A LOW NOISE FREQUENCY AGILE X-BAND SOURCE

Z. Galani
M. Bianchini
R. DiBiase

Raytheon Company
Missile Systems Division
Bedford, Massachusetts 01730

ABSTRACT

A low noise frequency agile X-band source designed for a missile seeker Master Oscillator is presented. The source consists of a push-push X-band VCO phase-locked to a single crystal oscillator using a sampling phase detector. The performance of the source is presented under static conditions and the severe missile vibration environment.

INTRODUCTION

The development of a new missile seeker created the need for a frequency agile X-band source with low noise performance capability under severe missile flight conditions. Other requirements included three-frequency operation, equal frequency spacing (Δf), 0.5 msec frequency switching time, very low spurious levels, small volume and digital frequency selection.

A simplified block diagram of the selected design approach is shown in Figure 1. The unique characteristic of this design is the absence of varactor diode frequency multipliers. The reference signal is generated by a temperature-compensated crystal oscillator at frequency $\Delta f/2$ (half the X-band frequency spacing). The output of this oscillator is amplified and drives the reference port of the sampling phase detector (SPD). The RF port of the SPD is driven by a C-band signal (half of the output frequency) coupled out of the C-band port of the VCO. The VCO is a push-push oscillator generating a low noise X-band signal by coupling two C-band oscillators in such a manner that at the X-band output the second harmonic frequency is enhanced and the fundamental is suppressed. The SPD is a sample and hold circuit which samples the RF signal at the reference period. Phase coherence is achieved at any C-band frequency which is an integral multiple of the reference frequency thus resulting in output frequency agility. The phase-lock loop is then closed through a video amplifier followed by a shaping filter.

Frequency switching is initiated by enabling the latch with a strobe signal and passing the new frequency code from its input to the multiplexer. The multiplexer selects one of the three preset voltages and applies it to the coarse tuning port of the VCO causing it to slew within the capture range about the selected harmonic of the reference.

A search oscillator extends the effective capture range of the phase-lock loop by sweeping the VCO over a prescribed frequency range when the loop is detected to be out of lock. The oscillator is disabled automatically when the loop becomes locked.

The frequency drift of the VCO is controlled by heating it with both pre-flight and in-flight heaters in conjunction with thermostatically activated switches. Finally, the crystal oscillator, sampling phase detector, and the entire X-band source module include resilient mounts to reduce sensitivity to the high vibration levels present during flight. Photographs of the Frequency Agile Source are shown in Figures 2 and 3.

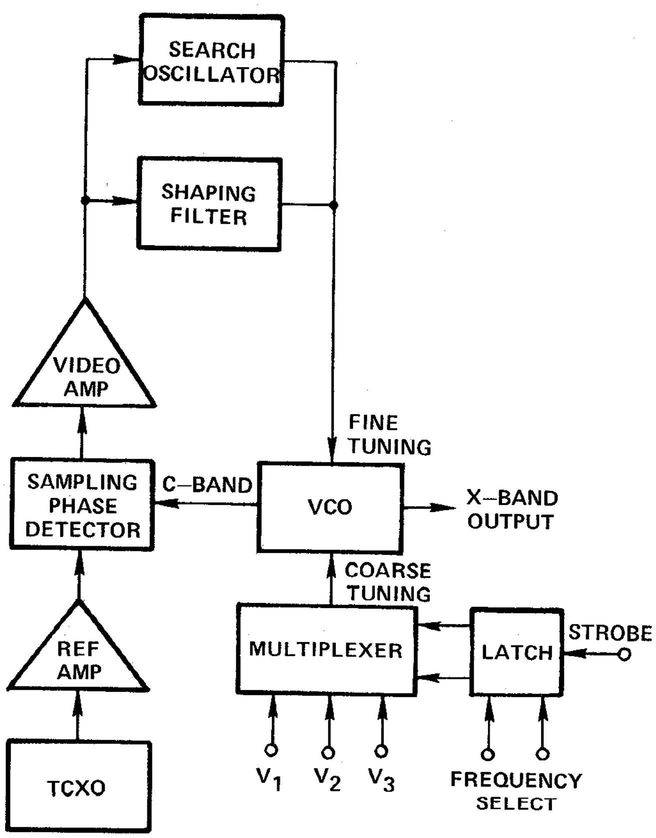

Figure 1 - X-Band Source Block Diagram

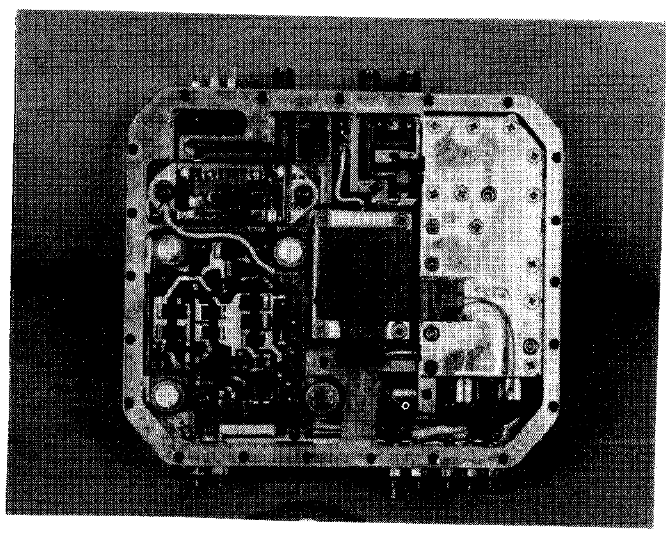

Figure 2 - Frequency Agile Source - VCO Side

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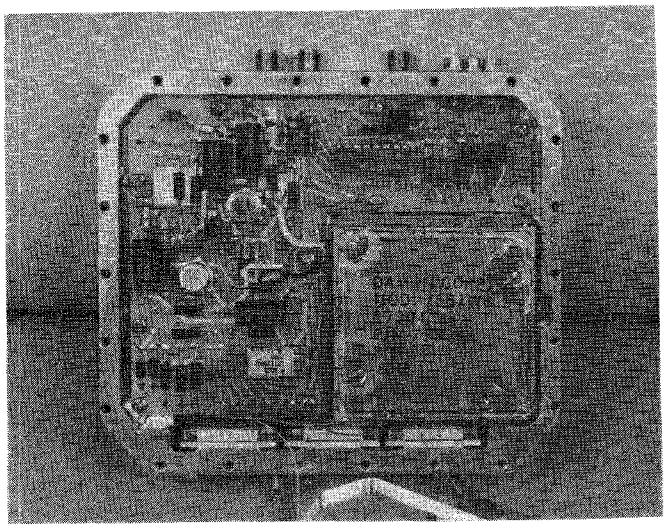

Figure 3 - Frequency Agile Source - PLL Side

DESCRIPTION OF KEY COMPONENTS

The VCO circuit, designed to provide approximately 125mW of X-band output power, couples two C-band oscillators in a distributed realization of a bridged-tee coupling network incorporating a pair of tuning diodes. In this configuration both terminals of the tuning diodes are available for frequency control and are used for coarse and fine tuning. A fundamental C-band signal is loop coupled at the plane of symmetry of the circuit and is passed through a C-band isolator to provide phase detector drive. A three-resomater bandpass filter is used to suppress spurious outputs at the X-band port.

The circuit diagram of the SPD is shown in Figure 4. The impulse generator, driven at the reference frequency, generates 300 psec pulses which are fed to a balun transformer via an attenuator. The outputs of the balun are two pulse trains of opposite polarity which drive the normally reverse biased phase detector diodes into conduction. The phase detector diodes are also driven (in phase) by the C-band signal coupled through a broadband power divider formed by a tee junction and 100 ohm microstrip lines with an electrical length of 50 psec. During forward conduction of the diodes, the sampling capacitor, located at the common junction of the diodes, charges toward the level of the C-band signal. The voltage across this capacitor constitutes the output of the phase detector. The sampling time is controlled by the electrical length of the 100 ohm microstrip lines and the amount of reverse bias. If the C-band frequency is an integral multiple of the reference frequency, the voltage across the sampling capacitor is the same at every sampling instant resulting in a DC output voltage which is a function of the relative C-band phase at the sampling instant. Any deviation from integral multiplicity results in a time varying output with frequency that is the difference between the C-band frequency and the nearest integral multiple of the reference frequency.

The loop design is based on a total X-band hold range of 36 MHz and a loop bandwidth of 500 KHz for VCO noise degeneration.

The search technique is implemented by connecting a Wein Bridge oscillator across the loop filter. This oscillator uses an RC network to provide positive feedback around an operational amplifier. The phase-lock loop is in parallel with this feedback network and, within

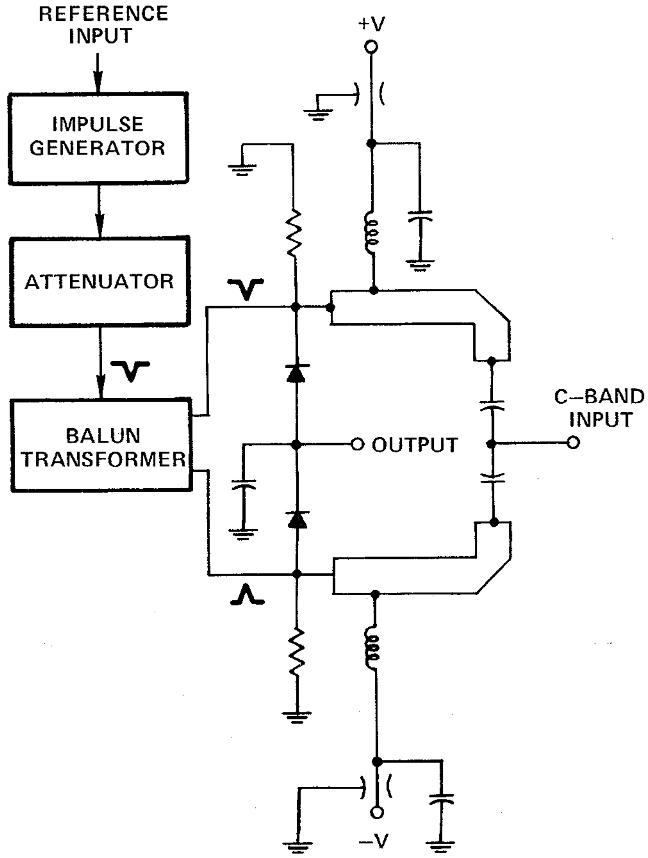

Figure 4 - Sampling Phase Detector Block Diagram

the loop capture range, generates negative feedback that disables the sweep oscillator. The oscillator remains disabled as long as the loop remains locked.

The Frequency Agile Source is packaged in a volume of 25 cubic inches.

EXPERIMENTAL RESULTS

A total hold range of 30 to 40 MHz was measured at the three X-band frequencies, the spread being attributed to variation in VCO tuning sensitivity. A typical FM noise performance is shown in Figures 5 and 6, measured statically and under vibration input levels of 13.9 Grms from 10 to 3000 Hz.

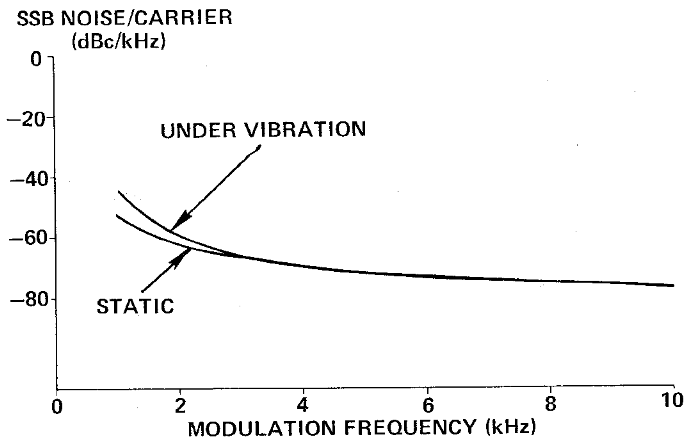

Figure 5 - FM Noise Data

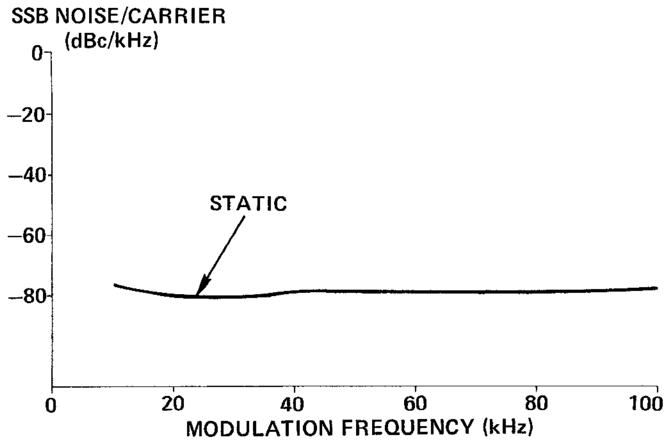

Figure 6 - FM Noise Data

The AM noise level was typically -135 dBc/KHz. Spurious levels of -77 dBc were measured within ±500 MHz of the carrier and the typical frequency switching time was 250 μsec.

CONCLUSIONS

A novel approach to the design of a low noise frequency agile X-band source has been presented. Although the source discussed was designed to operate at three equally spaced X-band frequencies, the concept could be utilized in the synthesis of an arbitrary number of equally spaced microwave signals.