



December 15, 1999

Mr. David Layer
National Association of Broadcasters
1771 N Street, N.W.
Washington, D.C. 20036

Mr. Ralph Justus
Consumer Electronics Association
2500 Wilson Boulevard
Arlington, Virginia 22201

Dear David and Ralph:

On behalf of USA Digital Radio, Inc., enclosed you will find a report to the NRSC on USADR's laboratory and field tests of its IBOC DAB system. This report consists of two volumes. Volume One contains USADR's written report. Volume Two contains associated CDs and Videotapes referenced in the report.

USADR is extremely pleased to have this opportunity to present to the NRSC the first comprehensive report on IBOC testing. We appreciate your efforts and the efforts of everyone involved with the NRSC to move forward toward the selection of an IBOC system for the United States. We believe the data will show USADR has significantly advanced the development of IBOC with a system that offers superior audio quality and is immune to multipath and noise. We are confident that you will find USADR's current IBOC system is an improvement over analog.

Please do not hesitate to contact me if we can provide any additional information or answer any questions.

Sincerely,

A handwritten signature in black ink that reads "E. Glynn Walden".

E. Glynn Walden
Vice President, Broadcast Engineering

Enclosure

cc: Charles Morgan (Chair, NRSC)
Milford Smith (Chair, DAB Subcommittee)
Donald Messer (Chair, Evaluation Working Group)

USA **DIGITAL** **RADIO**

**Report on Laboratory and Field Testing
Presented to the
National Radio Systems Committee**

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This report summarizes the results of laboratory and field tests USA Digital Radio, Inc. (“USADR”) conducted between May and December 1999 as part of its IBOC system development efforts. USADR has prepared this report to demonstrate its system is an improvement over current analog radio broadcasting in accordance with the guidelines established by the National Radio Systems Committee (“NRSC”). USADR conducted these tests using numerous facilities including (i) USADR’s DAB laboratory in Columbia, Maryland; (ii) digital radio laboratories of Xetron Corporation in Cincinnati, Ohio; (iii) the independent laboratory test bed established for the USADR system at the headquarters of the Advanced Television Technology Center (“ATTC”) in Alexandria, Virginia; (iv) WPOC-FM, Baltimore, Maryland; (v) WETA-FM, Washington, D.C.; and (vi) USADR’s digital AM station in Cincinnati.

The results reported herein represent a snapshot of the USADR system at the time the tests were conducted. USADR’s test program, however, is an ongoing process. In some cases, system improvements have been implemented after completion of certain tests and may not be reflected in test results. In other cases, ongoing system optimization efforts may change the results reported in these tests. Moreover, USADR has opted to provide only the level of information it views as necessary to demonstrate an improvement over analog. To protect proprietary information, USADR has not included additional information which would demonstrate the full range of features of USADR’s system. Nonetheless, this report will allow the NRSC to conclude the baseline system parameters and results, even without further optimization, are an important and necessary enhancement over existing analog radio service.

The results of the tests show that USADR has developed a system that offers superior audio quality over today’s analog service. In addition, the USADR system is immune to multipath and

noise, providing for a much improved listening experience. In short, the system offers a compelling service upgrade for listeners and broadcasters without harming existing analog broadcasting.

USADR's ongoing test program has focused on several objectives. The tests have examined the existing analog environments in the AM and FM bands. In conjunction with USADR's system development efforts, the test program has been used to consider the merits of various technical solutions and tradeoffs for the implementation of IBOC. Most recently, the test program has focused on compatibility and performance tests of USADR's AM and FM systems.

The main text of this report contains an introduction about USADR, an overview of USADR's test program and a summary of the test results demonstrating that the USADR system is an improvement over existing analog broadcasting. Following the main text are a series of appendices which describe in detail (i) USADR's test program; (ii) the USADR IBOC DAB system; (iii) tests of the performance of the USADR system; (iv) compatibility tests of the USADR system; (v) independent testing of the USADR system conducted by the ATTC; and (vi) field tests conducted using WPOC-FM, WETA-FM, and USADR's AM test station in Cincinnati. The second volume of the report contains related audio and video reference material.

USADR acknowledges this report only contains a summary and analysis of the raw data USADR has compiled in its test program. Inherent in any summary is the risk of oversimplification or misunderstanding from lack of access to the underlying data. USADR encourages the NRSC to contact USADR with questions about this report to avoid misunderstandings or misinterpretations.

Any questions concerning this report should be directed to E. Glynn Walden, Vice President, Broadcast Engineering, USA Digital Radio, Inc., 8865 Stanford Boulevard, Suite 202, Columbia, Maryland 21045, (410) 872-1526.

I. Background on USADR

In 1991 USADR conceived IBOC technology and since that time has been a pioneer in the development of DAB for terrestrial radio. USADR is backed by a coalition of interests including broadcasters, equipment manufacturers and research centers in the United States and abroad. Twelve of the nation's largest radio broadcasters, including the ten largest, own USADR. Owners include ABC, AMFM, CBS, Chase Capital Partners, Citadel Communications, Clear Channel, Cox Radio, Cumulus Media, Emmis Communications, Entercom Communications, Gannett, Hispanic Broadcasting, Radio One and Sinclair Broadcasting Group. USADR has assembled a board of directors of prominent radio broadcasters, government regulatory and emerging technology experts, including Mel Karmazin of CBS, Jimmy de Castro of AMFM and Alfred Liggins of Radio One. USADR's owners have coverage in 196 of the 270 Arbitron-rated markets, access to 200 million listeners and combined revenues equating to 46% of the radio industry's total revenues.

Other broadcasters representing more than 500 stations are participating in USADR's Early Adopter Station Enhancement ("EASE") program. The EASE program, targeted at small and mid-size radio stations, offers to help broadcasters stay abreast of IBOC developments, provides station assessments about compatibility of equipment with USADR's system and distributes announcements of key milestones. Of these EASE participants, more than 35% come from non-Arbitron-rated markets.

USADR is building on this ownership base and assembling the broad business coalition necessary to ensure radio's rapid transition to a digital future. It has entered into joint technology and marketing agreements with radio broadcast transmission equipment manufacturers, including Andrew Passive Power, Broadcast Electronics, Continental Electronics, Energy-Onix, Nautel, Orban, QEI, Shively Labs, and Telos/Cutting Edge; DSP chip manufacturer Texas Instruments; and

receiver manufacturer Kenwood. Each member of this growing coalition has agreed to develop coordinated strategies for the market launch of IBOC technology and their associated products. Additionally, USADR has several development partners including Fraunhofer Institut für Integrierte Schaltungen (IIS) which is coordinating establishment of an international standard for Advanced Audio Coding ("AAC"), Xetron for AM system development and testing, and Bittware for SHARC technology and receiver/exciter boards for development test efforts.

Moreover, under an agreement announced yesterday between USADR and Digital Radio Express ("DRE"), DRE will support efforts to commercialize USADR's IBOC DAB system. The companies will cooperate in the development of USADR's IBOC DAB technology and the regulatory process required for its adoption in the United States. DRE will focus its business on data ventures, including specialized data applications for USADR's system.

Over the last eight years, USADR has developed a comprehensive understanding of the AM and FM broadcasting environments through identification of system requirements and the completion of critical tests and complex simulations. As a result, its IBOC DAB solution is designed to be a total systems approach, combining multiple digital signaling techniques with coding algorithms to deliver a superior performing, robust digital radio service. Over forty world-class engineers and scientists are presently working on USA Digital Radio's IBOC DAB system and the company holds 27 patents, with numerous pending patent applications covering broad aspects of IBOC DAB technology.

USADR's mission since it was founded has been, and continues to be, the introduction of IBOC DAB which will allow for a rational transition from existing analog to digital broadcasting for broadcasters and listeners. Because IBOC allows for the introduction of digital broadcasting along with the existing analog broadcast, IBOC is spectrally efficient, avoids the need for new

spectrum, facilitates the upgrade to digital in the course of normal equipment replacement cycles, and does not require any adjustments in listener behavior in order for the public to find a favorite radio station on the dial.

The development of any IBOC system requires various tradeoffs between the amount of audio programming and auxiliary services provided, the quality of the audio and the robustness of the system, and the need to create a strong digital audio service without disrupting existing analog broadcasts. USADR has designed its system to maximize the benefits for listeners and broadcasters and provides for the smoothest possible transition to digital broadcasting. The system enhances audio quality and robustness to improve the listening experience. At the same time, USADR has emphasized flexibility to enable broadcasters and consumers to decide their own timetable for upgrading to IBOC DAB.

II. Description of Test Program

USADR's report is based on the results currently available from USADR's laboratory and field testing of its IBOC DAB system. USADR initiated its test program in 1998 as part of its development work on IBOC DAB. Initial simulations and preliminary test results were included in USADR's Petition for Rulemaking filed with the Federal Communications Commission ("FCC") on October 7, 1998. Based on the NRSC's laboratory guidelines and field test guidelines, USADR modified its test program for 1999 to address many of the tests recommended by the NRSC. Although extensive test results are attached, additional tests are scheduled for 2000 as USADR continues to optimize its system.

Compatibility lab tests were performed at Xetron and the ATTC. These tests compared the signal-to-noise ratio of various receivers in the presence of analog interference against the results obtained from the addition of hybrid IBOC signals to the host station or adjacent channel stations.

In field tests conducted using WPOC-FM, compatibility is demonstrated in the form of recordings depicting the quality of the recovered audio with and without the hybrid IBOC signal on the host station and its first adjacent channel stations.

Performance lab tests were conducted at USADR's DAB laboratory to demonstrate the performance of the IBOC system when challenged by interference, multipath and noise. Lab results were confirmed in the field using WETA-FM and USADR's experimental AM station in Cincinnati.

III. Test Results

USADR's test program demonstrates the USADR system offers a compelling improvement over existing analog broadcasting by providing superior audio quality and robustness within a station's service area. The USADR system offers a higher audio quality than existing analog broadcasting. In addition, the USADR system's unimpaired digital coverage extends to a point where analog is degraded. Laboratory tests also confirm the USADR system will not cause audible interference to either the host analog or co-channel and adjacent channel non-host analog signals within a station's listening area. At the same time, the USADR system offers acquisition performance, stereo separation, and a level of flexibility equivalent to analog broadcasting in order to address listener expectations. The overall conclusion to be drawn from these extensive tests is that the USADR broadcast system is superior to the current analog broadcast system.

A. Audio Quality

The results of USADR's test program demonstrate IBOC will offer an audio quality superior to that offered by existing analog radio. USADR and ATTC, as part of its independent test program, attempted to use an objective perceptual audio and speech quality measurement software package to conduct subjective listening tests. Unfortunately, the software evaluation tool that was used did not provide consistent results; therefore the data is not available for this report. Instead, USADR

has included as attachments to this report the actual sound recordings of analog and digital made during the unimpaired audio tests and the USADR field tests. These audio recordings will allow the NRSC to make its own evaluation of the sound quality of the USADR system and to conclude the system is an enhancement over existing analog FM and AM.

B. Service Area and Durability

The USADR system will offer high quality digital coverage with increased robustness throughout a station's current service area. USADR's laboratory and field tests have confirmed the IBOC system's service area will allow for a significant enhancement of service to the public over that provided by existing analog service.

Because the USADR system incorporates a blend from digital service to analog, the system will always provide coverage as extensive as that offered by existing analog. Of greater interest, however, is the extent of digital coverage before the blend to analog. USADR's laboratory tests analyzed the performance of the digital system with Gaussian noise (as a baseline), with multipath fading and in the presence of first adjacent, second adjacent and co-channel interference. In each case, the tests examined the quality of digital coverage until the threshold of audibility ("TOA") of signal degradation and compared that against the quality of analog at the same point. The tests demonstrate that the digital system provides unimpaired digital coverage to the TOA. At the point where the digital signal begins to degrade, the corresponding analog audio itself exhibits audible degradation. This implies that the analog audio is degraded at signal levels where digital audio degradation is not yet perceptible. As a result, up to the point of digital TOA, the performance of the digital signal surpasses that of the existing analog signal.

USADR's field tests confirm the benefits of the digital system. The tests which were conducted at digital power levels below 500 watts, demonstrated significant coverage for both AM

and FM, depending on terrain, noise and interference. Within that coverage area, the USADR system provides audio, free of degradation due to the noise, multipath and interference that is characteristic of existing analog. Moreover, there is no muting and virtually no blending. Outside that area, there is a region where the system blends back and forth between digital and analog. This begins near the 45-dBu signal strength contour for FM and 3mV/M for AM. The IBOC receiver, even while blending, delivers audio quality which is superior to the analog available at that location. In fact, the analog audio received from the IBOC receiver often sounds better than audio from current analog receivers due largely to proprietary FM demodulation techniques USADR developed to mitigate the effects of multipath. Beyond the point of failure of the digital signal, blend will allow the listener to receive the degraded analog signal that remains available at that point.

C. Acquisition Performance

The USADR system provides instant acquisition performance for the listener. The performance, from the listener's perspective, will be identical to current acquisition expectations for existing analog broadcasts. The listener will experience instant acquisition both for initial tuning of stations and for re-acquisition of lost signals.

USADR's system incorporates both analog and digital components. The receiver instantly acquires the analog signal, providing the listener with instant access to station programming. At the same time, the system searches for the digital signal. Upon frequency acquisition, the system tracks the digital symbols. Upon frame lock, the receiver blends from analog to digital. Although the total digital acquisition process takes several seconds, the listener is able to receive analog audio during that time.

D. Auxiliary Data

DAB, in its most basic form, is simply a digital bit-stream transmitted in the AM and FM bands. Because the digital bit stream can be devoted to either audio or data, the USADR system has the capability to provide data services in addition to the primary audio signal. In order to achieve the USADR system's design requirement of robustness and improved audio quality, a majority of the capacity of the USADR system is devoted to the primary audio signal. However, the system supports auxiliary data on FM, which greatly upgrade the existing SCA services, and a low rate data capability on AM.

The USADR FM system will allow broadcasters to provide ancillary services. The broadcaster can select a guaranteed data throughput by trading off audio quality for a dedicated data bit stream. For example, if the broadcaster runs a talk show, 64 kbps could be sufficient for audio, therefore, 32 kbps could be set aside for data. The AM system also has this same capability, only with a smaller amount of data throughput.

32 kbps of "opportunistic" data, available depending on audio programming can be sporadically multiplexed with the audio on a priority basis or when spare bandwidth is available on the FM system. For example, during quiet segments, commercials that do not require CD-like quality audio or talk shows, bits can dynamically be used for data. The AM system also features this same capability, only with a smaller amount of throughput.

E. Edge of Coverage

USADR's system is designed to provide listeners with the same performance at the edge of coverage as listeners have come to expect from analog broadcasts. Typically, digital systems experience muting at the edge of coverage. In essence, the signal is nearly unimpaired until it completely fails. This has been termed the "cliff effect." The USADR system blends from digital

to analog at the edge of coverage to provide the listener with more graceful degradation than can be provided with the loss of the digital signal. When the digital signal fails, the system gracefully blends to analog. Although analog may be severely degraded at the point of failure of the digital system, the blend to analog can extend the coverage area until the listener deems the analog quality to be unlistenable.

F. Stereo Separation

The USADR FM system provides full stereo separation to the extent of digital coverage. This is superior to existing analog receivers which frequently blend to mono within the core service area due to multipath, noise or interference. After the blend to analog at the edge of coverage, stereo separation is the same as that for existing analog. The USADR AM system provides stereo information within the digital coverage area, blending to analog at the edge of coverage similar to the FM system.

G. Flexibility

The USADR system has been designed to maximize flexibility for listeners, broadcasters, and equipment manufacturers. Because the USADR system can accommodate the new digital signal without adversely impacting existing analog broadcasts, broadcasters will be able to upgrade to digital at their own pace while retaining current analog service. The USADR system also is designed to facilitate future upgrades without disruptions to analog broadcasts. The system will permit the introduction of new features, such as data, without obsoleting the digital radios in the market prior to any such introduction. This backward compatibility will promote consumer acceptance of IBOC since consumers know their radios will continue to work in the future.

H. Host Analog Signal Impact

DAB power should be maximized to provide digital coverage consistent with existing analog service while at the same time minimizing impact on the host (and adjacent channel) analog signal. USADR's tests of host compatibility measured the degradation introduced to the host analog signal by its IBOC DAB sidebands. The tests measured the audio Signal Noise Ratio ("SNR") of the host FM signal with and without IBOC DAB signals, in-fading and non-fading environments. The test was performed at weak, moderate and strong signal levels and with ambient noise temperatures of 10,000K and 100,000K.

USADR's tests demonstrate a car stereo performs consistently better than a boombox and home HiFi, even in an all-analog environment, presumably because of superior filtering. However, all three radios were virtually unaffected by the addition of DAB at any level, regardless of the signal level or environment.

USADR confirmed these results in compatibility field tests conducted using WPOC. In those tests, the station's analog signal was measured as the digital signal was switched on and off. These tests showed no perceptible difference in the recorded audio upon addition or removal of DAB sidebands. The addition of DAB was not audible in a clean, high-signal, interference-free environment. The digital sidebands will cause less host interference in lower signal level environments due to noise and interference masking effects.

I. Non-Host Analog Signal Impact

USADR's tests of first adjacent compatibility measured the degradation introduced to the desired analog signal by a first-adjacent hybrid IBOC signal. USADR measured the analog audio SNR of the desired IBOC signal in the presence of a first adjacent signal, with its DAB turned on and off for both AM and FM signals. It also assessed the audibility of the first adjacent signal when

listening to both quiet and modulated desired FM signals. In addition, the test recorded the levels of the first-adjacent DAB sidebands at which the TOA and Point of Failure (“POF”) were reached for each of the receivers, with both quiet and modulated desired FM signals. The test was performed at weak and moderate levels with ambient noise temperatures of 10,000K and 100,000K and under fading and non-fading environments for FM and screen room low noise environments for AM.

The host compatibility tests indicated that better filtering in the car stereo results in better immunity to noise induced by DAB sidebands. However, the car stereo holds no clear advantage in rejection of first-adjacent DAB sidebands, due to their spectral occupancy under the desired channel. In fact, for both AM and FM the introduction of DAB to a -6-dB first adjacent signal has very little effect on audio SNR of the desired analog signal (less than 3 dB in even the cleanest environment), regardless of the receiver. Clearly, degradation due to the environment, such as noise and the analog portion of first adjacents, dominates over any additional noise added by baseline DAB. This finding was further validated in subjective audio tests, which showed that, with audio on the desired channel, the addition of baseline DAB to a -6-dB first adjacent signal is virtually inaudible under all signal strengths and environments.

The FM first adjacent compatibility results were confirmed in the field. USADR measured the impact of the WPOC digital sidebands on WMMR’s and WFLS’s 54-dBu and 40-dBu FCC contours. These points were chosen because they represent the strongest impact on the first adjacent stations. The tests demonstrated that there was no perceptible difference in the recorded audio upon addition or removal of the digital sidebands from WPOC except at WFLS’s 40dBu which is WPOC’s 74 dBu. At this location, because of the large disparity in signal strengths, a performance difference can be heard. However, the reception without WPOC’s DAB “on” of WFLS is so poor, it is not listenable. Therefore, USADR has concluded the addition of digital sidebands to the first

adjacent analog signal does not introduce audible degradation to the desired signal within its listenable coverage area.

In summary, USADR's laboratory and field tests represent a series of important tests in proving that this IBOC system offers the benefits of digital broadcasting. The USADR system is a quantitative enhancement over existing analog AM and FM broadcasts.