

Digital Audio Broadcasting

**Performance of the iBiquity Digital FM IBOC System in
Unimpaired Channel Conditions**

Summary of Test Results

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1 Introduction

1.1 Background

Over the course of the past year, the Advanced Television Technology Center (ATTC) has conducted an extensive laboratory test program designed to fulfill the requirements of the NRSC (National Radio Systems Committee) AM and FM IBOC DAB system evaluation and standardization processes.

This test program was conducted using the “first generation” of IBOC transmitters and receivers produced by iBiquity Digital. These first generation units incorporated an audio coding algorithm commonly referred to as MPEG AAC. However, iBiquity has announced that in the *final* IBOC systems, the MPEG AAC compression algorithm will be replaced with an iBiquity proprietary compression algorithm referred to as PAC (Perceptual Audio Coding). Consequently, certain elements of the NRSC test program were postponed until the PAC compression algorithm could be incorporated in the next generation of iBiquity IBOC transmitters and receivers.

Recently, iBiquity provided ATTC with a transmitter and receiver that incorporated the new PAC compression algorithm into the FM IBOC system. ATTC used this hardware to test the audio performance of the PAC compression algorithm under *unimpaired* RF channel conditions. These tests were conducted in accordance with Section I of the NRSC FM laboratory test procedures documentation.

1.2 Document Scope

This document contains a summary of the relevant test methodologies and a tabulation of audio recordings generated (the “test results”).

1.3 Related Documents

The tests summarized in this document were conducted in accordance with a detailed ATTC test plan, as described in:

ATTC Doc. 02-07, Digital Audio Broadcasting, Performance of the iBiquity Digital FM IBOC System in Unimpaired Channel Conditions, Test Procedures, February 2002.

The reader is encouraged to refer to this test procedure documentation for a more in-depth discussion of test procedures and measurement methodologies. Additional details regarding the construction and performance of the ATTC IBOC DAB test platform may be found in:

Digital Audio Broadcasting, Test Bed Proof of Performance Record, Document No. 01-01, Revision 1.0, January 2001, Advanced Television Technology Center, Inc.

Digital Audio Broadcasting, Test Bed Proof of Performance Plan, Document No. 01-20, Revision 2.0, November 2001, Advanced Television Technology Center, Inc.

2 Summary of Methodology

The “second generation” FM IBOC transmitter and receiver (described in Table 2-1) were connected to the ATTC IBOC DAB test platform in place of the original “first generation” equipment. The test platform was configured such that all adjacent channel interference, multipath, AWGN noise and impulse noise impairments were disabled, and the IBOC receiver was fed by an unimpaired (“clean”) FM IBOC Hybrid mode RF signal.

The AES digital audio output of the IBOC receiver was then recorded by a professional quality 8-track digital audio tape recorder, as a number of NRSC identified audio cuts were played back into the FM IBOC transmitter. For certain audio cuts, additional audio processing had been previously applied to the source material by an Orban 6200 DAB audio processor. For the remainder of the cuts, there was no audio processing applied. Details on the audio processing assignments may be found in Section 4, as well as the test procedures documentation referenced in Section 1.3.

Next, the audio outputs of four analog receivers (as enumerated in Table 2-2) were also recorded in unimpaired RF channel conditions. In this case, however, the RF signal was a –47dBm (Strong) conventional analog FM signal, containing no IBOC components. These recordings are referred to as “analog reference” recordings in the NRSC nomenclature. In this case, all of the audio cuts were processed by an Omnia-FM audio processor. The processing of these audio cuts was identical to the processing applied in previous stages of the NRSC FM laboratory test program. Additional details are available in the test procedures documentation.

All of the digital audio recordings were transferred to uncompressed computer audio files (*.wav format), edited to eliminate periods of silence at the beginning and end of each cut, and then leveled such that all audio cuts had the same perceptual loudness. These cuts were provided to the subjective test laboratory (Dynastat, Inc.) by way of a relay through the iBiquity Digital Internet ftp site. An archival CD of the recordings was also retained at ATTC.

Table 2-1 IBOC FM Transmitter and Receiver Under Test

Type	Make	Model	Serial #	Software Revision
Transmitter/ Exciter	iBiquity	2 nd Generation – with PAC	---006---	1.03
Receiver	iBiquity	2 nd Generation – with PAC	---003---	1.03

Table 2-2 Analog FM Receivers Under Test

Type	Make	Model	Serial #
OEM Auto	Delphi	09394139	89DDSTM103490265
Aftermarket Auto	Pioneer	KEH-1900	UHHI086599UC
Home Hi-Fi	Technics	SA-EX110P-K	GX9DA84758
Portable	Sony	CFD-S22	S01-0433905-A

3 Description of the Test System and Parameters

3.1 Test Bed Description

The ATTC DAB Test Bed configuration is described in detail in ATTC Document No. 01-01. The performance of the ATTC Test Bed was verified according to the proof of performance plan detailed in ATTC Document No. 00-05. The results of the proof are documented in ATTC Document No. 01-01 (all of these documents are referenced in section 1.3, above).

3.2 RF Signals

The following subsections describe the standard RF signals employed throughout this series of tests.

3.2.1 Desired Analog FM

In all cases, a desired analog FM signal had the following characteristics:

- 1) Main channel modulation:
 - a) Stereo transmission
 - b) 75 μ s pre-emphasis
 - c) 10% pilot injection
 - d) Test dependent audio
 - i) Appropriate critical listening material peaking at 90% modulation (67.5kHz deviation) with dynamic range processing consistent with the musical genre of the audio. Pilot contributes 10% for total modulation = 100%
- 2) Subcarriers: None
- 3) Main Carrier:
 - a) 97.9 MHz
- 4) Power
 - a) Strong: -47dBm

3.2.2 Desired Hybrid FM

A Desired Hybrid FM signal is defined as the spectral sum of an analog desired signal (as described in 3.2.1) and the digital carriers as generated by an iBiquity Digital 2nd Generation IBOC exciter in hybrid mode. The digital carriers utilize OFDM modulation, and the audio undergoes rate reduction/compression as implemented by the iBiquity Digital PAC algorithm. The sum of *all* digital carriers in the hybrid signal has an *average* power that is 20 dB less than the average analog power.

4 Digital Performance Results Summary

4.1 FM IBOC Performance in Unimpaired Channel Conditions (NRSC I)

Digital audio recordings were generated for each of the conditions shown in Table 4-1. The following information may be helpful in understanding the construction of this table:

1. Each row of the table represents a single test.
2. The # column indicates the ATTC assigned test number.
3. The *Desired* column indicates the mode and signal strength of the RF signal.
4. The *Analog Proc.* column indicates the audio processing preset applied to the analog portion of the signal (details of the processor setup for each preset may be found in the test procedures)
5. The *Digital Proc.* column indicates the audio processing preset applied to the DAB portion of the signal. (The phrase “Hard Bypass” indicates that there was no audio processing employed for that particular test.)
6. The *Audio Cut* column identifies the specific audio cut under test.
7. The *Receiver* column indicates the receiver under test. (Note that “4 Analog RX” refers to the receivers listed in Table 2-2)

Table 4-1 IBOC Quality Test Conditions (NRSC Test I)

#	Desired	Analog Proc.	DAB Proc.	Audio Cut	Receiver
1001	Hybrid: Moderate	Light	Hard Bypass	Woman	IBOC
1002	Hybrid: Moderate	Light	Hard Bypass	Man	IBOC
1003	Hybrid: Moderate	Light	Hard Bypass	Brokaw	IBOC
1004	Hybrid: Moderate	Light	Hard Bypass	Bach	IBOC
1006	Hybrid: Moderate	Light	Hard Bypass	Enya	IBOC
1008	Hybrid: Moderate	Light	Hard Bypass	Glockenspiel	IBOC
1011	Hybrid: Moderate	Light	Hard Bypass	Saito	IBOC
1012	Hybrid: Moderate	Light	Hard Bypass	Persian	IBOC
1014	Hybrid: Moderate	Light	Hard Bypass	1812	IBOC
1015	Hybrid: Moderate	Light	Hard Bypass	Trumpet	IBOC
1016	Hybrid: Moderate	Light	Hard Bypass	MMW	IBOC
1017	Hybrid: Moderate	Medium	Hard Bypass	Simon	IBOC
1018	Hybrid: Moderate	Medium	Hard Bypass	Clapton	IBOC
1023	Hybrid: Moderate	Medium	Hard Bypass	Travis	IBOC
1029	Hybrid: Moderate	Hard	Hard Bypass	Grant	IBOC
1034	Hybrid: Moderate	Light	2B Classical	Carmen	IBOC
1038	Hybrid: Moderate	Light	2B Classical	Messiah	IBOC
1044	Hybrid: Moderate	Hard	Contemporary2-5B	EarthWindFire	IBOC
1045	Analog: Strong	Light	None	Woman	4 Analog Rx
1046	Analog: Strong	Light	None	Man	4 Analog Rx
1047	Analog: Strong	Light	None	Brokaw	4 Analog Rx
1048	Analog: Strong	Light	None	Bach	4 Analog Rx
1049	Analog: Strong	Light	None	Carmen	4 Analog Rx
1050	Analog: Strong	Light	None	Enya	4 Analog Rx
1052	Analog: Strong	Light	None	Glockenspiel	4 Analog Rx
1053	Analog: Strong	Light	None	Messiah	4 Analog Rx
1055	Analog: Strong	Light	None	Saito	4 Analog Rx
1056	Analog: Strong	Light	None	Persian	4 Analog Rx
1058	Analog: Strong	Light	None	1812	4 Analog Rx

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#	Desired	Analog Proc.	DAB Proc.	Audio Cut	Receiver
1059	Analog: Strong	Light	None	Trumpet	4 Analog Rx
1060	Analog: Strong	Light	None	MMW	4 Analog Rx
1061	Analog: Strong	Medium	None	Simon	4 Analog Rx
1062	Analog: Strong	Medium	None	Clapton	4 Analog Rx
1067	Analog: Strong	Medium	None	Travis	4 Analog Rx
1072	Analog: Strong	Hard	None	EarthWindFire	4 Analog Rx
1073	Analog: Strong	Hard	None	Grant	4 Analog Rx

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The ATTC is a private, non-profit enterprise formed by a coalition of broadcasting companies and industry organizations. The Advanced Television Technology Center has been providing independent test and measurement services to the broadcast industry for over eleven years. The work of the ATTC has been a key component of numerous broadcast industry standards and FCC rules and regulations. Through this work, the ATTC has earned an industry reputation of conducting fair and impartial tests in a manner that maintains the utmost technical quality.

For the testing of the iBiquity IBOC DAB System, ATTC project staff included: Paul K. DeGonia, *Executive Director* • Charles W. Einolf, Jr., *Deputy Executive Director* • Debbie Espinoza, *Office Administrator* • Jacob Kirkland, *RF Test Engineer* • Jonathan Kreinik, *Audio Editor* • Steve Thomas, *Technology Specialist* • Sean C. Wallace, *Systems Engineer*