NRSC REPORT

# NATIONAL RADIO SYSTEMS COMMITTEE

## NRSC-R205
## Evaluation of iBiquity FM IBOC "Gen 2" hardware
## May 16, 2002


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# FOREWORD

NRSC-R205, Evaluation of iBiquity FM IBOC “Gen 2” hardware, documents the DAB Subcommittee Evaluation Working Group’s review of test results submitted to the NRSC by iBiquity Digital Corporation and the Advanced Television Technology Center (ATTC) pertaining to the performance of iBiquity’s second generation FM IBOC digital radio system hardware. The DAB Subcommittee chairman at the time of adoption of NRSC-R205 was Milford Smith; the NRSC chairman at the time of adoption was Charles Morgan.

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May 16, 2002

**M E M O R A N D U M**

**TO:** DAB Subcommittee, Milford Smith, Chairman

**FROM:** Evaluation Working Group, H. Donald Messer, Chairman

**SUBJECT:** Evaluation of iBiquity FM IBOC "Gen 2" hardware

The purpose of this memo is to report on the Evaluation Working Group's (EWG's) evaluation of tests results recently submitted to the NRSC by iBiquity Digital Corporation and the Advanced Television Technology Center (ATTC) pertaining to the performance of iBiquity's second generation ("Gen 2") 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 1/29/02 (Appendix A to this memo); the test results were contained in the documents listed in Table 1.

**Table 1. FM IBOC Gen 2 Test Data Report Documents**

| DATE | TITLE | AUTHORS | # OF PAGES | COMMENTS |
|---|---|---|---|---|
| 2/19/02 | Fourth Report to the National Radio Systems Committee – FM IBOC DAB Unimpaired Audio Quality Test | iBiquity Digital Corp. / Dynastat / ATTC | 69 | 6-page main report with 6 appendices |
| 4/16/02 | FM Laboratory Tests Using Generation 2 Hardware | iBiquity Digital Corp. / ATTC | 24 | 2-page main report with 2 appendices |
| 5/13/02 | Response to questions from 5/8/02 [EWG] conference call | iBiquity Digital Corp. | 1 | Statement regarding equivalence of Gen 1 and Gen 2 hardware et.al. |

This latest evaluation effort was conducted for two reasons: i) to determine the unimpaired audio quality of iBiquity's FM IBOC system, and ii) to confirm that the Gen 2 hardware performs similarly to the previous ("Gen 1") version of the system recently evaluated by the NRSC.[1] iBiquity's Gen 2 system is equivalent to its Gen 1 system in essentially all respects except for the audio codec employed.[2] The previous system used an MPEG-2 AAC perceptual audio codec, and the Gen 2 system uses a proprietary iBiquity codec based on Lucent Technologies' Perceptual Audio Codec ("PAC"), which is the codec iBiquity intends to use in its commercial equipment. Note that the EWG expects to conduct a similar

[1] See *Evaluation of the iBiquity Digital Corporation IBOC System, Part 1 – FM IBOC,* National Radio Systems Committee DAB Subcommittee, November 29, 2001.
[2] The FM IBOC receiver used by iBiquity for the Gen 2 testing also included a new RF front end.

effort on AM IBOC Gen 2 performance data once received, and will issue a report similar in form to this one at that time.

Information contained in the Gen 2 test data report documents was collected by either iBiquity or the ATTC in the presence of an NRSC observer (Tom Keller, T. Keller Corporation), a broadcast consulting engineer familiar with both the NRSC's FM IBOC test procedures as well as the underlying technologies and measurement techniques. Subjective evaluations performed on portions of this data were conducted by Dynastat and are documented in the test data report, as well. The NRSC observer ensured that the tests were conducted according to the NRSC's procedures and that the data recorded was in fact the data obtained.

## Findings - unimpaired digital audio quality

For the purpose of evaluating the unimpaired digital audio quality of the iBiquity FM IBOC Gen 2 system, two types of audio quality benchmarks 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 (i.e., no interfering signals and no multipath or other forms of signal impairment), and using critical audio material selected to stress these systems, subjective evaluation of the test results show that the audio quality of the iBiquity FM IBOC Gen 2 system is equivalent to the audio quality of a CD, and is better than FM analog audio quality (Table 2).[3]

**Table 2. Average audio quality MOS[4] under unimpaired conditions**

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

| | | FM ANALOG RECEIVERS | | | |
|---|---|---|---|---|---|
| GEN 2 | CD SOURCE | HOME HI-FI | OEM AUTO | AFTERMARKET AUTO | PORTABLE |
| 4.41 | 4.41 | 4.15 | 4.19 | 4.09 | 3.98 |

[3] iBiquity Digital Corporation, *Fourth Report to the National Radio Systems Committee, FM IBOC DAB Unimpaired Audio Quality Test,* February 19, 2002, Appendix F, p. 1.

[4] "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.

## Findings – digital performance under impaired conditions (Gen 2 hardware)

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 2 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 2 hardware were subjectively evaluated (Table 3).[5] The insignificant differences between the Gen 1 and Gen 2 results demonstrate nearly identical performance. Note that the results in Tables 2 and 3 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 3. Average audio quality MOS under impaired conditions**
5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = bad

| | | | SUBJECTIVE EVALUATION RESULTS (PROTOTYPE IBOC RECEIVER) | |
|---|---|---|---|---|
| TEST | COMMENTS | MULTIPATH TYPE | GEN 1 | GEN 2 |
| B1 – Digital performance in the presence of AWGN | Recordings made with AWGN power 2 dB below blend point | None | 4.53 | 4.49 |
| B2 – Digital performance in the presence of AWGN with multipath | Recordings made with AWGN power 8 dB below blend point | Rural fast | 4.56 | 4.50 |
| | | Terrain obstructed | 4.57 | 4.47 |
| | | Urban fast | 4.42 | 4.48 |

In accordance with the NRSC test procedures iBiquity had the ATTC conduct objective performance comparison tests on the Gen 1 and Gen 2 systems. The detailed results are shown in the iBiquity Fourth Report to the NRSC, Appendix C, Figures 5-1 through 5-8. At the point-of-blend (10% block error rate) the digital performance ($C_d/N_0$) of the Gen 1 and Gen 2 systems was identical under all conditions tested (rural fast, terrain obstructed, and urban fast).

## Conclusion

We believe these findings are consistent with the conclusions and recommendations in the NRSC's Evaluation of the iBiquity Digital Corporation IBOC System, Part 1 – FM IBOC, November 29, 2001.

NRSC approval:

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

Dave Wilson
Director, Engineering, CEA

(attachment)

[5] iBiquity Digital Corporation, *FM Laboratory Tests Using Generation 2 Hardware,* April 16, 2002, Appendix A.

## IBOC LABORATORY TEST PROCEDURES – FM BAND GEN 2
## OVERALL COMMENTS

1. The test laboratory (ATTC) will provide a detailed certification of the test bed.
2. In the test report document, iBiquity will certify that the 2nd 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 2nd generation system undergoing this re-test are:

   - replacement of AAC audio codec with iBiquity-developed audio codec;

   - new RF front-end in iBiquity prototype IBOC receiver.
3. Audio selections and processor settings will be as follows:

| ARTIST | ALBUM TITLE | SONG TITLE | ASIN NUMBER | Pre-processor settings | |
|---|---|---|---|---|---|
| | | | | Analog | Digital |
| Bach | Brandenburg Concerto #5, D Major | Allegro | B000003CZT | Light | Transparent |
| Bizet | Carmen | | B0000007DT | Light | Classical |
| Enya | Shepherd Moons | Angeles | B000002LRT | Light | Transparent |
| Eric Clapton | Best of Eric Clapton | Change the World | B00001U03Q | Medium | Transparent |
| Earth, Wind and Fire | Greatest Hits | Let's Groove | B00000FC5H | Hard | Contemp 2 |
| Glockenspiel | SQAM Disc | | N/A | Light | Transparent |
| Amy Grant | Heart in Motion | Baby, Baby | B000002GJB | Hard | Transparent |
| Handel | Messiah | Hallelujah | B000003CY | Light | Classical |
| Medewski, Martin and Wood | Shack Man | Hermeto's Daydream | B000003220 | Medium | Transparent |
| Kyoko Saito | Critical Listening Excerpts CD – Moulton Labs | | N/A | Light | Transparent |
| Saba | Persian Classical Music | The Yellow Sparrow | Foreign recording | Light | Transparent |
| Paul Simon | Rhythm of the Saints | Can't Run but | B000002LKF | Medium | Transparent |
| Tchaikovsky Classical Thunder | 1812 Overture | Track 17 | | Light | Transparent |
| Randy Travis | A Man Ain't Made of Stone | A Heartache In the Works | B00001QGNB | Medium | Transparent |
| Trumpet | SQAM Disc | | N/A | Light | Transparent |
| English Woman | SQAM Disc | | N/A | Light | Transparent |
| Tom Brokaw | The Greatest Generation | | 0375405666 | Light | Transparent |
| English Male | SQAM Disc | | N/A | Light | Transparent |

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4. Multipath scenarios used in these tests will be the same scenarios used in the EIA DAR laboratory tests conducted in 1995, utilizing nine desired signal paths (rays) and six undesired paths, as specified in Appendix E of the August 11, 1995 report ("VHF Rayleigh 9-path simulation"), except that the urban slow multipath fading scenario will not be used.
5. The detailed procedure for RF noise measurements will be supplied. See Appendix S of the EIA DAR Laboratory Tests Report, August 11, 1995.
6. For tests involving use of the multipath simulator, the RF level will be characterized according to the procedure described in the ATTC report "The Measurement of Power as applied to IBOC DAB signals in the Presence of Multipath for the FM-band," Document #00-02 November 16, 2000.
7. 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.
8. IBOC receiver point-of-blend is established by the "mode" signal, which is supplied by the receiver. IBOC receiver block error rate (BLER) is also observable.
9. The following three RF composite signal levels are used in the FM laboratory tests:

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

## IBOC LABORATORY TEST PROCEDURES – FM BAND GEN 2
## DIGITAL PERFORMANCE

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

## IBOC LABORATORY TEST PROCEDURES – FM BAND GEN 2
## DIGITAL QUALITY

| Test Group | Test & Impairment | TEST DESCRIPTION<br>Note:<br>1. Analog reference recordings will be obtained using non-IBOC exciter.<br>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 |
|---|---|---|---|---|---|
| I<br>IBOC quality | 1<br>Quality transmission test | 1. Tests will be conducted using the audio quality selections.<br>2. Each of the selections will be transmitted through the IBOC system without impairment and recorded for subjective evaluation.<br>3. For each measurement point, the mode signal status will be recorded.<br>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, and all four analog receivers) as well as for source material |

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

## 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:

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