High-Dynamic Range Receiver Technology

HDRR™ is the industry's most advanced technology for improving the performance of direct RF sampling receivers employed in EW, radar, SIGINT, wireless communications, medical imaging, and radio astronomy.

HDRR technology provides an order-of-magnitude improvement in reducing unwanted (spurious) signals to levels unachievable using other methods, improves spurious-free dynamic range (SFDR) by up to 15 dB, and allows wide instantaneous bandwidths to be achieved.

HDRR can be used in any RF or IF direct-sampling system, with any ADC, at any frequency or bandwidth of interest, without the need for self-calibration, and reduces anti-aliasing filter complexity.

In addition, employing PRI's Nyquist Tuning™ technique, HDRR can also tune-in any Nyquist zones presented to the input.

It can also simultaneously tune in all Nyquist zones at the same time, enabling systems to monitor expansive ranges of bandwidth.

This non-uniform sampling allows a receiver to determine the signal's Nyquist zone location and equips the receiver to extract additional information from the signal.

Application	Benefits
EW	• More precise and faster signal (amplitude and phase) identification • Enhances ability to match signals with those in threat libraries • Allows high-fidelity capture and reproduction of real-world threats
Radar, COMINT, ELINT, SIGINT	• Improves detection of low probability of detection signals • Reduces false-alarm rate • High rejection of aliasing, images, reflections, and quantization errors • Reduces staring receiver complexity
Wireless systems	• Increases coverage and network capacity • Reduces infrastructure required to cover a given area • Improves quality of service
Medical imaging	• Increased SFDR for 3-D scans • Allows more receiver channels to be combined • Keeps center of k-space linear without affecting signals at the periphery
Radio astronomy	• Enable detection of previously obscured, very weak signals • Allows wide-sky, wide-bandwidth signal acquisition through methanol (CH_3OH) spectral lines • Enables large, fast bursts of RF energy (Askaryan radiation) to be detected over broad bandwidths

Understanding the Problem

Direct RF sampling, in which the signal captured over the air and is immediately digitized, has become the architecture of choice for applications ranging from EW to SIGINT, COMINT, ELINT, radar, and communications.

The reason is simple: The approach eliminates nearly all RF components and their non-linearities in the signal chain before the input signal is digitized, so a system can be smaller and less complex. And once in the digital domain, the system benefits from the inherent advantages of digitization, with processing performed in a digital signal processor or an FPGA (Figure 1).

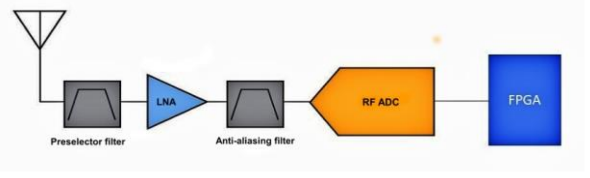


Figure 1 – In a direct RF sampling receiver there are typically only two filters and a low-noise amplifier before the ADC, as the mixer and local oscillator required in a heterodyne receiver are eliminated.

In these receivers, high performance can only be obtained when its signal-to-noise ratio (SNR) and spurious-free dynamic range (SFDR) are very high.

The component most important for achieving this is the analog-to-digital converter (ADC) because, as the first processing component after signal capture, it defines the performance that the entire receiver can achieve.

Unfortunately, an ADC introduces quantization, offset, gain, linearity, and timing errors that create spurious signals in its output. If the strength of these signals is high enough it becomes difficult and sometimes impossible to separate the signals of interest from the noise.

Techniques such as clock dithering, calibration, and commutating the ADC at lower rates have been used to mitigate the issues in the ADC, but none are very effective and have significant drawbacks that often cause as many problems as they attempt to solve, while requiring considerable compute power as well.

What is required is an approach that dramatically improves digital receiver performance without compromise, and without a complex learning curve, a massive investment in hardware or software, or a complete receiver redesign.

Until now, this has not been realized, but HDRR achieves this while simultaneously allowing ADCs to attain their highest ENOB and increasing overall receiver performance.

On the next pages, PRIs HDRR and Nyquist Tuning technology are described in greater detail.

PRECISION RECEIVERS

PRI's HDRR Solution

After years of research, PRI has created a much better solution for removing spurious distortion that has none of the shortcomings of other methods and is most effective when acting on signals with high dynamic range and a wide bandwidth. It also reduces the required amount of post-processing and signal analysis.

HDRR reduces the magnitude of spurious signals over an extremely wide bandwidth--nearly the entire Fs/2 and all Nyquist zones.

HDRR also reduces the magnitude of all spurious responses across the IF bandwidth and throughout the entire RF input bandwidth.

The result significantly increase the system's SFDR over the ADC's entire RF input range, especially in higher Nyquist zones where spurs plague the system.

It can be used in any RF or IF direct-sampling system regardless of its ADC and at any frequency or bandwidth of interest.

HDRR also does not require prior information about the signal or its environment, reduces anti-aliasing filter complexity, and minimizes the required amount of post-processing and signal analysis.

For example, Figure 2 is a spectrum analyzer display of the performance of a state-of-the-art direct-sampling receiver between DC and 8 GHz. The received CW signal is at 4.333 GHz. HDRR is not employed. There are many spurious responses from 20 to 30 dB above the –83 dBm receiver noise floor.

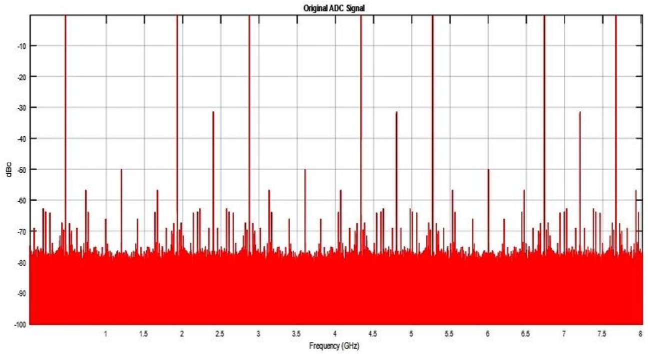


Figure 2–Without HDRR employed

Figure 3 shows the same receiver with HDRR deployed and the improvements are dramatic. Nearly all spurious signals are removed, leaving the signal of interest unobstructed.

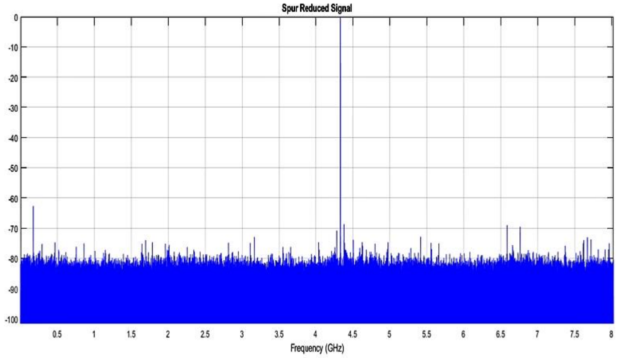


Figure 3 –With HDRR employed

PRI's 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.

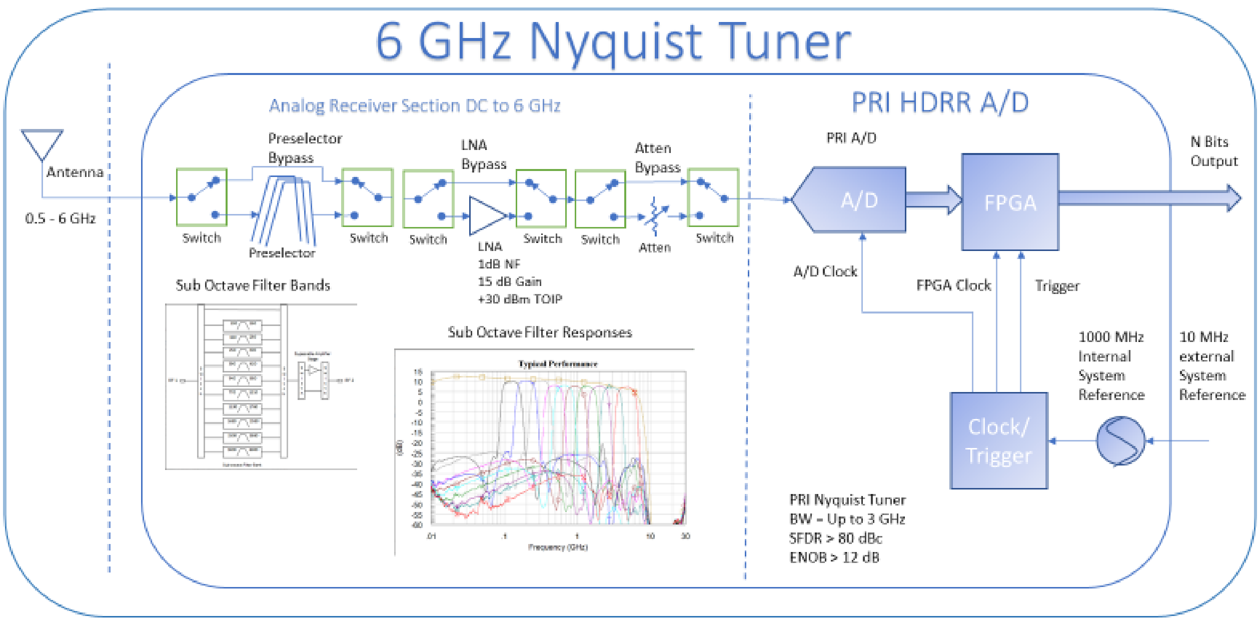
For example, some applications require looking for information within frequencies of interest while others look at the rejection of aliased frequencies folding over the Nyquist rate.

These aliased frequencies may not be completely 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 number of the Nyquist Zone is a parameter in the Nyquist Tuning calculation and is independent of the PRI acquisition process.

There is additional information available from the analog-to-digital conversion process and PRI uses that information, which is encoded in the PRI clocking method. After the PRI process is completed, the clocking information can be used to separate Nyquist information from different zones, which is helpful to keep the right frequencies in-band and reject the out-of-band frequencies.



Availability

As HDRR is tailored to the needs of each customer, PRI can work with you as well as provide a demonstration system for evaluation.

The demonstration system is 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 also 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 contract PRI directly.

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About PRI

Precision Receivers, Inc., was founded in 2019 in Virginia to develop technologies that improve direct-sampling receiver performance for both commercial, defense, medical, and scientific applications. Focusing on ADCs, Nyquist sampling, and advanced algorithms, the company has realized the ability to dramatically reduce the inherent limitations in current digital receiver designs.

The company's first product, HDRR, has solved these and other problems and can be implemented in both existing and new designs with little or no changes in hardware.

PRI continues to advance the capabilities of HDRR as it has the potential for achieving even greater performance in the future.