THE OLD METHOD:
STANDARDIZE THE SIGNAL

In the past, standardization activities have concentrated on the specification of a broadcast signal (Figure 1). Once the signal is defined and receivers are built for that particular signal, it is difficult to incorporate improvements. As technology improves, then the standard is either abandoned, or inflexibility limits its usefulness.

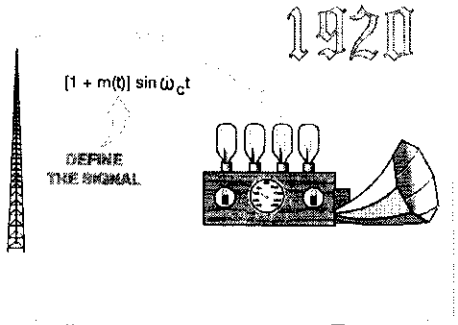
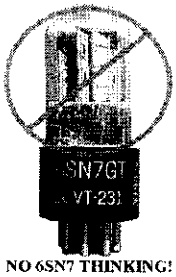


Figure 1 – Standardization by Defining the Transmitted Signal

Standardization activities often include highly competitive "systems battles," where considerable resources are expended in political as well as technical pursuits, promoting one's own technologies and attacking those belonging to others. The best technology does not necessarily emerge victorious. A software based system would eliminate "systems battles."

The old way of specifying the broadcast signal has been called "6SN7 thinking" (Figure 2). (For younger readers, "6SN7" refers to a type of vacuum tube developed well over half a century ago[2].) When the 6SN7 was in use, the only practical approach to standardization was to specify the transmitted signal.



NO 6SN7 THINKING!

Figure 2 – Archaic "6SN7 Thinking"

THE MODERN METHOD:
STANDARDIZE THE RECEIVER

Nowadays it is possible to instead standardize the receiver, allowing several different transmission methods to be used, invisibly to the receiver's user (Figure 3).

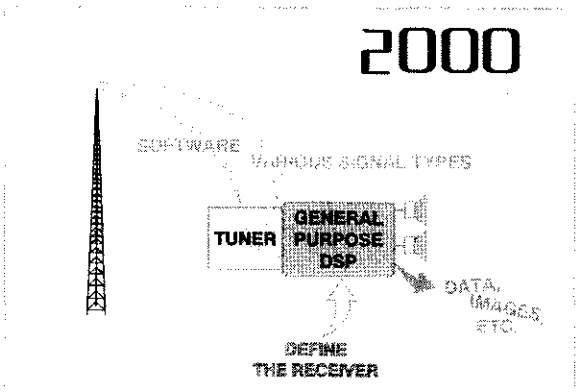


Figure 3 – Standardizing the Receiver Instead of the Signal

Regardless of what kind of digital AM broadcasting system is eventually implemented, the decoding will most likely be done with a general purpose DSP chip or core, as opposed to a dedicated single function hardware design. General purpose DSP chips are inexpensive, and allow fast development and easy product improvements.

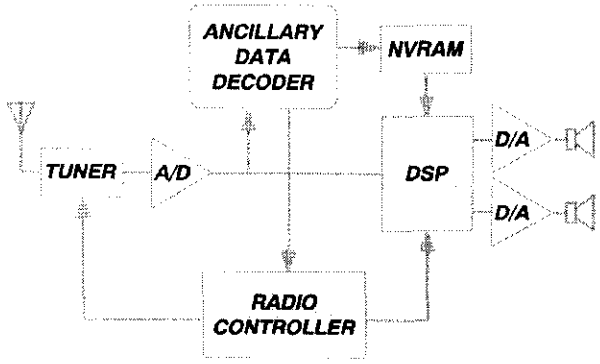
An example of consumer products using general purpose DSPs is certain car radios, which use a Motorola DSP chip set to do IF filtering, AGC, and demodulation of analog AM and FM stereo broadcasts[3].

Another example is computer modems. Several manufacturers have produced 33.6 kbit/second modems which may be software-upgraded in the field to 56 kbits/second. The modem example is particularly pertinent because a large part of a digital AM radio will be the decoding portion of a modem.

An example of an existing system where the receiver is specified is MPEG. The MPEG video standards are essentially specifications for decoders, not for an exact method of signal encoding. The MPEG standards define the operation of the decoder, and it is up to encoder manufacturers to develop their own methods of generating a compressed signal. The MPEG standards do not tell an encoder manufacturer exactly how to produce motion vectors, for example. This kind of standard allows different manufacturers to compete in providing different kinds of tradeoffs: performance, artifacts, cost, etc.

Even if the radio is single-function (AM radio only), the DSP could be expected to be basically general-purpose in nature. If the AM radio is part of a consumer item with other functions, such as a television receiver, a Compact Disc player, or a digital audio player which uses some sort of compression, there would be even more reason to use a general-purpose DSP because it could perform these various functions by executing different software.

The standardized digital AM receiver would consist of a tuner followed by a general purpose digital signal processor (DSP), with a predefined method of transmitting decoding software to the receivers (Figure 4). Digital AM receiver operation would be controlled by software, downloaded to the receivers over the air. The modulation and compression types could be almost anything. As new modulation coding and audio compression algorithms are developed, they could be coded into the receiver's known machine language and broadcast along with the program material. Importantly, it would allow new techniques to be used almost immediately after they are developed.



Conceptual Block Diagram of Software Controlled Digital AM Radio

Figure 3 – SDR Broadcast Receiver

A software based digital AM system could actually advance the introduction of digital AM by several years. The tasks of receiver design and signal specification could proceed in parallel rather than serially. The digital AM process would not have to be slowed by a long comparative investigation of different modulation types and audio compression methods.

OBJECTIVES FOR DIGITAL AM BROADCASTING

The objective of the DRM is to select a "...single, unique, tested, non-proprietary, evolutionary world-wide standard for digital broadcasting in the broadcasting bands below 30 MHz." To the extent that it is unlikely that a single modulation type and a single compression type will be clearly superior for all users on all frequencies under all propagation conditions for all time, a software based system becomes attractive.

The objectives of broadcasters and receiver users vary widely. Some broadcasters only care about their groundwave coverage area. HF broadcasters only care about skywave propagation. Some broadcasters have interference problems while others do not. Propagation conditions, interference, and antenna patterns frequently change with time of day.

A software based system would allow broadcasters to tailor the transmitted signal to best serve their listeners. There are many tradeoffs. Important ones include:

1. Daytime/nighttime modes. A station may transmit a higher data rate, with less forward error correction (FEC), and better audio quality due to lower compression during the daytime. At night, particularly if the station reduces power and/or uses a more restricted directional pattern, the tradeoff could be changed to make the signal more robust, but at the expense of a lower data rate, higher compression, and reduced audio quality.

2. Audio quality tradeoffs. Some of the proposed systems for digital AM broadcasting provide audio payload data rates of 6-48 kbits/sec[4], 32 kbits/sec[5], 20 kbits/sec[6], or up to 48 kbits/sec[7]. At these bit rates, the presently available audio compression algorithms provide audio which is perceptually lower than Compact Disc quality. The modulation method can be changed to provide a higher data rate and higher audio quality but at the expense of coverage area. Conversely, the coverage area can be improved but at the expense of data rate and therefore audio quality. Similarly, tradeoffs can be made between coding (and decoding) time delay versus audio quality.

3. Short fade immunity versus time delay. If a station serves a mobile audience in an area with many highway overpasses, or if an electrical storm is passing through the area, time interleaving can be increased to transform the burst errors from short fades or lightning into correctable errors. However, this tradeoff

would necessarily increase time delay. Unless redundant, non-delayed audio were transmitted, there would be a short delay from the time the station is selected until audio output from the receiver begins.

4. Adjacent channel interference. A station may broadcast a signal with more robust encoding (lower data rate) on the sideband with the most interference, and a higher data rate on the sideband which has less interference.

AUDIO COMPRESSION ALGORITHMS

Presently available audio compression algorithms require approximately 100 kilobits per second to provide audio quality comparable to FM stereo under good reception conditions, and somewhat more to sound similar to a Compact Disc. At the data rates which can be presently supported by digital AM systems, the audio quality will be somewhat worse. This has several implications.

First, unless compression technology improves significantly prior to the introduction of digital AM, at its introduction digital AM will not have audio quality comparable to FM or to Compact Discs.

Second, it will be highly desirable to have a digital AM system which will allow improvements in audio compression algorithms to be incorporated without changing the receivers.

Third, audio quality improvements through future compression technology advances will be possible only if receivers are easily field reprogrammable.

Audio compression technology seems to be progressing faster than modulation coding technology at this time. Even if a totally new audio compression technology (such as fractal audio) is developed, as long as it can be coded for the receivers, it can be implemented almost immediately.

ANCILLARY DATA SYSTEM

The signaling system used to transmit the decoding software to the receivers will be called the "ancillary data channel" in this paper. This would be a low speed signaling system which would occupy roughly 1-10% of the channel capacity. The other 90-99% of the channel would be occupied by the broadcast program material (which may include data, images, etc. in addition to audio programming).

When a receiver is tuned to a digital AM station, it first looks for the ancillary data channel. Ancillary data informs the receiver what the modulation type is, and what kind of audio compression the station is using. In most cases, the receiver will look in its nonvolatile memory (NVRAM) to find the particular decoding software for the station. If it finds it, it will then begin decoding the broadcast. In the rare situation when the receiver does not find the proper decoding software, it will download the decoding software to its NVRAM from the ancillary data channel. While the software is downloading, the receiver may provide an indication to the user that it is in a "learning" mode and that decoding will commence shortly. When the software has been downloaded, the receiver's audio outputs will unmute.

In most cases, however, use of new modulation formats will be preceded by software downloads beginning perhaps a month ahead of time . By that time, most receivers will have been updated, so that when a new modulation type is broadcast, the receivers can already decode it.

Broadcasters may also wish to cooperate by transmitting all publicly known decoding algorithms so that when tuning to a new station, the receiver will already know how to decode it.

Receivers which include other functions, such as digital audio broadcasting (DAB) receivers, computers, television receivers, etc., could receive software updates via alternative modes, such as FM broadcast subcarriers, the internet, or data included with TV or DAB.

Many receivers, including some battery operated types, may include a software search function. When the receiver is not in use it may periodically turn itself on and scan for stations using new transmission methods. If it finds a new transmission type, it would download the software for that kind of broadcast.

As transmission methods become obsolete, receivers could be made to sense the lack of use of a particular algorithm over time, and old decoding software could be automatically purged to make room in NVRAM for new software.

ANCILLARY DATA MODULATION METHODS

All of the candidate technologies for ancillary data transmission are well understood but some cooperation will be required among standardization bodies to define the method for transmitting decoding software to the receivers. This paper includes such a "straw man" proposal, intended as a starting point for discussion.

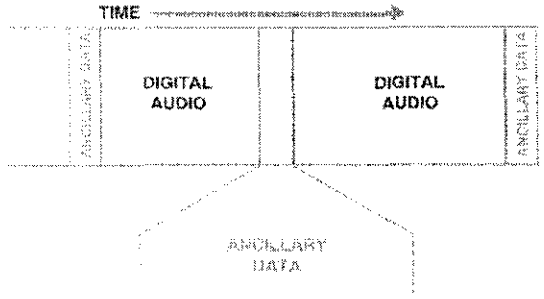
The ancillary data channel could be transmitted using a simple and robust bilevel phase shift keyed (BPSK) modulation system. The parameters of this signal would be adjusted depending on the program channel's basic modulation method.

At this time there are primarily two basic modulation methods for the program data: single carrier and multiple carrier modulation.

An example of a single carrier modulation system is quadrature amplitude modulation (QAM). Orthogonal Frequency Division Multiplexing (OFDM) is an example of a multiple carrier system.

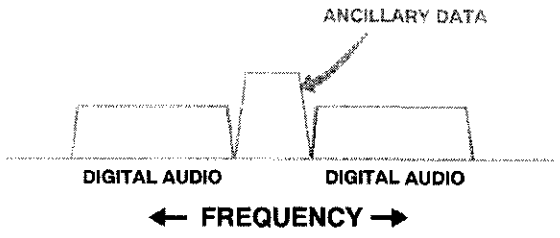
The ancillary data channel would operate at the station's "carrier frequency," meaning the frequency where the carrier would be if the station were broadcasting a conventional analog signal. Two methods of multiplexing the BPSK ancillary data channel modulation are proposed - one for single carrier and one for multiple carrier systems.

For single carrier modulation, the ancillary data channel would be time division multiplexed (Figure 5). For multiple carrier signals, the ancillary data channel would be frequency domain multiplexed (Figure 6).



Time Domain Multiplexing of Ancillary Data

Figure 5



Frequency Domain Multiplexing of Ancillary Data

Figure 6

The difference between the two forms of the BPSK ancillary data channel is that while one transmits in bursts at a high data rate, the other transmits slowly but continuously.

In either case, the ancillary data demodulator would also serve as a carrier reference (digital phase locked loop or DPLL) for whatever demodulation method is used by the receiver.

SINGLE CARRIER ANCILLARY DATA

In the time domain multiplexed single carrier systems, a short burst of BPSK carrier would be transmitted at either 0 degrees or 180 degrees with respect to the unmodulated carrier. A single bit could be transmitted in a 125 microsecond time interval.

The overall broadcast signal would transmit its normal single carrier modulation system most of the time, and would occasionally transmit short bursts of ancillary data. For example, 128 bits of ancillary data could be transmitted in an interval of 16 milliseconds. Then 384 milliseconds of compressed audio data could be transmitted, and the cycle would repeat. This would result in an ancillary data rate of 320 bits per second, using 4% of the available time in the broadcast signal.

Each ancillary data packet would consist of a BPSK header, a preamble, one or more subpackets, and FEC overhead. Subpackets contain station identification, decoding method, decoding software, etc. Each subpacket would, in turn, carry a header telling what kind of packet it is, a byte count, and FEC overhead. Ancillary data packets could vary in length and in frequency. So, if a raw data rate higher (or lower) than 320 bits per second is required, it can be obtained simply by changing the packet length and/or the packet frequency.

MULTIPLE CARRIER ANCILLARY DATA

In a multiple carrier system, a BPSK signal would still be transmitted at the station's carrier frequency. However, instead of occupying a percentage of the transmission time, it would occupy a percentage of the spectrum. The multiple carrier ancillary data channel would consist of a signal of approximately 320 Hz bandwidth. Using simple BPSK modulation, this could provide a raw bit rate of 320 bits per second, with the duration of each symbol being 3.125 milliseconds.

OFF AIR DOWNLOADS OF DSP SOFTWARE

Although the architecture and processing requirements of a general purpose DSP receiver are not yet defined, we can make estimates of software download time based on some assumptions.

Assume that the receiver's DSP capability is 100 million instructions per second (MIPs), and that there is one 16 bit word per processor instruction, and that the intermediate frequency (IF) signal is sampled at 44.1 kHz to allow a 20 kHz wide signal to be demodulated. Also assume that the DSP code is entirely "in-line;"

that is, there are no loops, and there is no branching (this will be close to worst case). Using these assumptions, the DSP will be able to perform 2268 instructions for each 44.1 kHz input sample. The DSP software would occupy 16*2268=36288 bits (4536 bytes) of program memory. At a net data rate of 256 bits/sec, this program could be downloaded to the receiver in about two minutes and 22 seconds. Additional time would be required for non-program data such as any DSP filter coefficients, and for packet overhead. The point of this illustration is that download time will be measured in minutes rather than seconds or hours.

If a receiver were to contain 256k bytes of NVRAM for decoding software, it would be able to hold 57 different programs of this size.

At least in the case of the single carrier system, more of the channel capacity could be allocated to ancillary data, which would provide for faster software downloads when a new system is being introduced.

PROPOSED ANCILLARY DATA STRUCTURE

Regardless of whether the ancillary data channel is present in bursts for single carrier or continuously for multiple carrier modes, the proposed ancillary structure is the same (Figure 7).

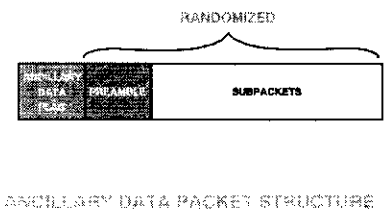


Figure 7

The ancillary data structure proposal is conventional, using several established techniques. It includes Reed-Solomon forward error correction, interleaving, and data randomization.

Each group of ancillary data bits is called a packet. Each packet, in turn, can contain several subpackets. The subpackets contain data such as decoding software, station identification, etc.

The ancillary data packets are BPSK coded, with a 0 corresponding to 0 degrees and a 1 corresponding to 180 degrees with respect to unmodulated carrier.

Each ancillary data packet begins with an ancillary data flag which has three components (Figure 8).

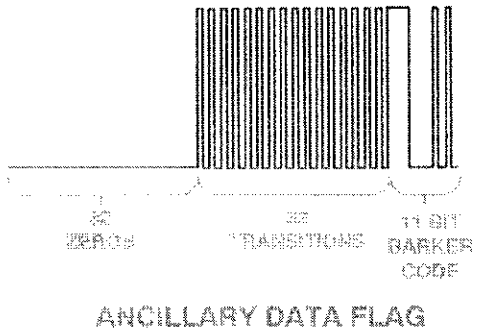
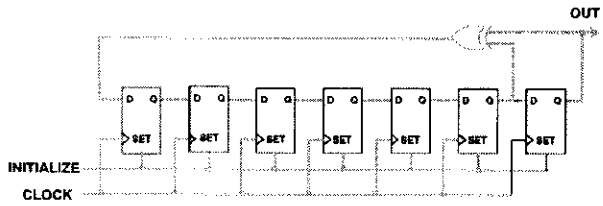


Figure 8

To aid in receiver PLL locking, each ancillary data flag begins with a 32 bit burst of carrier at 0 degrees. In other words, ancillary data begins with a string of 32 zeros. To aid in the locking of the bit clock, the next 32 bits are an alternating 101010... pattern. The final component of the ancillary data flag is an 11 bit Barker code, which assures proper byte alignment[8]. A Barker code minimizes the degree of agreement for shifted versions of the frame pattern. The particular 11 bit Barker code is 11100010010.

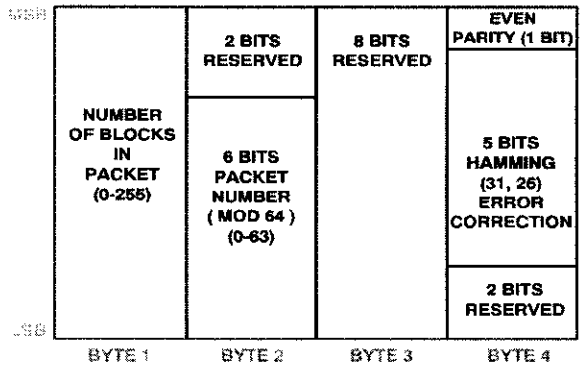
The rest of the data following the ancillary data flag is randomized with a pseudorandom sequence (Figure 9). The polynomial for this sequence is 1+X6+X7. This same randomization sequence is used in the SONET (Synchronous Optical Network) telecom standard. Although this sequence repeats after only 127 bits, the maximum run length is only 7 bits.



PSEUDORANDOM SEQUENCE GENERATOR

Figure 9

Following the ancillary data flag is a preamble (Figure 10). The preamble is four bytes (32 bits) long. The preamble is coded with a Hamming (31,26) linear error correcting code[9]. 26 bits are data and 5 bits are used for error correction. This code will correct single bit errors and detect double bit errors. The remaining bit is a simple even parity bit taken over all four bytes.



ANCILLARY DATA PREAMBLE

Figure 9

These bytes are transmitted least significant bit (LSB) (bit 0) first. Byte 1 contains an 8 bit integer which carries the number of blocks in the data portion of the packet. A block consists of 15 bytes; this number comes from a conveniently sized Reed-Solomon error correction code. If the data portion of the packet does not exactly fit within an integer number of blocks, the remainder of the block payload will be filled with zeros.

The second byte in the preamble contains a 6 bit value in its 6 LSBs which is a modulo 64 value for the ancillary data packet number. The purpose of this value is to allow the receiver to determine whether it has missed any ancillary data packets. The packets will be numbered 0, 1, 2,... 62, 63, 0, 1,...

The 2 most significant bits (MSBs) (bit 7) of the second preamble byte, along with all 8 bits in the third byte and the 2 LSBs in the fourth byte, are all reserved and should be set to zero. Bits 1-5 of the fourth byte are the Hamming code error correction bits. The LSB (bit 7) of the fourth byte is simple even parity for all four bytes of the preamble.

Subpackets occupy the remaining data space in the ancillary data packets (Figure 11). There are several different kinds of subpackets, containing station identification, receiver software, and other information.

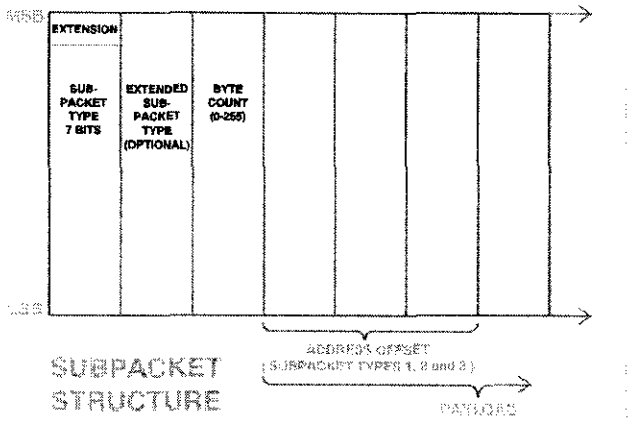
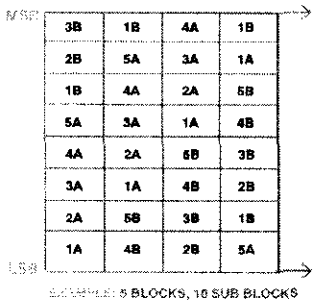


Figure 11

The data transmitted in the subpackets is bit-interleaved (Figure 12). The purpose of the interleaving is to transform burst errors into more correctable isolated errors within the data blocks. The level of interleaving is equal to twice the number of data blocks indicated in the first byte, because each block consists of two sub-blocks. For example, if the ancillary data packet contains 5 data blocks (75 bytes), then the LSB of the first byte is transmitted in sub-block #1A, bit 1 is transmitted in sub-block #1B, bit 2 is transmitted in sub-block #2A, etc. until bit 10 is transmitted in sub-block #1A again. The sequence repeats through the end of the packet.



SUBPACKET BIT INTERLEAVING

Figure 12

Each block consists of two sub-blocks (Figure 13), each coded with a Reed-Solomon expurgated (15,12) code which operates on a word size of 4 bits[10]. This code will correct any number of errored bits in a single word, and will detect, but not correct, two errored words. Each sub-block consists of 15 half bytes, and one block consists of 15 bytes.

SUBPACKETS

Each subpacket begins with a byte which indicates the subpacket type and its contents. The MSB of this byte is used to extend, if necessary, the subpacket type to the next byte. A single byte can indicate 127 subpacket types, with the MSB=0. If the MSB=1, then the subpacket type extends to the next byte, allowing an additional 32385 subpacket types. It is anticipated that subpacket types will be assigned through standards organizations and/or regulatory agencies.

Following the subpacket type byte(s), the next byte contains a byte count for the remainder of the subpacket. Therefore subpackets can carry a payload of 0-255 bytes.

SUBPACKET TYPES

Only a small number of subpacket types needs to be defined at the outset. When it leaves the factory, the receiver does not need to know about all 32512 possible packet types. The receiver's operating system software itself can be updated as necessary (self-modifying code) through on-air software updates.

Subpacket type 0 is for station identification. It will contain
the following:

a. modulation mode
b. audio compression mode
c. callsign

Optionally, it may also include:

d. station name (e.g. "Newsradio 1530")
e. station location
f. station format
g. emergency information
h. other ASCII messages, including:
   1. Traffic information
   2. Weather forecast
   3. Weather conditions
   4. Program schedules
   5. Time of day
   6. Advertising
   7. Music title & artist

The first two bytes are integers which are indicate modulation mode (0-255) and compression mode (0-255). The remainder of the information in this packet consists of strings of ASCII data. Each of the remaining data types, beginning with the call letters, is preceded by a byte which indicates the number of ASCII characters which follow (0-255). If the value is 0, then the string is not transmitted. For instance, to transmit "KFBK" in the call letters string, the bytes transmitted would be 04h
(byte count), 4Bh, 46h, 42h, 4Bh ("KFBK").

Packet 0 may be terminated early simply by omitting data after the callsign. The optional ASCII strings which follow must be transmitted in the order indicated. If an optional string is to
be transmitted, then all string types which precede it must also be transmitted, although they may be null strings (zero length).

Subpackets type 1, 2, and 3 are used to transmit operating system software for the radio, demodulation software, and audio decompression software respectively.

The first byte following the subpacket type contains a version number for operating system and decoding mode for demodulation and decompression software.

The next three bytes of these subpacket types contain an address offset for the machine code instruction data which follows. The words which follow are written into the radio's nonvolatile program memory starting at the offset address contained in these three bytes.

RECEIVER ARCHITECTURE

The architecture of the DSP portion of the receiver is beyond the scope of this paper. However, its computational power, RAM, NVRAM, instruction set, and other features will be determined by the requirements of present and expected future developments in modulation coding and audio compression algorithms.

A single architecture for a receiver's general purpose DSP would be the most straightforward way to implement a software based system. However, if more flexibility is required, it is possible to allow receiver manufacturers to use different DSP chips with different instruction sets. Such an approach could be implemented by changing the system architecture to transmit some form of abbreviated "source code" to the receiver, which would then compile it to run on the processor actually used in the receiver. Each receiver would include a compiler targeted to whatever DSP chip it contains.

IN-BAND ON-CHANNEL

Some proposed digital AM systems are hybrid analog and digital systems. The signal consists of an analog envelope modulated signal plus some digital modulation which is mostly concealed from the analog receivers. This software based system could be extended to include such in-band on-channel (IBOC) systems.

At least three methods could accommodate IBOC.

First, the ancillary data channel could either phase or preferably quadrature modulate the carrier of the "analog" part of the signal. The data rate would be slow, similar to that of the multiple carrier ancillary data channel.

Secondly, the continuously present multiple carrier version of the ancillary data channel could be moved some 5 to 9 kHz off the center carrier frequency to make room for the analog signal.

Finally, a different ancillary data modulation method could be used which would distribute its energy throughout the channel: spread spectrum.

POSSIBLE FUTURE ENHANCEMENTS

Although this approach would define a standard receiver, there would be nothing that would prevent the development of more advanced receiver types. If additional receiver types are specified in the future, then all that would be necessary would be to transmit several different versions of the decoding software. Each receiver would ignore the subpackets carrying decoding software to other receiver types.

CONCLUSION

A method has been shown which can provide a high degree of flexibility for digital AM. As new modulation and audio compression systems are developed, they can be used almost immediately. Broadcasters will be free to select the transmission methods which best suit their purposes and the needs of their listeners. Different methods can be used for LW, MW, SW, daytime, and nighttime use, with different tradeoffs.

As new modulation and audio compression algorithms are developed, they can be almost immediately applied.

Modern DSP hardware and software technology makes automatically reprogrammable receivers feasible. Use of this technology will allow digital AM to avoid an otherwise high risk of early obsolescence.

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[10] Ibid., 224-232.

MM Docket 99-325 NRSC-5 COMMENTS (filed as individual)

I am writing as a concerned and avid AM listener about what I see as the deleterious effects of the proposed NRSC-5 standards for HD radio. I am an owner of numerous kinds of AM receivers, some wide band, some narrow band, including a host of antique and classic receivers from the 1920s to the present.

More important, I live in the greater Philadelphia area, with reception of Philadelphia, Trenton and New York City radio stations, a very congested situation indeed.

Thus what concerns me is the prospect of first and second-adjacent interference from the IBOC signal. Some examples are as follows:

I am a regular listener to WCHR (AM), Flemington, NJ at 1040 kHz where according to radio-locator.com, I'm in that stations 2.5 mv coverage area. I already get some adjacent channel interference from WEPN, New York at 1050 kHz, but this is minor. What will happen if WEPN goes IBOC with the steady and louder noise produced by the IBOC signal? The same thing is true when I try to listen to Levittown-Fairless Hills based WBCB 1490. WDAS (AM), Philadelphia is now broadcasting IBOC and cuts into WBCB's Northeast Philadelphia coverage area. I use to listen to AM 620, WSNR, Jersey City, NJ with my GE Superadio III, but I can't anymore. WIP 610 is IBOC and the IBOC noise makes that impossible!

Another concern I have is the reduction of audio bandwidth to 5 kHz. Despite what is commonly assumed, I can hear a difference as to whether the bandwidth is 5 or 10 kHz on many of my receivers, both wide and narrow band. I can tell for example when WPEN, Philadelphia, an oldies station is broadcasting IBOC and when it is not because the frequency response changes and I can even hear the difference on an old Bradford AM/FM/Shortwave radio that obviously was not designed as a wide band radio. In addition, when I do listen to a wide band radio such as my Cambridge Soundworks model 88 table radio, I not only can hear the lack of bandwidth but I can hear the IBOC noise along with the analog signal, rendering the reception of those stations useless.

Finally, there's the issue of a lack of a codec standard. Ibiquity committed itself to an open standards policy and now it's keeping its codec secret. Will the HD radio I buy today work in the future? Will Ibiquity have a monopoly on digital radio and therefore maintain control over the price of transmitting and receiving equipment?

I haven't even begun to address the disaster that could occur if AM IBOC was granted nighttime authority.

In conclusion, I feel there's a lot more real world independent testing to be done before such a system is implimented. There need be no rush for AM DAB. Let's not destroy the Standard Broadcast Band.

John R. Packard

Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of:	)	
	)	
Digital Audio Broadcasting Systems	)	MM Docket No. 99-325
And Their Impact on the Terrestrial	)	
Radio Broadcast Service	)	

Reply Comments of Gregory J. Buchwald

Introduction

I am filing these comments on behalf of myself and as a stockholder in WRPQ-AM (Baraboo, WI). I have been working as a communications and systems research engineer for nearly 25 years and have been associated in radio broadcasting for over 25 years. My credentials were listed with my previous filing of Comments on this matter in July, 2005, but to sum up, I proposed the basis for the NRSC-1 / 2 standards, including the RF emissions mask which forms the basis of 47CFR 74.44. I performed and submitted measurements of broadcast receivers supporting the use of the 10kHz limitation and the NRSC pre-emphasis standard, which I also submitted to the NRSC committee, which was adopted in its original submitted form. I also performed measurements of numerous broadcast transmitters which formed the basis for the current AM RF emissions mask including the tapered 1dB/kHz slope, which was also adopted. Finally, as a matter of record, I submitted, in 1993 upon request of the Commission the exact text and equations that are now included as 47CFR 73.128. I have consulted for many broadcast facilities worldwide and have a strong background in, and understanding of, AM, FM, and HF broadcasting including the design of directional array systems, RF IM-reduction filters for use at AM broadcast facilities, audio processing systems including development of a reduced bandwidth system adopted for use in 1989 by Radio Free Europe and Radio Liberty (joint development with Mr. Gary Clarkson of CRL, Inc), and combined (diplexed) antenna systems for AM and FM broadcasting. The list of broadcast stations for which I have done some form of work / consulting for over the past 25 years is in excess of 500. In addition, I participated in the Unlicensed / Experimental Licensing Panel before the FCC in August, 2003 as an invited participant / speaker. I also hold the following commercial licenses: DMGB037428, DOGB037345, PGGB036848, and T2GB036913. Finally, I am a licensed amateur radio operator, Extra Class, callsign K9QI.

Executive Summary

The Commission now has a difficult task at hand. I respect and appreciate the ability and chance to offer my advice and discussion on the matter of Docket 99-325. Each topic will be discussed in some level of detail, but to summarize:

1) The Commission should not approve the use of the IBOC-AM system on the basis of Interference.
2) International Treaties prohibit the level of interference to be broadcast on AM channels as proposed and currently in use by a few AM broadcast stations.
3) The Commission should seriously consider the use of Channels 5 and 6 (76 – 88MHz) for deployment of digital services with the singular use of carrying programming by stations currently operating analog services in the AM band.
4) A substantial quantity of Comments filed to the Commission with regard to this docket indicate that the interference produced is excessive. Quantitative and qualitative data has been presented through many of the Comments filed during July, 2005.
5) Homeland security issues should preclude the use of the AM IBOC system as it currently exists. In addition, other warning systems such as EAS, severe weather, etc. will also be impacted if AM IBOC is deployed. This is particularly true in rural areas.
6) An open standard for the audio Codec should be mandated for use by the FM-IBOC system and any future system that might be contemplated for use in the AM band.
7) NONE of the proponents in favor of the deployment of IBOC-AM, including the system owner, Ibiquity, have filed quantitative, or even qualitative measurements supporting the performance of the system and the interference, or lack thereof, produced by the AM IBOC system.

The Commission should not approve the use of the IBOC-AM system on the basis of Interference.

My comments of intentional vs. unintentional radiation have now been echoed by others in the Comments of this proceeding as well as early Reply Comment filings. Specifically, Mr. Tim Cutforth has filed comments regarding this. Mr. Cutforth states this clearly and effectively in the following quote: "Adoption of NRSC-5 as a rule will make primary protected service area only a theoretical abstraction and only a distant memory for the for the many previously happy listeners who will find thousands of square kilometers of useable service area from their favorite station replaced with vast wastelands of digital noise."

Many others have raised the issue of interference as well. The specifics of these are discussed elsewhere in this submission.

Leonard Kahn also strongly advises against the use of IBOC-AM on the basis of interference. I would like to qualify my support of his comments on the interference issue: In the mid-1990's Mr. Kahn and I were on opposite sides of several lawsuits regarding AM stereo. Even during the time that we were at opposing viewpoints, we had discussions during breaks during which we both agreed that IBOC-AM would be a disaster in the AM band due to interference issues. I, to this day, agree with him on this fact. Furthermore, if he has a viable alternative in his CAM-D system as Mr. Cutforth and station owner Ralph Carlson (Salt Lake City, UT) have both filed Comments on, an industry committee of technical people (not dominated by single system proponent or their investors, as is the current case with the NRSC) should, at a minimum, evaluate the system as a viable alternative to the interference-ridden IBOC proposal. I will also add that I have not had discussions with Mr. Kahn on my Comments or Replies, though I have attempted to do so, and that my support of his comments regarding interference are entirely and only on the basis of good engineering practice, the physics of propagation and amplitude modulation in the AM band, and a mutual desire to make sure that the AM band is not allowed to degenerate further than it already has.

In addition, I would also point out that I believe that the patents pertaining to C-QUAM have now expired; it is in the public domain and is easy to implement in DSP today. In addition, I also believe that the basic patents pertaining to the demodulation of the Kahn ISB system have also expired – decoding of this system can also be done in DSP with little effort today. It would also be equally easy to today include Mr. Kahn's PowerSide technology in a demodulator to eliminate the noise and interference from one sideband, including use of his IPR under license to apply the correct de-emphasis on the demodulated audio and reduce quadrature distortion components by utilizing his proprietary demodulation techniques. In essence, the AM broadcast industry is in a unique

position to take advantage of DSP demodulation solutions of analog modulation systems such as PowerSide, Kahn ISB, and C-QUAM as well as CAM-D without increasing interference in the AM band, disenfranchising listeners due to IBOC interference, and providing alternative spectrum for "AM" digital broadcasting; the latter to be discussed elsewhere in this filing.

International Treaties prohibit the level of interference to be broadcast on AM channels as proposed and currently in use by a few AM broadcast stations.

Mr. Tim Cutforth, of Vir James Consulting Engineers filed comments with respect to this matter. Specifically, he directs the Commission to consider the implications to the WARC Rio 1981 protocol; specifically Annex 2, Chapter 4, and interference issues to adjacent and second adjacent channels in Mexico and Canada. He also notes that these agreements were adopted with Canada in 1984 and with Mexico in 1986.

We do not need to wait until the future to understand the effects of this to foreign stations: Radio station XEPRS (1090kHz) suffered from serious interference within their supposedly-protected service area from KNX on 1070kHz and KDIS on 1110kHz. They may be the first station to actually have to deal with second channel interference as a result of IBOC radiation on BOTH SIDES OF THEIR ALLOCATED CHANNEL. The results were / are disastrous. The operators of the programming content for XEPRS, Broadcast Company of the Americas, LLC. (BCA), have filed numerous letters from listeners as well as a map indicating the region that is most heavily interfered with. If IBOC-AM is allowed to move forward, a geometric increase in such interference problems will arise. Such interference will need to be dealt with on a case-by-case basis under the auspices of 47CFR 74.44 subsection c – Does the Commission really want to deal with a never-ending flood of complaints by affected broadcasters?

The chief engineer for BCA, Mr. William Lipis, has included well-documented evidence of the increased interference, including quantitative measurements of the interference from the IBOC stations noted above. The Commission is urged to look at this 2-page evidentiary document as filed within the BCA Comment submission. In addition, the listener comments are also well documented with a representative sampling of the letters. The Commission is also urged to consider that only a very small percentage of listeners will actually contact the station – the majority of people simply try to put up with it, and barring that, "vote" with their fingers to change the station. The potential lost revenue for a station due to IBOC interference is not to be taken lightly. The very ability of smaller stations to exist, even in rural markets, hinges upon the ability of other stations to effectively force them out of the market in an uncompetitive nature through the use of IBOC-AM interfering signals. Such anti-competitive action is unfathomable in any

marketplace, yet IBOC-AM, if approved, would effectively legalize just such a condition. This is not the way the free market is supposed to operate; theft of spectrum should not be a legal way to squelch your competition.

The Commission should seriously consider the use of Channels 5 and 6 (76 – 88MHz) for deployment of digital services with the singular use of carrying programming by stations currently operating analog services in the AM band.

In my July, 2005 Comment filing, I proposed the use of Channels 5 and 6 as a replacement band for the current AM allocation, providing an instant full digital service that does not discriminate against, nor increase interference to existing services within the AM band. This was actually my second choice; I had initially proposed the use of Band 3 VHF (174 – 216MHz) on a reallocation basis for the deployment of a well designed, E-147-like service that would accommodate AM and FM broadcasters. The politics of the NAB, large network providers, and a general misunderstanding of the technology as well as a mistrust of certain industry bodies that acquired the rights to the fundamental system, caused this approach to fail politically. When I consulted on the Motorola Symphony chipset, beginning in 1997, I proposed the use of 76 – 88MHz based on the fact that nearly all radios designed today are "worldband" designs that cover these frequencies, whether the microprocessor in the radio allows reception or not.

I have received numerous emails and comments regarding this proposal. I would like to attach one such comment, from the Chief Engineer / Engineering manager of a major market station who felt he could not comment directly.

> Comments for 99-325:
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> The position presented by commenter Greg Buchwald can possibly provide a solution to the obstacles that remain in the path of a successful IBOC rollout. When an impasse is reached, compromise is the only viable alternative. The Commission should consider the following advantages of the Buchwald proposal:
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> 1. Existing AM broadcasters would be able to begin transmissions in the proposed band (76 – 88 Mhz) with a fully digital version of iBiquity's HD system. This would put AM station operators on an equal footing with FM operators in that the option of having the full quality improvement that FM will enjoy by converting to HD will also be available for the AM operators. In addition, multi-casting would be an option as it is in the FM band.
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> 2. There would be no degradation caused to the existing AM band while the transition takes place. The existing band could even be enhanced by allowing operators to use techniques that were designed for the existing band such as Powerside, Cam-D and C-Quam stereo.
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> 3. The standard broadcast band would continue to provide service to the millions of existing AM radios. It is quite possible that many smaller operators would

choose to eventually abandon their original analog facilities because they had achieved similar coverage with higher quality in the new band. That would reduce the interference in the original band and strengthen the penetration of the larger stations, which cannot get equivalent coverage in the new band because the transmissions would be subject to line of sight characteristics as they are in the existing FM band. The AM stations that remained in the original AM band would be the large operators that would provide the backbone of the homeland security warning system. These larger stations would be more fully staffed and they would be positioned to provide immediate local wide area coverage during disasters as they have done for most of their existence.

4. The FM rollout of HD radio could continue without interruption as a hybrid system. The AM rollout could offer immediate 24-hour operation without disruption or degradation to the existing AM band.

5. Receiver manufacturers would be assured that a smooth transition was in process. They could then manufacture radios without fear that the AM problems might somehow cause the whole HD radio approach to fail, causing the public and manufacturers a great deal of frustration and loss of resources, time and money.

There are many details that would still need to be worked out but this would be a start. TV channels 5 and 6 will not be available in every market until the existing TV band is shut down in 2009. However, one of these channels is available in virtually every major market now. That would allow existing broadcasters an opportunity to immediately start operating in the unused channel in their area. If it was a congested area like New York/ Boston, some accommodation might be necessary to squeeze in all stations, perhaps by initially reducing the coverage to city grade only. When both channels become available, all stations could operate fully digital in all markets because the two channels combined will accommodate all markets.

We urge the Commission to consider this innovative approach that could remove the final obstacles to achieving a successful HD radio transition.

In addition to these comments, others filed in a similar fashion. These include the responses of Edgar Reihl, P.E., an interested party with a long history of work in the broadcast services, Larry Langford, owner of a small market station in the State of Michigan that will be adversely affected by the roll-out of IBOC-AM and a long time broadcaster and broadcast engineer, and Mr. William Barnett III, an engineer for a small market station have endorsed my proposal of using Channels 5 and 6 to roll out "digital AM" service. Also, a simple "Google" search will indicate many more that feel the same way, but are not inclined to comment formally on this matter.

While much would need to be considered before such an allocation could go forward, I have done an initial analysis of such a proposal, complete with recommended practices, and would be more than willing to share it with the Commission, industry regulators and standards bodies, and other interested parties should the need arise.

A substantial quantity of Comments filed with the Commission, in regard to this docket, indicate that the interference produced is excessive.

Quantitative and qualitative data has been presented through many of the Comments filed during July, 2005.

The Commission is urged to consider the qualitative responses from a number of Commenter in this Proceeding. While these filings lack hard data with respect to interference ration, power, and affected area calculation, they nonetheless provide the Commission with the flavor of what can be expected from the general public as the IBOC-AM system is rolled out.

As pointed out earlier in this submission, BCA and their engineer, Mr. Lipis, have supplied the Commission with substantial quantitative evidence of the interference that WILL arise if IBOC-AM is allowed to continue to be broadcast.

In a similar fashion, Mr. Warren G. Smith filed comments as a "broadcaster with more than 40 years experience" to the extent of the occupied bandwidth of the IBOC-AM system and its effects to other licensed services. He also points out that minorities and small market owners are at risk to loose coverage but may be unwilling to file directly for fear of loosing revenue and program streams. While Mr. Smith's Comments are very passionate, once must consider the effect of interference to the literally thousands of minority, small market, and ethnic radio stations that operate in the AM band today. They could all become disenfranchised from their listeners through the simple action of allowing IBOC-AM interference to continue to operate. This is certainly an issue that goes beyond the technical merits of the system; it goes to the fundamental rights of all owners of broadcast licenses to operate on their assigned channel without anticompetitive interference from others.

Barry D. McLarnon, PE also files quantitative evidence of IBOC-AM interference. He submits his comments based on his concern of interference to stations in his native country of Canada. Page 6 of his Comments state the level of interference increase he has calculated. He also sites the Rio 1981 agreements, to which the US is a signatory to, and that such operation is not legal under this agreement.

With regard to qualitative interference comments, the undersigned agrees with the Comments of Press Communications, Mr. Ralph McBride, Mr. John Pavlica, Jr., Mr. William Barnett III, Mr. George Frese, PE, Mr. Eric Bueneman, Mr. Bill Harms, and Reunion Broadcasting, LLC. on the interference conditions that exist with the few IBOC-AM stations that are currently operating. While many others have also filed, these Commenters did so without an undue level of passion which might otherwise cloud the issue. Reunion, in particular, echoes my comments at the end of their filing that the IBOC digital carriers (sidebands) must be reduced in power to the point that no additional interference is created to adjacent and second adjacent channel stations from their transmission. These people are a mix of station owners, engineers, and concerned citizens that simply to not want to see the AM band pushed further into entropy / chaos.

Homeland security issues should preclude the use of the AM IBOC system as it currently exists. In addition, other warning systems such as EAS, severe weather, etc. will also be impacted if AM IBOC is deployed. This is particularly true in rural areas.

I filed comments on this matter during the July, 2005 Comment period. My thoughts have not changed; and they are supported by the comments of others. Mr. Edgar Reihl, PE comments that "The harmful interference caused by NRSC-5 AM band transmissions seriously jeopardizes the utility of AM radio as a vital communications link in emergencies caused by severe weather or terrorist attacks."

Mr. Robert Foxworthy filed comments on this matter as well. "High power clear channel frequency AM broadcasting, especially at night, is an in-place, low-tech, widely dispersed mechanism to allow instantaneous multicast messaging...to get to get information to a vast audience in the event of a disaster." I suggest reading Mr. Reihl's reply comment to the Foxworth statement on page 4 of his filing. Mr. Reihl gets it 100% right – if for no other reason, this, alone, should be enough to discontinue the use of a spectrally inefficient, broadband system such as IBOC-AM in our broadcast spectrum.

Likewise, Mr. Kevin Redding also filed similar comments in his Brief Filing to the Commission: IBOC-AM should not be allowed to be used for broadcast for Homeland Security reasons.

Finally, the Consulting Firm of Cohen, Dippell, and Everest, PC have also filed comments asking the Commission to at least make further findings prior to adopting NRSC-5; at least for the AM band. They site the potential interference to PEP stations in the EAS network as well as determining if the IBOC-AM system is consistent with the Model 1 and Model 2 interference reduction rules that came into effect for the AM band in 1991. Many of us worked very hard to drive these rules in 1991, through the NRSC and others, and at considerable expense. Let us be sure that IBOC-AM does not turn back the hands of time and actually give us MORE interference than we had prior to all of the great work done now 12 years ago. Mr. Frese, in his comments to the Commission, also echoes this concern.

An open standard for the audio Codec should be mandated for use by the FM-IBOC system and any future system that might be contemplated for use in the AM band.

Without further remark, I agree with those who have commented that the CODEC standard should be an open standard. While Ibiquity can own the "broadcast channel technology" and license it appropriately, that transport mechanism should be a simple bit stream. CODECS are like fine wine and scotch – they improve with age. The problem with the E-147 standard is that they standardized on a specific MPEG format, thus locking them into what is now a dinosaur as far as CODECs are concerned. CODECs and compression techniques will continue to develop; PAC may be a good system, but better ones will come along – in fact, they have already been developed. Those that have commented that the audio encoding system should be an open standard – only the transport layer should be defined, are correct in their assumptions and concerns. Not only is this best for the industry, but for the long-term viability of the IBOC-FM system, should it be adopted.

NONE of the proponents in favor of the deployment of IBOC-AM, including the system owner, Ibiquity, have filed quantitative, or even qualitative measurements supporting the performance of the system and the interference, or lack thereof, produced by the AM IBOC system.

As Mr. Cutforth points out in his filed Comments, an overwhelming fraction of those filing in favor of the IBOC system have a vested ownership in the system and its proprietary licensing rights or are employed for a firm that has such a vested interest. One can not expect these people, and the companies they represent, to do anything BUT support an interest from which they expect to make a profit. Standards should not be decided by a body with such vested interests. The Commission must play a pivotal role and bring the high expectations of the IBOC-AM proponents back down to earth – the physics of the system, the channels / spectrum it occupies, and the allocations table to which we have built the current system out for do not support the use of the IBOC-AM proposal without substantial harm to many license holders.

Not a single positive comment filed has been supported with actual measurements in this latest round of filing, yet this is the first time that broadcasters have installed the equipment in any fashion other than a controlled test. This is first time that the true level of interference can be observed and measured by others and the impact can be felt by broadcasts that happen to have unlucky dial positions near an IBOC station.

If the interference were not an issue, one would expect a wealth of evidence to be submitted in this round of Comments. Furthermore, if the reduction of audio bandwidth to 5kHz were a plus, one would also expect to see filings talking about the positives yielded. Finally, if the coverage were anywhere near that of the analog channel (without IBOC) – the 0.25mV/m contour, one would expect to see that filed as well.

Rather, no quantitative evidence is produced. In fact, barely any qualitative evidence is produced by the operators of IBOC-AM systems in this round of filing.

It is interesting to note that several of the broadcasters that started IBOC transmissions have ceased operations to best of my knowledge. These include several stations that participated in early tests of the system such as WGCI, WIND, and, to the best of my knowledge, WLW. IN addition, even some staunch supporters such as WTMJ, KNX, and KDIS have also been reported to have ceased operations. In the case of WTMJ, I reported the interference that was caused to WMT in Cedar Rapids, IA in my filed comments as well as the increased noise to their on-channel listeners when off the side of the directional array. In the case of KNX and KDIS, if they have actually stopped operations at this time, there can be only two possible reasons:

1) They actually acknowledge the interference they slammed XEPRS with and have ceased operations out of an understanding that such interference is against international treaties, or
2) They have ceased operations only until this proceeding is complete as to not bring the problems to light any further than they already have been by BCA.

It is my clear hope that the former, rather than the latter, is the reason for any cessation of IBOC transmissions by these facilities. Either way, it indicates that IBOC-AM is a technical failure due to the substantial increase in interference it generates.

Conclusion

The current IBOC-AM system as defined in NRSC-5 should not be adopted for use in the AM broadcast band. It is only now that we have enough stations on the air, and enough experience with the interference, that such a determination can be made. The Commission is encourage to protect the AM band as-is; not only for national security and public service reasons, but also to preserve the secondary/rural, ethnic, and minority markets that are currently served, essentially interference-free, today. The Commission is also urged to take the unique opportunity to re-assign Channels 5 and 6 of the television band to digital broadcasting services. This spectrum is uniquely placed and can accommodate all existing AM broadcasters without disruption and negative impact to the existing AM band. The Commission is also urged to carefully analyze the data presented as to the actual increase in interference caused by AM-IBOC, the effects on many, particularly smaller, station, and international agreements to which we are bound.

I would like to thank the Commission for the opportunity to comment on this matter and would be more than happy to supply any additional data to back up my statements, if the Commission is compelled to request such input.

Respectfully Submitted,

Gregory J Buchwald
August 17, 2005
Via Electronic Filing