HIGH PERFORMANCE MILLIMETER-WAVE LOCAL OSCILLATOR MODULE FOR EW APPLICATIONS

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Abstract

A miniature high stability local oscillator module has been developed for EW applications. The module consists of a dielectrically stabilized FET oscillator, buffer amplifier and a planar varactor multiplier which are integrated to form a miniature planar circuit.

The module exhibits excellent phase noise, high efficiency, high frequency stability and good power stability (over temperature). The module has also been successfully tested over extremes of temperature and vibration environments encountered for military environments without degradation of the LO performance.

Introduction

Over the past many years, there has been a steady increase in the demand of millimeter wave systems for defense applications. As a consequence, a large emphasis has been placed on optimizing the performance/cost of these systems while retaining their inherent small sizes.

In the past, the receivers within these systems have traditionally employed cavity (Gunn or IMPATT) oscillators which exhibit poor stability. High stability requirements demanded phase locking or injection locked oscillators. A comparison of a DRO versus other source alternatives is shown in Table 1.

The PLL, cavity oscillators and the mulitplied crystal sources do not optimize performance/cost/complexity trade-offs for applications such as IFM based mm-wave receivers or channelized discriminator receivers used in EW systems.

The DRO stabilized source offers high performance in combination with low cost, small size and low complexity. As a result, this has led to the development described in this paper. A DRO stabilized oscillator and high efficiency doubler are combined to achieve a 40 GHz local oscillator which is small, low cost, and offers excellent performance for use in military EW systems. These may include ESM, ECM, ELINT, RWR, RDF or ARM receivers.

Local Oscillator Module Design

Basically the local oscillator is made up of a DRO stabilized FET power oscillator which is buffer amplified and used to pump a high effeciency planar varactor doubler. These planar circuits are integrated together into a miniature local oscillator module.

TABLE 1 : COMPARISON OF MM-WAVE LOCAL OSCILLATORS

PARAMETER	DRO/ MULTIPLIER	CAVITY	PLL	MULTIPLIED CRYSTAL
Stability	<5 ppm/°C	<50 ppm/°C	<.10/°C	<.10/°C
Spurious	-90 dBc	-90 dBc	-60 to -90 dBc	Filters Required
Phase Noise	excellent	poor	good - excellent	poor*
Complexity	low	low	high	high
Size	small	small	large	large
Cost	low-medium	low	high	high

* At >100 kHz Carrier Offset

DRO-Stabilized Power FET Oscillator Design

The circuit consists of a GaAs FET biased into the reverse channel mode, a dielectrically stabilized resonant network and an output matching circuit, Figure 1

The circuit is built using a medium power FET with source via-holes The GaAs FET is ideal for ampliers with the chip mounted directly on the carrier

The via holes provide very low source inductance thus enhancing high frequency performance For an oscillator application, this type of a mounting is ideal for use in the reverse channel mode

The feedback is generated internally in the FET without the need for feedback circuits

The oscillator circuit was designed using the standard oscillation criteria as given by [3], [4]. The circuit was designed to optimize the power output into a 50 ohm load Using an open circuit gate stub in conjunction with the output matching transformer, the circuit is optimized for high gain $|S21|>4$ while keeping $k<1$ (k = stability factor) and $|S11|>1$. This will insure oscillation when the resonant network, in this case the dielectric puck, is placed by the gate microstrip line

To isolate the oscillator from varying loads and increase the output power to a minimum of +23 dBm a medium power amplifier was designed, Figure 2.

The circuit is constructed using the same FET used for the oscillator. The circuit consists of wideband matching circuits tuned at the frequency of oscillation and fan biasing networks.

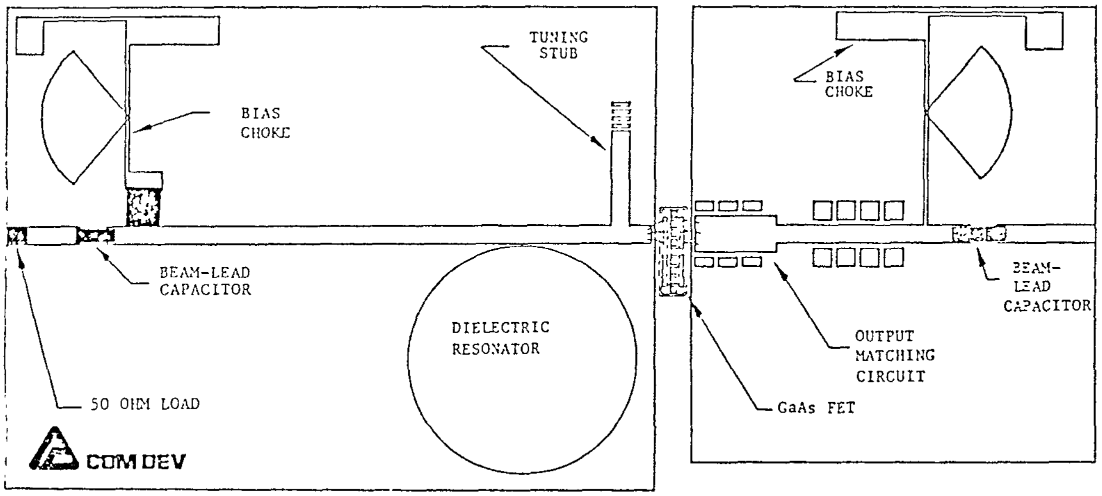

FIGURE 1: OSCILLATOR CIRCUIT

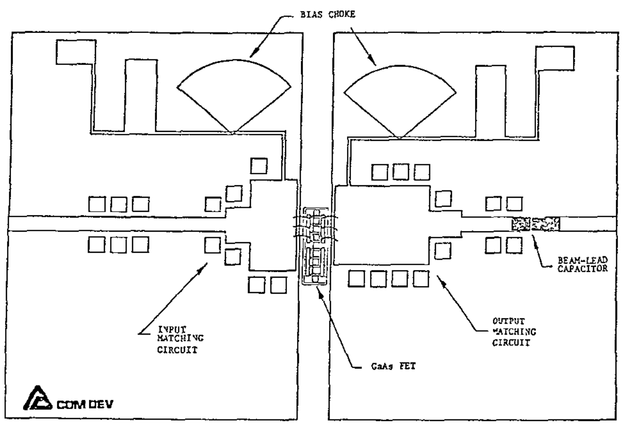

FIGURE 2: BUFFER AMPLIFIER

Planar Multiplier Design

The basic design of this type of multiplier has been outlined in an earlier paper [5]. The design consists of matching the input and output signals to the fully driven varactor (f_c>1000 GHz) and providing the appropriate rejection filters. The input and output impedances at the pump and output frequencies can be calculated using [6]. The resistive impedance matches to the diode are provided by simple quarter - wave transformers while the reactive matching is provided by properly phased rejection filters.

The input low pass filter is designed to pass the pump signal with low insertion loss and should provide greater than 25 dB of rejection at the output frequency. The output filter, a simple stub, is designed to provide 35 dB of rejection at the pump and passes the output signal with minimal insertion loss.

The circuit layout for this multiplier is shown in Figure 3. The final circuit size is typically .65 x .24 inches.

The 20 to 40 GHz doubler achieves a conversion efficiency of 32% with input powers between + 23 and + 25 dBm The input return loss is nominally better than 15 dB at 20 GHz up to a drive level of + 23 dBm. The reduced return loss performance at drive levels beyond this point may be due to the fact that the device is overdriven and does not behave as expected.

The output spectrum of the doubler showed better than 30 dB rejection of the fundamental and third harmonic.

The individually developed FET oscillator/buffer amplifier is integrated with the planar varactor multiplier in a common housing as shown in Figure 4.

The final assembly includes hybrid circuit regulation and turn-on/turn-off sequencing incorporated into the wall of the assembly. It was found that the multiplier performed well when run directly from crudely regulated switching power supply.

The output spectrum of this source is typically as shown is Figure 5

Figure 5 shows that the phase noise is approximately -90 dBc/Hz at a 50 kHz offset The nominal output power of the module is + 15dBm which is enough to drive single balanced, double balanced or dual (Rx/Tx) single balanced mixers.

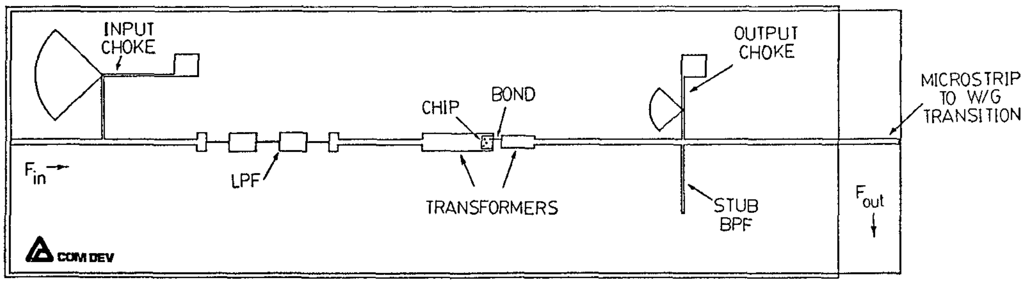

FIGURE 3: DOUBLER LAYOUT

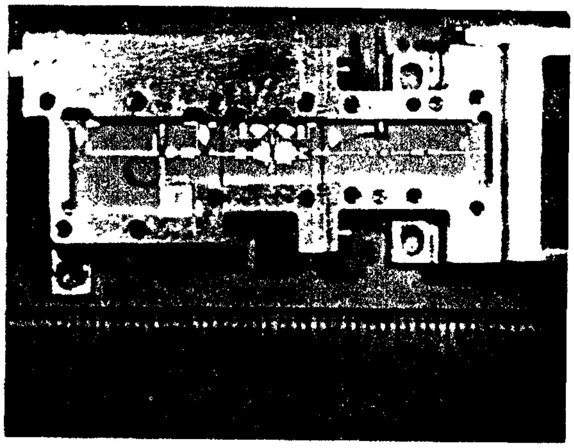

FIGURE 4:
INTEGRATED MILLIMETER-WAVE LOCAL OSCILLATOR SOURCE

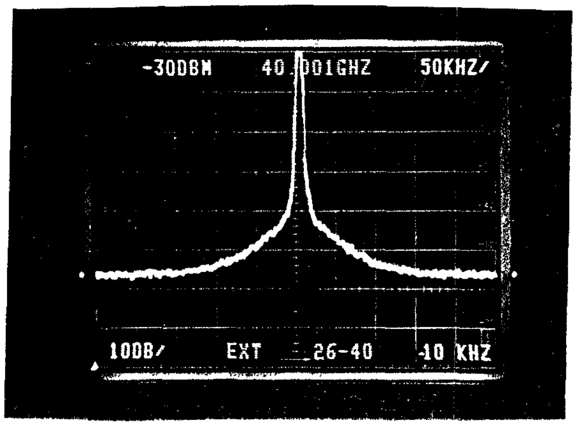

FIGURE 5:
LOCAL OSCILLATOR SOURCE OUTPUT SPECTRUM

A summary of the LO module performance is shown in Table 2.

TABLE 2 : LO MODULE PERFORMANCE SUMMARY

PARAMETER	SPECIFICATION
Operating Output Frequency, GHz	40
Output Power, dBm	+ 15
Phase Noise, dBc/Hz @ 50 kHz Offset	-90
Operating Temperature Range, °C	-55 to + 85
Frequency Stability Over Temperature, ppm/°C	2 5
Amplitude Stability Over Temperature, dB	± 1.5
Random Vibrational Survivability, G rms	66
Sine Vibrational Survivability, G	75

Conclusions

A miniature millimeter-wave local oscillator source module has been developed for application to EW systems

The module exhibits better frequency stability than other free running fundamental oscillator configurations and is considerably less complex than phase locked circuits

In addition to good phase noise and output power performance, the module has low amplitude and frequency variations over temperature and is vibrationally rugged

This technique has been applied to local oscillator frequencies as high as W-Band.

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