Utilization of Noise to Enhance the Performance of Radar Signal Processor

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Abstract—
Correlated Analog to Digital Converter (ADC) quantization noise can reduce the performance of radar signal processor by generation of spectral harmonics. Addition of noise to the analog signal prior to A/D conversion can be used to randomize the ADC quantization noise. This paper presents the simulated results of addition of white noise to the analog signal before ADC. It will lead to generation of randomized quantized noise thus suppression of spectral components. Also, in this paper it is presented how the addition of noise can increase the dynamic range of the ADC.

Keywords:- Analog to digital Converter, Noise, Radar Signal Processor

I. Introduction:

A radar digital signal processor requires low distortion for a very wide dynamic range of signals. Unfortunately, the distortion caused by digitizing an analog signal increases as the signal amplitude decreases, and is especially severe when the signal amplitude is of the same order as the quantizing step. In radar applications low level signals frequently occurs from small targets at far ranges. These low level signals sometimes occur alone or sometimes in the presence of large signals from a neighbouring large targets. Thus, the severe distortion caused by the quantization process will deteriorate the performance of the radar digital signal processor

II. Dithering and detection of low level signals

Dither - Adding white random noise to an analog signal to be digitized. The level of this white noise should be work out with respect to the level of noise the dither is expected to smooth out.

If we feed a low-level signal of 1-LSB amplitude as input to an ADC, then the resulting digitization will yield a square wave with a duty cycle dependent on the offset of the signal about the LSB's threshold. The output sequence will be clipped. Also, the quantization noise will be of periodic nature. Such type of digitized output will lead to spectral harmonics which could be misinterpreted as targets thus degrading the radar system performance.

For high-speed ADCs, a more commonly used parameter for linearity is spurious-free dynamic range (SFDR). It's the ratio of the rms signal amplitude to the rms value of the highest spurious spectral component. Addition of random analog noise to the input signal before it is digitized will result in reduced level of undesired spectral harmonics. This reduction is because of the randomization of the quantization noise of ADC, making it to follow uniform distribution.

III. Increasing the Dynamic Range of ADC

Addition of noise can help us to detect the signals with amplitude below the least significant bit (LSB) of ADC.The signal in the case study is a 2 MHz sinusoidal signal with 2.5 V as peak-to-peak voltage, sampled at 6 MHz. The signal is modeled as digitized output of a 16 – bit ADC. The LSB of the ADC is -84.4 dBm.

Following cases were observed:-

Case – 1: Amplitude of the fundamental signal is equal to LSB (-84.4 dBm) of the ADC. The spectrum of the digitized output is shown in the figure 1. It has led to harmonics and inter-modulation frequencies.

- If the signal is mixed with white noise having amplitude equal to 2 LSB. The harmonics will be removed and we would be able to detect the single tone signal.

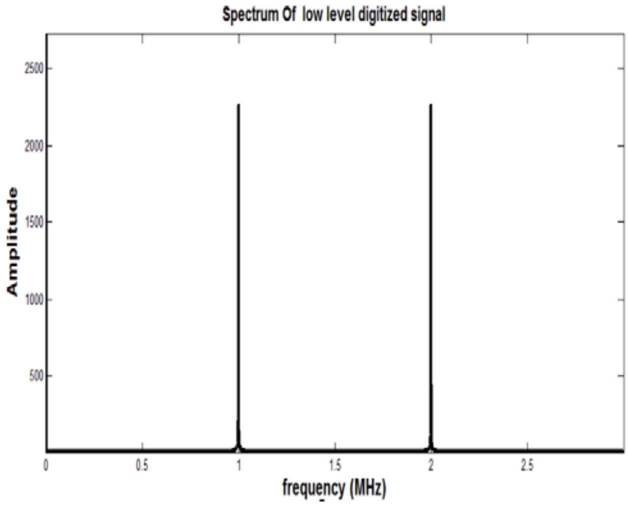

Figure 1. Spectrum of signal having amplitude equal to 1 LSB of ADC

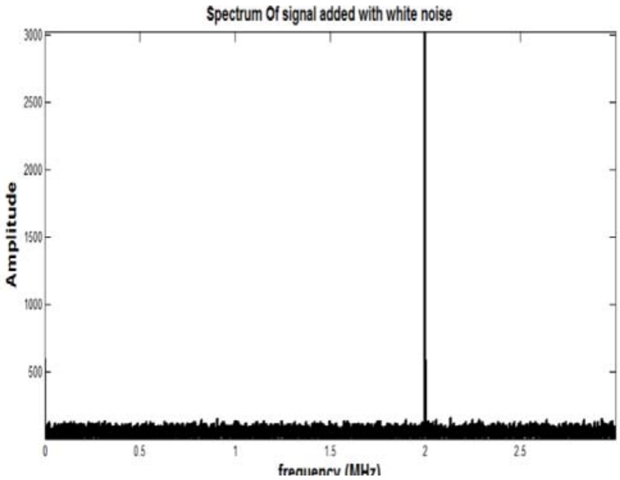

Figure 2. Spectrum of signal added with white noise.

Case – 2 : Amplitude of the fundamental signal is less than LSB (-90.4 dBm) of the ADC. The signal is not detected. The spectrum of the digitized signal is shown in the figure 3.

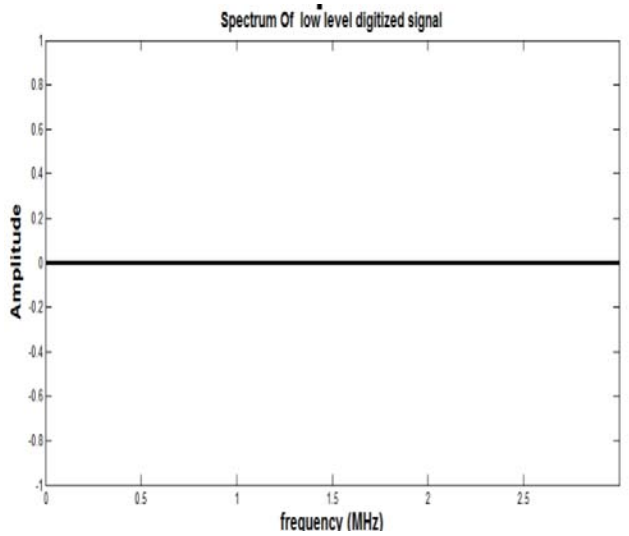

Figure 3. Spectrum of signal below LSB of ADC.

- The signal is recovered after mixing the analog signal with white random noise having amplitude equal to 1 LSB and the spectrum is shown below.

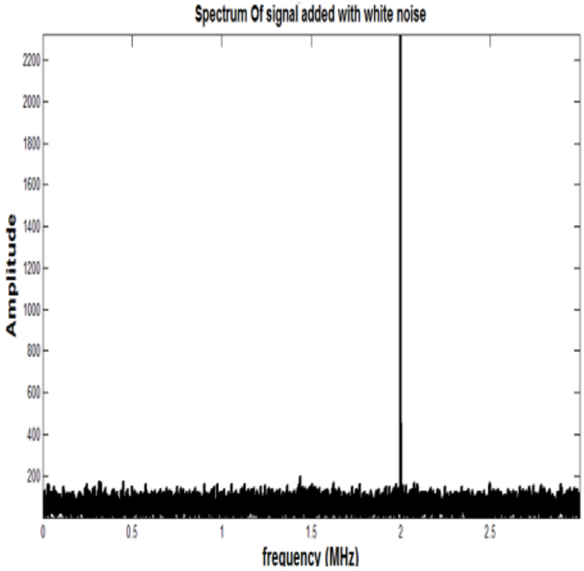

Figure4. Spectrum of signal added with random noise.

- If the amplitude of the noise is made equal to 2 LSB, the signal will be detected but with reduced SNR.

Case – 3: Amplitude of the signal is 2 bits below (- 96.4 dBm) the LSB of the ADC. This signal will be detected after the addition of noise having amplitude equal to 3 LSB of the ADC. The spectrum is shown in the fig 5.

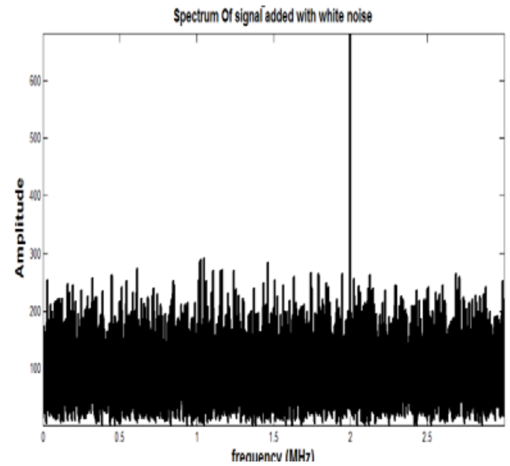

Figure 5. Spectrum of signal added with three bit noise

Case – 4: Amplitude of the signal is 2 LSB below the LSB of the ADC, but the amplitude of the noise added is 4 bits of the ADC. The signal is lost in the noise. The spectrum is shown in Fig 6. Thus, noise will be useful up to a certain limit only and after that its addition will lead to reduction in signal to noise ratio (SNR).

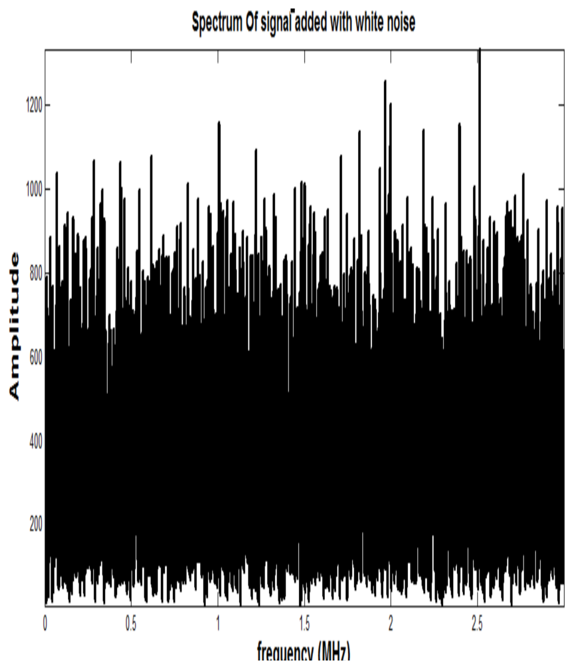

Figure 6. Spectrum of signal added with 4 bits of noise

IV. Conclusion

The dither will significantly reduce the harmonic and inter-modulationdistortion of low level signals caused by the quantization process. Also, it will help in the detection of signals with amplitude below the LSB, thus, increasing the dynamic range of radar signal processor.

V.Acknowledgement

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