RADIOWORLD

HD Radio Then & Now

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HD Radio Then and Now

Paul McLane
Editor in Chief

HD Radio in 2018 is simpler, more affordable and efficient than it was a decade ago. No longer an engineering "science project," the technology platform provides better coverage and reliability than ever on FM. And there is new interest in its possibilities on AM.

The latest Radio World ebook checks in on the state of HD Radio:

- We lead off with an interview with Dave Kolesar about Hubbard Radio's decision to take WWFD(AM) in Frederick, Md., all-digital this July. Does the future of all-digital radio on the AM band in the United States start here?

- Then we dive into the latest data from Xperi about HD Radio deployment. How many receivers are in the market? How many cars are shipping with HD Radio? Which cities have the highest penetration?

- The eBook concludes with Jeff Welton's white paper "HD Radio — Then & Now" from the spring NAB Show, reviewing the evolution of the IBOC system used in the United States, challenges faced by early adopters and improvements to installation techniques, hardware and software. Welton addresses what he describes as six myths about HD Radio implementations.

This is the latest addition to Radio World's growing library of eBooks. Read all recent editions for free at radioworld.com/resource-center.

WWFD: All-Digital AM Radio Starts Here

Our conversation with Hubbard's Dave Kolesar, a self-described evangelist for the MA3 mode

by **Paul McLane**

Many AM broadcasters have been heard to say, "I'll never turn off my AM analog." But in July, Hubbard Radio station WWFD "The Gamut" in Frederick, Md., did just that.

It announced it would become "the first full-time, all-digital AM radio station in the United States" — indeed the first all-digital station on either FM or AM — under a year-long experimental authority grant from the Federal Communications Commission.

"In an effort to keep up with the ever-evolving demand for digital, The Gamut will be turning off its analog signal and will no longer be accessible through regular AM radio beginning today, Monday, July 16 at noon," the company announced, informing analog listeners that they could hear the format on the station's FM translator at 94.3.

> *"Having a translator and then taking the parent AM station digital might change the conversation of how we look at AM broadcasting."*

WWFD is a Class B station on 820 kHz with 4.3 kW (non-directional) during daytime hours, and 0.43 kW cardioid directional at night. Its AM signal serves Washington, northern Virginia and parts of nearby Maryland. The Gamut format can be heard not only on the digital AM and its analog FM translator but also several of Hubbard's HD3 channels in the region.

This project grew out of a collaborative effort between The Gamut and HD Radio's parent Xperi Corp. The AM transmitter site is the same location where Xperi holds an experimental 1670 license. Also involved in the project are NAB Pilot, Kintronic Labs and Cavell, Mertz & Associates.

Hubbard believes that the experiment will be of significant value to the broadcast and consumer electronics industries. It told the FCC that the work is intended to support the feasibility of a possible transition to all-digital AM transmissions and that it hopes to give AM broadcasters "parity in the car dashboard" with FM HD Radio, satellite and internet streaming.

Given well-documented issues facing analog AM — poor sensitivity, technical upkeep, quality of receivers and narrow audio bandwidth — Hubbard thinks all-digital opens the door to a new audience for The Gamut and is an opportunity for "an enhanced in-vehicle AM experience," including better sound quality and more display features.

Radio World asked Dave Kolesar, the station's engineer and program director, about the project and the reasons behind it.

Radio World: *How did you and Hubbard get involved, and why?*

Kolesar: It was one of those "in-the-shower" realizations. I got the idea to take WWFD all-digital around Christmastime of 2016; with the approval of our local management, I approached Xperi at the Consumer Electronics Show in January of 2017 saying, "Hey, I'm the program director of this AM radio station in Frederick, Md., and I would like to take it all-digital. Can you help me?" I approached [Senior Manager for Broadcast Technologies] Mike Raide at the Xperi booth.

I'm normally the transmitter engineer in Hubbard Radio's D.C. cluster, and I have been fortunate enough to have been given an HD sub-channel to program as a music channel called "The Gamut." Over the course of its expansion it also encompassed WWFD.

As a result, I had effective control of this little AM radio station, and it was building up an audience. We were going to get a translator for it, and most of the audience would, predictably, migrate over to the FM translator. This gave me the idea, "Whoa, our analog audience is going to be parked on our FM signal. Why not try to do something with the AM, which has a much

WWFD plays on a SPARC HD Radio receiver, with metadata displayed.

larger footprint than the translator? Why don't we try to make the AM competitive as well in the long term? Then you could use your FM translator to promote the idea: 'Hey, as soon as the translator fades out, come back to the AM with your HD Radio and get another 40, 50, 60 miles of listening.'"

In Xperi I found a willing partner to give advice and technical help. This was going to be the first all-digital AM radio station. Not just all-digital AM radio station, this was the first all-digital radio station in the United States, if you exclude overnight tests. We're running full-time.

Even though we have a one-year experimental, we're going to try to find a way to renew it or do something to stay digital. I don't intend to look back.

***RW:** Somewhere Glynn Walden must be smiling.*
Kolesar: I did talk with him at NAB this year about this, and he was very excited about it.

***RW:** Are we close to the time when we might see stations able to do this on anything beyond an experimental basis?*
Kolesar: That is a question I genuinely can't answer; it seems something more for the lawyers. I would think other stations could get on the air with the experimental and the FCC would grant it, I would hope. To get the MA3 mode — the all-digital mode of AM HD — as a legitimate licensed mode of operation, I'm not sure what that would take — a formal rulemaking process, I guess. Part of that process probably would be informed by the data and the reports that we generate from this experiment.

I'm hoping that we're talking months or a few years as opposed to decades. I'm hoping this will happen a lot faster, because in a lot of places AM stations are running out of time. Something needs to be done. Listenership has declined. Of course a lot of legacy heritage stations are still hanging on [or] doing quite well for themselves, but there's a lot of AM stations that aren't doing a whole lot. Having a translator and then taking the parent AM station digital might change the conversation of how we look at AM broadcasting.

***RW:** Have you had feedback from analog listeners about losing the signal?*
Kolesar: Yes. I have had some people disappointed. I must confess it was not as many as I had anticipated, because a lot of people did migrate over to the FM translator. Some people wrote in or messaged me via Facebook or email.

Some people said, "What did you do? All of a sudden now I turn on my radio, I hear some noise, and then it goes to silence, and then it's so clear and it sounds so good. What did you do?" I'm gathering from that line of listener feedback that a certain amount of people aren't aware that they had HD receivers in their cars. All of a sudden they can pick it up in digital and it's amazing to them.

It hasn't been as disruptive as I had anticipated, but that was probably helped by the fact that we have an FM translator.

It's also worth noting that in the DC area about 20 percent of the vehicles on the road have HD capability. As a music station on AM, I would rather take my chances with that 20 percent than try to keep convincing people to give music on analog AM a try. Because it's just not working.

***RW:** You have an interesting perspective as both an engineer and a program director. Have you had other broadcasters talking to you about this?*
Kolesar: A few stations from around the country find me by email or Facebook asking about my experiences and asking, "When you're ready to really sit down and talk, can I hear your impressions of the system?" Typically they're smaller stations that you could say don't have a whole lot to lose.

Many station clusters have an AM that they're not really doing much with, that's underutilized. WWFD was ours. And so if you have a forward-thinking ownership, in our case Hubbard Radio, you can make the case: Why not try to invest in the future and use these stations as a test bed for all-digital?

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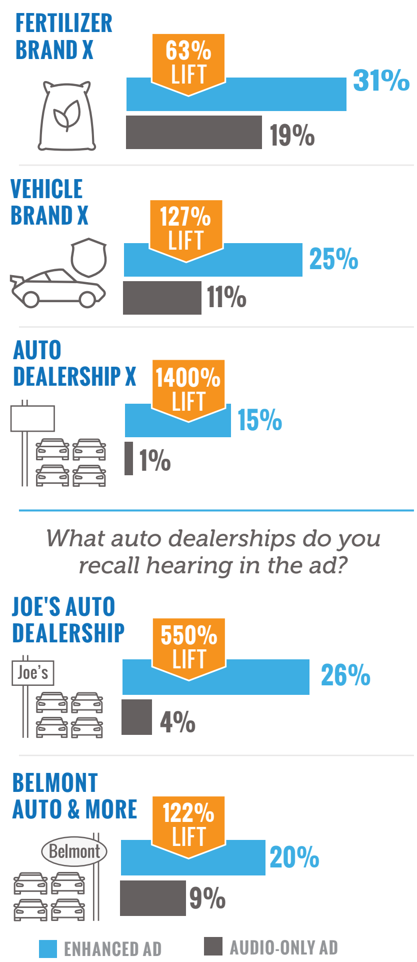

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The advertisers in our survey were a Home Improvement Retailer and an Auto Dealership. We presented listeners with two radio ads using graphics that simulate the driving experience. The spot began with a short piece of music, followed by an ad for the Home Improvement Retailer and the Auto Dealership. Ads were Enhanced or Audio-Only.

ENHANCED AD: Audio played with image and text appearing on in-vehicle display

AUDIO-ONLY AD Only the audio was played

CONTACT

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SOURCE & METHODOLOGY SOURCE: HD Radio Campaign Effect Study, conducted by Nielsen for HD Radio, Q3 2016
Survey respondents are 1,204 adults 18-64 who own or lease at least one vehicle. Survey dates 7/27/16-8/10/16.

* Listeners refers to the respondents of this survey

** Full survey question asked was: "When you are driving in your car and the radio is on, how often do you read any scrolling text that appears on your display?"

At the transmitter on the day the station went all-digital are Tom Casey, Hubbard Radio's operations manager in Frederick; Dave Kolesar, Hubbard senior broadcast engineer; and Mike Raide, Xperi senior manager of broadcast engineering.

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The added bonus is the positive feedback that we've gotten from listeners. Listeners have also asked technical questions about it; they're very interested in how it works and people have noted how digital AM behaves differently than analog AM in terms of reception and buffering. These are some of the effects we're hoping to quantify.

RW: *What can you tell us about the process?*

Kolesar: The first thing we had to do — the first step for anybody who really wants to have their station consider MA3 operation — is to have somebody evaluate your antenna system. In our case it was Kintronics; there are other companies, Phasetek is one.

They need to sweep your antenna and see if there's enough bandwidth to pass all-digital with enough linearity. They may come back and say, "Yeah, all good," or they may say, "It need some retuning" or "We might need to rebuild some networks and redesign the system a little bit."

Our system was the latter; we needed to modify our phasor and tuning networks to broaden the array. So we spent some time out at the transmitter installing more coils and capacitors, changing around the networks a little bit, learning as we go along.

I must say, this is quite fun and a learning experience for me. As we did this project, I read both of Jack Layton's books, "Directional Broadcast Antennas" and "Directional Antennas Made Simple." I also went to the more advanced level of learning, as my boss lent me a copy of Edmund Laport's 1952 tome "Radio Antenna Engineering."

RW: *How dramatically did you have to change the air chain? Did you have to go to a new transmitter or was it simply a matter of changing the mode on the existing one?*

Kolesar: We had two transmitters, a Gates 5 and a Nautel AMPFET 5. The AMPFET 5 was not going to do digital, it was just too old.

We brought in a Broadcast Electronics AM 6A to become our new main transmitter; currently we're running a Nautel exciter on it along with the Nautel Exporter Plus.

We converted the Gates 5 to all-digital as well for MA3; and we're using a refurbished BE ASi 10 [AM HD Radio signal generator]; the ASi 10 had come from WFED, the former WTOP 1500 AM. We put that back into service as what is now our aux transmitter.

The AM 6A has been around for a while; so has the

Gates 5. So for an AM station, it doesn't necessarily mean a new transmitter. It may mean some modifications to your existing transmitter, or some hardware upgrades.

RW: *Other important technical components that you had to change or think about?*
Kolesar: For the transmitters themselves, our current operating procedure is that you have to tune them up according to the manufacturers' specifications for MA1, which is the hybrid mode. You have to perform all the modifications that you need to do in order to make the transmitter pass MA1; once you do that, the transmitter should pass MA3. There may be some exceptions to that rule; Mike Raide of Xperi is a better person to talk with because he knows modifying transmitters for digital inside and out.

Much of our pain and frustration of course was getting the directional array in line and broadening it enough to pass the all-digital mode.

Much of our pain and frustration of course was getting the directional array in line and broadening it enough to pass the all-digital mode. It can pass the hybrid mode now too. The rule of thumb I believe is plus or minus 15 kilohertz at 1.4 SWR or better.

RW: *You don't need me to tell you that the history of HD Radio on the AM band was contentious, and that the issues around noise and night performance have been very provocative.*
Kolesar: Well, I'm probably not the most popular person on the "I Love AM Radio" Facebook group.

RW: *How would you summarize objections from that mindset, and how would you answer?*
Kolesar: There's a couple of things that I point out. One, the MA3 mode is spectrally cleaner than the MA1 mode in the sense that you are restricting yourself to plus or minus 10 kilohertz when you are transmitting MA3, whereas with the MA1 you're out to over plus or minus 15 kilohertz. You are cleaning up the band a bit there.

Of course, it sounds like white noise on an analog radio — but then again there's a lot of white

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Highlights of the STA

Some details from the application:

- Hubbard pointed out that the FCC has encouraged stations to make such experiments in all-digital AM as part of its ongoing AM revitalization initiative.

- The company said the purpose of the tests will be "multifocal, involving demonstrations of representative equipment, methods and techniques, subjective coverage testing and assessing the increasing potential for the general public (through HD Radio systems) to readily receive all-digital AM transmissions with commercially-available receivers (e.g., receiving systems already in use by listeners)."

- The digital mode of operation is MA3 as defined in the in-band/on-channel Digital Radio Broadcasting Standard NRSC-5-D developed by the National Radio Systems Committee. "This mode effectively replaces the usual analog modulation components between the carrier and +/- 10 kHz from the carrier, with multiple digital subcarriers." The digital power level will not exceed the analog power level by more than 5 percent of maximum power authorized.

- Based on nine prior all-digital AM experimental tests conducted by NAB, Hubbard does not expect interference to other stations; but its application lays out steps in the event any is reported.

- WWFD's FM translator W232DG provides 70 dBµ service over 88 percent of the population of Frederick, and all of its 60 dBµ contour. "As such, individuals within the community of Frederick who are employing older generation analog-only AM receivers will not be deprived of continued WWFD programming service while this experimental operation is underway." Additionally, two full-service FM stations (WYPF and WFRE) and one other AM (WFMD) are licensed to Frederick, and more stations serve the area.

- Because these experimental operations are in lieu of analog, the prohibition of sponsored programs and commercial announcements does not appear to apply, Hubbard said; but to the extent necessary, a waiver of Section 5.203(c)(4) was requested because the all-digital operations of WWFD will essentially replace the analog service.

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noise on AM right now. I don't really know that a listener in a home, if they're scanning around the AM dial, could tell the difference between the noise generated by the computer next to them or from the digital carriers.

That being said, the big benefit of course is the wow factor when it comes to the sound quality. In the MA3 mode you get 40 kilobits per second of bandwidth in core and enhanced mode, 20 kbps in core only mode. That's the size of the data pipe. With the MA1 you have a lot less, and it's a lot less robust too. Under ideal circumstances you can decode a MA3 carrier all the way down to the station 0.1 mV contour. Your average person driving in a car would probably not notice any significant dropouts that they would tune away from until perhaps 0.5 mV contour.

"You have a place to park your analog audience; and then you can actually revitalize the AM band with a technical solution."

In terms of relative immunity from power line interference and thunderstorms, nothing is going to be perfect, but we found useful coverage down to the .5 even during storms or under power lines. That's pretty good.

You can do things with the MA3 mode and HD Radio in general that you can't do on analog AM. You can display title, artist and album. With MA3 there's even the potential to implement Artist Experience. You could display a logo, and album artwork. Selling data services is a possibility.

There's a lot of things, like metadata for instance, that are just expected by listeners in the year 2018 that AM analog just doesn't provide. What I say to people who want to stick with analog broadcasting is, "The market is moving on from analog-only broadcasting; so there has to be a technical solution to give people what they want and to give AM broadcasters parity with digital services, HD FM and streaming in the car."

MA3 AM both visually and aurally gives AM broadcasters parity with these other services.

***RW:** I would think there'd be a lot of excitement about that from AM owners.*

Kolesar: The risk of course is you are turning off your existing analog audience. That's why I've viewed the translator concept as a very good intermediate step to AM revitalization. You have a place to park your analog audience; and then you can actually revitalize the AM band with a technical solution.

***RW:** Is NAB Pilot measuring the station? Are we quantifying this in some way for industry to study the results?*

Kolesar: Yes, and drive tests have already started. We're still fine-tuning the transmitter so we want to make sure that all the carriers are as clean as possible before we get too far out. We want to make sure that the transmitter is running optimally; we're not quite there yet in terms of being ready to start the testing in earnest. But yes, that is definitely coming.

***RW:** What comes next?*

Kolesar: We're working on making sure that the transmitter and antenna are truly optimized; after that I'm going to sit down with Xperi and hopefully the folks from Pilot, and we're going to formulate and finalize test plans so we do our testing methodically.

***RW:** What else should we know?*

Kolesar: I've become a bit of an evangelist for the MA3 mode. I'm more than happy to talk with people about my experiences. In addition to the Radio Show [in Orlando this month], Mike Raide and I have been asked to do a presentation at the IEEE BTS Symposium [in Washington in October].

We need to get the word out about the advantages and the tradeoffs so people can make informed decisions. I want to get people excited about all-digital AM and to think about it. Even though there's been some press and papers written about all-digital FM, it's all-digital AM that's going to happen first, because FM still has a very significant analog listenership, whereas AM is more ripe for disruption, the disruption of all-digital.

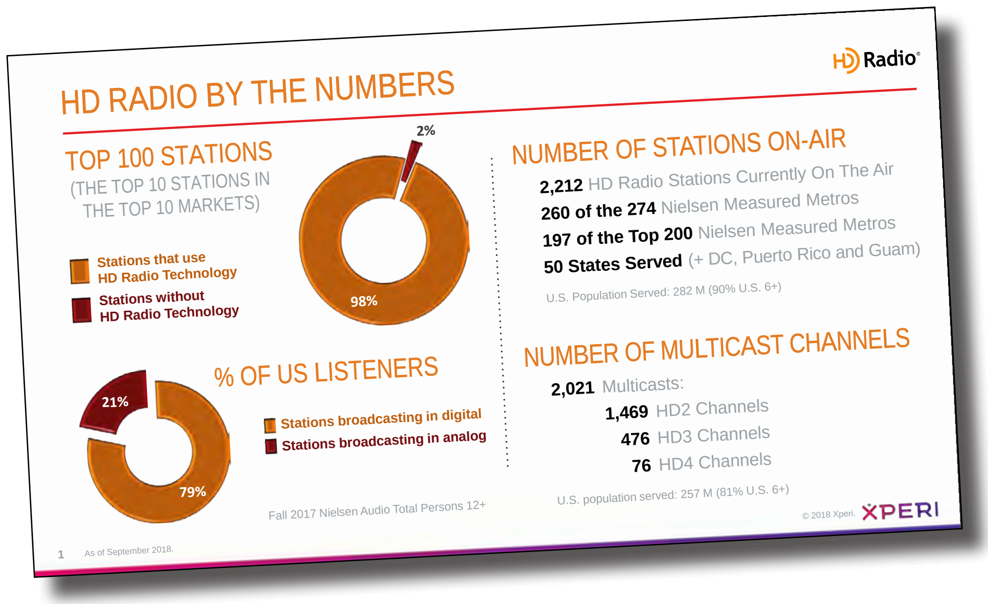
***RW:** You called yourself an evangelist for MA3. You probably are the first.*

Kolesar: Somebody's got to be Serial Number 1. Serial Number 2 is going to be a lot easier. ■

HD Radio by the Numbers

We asked Rick Greenhut to explain the significance of the most recent data

by **Paul McLane**



The HD Radio leadership at its parent company Xperi often cite various key data points in their public presentations, to document and promote the penetration of the digital radio format in U.S. auto dashboards and station air chains. The company's Director of Broadcast Business Development Rick Greenhut recently shared updated numbers with Radio World; we asked him to explore four of his slides with us in detail; our discussion is below.

First some top-line numbers as of September 2018:

Xperi says 98 percent of the "top 100 stations," meaning the top 10 from each of the 10 biggest U.S. markets, use HD Radio. It estimates that 79 percent of U.S. listeners tune to stations that use HD Radio each week, though many of course are listening to the analog of those stations.

There are 2,212 HD Radio stations on the air, including stations in all 50 states plus D.C., Puerto Rico and Guam; the great majority are FM, and there are 2,021 multicast channels (including 76 HD4's) associated with those. The company believes that the weekly reach or cume of those multicast channels alone is now more than 9 million, more than double five years ago.

The number of main-channel HD Radio stations airing Artist Experience is 874. The number delivering digital traffic services from iHeartMedia or the Broadcasters Traffic Consortium is around 700.

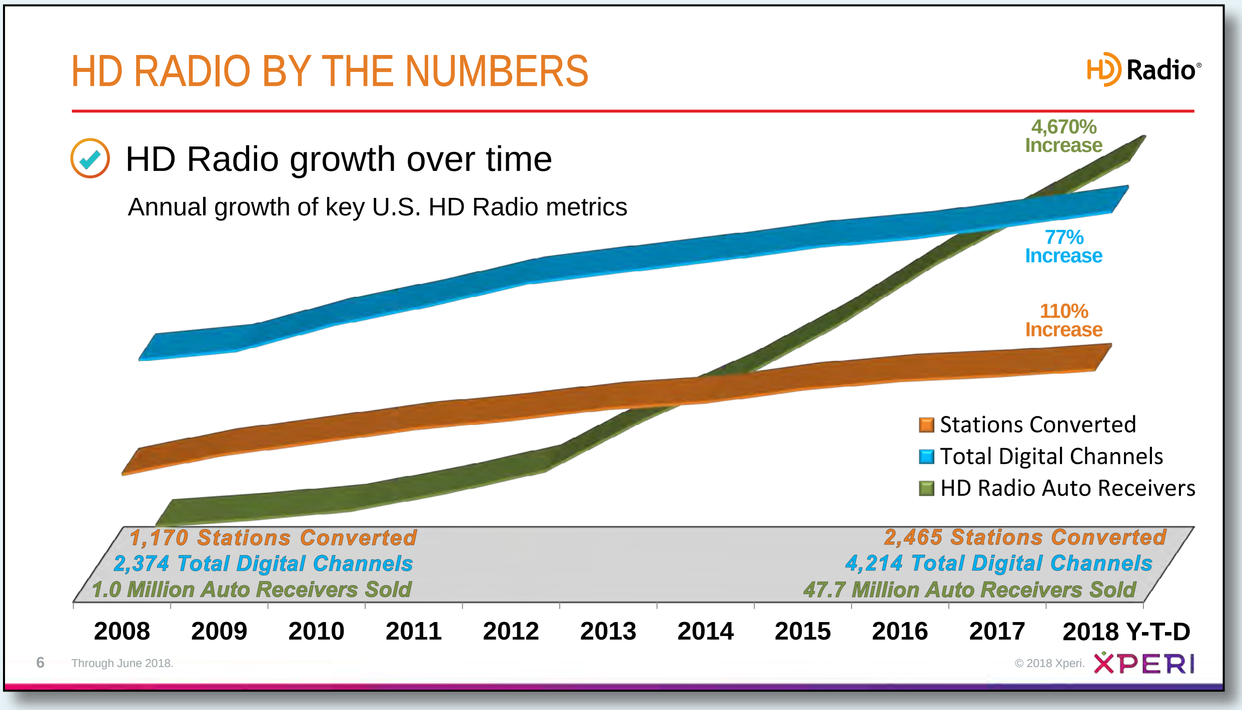
Importantly, the company estimates there are 47.7 million HD Radio-equipped cars in the country, or about 17 percent of the total, and that all major auto brands now offer factory-installed HD Radio. For the first time, more than half of new cars being delivered this year in the U.S. carry it standard.

> *"Since the automakers work 18 to 24 months out, the 2020 model year radios are on our benches as we speak, and I'm pleased to report that radio still has pride of place."*

AM stations that simulcast on HD FM channels total 234, the majority of which use the HD2 channel.

Those numbers refer to the United States. Meantime, Xperi says 40 percent of new vehicles sold in Mexico this year with have HD Radio, and that there are 90 HD1 stations in the country, plus another 60 multicast channels. Oaxaca and Mexico City are home to almost half of the total.

In Canada, it said, there are 22 stations in 10 covered markets, including 22 HD1 signals and 32 more multicast channels. One in three new vehicles sold in Canada this year have the format.



***Radio World:** Rick, looking at the slide above, while all these indicators trend up, the big story here seems to be the penetration in cars. Can you tell me more about the extent of this penetration; what percentage of new and of overall cars have HD Radio standard or available?*

Rick Greenhut: Our Detroit office has been working with the automakers for the last 15 years to emphasize the importance of keeping radio in tomorrow's dashboard and to encourage adoption of HD Radio technology, and the results have been significant.

In 2018 Y-T-D, some 51 percent of all new cars sold in the U.S. came with factory-installed HD Radio receivers. Best of all, it's not just the high-end models, as had been the case 5 to 6 years ago. While it's true that every new BMW, Volvo and Mercedes comes with HD Radio as standard, so does every Subaru, Mazda and Nissan. Right now, some 263 car models from 40 different automakers come with HD Radio, with 163 of those having HD Radio as standard equipment. The rest make it a part of an option package. So 62 percent of all the car models with HD Radio have it as standard equipment.

It's also interesting to note that more than half the HD Radio-equipped cars sold this year had MSRPs of $35,000 or below.

As for total U.S. auto penetration, our most recent data from the automakers indicates that 17.4 percent of all the cars on the road in the U.S. have an HD Radio receiver. The rate that the penetration number goes up is accelerating every quarter, as more and more automakers either add HD Radio as an option or make it a standard feature. This year alone, an HD Radio-equipped car is sold every 3 1/2 seconds, 24/7/365.

***RW:** We expected to see a flatter "stations converted" line in recent years. Does the trend shown here surprise you?*

Greenhut: I'm not really surprised. Station conversions are actually growing. By June of this year, we had converted more stations than we did in all of 2017. As smaller-market stations are seeing the creative ways they can use the technology to generate new listenership from new audiences (and the new revenue that comes with that), they are jumping on the bandwagon. And let's not forget that a radio transmitter tends to last about 15 to 20 years, and as stations need to replace aging equipment, it becomes natural and cost-effective to add HD Radio capability at the same time, especially since costs have come down in recent years.

***RW:** Presumably virtually all of the converted stations are FM, yes?*

Greenhut: Yes. Most, but by no means all, of the converted stations are FM.

***RW:** The story for receivers for home and portable can't be as good. What can you tell us about trends and the outlook for those segments?*

Greenhut: Let's talk about plain-vanilla radio receivers first. A few years ago, retailers like Best Buy had an

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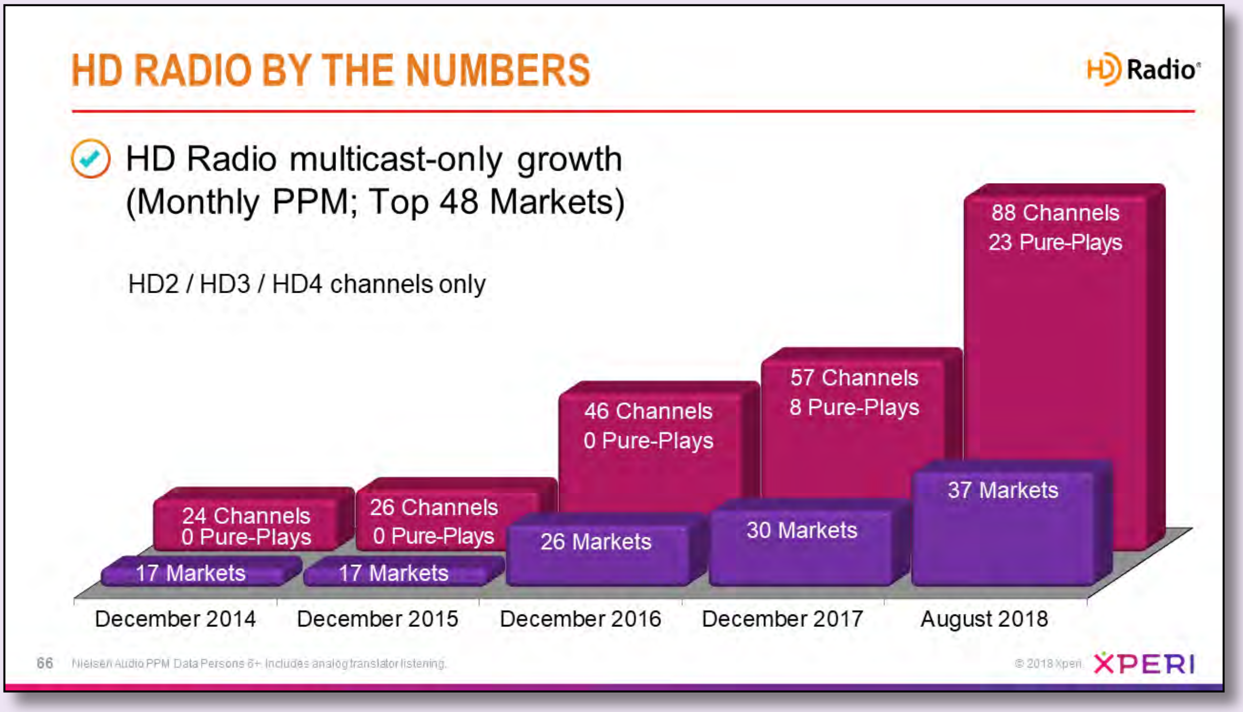
entire section devoted to various home and portable radio receivers. Now, with the possible exception of high-end audio systems, you'd be hard-pressed to find home or portable radios in any of the big-box retailers. Having said that, if they carry five radio receivers, typically at least two will have HD Radio technology.

The story is better among the audiophile market, where HD Radio's digital audio quality is more appreciated. But the overall market for home and portable radio receivers of any sort is small, and shrinking.

We have been working with various manufacturers to try and get more receivers into the marketplace. Right now, there are several brands being sold at various brick-and-mortar and online electronics retailers. They offer various models from Insignia, Sangean, Viewquest, Sparc and others. Your readers only have to Google "HD Radio" to see where to get them.

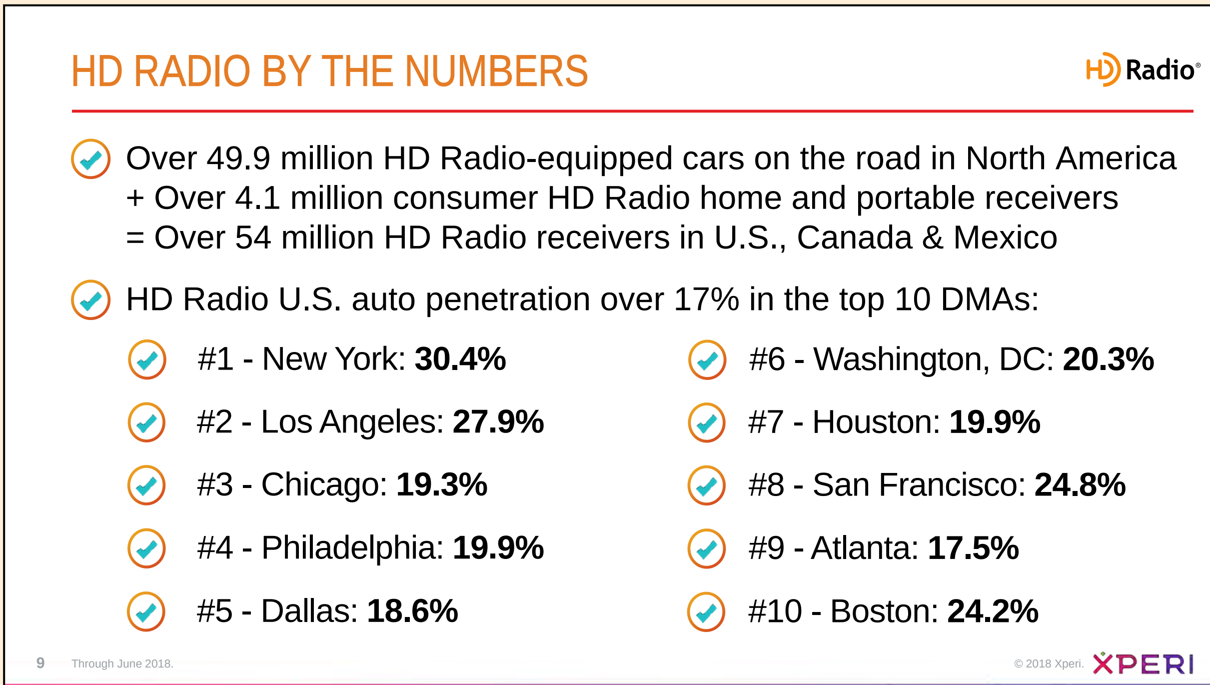


RW: *You've reported elsewhere that there are now almost 900 HD Radio multicasts with a weekly cume audience of about 9.5 million people. We're familiar with the role multicasts play in conjunction with analog FM translators, which drives a lot of that growth. But this next slide is telling an additional story within that bigger one. What is this image telling us?*

Greenhut: Basically, the message here is that as time goes on, more and more HD2, HD3 and HD4 channels are popping up in their Nielsen PPM local market monthly reports. For example, in December 2014, just 24 multicast channels showing up in the monthly PPM ratings in 17 markets. By August 2018, those numbers had grown to 88 channels and 37 of the 48 PPM markets.

This tells us that as more and more cars with HD Radio receivers are on the road, and more and more stations are beginning to promote their multicast channels, these new channels are generating listenership of their own. Best of all, as of the August PPMs, some 23 "pure-plays" were showing up. These pure-plays are HD Radio multicast channels that are not being simulcast on an analog translator. That means 100 percent of the listening is digital, via an HD Radio.

That is significant. It means that as many markets in the U.S. approach one-in-four or one-in-five of all cars on the road being HD Radio-equipped, these multicast channels are finding their own audience, all of whom are listening via the native HD Radio broadcast, not an analog simulcast. Just two years ago, in December 2016, none were showing up. A year later, there were eight. Less than two years later, there are now 23.



***RW:** You have seemed particularly excited to update us about auto penetration in certain markets. The top U.S. markets are shown above. What do you conclude from these numbers?*

Greenhut: That major markets are fast approaching one car in three being equipped with an HD Radio receiver. That is a significant milestone for broadcasters. It means that as the ability to receive these multicast channels grows, a station's ability to create new revenue streams from leases and new programming choices grows exponentially.

And let's not forget the added benefit that HD Radio brings that allows stations to replicate the look and feel of the streaming services consumers are already using "Artist Experience," HD Radio's capability to show album art as well as station and advertiser logos. A number of stations throughout the country are already using this feature to get larger portions of local add budgets by having the client's logo show up on car radios when their spot airs. In fact, one of radio's largest national advertisers recently ran a national campaign testing this image delivery capability on a national basis. Stay tuned for those results to come directly from the client when their post-buy analysis is completed.

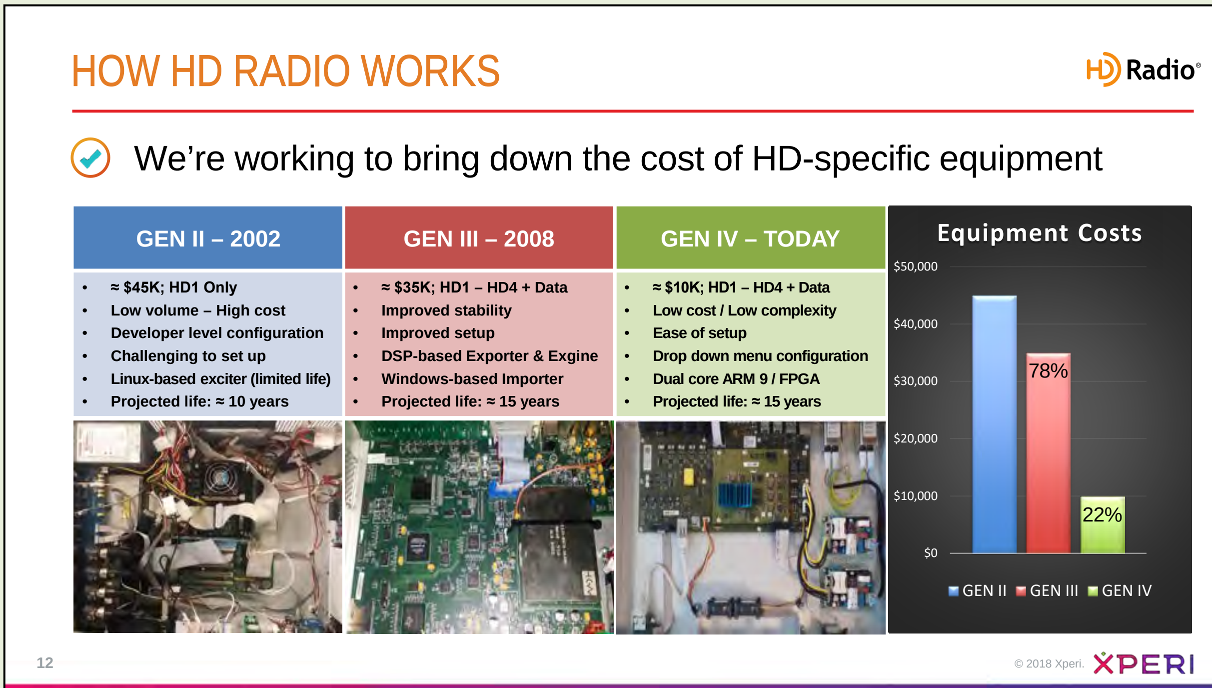
***RW:** Any idea why a New York or L.A. has a pretty significantly higher rate than an Atlanta or Philly?*

Greenhut: We used the Nielsen TV DMA geography to calculate all the auto penetration figures, since unlike radio metros, these geographies do not overlap so there is no danger of counting anyone twice. Since the DMA geography is defined by the percentage of TV viewing to home market stations, some DMAs are fairly circumscribed, while some are huge. Atlanta, for example, has many outlying counties in Georgia that are not near cities with their own local TV stations, so the majority of TV viewership in those counties will be to TV stations in Atlanta. In these rural counties, the average age of a vehicle may be much higher than the national average of 11 years or so, and average income may be lower.

Average vehicle age and average income tend to dictate how often the average person in a given DMA purchases a new car. The lower the average vehicle age and the higher the average income, typically the higher the HD Radio vehicle penetration. As more and more mid-priced cars come with HD Radio, the income criteria are becoming less important.

***RW:** On another slide not shown, you listed markets with the highest percentages, regardless of size. Any surprises?*

Greenhut: Burlington-Plattsburgh comes to mind. HD Radio-equipped vehicle penetration is 27 percent. That appears to be a straightforward function of vehicle age and average income. We see markets like Juneau, Alaska, and Odessa-Midland, Texas, having penetration numbers higher than you might think (23.2 percent and 21.7 percent, respectively), but that may be a function of their small populations and relatively small total number of registered vehicles.



RW: *This slide is about costs. Costs to the station are always an important consideration for our readers. Why has the hardware cost dropped so much in the past 10 years?*

Greenhut: Our engineers have been aggressively working this issue since HD Radio's inception. A significant part of our team is constantly working on streamlining the system technically and simplifying the user interface. It also helps that technology has moved at warp speed since 2002, with the costs of far more capable hardware coming down significantly. But our ultimate goal is to work towards a technical solution where there is no premium for adding HD Radio technology on the hardware side.

RW: *What's included in the $10,000 cost estimate above, and what related costs are not included in it?*

Greenhut: Besides having an HD Radio-capable exciter on their transmitter, stations need their transmission chain to have two pieces of equipment specific to HD Radio technology, called an importer and an exporter. When buying a new transmitter, including this equipment currently adds about $10,000–$12,000 to the total cost. Most transmitters sold in the last five to seven years from the major manufacturers are HD Radio-capable, and need only the additional equipment to begin HD Radio broadcasting.

Depending on the physical plant at the station, there may be a need to upgrade the signal processing equipment (compressor/limiter), the studio-transmitter link and in some cases, even the antenna. Every station is different, so there is no "one size fits all" answer to the total cost to upgrade.

RW: *What are the major advantages of today's tech vs. Gens II and III?*

Greenhut: Today's technology, not being PC-based like earlier versions, is far more reliable, cheaper to purchase and easier to configure. It's closer to being "bulletproof" after initial setup.

RW: *Can we expect another big hardware cost drop?*

Greenhut: We hope to be able to offer Gen V at no additional cost to our manufacturer partners. That's the goal — we hope further technical advances will allow us to reach that goal.

RW: *What are the other costs necessary to adopt HD Radio, such as licensing fees?*

Greenhut: Our licensing model has been quite straightforward for several years. Neither station class, market size nor format are factors in our pricing; all stations in a given category pay the same rate. Our current one-time license fee for a commercial FM station is just $10,000. Stations have the option to pay that as a lump sum, or use the payment plan. The payment plan allows them to pay just $2,500 down, then spread the remaining $7,500 over five years with payments of just $1,500 per year. There is no interest fee or carrying charge involved. If they choose to pay all at once, the fee is further reduced to a one-time cost of just $9,000. AMs and non-comms pay lower fees.

The only ongoing cost is the multicast fee when the station adds HD2, HD3 or HD4 channels. Each individual multicast channel costs the greater of either $1,000 per year or 3 percent of the incremental net revenue generated solely by that channel. To put it another way, until that multicast channel generates over $33,333 in new revenue annually on its own, all the station would pay is the $1,000 minimum. And the station is the one making that net revenue calculation, not our company. Simulcast of multicast channels on analog translators does not incur any additional charge.

***RW:** Rick, are there other data points that particularly stand out to you? What should we know about them?*

Greenhut: Just that in the 10 years I've been with the company, HD Radio technology has gone from being perceived as a "science project" by the average broadcaster, to being recognized as the way forward for radio to maintain its position in the dashboard of the future.

While some broadcasters were assuming that radio would always "own" the dash, our staff in Detroit was carrying the radio industry's water, constantly presenting the value of radio to automakers around the world. A month doesn't go by that they don't field questions from automakers asking about radio's future, and whether they need to continue to include radio in their future plans. In every case, we furnish details on radio's reach and the need consumers have to listen to their favorite stations.

We know how successful we've been because every HD Radio model that goes into a consumer product comes to our lab here in Columbia, Md., for testing and certification prior to manufacture. Since the automakers work 18 to 24 months out, the 2020 model year radios are on our benches as we speak, and I'm pleased to report that radio still has pride of place. With the mandate to place backup cameras in all new vehicles manufactured after May 2018, one of the major hurdles to adding HD Radio receivers to more models (the cost of the display) has gone away. Expect more models in coming years to have HD Radio as standard equipment, and many more models to offer it as an option.


Rick Greenhut

Radio is the last consumer medium not fully digital in an increasingly digital world. With it's unique "one-to-many" distribution model, it's no wonder every other audio service wants to call themselves radio. With autonomous cars just around the corner and more and more content competing for the consumer's time every day, radio can't afford to surrender the opportunity to be fully competitive in the coming connected car and the IoT revolution. We can't let radio as a medium become "just another stream." At HD Radio, our business is based on helping radio to maintain its continuing viability and our industry to grow and to thrive.

If radio doesn't succeed, neither do we. ■

Optimizing the Potential of HD Radio

Using HD2 or HD3 Channels for FM Translators

With stations increasingly taking advantage of multiple broadcast channels available in HD Radio, broadcasters have found new uses for HD2 and HD3 channels. One of those uses is to feed terrestrial FM translators.

For years now, broadcasters have used specialized HD Radio receivers to pick up and rebroadcast an HD2 or HD3 channel at an FM translator site. The need for a 'specialized' receiver is that, if the HD channel goes away or drops for any reason, the broadcaster does not want the receiver to blend back to the station's primary analog FM broadcast. Inovonics has for years made these specialized receivers and many engineers have used them to pick up the HD2 or HD3 and send the demodulated audio through a standard FM processor and into their translator's exciter. This worked and worked well, well enough for broadcasters to monetize the use of their HD2, HD3, and to look for simple more elegant solutions for making this all come together.

The missing piece in this system has been that there was no way for the HD2 / HD3 PAD data (think station identification, artist and song title info) to be converted into RDS data on the translator, as no manufacturer made an RDS encoder that could use an HD Receiver's data as a source.

Inovonics heard from a number of broadcasters that there was a need for an all-in-one box that could receive the off air HD2 / HD3 broadcast, process the audio, peak limit the MPX output and convert the PAD data into RDS.

We started working on the AARON 655 with the idea of something 'simple' that would do the basics. After floating that initial idea around the lab and the industry, we received feedback that more features and functions were needed.

We listened and added-in features such as Analog and AES inputs, in addition to being able to use a stream as a source! When using a stream, the AARON 655 converts the metadata from the stream and format it to RDS. Then there was remote web streaming and monitoring, SNMP control, email alarms and of course a terminal block with alarm closures and command inputs on the back panel.

As the AARON 655 evolved over time, it took on more of the architecture of an audio processor with a Stereo Generator, and an RDS Encoder all built into one box. The twist is that this 'audio processor' now has a number of different 'inputs': an HD Radio, AES, Analog, and Stream. All the inputs can be monitored simultaneously for audio loss, and other parameters like signal quality and signal strength. You can choose up to 4 sources and pick which order they will fail-over, with the ultimate goal of keeping your station on the air!

The end result is an extremely flexible and versatile box that makes intelligent decisions and keeps you on the air and your listeners happy.

What's not to love about that...?

INOVONICS
BROADCAST
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HD Radio — Then and Now

Technical challenges faced 15 years ago by the first adopters of IBOC technology have mostly been overcome

by **Jeff Welton, CBRE**
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Abstract — *The purpose of this paper is to discuss the evolution of HD Radio technology (specifically the In Band, On Channel — IBOC — system used in the United States). In discussing the evolution, focus will be maintained on some of the challenges faced by early adopters, as well as the improvements to installation techniques, hardware and software that have been developed to overcome these challenges. In the process, it is hoped that some of the myths currently being circulated regarding HD Radio implementations, many of which are based on the challenges referenced above, will be dispelled. This paper will focus almost totally on HD Radio technology for FM broadcast, although a few references to AM broadcast may also be used.*

INTRODUCTION

The first FM IBOC radio transmission was made on Aug. 29, 1992 on radio station WILL, in Urbana, Ill., as part of a proof of concept by USADR (USA Digital Radio). In 2000, USADR and Lucent Digital Radio merged, to form iBiquity Digital Corp., which held the licenses for IBOC technology as implemented in the USA and other parts of the world. The FCC authorized the use of IBOC in 2002 and broadcasters in the United States began implementing the technology in 2003. (See Reference [1] at the end of this article.) As of the time this paper was written, there are currently 2,441 HD Radio licenses; 2,103 of these are for FM stations — while there are a handful of LPFM and two translators currently licensed to use HD Radio technology, it can be assumed that roughly 20 percent of the FM stations on air today are broadcasting an HD Radio signal. Of these, 1,532 are broadcasting Secondary Program Services (multicasting of HD2, HD3 and HD4).

CONFIGURATIONS

Originally, the simplest way to implement an FM IBOC installation on an existing analog station was to add a separate digital-only transmitter and combine it with the analog through a 10 dB injector, with reject power from the injector being dissipated in a reject load (10 percent of analog power and 90 percent of digital power). This was tremendously inefficient, but resulted in the easiest installation with an existing analog transmitter. As a result of the significant heat dissipation from the reject load, these were typically installed outside the transmitter building, requiring additional RF plumbing and infrastructure, further adding to cost.

Fig. 1: High-level (injector) combining

Fig. 2: High-level (antenna) combining

Shortly thereafter, it was determined that space combining could be used, with the analog transmitter running into its usual antenna and the digital transmitter running into a separate antenna. This had the benefit of being much more cost-effective with respect to operating efficiency, but required a separate antenna and coax, adding weight and wind loading to the tower and frequently additional costs with respect to leasing space on the tower. To combat this, some antenna manufacturers created interleaved antennas, where the digital antenna bays were located between the analog bays — less space on the tower, but much more weight and again, dual coax cables required.

Then low-level (hybrid) combining was implemented, with the digital and analog signals being combined directly in the exciter and run through a single amplifier/filter to a common antenna. This had the benefit of not requiring additional coax, antenna cost or tower space/weight, but early transmitters were much less efficient and did require significant increases in electricity and cooling over a traditional analog transmitter (more on this later).

As a variation on low-level combining, one manufacturer developed "split-level combining," where a transmitter operating in hybrid mode was combined with an analog transmitter — the hybrid transmitter created the digital power and some of the analog power, with the analog transmitter making up the remainder of the analog power. While quite innovative for the time, this added levels of complexity and still had the challenge of poor overall efficiency for the hybrid transmitter.

COVERAGE

When IBOC was initially implemented on FM stations, injection of the HD carriers was limited to –20dBc, relative to the analog carrier, or digital power = 1 percent of analog power. Unfortunately, real-life testing proved repeatedly that coverage was somewhat limited, relative to analog coverage and there was a lot of blending back to the analog from HD1, or dropouts of HD2 and HD3 (there was no HD4 at this time).

On Jan. 27, 2010, the FCC approved an increase to –14 dBc HD carrier injection — 4 percent of analog power — for all stations broadcasting with HD Radio technology, with the exception of grandfathered "Super B" stations. In addition, for stations which could meet the criteria proving non-interference to first adjacent stations, an increase to –10 dBc injection (digital power = 10 percent of analog power) was allowed, subject to a consultant study proving the station meets the formula for non-interference and with notice provided to the FCC.

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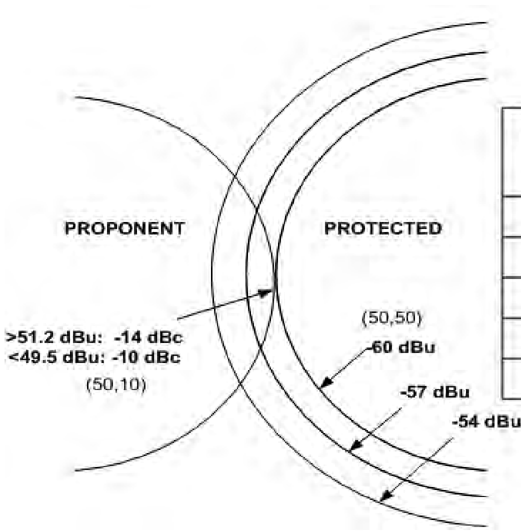

Proponent Analog F(50,10) Field Strength at Protected Analog 60 dBu F(50,50) Contour	Maximum Permissible FM Digital ERP
51.2 dBμ and above	-14 dBc
50.7 dBμ - 51.1 dBμ	-13 dBc
50.3 dBμ - 50.6 dBμ	-12 dBc
49.6 dBμ - 50.2 dBμ	-11 dBc
49.5 dBμ or less	-10 dBc

Fig. 3: protected contour limits

Continued from page 21

Further, a station that was limited in its ability to increase due to a nearby first adjacent station on one sideband still has the option to increase the other sideband (again, providing the criteria are met). This does require an application process and is still treated as an experimental situation, but has been proven successful in dozens of situations.

The criteria for determining non-interference to adjacent channel stations was presented as a formula to the FCC by NPR Labs, in November 2009. The formula is: Allowable IBOC power = [2.27*(60-(IBOC station F(50,10) dBm))-33.6]. From this, a graph was created limiting maximum IBOC injection level based on the highest field strength of the digital station found on any adjacent channel's 60 dBu contour edge. The FCC has represented this in chart form, as shown in Fig. 3.

Another factor that can directly impact coverage is one that will already be familiar to engineers working with DTV stations, that is MER (Modulation Error Ratio). Simply put, MER is a means of comparing the signal being sent by a digital transmitter against a theoretical idea transmitter, where error vectors are determined by measuring how the constellation points for digital vectors fall in an ideal setting, vs. how they are received by a receiver. It is similar to S/N in an analog system, also expressed in dB.

Essentially, the higher the MER is, the less fragile the signal will be and less prone to breaking up in conditions of noise or other interference. For reference, the iBiquity/Xperi specification for MER is 14 dB, however, the higher the MER is above that, the more robust the signal will tend to be. Several factors can impact MER. Some, such as external noise, can't be changed, while others — group delay, for example, can be compensated for with precorrection in the transmitter system. To this end, some manufacturers of HD Radio transmitters are able to provide group delay correction as part of the package. This is an improvement over original systems which did not have this feature.

MYTH #1 – IBOC coverage is terrible and the digital is always dropping out or blending to analog

As indicated above, original implementations at –20 dBc of HD carrier injection did, indeed, find that digital coverage was lacking in comparison to analog. Unfortunately, many of these stations are in situations to do not lend themselves to easily increasing IBOC injection levels (backfed combiners/master antennas that are at capacity, or hybrid transmitters with no headroom to accommodate higher digital power). Thus, despite the problem being solved almost 10 years ago, this challenge persists. So, how well does the IBOC signal compare to analog? In 2008, the Corporation for Public Broadcasting commissioned NPR Labs to do drive tests for several stations and found that, "In general, based on terrain-sensitive, computer model-predicted coverage comparing listeners with a protected signal to station IBOC coverage, the lab found mobile reception for FM IBOC was 70 to 90 percent of analog, on a population basis, using data from the 2000 U.S. Census. Indoor and portable reception were both 50 to 60 percent of the analog" [2]. Note that this data is based on –20 dBc of HD carrier injection. With the subsequent increase to –14 dBc for almost all stations and –10 dBc, or asymmetric sidebands, for many, IBOC coverage will frequently surpass analog and is definitely solid out to and beyond the 54 dBu contour in almost every case [3].

INTERFERENCE

One of the other issues encountered in IBOC installations has been interference, both with the analog portion of the station broadcasting with HD Radio technology and to stations on adjacent channels. In order to understand this, it is necessary to look at the transmitted waveform in more detail. First, a look at the digital carriers, relative to the analog, shows that the occupied bandwidth of the HD carriers is well separated from the analog. However, as the signal passes through non-linear circuitry, some active (amplifiers), some passive (filters, combiners and antennas), some interesting things can

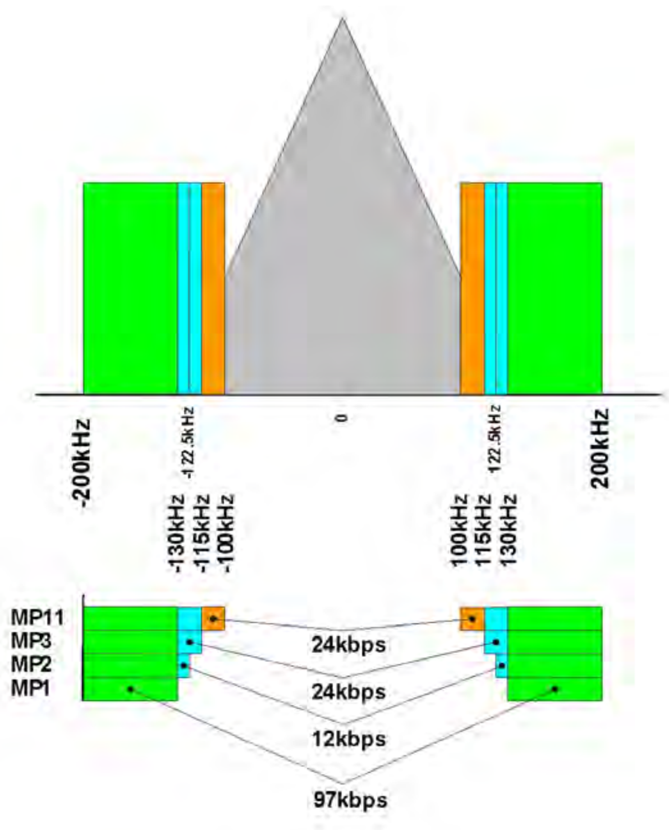

Fig. 4: Anatomy of an FM+HD signal

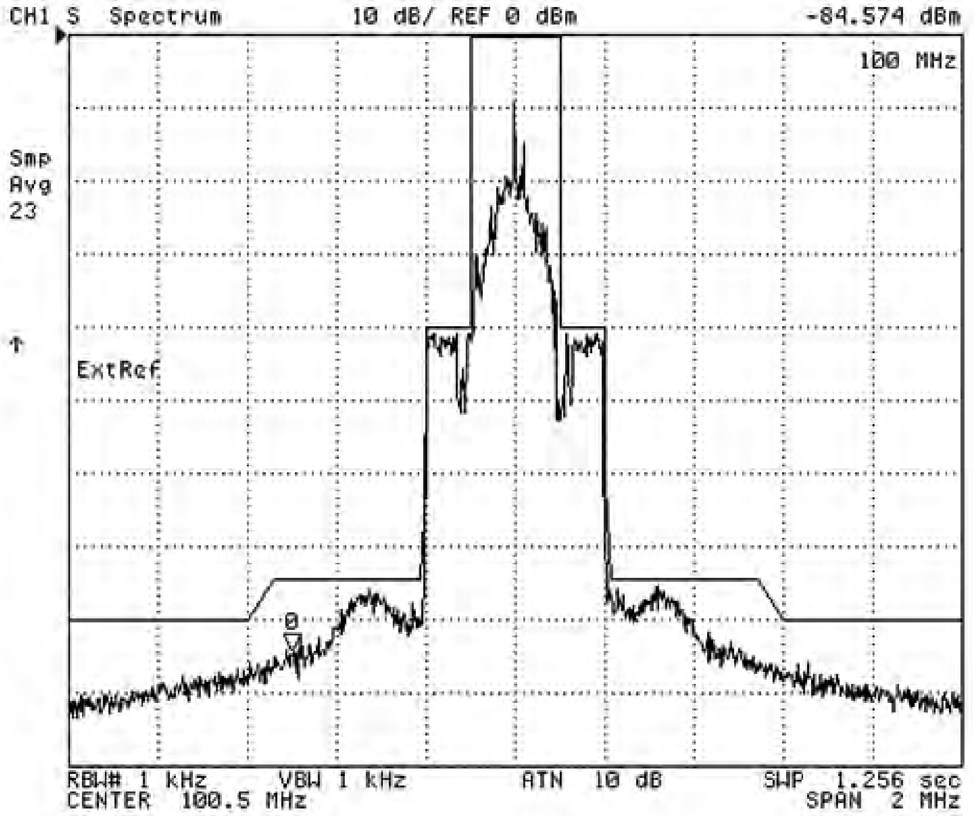

Fig. 5: IBOC signal with NRSC-5-C mask

happen, including intermodulation between the digital carriers and between the digital carriers and the analog.

As can be seen from Fig. 4, although the HD carriers do not begin until 100 kHz from Fc, if there is any significant amount of overmodulation, it is quite easy to splatter the analog signal into the digital carriers, especially when operating in expanded mode (MP3 is a fairly common mode of operation, especially with stations using SPS2 (HD3) and almost always with stations broadcasting audio on SPS3 (HD4).

If a station is operating without overmodulation, there can still be situations where interference could potentially occur, either to adjacent channels or to the analog portion of the station itself. Assuming low-level injection, or matched analog and digital antennas, so that pattern replication in the near field is the same between analog and digital, typically any interference will be the result of either not clearing the NRSC5 mask, or clearing it at the transmitter, but operating into a very narrowband load, such as a short-spaced channel combiner.

In this situation, a free air measurement of the occupied bandwidth should show intermodulation products (aka, spectral regrowth) above the NRSC limit. As well, earlier implementations by some manufacturers had fixed precorrection curves, vs. adaptive precorrection, which can make the system very load-dependent — thus a change in characteristics of the antenna system can result in increased chance of higher spectral regrowth and potential interference issues.

In Fig. 5, we see an example of an IBOC signal, at –20 dBc HD carrier injection, with the analog in the center, the HD sidebands to left and right and the spectral regrowth (intermodulation between analog and digital carriers) clearly shown on each side of the IBOC carriers. The further down from the analog carrier that the intermodulation products are, the less chance of interference.

Conversely, this also indicates that the system is running as linearly as possible, which means lower efficiency. In some products, the ability exists to manually tell the system how much mask clearance is needed, allowing the transmitter to dynamically adjust amplifier bias to maintain that level of clearance while permitting less linearity and improving efficiency.

MYTH #2 – IBOC interferes with itself

As indicated above, this was certainly a potential problem with early iterations, depending on equipment manufacturer and overall configuration. However, this issue, except for in the near field of separate antenna installations, has pretty much been resolved through precorrection of the FM+HD signal, greater mask clearance and attention to installation details (for example, not using an

Continued on page **24**

❱ *Continued from page* **23**

antenna combined system when the tower is in the middle, or within a mile, of the target audience).

Remaining self-interference cases will almost always be the result of earlier equipment with the aforementioned limitations and will be resolved as early installations are upgraded over time. Given that the early adopters were installing equipment in the 2003–2005 time frame, this should be a non-issue within the next 5–10 years and is already becoming a much smaller percentage of the installed base.

MYTH#3 – IBOC interferes with adjacent stations

Certainly, potential exists for adjacent channel interference. The days of being able to expect rock-solid coverage in every direction to the limits of the receiver are gone — in part due to increased noise floor (switching power supplies on the consumer end, CFL and LED lights, power company noise and the like) and in part due to stations being spaced closer together than in decades past. Certainly, adding digital carriers on the sidebands of an analog signal does nothing to help this. However, through the work of the CPB, NPR and NAB Labs, the NRSC and the FCC, interference within a station's protected contour should be non-existent.

In fact, as more stations start broadcasting with IBOC technology and more receivers become equipped with HD receivers, this should start to be less an issue, not more of one, since the receiver only needs to see one sideband in order to turn on the HD decoder, at which point the other sideband can frequently be pulled out of the noise, in an interference situation. In addition, newer technology such as asymmetric sidebands will allow stations with an adjacent channel on one side, but not the other, to be able to increase HD carrier injection on the non-adjacent side, to improve coverage without impact to the adjacent station.

There will be some interference complaints — but assuming the HD station is well within its mask (again, older technology can have bigger challenges in this regard), interference within the protected contour should be a non-issue.

AUDIO QUALITY

Another challenge seen by broadcasters using HD Radio technology has been keeping the audio signal clean. One of the biggest complaints with satellite radio has typically been the audio quality resulting from very low bitrate audio signals and a goal of IBOC has been to avoid that. Audio quality is a very subjective topic, so this can be hard to quantify.

Many studies have been done on perceptual coding — reducing bitrate by removing the portions of an audio signal that the human ear would perceive as noise — and this has enabled significant improvements in audio quality at lower bitrates, as heard by the average listener.

In addition, one of the biggest challenges in this area is seen from the installation perspective … studios with multiple audio conversions happening in the chain, heavy levels of compression or processing and a general lack of understanding of what is happening to the audio signal.

For audio codecs or sample rate converters, a general rule of thumb is that fewer is better, up is bad and down is acceptable. Obviously, the fewer times that audio sample rates are changed, or audio is converted back and forth between digital and analog, the less chance there is of objectionable artifacts being introduced. When sample rate conversion is necessary, the attempt should always be made to only convert from a higher bitrate to a lower one — in short, bits can't be put back in, once removed, without creating some artifacts … enough of these added together will quickly become noticeable and objectionable.

Another challenge seen by broadcasters using HD Radio technology has been keeping the audio signal clean.

One suggestion that can frequently make it easier to troubleshoot any audio issues in a facility is to pick a reference level, –10 dBm, –4 dBFS or whatever is most convenient, and standardize on that from one end of the facility to the other. This makes finding any anomalies much simpler, as well as reducing the changes of anything in the chain being overdriven and creating distortion, whether digital or analog. In addition, it simplifies equipment replacement, as the gain level for any item can easily be set to match the reference.

Finally, clipping and square waves are the enemy of any digital audio signal — the challenge here becomes that analog signals have traditionally been compressed and processed to the point where dynamic range is minimal. This is a definite throwback to the loudness wars of the 1980s and 1990s which are still quite prevalent in some markets. However, from a quality perspective, this presents a huge challenge to the digital audio signal, in that these perceived square waves create very noticeable artifacts (ringing and sizzling) in the received signal.

With a heavily compressed signal, matching the digital to the analog with respect to sound quality and level is

Continued on page **26** ❱


AM HD-capable Antenna Systems
Diplexing & Triplexing Systems
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Matching Units & Filters
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FM Test Loads
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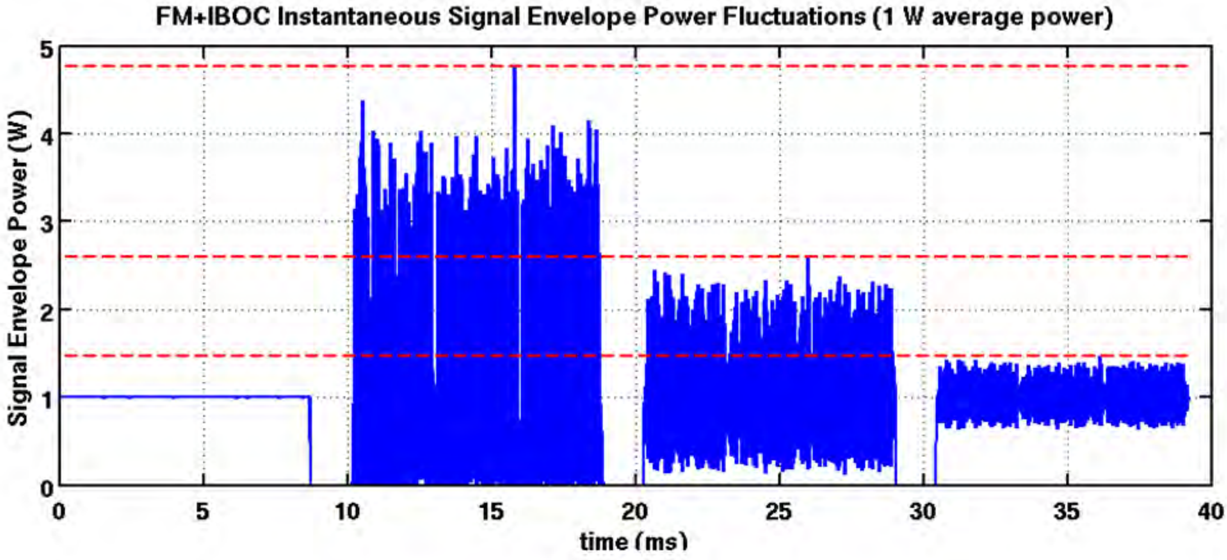

Fig. 6: IBOC Power Requirements

Continued from page 24

not going to be possible, without creating some audible distortion in the digital signal. In this case, it is usually a better plan to back off the compression on the digital signal somewhat, preserving some dynamic range and minimizing artifacts.

In addition, several installations use spare processors that they have on hand for the digital signals — however, this is not the best solution. FM audio processors (or AM, for that matter) are not optimized for use with low bitrate audio. Processors designed for low bitrate audio (such as web streams) are much better suited for this task, as they will frequently employ perceptual coding that is designed to overcome the challenges of the lower sample rates.

MYTH #4 – the low bitrate audio sounds terrible

This is not really a myth — in many cases, the low bitrate audio DOES sound terrible. However, this is more an implementation issue, than a shortcoming of the technology itself. Minimizing the use of sample rate converters and digital/analog audio converters, maintaining a reference level throughout the audio chain, keeping compression as low as reasonably possible and using processing designed for use with low bitrate audio all can make a vast and very noticeable difference in the audio quality of the HD streams.

POWER CONSUMPTION AND COST

Another challenge that has traditionally caused stations to hold back from implementation of HD Radio technology has been power costs. Because the digital radio signal requires as linear a path as possible from transmitter to antenna, amplifiers are typically biased in a class A/B mode, causing them to be much less efficient than a non-linear amplifier would be. Prior to IBOC, state of the art for solid state FM transmitters had reached efficiencies seen by tube transmitters, with overall efficiency of 60–65 percent being the norm. Early IBOC configurations typically involved a separate digital transmitter, running at a nominal 25 percent efficiency, with a 10 dB injector (combiner) to add this to the analog signal. Loss in the combiner was typically 10 percent of the analog input and 90 percent of the digital input.

Therefore, for a 10 kW analog TPO, for example, the analog transmitter would need to be turned up to 11 kW and the digital transmitter, at –20 dBc injection (1 percent of analog power or 100 W of digital power) would need to put 1 kW into the combiner. Added to this was the 6 dB Peak to Average Power, which meant that a 3.5–5 kW transmitter would be needed to be able to create the desired level of HD input power to the combiner. This system also had a severe limitation with respect to the fact that upgrading injection level was virtually impossible … it would frequently require replacement of the 10 dB injector with a different injection level (for example, 7 or 8 dB) to reduce wasted energy from the digital transmitter and usually replacement of the complete digital transmitter, making it extremely cost prohibitive.

To expand on this, look at a station with a 10 kW analog FM TPO with an HD injection of –20 dBc (100 W). With a 10 dB injector, a 1 kW HD input signal would be required to obtain 100 W of digital power (90 percent loss in the injector). Due to PAPR limits, at the time this would have required a 4 kW transmitter to create the digital signal. Upgrading to –10dBc injection, assuming the injector input ports were sufficiently rated to handle the power (typically not the case), would have required a 40 kW signal to generate the digital power! Changing to a 7 dB injector, while increasing loss on the analog side, would significantly reduce power requirement on the digital side.

Theoretically, changing to a 3 dB injector would be most efficient overall, however this would require doubling the input power on the analog side … the whole point of high level injection, beyond simplicity, was the ability to keep the existing transmitter.

Early low-level combined signals (the FM+HD signal created in the exciter and amplified through the transmitter as a single hybrid signal) helped in this regard, in that they did not require the separate injector and increasing injection level was a simple matter of ensuring that the transmitter was sized to allow for the PAPR overhead of the increased digital power. However, efficiency typically was impacted quite severely by increased HD carrier injection, dropping as low as 40 percent at –14 dBc of HD injection.

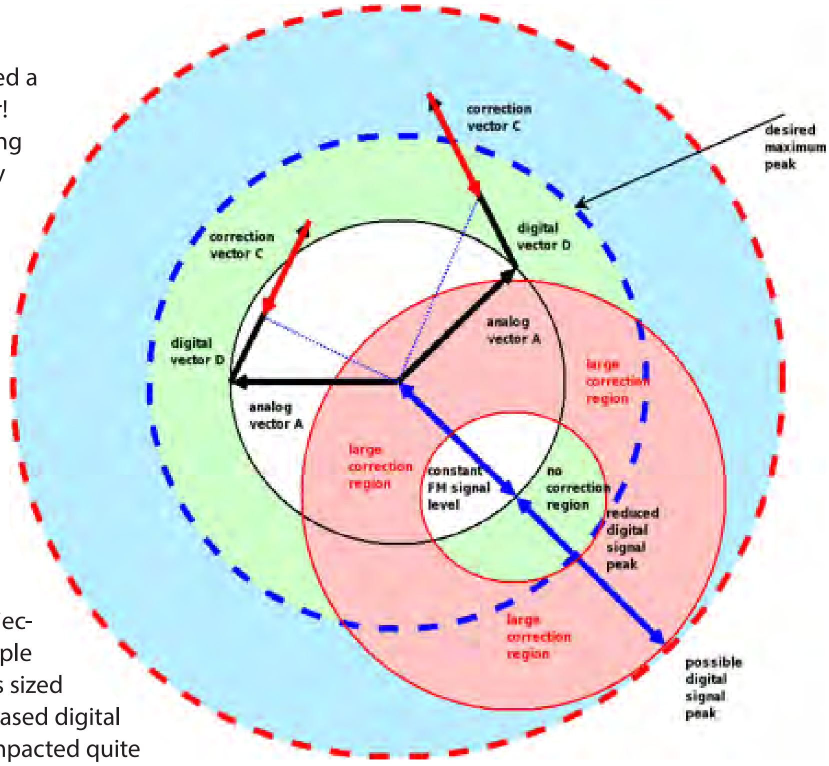

Fig. 7: First generation PAR algorithm

Significant work has been put into studying the PAR algorithms used to minimize peak power requirements, both on the part of iBiquity (now Xperi) and equipment manufacturers.

Compare this to the previously mentioned 60–65 percent overall efficiency of an analog only transmitter and it's quite easy to see how impact on the power bill was very noticeable.

Fig. 6 shows instantaneous power requirements over time for various HD carrier injection levels vs the analog carrier (shown at left). Proceeding right, we see power requirements for –10 dBc HD carrier injection, –14 dBc HD injection and –20 dBc injection. As can be seen, since the digital carriers are amplitude modulated onto the analog, this results in a significant requirement for additional power headroom.

This is an area where IBOC did have a significant impact in cost — in early implementations, especially with the Peak to Average Reduction algorithms being used to minimize the impact of the peak power requirement, it would frequently take a much bigger transmitter than expected to accommodate a given TPO. As an example, an early iteration HD capable transmitter that could make 10 kW in analog mode would be able to make roughly 7300 W of analog power if operated in FM+HD mode at –20 dBc injection. As a result, significant work has been put into studying the PAR algorithms used to minimize peak power requirements, both on the part of iBiquity (now Xperi) and equipment manufacturers.

Fig. 7 shows an early iteration of the iBiquity Peak to Average Reduction algorithm. This is difficult to display as a static image, as each of the digital vectors are rotating around the axis of the analog vector. Effectively, early iterations looked at the magnitude of the digital vectors and, based on their excursion beyond the desired maximum peak, applied a correction signal of various magnitude to attempt to reduce.

Where they tended to fall short was that they only looked at the digital vectors, without consideration to the analog power. In many cases, a large magnitude digital vector could be negative with respect to the analog signal, so applying a correction factor in that situation would be counterintuitive, as shown at the top of Fig. 8. This results in the higher peak power requirements described in the previous paragraph.

Fig. 8 represents a newer version of the same vectors, using Nautel's HD Power Boost PAR algorithm. Note that

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iBiquity/Xperi has also adopted a similar algorithm in their latest gen4 software. The benefit to this particular algorithm is that it factors in the analog signal as well as the digital vectors, only applying a correction factor when the addition of analog and digital exceeds the desired maximum peak.

With the implementation of this type of algorithm, peak power requirements on transmitters are reduced, to the point that the 10 kW transmitter mentioned earlier, which could only produce 7300 W analog power at –20 dBc of HD injection, can now produce the full 10kW of power at –20 dBc injection, 9 kW at –14 dBc injection and 6600 W of analog power at –10 dBc of HD injection. In addition, between this and the advent of LDMOS amplifier technology, the transmitter that produced 7300 W of analog power at –20 dBc of HD injection, with an overall efficiency of roughly 50 percent, now can produce 25 percent more power at –20 dBc injection with an overall efficiency of 70 percent. In fact, efficiency is 55 percent even at –10 dBc injection, so the improvement has been significant.

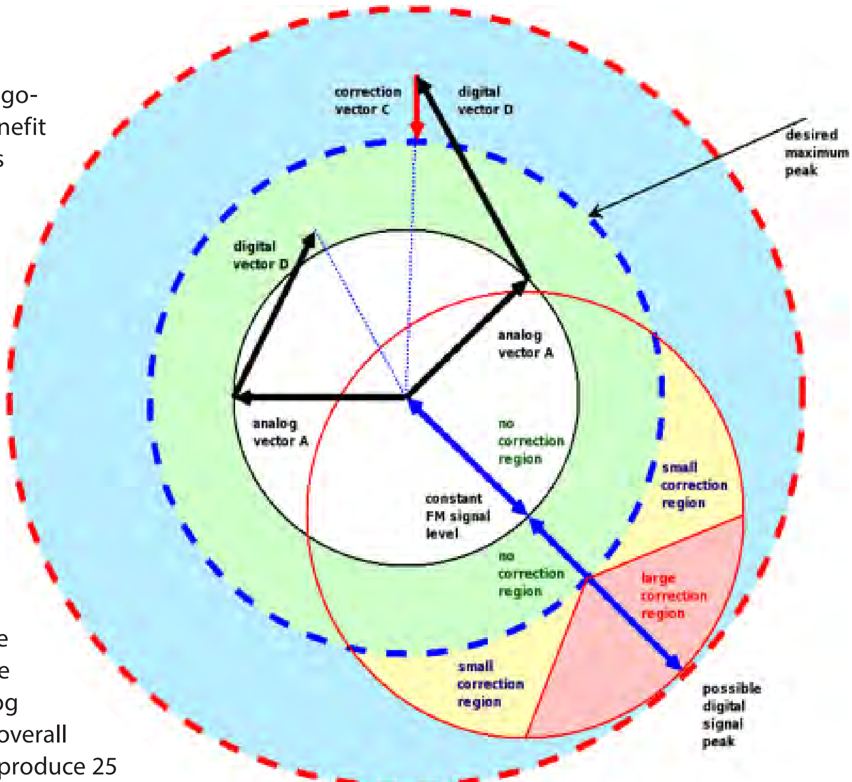

Fig. 8: Nautel HD Power Boost PAR algorithm

Most of the negative comments currently being encountered with respect to IBOC upgrades are based on reality encountered during early implementations.

The downside to this algorithm is that it relies on a real-time sample of the analog signal, so it, at the moment at least, is only used in low-level combined systems, however it's less an issue for space-combined systems, where LDMOS technology has also improved efficiencies to the point where 50 percent overall efficiency or higher is attainable or a digital only transmitter, vastly reducing cost of implementation even in that regard.

MYTH #5 – IBOC causes the power bill to go sky high

As indicated above, this was definitely the case for early implementations, especially as stations started to look at the feasibility of increasing HD injection levels. However, improvements in technology, both in the algorithms used to reduce PAPR and in amplifier efficiency with the advent of LDMOS technology, have gone a very long way toward improving this. Thus, depending on the analog transmitter being used for comparison, it is still possible to implement HD Radio technology and see a decrease in power bill.

Also, for separate antenna installations, even operating a current transmitter in digital only mode sees the efficiency more than double what it was even 10 years ago. Therefore, while legacy installations did see an increase on the power bill over analog only operation, this has not been the case for several years. Again, this does depend to an extent on injection level, manufacturer used, combining method for the analog and HD signals and the original analog transmitter used … relative to a grounded grid transmitter, for example, upgrading to a low-level combined FM+HD system, even at –10 dBc HD injection, should not result in any increase in the power bill.

Where there can be a difference is more related to infrastructure … because tube transmitters would function (albeit with shortened lifespans) at higher temperatures, it has been quite common for air handling in the facility to be ignored. Frequently this is upgraded during a new transmitter install and the improved cooling sometimes can increase power costs — but for the purpose of this paper, it is noted that the improved cooling would have benefitted the original transmitter as well as the new one and should not be considered a factor. Given that two transmitters of equal efficiency will produce the same amount of waste heat, cooling should have been equal all along.

MYTH #6 – IBOC costs an arm and a leg to implement

Again, as with most points raised during this paper, there are costs associated with an IBOC installation that do not apply to an analog-only installation. These would include the one-time license for the right to use the technology and the annual fee for secondary program services, in addition to the hardware for the HD generating equipment (Exgine, Exporter and Importer) and processing for additional audio signals.

However, hardware costs have decreased significantly — as an example, combining Exporter and Importer units into one chassis has significantly dropped the costs of these items. Improvements in low level combining efficiency has reduced power headroom requirements, so smaller transmitters can be considered and more efficient transmitters mean lower infrastructure costs for cooling or air handling. Thus, while there is an additional cost, it is nowhere near what was seen by early adopters.

SUMMARY

In short, most of the negative comments currently being encountered with respect to IBOC upgrades are based on reality encountered during early implementations. Some are the result of shortcomings in the installation process. One or two are still valid, in some situations.

In addition, this paper does not address programming at all — ultimately, if nobody wants to hear what is being broadcast, whether on the analog or the HD channels, nobody will listen. By the same token, if program is being broadcast that the market wants to hear, that can drive receiver sales (assuming time is taken to educate the people selling receivers as to the benefits of HD Radio technology) and there is a chance for the additional signals to add to the station's bottom line. Ultimately, that is a decision that needs to be made by the individual stations, but it would be very difficult to argue against the fact that the technical challenges faced 15 years ago by the first adopters of IBOC technology have mostly been overcome. ■

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