VCO Based Chirp Generation for Broad Bandwidth Compressive Receiver Applications

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ABSTRACT

This paper discusses an advance in state-of-the-art broadband chirp generation for compressive receiver applications. Linear chirp of 1-GHz bandwidth and 1-µsec duration were generated with an ultralinear, millimeter wave, Gunn VCO and sawtooth waveform driver. The chirp generation circuit was developed for use as a swept local oscillator for a 500-MHz instantaneous bandwidth compressive receiver. Compressive receiver performance with this SLO approach demonstrates a >10 dB improvement in receiver noise floor relative to that obtained with a conventional impulse based SLO.

INTRODUCTION

Wide instantaneous bandwidth (500 MHz) compressive receivers have use in electronic warfare (EW) receivers as IF processing circuits that provide multiple simultaneous signal measurement capability, with high sensitivity (–90 dBm), and good frequency accuracy (1 MHz) (1, 2, 3). Multiple simultaneous signal measurement capability is essential for an EW receiver to function with a high probability of signal interception in a dense signal environment (e.g., many simultaneously transmitting radars). A critical measure of the multiple signal performance of an EW receiver is the receiver's multiple signal dynamic range (MSDR). Several factors determine the MSDR of a compressive receiver. Three of these factors are: the signal-to-noise ratio (S/N) of the compressive receiver's swept local oscillator (SLO), linearity of the SLO, and frequency slope matching of the SLO to the compressive receiver's dispersive delay line (DDL). This paper addresses only the effect of SLO performance on the MSDR of the compressive receiver, and describes the performance of a voltage controlled oscillator (VCO) based SLO approach. The VCO based SLO uses an ultralinear (<0.1%), millimeter wave Gunn VCO and a sawtooth driver circuit, and its performance is compared with a conventional impulse based SLO in a 500-MHz compressive receiver. With the VCO based SLO approach, the MSDR of the compressive receiver was improved by >10 dB.

SLO GENERATION TECHNIQUES

Current SLO generation techniques for compressive receivers can be categorized as:

- VCO based techniques
- Impulse excitation of dispersive delay lines (DDL)
- Direct digital synthesis (DDS)
- Acoustic charge transport techniques (ACT)

Only the VCO and impulse based techniques, have application to wide-bandwidth compressive receivers. The SLO requirement of a typical wide-bandwidth 500-MHz compressive receiver is a 1-GHz bandwidth, 1-µsec duration linear chirp with as close to a 1-MHz repetition frequency as possible (typically 0.95 MHz). The other techniques, DDS and ACT, do not currently possess the time-bandwidth products necessary to meet these requirements, although they have application in narrower bandwidth (<100 MHz) compressive receivers (4).

A past limitation to the use of a VCO based SLO for wide-bandwidth compressive receivers has been the unavailability of ultralinear (<0.1%), high tuning speed (>100 MHz) VCO's. Due to the short duration (1 µsec) of the required chirp, linearity compensating techniques, such as digital compensation or modulation predistortion, are not effective in providing the required linearity. However, recent progress in VCO technology has made available a new VCO that satisfies the performance requirements of a wide-bandwidth compressive receiver SLO. The new VCO has excellent linearity (<0.1%), high tuning speed (200 MHz) and broad linear bandwidth (>1 GHz) (5, 6).

A typical impulse based SLO block diagram is shown in Figure 1. Most wide-bandwidth compressive receivers use this approach. This type of circuit yields excellent chirp linearity and can provide excellent slope matching to the DDL of the compressive receiver. However, due to the expansion S/N loss inherent in the impulse excitation of the DDL used in this technique, the S/N performance of the SLO is typically only 40 dB. This limited SLO S/N limits the overall MSDR of the compressive receiver. By contrast, a VCO based SLO exhibits a S/N of >60 dB, which is 20 dB better than that of the impulse based SLO.

A breadboard model of a VCO based SLO was developed and tested, and provided validation that the linearity performance of the SLO met the requirements of the compressive receiver. The breadboard SLO circuit block diagram is shown in Figure 2. The VCO is a millimeter wave, second harmonic Gunn VCO, whose broadband linear range is downconverted into the microwave range. A summary that compares the performance capabilities of the VCO and impulse based SLO's is shown in Table 1. This table clearly indicates the superiority of the VCO based approach.

Table 1. Performance Limitations of SLO Techniques

SLO Technique	Impulse	VCO
Maximum Frequency	1,500 MHz*	>60,000 MHz
Maximum Chirp Rate	1 MHz/nsec*	100 MHz/nsec
Signal-to-Noise Ratio	~40 dB	>60 dB
% Linearity	<0.1%	<0.2%
Slope Match to Compression DDL	Fixed ~1% Error	Adjustable <1% Error

*Limited by DDL Technology, assumed to be SAW Technology

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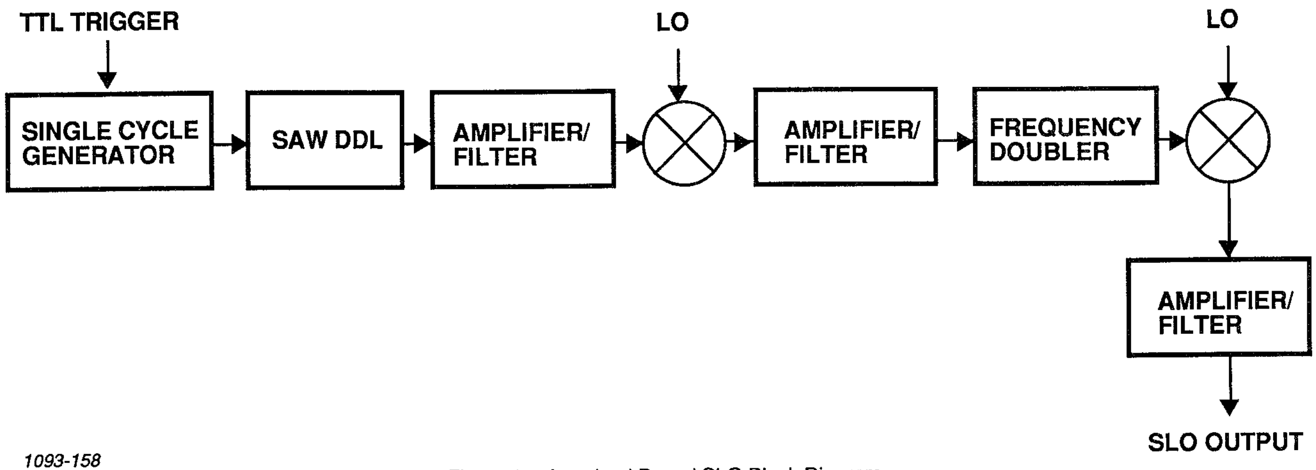


Figure 1. Impulsed Based SLO Block Diagram

COMPRESSIVE RECEIVER PERFORMANCE WITH VCO AND IMPULSE BASED SLO's

Compressive receiver performance with the VCO and impulse based SLO's was measured. The VCO based SLO exhibited equivalent linearity and a >10 dB noise floor improvement. It is probable that the actual noise floor improvement was >20 dB based on the measured S/N performance improvement of >20 dB described. However, the evaluation compressive receiver had a measurement limitation of the 10-dB level of performance improvement. This noise floor improvement translates directly to MSDR improvement. Therefore, the compressive receiver with the VCO based SLO provides a >10 dB MSDR improvement relative to the performance of the same receiver with an impulse base SLO. The measured wide-band performance of the compressive receiver is shown in Figure 3A and B, for impulse based and VCO based SLO's respectively. The 10-dB improvement in the noise floor of the compressive receiver with the VCO based SLO can clearly be seen.

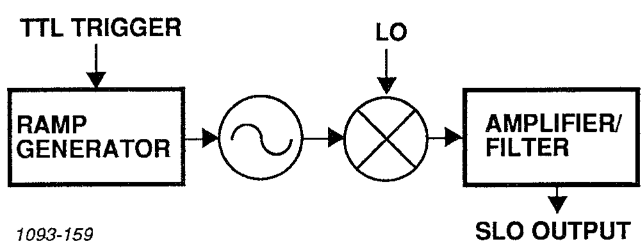
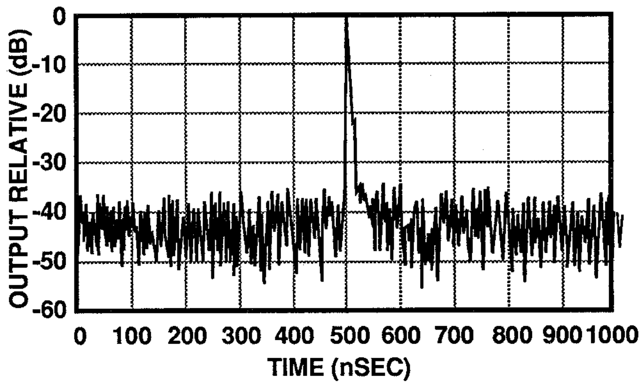


Figure 2. VCO Based SLO Block Diagram

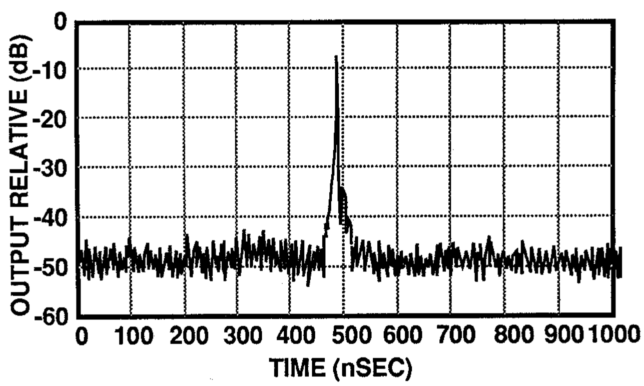
As a measure of performance, the quality of the linearity match of the SLO to the compressive receiver's DDL can be estimated by the close-in sidelobe rejection achieved in the compressive receiver output pulse. This qualitative measure is necessary because it is impossible to measure the dynamic linearity of the VCO based SLO directly, while it is simple to measure the linearity of the DDL and therefore, the linearity of the impulse based SLO. As can be seen in Figure 4A and B, the VCO based SLO has better close-in sidelobe rejection than the well-matched impulse based SLO. Therefore, there is a better linearity match between the compressive receiver's DDL and the VCO based SLO than the impulse based SLO. In summary, the VCO based SLO has improved performance over the impulse based SLO in S/N performance and linearity matching, thereby improving the MSDR of the compressive receiver.

SUMMARY

The 1-GHz bandwidth, 1-µsec duration linear chirp generation circuit that has been developed and tested will meet the needs of advanced 500-MHz instantaneous bandwidth compressive receivers and will increase the MSDR capabilities of these receivers by 10 to 20 dB. This technology is extendible to broader instantaneous bandwidth compressive receivers and is capable of generating linear chirp signals with >3 GHz bandwidths. This technology, in addition to improving the MSDR performance of broad bandwidth compressive receivers, has potential application in other areas. One area of application is in short range FMCW radar where resolution is a function of the time-bandwidth product and the linearity of the chirp wave form (7). Another potential application is in millimeter wave pulse compression radar. Since the VCO used in the described SLO is a millimeter wave VCO (60 GHz), its output can be directly transmitted, producing a millimeter wave chirped signal with good linearity, a large time-bandwidth product, and moderate power (15 dBm). This new technology provides a low cost potential for millimeter wave FMCW or pulse compression radars.

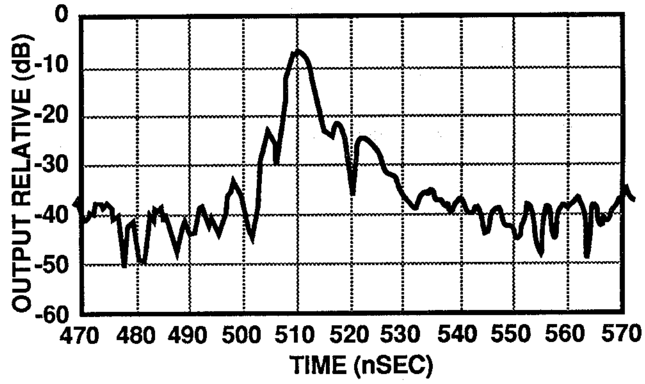


A. WITH IMPULSE BASED SLO

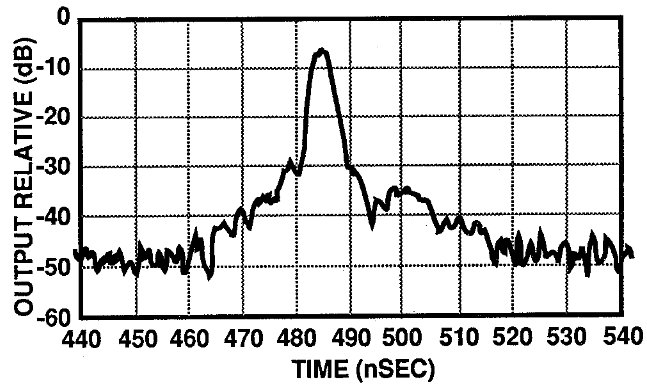


1093-160 *B. WITH VCO BASED SLO*

Figure 3. Compressive Receiver Video Output (0 – 1000 nsec)



A. WITH IMPULSE BASED SLO



1093-161 *B. WITH VCO BASED SLO*

Figure 4. Compressive Receiver Video Output (440 – 540 nsec)

ACKNOWLEDGMENTS

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