A SOLID STATE, X-BAND, EXCITER/LOCAL OSCILLATOR/ DOWN CONVERTER SUBSYSTEM FOR AN AIRBORNE, COHERENT RADAR FIRE CONTROL SYSTEM.

Jim B. Vuong*, Geoffrey Keogh,** Asad M. Madni*, Dr. Lawrence A. Wan*

*Systron Donner Corporation, Microwave Division
Van Nuys, California

**Emerson Electric Company, Electronics and Space Division
St. Louis, Missouri.

Summary

A "state-of-the-art", low cost, lightweight Exciter/Local Oscillator/Down Converter (EX/LO/DC) subsystem is presented for use in airborne applications. It plays a triple role of providing TWT excitation, local oscillator drive and dual channel RF-IF conversion. The overall subsystem design together with experimental results is presented.

Introduction

This paper presents the design techniques used in developing a "state-of-the-art" Exciter/Local Oscillator/Down Converter (EX/LO/DC) subsytem by Systron Donner Corporation, Microwave Division for Emerson Electric's (Electronics and Space Division) AN/APG-69(V) Coherent Radar. A variety of scan patterns are available from wide angle multibar search to dedicated tracking of a single target. Two basic signal processing modes are used: (1) a non-coherent frequency agile mode for surface vessels and clutter-free airborne targets, (2) a fully coherent pulse doppler mode for airborne targets in the presence of clutter.

The EX/LO/DC plays a triple role of providing TWT excitation, local oscillator drive and dual channel RF-IF frequency down conversion. While operating in a coherent mode, the TWT and LO drive are synthesized from a common crystal oscillator. Four operating frequencies can be selected by an appropriate command from the radar processor. When opoerating in a non-coherent frequency agile mode, the TWT and LO can be slewed up to a maximum rate of 15 MHZ/msec to provide independent clutter and/or target samples on a pulse-to-pulse basis. In both the coherent and frequency agile modes, the TWT and LO drive signals are derived from a common source oscillator to assure LO and TWT drive frequency tracking. The EX/LO/DC also provides the front end RF to IF signal conditioning required for proper radar operation. This includes RF amplification and noise figure establishment, RF to IF down conversion, image frequency rejection. channel-to-channel phase balancing and automatic gain control.

Figure 1 shows the overall block diagram of the EX/LO/DC. The subsystem consists of two main sections: the Exciter/Local Oscillator which is the signal source and the Downconverter which is the receiver.

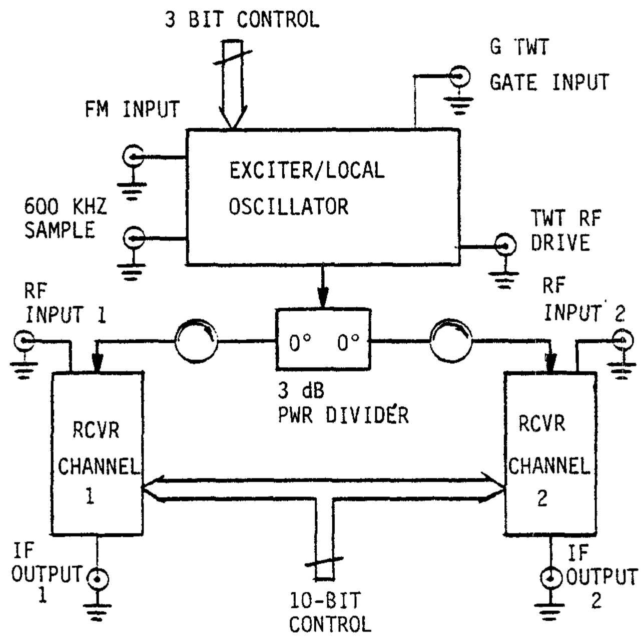

Fig 1 Exciter/Down Converter Block Diagram

Exciter/Local Oscillator

The Exciter/Local Oscillator section is divided into two modules: the Exciter which is the transmitter signal source (TWT drive) for the radar system and Local Oscillator which is the LO source for the downconverter section. Both these sources are coherent in phase with low phase noise and high frewquency stability and are separated by 60 MHZ. The four exciter output frequencies are 9.15, 9.25, 9.35 and 9.45 GHZ with corresponding local oscillator frequencies of 9.09, 9.19, 9.29 and 9.39 GHZ.

In order to meet the above mentioned requirements, the TWT drive and the LO signal are both generated from a common crystal oscillator source. (see Figure 2).

A 600 KHZ crystal oscillator output is multiplied by 5 and by 6 in the IF OFFSET GENERATOR to produce a 3 MHZ and 3.6 MHZ signal respectively.

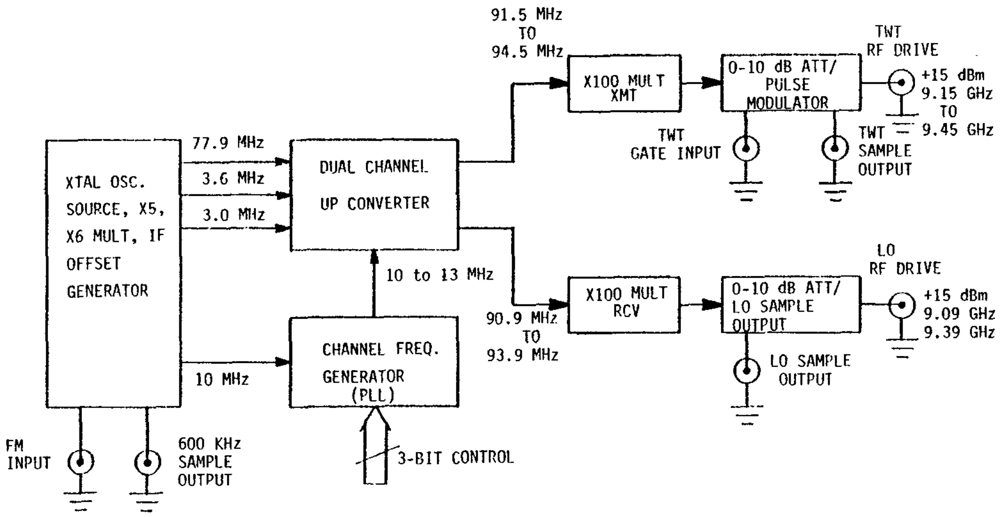

Fig 2 Exciter/Local Oscillator Section Block Diagram

These two signals are then mixed with the 77.9 MHZ crystal oscillator output and upconverted to generate an 80.9 MHZ and 81.5 MHZ signal respectively, in the dual channel up converter module. At the same time a phase lock loop (PLL) channel frequency generator with a 10 MHZ crystal oscillator as a reference generates 10, 11, 12 and 13 MHZ frequencies which are selected by a 2-bit digital code. The PLL is used to achieve FM modulation at the output by modulating the 10 MHZ reference.

The 80.9 MHZ and 81.5 MHz RF signals are mixed with the PLL output of 10, 11, 12 and 13 MHZ, upconverted and multiplied by 100 to generate the 9.09, 9.19, 9.29 and 9.39 GHZ signals for the LO drive and 9.15, 9.25, 9.35 and 9.45 GHZ signals for the TWT drive. By using this approach the phase noise at both outputs are theoretically 40 dB higher than that of the crystal oscillators. The electrical and mechanical specifications laid on the X100 multiplier were one of the most difficult aspects of the design (1). The inputs to the X100 multipliers are at + 20 dBm level, and have phase noise spectral densities, as measured in a 1 HZ bandwidth, as listed in Table 1.

DEVIATION FROM CARRIER	PHASE NOISE
100 Hz	-110 dBc
1 KHz	-135 dBc
10 KHz	-150 dBc
100 KHz	-150 dBc
1 MHz	-160 dBc

TABLE I

Phase Noise Spectral Densities of Synthesizer Outputs

The harmonic content of the synthesizer output is -70 dBc in band, and -55 dBc out-of-band. To meet system specification, the X100 multiplier was required to have an output phase noise spectrum, in a 1 HZ bandwidth as listed in Table II.

DEVIATION FROM CARRIER	PHASE NOISE
100 HZ	-64 dBc
1 KHz	-92 dBc
10 KHz	-106 dBc
100 KHz	-106 dBc
1 MHz	-116 dBc

TABLE II

Phase Noise Spectral Density of X100 Multiplier

Reference (1) treats the X100 Multiplier design in detail.

Down Converter

The down converter section which is a dual channel receiver (see Figure 3) includes two identical modules.

At the receiver RF input, a waveguide isolator is followed by a low noise amplifier (LNA) with a 3.0 dB noise figure. Within the LNA are three electronic RF attenuators with values of 20, 10 and 10 dB. These attenuation values are selected via a 3-bit digital control. The RF signals are downconverted to a 60 MHZ IF using the LO drive from the exciter section as a local oscillator. Both IF signals are fed into a phase switching network in order to provide the ability of having the signals in phase or 90 degrees out of phase. Additionally, a quadrature hybrid under digital control provides the sum and difference capability for each IF channel. A programmable attenuator at the output of each channel allows 0 to to 30 db of attenuation in 2 dB steps for amplitude tracking with $\pm$ 1 dB accuracy.

Figure 4 shows the production protoype of the EX/LO/DC.

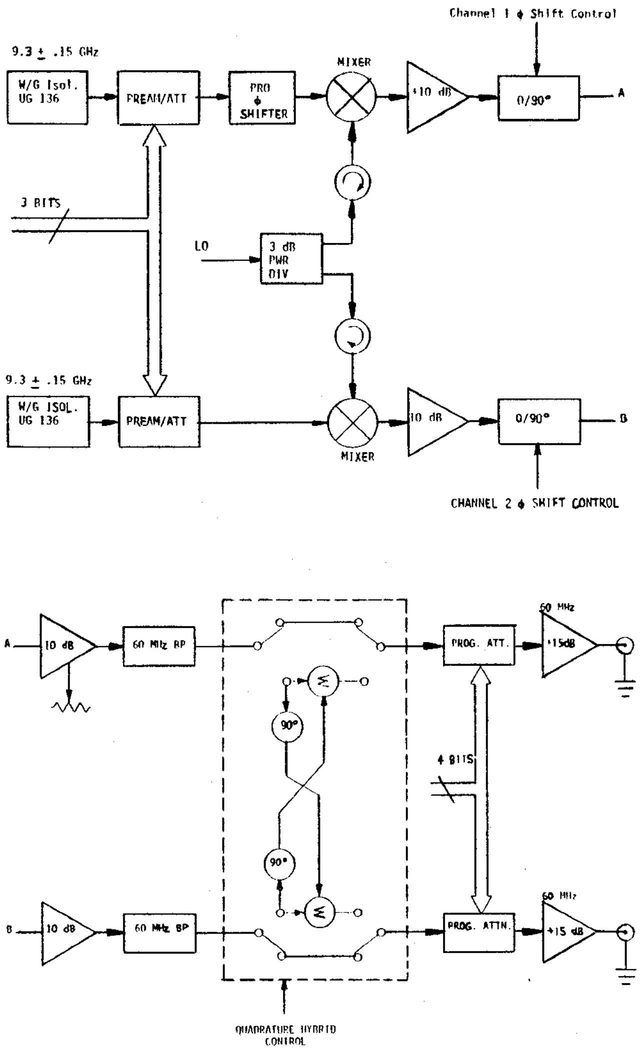

Fig 3 Receiver/Down Converter Section

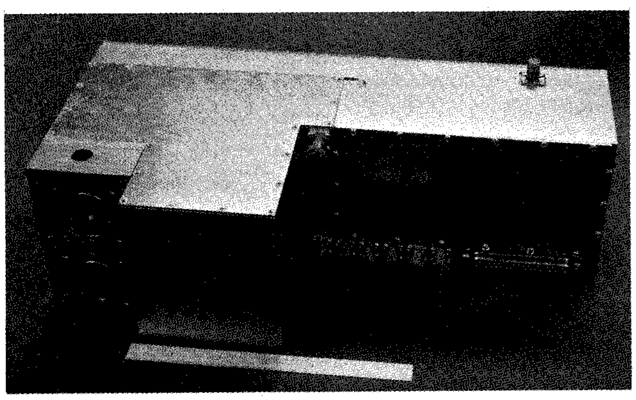

Fig 4 Production Prototype of the EX/LO/DC

Test Results

Table 3 summarizes the measured performance of the X-band EX/LO/DC.

PARAMETER	MEASURED PERFORMANCE	
Operating Frequency	9.15 to 9.45 GHZ	
Receiver		
Noise Figure	4.1 dB	
Image Rejection	20 dB	
Instantaneous dynamic range	52 dB	
Phase Tracking	±35°	
Amplitude Tracking	± 3 dB	
Exciter		
Power Output	+ 15 dBm	
Pulsed ON-OFF Ratio	50 dBm	
Single Sideband Noise (1 HZ bandwidth)	FREQ OFFSET	DBC
	100 HZ	-64
	1 KHZ	-92
	10 KHZ	-106
	1 MHZ	-115
Spurious	-70 dBc in band	
	-55 dBc out of band	

TABLE 3

Measured Perforamnce of the X-band EX/LO/DC

For coherent doppler processing the spectrum of the transmitt pulse must have low phase noise particularly close in to the carrier. The cleanliness of the signal is apparent from the photograph of the exciter output spectrum in the CW mode which appears in Figure 5.

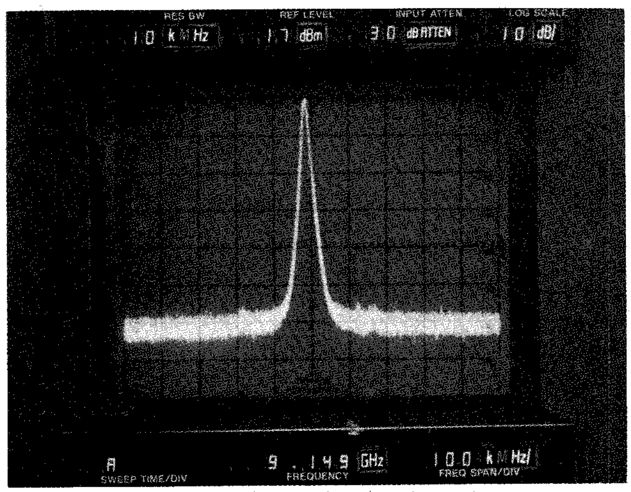

Fig 5 Exciter Output Spectrum

The noise floor for frequency offsets greater than 10 KHZ is set by the phase locked loop noise and the total multiplication factor to the final frequency. Since the close in noise <10 KHZ is determined by the crystal oscillator performance, these were optimized for best short term stability.

References

(1) H. Endler, "A Wideband X100 Low Noise Microwave Frequency Multiplier," 1984 IEEE Aerospace Applications Confrerence Digest, pp. 107-116.