Appendix D

Summary of ATTC FM IBOC Compatibility Tests

1. Background

USADR commissioned the Advanced Television Technology Center ("ATTC") of Alexandria, Virginia to test the compatibility of their FM hybrid IBOC system with existing analog radios. The ATTC is an independent system evaluation organization, with expertise in the verification and testing of broadcast systems.

2. Test Overview

2.1 Receiver Selection Process

Three consumer FM receivers were randomly selected from each of the following broad classes:

- Automotive - Delco 16195161 FM stereo
- Home HiFi - Yamaha HTR5130
- Portable - Philips AZ1020/17 boombox

2.2 ATTC Test Bed

An automated test bed was constructed at the ATTC facility for compatibility testing of the USADR FM hybrid IBOC system. The system is capable of testing receivers under static and fading conditions, with up to two simultaneous interferers. The desired signal and its undesired interferers can be configured as either conventional analog signals or hybrid IBOC signals.

The equipment employed in the test bed is controlled by a custom computer program that was designed to implement the NRSC test suite; it can be easily modified to accommodate additional tests, as necessary. This flexible architecture allows the ATTC to fully test a receiver by performing 558 tests and record 27,900 signal-to-noise ratios in a period of less than ten hours. This automated system ensures accurate recording of data, and allows the expeditious completion of the test program.

The test bed employs commercial off-the-shelf broadcast exciters, audio processing equipment, and subcarrier generators. The digital portion of the hybrid IBOC signal was generated using the USADR IBOC 2000 Exciter. The digital signal was subsequently summed with the output of the analog broadcast chain to create the hybrid IBOC signal. The level of the DAB sidebands was 22 dB below the level of the analog host. The equivalent of 100,000K

Gaussian noise was added to the signal to accurately reflect the actual environment in which receivers operate. [1]

2.3 Test Description

The ATTC essentially performed two tests to evaluate the compatibility of the USADR FM hybrid IBOC system.

2.3.1 Objective Evaluation

These tests measured the resulting change in audio signal-to-noise ratio ("SNR") and total harmonic distortion ("THD") when DAB sidebands were added to an existing analog host or interfering signals for each of the receivers in static conditions (i.e., no fading). This test is comprised of the following procedures:

- Single Interferers – These tests measured SNR and THD changes caused by the addition of DAB to the interfering signals, over a range of desired-to-undesired signal ("D/U") ratios, with single upper or lower, first or second adjacent interferers.

- Dual Interferers - These tests measured SNR and THD changes caused by the addition of DAB to the interfering signals, over a range of D/U ratios, with various combinations of dual upper and lower, first and second adjacent interferers.

- Co-channel interferers – These tests measured SNR and THD changes caused by the addition of DAB to the interfering signals, over a range of D/U ratios, with a single co-channel interferer.

- Host compatibility - These tests measured SNR and THD changes caused by the addition of DAB to the host signal, over a range of desired signal levels.

2.3.2 Subjective Evaluation

These tests recorded audio before and after DAB sidebands were added to an existing analog host or interfering signals for the automotive receiver in fading conditions. This test is comprised of the following procedures:

- Single Interferers – These tests recorded audio before and after the addition of DAB to the interfering signals, over a range of D/U ratios, with single upper or lower first adjacent interferers.

- Dual Interferers - These tests recorded audio before and after the addition of DAB to the interfering signals, over a range of D/U ratios, with dual upper and lower first adjacent interferers.

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[1] Based on USADR's study of ambient noise levels, 100,000K was selected as a representative noise level for these tests.

- Co-channel interferers – These tests recorded audio before and after the addition of DAB to the interfering signals, at a fixed D/U ratio, with a single co-channel interferer.

- Host compatibility - These tests recorded audio before and after the addition of DAB to the host signal, over a range of desired signal levels.

3. Test Results

The ATTC reported the results of over 546 interference scenarios, 1674 desired to undesired signal ratios, and 83,700 SNR tests. The report in Appendix E focuses the presentation of results on the following interference scenarios, which might be expected at the edge of the protected contour of a typical FM station.

Desired Signal Levels	Level of Desired Signal Relative to the Interferer (D/U)		
	Co-Channel	1st Adjacent Channel	2nd Adjacent Channel
Moderate: -62 dBm	+20 dB	+6	-20

For these D/U ratios, the ATTC objective test report presents the changes in host analog SNR and THD caused by the addition of –22-dB DAB sidebands to an analog interferer or to the host. The ATTC also provided audio recordings from the automotive receiver in various interference and fading conditions, with both analog and hybrid signals.

3.1 Objective Test Results

The results presented by ATTC may be summarized as follows:

- Single first adjacent. The addition of –22-dB DAB sidebands to a single, -6-dB analog first adjacent degrades the audio SNR by an average of 4.2 dB.

- Single second adjacent. The addition of –22-dB DAB sidebands to a single, +20-dB analog second adjacent degrades the audio SNR by an average of 1.85 dB.

- Dual interferers. The addition of –22-dB DAB sidebands to various combinations of dual adjacent interferers degrades the audio SNR by an average of 4.1 dB. Simultaneous adjacent channel interference is generally not found in the real world, given the present allocation structure, at the levels tested in the ATTC compatibility document. However, that does represent the extreme and was worthy of investigation by the ATTC.

- Co-channel interference. The addition of –22-dB DAB sidebands to a single, -20-dB analog co-channel degrades the audio SNR by an average of 0.06 dB.

- Host compatibility: The addition of –22-dB DAB sidebands to a desired analog host degrades the audio SNR by an average of 0.4 dB over a range of desired signal levels.

3.2 Subjective Test Results

USADR has provided with this report eight samples of ATTC subjective recordings. The selections include cuts covering host compatibility, co-channel interference, and various combinations of first- and second-adjacent channel interference. Note that all selected samples were recorded using the EIA urban-fast fading scenario, since it represents the most challenging fading conditions.

4. Conclusions

The objective compatibility tests conducted by the ATTC have demonstrated that the addition of DAB sidebands to analog signals may slightly degrade the audio SNR. In the majority of signal environments, the addition of DAB sidebands to the analog host causes negligible degradation. Even though slight decreases in audio SNR were measured, the effects should largely go unnoticed in normal listening environments.

These conclusions are supported by the subjective audio recordings provided on the companion CD to this appendix. These tests demonstrate that the degradation of analog signals caused by the addition of DAB sidebands to co-channel or adjacent-channel interference in a mobile environment is virtually inaudible.