Reducing Spurious Signals: A Critical Requirement for the Warfighter

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In the not-too-distant future, a fighter aircraft patrols the carrier group defensive perimeter. The night sky is clear and calm, but the pilot is more focused than usual for peacetime operations. International tensions are escalating, and the carrier group is moving through a disputed sea lane.

Potential danger crystallizes into imminent threat with electronic speed. The plane's new EW system identifies an approaching missile that has locked on with a stealthy radar signal using a single high-frequency burst every second, each burst lasting less than 100 ns. The pilot instantly initiates EW countermeasures, then makes an accelerated dive to a lower altitude. Seconds later, the sky is illuminated with an explosion where the plane would have been.

Current rules of engagement prohibit the pilot from seeking and destroying the attacker. She returns to the carrier, keenly aware that last year's EW capability would not have detected the sophisticated missile.

Owning the Electronic Battlefield

For over 70 years, the defense electronics industry in the West has delivered superior technology to its military and allied forces, enabling dominance on the electronic battlefield. Recurring sets of challenges have been met, keeping our forces one step ahead of adversaries. However, challenges from Russia and China have awakened DoD to the need for faster technology insertion.

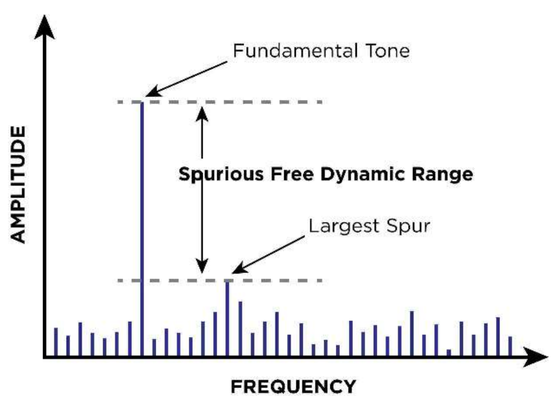
The scenario above paints a picture of just one emerging challenge that must now be met-stealthy, high-frequency radars. Radar pulse widths are now lasting only nanoseconds. These short pulses require very wide bandwidth capability in any sensing system as bandwidth is the reciprocal of pulse duration. Digital receivers must span correspondingly higher frequencies and operate across broad bandwidths to detect these new radar signals and extract their defining parameters. In addition to single frequency bursts, frequency-hopping and other spread spectrum signals are appearing in radar and are widely used in wireless communication systems.

Radar jamming and anti-jamming applications face a similar challenge, as they must first detect signals within a huge bandwidth and then extract parameter information before responding, all with lightning-fast latency. Meeting these challenges will require finding new ways to deal with significant underlying technical issues, as current EW system design methods are facing frequency and bandwidth limitations.

The Challenge of Spurs

Spurs (i.e., ‘spurious signals’ or ‘spurious emissions’) are an inherent part of RF systems. Introduced by noise, harmonics, non-linearities, of receiving system components, they are anomalies and aliases that can be present not just in the external RF environment but in the equipment itself,

The most useful metric for understanding the scope of the spurs problem in a given situation is Spurious Free Dynamic Range (SFDR). In a digital receiver, SFDR is defined as the ratio between the fundamental tone and the largest harmonically or non-harmonically related spur across the bandwidth of interest. It describes the useable dynamic range of the receiver. SFDR is essential for understanding the effectiveness of a receiver, even when the signal of interest is not the strongest but rather a weaker one that is buried among the spurs internally generated by the system.



The relationship between SFDR, spurious signals (blue), and the signal of interest (fundamental tone).

For EW systems, spurs have always been a critical issue. Locating a signal of interest in real-time and with low latency is central to all types of EW applications; spurs can make that difficult or impossible. Finding ways to increase a system’s SFDR is critical to effective operations.

RF technology has evolved over time to deal with spurs. Most significantly, analog-to-digital converters (ADCs) have increased in speed and bit depth to deliver continual improvements to SFDR, as well as enhancing other metrics such as signal-to-noise ratio (SNR), instantaneous bandwidth, and effective number of bits (ENOB).

However, quantization errors, timing errors, and nonlinearities, all generated by combinations of digital receiver components, are persistent causes for spurs. Various types of compensation have been developed to address these errors, including dithering, calibration, and commutating ADCs at lower rates. These techniques have made modest improvements to SFDR, but each introduces other drawbacks. For example, clock dithering increases phase noise, while commutating ADCs introduces another source of error--interleaving spurs.

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.

This is not an academic issue. Interviewed pilots have said they are getting nervous with the narrowing gap between the threat and their own EW capability. "I fly an expensive and sophisticated aircraft, but now I can't tell if a signal represents a threat or is just a ghost in the machine. I don't want to abort a mission because of a ghost, but what if the threat is real?"

To meet the next generation of challenges, tomorrow's EW systems will require a large-scale leap in SFDR without introducing additional calibration and training time or massive power for computation. A 9-dB increase in SFDR will improve a system's effective reception range by 75%; a 12 dB improvement expands that, for example, extends radar range by a factor of 2. These are the levels our industry must achieve to maintain EW superiority.

A Powerful Innovation

There is a unique new technical enhancement to digital receiver design called High Dynamic Range Receiver (HDRR™) created by Precision Receivers (PRI) that delivers the required leap in measured SFDR. HDRR's channel clocking scheme improves system SFDR by 9 dB or more. PRI technology can also tune in any Nyquist zones presented to the input or simultaneously tune in all Nyquist zones at the same time, enabling systems to monitor expansive swaths of bandwidth and reducing the complexity of anti-aliasing filters or even eliminating them.

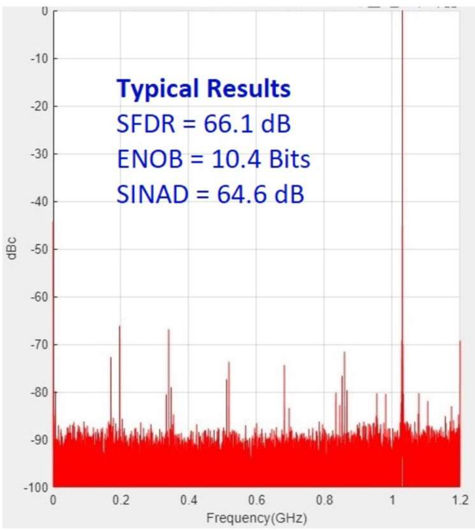
Non-uniform sampling allows a receiver system to determine the signal's Nyquist zone location and equips the receiver to extract additional information from it. PRI developed a unique, non-uniform sampling technique, with an advanced clocking and sampling approach that mitigates the spurs and the resulting intermodulation distortion. Further, the technique preserves the original phase and amplitude of the signal as measured at the antenna.

This clocking method is compatible will 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 is still easily 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.

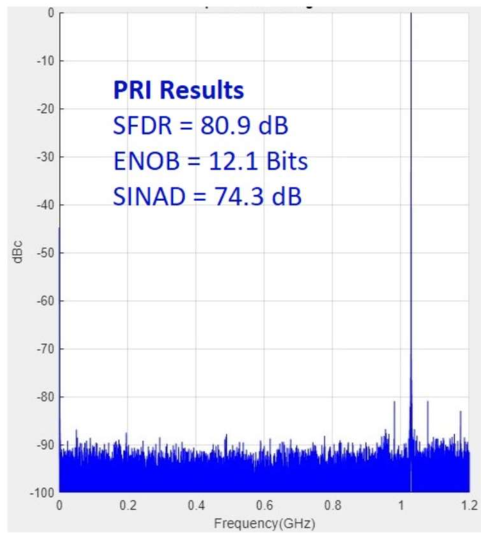
The two spectrum analyzer displays below show the dramatic improvement that can be achieved with HDRR.

Nyquist Zone 1 – 1030 MHz

Typical ADC Data



PRI Enhanced Data



Zone 1
1030 MHz
Improvements
SFDR = 14.7 dB
ENOB = 1.6 Bits
SINAD = 9.7 dB

The Benefits of Nyquist Tuning

Nyquist Tuning is PRI's technology for digitally isolating one Nyquist zone from another, typically without the need for anti-aliasing filters. This allows the amplitude and phase of frequencies within one Nyquist zone to be distinguished from their aliased counterparts in other Nyquist zones. The result is much more precise signal representation.

For example, some applications require looking for information within frequencies of interest, while others look at the rejection of aliased frequencies folding over the Nyquist rate. These aliased frequencies may not be entirely removed by analog filtering and leak into an adjacent Nyquist zone. Nyquist Tuning rejects these leaked signals, revealing signals of interest, free of the phase distortion caused by analog filtering.

Nyquist Tuning also allows the calculation of multiple Nyquist Zones simultaneously without using multiple stitched receivers, avoiding the phase and amplitude distortion caused by stitching the different frequency bands together. PRI accomplishes this because the Nyquist Zone number is a parameter in the Nyquist Tuning calculation and is independent of the PRI signal acquisition process.

Additional information available from the analog-to-digital conversion process used within HDRR's encoded clocking method. After the process is completed, the clocking information can be used to separate the different Nyquist zone information, which is helpful to keep the right frequencies in-band and reject the out-of-band frequencies.

Enhance Your System's Capabilities

PRI’s technology can be deployed without wholesale changes to a current EW system. It is ADC-type, clock-frequency, and CW frequency agnostic, requires no a priori information, no calibration or learning time, and minimizes the amount of post-processing or errant signal analysis in the end-user application.

Because of this design flexibility, HDRR can be used to upgrade currently deployed systems, boosting SFDR and expanding mission capability without necessarily modifying the analog or digital signal chains. A cost-effective system upgrade can be implemented in various ways, depending on the system design and types of devices it uses.

As HDRR is tailored to the specific needs of each system, PRI works with customers and provides a demonstration system for evaluation. The demonstration system a 4-channel acquisition configuration with state-of-the-art 2.5 GHz ADCs and a compute system to perform the PRI-specific spur reduction algorithm and deliver a spur-free time-series of data from the four channels. An 18 GHz step-down is offered on the front end, or you can supply your own anti-alias filters to achieve an available bandwidth of DC to 8 GHz.

For more information, please call or email PRI and visit PRI’s Web site, precisionreceivers.com.

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