A Appendix A - Receivers Under Test

Table A-1 IBOC FM Transmitter and Receiver Under Test

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

Table A-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

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B Appendix B - Audio Cut Lis t

Table B-1 lists the audio cuts used throughout the test procedures. In the test procedures, audio cuts are specified by their "nickname". The table below may be used to relate this nickname to the original source material. The table may also be used to determine what type of dynamic range processing should be applied to each individual audio cut. Note that the dynamic range processing is different, depending on whether the material is to be played through an analog FM or DAB system. Information on the processor settings which implement these different types of dynamic range processing may be found in Appendix C.

In cases where DAB processing is required (note that most cases do not require processing for DAB), the audio material shall be "pre-processed" in advance, by iBiquity Digital, using their Orban 6200-DAB audio processor.

Table B-1 Audio Test Material and Associated Processor Settings

Nickname	Artist/ Composer	Album/ Work	Song/ Movement	Type*	DAB Processing	FM Processing
1812	Tchaikovski (Classical Thunder)	1812 Overture	Track 17	CI	None/Bypass	Light
Bach	Bach	Brandenburg Concerto #5, D Major	Allegro	CI	None/Bypass	Light
Basil	Toni Basil	VH1, More of the Big 80's	Mickey	RFV	Contemp1-5B	Hard
Brokaw	Tom Brokaw	The Greatest Generation	---	SMV	None/Bypass	Light
Carmen	Bizet	Carmen	---	CI	2B-Classical	Light
Clapton	Eric Clapton	Best of Eric Clapton	Change the World	RMV	None/Bypass	Medium
Cole	Paula Cole	Harbinger	Happy Home	RFV	Light5B-20k	Medium
Cray	Moulton Labs	Bang&Olufsen Test Sequence	Roberty Cray	BJM	Contemp1-5B	Medium
Crowded	Crowded House	Woodface	Weather With You	RMV	2B-Classical	Medium
CSNY	Crosby, Stills, Nash & Young	Looking Forward	Sanibel	RMV	Light5B-20k	Medium
Debussy	Debussy	String Quartet in G Minor	Anime et tres decide	CI	None/Bypass	Light
Enya	Enya	Shepherd Moons	Angeles	NAI	None/Bypass	Light
EWF or EarthWindFire	Earth, Wind & Fire	Greatest Hits	Lets Groove	RMV	Contemp2-5B	Hard
Fagen	Donald Fagen	The Nightfly	I.G.Y.	RMV	None/Bypass	Medium
Fleetwood	Fleetwod Mac	Tango in the Night	Big Love	RMXV	2B-Classical	Medium
Glock	Glockenspiel	SQAM Disc	---	CS	None/Bypass	Light
Grant	Amy Grant	Heart in Motion	Baby, Baby	RFV	None/Bypass	Hard
Ibert	Jaques Ibert	Summertime Music for Oboe	Entr'acte	CI	None/Bypass	Light
Man	English Man	SQAM Disc	---	SMV	None/Bypass	Light
Messiah	Handel	Messiah	Hallelujah	CC	2B-Classical	Light
MMW	Medewski, Martin and	Shack Man	Hermeto's Daydream	JI	None/Bypass	Light

Nickname	Artist/ Composer	Album/ Work	Song/ Movement	Type*	DAB Processing	FM Processing
	Wood					
Persian	Saba	Persian Classical Music	The Yellow Sparrow	FI	None/Bypass	Light
REO	REO Speedwagon	Hi Fidelity	Keep on Loving You	RMV	None/Bypass	Hard
Saito	Moulton Labs	Critical Listening Excerpts CD	Kyoko Saito	CF	None/Bypass	Light
Santana	Carlos Santana	Supernatural	Smooth	RMV	Contemp1-5B	Hard
Simon	Paul Simon	Rhythm of the Saints	Can't Run But	RPI	None/Bypass	Medium
Stansfield	Lisa Stansfield	Lisa Stansfield	The Real Thing	RFV	None/Bypass	Hard
Stravinski	Stravinski (Bernstein Conducts)	Firebird	Track 5	CI	2B-Classical	Light
Travis	Randy Travis	A Man Ain't Made of Stone	A Heartache in the Works	CMV	None/Bypass	Medium
Trumpet	Trumpet	SQAM Disc	---	CS	None/Bypass	Light
Vega	Suzanne Vega	Nine Objects of Desire	Caramel	RFV	None/Bypass	Medium
Woman	English Woman	SQAM Disc	---	SFV	None/Bypass	Light

***Type Codes**

CI = Classical Instrumental
SMV = Speech Male Vocal
RMV = Rock Male Vocal
BJM = Blues/Jazz Male
CS = Critical Sample
CC = Classical Chorus
CF = Classical Female
CMV = Country Male Vocal
RI = Rock Instrumental
SFV = Speech Female Vocal
NAI = New Age Instrumental
RMXV = Rock Mixed Vocals
RFV = Rock Female Vocal
JI = Jazz Instrumental
RPI = Rock/Pop Instrumental
FI = Folk Instrumental

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C Appendix C – FM Audio Pr ocessor Settings

The tables in this Appendix provide detailed information on the setup of the FM audio processing equipment for several different"presets". These processing presets are applied to audio material depending on the genre of the audio. A complete list of audio cuts, their genre and their corresponding processor presets may be found in Appendix B.

For analog FM, the audio processing hardware consists of a Cutting Edge Omnia 4500. Settings for the Omnia 4500 FM processor were developed by the NRSC DAB Subcommittee - Test Procedures Working Group. These settings were designed to be *representative* of typical, real-world radio station processing.

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			
Low Gain	0.0	**PR-LIMITER**	
Mid Gain	0.0	Drive	0.0
Pres Gain	(+)1.0	Threshold	0.0
High Gain	(+)1.5	Attack	3
		Release	2
LF-AGC		Hold Thresh	4
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

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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

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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**	

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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		

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Appendix C

ATTC Results

Digital Audio Broadcasting

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

Summary of Test Results

Document No. 02-08B

February 2002

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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.

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2 Summary of Methodology

The "second generation" FM IBOC transmitter and receiver (described inTable 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 Section4, as well as the test procedures documentation referenced in Section 1.3.

Next, the audio outputs of four analog receivers (as enumerated inTable 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	2nd Generation – with PAC	---006----	1.03
Receiver	iBiquity	2nd 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

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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 section1.3, 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) 75μs 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.

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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 inTable 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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Acknowledgements

The Advanced Television Technology Center (ATTC) and its staff are grateful to the representatives of iBiquity Digital and the National Radio Systems Committee (NRSC) for their support during this testing.

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*

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Appendix D

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DYNASTAT – AUDIO TESTING METHODS AND PROCEDURES FOR EXPERIMENT RF1

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14 February 2002

INTRODUCTION

Dynastat performed the raw data collection for iBiquity Digital Corporation for the audio subjective testing in experiment **RF1**. Dynastat received digital audio files for 224 conditions from iBiquity, recruited a crew of listeners, presented the materials to the listeners, and delivered the raw data to iBiquity.

SUBJECTIVE TESTING FACILITIES

Dynastat has a Subjective Test Laboratory specifically designed for Audio Testing. The laboratory is contained in a quiet interior room that will accommodate the testing of up to four listeners at a time. Each listener is seated in an individual sound-treated Tremetrics audio testing booth with a measured ambient noise level < 35dBA. Audio samples are presented to listeners binaurally over Sennheiser HD-600 open-backed headphones. The subjective rating scales are displayed on a flat-screen Viewsonic VG150 LCD monitor located on a table opposite the window of each booth and the listeners enter their responses using a PC mouse. The only equipment inside the booth is a chair, a laptop desk, a pair of headphones, and a PC mouse.

Each listening station includes the sound-treated booth, an HP Vectra VL400 PC, a high-quality Lucid DA9624 digital to analog converter, and the Sennheiser headphones. Figure 1 shows two views of listening stations contained in Dynastat's Audio Testing Laboratory. The PC's, A/D converters, and headphones were provided to Dynastat by iBiquity. Sound samples are stored on the hard-disk of each PC and are presented to the listeners under program control using a software package developed by iBiquity. The software also displays the appropriate rating scale(s) on the monitor and collects and stores the listener's responses. Each listening station is independent and self-contained and requires no experimenter control or interaction once the listener has started an experiment. Dynastat's Audio Laboratory includes four listening stations with the individual PC's networked to a server PC used for loading audio files and compiling listener responses.

LISTENER SAMPLE

The sample of listeners for this experiment was stratified both for listener gender and age-group. Listeners were recruited to represent approximately equal representation in eight categories: four *Age-Groups* (16-24, 25-32, 33-42, 43-50) for each *Gender* (male, female). The experiment required Dynastat to deliver the subjective data from 40 *qualified* listeners, where *qualification* was based on performance on an initial screening-test developed by iBiquity and a post-hoc screening test designed to eliminate obvious outliers. To achieve balance in the stratification of the sample and at the same time account for disqualifications due to failures of

the screening-tests, 48 listeners were recruited for this experiment. Listeners were recruited primarily

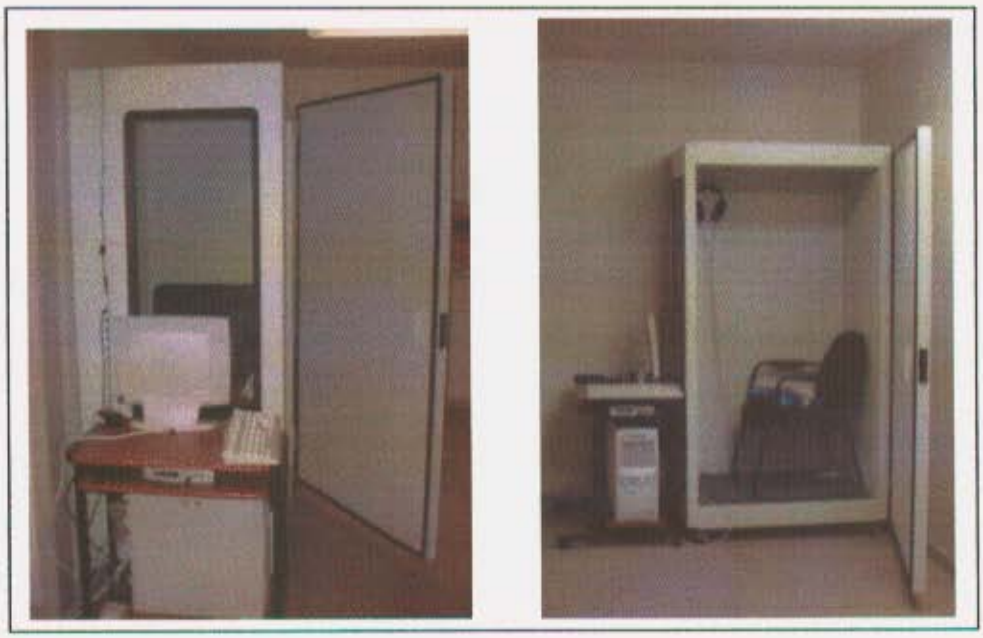

Fig. 1 Two views of a listening station contained in Dynastat's Audio Testing Laboratory.

from a pool of more than 2000 listeners contained in Dynastat's subjective testing database. This database is a continually evolving and expanding pool of listeners that Dynastat has maintained for use in subjective evaluation of speech-coding and voice-communications systems. Membership in Dynastat's subjective database is largely dictated by guidelines specified by ITU-T[1] and other standardization bodies.

PROCEDURES

Upon arrival at Dynastat, listeners completed a brief biographical data-sheet and received written instructions on the specific tasks to be performed in the experiment. Exhibit A shows the instructions that were provided to the listeners. Each listener was assigned a unique eight-character listener ID (i.e., **Eeesai**) coded for experiment (**Eeee**), gender (**s** = 1 for male, 2 for female), age-group (**a** = 1 for 16-24, 2 for 25-32, etc.), and individual (i.e., individual within the category, **i** = 1, 2, etc.). For example, the ID "RF1x*12*" would identify the 2nd individual listener who was a male listener in age-group 16-25 participating in Experiment RF1. The test administrator entered the listener's ID and biographical information into an Excel *Participant* file specific to the experiment. The overall duration of the experiment was approximately 2 hours and included three phases: a training phase, a screening phase, and a testing phase consisting of

[1] ITU-T Recommendation P.800, Methods for subjective determination of transmission quality, Aug., 1996.

four test sessions. The overall test duration is within the maximum testing time recommended by the ITU-T's recommendation P.800.

Training Phase

During the training phase listeners were presented a range of audio impairments typical of those involved in the testing phase of the experiment. The training phase was developed and provided to Dynastat by iBiquity and was used to expose and familiarize the listeners to the variety and range of conditions they were likely to hear in the subsequent screening and testing phases. The impairments presented in the training phase served to train the subjects to listen carefully for potential impairments in the audio samples. The listeners were given written instructions prior to the training phase. Exhibit A shows those written instructions. The training materials were presented to the listeners in the individual listening stations. There were six training trials, each involving two samples. In each training trial, the first sample was a "clean" cut followed by a second sample, an "impaired" cut of the same audio materials. Listeners entered a response using the ACR scale (described in a later section) for each of the two samples within each of the six training trails. The experimenter never discussed the specific types of impairments involved in the training samples or how the listeners should judge or value those impairments.

Screening Phase

Immediately after the training phase, listeners participated in a pre-test screening phase to ensure that they were able to reliably distinguish between "clean" and "impaired" samples. The listener's task in the screening phase was a "Reference-A-B" comparison in which the listener was required to decide which of two "test" samples (A or B) was the same as the reference sample. In each trial one of the test samples was the same as the clean or unimpaired reference sample and the other sample was an impaired sample. Figure 2 shows the PC response display that was used for the screening task. Playback of samples was under the individual listener's control, but the screening software required him to listen to all three samples, reference and two test samples, before the response options were available. Listeners were free to replay any or all of the three samples until they were ready to enter their response and proceed to the next trial. The screening phase consisted of one practice trial and ten test trials. Listeners were provided no feedback on the "correctness" of their responses during the screening test. After completion of the screening phase, the listeners exited their booth for a short rest-break during which the test administrator scored their screening responses. Listeners were not informed of their specific performance in the screening phase, but depending on their score, were allowed to continue in the experiment or were dismissed. If a listener scored less than 80% correct he was paid a partial fee for his participation and was not allowed to proceed to the test phase of the experiment. Listeners who scored 80-100% proceeded to the test phase as a "qualified" listener and their

rating data was used in "post-hoc" screening designed to provide the most reliable data possible. Description of the "post-hoc" data screening is provided in a later section.

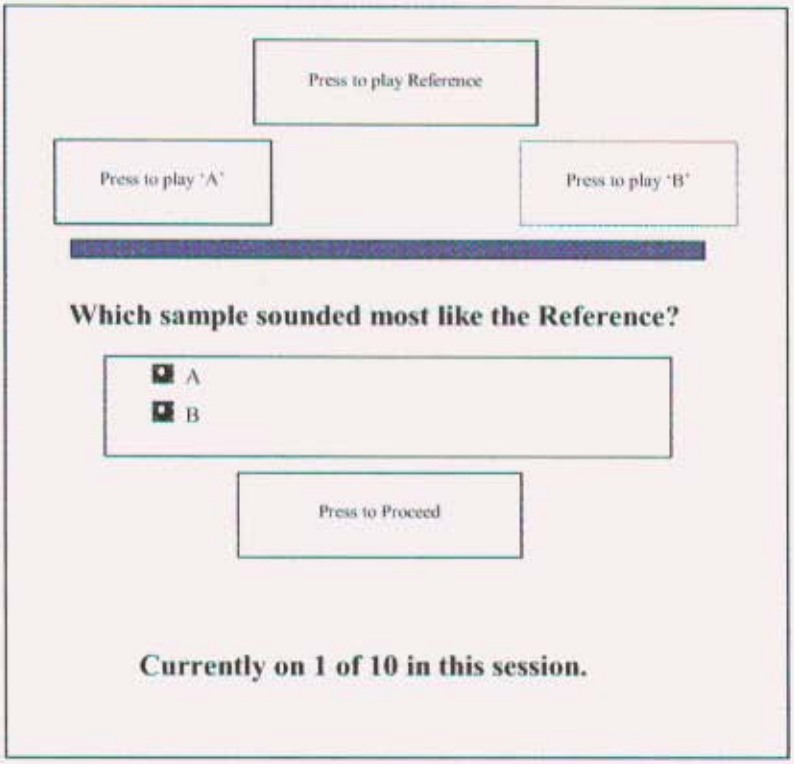

Fig.2 Response display for the Ref/A/B task in the screening phase.

Testing Phase

The Absolute Category Rating (ACR) method was used in this experiment to evaluate the subjective quality of the audio conditions. The ACR yields the Mean Opinion Score (MOS), a measure of overall audio quality. The ACR requires the listener to judge the quality of an audio sample using a five category rating scale where: Excellent=5, Good=4, Fair=3, Poor=2, and Bad=1. The category judgments are reported as a measure of overall audio quality, or MOS, on a scale of 1 to 5. A response display for the ACR testing task is shown in Fig. 3. The listener controlled playback of the audio samples but on each trial he could enter his response only after listening to the entire sample. The testing phase consisted of two practice trials followed by 224 test trials. The listener could adjust the playback volume during the practice trials. The playback volume set by the listener during the practice trials was then maintained throughout the remainder of the experiment. Test trials were grouped into four sessions of 56 trials each, separated by rest-breaks. During the rest-breaks listeners were required to remove the headphones and leave the booth.

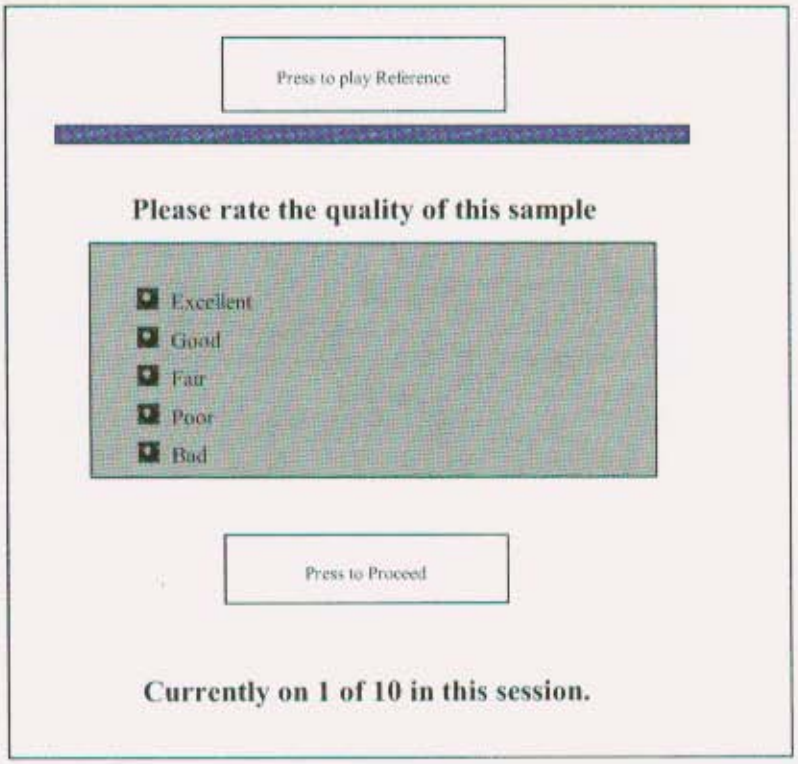

Fig. 3. Response display for the ACR task in the testing phase.

AUDIO MATERIALS

For this experiment 224 processed audio samples were supplied to Dynastat by iBiquity via Internet FTP. The files were provided in digital format (44.1KHz, 16 bit linear WAV). The digital files were loaded onto the hard-disk of the server PC and then distributed to the hard-disks of the individual PC's though a local area network.

AUDIO FILE PRESENTATION AND DATA COLLECTION

Dynastat prepared an Excel file that controlled the audio file presentation and data collection software. During this process the audio files were loaded and verified, file order randomizations were created, and the overall layout of the experiment was established (i.e., number of test sessions, number of trials per session, and number of rest-breaks). The iBiquity software package automatically accumulated the listener responses into an Excel *Response* spreadsheet. Once a test session had been initiated, the iBiquity software required no input from the test administrator. File presentation and data collection were controlled by the interaction of the listener and the software.

POST-HOC DATA ANALYSIS AND LISTENER SCREENING

At the conclusion of the raw data collection, the total set of listener data (i.e., the *Response* Excel file) was subjected to a post-hoc analysis to ensure the validity and the reliability of the data for each individual listener. A "Figure of Merit" (FoM) was calculated for each listener participating in the experiment. The FOM was the "coefficient of correlation" between the individual listener's vector of ratings and the vector containing the average ratings for the remainder of the listeners involved in the experiment. Thirty years of experience with subjective rating data has shown this FoM to be a valuable screening measure to remove clear "outliers" from the rating data (i.e., listeners who either can't or won't perform the rating task). A practical lower threshold for the identification of "outliers" is derived empirically from the data. Since the FoM is based on a correlation coefficient, it is largely determined by the range and variation in the experimental conditions. The threshold FoM for experiment RF1 was .380.

DATA DELIVERY

Dynastat compiled and delivered two Excel workbooks to iBiquity. The *Participant* workbook contained biographical and ID information. One worksheet within the Participant workbook contained the ID information for the 40 listeners retained in the final data set; a second worksheet contained the ID information for the 8 listeners removed from the final data set. The *Response* workbooks contained corresponding worksheets, each containing the raw response data for the two sets of listeners. Exhibit B shows the Participant worksheet for experiment RF1.

Exhibit A - Instructions for Experiment RF1

Training Phase

Prior to the actual tests you will have a training session. The purpose of the training session is to help you establish a personal reference for rating the audio samples. The format of the training session is exactly the same as the actual test. You will be asked to grade the samples on a 5-point quality scale. The training session consists of six pairs of samples (a total of 12 samples). In each pair the audio is the same, however, the first sample will be of high quality and the second sample will be of lesser impaired quality.

Testing Phase

Overview

Welcome to this audio testing session. Today, you will be participating in a listening experiment which should last about two and a half hours. You will be listening to music and speech samples over headphones. We are studying how various radios sound under different transmission conditions. There are three parts to this study. The first part is training, where you will listen to the music you will be encountering in your tests. The second part is a discrimination test. The third part is an opinion test.

Training Task

In the training session, you will hear a variety of sound samples. These sound samples include typical transmission "impairments" you might hear during the discrimination and opinion tests. These impairments should be noticeable. During the course of each sample you will hear varying degrees of the "impairment". You will indicate to the administrator if differences are heard.

Discrimination Task

In the discrimination task we will be testing your ability to hear different impairments. In this task your job is to decide which of two samples (A or B) is most nearly the same as the reference sample. The response display is shown in Fig. 1. To begin click on the box labeled "Press to Play Reference". The complete reference sample will be played. Similarly, you will click on "Press to Play A" and "Press to Play B" to play these complete samples. The program will not let you enter a response until you have heard all three samples completely. After listening to the complete Reference, A, and B samples you can enter your response to the question "Which sample sounded most like the reference?". After indicating your response click on the box labeled "Press to proceed". If you would like to play any of the samples again, you can press the appropriate box and do so as much as needed until you have made your decision. Once you have indicated your response and clicked on the "Press to proceed" you will be ready to start your next trial. During the course of your practice trial for this task you can set the volume level my moving the slider box. Once this level is set it cannot be changed for the rest of the session.

The discrimination session will consist of one practice trial and 10 test trials. When you complete the task open the door and proceed to the waiting room for a 10-minute break. During the break the administrator will score your data and let you know if you passed the test. If you passed the test then you are eligible to participate in the opinion test. If you did not pass you will be paid $20 for your efforts.

Opinion Task – The ACR-MOS Test

In this part of the experiment we are evaluating systems that might be used for the radio transmission of sound samples. You are going to hear a number of recorded samples and rating how good you think they sound.

On each trial a single sample will be presented. Each sample will consist of a 10-15 second music or voice passage. Please listen to the complete sample, then indicate your opinion of the overall sound quality of the sample using the following 5-point scale: Exellent, Good, Fair, Poor, Bad. Figure 3 shows the response display.

This task is different from the discrimination task. There is no stated reference against which to compare the samples you are hearing. You simply hear a passage and then make a rating. You will have to use an internal reference to judge ''the goodness'' of the sample. By that we mean, when you are listening to a particular sample, think about how a very good radio station would sound in your car and over your home radio. Judge the sample in relation to your memory of those two references.

Many things go into a quality rating. You'll be listening for impairments as well as the overall aesthetic quality. By aesthetic we mean beauty, musicality, character, sound quality, etc. Try to judge each sample in an overall sense. This is especially hard to do if a big impairment happens to occur at the end of the sample. So, before you rate each sample, take a few seconds to think about the entire sample you just heard. In that way, it won't be just your last impression that carries the most weight.

The experiment will involve four test sessions separated by short rest periods. In the first session you will have a practice block of 2 trials to familiarize you with the rating task and adjust your listening volume. The practice block will be followed by 4 test sessions of 50 trials each. If you have any questions, please feel free to ask the test administrator.

Please do not discuss your opinions with any other listeners participating in the experiment. Thank you in advance for your participation.

Exhibit B

Participant Worksheets for Experiment RF1.

40 Listeners Retained in Final Data Set

Experiment Code	Sex	Age Group	FoM	Experiment Code	Sex	Age Group	FoM
RF1x111	Male	1	0.655	RF1x211	Female	1	0.521
RF1x112	Male	1	0.658	RF1x213	Female	1	0.529
RF1x113	Male	1	0.449	RF1x214	Female	1	0.502
RF1x114	Male	1	0.596	RF1x215	Female	1	0.654
RF1x115	Male	1	0.509	RF1x216	Female	1	0.664
RF1x121	Male	2	0.552	RF1x217	Female	1	0.552
RF1x122	Male	2	0.657	RF1x221	Female	2	0.672
RF1x123	Male	2	0.615	RF1x222	Female	2	0.578
RF1x124	Male	2	0.705	RF1x224	Female	2	0.505
RF1x125	Male	2	0.530	RF1x225	Female	2	0.415
RF1x126	Male	2	0.382	RF1x226	Female	2	0.643
RF1x131	Male	3	0.506	RF1x232	Female	3	0.372
RF1x132	Male	3	0.520	RF1x234	Female	3	0.427
RF1x133	Male	3	0.525	RF1x235	Female	3	0.454
RF1x134	Male	3	0.601	RF1x236	Female	3	0.435
RF1x135	Male	3	0.734	RF1x237	Female	3	0.600
RF1x136	Male	3	0.491	RF1x241	Female	4	0.415
RF1x142	Male	4	0.525	RF1x243	Female	4	0.570
RF1x143	Male	4	0.380	RF1x244	Female	4	0.478
RF1x144	Male	4	0.401	RF1x246	Female	4	0.579

8 Listeners Deleted from Final Data Set

Experiment Code	Sex	Age Group	FoM
RF1x116	Male	2	0.255
RF1x145	Male	4	0.299
RF1x146	Male	4	0.266
RF1x212	Female	1	0.466
RF1x231	Female	3	0.333
RF1x233	Female	3	0.299
RF1x242	Female	4	0.363
RF1x245	Female	4	0.318