MPD
MICROWAVE PRODUCT DIGEST

### Editorial Statement of Purpose

Microwave Product Digest serves RF and microwave design engineers, research and development engineers, applications engineers and engineering managers. These professionals, working in facilities that serve both the commercial and government markets, are involved with the design, development, application, and use of systems and subsystems, devices, and techniques involving frequencies from RF to light.

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FROM THE EDITOR

Karen Hoppe

# Welcome to the View From the Top...and the End of 2020!

In the 23 years that I've been with MPD, we've had three major events that have had serious global impact...starting with 9/11, then the crash of 2008, and now the novel coronavirus. Fallout from those first two events continues today, and we are still in the midst of a global pandemic. Yet, we've adjusted on the fly to everything that's been thrown at us. That's how we roll. And all of you deserve special thanks for keeping our essential industry going under unprecedented conditions, while ensuring that everything that can be done to ensure the safety of all employees is in place.

You can read about how a number of companies approached this seemingly impossible challenge in our View From the Top feature, starting on page eight. All of us at MPD wish you and yours happy, healthy, and safe holidays...and a much brighter 2021.

## In My Opinion

# It's Time to Advance the Direct-sampling Receiver State of the Art

Paul Jackson
*President*
***Precision Receivers***

The digital receiver has transformed both commercial and defense systems in a span of only a few years, a trend almost certain to continue, and for good reasons. Nearly all signals today are ultimately digitized, and the earlier the analog to digital transformation takes place, the better. Digital signals offer much greater processing flexibility and a long list of other benefits, not the least of which is reducing the number of analog components.

That said, building a high-performance digital receiver is not a simple task, and optimizing the performance of analog-to-digital converter (ADC) is one of the greatest challenges. An ADC is one of the receiver's most critical components as this single device effectively determines how well the entire receiver can perform.

However, like all components, ADCs have their own problems that if left unchecked can actually reduce that performance. It is bad enough that a receiver must deal with the increasing amount of external interference, but when the equipment itself generates it, there's little excuse for not effectively removing it.

The need to do this has never been more important because regardless of the application, whether EW SIGINT, COMINT, or communications, receiving and accurately depicting the signal has never been more important. And for the warfighter it can make the difference between life and death.

The problem in achieving this is that an ADC creates quantization, offset, gain, linearity, and timing errors, resulting in spurious signals at its output. These "spurs" can make it exceedingly difficult, and sometimes even impossible, to separate a signal of interest from the noise, reducing the signal-to-noise ratio and spurious-free dynamic range (SFDR).

These spurs can also interfere with signals of interest,

*Opinion, Con't on pg 30*

## In This Issue

*Opinion, Con't from pg 3*

compromising their data and causing among other things high bit-error rates and distortion to the point where signals of interest could be compromised or even worse hidden by the spurs and go undetected. Unlike the desired signal, spurs are not affected by analog filters earlier in the signal path but instead at any frequency in the ADC samples' frequency range. They can also occur at frequencies well beyond the ADC sampling frequency and then be aliased down to frequencies below the sampling frequency.

Dealing with spurs is nothing new for veterans of digital receiver design, but even they have difficulty reducing these onerous emissions. A variety of techniques have been developed or this purpose, including moving the spurious signal away from the spectrum of interest, "smearing" them to reduce their coherence and peak values, and post-processing.

A designer can also choose an ADC with the same number of bits but better spurious performance, if such a device is available. Another technique is to add a dither signal that adds noise at a level greater than the nominal quantization step size. Unfortunately, out-of-band noise dithering reduces the dynamic range of the ADC. And while it might seem that compensating for them in the data would solve the problem, this is difficult to achieve and somewhat unreliable.

ADC calibration can help, but as it is temperature sensitive it poses a major problem for aircraft that experience extreme wide temperature swings, requiring changes to be made in real-time. In short, all of these measures work to some degree but are either complicated, unreliable, require considerable processing resources, or are not particularly effective.

In some cases, they may even cause problems to arise that were not previously present. Significantly, all these current techniques for mitigating spurs become increasingly ineffective as systems monitor bandwidths extending to higher frequencies. Using today's system design techniques, the required sample rates create an overwhelming number of spurs.

Another promising technology has emerged that does not suffer from the problems associated with previous efforts because it does not use any of their approaches. It can be integrated within existing receivers and does not require a significant investment in hardware or software.

The approach, called High Dynamic Range Receiver (HDRR) technology, employs non-uniform sampling and an advanced clocking and sampling approach that mitigates the spurs and the resulting intermodulation distortion. It also preserves the original phase and amplitude of the signal as measured at the antenna. Non-uniform sampling allows a receiver system to determine the signal's Nyquist zone location and equips the receiver to extract additional information from it.

As the technique does not introduce dithering there is no added phase distortion and is compatible with all ADC types. The SFDR improvements, especially in the higher Nyquist zones, is substantial, with a typical increase of 9 to 12 dBc. It also allows ADCs to attain their highest effective number of bits (ENOB), typically by about 1.5 bits. A 9-dB increase in SFDR will improve a system's effective reception range by 75%; a 12 dB improvement expands that by a factor of 2.

The approach can also tune in any Nyquist zones presented to the input or simultaneously tune in all Nyquist zones. This allows systems to monitor broad bandwidths while also reducing the complexity of anti-aliasing filters or even eliminating them. This clocking method is compatible with all ADC types and because the technique does not introduce dithering, there is no added phase distortion.

While there is some processing to 'unwind' the non-uniform sampling, a time-series or a frequency-domain series can be delivered at user-specified, low-latency update intervals. The SFDR improvements, especially in the higher Nyquist zones, mean that designers can utilize direct sampling in more applications and at higher frequencies.

HDRR uses information available from the analog-to-digital conversion process, which is encoded in the HDRR clocking method. After the process is completed, the clocking information can be used to separate Nyquist information from different zones, which keeps the desired frequencies in-band and rejects the out-of-band frequencies.

These improvements are sorely needed if the U.S. is to meet the challenges posed by adversaries whose EW and radar systems have advanced substantially in recent years, a fact that was first revealed by Russian forces in Ukraine and Syria. Along with improvements in direct RF sampling receivers in general, HDRR should allow them to receive and effectively process weak signals that were previously impeded not just by external interference, but unwanted signals generated by the equipment of friendly forces as well.

• PRECISION RECEIVERS •