

*NRSC
REPORT*

NATIONAL RADIO SYSTEMS COMMITTEE

**NRSC-R206
Evaluation of iBiquity AM and FM
IBOC "Gen 3" hardware
June 30, 2004**



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>

NRSC-R206

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

©2008 CEA & NAB. All rights reserved.

This document is available free of charge via the NRSC website at www.nrscstandards.org. Reproduction or further distribution of this document, in whole or in part, requires prior permission of CEA or NAB.

NRSC-R206

FOREWORD

NRSC-R206, Evaluation of iBiquity AM and FM IBOC “Gen 3” hardware, documents the DAB Subcommittee Evaluation Working Group’s review of test results submitted to the NRSC by iBiquity Digital Corporation and Sheffield Audio Consulting pertaining to the performance of iBiquity’s third generation FM IBOC digital radio system hardware. The DAB Subcommittee chairman at the time of adoption of NRSC-R206 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.

NATIONAL RADIO SYSTEMS COMMITTEE

June 30, 2004

MEMORANDUM

TO: DAB Subcommittee, Milford Smith, Chairman
FROM: Evaluation Working Group, H. Donald Messer, Chairman
SUBJECT: Evaluation of iBiquity AM and FM IBOC "Gen 3" hardware

The purpose of this memo is to report on the Evaluation Working Group's (EWG's) evaluation of test results recently submitted to the NRSC by iBiquity Digital Corporation and Sheffield Audio Consulting pertaining to the performance of iBiquity's third generation ("Gen 3") AM and FM in-band/on-channel (IBOC) digital radio system hardware. These tests were conducted in accordance with procedures approved by the Test Procedures Working Group on 11/14/03 (Appendices A and B to this memo, for AM and FM respectively); the test results are contained in the documents listed in Table 1.¹

Table 1. FM IBOC Gen 3 Test Data Report Documents

DATE	TITLE	AUTHOR	# OF PAGES	COMMENTS
9/25/03 (revised 11/10/03)	iBiquity Test Bed Characterization Observer Report	T. Keller	39	5 page report with 32 figures, 1 attachment
2/25/04	Subjective test results for FM IBOC DAB Generation 3 Hardware – Unimpaired and impaired test conditions	Sheffield Audio Consulting	15	9 page main report with 4 appendices
2/26/04	Digital Audio Broadcasting – Digital Performance Regression Tests of the iBiquity Generation 3 Digital HD Radio System in the AM & FM Bands – Subjective Audio Evaluation Sample Preparation Procedure	iBiquity Digital Corp.	51	7 page main report with 3 appendices
3/29/04 (revised 4/12/04)	Subjective test results for AM IBOC DAB Generation 3 Hardware – Unimpaired and impaired test conditions	Sheffield Audio Consulting	14	9 page main report with 4 appendices
4/14/04	Letter from A. Shuldiner to D. Wilson re: NRSC Gen 3 Audio Tests	iBiquity Digital Corp.	4 4	Objective test data from Gen 3 tests (AM and FM IBOC), and statement regarding equivalence of Gen 1 and Gen 3 hardware

¹ One part of the AM IBOC subjective evaluation specified in the test procedures memo, specifically, the inclusion of AM IBOC Gen 1 impaired audio cuts in the impaired portion of the experiment, was omitted due to an oversight. Despite this omission the EWG was able to establish, based on the submitted data, that the AM IBOC Gen 3 and Gen 1 hardware performed similarly.

This evaluation effort was conducted for two reasons: i) to determine the unimpaired (i.e., no interfering signals and no multipath or other forms of signal impairment) audio quality of iBiquity’s AM and FM IBOC Gen 3 systems which utilize “HDC” audio coding, and ii) to confirm that the Gen 3 hardware performs similarly to the previous (“Gen 1”) version of the systems evaluated by the NRSC in 2001 and 2002.² When assessing unimpaired audio quality, the EWG has relied upon performance goals established during the Gen 1 evaluation used to determine if the iBiquity HD Radio system represents a “significant improvement over existing analog services,” as directed by the Subcommittee’s Goals and Objectives statement.³ These performance goals (as they apply to audio quality) are excerpted in Table 2 and Table 3 below.

Table 2. Fidelity Performance Goals – FM IBOC⁴

CATEGORY	PERFORMANCE GOALS
Frequency response & distortion	Frequency response & distortion fidelity should be comparable to or better than the best FM
	To alleviate the effects of channel impairments and interference, it may be acceptable to diminish distortion and frequency response fidelity to maintain audio free of dropouts and noticeable artifacts.
Noise	May be acceptable to compromise noise fidelity to maintain dropout- and artifact-free audio
Stereo separation	May be acceptable to compromise in response to channel impairments
Fidelity of digital technologies	a) Source coding should not cause artifacts that noticeably reduce fidelity throughout the service area
	b) Should have sufficient apparent dynamic range so that low level and dynamic content reproduce with the same fidelity as aggressively processed audio

Table 3. Fidelity Performance Goals – AM IBOC⁵

CATEGORY	PERFORMANCE GOALS
Frequency response & distortion	Deliver fidelity that approaches present FM analog fidelity
	To alleviate the effects of channel impairments and interference, it may be acceptable to diminish distortion and frequency response fidelity to maintain audio free of dropouts and noticeable artifacts.
Noise	May be acceptable to compromise noise fidelity to maintain dropout- and artifact-free audio
Stereo separation	May be acceptable to compromise in response to channel impairments
Fidelity of digital technologies	a) Source coding should not cause artifacts that noticeably reduce fidelity throughout the service area
	b) Should have sufficient apparent dynamic range so that low level and dynamic content reproduce with the same fidelity as aggressively processed audio

iBiquity’s Gen 3 systems are functionally equivalent to the Gen 1 systems in essentially all respects except for the audio codec employed.⁶ The Gen 1 systems used an MPEG-2 AAC perceptual audio codec, while the Gen 3 systems use a proprietary iBiquity codec called HDC, which is the codec now being used in commercial HD Radio equipment.

² See *Evaluation of the iBiquity Digital Corporation IBOC System, Part 1 – FM IBOC*, National Radio Systems Committee DAB Subcommittee, November 29, 2001, and *Evaluation of the iBiquity Digital Corporation IBOC System, Part 2 – AM IBOC*, National Radio Systems Committee DAB Subcommittee, April 6, 2002.

³ See “DAB Subcommittee Goals & Objectives,” as adopted by the Subcommittee on May 14, 1998.

⁴ See footnote 2, Part 1, Table 8.

⁵ See footnote 2, Part 2, Table 7.

⁶ iBiquity has stated that the Gen 3 hardware implementations, however, are significantly more advanced than were the Gen 1 implementations.

Data contained in the Gen 3 test data report documents were collected by iBiquity in the presence of an NRSC observer (Tom Keller, T. Keller Corporation), a broadcast consulting engineer familiar with both the NRSC’s IBOC test procedures as well as the underlying technologies and measurement techniques. The NRSC observer ensured that the tests were conducted according to the NRSC’s procedures and that the data recorded were in fact the data obtained. Subjective evaluations performed on portions of this data were conducted by iBiquity under the supervision of Dr. Ellyn Sheffield and are documented in the test data reports, as well. All of these tests were conducted using methods and procedures consistent with earlier (i.e. “Gen 1” and “Gen 2”) system tests evaluated by the NRSC.

Findings - unimpaired digital audio quality – FM IBOC

For the purpose of evaluating the unimpaired digital audio quality of the iBiquity FM IBOC Gen 3 system, two types of audio quality benchmarks⁷ were used. The first was the compact disc (“CD”) source audio, and the second was analog audio recorded off of the four FM analog receivers used by the NRSC for IBOC compatibility testing.

Under unimpaired signal conditions, and using critical audio material selected to stress these systems, subjective evaluation of the test results shows that the audio quality of the iBiquity FM IBOC Gen 3 system is a significant improvement over the existing analog service. It is equivalent to the audio quality of a CD, and is better than FM analog audio quality (Table 4).⁸ These results were consistent across all audio formats tested (classical, critical, rock, speech).

Table 4. FM IBOC subjective evaluation - average audio quality MOS⁹ under unimpaired conditions

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

GEN 3 (96 KBPS)	GEN 3 (64 KBPS)	CD SOURCE	FM ANALOG RECEIVERS			
			HOME HI-FI	OEM AUTO	AFTERMARKET AUTO	PORTABLE
4.12	4.11	4.24	3.78	3.81	3.79	3.71

Findings - unimpaired digital audio quality – AM IBOC

For the purpose of evaluating the unimpaired digital audio quality of the iBiquity AM IBOC Gen 3 system, two types of audio quality benchmarks were used. The first was unimpaired FM audio, and the second was analog audio recorded off of the four AM analog receivers used by the NRSC for IBOC compatibility testing.

The subjective evaluation results for AM IBOC, under unimpaired signal conditions and using critical audio material selected to stress these systems, show that the audio quality of the iBiquity AM

⁷ Listeners participating in the Gen 3 subjective evaluation tests in effect compare the unimpaired IBOC audio cuts against the benchmarks. This makes it possible, during evaluation of the subjective test results, to determine if the IBOC is a significant improvement over existing analog services (comparison against the analog audio cuts) and also to see how the IBOC compares against the audio quality of a CD (for FM IBOC) or unimpaired FM (for AM IBOC).

⁸ Note that these Gen 3 results for FM IBOC are not directly comparable with the corresponding data evaluated by the NRSC in the “Gen 2” FM IBOC evaluation because the subjective evaluation results were obtained during different experiments using different groups of listeners. See “Evaluation of iBiquity FM IBOC ‘Gen 2’ hardware,” NRSC Memo from H. Donald Messer, Chairman, DAB Subcommittee Evaluation Working Group to Milford Smith, Chairman, DAB Subcommittee, May 16, 2002.

⁹ “MOS” is the “mean opinion score” from the “absolute category rating – mean opinion score” subjective evaluation procedure, described in detail in the FM IBOC Test Data Report submitted by iBiquity to the NRSC on August 8, 2001.

IBOC Gen 3 system is a significant improvement over the existing analog service. It approaches the quality of analog FM audio, and is better than analog AM audio quality. The results were different depending upon the audio format under test:

- For “classical,” subjective evaluation of the test results shows that the audio quality of the iBiquity AM IBOC Gen 3 system is better than AM analog audio quality and is equivalent to the audio quality of unimpaired FM (Table 5);
- For “rock,” subjective evaluation of the test results shows that the audio quality of the iBiquity AM IBOC Gen 3 system is better than AM analog audio quality, and is equivalent to (36 kbps) or slightly lower than (20 kbps) the audio quality of unimpaired FM (Table 6);
- For “commercial” and “speech,” subjective evaluation of the test results shows that the audio quality of the iBiquity AM IBOC Gen 3 system is better than AM analog audio quality, and is slightly lower than the audio quality of unimpaired FM (Table 7 and Table 8, respectively).

Table 5. AM IBOC subjective evaluation for “classical” format - audio quality MOS under unimpaired conditions

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

			AM ANALOG RECEIVERS			
GEN 3 (36 KBPS)	GEN 3 (20 KBPS)	UNIMPAIRED FM	HOME HI-FI	OEM AUTO	AFTERMARKET AUTO	PORTABLE
4.5	4.2	4.3	3.6	3.7	3.7	3.8

Table 6. AM IBOC subjective evaluation for “rock” format - audio quality MOS under unimpaired conditions

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

			AM ANALOG RECEIVERS			
GEN 3 (36 KBPS)	GEN 3 (20 KBPS)	UNIMPAIRED FM	HOME HI-FI	OEM AUTO	AFTERMARKET AUTO	PORTABLE
4.2	3.9	4.4	2.7	2.8	3.0	3.4

Table 7. AM IBOC subjective evaluation for “commercial” format - audio quality MOS under unimpaired conditions

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

			AM ANALOG RECEIVERS			
GEN 3 (36 KBPS)	GEN 3 (20 KBPS)	UNIMPAIRED FM	HOME HI-FI	OEM AUTO	AFTERMARKET AUTO	PORTABLE
3.6	3.7	4.1	3.2	3.1	3.1	3.4

Table 8. AM IBOC subjective evaluation for “speech” format - audio quality MOS under unimpaired conditions

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

			AM ANALOG RECEIVERS			
GEN 3 (36 KBPS)	GEN 3 (20 KBPS)	UNIMPAIRED FM	HOME HI-FI	OEM AUTO	AFTERMARKET AUTO	PORTABLE
3.9	3.9	4.4	3.5	3.6	3.4	3.5

Findings – digital performance under impaired conditions – FM IBOC

For these tests, the benchmark of performance used was the digital performance of the Gen 1 FM IBOC hardware, since the goal here was to confirm that the Gen 3 hardware performs similar to the Gen 1 hardware which was extensively evaluated by the NRSC.

Under four different types of impaired signal conditions, recordings from Gen 1 and Gen 3 hardware were subjectively evaluated (Table 9). The minor differences between the Gen 1 and Gen 3 results demonstrate equivalent performance. Note that the results in Tables 4 and 9 are not comparable because critical audio cuts were used in the unimpaired tests. Critical audio cuts would be expected to produce lower scores than typical audio samples, like those used for the impaired tests.

Table 9. FM IBOC - average audio quality MOS under impaired conditions

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

TEST	COMMENTS	MULTIPATH TYPE	SUBJECTIVE EVALUATION RESULTS (PROTOTYPE IBOC RECEIVER)	
			GEN 1	GEN 3 (96 KBPS)
B1 – Digital performance in the presence of AWGN	Recordings made with AWGN power 2 dB below blend point	None	4.33	4.30
B2 – Digital performance in the presence of AWGN with multipath	Recordings made with AWGN power 8 dB below blend point	Rural fast	4.30	4.23
		Terrain obstructed	4.10	4.17
		Urban fast	4.40	4.10

In accordance with the NRSC test procedures iBiquity conducted objective performance comparison tests on the Gen 1 and Gen 3 systems.¹⁰ At the 10% block error rate point the digital performance (C_d/N_0) of the Gen 1 and Gen 3 systems (Table 10) was either identical (AWGN) or the Gen 3 system performed slightly better (rural fast, terrain obstructed, and urban fast).

¹⁰ The detailed results are included in the letter from A. Shuldiner to D. Wilson re: NRSC Gen 3 Audio Tests, dated 4/14/04.

Table 10. FM IBOC – objective system performance – 10% block error rate (BLER) point

TEST	COMMENTS	MULTIPATH TYPE	10% BLER POINT (PROTOTYPE IBOC RECEIVER) Cd/No (dB)	
			GEN 1 ¹¹	GEN 3 (96 KBPS)
B1 – Digital performance in the presence of AWGN	Recordings made with AWGN power 2 dB below blend point	None	54.2	54.3
B2 – Digital performance in the presence of AWGN with multipath	Recordings made with AWGN power 8 dB below blend point	Rural fast	58.0	57.0
		Terrain obstructed	57.5	56.5
		Urban fast	58.0	56.5

Findings – digital performance under impaired conditions – AM IBOC

For these tests, the benchmark of performance used was the digital performance of the Gen 1 AM IBOC hardware, since the goal here was to confirm that the Gen 3 hardware performs similar to the Gen 1 hardware which was extensively evaluated by the NRSC.

Under AWGN impaired signal conditions, recordings from the Gen 3 hardware were subjectively evaluated (Table 11). Due to an oversight, the corresponding Gen 1 audio cuts were not included in the subjective evaluation experiment hence a statistically valid comparison between Gen 1 and Gen 3 subjectively evaluated audio under AWGN conditions is not possible. Instead, the comparison shown in Table 3 is between the Gen 3 results and corresponding Gen 1 results obtained during the comprehensive NRSC evaluation conducted in 2001. While statistical tests cannot be performed on these data, the results indicate that the differences between Gen 1 and Gen 3 ratings are negligible.

Table 11. AM IBOC - average audio quality MOS under AWGN impairment conditions – Gen 3 tests (2003) vs. Gen 1 tests (2001)

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

AUDIO SAMPLE	SUBJECTIVE EVALUATION RESULTS (PROTOTYPE IBOC RECEIVER)	
	GEN 1 ¹²	GEN 3 (96 KBPS)
Ibert	4.7	4.7
Riverdance	3.9	3.7
Santana	4.5	4.1
Female A1	4.0	4.3

¹¹ See *Digital Audio Broadcasting – Analog Main Channel Compatibility and Digital Performance of the iBiquity Digital IBOC System in the FM Band – Summary of Test Results*, ATTC, Document #01-13, Revision 1.1, July 31, 2001, pp. 25, 27-28.

¹² See footnote 2, Part 2, Appendix G, pg. 4.

In accordance with the NRSC test procedures iBiquity conducted objective performance comparison tests on the Gen 1 and Gen 3 systems.¹³ At the 10% block error rate point the digital performance (C_d/N_0) of the Gen 3 system was slightly better than the Gen 1 system for both blend point cases tested (Table 12).

Table 12. AM IBOC – objective system performance – 10% block error rate (BLER) point

TEST	COMMENTS	BLEND POINT	10% BLER POINT (PROTOTYPE IBOC RECEIVER) Cd/No (DB)	
			GEN 1 ¹⁴	GEN 3 (36 KBPS)
B – Characterization of signal failure with AWGN	Recordings made with AWGN power 2 dB below blend point	Enhanced to core	74.5	74.25
		Core to analog	67.0	63.7

Conclusion

These findings demonstrate that the AM IBOC audio fidelity approaches FM analog audio quality and the FM IBOC audio fidelity is comparable to or better than the best FM analog audio quality. We believe these findings are consistent with the conclusions and recommendations in the NRSC’s Evaluation of the iBiquity Digital Corporation IBOC System, Parts 1 and 2 (FM IBOC – November 29, 2001; AM IBOC – April 6, 2002), and conclude that the Gen 3 systems satisfy the original “Goals and Objectives” of the DAB Subcommittee by providing a digital signal with significantly improved audio quality over AM and FM analog systems that presently exist in the United States.”

Based on the above the NRSC re-affirms its recommendation that the iBiquity AM and FM IBOC systems be authorized by the FCC as enhancements to the analog broadcasting systems in the U.S.

NRSC approval:



John G. Marino
Vice President, Science & Technology, NAB



Dave Wilson
Director, Engineering, CEA

(attachments)

¹³ See footnote 5.

¹⁴ See *Digital Audio Broadcasting – Digital Performance of the iBiquity Digital IBOC System in the AM Band – Summary of Test Results*, ATTC, Document #01-25, December 2001, pg. 9.



November 14, 2003

MEMORANDUM

TO: DAB Subcommittee – Evaluation Working Group (EWG)
FROM: D. Layer
SUBJECT: AM IBOC system 3rd generation hardware (“Gen 3”) re-test

Given below is a summary of the test plan agreed to by the EWG at the 11/12/03 Evaluation Working Group meeting, for the limited re-testing of the iBiquity AM IBOC 3rd generation hardware:

System description: in the Gen 3 test report document, iBiquity will certify that the 3rd generation system hardware tested fully complies with Appendix A of the AM test data report submitted to the NRSC on January 4, 2002, and that the only significant functional changes made between the hardware originally tested by the NRSC and the 3rd generation system undergoing this re-test are:

- replacement of AAC audio codec with HDC audio codec;
- new RF front-end in iBiquity prototype IBOC receiver.

Baseline test procedure: IBOC laboratory test procedures – AM band, rev. 6d, February 6, 2002 (only tests G and B.1 are performed for the Gen 3 test). Audio cut list (pg. 2 of this memo) is taken from “*Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware,*” prepared for the National Radio Systems Committee and iBiquity Digital Corporation, Ellyn Sheffield, Ph.D., Sheffield Audio Consulting.

NRSC observer: start-to-finish, omnipresent NRSC observation will be required for the Gen 3 tests to allow the NRSC to evaluate the resulting data.

IBOC quality (Test G): see revised procedure and list of audio selections and processor settings (attached). This test will be conducted twice – once with the system operating in “enhanced” digital audio mode (36 kbps) and once with the system operating in “core” digital audio mode (20 kbps).

AWGN (Test B.1): see revised procedure (attached). Note that analog reference recordings will be made using all four NRSC analog test receivers at the operating points established in steps 3 and 4 of test B.1.

(attachments)

Table 1: Samples and post-processor settings for AM Tests

ARTIST	ALBUM TITLE	SONG TITLE	Digital Post-processor settings	TEST
Bizet	Carmen		Orban 8400-HD-20-01	Unimpaired
Eric Clapton	Best of Clapton	Change the World	No Processing	Unimpaired
Crosby, Stills, Nash, & Young	Looking Forward	Sanibel	No Processing	Unimpaired
EWf	Greatest Hits	Let's Groove	No Processing	Unimpaired
Handel	Messiah	Hallelujah	Orban 8400	Unimpaired
Jaques Ibert	Summertime Music for Oboe	Entr'acte	Orban 8400	Unimpaired
Moulton Labs	CriticalListening Excerpts	Kyoko Saito	Orban 8400-HD-20-01	Unimpaired
REO Speedwagon	Hi Fidelity	Keep on Loving You	No Processing	Unimpaired
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	No Processing	Unimpaired
Suzanne Vega	Nine Objects of Desire	Caramel	No Processing	Unimpaired
Ballet Woman	Voice Over	From WTOP	No Processing	Unimpaired
Camera	Voice Over	From WTOP	No Processing	Unimpaired
From Richmond	Voice Over	From WTOP	No Processing	Unimpaired
Riverdance	Voice Over	From WTOP	No Processing	Both
Santana	Supernatural	Smoth	Orban 8400-HD-20-01	Impaired
Ibert	Summertime Music for Oboe	Entr'acte	Orban 8400-HD-20-01	Impaired
Fleetwood Mac	Tango in the Night	IGY	No Processing	Impaired
Imagine	Voice Over		No Processing	Impaired
Debussy	String Quartet in g minor	Anime et tres decide	Orban 8400-HD-20-01	Impaired
FemaleB2	Brown	The Switch	Orban 8400-HD-20-01	Impaired
FemaleA1	Austen	Northanger Abbey	Orban 8400-HD-20-01	Both
FemaleC10	Scottline	The Vendetta Defense	Orban 8400-HD-20-01	Unimpaired
MaleA1	Coonts	Hong Kong	Orban 8400-HD-20-01	Unimpaired
MaleB4	Glenn	John Glenn: A Memoir	Orban 8400-HD-20-01	Unimpaired

The Optimod 9200 will be configured as follows:

(The AES/EBU outputs of the Orban will be connected to the Digital Input of the LynxOne audio card for recordings. Cooledit Pro will be used to perform the recordings. Once the processed recordings are completed, they will each be cropped to the section of interest. These cropped files are then written to CD in stereo 16 bit, 44.1 kHz format for use in the subjective testing.)

Voice cuts:

Processing:

Preset: News

HF Curve: NRSC

Setup:

INPUT: Digital

POS PEAK: 125%

BANDWIDTH:

HP FLTR: 50 Hz

LP FLTR NRSC or 4.5 kHz

Digital Input:

DI MODE: DIG-L

DI REV VU: -11.0 dBFS

DI REF PPM: -3.0 dBFS

Digital Output:

DO 100%: -3.6 dBFS

DO RATE: 44.1 kHz

DO SYNC: Internal

HF DELAY: Off

HF Shelf: off

Classical cuts:

Processing:

Preset: Fine arts

HF Curve: NRSC

Setup:

INPUT: Digital

POS PEAK: 125%

BANDWIDTH:

HP FLTR: 50 Hz

LP FLTR NRSC or 4.5 kHz

Digital Input:

DI MODE: DIG-L

DI REV VU: -11.0 dBFS

DI REF PPM: -3.0 dBFS

Digital Output:

DO 100%: -3.6 dBFS

DO RATE: 44.1 kHz

DO SYNC: Internal

HF DELAY: Off

HF Shelf: off

Rock and Voice-over cuts:

Processing:

Preset: Music Heavy

HF Curve: NRSC

Setup:

INPUT: Digital

POS PEAK: 125%

BANDWIDTH:

HP FLTR: 50 Hz

LP FLTR NRSC or 4.5 kHz

Digital Input:

DI MODE: DIG-L

DI REV VU: -11.0 dBFS

DI REF PPM: -3.0 dBFS

Digital Output:

DO 100%: -3.6 dBFS

DO RATE: 44.1 kHz

DO SYNC: Internal

HF DELAY: Off

HF Shelf: off

<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"> The audio will be restarted for each test. Analog reference recordings will be made using all four NRSC analog test receivers at the operating points established in steps 3 and 4 of test B.1. 			
B	1 AWGN	<ol style="list-style-type: none"> The level of AWGN corresponding to system point of loss of enhanced audio will be established. The level of AWGN corresponding to system point of blend will be established. 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. 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. 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

<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). (For Gen 3 testing, the analog reference recordings obtained during the Gen 2 tests will be utilized.) 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). 3. This test will be conducted twice – once with the system operating in “enhanced” digital audio mode (36 kbps) and once with the system operating in “core” digital audio mode (20 kbps). 			
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



November 14, 2003

MEMORANDUM

TO: DAB Subcommittee – Evaluation Working Group (EWG)
FROM: D. Layer
SUBJECT: FM IBOC system 3rd generation hardware (“Gen 3”) re-test

Given below is a summary of the test plan agreed to by the EWG at the 11/12/03 Evaluation Working Group meeting, for the limited re-testing of the iBiquity FM IBOC 3rd generation hardware:

System description: in the Gen 3 test report document, iBiquity will certify that the 3rd generation system hardware tested fully complies with Appendix A of the FM test data report submitted to the NRSC in August 2001, and that the only significant functional changes made between the hardware originally tested by the NRSC and the 3rd generation system undergoing this re-test are:

- replacement of AAC audio codec with HDC audio codec;
- new RF front-end in iBiquity prototype IBOC receiver.

Baseline test procedure: IBOC laboratory test procedures – FM band, rev. 19g, February 6, 2002 (only tests I, B.1 and B.2 are performed for the Gen 3 test). Audio cut list (pg. 2 of this memo) is taken from “*Proposal for Subjective Evaluation of Generation 3 HD Radio Hardware,*” prepared for the National Radio Systems Committee and iBiquity Digital Corporation, Ellyn Sheffield, Ph.D., Sheffield Audio Consulting.

NRSC observer: start-to-finish, omnipresent NRSC observation will be required for the Gen 3 tests to allow the NRSC to evaluate the resulting data.

IBOC quality (Test I): see revised procedure (attached). This test will be conducted three times, each time at a different main channel audio bit rate. The three rates to be used are 96 kbps, 64 kbps, and 32 kbps. Audio selections and processor settings will be per Appendix I to iBiquity memo to TPWG dated 1/25/02.

AWGN (Test B.1): see revised procedure (attached). Note that analog reference recordings will be made using all four NRSC analog test receivers at the operating point established in step 2 of test B.1. This test is performed for an audio bit rate of 96 kbps only.

Multipath with noise (Test B.2): see revised procedure (attached). Test bed calibration with multipath simulator installed must be checked prior to running this test. Note that the urban slow multipath fading scenario will not be done. This test is performed for an audio bit rate of 96 kbps only.

(attachments)

Table 4: FM Digital Post-Processor Settings

ARTIST	ALBUM TITLE	SONG TITLE	Digital Post-processor settings	TEST
Bach	Brandenburg Concerto #5, D Major	Allegro	Orban 8400-HD-20-01	Both
Bizet	Carmen		Orban 8400-HD-20-01	Unimpaired
Enya	Shepherd Moons	Angeles	Orban 8400-HD-20-01	Unimpaired
Eric Clapton	Best of Eric Clapton	Change the World	No Processing	Unimpaired
Paula Cole	Harbinger	Happy Home	No Processing	Impaired
Crowded House	Woodface	Weather With You	No Processing	Impaired
Earth, Wind and Fire	Greatest Hits	Let's Groove	No Processing	Unimpaired
Fagen	The Nightfly	IGY	No Processing	Impaired
Glockenspeil	SQAM Disc		No Processing	Unimpaired
Amy Grant	Heart in Motion	Baby, Baby	No Processing	Unimpaired
Handel	Messiah	Hallelujah	Orban 8400-HD-20-01	Both
Medewski, Martin & Wood	Shack Man	Hermeto's Daydream	No Processing	Unimpaired
Moulton Labs	Critical Listening Excerpts	Kyoko Saito	Orban 8400-HD-20-01	Unimpaired
Prince			No Processing	Impaired
Persian Music			No Processing	Both
Paul Simon	Rhythm of the Saints	Can't Run But	No Processing	Unimpaired
Tchaikovski	1812 Overture	Track 17	Orban 8400-HD-20-01	Both
Randy Travis	A Man Ain't Made of Stone	A Heartache In the Works	No Processing	Unimpaired
Trumpet	SQAM Disc		No Processing	Unimpaired
English Woman	SQAM Disc		Omnia AC	Both
Tom Brokaw	The Greatest Generation		Omnia AC	Both
English Male	SQAM Disc		Omnia AC	Both

Table C-1 Analog FM Processor: Light Preset

Processor Name: Cutting Edge Omnia 4500 Preset Name: Light			
Parameter	Value	Parameter	Value
WB-AGC	IN	LF-LIMITER	
AGC Drive	(+6.0	Drive	0.0
Attack	3	Threshold	(+2.0
Release	0	Attack	3
Make-Up Gain	1	Release	2
Gate Thresh	4	Hold Thresh	4
BASS		MF-LIMITER	
Deep Bass	0.0	Drive	0.0
Phat Bass	0.0	Threshold	0.0
		Attack	3
WARMTH	0.0	Release	1
		Hold Thresh	2
X-OVER		PR-LIMITER	
Low Gain	0.0	Drive	0.0
Mid Gain	0.0	Threshold	0.0
Pres Gain	(+1.0	Attack	3
High Gain	(+1.5	Release	2
		Hold Thresh	4
LF-AGC			
Attack	2		
Release	0	HF-LIMITER	
Make-Up Gain	2	Drive	(+1.0
Gate Thresh	3	Threshold	(-7.5
RTP Speed	Slow	Attack	3
RTP Level	(-)10	Release	2
		Hold Thresh	1
MF-AGC			
Attack	3	MIXER	
Release	0	Low Band	0.0

Processor Name: Cutting Edge Omnia 4500 Preset Name: Light			
Make-Up Gain	2	Mid Band	0.0
Gate Thresh	3	Pres Band	(-)4.0
RTP Speed	Slow	High Band	(-)5.5
RTP Level	(-)10		
		CLIPPER	
PR-AGC		Drive	(+0.5
Attack	3		
Release	0	COMP CLIP	
Make-Up Gain	3	Drive	0.0
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)10		
HF-AGC			
Attack	4		
Release	1		
Make-Up Gain	3		
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)5		

Table C-2 Analog FM Processor: Medium Preset

Processor Name: Cutting Edge Omnia 4500			
Preset Name: Medium			
Parameter	Value	Parameter	Value
WB-AGC	IN	LF-LIMITER	
AGC Drive	(+)6.0	Drive	(+)1.5
Attack	3	Threshold	(+)1.5
Release	0	Attack	4
Make-Up Gain	1	Release	2
Gate Thresh	4	Hold Thresh	4
BASS		MF-LIMITER	
Deep Bass	(+)4.0	Drive	(+)1.5
Phat Bass	(+)2.0	Threshold	0.0
		Attack	3
WARMTH	(+)1.0	Release	1
		Hold Thresh	3
X-OVER			
Low Gain	(+)2.0	PR-LIMITER	
Mid Gain	(+)2.0	Drive	(+)1.5
Pres Gain	(+)3.0	Threshold	0.0
High Gain	(+)4.0	Attack	3

Processor Name: Cutting Edge Omnia 4500			
Preset Name: Medium			
		Release	2
LF-AGC		Hold Thresh	2
Attack	2		
Release	0	HF-LIMITER	
Make-Up Gain	2	Drive	(+)2.0
Gate Thresh	3	Threshold	(-)7.5
RTP Speed	Slow	Attack	3
RTP Level	(-)10	Release	2
		Hold Thresh	1
MF-AGC			
Attack	2	MIXER	
Release	2	Low Band	0.0
Make-Up Gain	2	Mid Band	0.0
Gate Thresh	3	Pres Band	(-)4.0
RTP Speed	Slow	High Band	(-)5.0
RTP Level	(-)10		
		CLIPPER	
PR-AGC		Drive	(+)1.0
Attack	2		
Release	2	COMP CLIP	
Make-Up Gain	3	Drive	(+)1.0
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)10		
HF-AGC			
Attack	3		
Release	2		
Make-Up Gain	3		
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)5		

Table C-3 Analog FM Processor: Hard Preset

Processor Name: Cutting Edge Omnia 4500			
Preset Name: Hard			
Parameter	Value	Parameter	Value
WB-AGC	IN	LF-LIMITER	
AGC Drive	(+)6.0	Drive	(+)2.5
Attack	3	Threshold	(+)1.0
Release	0	Attack	4
Make-Up Gain	1	Release	2
Gate Thresh	4	Hold Thresh	4
BASS		MF-LIMITER	
Processor Name: Cutting Edge Omnia 4500			
Preset Name: Hard			
Deep Bass	(+)6.0	Drive	(+)2.5
Phat Bass	(+)3.0	Threshold	0.0
		Attack	4
WARMTH	(+)1.0	Release	3
		Hold Thresh	3
X-OVER			
Low Gain	(+)3.5	PR-LIMITER	
Mid Gain	(+)3.5	Drive	(+)2.5
Pres Gain	(+)3.5	Threshold	0.0
High Gain	(+)4.0	Attack	4
		Release	3
LF-AGC		Hold Thresh	2
Attack	2		
Release	0	HF-LIMITER	
Make-Up Gain	2	Drive	(+)3.0
Gate Thresh	3	Threshold	(-)7.5
RTP Speed	Slow	Attack	3
RTP Level	(-)10	Release	3
		Hold Thresh	1
MF-AGC			
Attack	2	MIXER	
Release	4	Low Band	(+)0.5
Make-Up Gain	4	Mid Band	(+)0.5
Gate Thresh	3	Pres Band	(-)4.0
RTP Speed	Slow	High Band	(-)5.0
RTP Level	(-)10		
		CLIPPER	
PR-AGC		Drive	(+)1.5
Attack	2		
Release	4	COMP CLIP	
Make-Up Gain	4	Drive	(+)1.5
Gate Thresh	2		
RTP Speed	Slow		
RTP Level	(-)10		
HF-AGC			
Attack	3		
Release	2		
Make-Up Gain	3		
Gate Thresh	1		
RTP Speed	Slow		
RTP Level	(-)5		

<p align="center">IBOC LABORATORY TEST PROCEDURES – FM 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 non-IBOC exciter. (For Gen 3 testing, the analog reference recordings obtained during the Gen 2 tests will be utilized.) 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). 3. This test will be conducted three times, each time at a different main channel audio bit rate. The three rates to be used are 96 kbps, 64 kbps, and 32 kbps. 			
I 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. 	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 source material. For IBOC recordings, only 96 kbps, 64 kbps to be subjectively evaluated.

<p align="center">IBOC LABORATORY TEST PROCEDURES – FM BAND DIGITAL PERFORMANCE</p>					
Test Group	Test & Impairment	TEST DESCRIPTION Notes:	Desired Signal Level	Type of Evaluation	Test Results Data to be Recorded
B AWGN	1 Linear channel	<ol style="list-style-type: none"> The level of AWGN corresponding to system point of blend will be established. 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. The BLER will be recorded with the AWGN set at a level 4 dB below (i.e. before) the point of blend, then with the AWGN level increased in 1 dB steps until at the point of blend, then at 2 dB and 4 dB above (i.e. after) the point of blend. 	M	Objective	Cd/No, BLER for each measurement point (with point of blend identified)
				Subjective	Subjective impairment rating for recording made in step 2
	2 Multipath fading channel	<ol style="list-style-type: none"> This test will be conducted four times, each with a different Rayleigh multipath scenario. The multipath scenarios will be those specified on the “general comments” page of this procedure. Each cut will be recorded for subjective assessment. For each multipath scenario, the level of AWGN corresponding to system point of blend will be established. The desired impairment audio segments will be recorded with the AWGN set at a level 8 dB below (i.e. before) the point of blend. The BLER will be recorded with the AWGN set at a level 8 dB below (i.e. before) the point of blend, then with the AWGN level increased in 2 dB steps until 6 dB above (i.e. after) the point of blend. An analog reference recording will be made using NRSC analog test receivers #1 and #2 (automobile receivers) for each multipath scenario, at the measurement point of step 3. 	M	Objective	Cd/No, BLER for each measurement point (with point of blend identified)
				Subjective	Subjective impairment rating for each multipath scenario and audio cut, for IBOC digital and analog reference recordings made in steps 2 and 5

NRSC-R206

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:	TEL:	
COMPANY:	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

