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GUEST COMMENTARY

Audio Processing Primer for HD Radio

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CLEVELAND The following is an excerpt from a paper written about audio processing for HD Radio. There are questions to be answered about this new transmission system. The following sections offer insight on some key areas that need consideration.

Sonic differences

Before considering processing for HD Radio, the technical differences between the mediums of HD Radio and FM analog need to be understood.

The most obvious difference is that HD Radio has a wider audio bandwidth of 20 kHz, as compared to FM analog, which only offers 15 kHz response, due to a limitation of the FM stereo system that we use.

Important: To achieve 20 kHz audio response with HD Radio, your audio processor must provide that response as well. This means that your processing must employ a base sampling rate of 44.1 kHz or above. Any processor that employs 32 kHz sampling, as a base rate, will not provide the full audio response of 20 kHz.

This is critically important in order to take advantage of the added frequency response. HD Radio was developed with the goal of providing CD-like audio. As we know, compact disc offers 20 kHz response, and the HD Radio system does as well.

Another significant difference is that HD Radio does not use any form of emphasis in the audio path, whereas FM analog uses 75µs preemphasis. The response of this HF curve yields a 2.2 kHz breakpoint resulting in a 17-dB boost at 15 kHz. This creates a hurdle for audio processors as they must manage the high-frequency gain generated by preemphasis.

The signal path for HD Radio is a flat response. There are two benefits relating to this:

1. The high-frequency content of the HD Radio system will sound cleaner! This occurs because, without preemphasis, there is no need to boost 15 kHz by 17 dB, thereby driving the HF spectrum deeper into the final limiter(s). This causes more processing side effects, such as intermodulation and harmonic distortion as heard with FM analog processors. HD Radio processors are operating on a flat signal, which dramatically reduces the depth of processing on high-frequency content. This definitely changes the effected perceived sound of the transmitted audio, which leads to the second item.

2. Due to the nature of the preemphasis boost, it creates what some industry insiders refer to as the "sounds like radio" effect. No matter how much processing they will employ, the aesthetic sound will differ and this is the major reason.

What transpires in the FM analog system is that the preemphasis boost usually is coupled into a final limiter design that employs some type of distortion control. The effected sonic result of this method yields the radio-like sound that many of us are used to hearing. Processing for HD Radio will change all of this, as the HF content will appear dramatically more open and cleaner sounding.

> ***That larger-than-life big phat sound is quite possible. But the synthetic smash-mouth sound characteristic of many FM analog stations is far less possible in HD Radio.***

The biggest difference between HD Radio And AM analog is the frequency response. To implement HD Radio for AM, the audio bandwidth of the analog channel must be further restricted to 5 kHz, as compared to the 10 kHz NRSC spectrum that has been in effect. This is necessary to eliminate any interference from the analog channel into the digital spectra.

At the time of this writing, there are on-going efforts regarding the AM system for HD Radio. Therefore, it wouldn't be fair to delve too deeply into what can or can't be done regarding the analog and digital channels. As work progresses, more information will become available. For now, we'll primarily deal with the FM system.

Changed landscape

A processor for HD Radio has a completely different set of requirements.

The most important issue is in dealing with data reduced audio. The processor needs to be thought of as a partner with the audio encoder. In this case, the processor has the ability to understand, in advance, what needs to be done in managing the audio spectrum so that the least amount of coding artifacts are created.

It is possible to predict what spectral conditions will exist that can generate audible artifacts due to coding. Dynamic algorithms in the processor can offset these conditions and in many cases remove unwanted artifacts, especially at higher bitrates, such as 96 kilobits per second. In essence, the audio processor can improve the efficiency of the encoder.

While peak control is required in order to keep the modulation input from exceeding the full-scale headroom limit of the system, the aggressive function like clipping is not required, and actually becomes a deterrent to the codec process. There is the need for peak control, but the possibility for over-modulation is removed as the audio level cannot exceed digital full-scale of the encoder.

The end of clipping?

Precision peak control can be achieved using numerous methods.

Probably the most common is the hard limiter or peak clipper. By truncating the peak segment of the audio signal, precision limiting is achieved and over-modulation is avoided. Most audio processors designed over the last 20 years also employ some form of distortion masking means as a tool to suppress the total harmonic distortion (THD) that is created by the clipper. This makes it possible to utilize more of the clipping function, which directly transposes into perceived over-the-air loudness.

Employing a clipper as a peak limiter in a HD Radio system will work with regards to precision limiting, but there are sonic penalties to be paid when considering the clipping by-products and the encoder. Any clipping process will yield harmonics of the fundamental source signal. Even with distortion masking employed, there will, at least, still be some second order harmonic content remaining.

It is this added content that, upon entering the encoder process, adds to the audio spectrum and aggravates the encoder, which in turn yields additional sonic artifacts.

Looking ahead

There is another form of peak limiter that is the perfect companion for the HD Radio application: the Look-Ahead Limiter. It suits this application so well because, while it provides excellent peak control, it does so with very little, if any, harmonic content that can adversely affect the encoder.

Here is a quick look at how a basic look-ahead processor operates. In essence, the processor has the ability to calculate the peak level of a signal over a specified period of time. While that is occurring, the audio is delayed by a like amount. Then as the control signal is applied to the audio gain function, the audio peak is reduced at the precise time that the control signal reaches the maximum control level and the crest of the peak is reduced without truncation. This is how clipping is avoided.

Peak control is achieved without creating any harmonic distortion. In observing sine waves, there would not be any peak truncation during the period of processing. Unfortunately there is no free lunch! A basic wide-band simple look-ahead processor will not create harmonic distortion, but will generate intermodulation distortion, or IMD. This type of distortion has a different type of sound to it, sort of a busy quality and can be as annoying as harmonic distortion (THD) especially with music.

Integrating an audio processor into the HD Radio transmission path would appear to be straightforward, and in concept it is. But there are a few items that need consideration.

Of importance is the issue regarding the blend-to-analog mode in the receiver. Even though the HD Radio system has designed time diversity into the transmit/receive path, so the audio from both the digital and analog signals arrive at the same time, there is an issue of audio spectrum and phase relationships that must be considered between the digital and analog transmission paths.

Should there exist significant phase relationship differences across the audio spectrum of the HD Radio and FM analog signals, the blend-to-analog mode will not appear as a smooth transition. If this occurs, it will be perceived audibly.

Therefore it is imperative that the two audio processors employed for the HD Radio and FM analog paths have the same, or very close to the same, phase relationships across the audio spectrum. It is understood that the FM analog signal will possess less spectrum, as the FM stereo system will only allow a 15 kHz audio bandwidth. So it is essential that phase linearity exist over that range of spectrum between the two transmission paths.

Level normalization

A critical component to the HD Radio transmission system is the reference audio levels of the HD Radio and FM/AM-analog signals in the receiver.

The key issue here is being able to create audio levels that are perceived subjectively to be relatively the same, in average volume, when compared to one another. The listener experience could be adversely affected if the audio level abruptly changes when the receiver switches between either the HD Radio or FM/AM analog signal path.

How can this be normalized, and what are the operating levels required to accomplish this?

Based upon the results of a subjective test done at Ibiquity's offices in Maryland and New Jersey and Omnia's office in Ohio, it is recommended that to normalize the audio levels between the HD Radio and FM/AM analog signal paths, a 5.0 dB relational difference in level needs to be implemented.

This number, for FM operation, is derived from the 3.57 dB determined through subjective evaluation and approximate 1.5 dB of pad to allow broadcaster flexibility. To ensure proper blending, every HD Radio radio, independent of manufacture, will be required to have the same relative offset.

A tool, not a weapon

All too often, the application of processing in the broadcast chain is employed to a level where it's thought more so as a weapon. The new landscape that HD Radio offers, requires it to be considered more to be a tool rather than the arsenal that normally transpires.

Due to the ability of the processor to enhance or improve the efficiency of the audio encoder, it will act as more of a partner or tool to the transmission system. At low bit rates, processing actually will improve the intelligibility of the perceived audio.

Processing for effect is still possible, make no mistake. Creating the appearance of that larger-than-life big phat sound is quite possible. But the synthetic smash-mouth sound characteristic of many FM analog stations is far less possible in HD Radio.

As HD Radio continues to evolve, for both FM and AM, there will be more that to learn. Luckily, we were able to have access to the transmission system before deployment, with regards to processing, so hopefully we're a bit closer to what the system needs as compared to the rollout of FM stereo. It's a fair bet that additional research along with field experience will further the path for digital broadcasting.

RW welcomes other points of view.