Digital Radio Primer

NPR Engineering & Member Services
DTAC II
February 2003
NPR Digital Radio Primer

Table of Contents

Digital Radio
What's in it for me, my station, and my listeners?

You've read about it in the press and in practically every issue of the trade journals. Whether it's been called IBOC or Digital Radio or HD Radio, you've seen assessments that it will never work, that it can't work, and that even if it works, it isn't good enough. Fear, uncertainty, and doubt have been cast at many turns. And over a decade has passed since compatible in-band digital radio was first pursued in earnest. Today, the HD Radio system works (compatibly and with secondary program capacity) and both the NRSC (the broadcast engineering standards review board) as well as the FCC have endorsed "HD" as a substantial enhancement over existing analog broadcasting.

Will HD succeed in the marketplace? No one really knows. This much we do know: the FM band, home to 94% of today's public radio stations, faltered for a quarter century before it quickly began to supplant AM radio broadcasting. We know that "HD" has the backing of nine of the top 10 commercial radio broadcasters, as well as an unprecedented number of broadcast equipment, silicon chip makers, and receiver manufacturers. iBiquity holds, or has applied for, some 80 patents in developing the technology that has been FCC-endorsed. Is it the best digital radio technical system? No, it's not, but neither was VHS compared to Betamax. But even with subdividing for secondary program transmission, it's better than the "digital sound quality" of the satellite radio services (available without a monthly subscription fee).

From 1938 when W2XMN signed on at Alpine New Jersey, until the era of passage of the Public Broadcasting Act in 1967, FM was an interesting technical achievement in search of an audience. A few broadcasters had faith the medium would eventually fare well and worked hard through successive issues like being displaced to a new band, the need for "automatic frequency control," the advent of "storecasting" SCAs in an attempt to rescue the medium in the 1950's, the launch of stereo in 1961, and eventually the forced mandate to phase out simulcast authority with sister AM stations. Many lost heart, including the inventor. Numerous FM's were donated to local colleges to shed the operating loss. Still others maintained faith and kept the FM running. Public radio was born and seized the emerging medium to stake our claim on the ether. Thirty-five years later, we are a vibrant and growing industry.

At DTAC I, the robust discussions of that meeting lead to public radio's support for adoption of the IBOC proposal provided it would be compatible with our existing transmissions and provided we have the potential to pursue new public services and program channels within the new system. Those goals have been endorsed and demonstrated, but much work lies ahead. Will we wait and see before moving forward in earnest? Will we seize an opportunity with faith and perseverance? DTAC I lead to an uncommon act of common faith, signing off on a potentially revolutionary change in our industry. Let's have a great conversation about our common future.

Mike Starling　　　　Dana Davis Rehm
DTACII Co-Chairs

I. Introduction - The Five W's of HD Radio

Digital radio broadcasting was pioneered by the European Eureka 147 Project in the mid-1980's, with the first over-the-air public demonstrations taking place at the Orbital-'88 Conference in Switzerland.

The European community, as well as Canada and Australia, adopted the Eureka 147 transmission scheme and began operations on a variety of new frequencies in the mid-1990's. Meanwhile, in the United States, the Eureka model, which relied on multi-station transmissions from common antenna systems and new spectrum, found little support despite being an impressive technical achievement.

FIGURE 1: Early Eureka 147 project demonstration *[BBC]*

In the United States, NPR, its member stations, and other public radio stations have been at the forefront of digital radio development since its inception. WGUC Cincinnati experimented with F1-digital stereo transmissions, requiring a full cable television channel in 1985. WGBH Boston conducted similar experimental broadcasts in the evening hours over UHF station WGBX in the late '80's. In 1987, in the ATV proceeding, NPR became the first broadcaster to suggest the need for system development and future frequency allocations for digital radio to the FCC.

What evolved into compatible HD Radio was first reported as a conceptual model in the trade press in November 1990[1]. The United States declined to adopt new spectrum for digital radio at the 1992 World Administrative Radio Conference[2] and work began in earnest to test the viability of "in band" approaches using existing AM and FM stations. NPR Member station WILL Urbana was among the very first test-beds for what was then called In-Band On-Channel (IBOC) digital radio. Subsequently, WAMU Washington, DC, WETA Washington, DC, KNPR Las Vegas, and WBJB Princeton provided important testing and public demonstrations for the compatible digital radio efforts of USA Digital Radio (USADR) and Lucent Digital Radio.

In 1995 compatible digital radio was dealt a major setback when the National Radio Systems Committee (NRSC), meeting in Monterey, California, concluded that the systems being demonstrated produced unacceptable interference to host stations. Many declared the concept of compatible digital radio a dead issue. USADR and Lucent retooled their designs, ultimately lowering the transmission level of the digital carriers by

---

[1] See Starling, Mike, "The Promise and Perils of Digital Radio," BE Radio, December, 1990, page 68

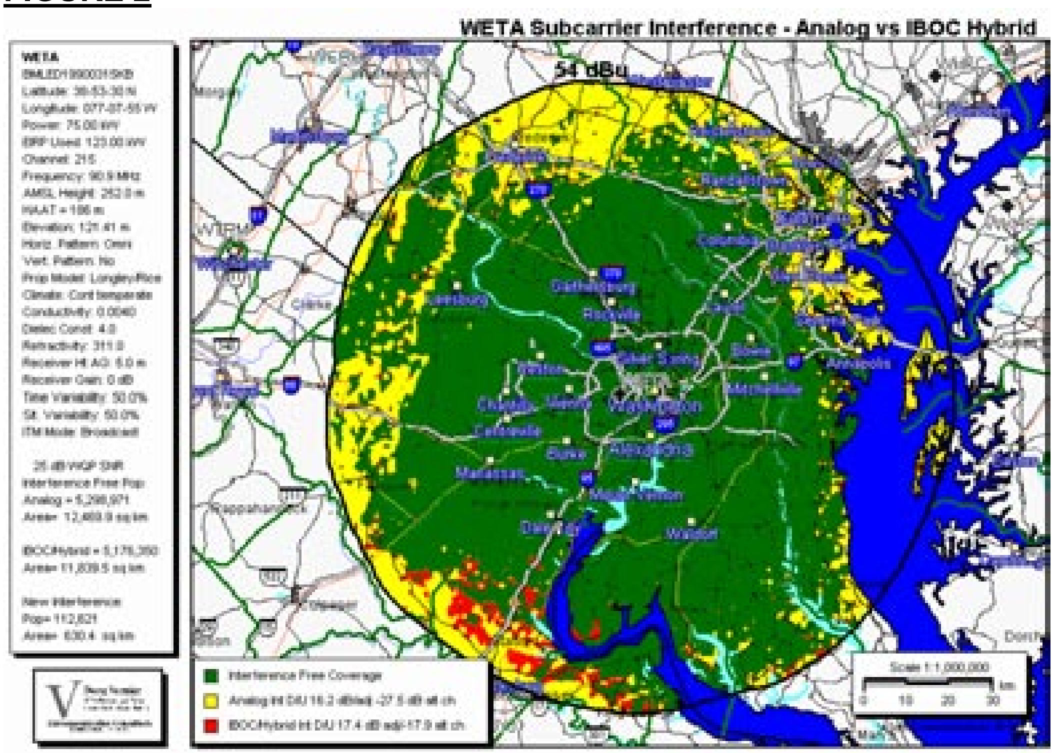
[2] The U.S. position on digital radio at WARC 92 was influenced by the Department of Defense's use of L-Band frequencies for aeronautical telemetry. The 1991 Persian Gulf War had just ended and the growing movement for adoption of a worldwide L-Band allocation for DAB introduction, including significant support throughout Europe, Canada and Australia was insufficient to justify federal support for moving DOD users to another band.

providing redundancy in the upper and lower sidebands and by adopting a vacant guard interval between the analog and digital carrier frequencies.

In 1999 USADR and Lucent Digital Radio merged and finalized system designs in December 2000. Some $100 million had been spent by this date and over 80 patents applied for by the newly named iBiquity Digital Radio Corporation.

NPR hosted the first in-depth two-day digital radio workshop at the Public Radio Engineering Conference at the NAB 2001. By November 2001, the National Radio Systems Committee, after months of additional testing and evaluation, declared the iBiquity system to be "compatible" and "a substantial enhancement" over existing analog broadcasting. However, one issue remained – the resolution of inconclusive compatibility issues associated with FM subcarriers. NPR and the International Association of Audio Information Services (IAAIS) sought additional testing from iBiquity to address these concerns. iBiquity readily agreed to fund the additional testing, and the parties jointly crafted a test plan which was carried out by the Advanced Technology Test Center in March 2002. In May 2002, NPR and the IAAIS filed a generally favorable review on the outcome of those tests with the FCC. On average, it appeared that 2.6% of existing population within SCA receiving areas would be adversely affected by the introduction of digital radio. In general, the higher the power and flatter the terrain involved, the lower the impact of interference (see Figure 2).

FIGURE 2



Typical FM IBOC Interference to SCAs (shown in red); existing analog interference (shown in yellow); and analog coverage area (shown in green). *[NPR/IAAIS SCA Study]*

The Commission and NAB took notice of the NPR/IAAIS/iBiquity subcarrier tests and adopted the Report and Order endorsing the iBiquity system for US radio broadcasters in October 2002.

During this period, in August 2002, the Corporation for Pubic Broadcasting adopted recommendations by the Digital Transition Consultancy group to allocate $4.5 million for matching funds to assist public radio broadcasters in 13 seed markets with digital radio implementation; $3.5 million was targeted for matching funds to assist the 55 stations meeting threshold eligibility criteria; in addition $1 million was set aside for research on AM antenna system issues, and $500,000 was set aside for PBS interconnection development and guidelines. The consultancy also endorsed the allocation of $24 million for public television to address the costly and time-mandated initiation of digital TV services.

Fall 2002 estimates for broadcasting's conversion to digital transmission were slated at over $1 billion for the conversion of all public television stations and $116 million for the conversion of all public radio stations. With manufacturers in actual production, and the universe of stations expanded to include all NPR-affiliated and CPB-qualified stations, the actual projected costs for public radio conversion moved up to $146,216,000 in early 2003. An additional $25,520,000 was estimated for FM translator conversions, although this number was estimated without any products having reached the market.[3]

At the 2003 Consumer Electronics Show (CES) in Las Vegas, six receiver manufacturers displayed digital radios, with first products expected to appear at retailers in the six initial seed markets in Spring 2003.

TABLE 1

iBiquity-Targeted Saturation Markets
New York
Los Angeles
Chicago
San Francisco
Miami
Seattle

TABLE 2

iBiquity-Targeted Seed Markets
Dallas
Boston
Detroit
Atlanta
Denver

[3] According to CPB, the number of public radio FM translators as of February 2003 is 638.

TABLE 3

iBiquity-Targeted Promotion Markets
Las Vegas
Washington, DC

On January 10, 2003, NPR announced the initiation of the Tomorrow Radio project, which will test the viability of secondary program channel capacity in the third quarter of 2003. Project partners are Kenwood USA, Harris Corporation, and KKJZ in Long Beach, California.

Meanwhile, issues concerning low cost HD Radio implementation with secondary antenna systems were being pressed within the NRSC community, with aggressive testing scheduled during the first quarter of 2003 and with active FCC interest and involvement. Secondary antenna techniques were touted as having the potential to eliminate the costly 90% loss of digital transmitter power with high level combining techniques. AM nighttime issues were similarly being researched and tested.

WUSF Tampa will become the first public radio station to commence HD Radio operations just after the convening of NPR's historic Digital Transition Advisory Committee (DTAC) II meeting in Washington, D.C., on February 10th.

II. New Service Offerings - A Listener's Perspective

Digital radio won't go anywhere unless millions of consumers decide they want the features of new digital radios enough to buy them en masse. Potential sales for after-market receivers was the criteria for establishing the saturation and seed markets chosen by iBiquity for service launch. True mass adoption of HD Radio technology will follow when automotive manufacturers stimulate the market by including it as standard equipment in new cars. This will represent a sizeable market segment itself.

A well-known fact in the automotive industry is that new car returns over issues associated with radio reception is a high percentage of the returns experienced. These returns deplete the profit margins as each return costs the dealerships and manufacturers an average of $400 for each warranty visit. The robust coverage of the HD Radio signal is expected to nearly eliminate multi-path issues, and is an appreciable incentive for adoption by the major automotive manufacturers.

What's in first generation HD Radios for the listener?
Among the first "value-added" features in HD Radios will be standardized artist and title displays to accompany music programs. It is reported that one of the satellite radio providers conducted early market research by providing satellite radios to a sample group of consumers. After several weeks, they took the radios back and then asked what

the users missed most. The answer wasn't the "digital sound quality" (at these low bit rates, even average consumers aren't fooled by what they're hearing - despite the "digital" moniker) and it wasn't the wide choice in format selections. The most missed feature was having *artist and title information* displayed. It's a rudimentary, but addictive, feature and it will be standard fare in most HD Radio designs.

FIGURE 3: HD Radio receiver faceplate design *[iBiquity]*

Radiotext messaging will be a supplemental feature for stations to deploy when artist and title information isn't displayed, such as promotional announcements for other non-music events.

Second generation radios: Introducing on-demand content

Second generation radios are expected to offer continuously updated "on demand" traffic and weather announcements from stations offering this service. This information is part of the standardized "ID3 tags" that will generate receiver displays for most applications. The information will likely be transmitted as a text message, but one that in some models will be "spoken" via text-to-speech technologies such as the current generation of NOAA weather radio "virtual announcers." It is expected that many weather and traffic providers will tool up to transmit this information to each station for inclusion in the combined HD Radio signals.

Subsequent generations of receivers will likely support automatic capture of a number of less universal, but large market appeal services such as stock quotes (including selected stocks only), topic-based news streams (law, medicine, education, Nashville notes, law enforcement, firefighting, college sports, winery news, and distant community weather and news are likely to be offerings various stations provide listeners). Knowing your audience by tracking interests and satisfaction will become heightened necessities in order to astutely manage content offerings and reinforce station loyalty. The secondary program channel, if proven viable and adopted, could be an additional resource in addressing sizable audience interests that do not achieve carriage on the main FM program service.

A word about driver clutter issues

Since scrolling displays are deemed to be a driver distraction, they will likely require very short messaging or force the consumer to hit a "more" button to see the rest of a message – or speech annunciation will be used as described above. The inclusion of "album" cover thumbnails or other graphics for display on the new receivers will be static displays with image changes done very infrequently. As computers invade every nook and cranny of our daily lives, these same issues are being evaluated by traffic routing devices such as the Hertz *Neverlost* system and in the advanced automotive display and control surfaces that are being developed for dashboard display.

Lockout sensors are being developed to disable moving pictures and highly interactive activities, such as selecting coordinates when the car is in gear. Many manufacturers, including radio receiving manufacturers, are also moving control switches onto the steering wheel to minimize look-away time for frequently initiated activities. In 2000, the National Highway Traffic Safety Administration (NHTSA) initiated a study of issues appropriate to minimize driver distractions but concluded the inquiry with a series of white papers and summaries of the issues involved – without adopting any specific regulations concerning driver distraction. State governments, however, are becoming active in this area, with several dozen bills being introduced – most aimed at responsible use of cell phones in moving vehicles. Europe and Japan have active driver distraction efforts underway and it is likely that more formal regulations will eventually be adopted in the United States. At least one source has indicated that look-away times for any specific task or information search must never approach a maximum of 5 seconds.

Third generation radios: What I Want, When I Want It ("Tivo-Radio")
Eventually, the advent of "personal video recorders" is expected to become a household feature in most homes, along with broadband, PDAs, and a cell phone within every arm's reach.

Not surprisingly, HD Radio is designed to support a new generation of Personal Audio Recorders (PAR's) as well. iBiquity Digital has partnered with Command Audio to prototype and design the protocols for a future personal radio service. The first working prototype was displayed at the 2003 CES using a current-production Visteon HD Radio as the control head for the demonstration.

FIGURE 4: iBiquity's Personal Radio Service demonstration at CES, January 2003 *[iBiquity]*

The content demonstrated included *Car Talk, Morning Edition, Wait Wait…Don't Tell Me!,* and *Performance Today*. In addition to starting the programs "on command," users could jump to the next program segment just as they can with CDs. Segment ids/tags will be marked by the broadcaster. Thus, you could jump to the next caller during *Car Talk*, or past the callers with a few quick "next" button pushes to get to the "Puzzler." The Personal Radio Service radio could also display the station's upcoming live program schedule and could store programs requested by the user. As with "Tivo," radio users are expected to be able to request a “season pass” to their favorite programs so they won’t miss any of the yucks from Click and Clack, a single Garrison monologue, or the best of what’s new in child-rearing from the Parent’s Journal. Although the final protocols are not fully defined, it is expected that radios supporting the Personal Radio Service may hit the market as soon as 2005.

Beyond “3G” radios: What’s possible in the all-digital formats
Many years beyond our retirement, when so many HD Radios are in use that it’s no longer necessary to support “ancient analog” broadcasts, the throughput of the digital radio channel will triple by ceasing FM analog transmissions. Obviously, multiple channels of near-CD quality programming would be possible in such an environment in addition to the then-current methods for Surround Audio transmission (over 2,000 albums have been released in Surround Sound using DTS, Dolby Digital, or the SACD formats). Already, carmakers such as Volvo have begun including surround capable audio systems in certain model lines to capitalize on the steady growth in this still nascent market. It is likely that some public radio stations will be pioneers of the possibilities by developing program offerings under experimental authorizations late at night in the years ahead. For those of us of a certain age, it’s reminiscent of the great leap forward of FM Stereo in the late 1960’s when Album Oriented Rock stations became an overnight phenomenon by playing the full 18 minutes of “Inna Godda Davida” (usually right on schedule at 3:30 pm when high school was out). What would you do with 300 kb/s of throughput if you only need 96 kb per near-CD quality channel?

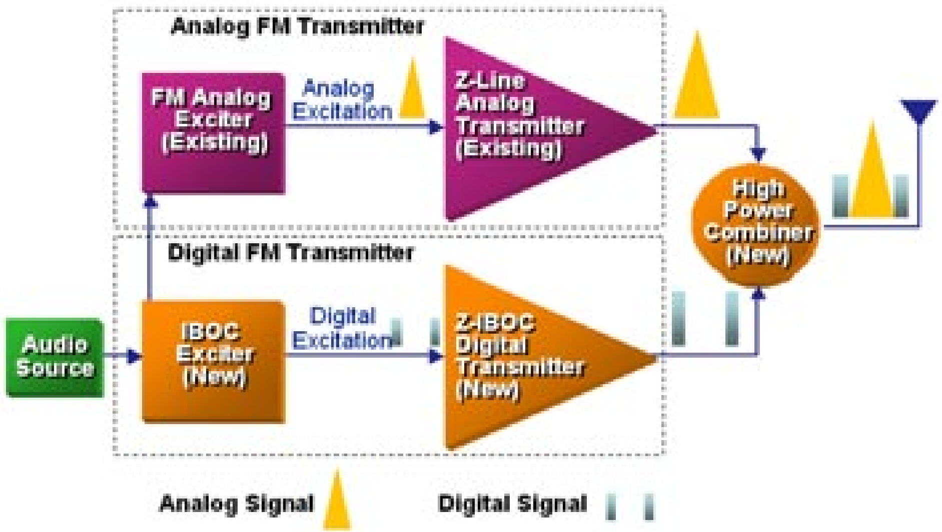
III. Basic HD Radio Conversion Requirements

One of the best aspects of HD Radio transmissions is that it requires only 1/100 – one percentage of the power output in the digital transmission mode to serve your coverage area with digital radio signals. Thus a station running 10,000 watts of transmitter power will only need to transmit 100 watts of digital power for full coverage digital. But, as with most things that sound incredibly appealing, there are a few twists in how you achieve this outcome.

At this writing, for FM stations there are only three primary ways envisioned to add HD Radio transmissions: high-level combining, low-level combining, and using a separate antenna.

High-level combining employs a second digital transmitter, whose output is combined with the output from existing transmitters through a “combiner” (see Figure 5). To isolate the two signals from interfering with each other, this combining technique is somewhat lossy. High-level combined stations will need an additional 10% of transmitter power from their current FM transmitter to make up for this loss. These stations should have 10% headroom in their existing transmitters to avoid losing power in the analog FM signal. Moreover, you will be dissipating as heat 90% of the digital transmitter’s power in a dummy load attached to the combiner.

FIGURE 5: Block diagram of high-level FM combining approach *[iBiquity]*

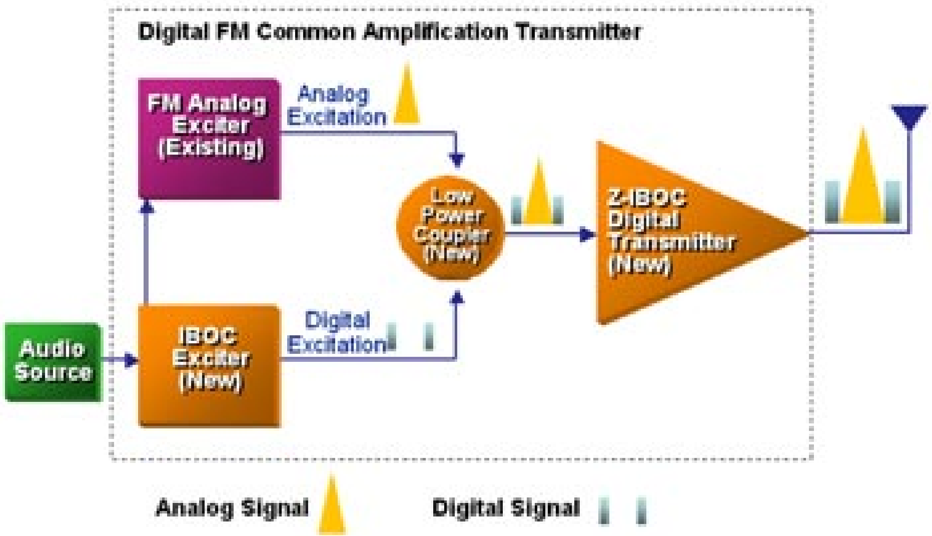


Thus, if the station needs 100 watts of digital power, the digital transmitter will need to run 1,000 watts with 900 watts being dissipated in the dummy load and 100 watts of digital reaching the antenna. While it might help to keep the transmitter engineers warm on cold, lonely mountaintops, it's an inefficiency that a civilized industry will address as technology improves.

Low-level combining does not require a separate high power analog and overpowered digital transmitter (see Figure 6). Instead the signals are combined and applied in unison at low power levels directly at the exciter stage of the transmitter. The only catch is that transmitters capable of accurately amplifying the low level combined signals must have linear amplifiers, which have the advantage of being faithful amplifiers of the complex digital transmission. Unfortunately, most FM transmitters were not built as linear "Class AB" amplifiers, but were instead built as Class C amplifiers, perfectly suitable for FM analog broadcasts.

Thus, to use low-level combining, most stations will have to purchase new transmitters capable of linear operation. The only issues are (1) cost of buying a new full power transmitter and (2) the side effect of lower operating efficiency of the linear mode (typically on the order of 60% for new linear operation vs. 80% for typical 80's vintage FM transmitters).

FIGURE 6: Block diagram of low-level FM combining approach *[iBiquity]*



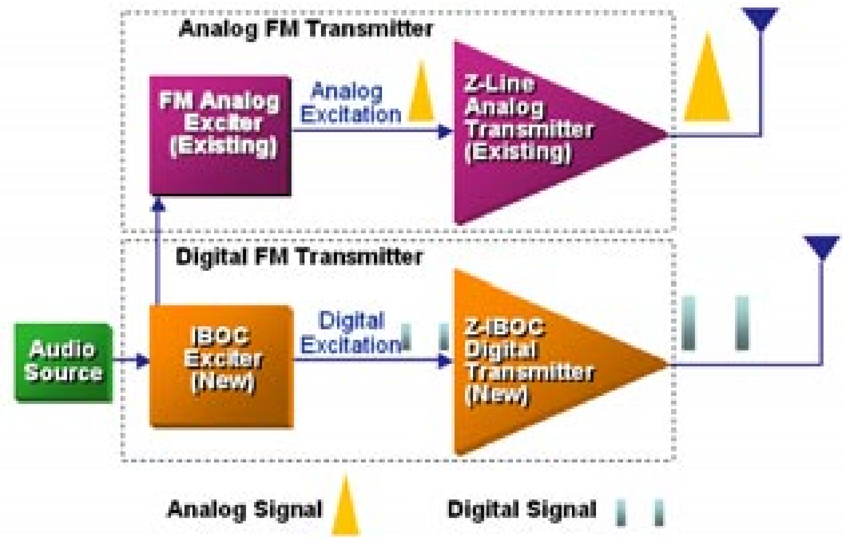
This, of course, isn't all of the story, since older tube transmitters consume a lot more power than that required by the fairly high efficiency final amplifier in operating blowers and other stages of the transmitter. In fact, for stations needing to buy new transmitters, the overall basic electrical savings for FM-only operation will result in a range of $200-$3,000 annually. This means the 20% higher solid state costs would be made up by power bill savings in typically 18 months to 10 years, with earlier payoffs realized at higher power levels. All in all, if you need a new transmitter, you should consider buying a solid state unit capable of low-level combining of the analog and HD Radio signals.

The Secondary Antenna Initiative: Why buy a new high power analog or higher power digital transmitter at all?

The premise of the secondary antenna initiative is to test the viability of eliminating the costs associated with the inefficiencies of high-level combining, as well as the purchase capital required for new low-level combining transmitters. Wouldn't it be advantageous to simply transmit the new low power digital signal through a small secondary antenna wherever tower space and wind load capacity exist? Additionally, in densely packed transmitter plants, the space savings of small all-digital transmitters and eliminating the need for antenna combining, dummy loads and heat exchangers, would likely make the difference in how quickly such stations can commit to a digital radio transmission.

Since the HD Radio digital transmissions are separate signals operating on adjacent spectrum to the FM station's signal, discussion has emerged on using non-combined analog FM and new HD Radio transmissions. Antenna manufacturers, including ER1 and Shively have devised competing methods to test this concept under specific combinations of power and frequency (see Figure 7). This concept was first discussed publicly at the NPR Public Radio Engineering Conference in 2001.

FIGURE 7:
Block diagram of secondary antenna FM approach
[iBiquity]

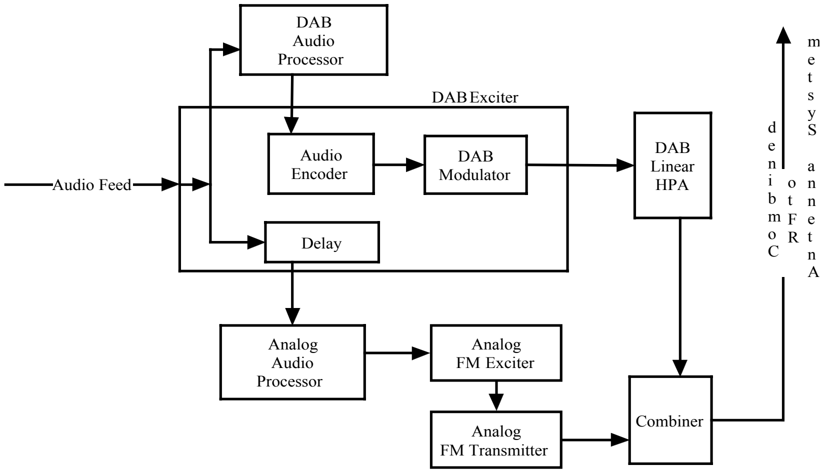


Once the FCC endorsed HD Radio in October 2002, several group engineering teams met at NAB headquarters to discuss tests to demonstrate the viability of this approach to the FCC and other interested parties. An engineering consultant was hired and several conference calls have been held to focus on the parameters that need testing to help the Commission set rules for secondary antenna utilization; preserving and safeguarding analog and digital coverage areas; minimizing interference issues; and maintaining as nearly as practical identical coverage under such an approach.

The FCC has been very cooperative in exploring this possibility and has issued experimental authorizations to aid the participants. Preliminary discussions will focus on the likely situations where existing tower capacity is not available and hopes to prove secondary digital antenna viability within several hundred feet of the existing FM antenna on adjacent, lower elevation masts. This is a very interesting approach since the desired to undesired ratios between the analog FM and HD signals for maintenance of compatible transmissions is deemed critical. It is expected that initial results of such testing will be available shortly after the April 2003 NAB conference in Las Vegas.

Getting the signal to the transmitter
Over time, station operations will evolve significantly from their current design approaches. Instead of our current status as live operations that are assisted by computers, managing datacasting content will require computer operations that are assisted live by humans who combine “just in time” data content from a variety of network and other sources (see Figure 8). Ultimately, an encapsulator will multiplex the subsets of data into the digital radio signal, whether consisting of audio, text, or other data.

FIGURE 8: Equipment configuration for typical FM high-level combined station *[iBiquity]*



In the immediate future, stations will need a minimum of two additional resources in turning on HD Radio transmissions: separate audio processing and the capacity to send the digital signal to the transmitter.

A high capacity digital studio-to-transmitter link or a digital telecommunications circuit will be necessary. Both approaches are in current production by various manufacturers.

Over time, as new services are combined into the digital transmission protocols, it is expected that activity will be handled by Content Management workstations at each station. Several prototypes have been demonstrated to merge artist, title, weather, traffic, audio, and text messages into the HD Radio transmission stream (see Figure 9).

Control room monitoring will necessarily become in-studio monitoring only with on-air monitoring of the delayed digital and analog signals done by silence sensors or at periodic intervals by the operators on duty. This is similar to how stations have to handle talk shows where delay units are employed to safeguard on-air content. Live traffic reports from airborne vehicles will have to migrate to receiving studio cues by means of remote pickup transmitters or other non-cellular real time communications links.

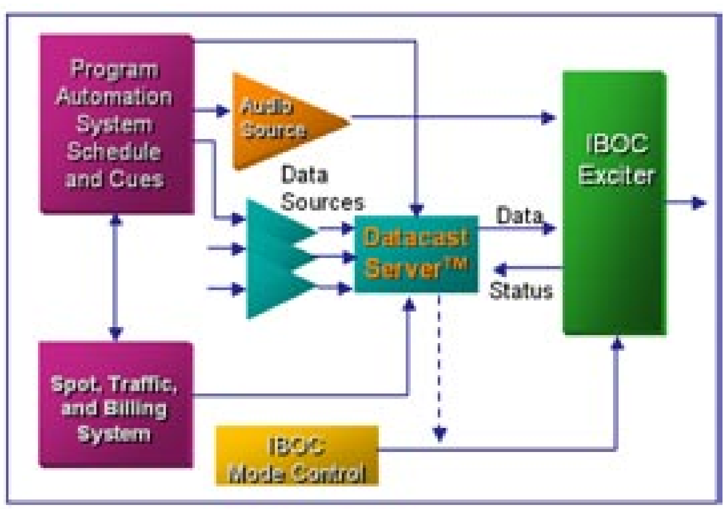


FIGURE 9: Data multiplexing will become a new activity for digital radio station *[iBiquity]*

IV. FM Conversion Costs – Let's Do the Numbers

At the outset, each station's mileage will vary. There is no guarantee that the simplified scale of magnitude costs delineated for purposes of illustration in this section will be within any specific percentage of the actual costs to be borne in individual cases. There is no substitute for completion of an assessment form available from manufacturers such as Harris Corporation or Broadcast Electronics. Others are likely to exist and are not excluded on the basis of any qualitative assessments.

However, in general, average station costs are very close to $171,000 per FM station and $136,000 per AM. There is considerable variation in the numbers generated by the 52% of stations that have responded at this writing with completed EASE forms.

Costs are as low as $90,000 for lower power stations (less than 3.5 kW transmitter power output) and as high as $300,000 for two higher power stations that will require new transmitters and high-level combining methods.

At a minimum, almost every station will require a starting investment of $77,000,* which consists of:

HD Radio Exciter	$31,000
Digital STL Link	16,000
Digital Audio Processor	12,000
Installation & Parts	15,000
Subtotal	$77,000

Big Coverage, Big Ticket

The largest cost variable to add to the core HD Radio capital expenses shown above occurs when higher power stations (those running over 20,000 watts of transmitter power) have insufficient transmitter overhead (less than 10% power headroom). Ten percent (10%) of the analog power will be lost in combining the digital and analog signals. At the higher power levels, low-level combining is infeasible due to the practical range of about 10 kW for solid state FM transmitters. For stations with insufficient headroom, the total cost for a new analog transmitter and digital transmitter will cost roughly as shown in Table 4.

TABLE 4

Transmitter Power Output	Transmitter Cost
3.5-5.0 kW	$51,000
3.6-5.0 kW	$56,500
5.0-7.5 kW	$90,000
7.5-10 kW	$106,000
10.0–20.0 kW	$137,000
20.0–30.0 kW	$147,000

Stations in this category are expected to require a new analog transmitter, a new digital transmitter, and a $10,000 combiner network.

These are also the stations that will save the most if a dual antenna approach proves to be viable for their facility. Often, stations can save a projected 50% of the capital expenses, and in some cases even more – in capital costs. Although the dual antenna concept is in the earliest stages of testing, it is estimated that a station's transmitter costs would save at least 20% among the stations benefiting from this scenario.

Some low-level combined stations (those operating less than 3kW) will save more money by avoiding the new antenna system for dual operation. Most stations, however, will save money under a dual antenna approach, and more money will be saved at the higher power levels. It is likely that may higher power Class C stations would save over $100,000 vs. traditional high-level combining solutions, especially where new analog and digital transmitters would be required due to insufficient transmitter combiner loss capacity.

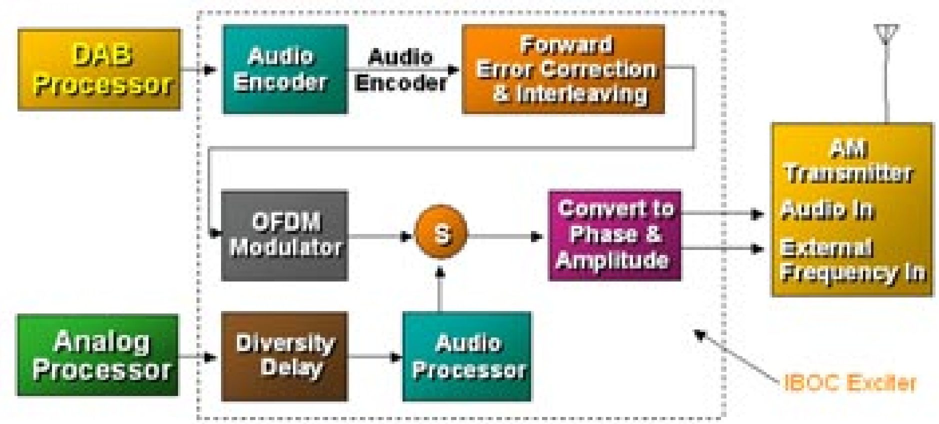
Translator Costs & Operating Limitations
Typical 10-watt translator cost is not known with any certainty as no products are yet available to address this need. One manufacturer has estimated such translators will cost on the order of $40,000, and it is indicated that this is probably safe for budgeting purposes. Since the cost of HD Radio exciters capable of generating up to 30 watts of RF output is roughly $31,000, it is assumed that a high performance receiver capable of receiving and converting at baseband the IBOC and analog FM signals will be on the order of an additional $10,000. Note that this approach will mean that the signals passed through the translator must be identical to those received from the parent station. This approach is not compatible with analog methods of injecting analog audio from a local cart machine or other audio playback device for customized station identifications or underwriting acknowledgements.

V. <u>AM Conversion Costs</u>

There is good and bad news concerning AM conversion costs. The good news is that most stations will be capable of transmitting the HD Radio waveform throughout their coverage areas. The bad news is many, if not most stations, will require on-site engineering inspections to determine whether or not their system will pass the HD Radio signals for full coverage.

The basic HD Radio transmission requirement is the same as existed for the now obsolete AM Stereo standard, namely reasonably flat bandwidth out to 10 kHz above and below the assigned carrier frequency. This is known as having Hermitian symmetry and simply means that reactance is equal and opposite above and below the carrier frequency. AM stations with poor ground systems and some with problematic pattern bandwidth may require expensive upgrades to transmit the HD Radio signal to the projected coverage limits. Stations without +/- 10 kHz bandwidth possessing Hermitian symmetry will still be able to transmit the HD Radio signal, but digital coverage will be restricted to the higher station coverage contours. If you do not know the bandwidth of your AM facility, you may want to contact one of the noted AM consulting engineering firms for an on-site inspection.

FIGURE 10: Block diagram of hybrid AM IBOC system *[iBiquity]*



There is a definite tradeoff in transmitted analog audio quality when adding the HD Radio waveform to AM stations. The analog bandwidth must be restricted to 5 kHz, making room for the digital carriers in the region between 5 kHz and 10 kHz above and below the carrier frequency. This is considered a modest tradeoff by most engineering professionals since little energy from human speech is found above 5 kHz and since many commercial AM radios have such selective bandwidths that they only marginally reproduce frequencies beyond 5 kHz.

As with FM, timing delays to synchronize the analog AM and digital AM signals will be required, meaning live monitoring of the air signal by on-air talent will not work. The good news for AM stations is that the 36 kb/s digital audio signal has been characterized as “near FM quality” and will pass stereo during music programming. iBiquity is also working to adopt a higher quality mono mode for stations that want to further improve the AM HD Radio sonic performance on spoken word programs.

As has been widely reported in the press, nighttime AM digital operations have not been sanctioned, but they are currently being tested by iBiquity and others interested in achieving some measure of nighttime AM digital operation. Due to the vagaries of skywave propagation and the difficult performance characteristics of low bit rate digital signals under such conditions, it is likely that nighttime service will be a restricted coverage service, not unlike the typical low-power post-sunset authorizations that the FCC authorized in the 1980s.

Should AM HD Radio make excellent progress in market penetration, some stations may seek to operate in AM Digital mode, which is likely to fare much better than the hybrid system due to sideband interference. DRM uses all digital mode in AM-like bandwith and operates quite acceptably even with the dynamics of SW propagation.

For public radio, the promise of notably higher fidelity AM transmissions, and relatively lower purchase prices of AM properties in general may present acquisition opportunities in underserved markets. Public Radio Capital in Denver has expertise in building business plans to execute purchase opportunities where favorable conditions exist. A number of astute public radio managers have kept a good ear to the ground in listening and seeking out AM acquisition opportunities – especially where distress conditions can combine to yield highly favorable acquisition terms for a noncommercial licensee.

VI. Sources of Funding

The Corporation for Public Broadcasting has been a key player in building the readiness of public radio stations to participate in the successful migration to HD Radio transmissions. CPB sought funds for digital migration from Congress and was awarded a $45 million appropriation in 2002. Although the bulk of the funds were set aside for the costly migration of public television stations to the digital Advanced Television Service, some $4.5 million was earmarked for the initial needs of public broadcasting stations in the 13 initial seed markets identified by iBiquity.

Digital Radio Terminology

All-Digital – the HD Radio mode using the full analog FM and HD Radio channel for transmitting information in purely digital format. All Digital transmissions will require new receivers for reception and is not expected to be in common practice for 10-15 years under a voluntary industry migration. Some experimental activities have been proposed to test this transmission mode, such as late night surround audio broadcasts.

DAB (Digital Audio Broadcasting) - a generic term for digital radio broadcast transmissions

CEA (Consumer Electronics Association) - an Arlington, Virginia, based trade organization representing consumer electronics manufacturers in the United States

COFDM (Coded Orthogonal Frequency Division Multiplexing) – the digital transmission technique that interleaves data in time and frequency to achieve robust, reliable signal delivery. COFDM is sometimes shortened to OFDM but is a common method for sending digital transmissions, especially in mobile environments. OFDM techniques are used in both the Eurkea 147 and HD Radio transmission systems.

CPB (Corporation for Public Broadcasting) – a private, nonprofit corporation created by Congress in 1967 to facilitate the development of, and ensure universal access to, non-commercial high-quality programming and telecommunications services.

DataCast Server – a computer server which multiplexes audio and additional data in synchronized frames for transmission in real time.

Delphi – the radio receiver manufacturer that produces receivers largely for General Motors

DRM (Digital Radio Mondiale) - a company and digital radio format that is entirely digital and designed to work despite the vagaries of shortwave transmission. DRM has been adopted by the International Telecommunications Union (ITU) as a standard for short- and medium-wave digital radio transmissions.

DTAC (Digital Transition Advisory Committee) – an advisory committee of NPR members and related public radio professionals dedicated to issues associated with the digital radio conversion.

Dual Antenna approach – a proposed digital radio transmission scheme which uses a second digital only antenna to avoid the need and costs of a combiner system. Also called a space combining or secondary antenna approach

EASE (Early Adopter Station Enhancement) – the project is a systemized analysis sponsored by iBiquity Digital to document the conversion costs and equipment requirements for adding the HD Radio format. The free service was initiated in 2001 and has been updated as system refinements, such as the secondary antenna approach, have emerged.

EBU (European Broadcasting Union) – the organization representing major European broadcasers before the ITU and other bodies

Eureka 147 – the name of the Digital Audio Broadcasting project (DAB) sponsored by the European Union that led to the first ITU recognized standard for digital radio transmissions. This format relies on grouped transmissions and new frequencies but offers a highly robust digital radio delivery platform. Eureka 147 has been on the air for several years in Europe and Canada and has achieved mixed, although improving, results and adoption by consumers.

Encapsulator – a device that multiplexes data in predetermined associations for transmission

Extended Hybrid – an HD Radio transmission mode that adds additional data capacity by activating partitions within the FM “guard band” located between analog subcarriers and the standard hybrid digital radio carriers.

FCC (Federal Communications Commission) - the federal agency that regulates broadcasting and other telecommunications activities

HD Radio – the trademark brand name for iBiquity Digital’s digital radio transmission format

HXVC – Harmonic eXcitation Vector Coding – a form of low bit-rate voice coding that is a subset of MPEG-4 and which achieves moderately good quality at very low bit rates on the order of 4 kb/s.

iBiquity Digital – the corporation that owns the transmission format that has received favorable reports from the National Radio Systems Committee and which was sanctioned by the FCC on October 12, 2002, as the method of transmitting digital radio programming in the United States. iBiquity Digital is a defacto “grand alliance” as the surviving corporation of the prior competing digital radio system proponents, USADigital Radio, and Lucent Digital Radio. Partners in iBiquity include 10 of the top 12 commercial radio groups in the United States, as well as manufacturers like Harris Corporation, Texas Instruments, and Visteon.

IBOC (In-Band On-Channel) - an acronym denoting transmission of digital information within the transmission allocation of existing AM and FM stations. To engineering purists, this is a misleading label since the digital information is actually transmitted at low levels in the immediately adjacent channels above and below each station’s FM assignment.

Nonetheless, the information is contained entirely within the emission mask of the station since immediately adjacent stations are precluded in the local vicinity as part of the long-standing interference criteria.

ID3 Tags – the standard whereby supplemental information such as artist and title information, and basic radio station information, including call letters, frequency and operating slogan will be transmitted to HD Radio receivers.

ITU (International Telecommunications Union) - a United Nations sponsored non-governmental entity that can trace its roots to the Berlin radio conference of 1903. The ITU is the only international organization devoted to maximizing the efficient use of spectrum by minimizing interference and maximizing interoperability. World Radio Conferences (WRC) are the "plenary" bodies that meet on specific topics on a semi-regular basis to consider radio communications issues.

Hybrid Transmissions – transmissions that simultaneously send analog radio broadcasts in additional to digital radio transmissions of the same and additional data.

NAB (National Association of Broadcasters) - the trade organization representing radio and television broadcasters in the United States

NABA (North American Broadcasters Association) - the North American equivalent of the European Broadcasting Union (EBU). Membership includes the major television networks as well as a shared membership among CPB/PBS and NPR. NABA has one vote within the ITU, as does the EBU.

NPR (National Public Radio) – a membership organization based in Washington, D.C., that was the first organization to petition the FCC in 1987 to consider the likely migration needs of radio broadcasters to digital radio transmission (raised in the putative phases of the Advanced Television rulemaking).

NRSC (National Radio Systems Committee) - an industry standard-setting body sponsored by the National Association of Broadcasters and the Consumer Electronics Association. Participation within the NRSC is open to any interested stakeholders in the subjects of discussion but voting eligibility is limited to organizations that maintain ongoing attendance and participation.

PAC – Perceputal Audio Coder, a Bell Labs codec that was one of the first of the more advanced coding algorithms pioneered in the early 1990's. PAC is used in the iBiquity Digital system design and the Sirius satellite service.

PTFP (Public Telecommunications Facilities Program) - a unit of the National Telecommunications Information Administration whose mission is to foster the reach of public telecommunications entities in the United States

Radiotext Messaging – a method of transmitting text to receiver displays via a digital transmission

SCA (Subsidiary Communications Authorization) - the regulatory term applied to FM subcarriers where subchannels for the visually impaired and other special program and data services operate

Simulcast – transmission of the same program information in two different channels. Early FM broadcasts were often the "simulcast" broadcast of AM stations and during the 1980s, prior to the adopted and spread of the TV Stereo format, many FM stations would "simulcast" in stereo the audio of television performance programs. The HD Radio format adopted by the FCC in 2002 was initially adopted as a simulcast format of the analog FM audio. NPR and several FCC Commissioners urged exploration of the possibility of sending secondary program information as well as the simulcast audio.

SMIL (Synchronized Multimedia Integration Language) - a programming language that allows users to send text, graphics, audio and even video in a time locked sequence aimed at consumers. SMIL is the basis of several internet based multimedia offerings, is a recognized standard by the world wide web consortium (W3C), and is supported by iBiquity Digital as the sanctioned method for sending multimedia content over the HD Radio format.

Surround Sound – the common name for sending audio in an enveloping environment to consumers. Dolby Digital, DTS, 5.1, etc., are common names associated with surround audio, which has become the most rapidly adopted new consumer electronics technology introduced, primarily due to the proliferation of DVD players.

Tomorrow Radio Project – a project initiated by NPR, at the urging of members of the Digital Transmission Advisory Committee (DTAC), to test the viability of secondary program transmission. The initial project objective included support from iBiquity Digital, Kenwood USA, Harris Corporation and NPR member station KKJZ in Long Beach to test performance characteristics of supplemental digital only audio transmissions within the HD Radio format.

Visteon – the receiver manufacturer that produces radio for the Ford Motor Company

WBJB, Princeton, New Jersey - an NPR member station licensed to Brookdale Community College, Lincroft, NJ, which served as a test bed for the Lucent Digital Radio transmission system

WETA, Washington, D.C. – an NPR member station licensed to the Washington Educational Television Authority, which served as an iBiquity test bed during the final refinements of the iBiquity transmission protocol.

WILL, Urbana, Illinois – an NPR member station licensed to the University of Illinois at Urbana and the first U.S. radio station to act as a test bed for IBOC technology.

WGBX – a PBS affiliate which pioneered early digital audio transmissions by sending the F1 format in late evening hours under experimental authority in the late 1980’s.

WGUC, Cincinnati, Ohio - an NPR member station that first broadcast digital audio using the F1 format to listeners over the local cable system in 1985.

WUSF, Tampa, Florida – an NPR member station licensed to the University of South Florida at Tampa, expected to become the first public radio station transmitting the FCC-sanctioned HD Radio digital format in February 2003.

5.1 – An audio transmission format that sends five full-fidelity discrete audio channels: Left Front, Center, Right Front, Left Rear and Right Rear plus a sixth channel of “low frequency” information denoted by the “.1” suffix.