HD Radio
Where We've Been, Where We're Going
And How to Get There

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***Abstract**: In a very short time, HD Radio has moved from concept to reality. Early adopters have blazed the trail for those who came later and continue to join their ranks. Those early adopters learned a great deal and those now contemplating a move to the digital realm can benefit from their experience. In this paper, we will look at where we came from, where we are now and where we are likely headed. We will also look at the ins and outs of HD Radio conversion and the various options available for AM and FM stations.*

1.0 Introduction

Just a few years ago, HD Radio was still "DAB" and in a very real sense, "vaporware." A few manufacturers were starting to produce and ship some HD-R equipment, and early adopters began to get aboard. Those stations were very much on their own, however, pioneers in the truest sense of the word.

In the years that followed, more and more stations got aboard, driven mostly by licensing incentives offered by iBiquity Digital Corporation. Several large companies such as Crawford Broadcasting Company, Clear Channel, Cumulus, CBS, Entercom and others received significant license fee incentives in exchange for a commitment to convert the bulk of their stations to HD-R within a certain time frame. These companies have been the driving force behind the HD-R conversion and responsible for most of the 1,000+ HD-R stations now on the air.

We have learned a lot over the past four years, and much of this came about through cooperation between otherwise competing entities. Some of this came about through the Consortium but most took place because station engineers picked up the phone or emailed and contacted other station engineers. Together, engineers figured out what worked and what didn't, and they figured out how to do it better. Manufacturers (like Omnia Audio) tuned in to some of these exchanges and brought us products that better addressed our real-world needs.

Today, the HD-R rollout continues. More and more stations are added every week, moving into the medium markets now and eventually into the smaller markets. More and more receivers are coming on the market, and the price point is dropping. The HD-R train has left the station and it is gaining momentum.

2.0 Improving the State of the Art

With the HD-R signals now on the air, the focus seems to be on some of the secondary factors. Multicast formats are becoming real formats now instead of simulcasts of main channel audio or other co-owned stations. Stations are working on the program-associated data

(PAD) text, getting it to work properly on main and multicast channels and using products such as The Radio Experience (TRE) to format it and insert messaging.

Many stations got on the air with their HD-R signals using the most expedient means available. A lot of higher-powered stations used high-level injection. Some used their licensed auxiliary antennas in a dual-antenna arrangement, often settling for smaller digital coverage areas because of the lower HAAT of the auxiliary/digital antenna. Now, many stations are evaluating their digital coverage and performance, taking a hard look at their options for improvement. Dual-input antennas, interleaved antennas, high-power FM+HD transmitters and other options are being looked at and implemented.

2.1 AM Considerations

A lot of AM stations are finding out that it very much matters what you feed their HD Radio coders. We are finding out that feeding the HDC codec from the output of a 128k MPEG stream (such as many of the satellite feeds coming our way – including CRC satellite feeds) results in a grungy on-air sound with all sorts of artifacts. Stations that have MPEG STL systems like the Intraplex may find their on-air sounds grungy no matter what the source. This is forcing a move to linear STL paths, the elimination of sample rate conversions and a lowering of the compression in studio digital media systems.

2.2 FM Considerations

Another thing we are learning is that we need different processing on our HD-R audio than we do on our main channel (analog FM or AM) audio. The early approach was to use common processing right up to the final stage limiter. This was a good economical approach, but we are finding that listeners expect the HD-R signal to sound *different* than the analog. One of the comments that is frequently seen in online chats about HD-R says that FM HD-R doesn't sound any different than analog FM. We've got to find a way to address that.

2.3 Interference Issues

There are, at this late date, some HD Radio naysayers out there. We all read their criticism in the trade press and elsewhere. They are particularly critical of AM HD-R but also have problems with FM. Almost all the criticism has to do with occupied bandwidth/interference issues. In response to this criticism, I offer the following:

1. *The iBiquity HD-R system is a compromise*, as is every practical deployment of technology. The FM system stuffs 10 gallons of bandwidth into a 1-gallon bucket. The AM system stuffs 3 gallons of bandwidth into a 1-pint jar. This is amazing, and it is what the best minds in our industry came up with after more than a decade of work. There is not a better way given the constraints placed upon us.

2. *HD-R does cause interference*, but it is primarily outside the protected contour. Many stations, particularly "rim shots," rely on extra-contour coverage for their business. These stations are not entitled to that coverage and any such coverage lost as a result of

HD-R is no different than if a contour-protection move-in took place in the same area. There is more interference out in "B" country than here in the west, where stations are more spread out. There are cases of third-adjacent AM HD-R interference within the same market, primarily within the blanketing contour of the interfering station.

3. *AM HD-R interference has been exaggerated*. Those that report a loud buzz on empty channels adjacent to HD-R AMs are correct, but the loudness is due to the lack of carrier, not the strength of the interfering signals.

4. *Nothing better is going to come along*, and we can't start over and do something else for many reasons, the greatest of which is the receiver manufacturers, still wary after the AM Stereo mess of the early 1990s.

5. *We need a digital mode* on terrestrial digital radio. Long term, we will not survive without it.

3.0 Conversion Options

Early HD-R adopters were pioneers in every sense of the word. It's true that manufacturers had equipment available to produce HD-R signals for FM and AM, but this was "first generation" or "version 1.00" equipment, often buggy and short on features. There had been something of a rush to market and as a result, those who installed this equipment were "test pilots," learning how things work the hard way, through trial and error.

3.1 FM Options

Crawford Broadcasting Company was on the "bleeding edge" of the HD-R rollout with both its FM and AM stations. We were somewhat in a hurry to get the conversions done in order to advance HD Radio, so we had to figure out both the fastest and most economical means of conversion. With AM HD-R conversions, there are really *no options*. There is only one path to take. But with FM, there are often several different paths available. I am often asked which of these is the best way to go. The answer: it depends.

Some of the options currently available are:

- Low-level injection (common amplification)
- High-level injection (separate amplification)
- Separate antenna
- Dual-input antenna
- Interleaved antenna
- Split-level combined

The best option to use is totally *situation dependent*.

3.1.1 Low-Level Combined

Stations with higher transmitter power output (TPO) may find that high-level injection is the only realistic option. That has certainly been the case in the past because there were no linearized transmitters available capable of producing more than about 12 kW. In just the last year, however, manufacturers have come out with linearized transmitters that are capable of up to 25 kW of FM + HD, providing another option for class B or C FM

stations with high TPOs. In the next year or two, I think we can expect FM + HD TPOs in the 35 kW range.

FM stations with TPOs in the 25 kW and under range can often use low-level combined or common amplification to get their HD-R signals on the air. This is without a doubt the fastest and easiest way to convert and in the long term, the easiest to operate and maintain. This method is expensive, however, both on the front end and in operational costs. Such transmitters are expensive to manufacture and those costs are reflected in the price. Linearized transmitters capable of passing the HD-R signal are of necessity inefficient, often in the 30-40% range. As such they take more electricity to operate. More power is wasted in heat and more cooling is required. It can thus cost three times as much to operate a linearized transmitter than a non-linearized transmitter with the same TPO.

3.1.2 Dual-Input/Interleaved Antennas

In terms of operational efficiency, it's hard to beat the separate antenna, dual-input antenna and interleaved antenna options. A low-power HD-only transmitter can be used to feed the HD-antenna and the existing analog transmitter can continue to feed the main (analog) antenna. As such, the HD-R transmitter is much less expensive on the front end and it is much less expensive to operate. But there is no free lunch. The costs with this option are often on the front end.

The process starts with a structural analysis of the tower with an eye to supporting the load of the much heavier dual-input or interleaved antenna. Chances are, a structural upgrade to the tower will be necessary. If you're lucky, only a few guy wires will have to be upgraded to a larger diameter. More typically, you will have to change guy wires and install additional stiffeners, horizontal and diagonal members. This can be very expensive and may rival the cost of a new tower.

Manufacturers are working on new antenna designs even now and will hopefully have some smaller, lighter options available in the coming year or two.

3.1.3 Separate Antennas

The FCC will allow separate antennas for the analog and HD-R operation if and only if a licensed auxiliary antenna is employed for this purpose. This is not a huge impediment for those stations that do not have a licensed aux antenna. It is a relatively simple thing to file a Form 301 and Form 302 with the FCC to license an auxiliary antenna. The bigger concern may be structural, if the auxiliary antenna is not already on the tower. A structural analysis will be required and a structural upgrade may be required.

The advantage of the separate antenna over the dual-input or interleaved options is that a smaller antenna with fewer bays can be used, and this antenna can be fed with a smaller transmission line. An educational-FM antenna fed with 7/8-inch transmission line weighs a lot less and has a lot less wind load than a full-sized antenna and feed line.

The disadvantage of the separate antenna is that with the auxiliary/digital antenna located lower on the tower than the main/analog antenna, the HD-R coverage will be less than the analog. This may or may not be a factor,

depending on the relationship of the tower location to the populated area. "Rim shot" stations will find this option unacceptable while stations with their tower located in town or close by will likely find the arrangement to work fine.

3.1.4 High-Level Injection

Stations with high TPOs may find that high-level injection is the most economical way to go, both initially and for the long term. In this arrangement, a separate digital transmitter that produces 10% of the power of the analog TPO is used. An injector in inserted into the transmission line and the HD-R signal is injected. Such injectors have 10 dB of insertion loss, meaning that only 10% of the power is coupled to the antenna; the other 90% is wasted in a reject load as heat. There is also about 11% loss in the analog path, meaning that the analog transmitter must produce 11% more power than it does now to maintain the licensed ERP. That 11% of the analog power is also wasted as heat in the reject load.

This represents one of the fastest ways to get on the air with an HD-R signal for most higher-TPO stations. It is economical because the existing analog transmitter can be retained and used until the end of its useful life. It is also economical because the analog transmitter operates with its normal high efficiency. While 90% of the digital power and 11% of the analog power is wasted, the overall operational efficiency is often much higher than were a low-level combined transmitter with high TPO used. Additional up-front costs are incurred for the injector and reject load as well as the transmission line parts to connect everything together.

3.1.5 Split-Level Combining

Split-level combining uses the existing analog transmitter for part of the analog power and the FM + HD output of a linearized transmitter for the remainder of the analog power and the digital. This method has the advantage of allowing the use of the existing analog transmitter along with its high efficiency. It also permits the use of a lower-TPO linearized FM + HD transmitter, providing for higher operational efficiency. The up-front cost is relatively high because of the combiner and higher-powered linearized transmitter.

This may be a good option for very high TPO stations that feed a master antenna with 40 kW or thereabouts. It is complex, however, and will take some engineering horsepower to design and maintain such a system.

3.1.6 Finding the Best FM Option

Except in cases where the answer is apparent from the outset, the best means of getting an FM HD-R signal on the air is determined by careful analysis in a spreadsheet. Capital and operating costs over the life of the equipment (typically 15 years) are entered into a spreadsheet for each option.

On the capital side, include costs for transmitters, antennas, transmission lines, injectors, reject loads, combiners, structural analysis, the estimated cost of structural upgrade and the cost of enlarging or replacing the transmitter building if necessary. Don't forget a bigger generator if one will be required. The total on this side will show the upfront cash layout for each option.

On the operational side, include the power consumption of the transmitters times the electrical cost times the number of operating hours in a

year times 15 years. Include the cost of additional cooling using the same formula. Don't forget the cost of tube replacements if necessary for some of the options. The totals on this side will show the monthly, annual and lifetime operating costs.

With these numbers in hand you can decide which option is best for you. Some may opt for a lower up-front cost and higher operating costs. Others may take the long view. The bottom line is that you cannot accurately evaluate the options without doing this type of analysis.

3.2 AM Options

As mentioned above, there are not multiple means of producing an AM HD-R signal. All AM HD-R is produced by low-level combining, generating the HD-R signal along with the analog carrier and amplifying it along with the analog carrier.

This requires a linearized AM transmitter. Most modern pulse-width or pulse-duration modulation transmitters can be made to operate linearly, although significant modification may be required. Check with your transmitter manufacturer, who can tell you whether your existing transmitter can be modified and how much it will cost. If it cannot be modified, get quotes from several manufacturers on HD-ready transmitters. The choice then becomes one of brand preference and price.

The most critical factor in AM HD-R conversions is the antenna. Many AM antennas will require significant work to get them to pass the HD-R signal properly. Directional antennas represent a bigger challenge than non-directional radiators.

While there is an iBiquity specification for sideband VSWR values, the orientation of the load is more important. In some cases this can be taken care of with simple modifications to the matching or common point networks, but often it requires an outboard "line stretcher" network.

The best way to approach an AM antenna vis-à-vis HD Radio is to start with a careful analysis. Measure all the ATU input impedances and if necessary, adjust them to match the transmission line impedances. Then use a network analyzer on the input to the antenna system where the transmitter connects. The best place to connect the analyzer is right at the transmitter output. That will tell you what load the transmitter is seeing and together with your phasor or matching network schematic, that will tell you what you need to do to get the antenna HD-ready.

3.3 Other Considerations

A new processor will be required for HD-R. There are numerous choices, and like all processor choices, most of this is personal preference. The most economical way to go is with a combination AM/FM and HD processor. This is, in my view, the best option for AM. For FM, if you want your HD-R audio to sound different than your analog, the best option is to use a separate processor for HD-R, employing much less compression and clipping while using look-ahead limiting for peak control.

For multicast, a very economical option is the PC-card processor. Some transmitter manufacturers are offering such a processor as an integral option with the importer, or it is a simple thing to add such a processor in the field.

A major consideration is that th audio routing must be made in such a

way that the bread-and-butter analog signal is protected no matter what happens to the digital. Typically, the analog diversity delay which time-aligns the analog and digital audio for the listener, is done in the HD-R exciter. The problem comes when the HD-R exciter, essentially a computer, needs a reboot or otherwise fails. The analog audio is lost and the station is off the air. A good option to avoid this is an audio processor that performs this delay function. Another workaround is to use a distribution and routing scheme that allows bypass of the HD-R exciter in the event of a failure. But the time to think of this is during the design phase, not during afternoon drive with the station off the air.

Another important consideration is off-air monitoring. With HD-R on the air, the analog audio is delayed about 8.4 seconds and as such, it will no longer be possible to monitor in real time. Some sort of processed program audio will be needed for studio headphones while an automatic "silence sense" will be needed to listen to the actual off-air audio and generate alarms if a failure occurs.

4.0. Where Do We Go from Here?

We're all waiting on the FCC to tell us what the digital rules are. We've been waiting for a long time. Back in the summer of 2006, it looked like a rulemaking was imminent, but other pressing issues such as ownership pushed the new terrestrial digital rule set to the back burner. We heard from the FCC at the NAB Radio Show in Dallas that the new rules are all agreed upon but that commissioners are taking their time with them because they feel they were blindsided on the DTV operating rules. Hopefully we will see action on this early this year.

Included in this rule set we should see items pertaining to antennas, hopefully eliminating the need for an STA to operate with separate collocated antennas; multicasting, hopefully eliminating the need for an experimental authorization to multicast; EAS requirements; station ID requirements; public service requirements… essentially everything we need to know to operate.

Perhaps the biggest question has to do with AM nighttime. Will the FCC authorize AM nighttime HD-R? What form will it take? What restrictions will be put on it? What safeguards will be put in place? I think the FCC will authorize AM nighttime HD-R in some form. I sincerely hope that the safeguards are at the same time effective and *reasonable*. It would not be reasonable for a station with a statutory night limit of 2 mV/m to complain of interference from an adjacent-channel HD-R station outside his 2 mV/m contour and expect the interfering station to take remedial action. Interference produced within the interference-free contour, on the other hand, should trigger remedial action.

5.0 Conclusion

The HD Radio train has left the station. We're building momentum with every passing day.

HD Radio has a lot to offer broadcasters and listeners. For AM stations it offers FM-like audio quality, a night-and-day difference from the existing analog. For FM stations, it offers improved audio quality and multicast channels. For all of us, it offers the all-digital transmission path that today's consumers demand.

The success or failure of this new digital medium is in large part up to us, the broadcasters. And it's not just up to

corporate, station management, programming and the promotions department. The listener's experience with HD-R is largely up to station engineers. They determine what the listener hears. Audio quality, time alignment, level alignment and *consistency* are all in their court. It's up to them to make that experience a good one and make HD-R a desirable medium for the masses. It's up to management to give them the tools they need to do that.