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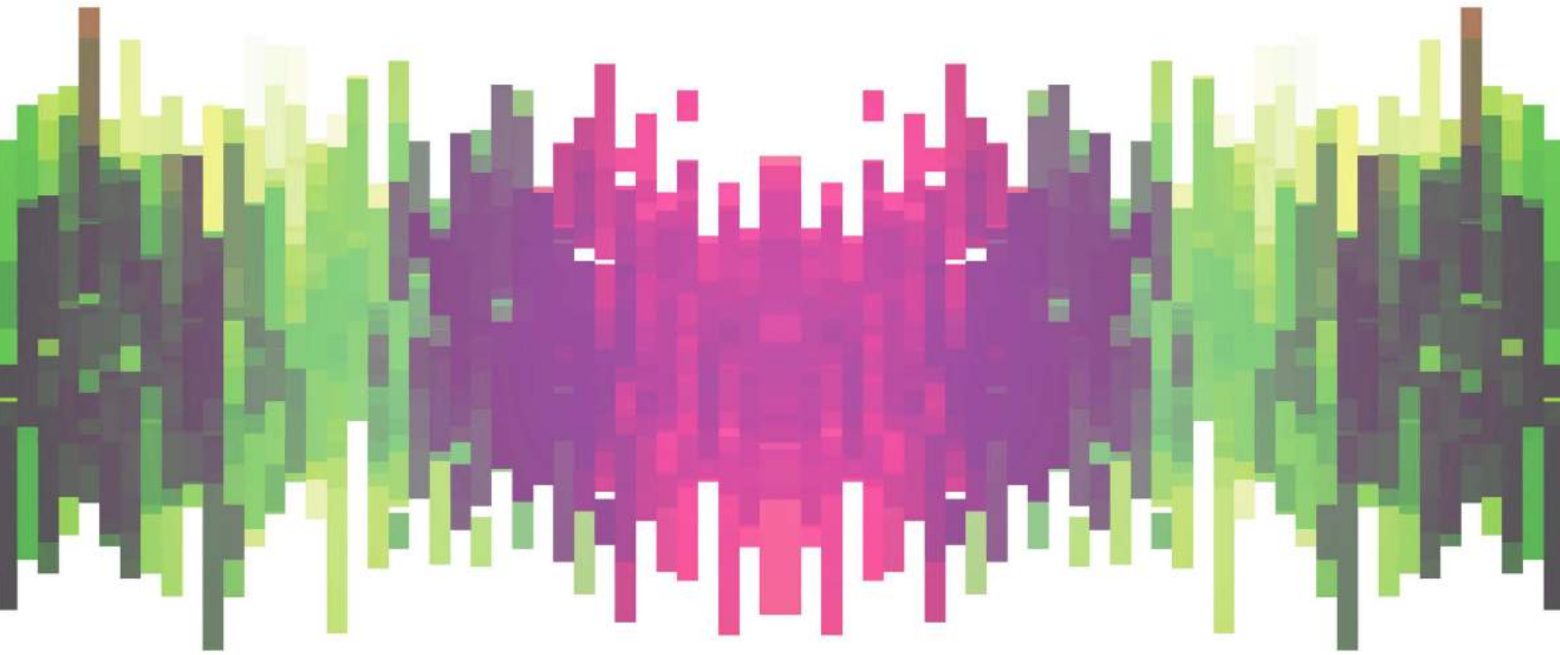

NEW DIRECTIONS FOR HD RADIO

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From the Publishers
of Radio World

NewBay

New Directions for HD Radio

Cover image: iStockphoto/Akrain

Paul McLane
Editor in Chief

Radio World's eBook "New Directions for HD Radio" explores what's next for the digital radio format as well as best practices for 2018 and beyond. Nothing sparks passion among radio technologists like discussion of the future of digital radio.

Among other things, the ebook explores:

– The new NRSC-G203 IBOC Time and Level Alignment Guideline, described as "the first comprehensive, collaborative effort of the industry to consolidate what's known regarding this important topic that directly impacts the listening experience."

– Perspectives on the preprocessing of low-bitrate audio for HD Radio.

– A case study in the creation of an HD Radio single-frequency network.

– What's next for the idea of "all-digital" testing in the United States.

– Other issues on the minds of HD Radio industry experts.

This is the 39th eBook in Radio World's growing library of online resources to help you in your job and career. Thanks to you for making this series a success!

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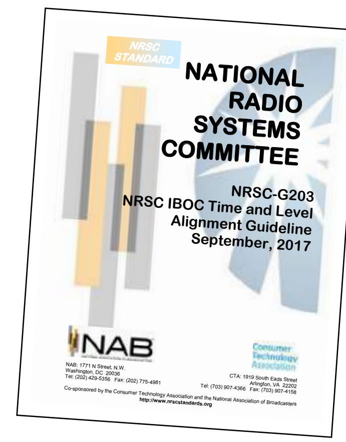
New Guideline Aims at Alignment Issues

Ambitious NRSC document seeks to gather industry's collective wisdom about alignment in one place

By **Tom Vernon**



It has been an engineer's bugaboo since the dawn of HD Radio more than a decade ago.

In theory, when a digital HD signal drops below a threshold at which stable reception is no longer possible, a seamless transition to analog should take place. The reverse should occur when a usable HD signal returns.

In practice, the listener's experience can be more like hitting a pothole in the road. A noticeable switch between digital and analog takes place. To make matters worse, this transition can occur repeatedly as one travels through areas where digital signal strength is marginal.

What's happening is that the time and level alignment between the FM and HD signals are not in sync. This problem was recognized early on but an entirely satisfactory solution has been difficult to come by.

Over time, the industry's brain trust focused its energies on the digital delay quandary. Articles were written for trade magazines, papers were delivered at the NAB Show, documents were circulated within radio groups.

Publication of the NRSC-G203 IBOC Time and Level Alignment Guideline by the National Radio Systems Committee in September of 2017 is another step in dealing with these issues. It represents the first time collective wisdom about the issue has been gathered in one place.

The document discusses the causes of time and level alignment drift and how stations can implement automated methods to keep alignment within a specified tolerance. Though many scenarios can cause drift, it reports, the biggest culprit seems to be separation of the Exporter and the exciter engine components over a wide-area network. The guideline discusses implementation of various hardware and software configurations to address timing instabilities. It concludes that ultimately, "the most effective solution to insure good time and level alignment is automated, continuous, real-time monitoring and adjustment of this alignment so as to reduce or eliminate objectionable blending artifacts."

MONTHS OF WORK

The work is published jointly by the Consumer Technology Association and the National Association of

	Analog and digital audio processors		Audio processor and Exporter location		Importer location		
Figure	Separate†	Combined	Studio†	Transmitter	Studio	Transmitter	Comments
Figure 5	✓			✓	(none)		
Figure 6		✓		✓	(none)		Preferred
Figure 7		✓		✓		✓	Preferred
Figure 8		✓		✓	✓		Preferred‡
Figure 9	✓		✓		✓		
Figure 10		✓	✓		✓		
Figure 11	✓		✓	✓	✓		Single Exporter feeding multiple transmitters†

† Not recommended
‡ Assumes appropriate data link between Importer and Exporter

Fig. A: This table in the document shows commonly used HD Radio transmission topologies; automatic correction is summarized separately in the guideline. Figure numbers refer to the actual NRSC document (read it here).

Broadcasters, co-sponsors of the National Radio Systems Committee.

As noted in the foreword, audible blending artifacts are the top complaint from automakers and consumers regarding HD Radio; and most of the problems can be traced to broadcast stations, where manual management of time and level alignment leads to drift over time.

So the recommendations were developed by a working group of the NAB Radio Technology Committee, whose members are radio engineers and other tech experts. Engineers involved work for companies including Beasley Broadcast Group, Cox Media Group, CBS Radio, Emmis Communications, Hubbard Media, iHeartMedia and NAB. Those were then submitted to the NRSC with a request that it incorporate the information into an NRSC Guideline.

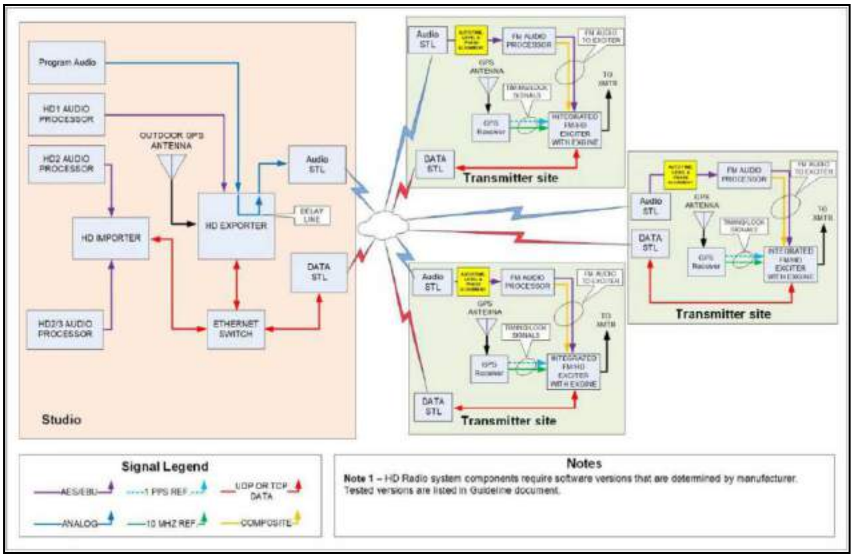


Fig. B: The document provides good visuals of various use cases — here, a single exporter feeding multiple transmitter sites, corrected by placing in-line alignment devices in analog audio path at each transmitter site.

We spoke with industry experts about the importance of this issue, how stations can put these guidelines to use and how we got to where we are with time/level alignment.

Alan Jurison — a senior operations engineer for iHeartMedia's Engineering and Systems Integration Group and chair of the NRSC RDS Usage Working Group — was a major contributor to the NRSC-G203 document.

He summarized problems that have unfolded over the years with HD timing: "First off, NRSC-5 specifies a timing standard of +/- 3 samples. That was set up in 2005, at the beginning of HD Radio. But it wasn't made clear exactly what the standard meant, or why it was important.

"Another factor was that 10 years ago, HD Radio penetration in cars was miniscule, so the problem wasn't really noticed that much," he said. "Also, we've learned a lot about the technology since it was introduced. We used to say separate audio processors for FM and HD were the way to go. Now, we understand that having two processors actually causes a lot of the blending problems, and the best thing is to have both signals processed in one box."

Another issue is the standard itself. "NRSC standards compliance is mostly voluntary; the FCC isn't going to fine you for non-compliance with the time alignment specifications in NRSC-5. That being said, good engineering practice suggests that compliance is important, both for the success of your station and the industry as a whole."

Today, Jurison said, getting the timing right is more important because the number of cars equipped with HD Radio has increased dramatically.

"We're now seeing the market penetration of HD-equipped cars at 46 percent of new vehicles sold per year. When these radios abruptly blend from HD to FM and back, listeners usually blame the radio and take the car back to the dealer. But these problems have been created by broadcasters, and we need to fix them."

Rick Greenhut, director of broadcast business development at Xperi Corp., parent of HD Radio, said that from a financial perspective the decision for first-timers to switch to HD is far less daunting.

"When HD started in 2005, first-generation equipment cost around $45,000, and the license was $25,000. A lot of engineering expertise was

NRSC, continued on page 6 ›

	Correction	Analog and digital audio processors		Audio processor and Exporter location		
Figure	Type	Separate†	Combined	Studio†	Transmitter	Comments
Figure 15	In-line		✓		✓	Preferred in-line approach
Figure 16	In-line	✓			✓	
Figure 17	Monitor-based		✓		✓	Preferred monitor-based approach
Figure 18	Monitor-based	✓			✓	
Figure 19	In-line		✓	✓		
Figure 20	In-line	✓		✓		
Figure 21	Monitor-based		✓	✓		
Figure 22	Monitor-based	✓		✓		
Figure 23	In-line	✓			✓	

† Not recommended

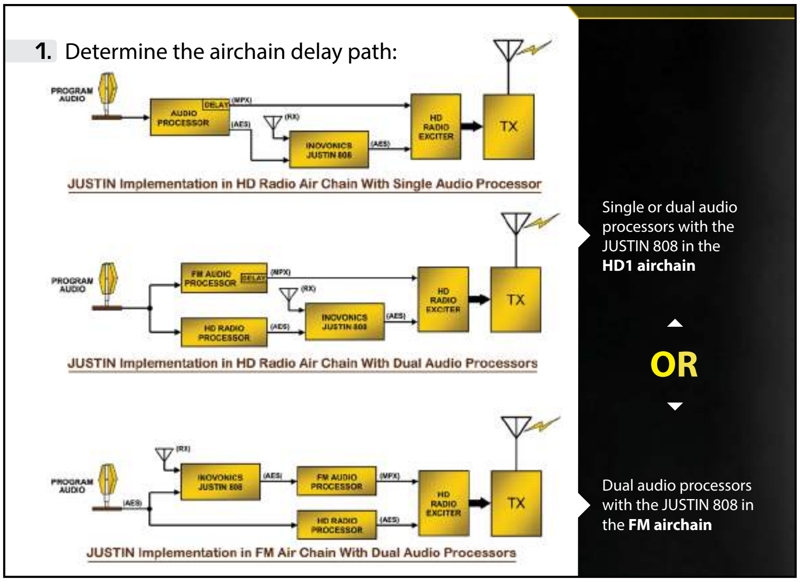
Fig. C: This table shows correction methods and station configurations in the section about methods for automated alignment.

› NRSC, continued from page 5

also required," he said.

"Today, fourth-generation HD equipment costs less than $10,000, licensing fees are a lot less, and installation is largely a plug-and-play operation. In most markets, there are opportunities to lease out your HD3 and HD4 signals, so the payback time is greatly reduced. We expect the costs to continue to drop in the future."

Another driving force is the connected car, where AM/FM signals are the only analog ones left in the entertainment system, and an HD digital signal is really required for a station to be competitive, Greenhut said.



An Inovonics product brochure depicts three ways to connect an alignment processor in an FM/HD airchain.

COMPLEX TOPIC

After opening by explaining important terms and providing background including examples of the problem, the document lists examples of typical HD Radio transmission topologies. These are summarized in helpful table form (Fig. A in this article) and detailed in individual block diagrams (Fig. B). The subject is complex and there is no way to simplify it to a one-size-fits-all solution. The requirements of various stations make for a variety of transmission topologies, some of which work better than others in maintaining alignment. To the extent that an engineer can configure equipment to match one of the recommended schemes, improvements can be made.

General guidelines and best practices then are discussed in Section 5 of the document. For time, level and phase alignment it says a user should:

- Ensure HD Radio subsystems are running the latest software versions as recommended by the manufacturer.
- Make sure GPS connections are properly installed and operational.
- Collocate the Exporter physically at the same site as the Exgine/Exciter (in most cases this will be the transmitter site).
- Consider collocating the Importer with the Exporter and Exgine/Exciter if additional program link channels and LAN extension bandwidth are available.
- Use an integrated, single-box main-channel analog and digital audio channel processor for setting delay and processing for digital and analog audio signals.

Suggestions for manual hybrid FM HD Radio time alignment include:

- After rebooting or reconfiguring HD Radio transmission components, wait before adjusting the time delay. This is important in any configuration that uses Exporter-to-Exciter (E2X) clocking, i.e., when the Exporter is not collocated with the exciter. Most systems take several minutes to several hours to establish a stable delay.
- If available, use a precision diversity delay monitor that can show continuous measurements to detect any drifting before making manual corrections.
- When using an older monitor that provides single-point-in-time measurements, make several measurements over time to ensure the setup is stable before making a manual adjustment.

A detailed table provides current software versions for HD Radio transmission equipment from various manufacturers.

Then the authors turn in Section 6 to methods for automated alignment. They note that there are several available methods for automating time, level and phase alignment to maintain long-term stability and that these fall into two categories, "in-line" and "monitor-based."

Within these categories, choices are available regarding manufacturer and topology; and a subsequent section provides a list of currently available equipment, many of which were evaluated by members of the working group. That table of auto-alignment products is found on pages 37 and 38 of the guideline.

NRSC, continued on page 9 ›

NAB Promotes Metadata Best Practices

David Layer talks about station audits, FM field tests and digital experimentation

David Layer is vice president, advanced engineering at National Association of Broadcasters. He is the primary NAB staff person on NAB's Radio Technology Committee and the National Radio Systems Committee, a technical standards setting body co-sponsored by NAB and the Consumer Technology Association.

Radio World: *You've watched HD Radio develop as closely as anyone in the industry. What is the most important next step for the platform or biggest question we should watch for in 2018?*

David Layer: NAB has been raising broadcaster awareness regarding the importance of delivering a quality "metadata" experience (for example, song title and artist, and album artwork for FM broadcasters) to the digital dashboard. As part of this effort we have been working with broadcasters on doing "station audits" to assess how well individual stations look on the dashboard and to offer recommended practices on what should be done. I am hopeful that in 2018 you will see more HD Radio broadcasters deliver the very best experience they can on dashboards, which will improve the listener experience and will better position radio to compete with all of the other audio services becoming available in cars.

RW: *The hardware for stations to implement HD Radio has always been something of a complicated topic, but this seems to be changing. What trends are you seeing that engineers should know about?*

Layer: Over the last couple of years, equipment manufacturers have been developing lower-cost solutions for broadcasters to implement HD Radio, and one positive development for 2018 would be to see more analog-only broadcasters deciding to "take the plunge" and start broadcasting an HD Radio signal. This lower-cost equipment also provides a good opportunity for existing HD Radio broadcasters to update their aging equipment.

The NAB recently published a series of best practices for radio operators with the digital dashboard in mind. Click on the image to read the document.

RW: *Please update readers about the status of tests into the possibility of "all-digital" operation for U.S. radio.*

Layer: For background, currently the FCC only authorizes the broadcast of "hybrid HD Radio" signals, which include both legacy analog as well as digital components. (Note that I am discussing hybrid HD Radio here, not to be confused with "hybrid radio" services like NextRadio that combine over-the-air radio with mobile broadband content.)

Virtually all HD Radio receivers in the marketplace, however, will work not only with these hybrid HD Radio signals but also with a more advanced, all-digital HD Radio signal that offers higher digital throughput and greater robustness, but is not receivable on analog-only radios. Looking to the future when the penetration of HD Radio receivers in the marketplace is higher than it is today and these all-digital services become feasible, NAB has been working with Xperi and broadcasters to test these all-digital signals and develop a technical record, which is a necessary prelude to FCC authorization, and in addition to raise awareness among broadcasters and the industry at-large as to the capabilities and benefits of these all-digital services.

David Layer speaks at a GM hackathon in Boston in September.

For AM, a series of all-digital AM lab and field tests were conducted from 2012 to 2014. In early 2018, NAB plans to do some limited all-digital FM field testing, and we plan to discuss this test program and share some results at the 2018 NAB Show during the Broadcast Engineering and Information Technology Conference.

RW: *How close are we to seeing voluntary all-digital operation allowed for FM stations on a widespread basis? For AMs?*

Layer: I do not foresee FCC authorization of all-digital services in the near future simply because the penetration of HD Radio receivers in the marketplace has not yet reached the level where it would make sense for the broadcast industry to start transitioning from hybrid digital to all-digital.

LAYER, continued on page **10** ❱

❱ *NRSC, continued from page* **6**

We asked Ben Barber, president/CEO of Inovonics, to describe how an HD alignment processor works:

"It starts with the cross-correlation of 32K samples of the FM and HD signals. That works out to be 3/4 second at 44.1. The firmware in the processor looks for similarities in the audio, and measures the time difference. The best place to put the processor is in the HD1 digital audio feed to the HD exciter or exporter. This gives the processor 8 or 9 seconds to work. The FM is put on a fixed 10-second delay. This gives the processor enough leeway to add or subtract time from the HD signal until the two are perfectly aligned."

He emphasizes that all adjustments and corrections are done very slowly so they are not audible to listeners. Barber said that the engineer's maintenance schedule should include having the processor's log emailed every day for the first week or two after the installation, and checking for glitches. After that, weekly log checks should suffice.

Section 7 of the guidebook contains a table that lists existing monitoring and alignment solutions. Many of these products were evaluated by the members of the working group, and software versions of the various components as released by the manufacturers are listed.

An annex provides some of the configuration settings required in the engineering user interfaces of specific HD Radio exciter products, for setting up direct clocking from 10 MHz or 1 pps. Another annex republishes Alan Jurison's full paper at the 2016 NAB Show "HD Radio Diversity Delay Field Observations: The Need for Automatic Alignment."

The main part of the document concludes with a description of planned activities for the NAB Radio Technology Committee. These include expanding the guidebook to cover AM hybrid HD Radio systems, which can suffer the same alignment problems as their FM brethren. Another project is to assist in the development of next-generation HD equipment, which will be able to maintain time alignment without external devices.

Additional goals for new equipment include lower acquisition and operation costs, which should make the implementation of digital radio more desirable and affordable for the many broadcasters who have yet to participate in the transition.

The guideline is available for download at *http://www.nrscstandards.org/.* ■

Keep Your HD Radio House in Order

David Day on how pre-processing has changed, and current issues of operational concern

David V. Day is president of Orban Labs Inc.

Radio World: *Orban has been active for years in pre-processing of audio to minimize artifacts in low-bitrate codecs such as used in HD Radio. With 2018 upon us and with the HD Radio marketplace well established, how has LBR processing for HD Radio changed lately? What should radio engineers know about the state of LBR processing these days?*
David Day: There have been a lot of big changes in audio processing since HD Radio started its rollout in 2004. Many FM processors back then didn't have a non-preemphasized output, or if they did they didn't have frequency response above 15 kHz. There were many "Frankensteined" processing schemes that used disparate processors for FM and HD, and some worked better than others.

But there were still big issues with loudness at blend, and nothing addressed dealing with HD Radio's lossy codec, until a couple of years down the road so to speak.

DAY, continued on page **12** ›

David Day

› LAYER, continued from page **9**

Having said that, I would not be surprised to see requests for experimental authorization of all-digital services by pioneering broadcasters who are looking to the future and whose circumstances are such that experimentation makes sense.

For example, an AM radio station that has an FM translator might be interested in experimenting with an all-digital AM service, since they can use their AM signal all-digital to reach listeners with HD Radio receivers, and still reach listeners with analog radios with their FM translator signal.

I am very excited about that kind of experimentation, it would be a great way to raise consumer awareness as to the benefits of all-digital for AM, and it also highlights how important FM translators can be for AM broadcasters in a possible transition to an all-digital service.

RW: *What other technical issues is the National Radio Systems Committee or NAB watching with digital radio?*
Layer: One exciting project the NRSC is working on right now is an updating of the NRSC-G200 Guideline, "Harmonization of RDS and IBOC Program Service Data (PSD)," to address the widespread use by radio broadcasters of streaming their audio programs over the internet. It is important for broadcasters to provide a good "metadata" experience not just on over-the-air receivers but also to streaming audio players. The goal is for the updated NRSC Guideline to help broadcasters understand the different metadata capabilities of all platforms that radio listeners are using, and to offer information on how to efficiently provide a premium metadata experience to all of these platforms. ■

DAY, continued from page 10

Orban's parent, DaySequerra, delivered its first HD Radio codec preconditioning back in 2006 after looking at the problems of its lossy codec and how to minimize the resultant artifacts. The DaySequerra LBR4 provided four channels of codec preconditioning for all of the HD Radio bitrates. Users reported that it gave them near 96 kbps audio quality at 48 kbps data rate. It allowed them to run music programming on HD2 and HD3, and many of them did.

***RW:** What are key considerations or best practices to proper pre-processing for HD Radio?*

Day: First, the NRSC has a great white paper on HD Radio best practices; it's free and you can download it from the NRSC website. It is a "must read" for anyone broadcasting HD Radio. NRSC-G203 has 40 pages of case studies and solutions to all of the common problems of diversity delay alignment and processing.

To paraphrase it: Use a single audio processor designed for FM and HD1 processing. Codec precondition the HD1 output — and off you go. HD2 and HD3 can be handled independently (based upon program material) and again precondition after the processor.

We are in a fight to maximize HD Radio's importance in the dashboard, and we need to make sure we have our "house" in order with proper diversity delay alignment and loudness at blend.

— David Day

***RW:** What is Orban's offering for preprocessing for low-bitrate HD Radio, and why is it different from others on the market?*

Day: DaySequerra has been doing audio codec preconditioning since 2006. We worked really hard with iBiquity (in those days, now DTS/Experi) and lots of the early HD Radio adopters (mostly public radio) to make the HD1/HD2/HD3 audio as best as possible. Our patented preconditioner uses applied psychoacoustical processes to minimize artifacts at the lowest HD Radio bitrates. We are on the fourth generation of preconditioning technology, and users tell us that is giving them near 96 kbps audio at 32 kbps data rate.

***RW:** As you talk with broadcast engineers and other users, what's your sense of the health of HD Radio, and where do you think the technology is going?*

Day: There is solid adoption from the broadcaster side, including a fair number of AM stations! We still have issues with time alignment, and the last time I took a look at a market with one of our MAM3 monitors, about 40 percent of the FM stations were well outside of being in good diversity delay time alignment. It's a real problem for the automotive industry with consumer complaints — the dealer fix is to lock the car HD Radios into "analog only" mode to resolve it, and that's bad for broadcasters.

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

Day: We are in a fight to maximize HD Radio's importance in the dashboard, and we need to make sure we have our "house" in order with proper diversity delay alignment and loudness at blend. I drive a small fleet of rental cars every year; and when I plug in my iPhone it takes over the system — and AM and FM radio goes away … That's a huge issue for our industry, one that I know the NAB is working on. But many broadcasters don't know that Apple's CarPlay and the equivalent Android software kill the ability to listen to AM and FM stations. This is not good for our industry, in the least. A couple of auto manufacturers actually recently dropped AM support, probably due to RFI being generated in the vehicle hybrid drive system killing AM reception. ■

Radio Needs to "Solve for Greater Challenges"

Brenner says broadcasters need to reinvent the interface for consuming radio and its content

Paul Brenner is president of the Broadcasters Traffic Consortium, a coalition of more than 30 U.S. and Canadian broadcast groups that sells data delivery capacity to third parties such as HERE Traffic using member stations' HD Radio Data Services and analog RDS-TMC subchannels. Brenner works at Emmis Communications, the BTC founding member, and is president of its wholly owned subsidiary NextRadio/TagStation. He is vice chair of the North American Broadcasters Association, where is acting chair until mid-2018.

Radio World: *What is the most important next step for the HD Radio platform or the biggest question radio executives should watch for in 2018?*

Paul Brenner: The range of consumer options inside the vehicle is accelerating and will cause more fragmentation. Effects on in-car radio listening are inevitable. HD Radio and broadcast radio listening in general should be looking well beyond simplistic things like consistent radio tuner dashboard experience and solve for greater challenges. Broadcast radio needs to consider the choices and methods that consumers have and will continue to gain, and reinvent the interface for consuming broadcast radio and the content they consume. For example, exposing HD Radio multiple audio channels as well as our work with the Broadcaster Traffic Consortium and HERE Traffic services. BTC is enjoying immense year-over-year growth because the digital data services are helpful to the customer.

RW: *In your role at the Broadcasters Traffic Consortium, what would you like to see next for HD Radio?*

Brenner: Two things.

Find ways to make the technology cheaper for broadcasters and automakers. Over time, the cost of technology must go down to drive adoption and remain competitive to newcomers. With the changes in the car, HD Radio is being challenged to compete against new business models and technologies.

Paul Brenner, shown speaking at a trade show in 2014.

Broadcasters need to reinvest in the technology. Versions have improved. Equipment has aged. Given the amount of time it has taken to launch in-car solutions both versions and equipment need reinvestment across all markets.

RW: *How relevant is HD Radio now in the car environment?*

Brenner: Relevancy depends on the services and automaker because, as I mentioned, the rate of change and new services in a dashboard is rapid. Anyone can see the ongoing evolution towards all-electric, semi or fully autonomous vehicles, AndroidAuto or CarPlay integrations. A matrix of choices is being, considered, planned or implemented by automakers. HD Radio, like broadcast

BRENNER, continued on page **14**

BRENNER, continued from page 13

radio, is facing stiff challengers with aggressive plans to take our consumers. Broadcast radio needs to have solutions showing why we are still relevant. With BTC/HERE Traffic services, the relevance is actually growing as we use the mass-market capability of broadcast digital radio to provide a utility service everyone wants over the most efficient way to access.

An image from wireless tech company Parrot gives a sense of the environment that media companies now compete in for the car.

RW: *What about in mobile devices or the home? It feels like uptake there stopped, compared to the car.*
Brenner: I am not aware of any uptake for HD Radio in mobile handset or home devices.

RW: *You've taken an active role at the North American Broadcasters Association, so you have a grasp on developments in Canada. Assess the interest in HD Radio there.*
Brenner: HD Radio adoption in Mexico and the United States have been the primary driver behind the interest by Canadian broadcasters. Readers should recall a previous attempt at DAB by Canadian broadcasters that made major investment but eventually ended with no receiver adoption. Because of this history, Canadian broadcasters move forward cautiously and carefully.

While I see certain revenue-generating aspects of HD Radio being pursued, such as Canada broadcast stations adding HD Radio for the Broadcaster Traffic Consortium HD Radio data services, and some testing of HD multicast for AM simulcasting, new station activations will be slower than the U.S.

One issue is that Canadians are more sensitive to interference and FM complaints. At any sign of either, their action is shut down HD until the problem is solved, versus the U.S. where you would typically see a reduction in power until solved as opposed to shutoff. On the content side there continues to be some debate about CRTC [Canadian Radio-television and Telecommunications Commission] policy that could have an impact on mandating competitive content on multicast channels. Both ISED [Innovation, Science and Economic Development Canada] and CRTC seem to be supportive of HD Radio and providing the permissible actions allowing broadcasters to proceed. Broadcaster caution will continue to be the governor on adoption.

RW: *What role do you see in future for HD Radio single-frequency networks?*
Brenner: I know there are technical debates about HD Radio SFN, and I am not informed enough to discuss those items. Historically speaking though, analog alternative frequency (AF) technology never led to any level of significant adoption or use outside of Europe. Europe's use of multiple lower-powered transmission sites for national coverage is a better application of SNF. U.S. radio now has so many variations on coverage — AM/FM/HD, translators, boosters, HD multicast — SFN would be difficult to bubble up as a valued and interesting proposition.

RW: *What other technical issues are you watching with digital radio, wearing any of your hats — Emmis, NextRadio, BTC or NABA?*
Brenner: My exposure through NextRadio and BTC to what is being planned by automakers and handset makers between two and five years into the future shows me that the radio industry must be working together on common solutions for both mobile devices and automotive technologies. I am not referring to streaming, as that is not a business that can produce the audiences and revenue to sustain.

Broadcast radio has many benefits to the consumer, and the products we build and program must change with the times. For example, considering the move towards fully digital cars and devices, how do we as an industry justify the extra cost for analog support? Just to geek out for a minute, what if a smartphone or a car no longer had any analog capability or willingness to build for interference issues? What will we have done to prepare for that argument and justify the work and investment to keep broadcast radio as an option?

There are things we must be doing right now to prepare for that discussion; and the discussion needs to be now. ■

Sonic Tonic for Digital Radio

What sets apart great-sounding digital channels or streams, especially at lower bitrates?

By **Frank Foti**

The author is CEO of the Telos Alliance and founder of Omnia Audio.

Frank Foti

Achieving great-sounding digital radio is easier said than done. What are the critical elements that set apart great-sounding digital channels or streams, especially at lower bitrates? Improving performance is accomplished through innovative signal conditioning and processing means. Coded audio is now a way of life in the professional and consumer sound industry. It is commonplace in all forms of media that utilizes sound in one form or another.

This excerpt is not written to sell the reader on the benefits of coding, or how it works. The writer assumes this to be a *given,* that the reader understands what audio coding is. The purpose here is to educate about the aspects of the coded transmission system, where the stumbling blocks are, and seek methods that provide smooth sonic sailing.

Enclosed is detailed and comprehensive information regarding the causes of perceptable problems in audio coding, how to avoid them, along with a method that improves the sound quality of coded audio.

MOVING TARGETS

Since the early 1990s, audio coding has been around the professional sound industry. Codec developers have been on a fast track, and they continue to be. Audio quality, judged by MPEG (Motion Picture Experts Group) to be excellent at 256 kbps and 128 kbps, are now offering the same judgment at bitrates much lower. As codecs improve payload efficiency, it becomes possible to add more transmission channels to the existing infrastructure. It's much easier to improve the data payload, as compared to expanding the pipe. This is how program services are able to expand their range of content offerings with additional channels.

To accomplish this requires using lower bitrate codecs. Lowering the birate increases potential degradation of audio performance. Advancement of codec design has allowed lower bitrates to be employed, and most codecs sound *decent* at these rates, but they are much more fragile with regards to distortion, and susceptible to artifacts. Due to the various types of codecs, and lower bitrates, makes getting a handle on the issues that annoy these functions a moving target, so to speak. The goal of this dissertation is to seek out the gremlins, then offer ways and means to avoid them. Getting under the hood and removing the veil of the codec itself is beyond the scope of this paper.

HISTORY

All transmission systems suffer from some form of problem, one way or another. Doesn't matter if the system is linear or not, suffice it to say that all of them have something to overcome. The simple phrase *no free lunch* applies.

The key to improving audio quality through a coded system is in understanding where the challenges are located, and what can be done to avoid causing them. Performance advancements in prior transmission methods came about due to investigating what caused the *ills* in that particular method. By example the FM-Stereo system: High-frequency distortion and peak level overshoots were very common in early FM-Stereo generators. Both the preemphasis boost, and sharp cutoff of the required low pass filters, caused severe problems within the system. In-depth analysis of the system lead to the discovery of embedded preemphasis management and non-overshooting low pass filters, which dramatically improved FM-Stereo performance. By researching the difficulties within the system, and then utilizing the gathered information, it enabled new means by which the challenges were overcome. The same applies to coded audio systems too.

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While the concern for FM-Stereo was distortion and overshoot, coded audio suffers from what are referred to as *sonic artifacts*. These are the perceptible annoyances that bother the listener. Most sound anomalies are categorized as one form of distortion or another. Most common are harmonic distortion (THD) and intermodulation distortion (IMD). Coding artifacts are neither. When they are perceived, they occur due to inadequacies of the coding algorithm. Basically, this is the point where the coder runs out of capability to reduce the audio data without the process of data reduction being heard. While there have not been specific technical terms assigned to describe these artifacts, they can be referred to as *swishy-swirly, underwater-like, gurgle-like,* and sometimes *synthetic-metallic.* All of these characteristics degrade sound quality, and reduce intelligibility.

CODEC PROVISIONING

Traditional dynamics processors are designed to fulfill the requirements of a medium where the functions are *static*, such as precision peak control and bandwidth limiting for conventional broadcasting, or the normalization needed for recording and mastering. Each of these functions is a known static entity. They are singular, one-dimensional functions where the target is known and the audio processor is designed to accommodate this.

The audio codec, on the other hand, is a moving target. No two codecs are alike, or sound the same. They vary in sonic quality based upon bitrate … *and* … more importantly they vary within the same architecture based upon audio content! Here is where conventional audio processors fall short when used in a coding environment.

Until now, dynamics processing has been able to address *some* of the hurdles and artifacts generated by audio coding. The codec has the ability to adapt and modify its algorithm internally, in order to provide maximum throughput, and this alters the sonic artifacts created by the coding process. Unless an audio processor can do the same, it will *hit and miss* regarding how well it provisions the audio to avoid artifacts. Sometimes coded audio sounds acceptable, and sometimes it doesn't. Conventional processors play games with HF limiters and static low-pass filtering to minimize coding anomalies. In order to condition audio in hopes of artifact avoidance, the processing will over-compensate audio bandwidth and dynamics. The result is dull, lifeless sounding audio that still contains audible gremlins.

SENSUS EXPLAINED

Sensus technology takes dynamics processing into a new realm. Instead of two-dimensional static architecture and functionality, Sensus adds a third domain where it modifies processing algorithms, architecture and functions based upon conditions that are understood by the system. Sensus has the ability to sense what must be done to a signal, and then "rearrange the furniture" to accomplish its goal. There are numerous derivatives to this innovative tech, and it can be scaled to many applications. Following is a discussion of how this method is applied to a processor used in a coded audio environment.

The Sensus algorithm detects troublesome content for a codec, modifies the processor's architecture and then makes the appropriate changes. These could be dynamics, bandwidth adjustment, a combination of both, or the elimination of a not needed function. The result is consistent quality through the coded transmission system, even at low bitrates; i.e. 18 kbps–21 kbps. Voice by example, especially without any other accompaniment, is very difficult to code at low bitrates without the quality and intelligibility suffering. This new process generates clean, smooth, intelligible, and clear audio that is consistent-sounding no matter what the content is.

HEADROOM CONSIDERATIONS

Another important factor regarding the coded system is headroom. Digital systems have an absolute maximum ceiling of 0 dBfs. Theoretically, audio levels for transmission should be able to be set right up to this level. But, depending upon the encode/decode implementation, overshoots may occur. This is not consistent from

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codec to codec, but more so due to the implementation of the codec by various manufacturers. Additional input low-pass filters in the encoder may cause headroom difficulties. A well-designed encoder will ensure that any added input filter possess the same headroom as the system, along without generating overshot that reduces headroom. Note: Most filter overshot is of the 2 dB–3 dB magnitude, but can exceed this amount depending upon filter characteristics.

It would be wise to test any codecs within a specified infrastructure to make sure that 0 dBfs is attainable without system overload or clipping. For this reason, setting the absolute peak level 2 dB–3 dB below 0 dBfs, offers insurance to avoid clipping.

PROCESSING FOR MULTICAST, STREAMS, DAB, DRM, ETC: SONIC TONIC

The advent of HD Radio has introduced the capability to broadcast multiple content streams within the 96 kbps digital channel. To facilitate multicast requires the use of lower-bitrate audio coding. The broadcaster can choose the bitrate for each content channel, as well as the number of desired channels, with a maximum limit of seven. Therefore it is possible that extremely low bitrate audio channels will exist, and those will require dynamics processing capable of consistent sound quality that yields low, or no sonic artifacts.

Various signal processing and conditioning means can be used to bring to life coded sound.

Research on which this article is based has yielded a new audio processor for multicast. An innovative codec provisioning algorithm using Sensus Technology and LoIMD limiters yields consistent audio quality that contains little, if any, coding artifacts. Yet, audio quality does not suffer the dull or muffled quality due to extreme bandwidth reduction that would normally be employed to mask codec "nasties."

Now it is possible for lower-bitrate channels to offer high quality and clear intelligibility through the use of a dedicated processor that employs the means to understand and handle the challenges of the coded audio path.

For those who wish to tweak on their own, with existing processing equipment, the following should be observed:

1. Avoid dense processing that contains fast limiting time constants. Try to reduce the attack time on functions when 5 dB, or more, depth-of-compression is desired. This will reduce upper frequency processor-induced IMD.

2. Make sure that the coding system provides full headroom. If the system clips on its own before 0 dBfs, then reset the maximum input level to avoid system headroom problems.

3. Low bitrates will benefit from bandwidth control. A static low pass filter will reduce artifacts. The tradeoff will be perceived high frequencies vs. quality. A specialized processor for coded audio will offer some dynamic method to accomplish this.

4. Do not use *any* final limiter that contains a clipper. The THD generated by the clipping function will cause more trouble than it's worth. Precision peak control is needed in the coded system. As mentioned, specialized processing for this medium will provide a look-ahead limiter to accomplish this task.

5. It is vitally important to make sure the audio processing system operates in a synchronized clock environment. Most processors can slave off the digital radio transmission gear, which will suffice as a master clock. Failure to do so may result in audio glitches and affect time alignment of the FM-Analog and HD signal paths.

6. Likewise, maintain correct diversity delay of the conventional FM audio path with the HD path, as this will ensure a smooth blend function in the receiver. Today, there are numerous monitors available to indicate the status of diversity delay performance.

If the above items are followed, improved coded audio will result. Various signal processing and conditioning means can be used to bring to life coded sound. While signal processing, conditioning and peak limiting is required for coded audio, the processing must employ methods that do not contribute additional distortion aspects, as this is what degrades clarity and quality at low bitrates, and sometimes even at moderate to higher rates. Data channels are at a premium today, which further requires every effort to offer the best sounding transmission path possible. ■

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Unique Single-Frequency Network Incorporates HD Radio

"If properly designed, an HD SFN can have a seamless hand-off between network nodes"

A single-frequency FM network of three signals transmitting on 88.5 for KCSN and KSBR in southern California has gotten a lot of attention in recent months. [(Learn more about that project.)]

But one interesting aspect is that engineer Mike Worrall wants HD Radio to be part of this SFN. His consultants originally thought HD Radio wasn't going to work for this, but Worrall said he was impressed with reports by Philipp Schmid of Nautel about [work being done at KUSC]. We checked in with Worrall for a quick update on his own project, which is in its early days, and asked what's next.

Mike Worrall

Radio World: *Mike, are all three FM signals in your network now fully HD Radio? If not, what's the timetable?*

Mike Worrall: Yes, all three "nodes" of our SFN are now operating in HD, which consists of full-service FM stations KCSN, KSBR and a booster. We launched the SFN in early September 2017 and discovered that the KSBR antenna system presented a high VSWR to the Nautel VS-1 transmitter when operating in the HD mode. Field tuning the antenna for a better match solved this minor issue, and KSBR added the HD component around Oct. 1.

RW: *Analog single-frequency networks have a reputation for being difficult to get exactly right. What will the technical challenges of this HD Radio project be?*

Worrall: Analog SFNs, sans terrain shielding, are almost impossible to get "exactly right" for analog FM stereo reception throughout the listening area. Even if every aspect of the FM signal is optimized, there will be a relatively small area that most would consider "non-impacted" listening, which is exacerbate in a "mainly mobile" listening environment. This impairment is experienced (by the listener) as a multipath-like effect; if everything is precisely synced (which is now possible with the newest equipment) this subjective stereo impairment can become manageable, and is largely dependent on the RF signal ratios and timing offsets between the network transmitters.

Fortunately, HD Radio is much more tolerant of competing (co-channel) signals. HD receivers use significant forward error correction; even with bit errors as high as 1 : 100, HD receivers will remain locked provided the timing differential between the SFN transmitters is reasonable. There is no "audio impairment," HD data is either being received or is not, so if properly designed, an HD SFN can have a seamless hand-off between network nodes. Something to look forward to when analog modulation finally "goes away" …

RW: *As we understand your plan, you will be using a beta version of a Nautel product provided by Philipp Schmid to experiment in creating an SFN in HD Radio. What exactly*

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will your process entail?

Worrall: The "Nautel solution" for implementing HD in an SFN is to use GPS provided 1 PPS (pulse-per-second) signals introduced at the HD Exporter (at the studio), which migrate through any STL system to the Exgine, in Nautel's VSHD component at the transmitter, which in turn is connected to its own 1 PPS reference *in a series of processes that take exactly 1 second.* (The studio GPS receiver is integral to Nautel's Exporter Plus).

For example, "time zero" is audio entering the Exporter Plus, time zero plus 1 second is this same audio exiting the Exporter Plus as HD data, time zero plus 2 seconds is the HD data exiting the STL system, time zero plus 4 seconds is the HD signal out of the transmitter.

So in terms of implementing HD in an SFN with the Nautel suite of hardware/software, it's really no different than adding a standalone HD, save for the absolute requirement to have 1 PPS available at both the studio (Exporter) and the transmitter. It's my understanding that other manufacturers may soon have their own HD SFN products.

RW: *What testing do you plan?*

Worrall: Objective testing of the HD component has been a goal from Day 1, but has taken some time to coordinate. The hope was to find a tool similar to the Audemat Navigator 100, which records many aspects of a multiplex FM stereo signal and can be used in a mobile environment with a GPS receiver. The collected data can then be exported to a map for a very precise look at how well a station's FM signal is performing throughout its coverage area. However, we have been unable to source a similar off-the-shelf tool for HD Radio.

Our project consultant, John Kean, developed and used a "mobile HD analyzer" during his days at NPR Labs built around a Kenwood KTC-HR100 HD Radio "head-end." We considered attempting to re-create John's work, then became aware of a soon-to-be-launched commercial product from Octave Communications, their Mobile HD Radio Receiver-Analyzer. This software suite works in conjunction with a DaySequerra MAM-2 tuner and a GPS receiver and should provide a complete HD performance picture.

However, the Octave product is still in development, scheduled for release in early 2018; and we're anxious to perform an HD analysis now. John discussed our need with Russ Mundschenk at Xperi, who said "I am able to [loan] you our new and improved HD Prospector test receiver and Prospector 9 software. The system generates two files — a .kml for Google Earth and a .txt tab delimited text file with multiple parameters including Cd/N0 and Analog Signal Strength." Cool! We're planning on using this tool the second week of January.

RW: *What people and organizations are involved in this?*

Worrall: Our SFN project is somewhat unique in that we're two, co-channel, independent, full-service stations on opposite ends of a large metropolitan area that have historically "interfered" with one another. The goal was to minimize this mutual interference by joining forces via a combined programming format. One of us was in HD, KCSN and its Beverly Hills booster; KSBR was not.

We asked, "If we create a SFN, can we add HD to KSBR, and if we do, what will be the sonic consequences on mobile HD receivers?" Initially, both [consultants] John Kean and Bert Goldman said, "You can't do it. Xperi's Gen-4 HD architecture has a non-deterministic delay between the analog FM and HD components. Let's hold off on HD until they get this resolved." We said, "OK, no HD initially — we'll turn it off on KCSN …"

We then read of Nautel's work with implementing HD on a booster at KUSC, which gave us some hope. We talked to the Nautel folks about our project which, although it includes a traditional booster, is "ramped up a notch" from the KUSC project in that it includes two full-service stations.

After some pleading, Nautel agreed to configure our three new transmitters / Exporter with their HD Solution beta software, which is now on-air. The testing referred to earlier will provide both us and Nautel with valuable insight into how well (or not!) this works.

RW: *What will you be watching or listening for during the tests?*

Worrall: With HD, it's either on or off! Either the receiver is able to lock onto the HD signal or it's not. With the Xperi GPS mapping software (and perhaps soon the Octave product), we'll be able to see exactly where HD is working, which we can then use in planning system upgrades, for example antenna changes, or even transmitter site re-location(s).

RW: *What else should we know?*

Worrall: A really cool Nautel Webinar is available on You Tube that discusses both SFNs in general and HD SFN implementation in detail. Well worth a look for anyone contemplating either or both.