A radio designed for purchase and installation some time after purchasing an automobile.

All-digital IBOC – The "final" mode of the iBiquity AM IBOC system that increases data capacity by increasing signal power and adjusting the bandwidth of the digital sidebands to minimize adjacent channel interference. All-digital AM IBOC uses four frequency partitions and no analog carrier. In this mode, the digital audio data rate can range from 40 kbps to 60 kbps, and the corresponding ancillary data rate will remain at 0.4 kbps.

ATTC – The Advance Television Technology Center, the primary 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 AM IBOC system tests, AWGN at radio frequencies was utilized in the laboratory tests to simulate the background noise present in the AM spectrum, which affects the quality of radio reception.

Blend to Analog – The point at which the BLER of an AM IBOC receiver falls below some predefined threshold and the digital audio is faded out while the analog audio is simultaneously 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 erroneous 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 context of this report, compatibility testing has been performed to determine the extent to which the addition of an AM IBOC signal will impact current analog performance.

DAB – Digital Audio Broadcasting.

D/U – Ratio of Desired to Undesired signals.

EWG – Evaluation Working Group of the NRSC DAB Subcommittee.

Hybrid IBOC – The initial mode of the iBiquity AM IBOC system that adds digital audio capacity to an AM signal by inserting digital sidebands in the spectrum above, below and

within the analog AM signal. The digital audio data rate can range from 36 kbps to 56 kbps, and the corresponding ancillary data rate will be 0.4 kbps in both cases.

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, such as in the area where the first reflection from the ionosphere arrives back at Earth and meets the station's groundwave signal, analog reception of AM radio broadcasts can become distorted.

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.

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.

RMS – Root Mean Square, the root mean square value of a periodic function, like a sine wave used for audio measurements, is the square root of the average of the square of the value of the function taken throughout one period.

RSS – Root Sum Square, a method for combining the power of multiple signals by taking the square root of the sum of the squares of all of the signals.

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, refers to a fast attack, slow-decay detector circuit that approximately responds to signal peaks, and that has varying attenuation as a function of frequency so as to produce a measurement that approximates the human hearing system.

Xetron – Xetron Corporation, a test contractor employed for laboratory and field testing of the AM IBOC system.

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
Technology & Standards Department
1919 S. Eads St.
Arlington, VA 22202
FAX: 703-907-4190
Email: standards@ce.org

DOCUMENT NO.	DOCUMENT TITLE:
SUBMITTER'S NAME: COMPANY:	TEL: FAX: EMAIL:
ADDRESS:	
URGENCY OF CHANGE: _____ Immediate _____ At next revision	
PROBLEM AREA (ATTACH ADDITIONAL SHEETS IF NECESSARY): a. Clause Number and/or Drawing: b. Recommended Changes: c. Reason/Rationale for Recommendation:	
ADDITIONAL REMARKS:	
SIGNATURE:	DATE:

FOR NRSC USE ONLY

Date forwarded to NAB S&T: _____
Responsible Committee: _____
Co-chairmen: _____
Date forwarded to co-chairmen: _____


CEA
Consumer Electronics Association


NAB
NATIONAL ASSOCIATION OF BROADCASTERS