AN 18-40 GHz PHASE LOCKED DOWNCONVERTER SUBSYSTEM

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ABSTRACT

A high performance frequency conversion module (FCM) has been developed for ground based EW system applications. The FCM unit is built using integrated finline and hybrid MIC techniques to achieve a low noise high performance millimetre-wave front-end without the use of a mm-wave LNA.

The FCM unit chanellizes the 18 to 40 GHz into three bands and downconverts each band to a common 8-18 GHz IF. The FCM design includes a novel wideband mm-wave limiter and mm-wave L.O. for each of the bands. A noise figure of <13 dB was achieved in all three bands with a 50 dB dynamic range.

INTRODUCTION

In the past most millimetre-wave (mm-wave) wideband downconverters consisted of a front-end filter followed by a mixer and an IF LNA. The local oscillator was usually a GUNN diode oscillator or a free-running DRO multiplied to the L.O. frequency.

In recent years the use of the mm-wave region (18-40 GHz) has grown such that the parameters like frequency accuracy and stability have become important factors in mm-wave front ends. The high power of mm-wave emitters also demands power limiters for the protection of receivers.

The FCM was built using newly developed mm-wave high power limiters and mm-wave phase locked local oscillators. The subsystem achieves high power handling capabilities, excellent frequency stability and low phase noise characteristics.

SUBSYSTEM CONFIGURATION

A block diagram of the 18-40 GHz front end is shown in Figure 1.0. The subsystem can use a single mm-wave feed thus enabling the use of a coaxial rotary joint to feed a spinning antenna. The 18-40 GHz band is then multiplexed into three bands such that the downconverter can feed an existing 8-18 GHz receiver.

The band selection is achieved using a single pole four throw switch. The SP4T switch is capable of withstanding an input signal power of 2 W CW without degradation. The L.O. assembly is built in its entirety using MIC techniques. The FCM developments included wideband finline limiters and mixers, phase locked DROs at 17.5 GHz and 24 GHz, varactor and FET MIC doublers, harmonic mixers and a high power switch.

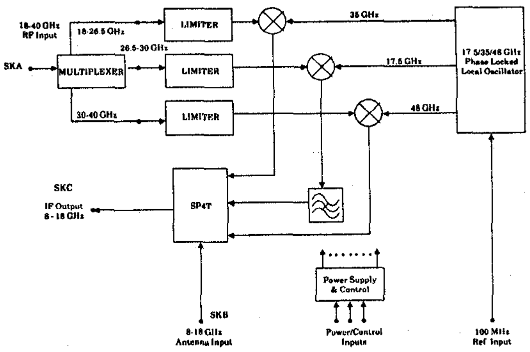

Figure 1.0: FCM Block Diagram

LIMITERS

The limiters were built in finline using beam-lead pin diodes. The beam leads exhibit very low junction capacitance and low turn-on resistance at zero bias thus enabling low loss and high isolation. To achieve turn on at 20 dBm the diodes had to be pre-biased to 0.4 V. This allows a maximum leakage of 22 dBm into the mixers at an input power level of 30 to 33 dBm. The typical limiter resonse for a CW and pulsed power signals is shown in Figure 2.0 and Figure 3.0 respectively.

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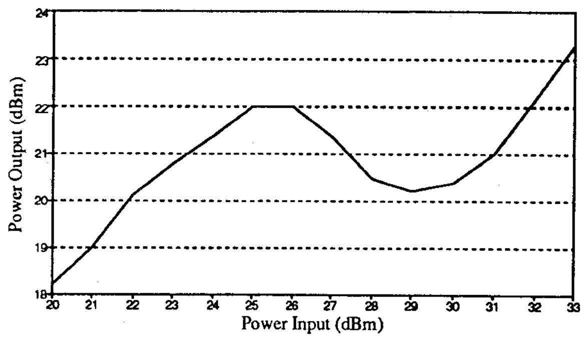

Figure 2.0: Limiter CW Response

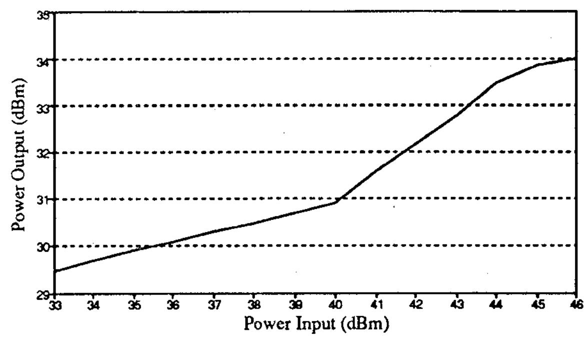

Figure 3.0: Limiter Pulsed Response

MIXER

The mixer was built in finline to achieve low conversion loss across a wide band. A single balanced configuration using the high side L.O. achieves excellent harmonic and spurious response. The circuit consists of a finline taper, (designed to match the input, RF diode impedance) to a pair of beam lead mixer diodes, a co-planar IF matching network and a suspended substrate IF filter. The L.O. is injected and phase matched to the diodes using a suspended substrate transition. Typical conversion loss for the mixer is shown in Figure 4.0.

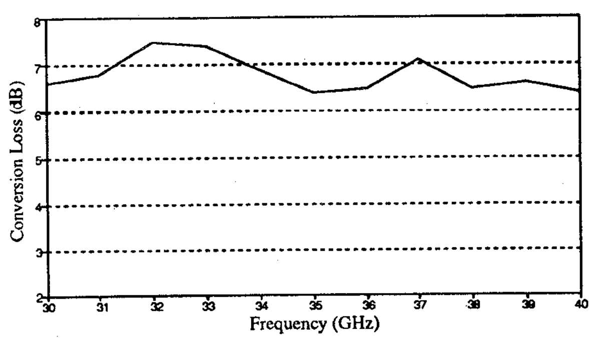

Figure 4.0: Mixer Performance

IF SWITCH

The switch uses a typical series-shunt configuration. The first element is an integrated pin diode series-shunt chip followed by two more shunt diodes (Figure 5.0). The series-shunt chip features GaAs pin diodes integrated on alumina.

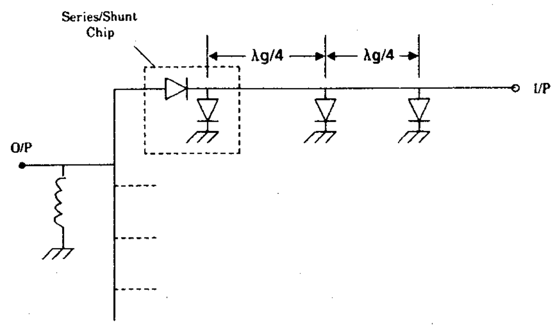

Figure 5.0: Pin Switch Schematic

The pin switch was built in 5 mil duroid microstrip (Er = 2.2). The Switch achieved an insertion loss of <2.5 dB and >70 dB isolation in the 8-18 GHz frequency band.

MM-WAVE L.O. ASSEMBLY

Figure 6.0 shows the L.O. block diagram.

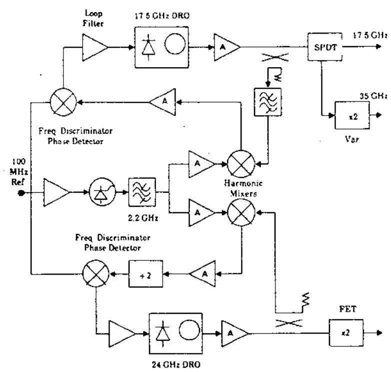

Figure 6.0: Local Oscillator Block Diagram

The phase lock L.O. development included varactor tuned DROs at 17.5 GHz and 24 GHz, varactor multiplier, FET multiplier to 48 GHz and MIC harmonic mixers. The integrated L.O. assembly provides 8 dBm min. power output at 17.5, 35 and 48 GHz. The integrated module of the 48 GHz L.O. is shown in Figure 7.0. It includes the DRO, buffer amplifiers, microstrip coupler, the FET doubler and the harmonic mixer.

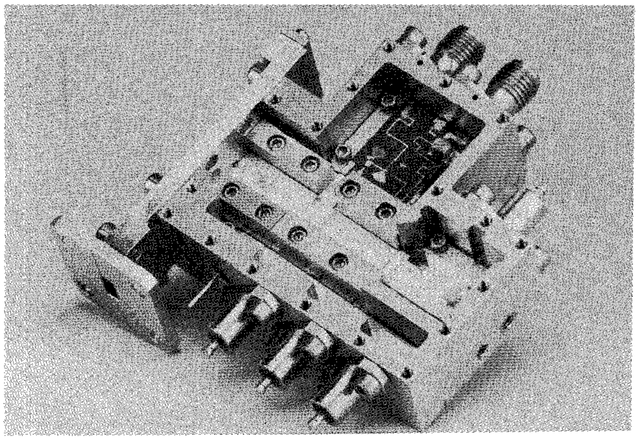

Figure 7.0: 48 GHz LO Assembly

17.5/24 GHz DRO Design

The oscillator circuits use series feedback in the common source configuration, Figure 8.0.

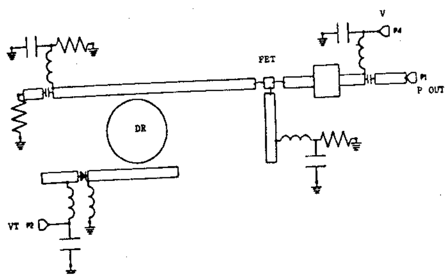

Figure 8.0: DRO Configuration

The oscillator is stabilized by the TE_{01} -mode dielectric resonator which is coupled to the gate microstrip line. The dielectric resonator was chosen experimentally to optimize the temperature drift of the oscillation. The temperature coefficient used for both the 17.5 GHz and 24 GHz DROs was +9 ppm/°C. The DR is also magnetically coupled to a varactor tuned microstrip line resonator. The varactor is placed between a (3/4) g open stub and a g/4 open stub to form a one wavelength resonator at the frequency of operation. The resonant frequency of this configuration varies according to the varactor voltage. The performance of the 17.5 GHz and 24 GHz voltage tuned DROs are shown in Figure 9 and Figure 10 respectively. The 17.5 GHz varactor tuning range can vary between 16 to 25 MHz over temperature. The 24 GHz varactor tuning ranges from 12 to 18 MHz over temperature.

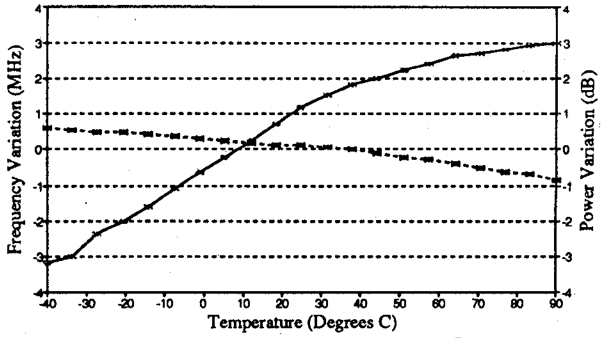

Figure 9.0: 17.5 GHz DRO Performance

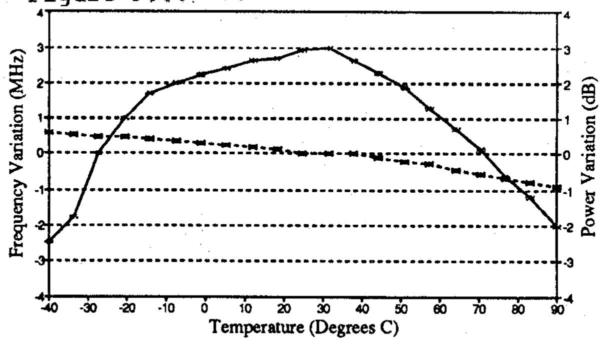

Figure 10.0: 24 GHz DRO Performance

Multipliers

The 17.5 to 35 GHz multiplier is built using a COM DEV GaAs varactor diode in a series configuration. The 24 to 48 GHz doubler uses a FET in the shunt configuration. Both multipliers consist of input and output matching circuits with rejection filters phased at the input and output to provide efficient rejection of unwanted harmonics. The multipliers are built on planar circuits making them easily integrable into the microstrip assembly.

The doublers achieve a 10 dB maximum conversion loss at the desired frequency with a minimum of 15 dB input match.

Harmonic Mixer

The harmonic mixer schematic is shown in **Figure 11.0.**

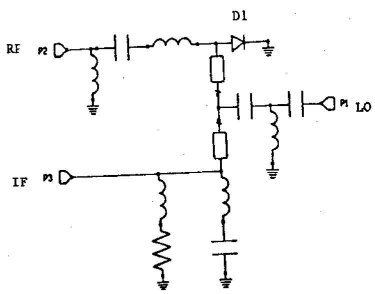

Figure 11.0: Harmonic Mixer

The harmonic mixer was built in microstrip on 10 mil (Er=2.2) duroid substrate. The mixer conversion loss for both 17.5 GHz and 24 GHz using a 2.2 GHz L.O. drive of 18 dBm ranges from 25 to 35 dB for RF inputs of 4 to -4 dBm.

System Performance

Figure 12.0 illustrates the integrated mm-wave front-end. The system performance is listed in Table 1.0.

Table 1.0: MM-wave Downcoverter Performance Summary

PARAMETER	PERFORMANCE
Frequency RF (GHz) IF (GHz)	18-40 8-18
Noise Figure (dB)	17 max. 13 dB typ
Crossover Loss (dB)	5 max.
1 dB Compression Point (dBm)	-10 min.
Spurious and Harmonic Levels @ -20 dBm signal input	-80 dBm
L.O. Frequency Error (kHz)	± 20
L.O. Noise (dBc/Hz)	-80 @ 10 kHz -90 @ 100 KHz
Reference Input (MHz)	100 ± 50 Hz
Power Handling @ SKA @ SKB	1 W CW 50 W 1μs pulse .001 duty 2 W CW 100 W 1μs pulse .001 duty
L.O. Leakage @ SKA (dBm) @ SKB (dBm) @ SKC (dBm)	-50 -70 -25
D.C. Supply Limits	+ 15V @ 1.0A max. -15V @ 0.2 A max. + 5V @ 0.25 A max.
Operating Temperature	-35°C to 85°C

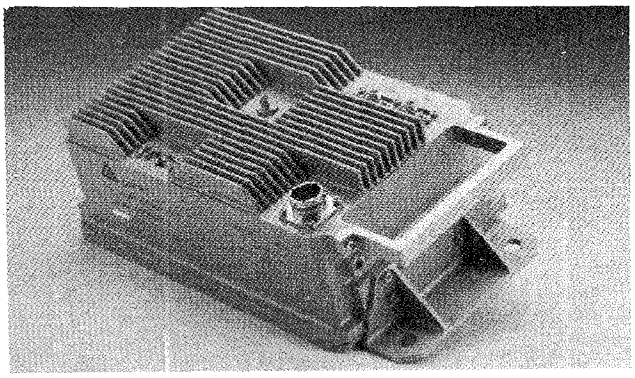

Figure 12.0: MM-wave Downconverter

CONCLUSIONS

A high performance mm-wave downconverter has been developed. The system contains mm-wave phase locked sources which have been developed using standard MIC techniques. The local oscillators achieved have low power consumption and small size with excellent phase noise and stability. The system includes wideband high power limiters to protect the receiver from high power signals.

The system has achieved low noise figure (13 dB typ) with low level spurious and harmonics. The system has been ruggedized over wide range of temperature and mechanical vibration.

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