Wheatstone
WHITE PAPER

All-Digital Air Chain Arrives:

A Primer on Wheatstone baseband192

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Introduction

Recently, a Minneapolis station became the first to broadcast from an all-digital air chain using Wheatstone® baseband192 technology. KTWN-FM opened the door to the 100% digital air chain because of a simple, open-standard interface now being offered as a standard feature in most Wheatstone FM processors.

With this, we have effectively arrived at the completely digital FM air chain, from the audio playout system to the transmitter's digital FM modulator.

No analog MPX signals to deal with and no messy AD/DA conversion. It's digital all the way from here on out.

What is baseband192 and why now?

Wheatstone baseband192 is an open standard technology that eliminates the need for an analog composite interface between audio processing and transmission – a.k.a. the last digital mile. It provides AES-EBU output into FM transmitters now equipped with a digital baseband input, something that hasn't been possible until now.

Baseband192 was built into the original AirAura audio processor four years ago but had been shelved until FM transmitter manufacturers could offer a digital multiplex interface to their transmitters.

At the recent NAB 2013 convention, transmitter manufacturers announced upgrades to their FM exciters that could accept the necessary digital multiplex signal. The result is Wheatstone baseband192. A single AES-EBU cable between the Wheatstone processor and the transmitter carries the baseband signal, bypassing the need for multiplexing in the exciter and eliminating the resulting signal overshoot and associated loudness tradeoff.

Because the baseband192 signal encompasses the entire multiplex spectrum after stereo generation, it includes any loudness increases that may have been contributed by the FM processor's composite clipper.

A tale of two exciter input methods

Baseband192 gives broadcasters a third choice in interfacing the audio processor to the exciter.

Until now, they had to choose between two exciter modulation input methods: analog composite or digital AES/EBU (AES3). Using the analog composite signal carries with it the competitive benefit of any additional loudness generated by the FM processor's composite processing. But using the analog composite interface also brings with it at least one D/A conversion if the exciter is analog, and both a D/A and an A/D conversion if the exciter happens to be digital.

The other choice is AES3. Although this is 'digital', the AES3 signal is carried to the exciter as separate left and right channels so any loudness benefit that could have been generated by the FM processor's composite clipping is lost. Sample rate conversions may also be involved, and the exciter's stereo generator is tasked with creating the composite multiplex signal, though most do this function just fine.

Many digital exciters have an overshoot clipper or composite processor as part of their stereo generator technology for when the AES input is being used, but they typically don't have the high performance of clippers in digital FM processors. Nor do most exciters' composite processing schemes generate the same loudness increase without adding significant distortion.

What the industry needed was a digital method of handing off the FM processor's stereo generator output directly, and digitally, to the FM exciter. That is precisely why we developed Wheatstone baseband192.

The science behind Wheatstone baseband192

Baseband192 is a 192kHz sample rate, pure digital interface between the FM audio processor's stereo generator and the FM modulator of digital exciters so equipped. The baseband192 signal represents the FM processor's entire stereo multiplex spectrum – including most subcarriers. Because the baseband192 signal encompasses the entire multiplex spectrum after stereo generation, it also includes any loudness increases that may have been contributed by the FM processor's composite clipper.

The stereo multiplex signal remains in the digital domain after stereo generation so there are no D/A conversions, no sample rate conversions, and no imperfect analog circuitry standing in the way of a perfect handoff of the stereo baseband signal to the FM exciter. It is the best of all worlds.

Why 192kHz?

The Nyquist sampling theorem states that any band limited analog signal can be perfectly reconstructed from a sequence of digital samples as long as its maximum signal frequency is no greater than 1⁄2 the digital sampling rate. For a stereo multiplex signal whose signals extend to 53kHz (no subcarriers) a theoretical minimum sample rate of 103kHz is required. With a 192kHz sample rate, signals up to 96kHz can be represented, which implies that RDS and subcarriers extending up to 96kHz could be accommodated. But in professional audio we almost never operate all the way up to the Nyquist frequency, so for best audio performance and so as not to tread on Mr. Nyquist, we specify the baseband192 audio bandwidth as 75kHz, leaving a very generous 21kHz guard band.

baseband192's history

When Wheatstone was involved in the development of our new AirAura product (nearly four years ago now!) one of the many features on our bucket list was the ability to provide a digital multiplex output using the FM processing chain's AES3 digital output. Side note: we utilize the same hardware platform in all Wheatstone FM processors, so features destined for AirAura could, in fact, be implemented in any or all of our FM processors, and many have.

At the time we developed this new hardware, there were no FM exciters on the market that could accept a digital multiplex signal. In fact, it was impossible to predict what data format might emerge as a standard, or even if one standard would emerge. We designed in a high-speed AES digital output interface anyway, and gave it more than enough bandwidth to accommodate a digitized multiplex spectrum. We even put in the relevant control software and firmware, just in case. Then we waited, quietly, so as not to promise or promote a feature that might never be implemented by transmitter manufacturers.

Fast forward to 2013. Since the spring NAB show, FM transmitter manufacturers have been keen to add a digital multiplex interface to their current or upcoming hardware. In fact, all of the transmitter manufacturers I've spoken with have either already implemented the feature or plan to do so. This is very good news for the industry.

The data format that transmitter manufacturers chose is a high-speed version of AES3 in that the stereo multiplex spectrum is handed to the exciter as a 192kHz AES3-formatted signal. Choosing this format also allows for maximum flexibility around the broadcast plant because it uses standard 110 ohm balanced digital cables and the all too familiar XLR connectors.

How does baseband192 work?

In 'all digital' FM processors the stereo generator generates a digital version of the composite baseband signal. This signal is then fed to a high-speed D/A converter and post-D/A filter, which brings the composite signal down into the analog domain.

But wouldn't it be cool if the digital stereo multiplex signal going to the high speed D/A converter could be picked off, reformatted as a 192kHz sample rate AES3 audio signal, and selectively routed to the FM AES output? It would be cool. And that's exactly what we did to create baseband192.

There is another benefit to Wheatstone baseband192 technology besides the removal of the D/A conversion process, one that is unique to Wheatstone FM processors. Our FM processors digitize the signals applied to the SCA inputs and add those signals to the stereo MPX signal in the digital domain – RDS and SCA signals automatically become part of the baseband192 signal. In essence, baseband192 digitizes the entire multiplex spectrum including the RDS and SCAs up to 67 kHz for direct AES-EBU into the FM exciter.

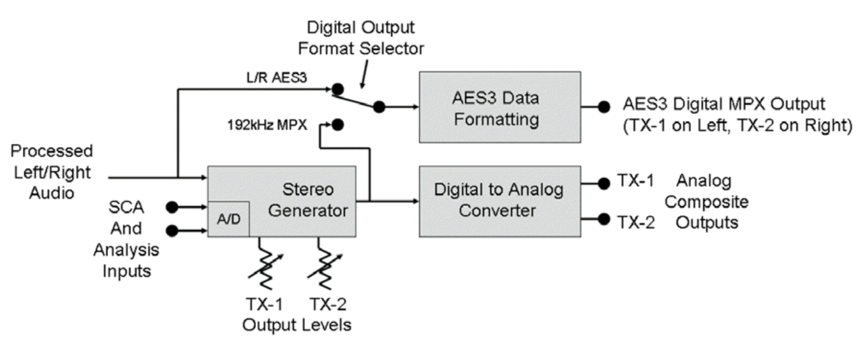
Other processors accept the RDS and SCA signals in analog form and passively mix them into the stereo multiplex signal, post D/A, after they, too, have become an analog signal. What this means is that when using the digital multiplex feature in those processors, the user must reroute his RDS and SCA signals directly to the FM exciter instead of to the processor's subcarrier inputs.

The block diagram below shows the signal flow of our baseband192 technology.

One more benefit of Wheatstone's baseband192 technology is that the composite MPX outputs – both TX1 and TX2 – are present within the baseband192 signal as AES formatted 'left' and 'right' audio channels, each with its own 192kHz sample rate. But they are not AES 'left' and 'right channels' in the usual sense; they are the stereo generator's TX1 and TX2 MPX outputs, each with its own output level control in the processor's GUI.

By choosing to format our data in this way, one processor can feed the baseband192 signal to two separate FM exciters, even from different manufacturers. The exciters can be told which digital MPX signal to use and the modulation levels for each can be adjusted independently via the processor's GUI, just as we do now with the analog MPX signals.

Because the rear panel BNC jacks are still live with analog MPX signals when the baseband192 option is active, those MPX outputs are also available for whatever the broadcaster might wish to use them for.



In summary

Baseband192 finally opens the door to a completely digital air chain, all the way from the audio playout system to the transmitter's digital FM modulator.

There are no analog MPX signals to deal with; no AES left/right audio without the loudness benefit gained from composite processing. Stereo separation and modulation accuracy are maximized. Modulation overshoots are no larger than what exits out of the processor's final limiter. RDS and SCA subcarriers enter and never leave the digital domain. Routing of RDS and SCA signals to the processor is the same, regardless of whether or not baseband192 is in use.

In short, the all-digital air chain has finally arrived.

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