18-40 GHz 13 dBm LOW NOISE GaAs FET YIG TUNED OSCILLATOR

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ABSTRACT

A fundamental YIG-tuned oscillator has been developed using a submicron GaAs FET to cover 18 to 40 GHz. Power output of +13 dBm and phase noise of better than -100 dBc/Hz at 100 kHz from the carrier has been achieved. The approach used to design the oscillator circuit and the magnet for the oscillator will be discussed and test data will be presented.

INTRODUCTION

In an attempt to reduce the number of YIG-tuned oscillators required to cover the widely-used 2 to 40 GHz frequency range, an oscillator covering 18 to 40 GHz has been developed. This oscillator may be used with an existing 2 to 18 GHz source to provide full 2 to 40 GHz coverage. These oscillators are intended to be used in instruments, and as local oscillators in wideband EW systems.

Published literature on GaAs FET wideband YIG-tuned oscillators beyond 26 GHz has been very limited[1,2]. The existing commercially-available fundamental YTOs cover 18 to 26.5 and 26.5 to 40 GHz[2]. These bands were more or less dictated by the WR42 and WR28 waveguide bands. The recent availability of coaxial connectors covering dc to 40 GHz or beyond has prompted microwave designers to question the validity of this particular bandsplit point. A number of component developers have already started extending the frequency range of their components to 40 GHz and beyond.

A fundamental GaAs-FET-based YIG-tuned oscillator has been designed to cover the frequency range of 18 to 40 GHz. This new oscillator significantly reduces the need for drivers, switches and switching circuits, thus improving the reliability and decreasing the cost of the wideband system. A minimum of +12 dBm power output has been achieved over the temperature range of 0° to 65° C.

DESIGN APPROACH

The oscillator device selected is an Avantek GaAs FET with 0.2 µm gate length and 75 µm gate width, fabricated on vapor-phase epitaxial material using the hydride process. The measured gain of the device was better than 9 dB at 45 GHz. An equivalent circuit model of the device was developed based on S-parameters measured at frequencies through 26.5 GHz. The model was then used to calculate S-parameters at the frequencies of interest. The small signal CAD analysis was used to determine the required FET terminal impedances[3].

The source terminal of the FET required an inductive feedback to generate the necessary negative resistance over the wide range. Figure 1 shows the negative resistance vs. frequency of the modeled circuit.

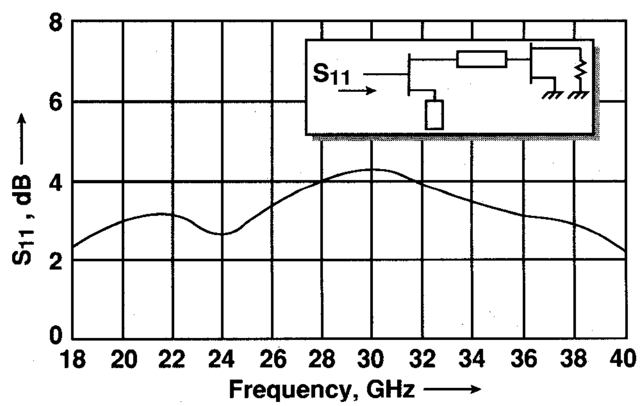

FIGURE 1. NEGATIVE RESISTANCE BANDWIDTH FOR THE GaAs FET

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An .008-inch diameter pure YIG sphere with a saturation magnetization ($4\pi M_s$) of 1780 to 1800 Oe was used as the frequency determining element in the gate circuit. The degree of the YIG sphere coupling to the active device is optimized in order to achieve the desired wide bandwidth, without generating oscillations at spurious modes. The drain matching circuit was optimized to satisfy the oscillation conditions at the gate over the entire band of 18 to 40 GHz[3]:

$$|S_{11}'|\ |\Gamma_1| \geq 1$$
$$\angle S_{11}' + \angle \Gamma_1 = 1$$

Where S_{11}' represents the modified reflection coefficient of the active device and Γ_1 the resonator reflection coefficient at that frequency (Fig. 2). The high value of the quality factor in a pure YIG resonator helps in satisfying the oscillation condition close to the center frequency of the resonator, resulting in improved frequency linearity and low phase noise for the oscillator. The oscillating device is followed by a single-ended active buffer stage on the same substrate, using a device similar to the one used as the oscillator. This device helps in providing the necessary matching circuit as well as amplification of the oscillator output signal to greater than +5 dBm over the frequency range.

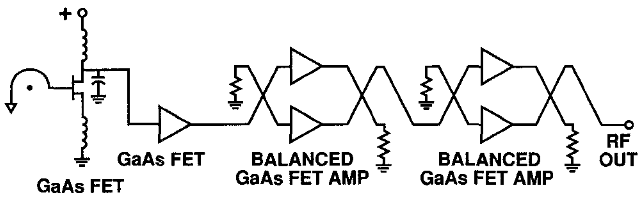

FIGURE 2. BLOCK DIAGRM FOR THE 18-40 GHz YTO

Two standard balanced amplifier stages on independent carriers follow the first substrate to increase the power output to greater than +13 dBm. The modularity of the design is aimed at providing a design that can be easily tested, since the oscillator and amplifier substrates are individually testable. The amplifier modules use GaAs FET devices similar to those used in the oscillator and buffer. These amplifiers have a small signal gain of greater than 5 dB and P_{-1dB} level of greater than +12 dBm.

The magnet structure of the YTO is based on a configuration utilizing a single pole piece[2]. The magnet is a hybrid design using two materials: standard 48% nickel-52% iron alloy for most of the magnet, and high-saturation material in the areas of highest flux density. This allows linear operation up to 50 GHz, while minimizing hysteresis. The interface between the two materials was chosen to provide temperature compensation to minimize frequency drift vs. temperature. Additionally, the use of pure YIG at these frequencies makes it possible to achieve the desired frequency drift and mode-free operation of the oscillator, without the use of a heater for the YIG sphere.

EXPERIMENTAL RESULTS

The oscillator is built with thin-film gold-on-ceramic construction. The output RF connector is a standard K connector. Figure 3 shows the spectral purity of the oscillator at 37 GHz measured with a HP8562 spectrum analyzer using the HP11974Q Q-band downconverter. At 100 kHz offset from the carrier, the phase noise across the band was typically -100 dBc/Hz. The excellent spectral purity and medium power output makes this oscillator a state-of-the-art wideband tunable millimeter-wave source. In fact, the phase noise of this wideband tunable source is similar to that of a low-noise fixed-frequency 36 GHz DRO[4].

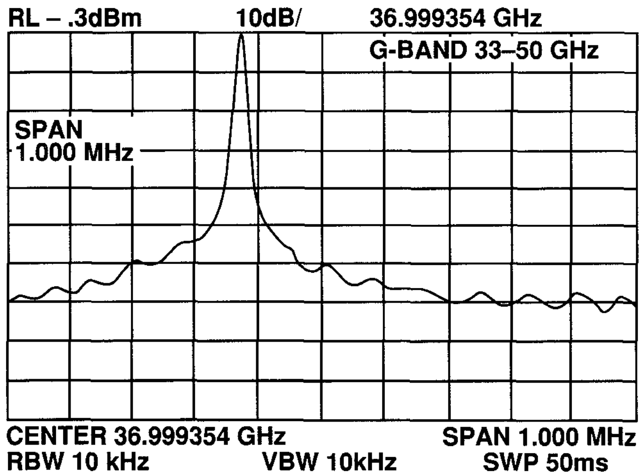

FIGURE 3. SPECTRAL PURITY AT 37 GHz

Figure 4 shows power output, linearity and harmonics of the 18-40 GHz YTO at +25°C. Minimum power output across the band was better than +13 dBm. The linearity was measured to be within ±0.25% over the entire frequency band and harmonics were better than -13 dBc. A voltage regulator is used on the YIG oscillator substrate to minimize the bias pushing. The two balanced amplifiers in the output reduce the frequency sensitivity to load variations. The frequency pulling into 12 dB return loss and the frequency pushing due to bias voltage were measured to be less than 0.5 MHz and 0.1 MHz, respectively.

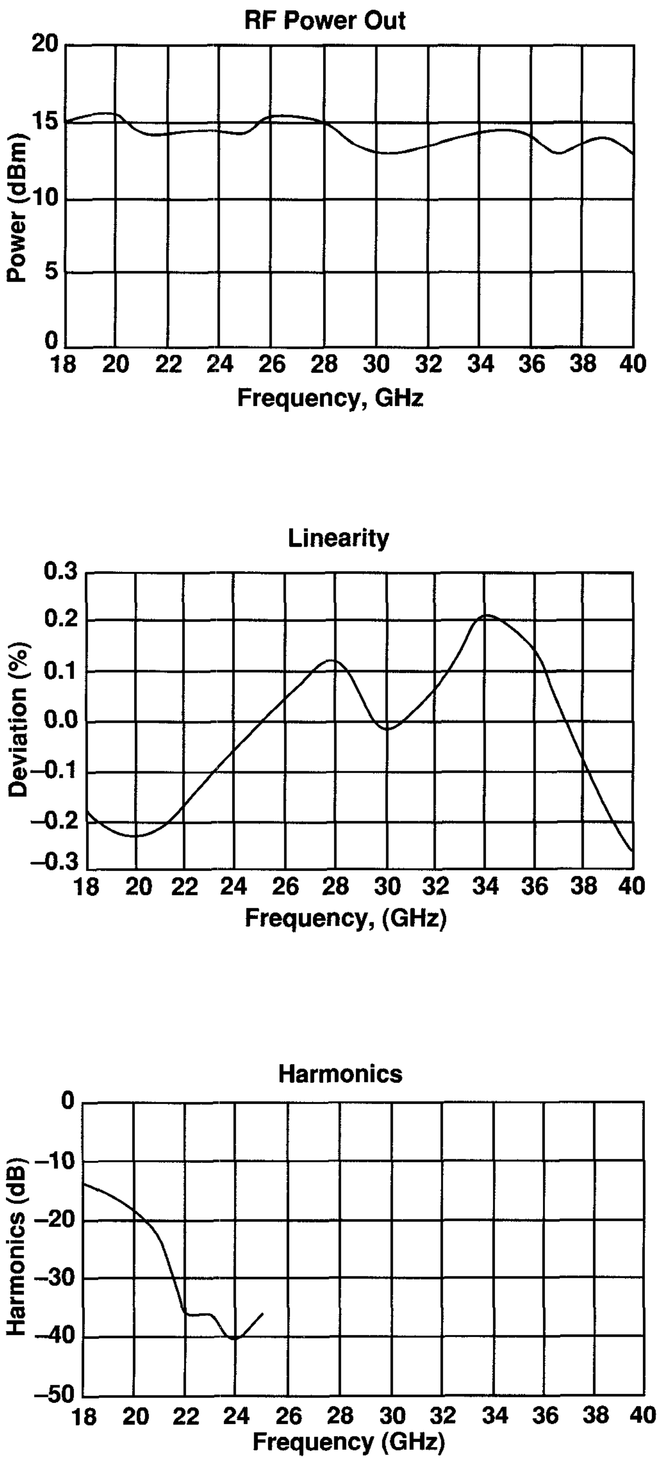

FIGURE 4. TEST DATA ON 18-40 GHz YTO POWER OUTPUT, LINEARITY AND HARMONICS

Table 1 provides typical data for the 18-40 GHz YTO. Over the commercial temperatures of 0 to +65°C a minimum of +12 dBm power output has been achieved.

TABLE 1. Typical Performance Data 18-40 YTO

Frequency Range	18-40 GHz
Power Out, Min. (0 to +65°C)	12 dBm
Linearity	± 0.25%
Second Harmonic	-13 dBc
Third Harmonic	N/A
Pushing	0.1 MHz/V
Pulling (12 dB RL)	0.5 MHz
Freq. drift (0 to +65°C).	30 MHz
Phase Noise @100 kHz	-100 dBc/Hz
Sensitivity:	
Main Coil	40 MHz/mA
FM Coil	500 kHz/mA
Bandwidth:	
Main Coil	2 kHz
FM Coil	500 kHz
DC Bias	+9 V, 150 mA (No YIG heater)
RF Output Connector	Coaxial (type K) (SMA Compatible)
Dimensions	2.0" dia. x 1.5" length
Weight	18 oz.

CONCLUSION

The design approach and the results of a new GaAs FET YIG tuned oscillator covering 18 to 40 GHz are presented. This industry-first oscillator represent state-of-the-art performance in terms of frequency coverage, power output and phase noise.

REFERENCES

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3. A.P.S. Khanna, "GaAs MESFET Circuit Design," Artech House, edited by R. Soares, 1988 Chapter 7.

4. A.P.S.Khanna and Ed Topacio, "A Highly-Stable 36 GHz GaAs FET DRO with Phase-Lock Capability" *Microwave Journal* July 1989, pp. 117-122.