2-22 GHz LOW PHASE NOISE SILICON BIPOLAR YIG TUNED OSCILLATOR USING COMPOSITE FEEDBACK

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ABSTRACT

A fundamental YIG Tuned Oscillator is presented to cover, for the first time, the frequency range of 2 to 22 GHz, using a high frequency silicon bipolar transistor and a single YIG sphere. A unique composite feedback approach has been utilized to demonstrate a minimum of 10 dBm power output and phase noise of -95dBc/Hz @ 10KHz across most of the band. The design approach and performance results of this widest band & low noise oscillator are described.

INTRODUCTION

Wideband YIG tuned oscillator(YTO) is a key component not only for a microwave instrument like signal generator, network analyzer or a spectrum analyzer but also for many military applications. Need for obtaining wider bandwidth has been increasing for obvious reasons. GaAs FET as well as Si-Bipolar transistor based wideband YTOs have been reported in the past. The widest GaAs FET based YTO reported using single YIG sphere covered 3.5 to 19.5 GHz[1]. Wideband 2-20 GHz[2] & 4-21 GHz[3] GaAs FET YTO have been reported using two YIG spheres, a difficult to manufacture approach. Silicon Bipolar transistor represents an inherent advantage over GaAs FET by offering low 1/f noise and wide tunability. The widest frequency band coverage of 4-18 GHz and 8-22 GHz using a Si-Bipolar transistor have been reported[4]. Presently more than one oscillators have to be used to cover the desired frequency bands of 2-18 GHz/ 2-20 GHz and 2-22 GHz for microwave instrumentation and wideband military applications.

In this paper a unique approach is described to cover 2-22 GHz using a single oscillator. The oscillator uses a Si-Bipolar device making it a low phase noise source for multitude of applications. By replacing two or more oscillators with one to cover the same frequency band, this approach allows engineers to eliminate multiple YIG drivers, switches and switch drivers as well, resulting in a low cost, small size and higher reliability system.

DESIGN APPROACH

The 2 to 22 GHz YTO uses a commercially available high frequency silicon bipolar device with an fmax greater than 30 GHz and ft of 11 GHz.The MAG at 4 GHz of this device is better than 16 dB. The arsenic emitter silicon bipolar transistors were fabricated using nitride self-alignment, thick planar field oxide, ion implantation, gold metallization, subhalfmicrometer photolithography and nitride scratch protection to achieve excellent performance, uniformity and reliability[4]. The device was mounted on alumina substrate using gold silicon die attach at 400 deg.C 0.5 mil gold bond wires were used to assemble the device to the circuit.

A sphere of Yttrium-iron-garnet(YIG), a ferrimagnetic material, was used as a resonant element for its inherent high Q, linearity and wide tunability. The size, doping and coupling of the YIG sphere were optimized for high Q mode free performance and the wide frequency range of the oscillations desired. The YIG resonator used is 10 mils in diameter with the 4iiMs value of 650 -700 Gauss. The unloaded Q factor was measured to be greater than 4000 at 10 GHz. This high value of Q coupled with the Si-Bipolar transistor provides excellent phase noise and linearity characteristics.

Figure 1 shows the composite feedback configuration[6] which uses a unique combination of series and parallel feedback using the same high Q YIG sphere. Figure 2 shows the transmission gain S21 and reflection gain S11 modeled using the MMICAD small signal analysis program. The base inductance is selected for wideband negative resistance from 5 to 22 GHz. The

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impedance at the collector is optimized for providing transmission gain between emitter and collector at low end (2-5 GHz). The YIG sphere is coupled as a parallel feedback element between the emitter and collector (output) to provide oscillations at lower frequencies from 2 to about 5 GHz. The YIG sphere is also coupled as a reflection resonator to the emitter of the bipolar transistor to provide oscillations from 5 to 22 GHz as in the case of a conventional YTO[5]. The combination of the impedances connected at the collector and base provide the desired composite feedback to satisfy the oscillation conditions over 2-22 GHz[6].

The wideband YIG oscillator stage is followed by three Avantek GaAs FET MMICs(fig.3). The MMICs used are distributed amplifiers utilizing dual gate FETs resulting in a fully matched gain block useful in the 2-22 GHz frequency range. The die is fabricated using Avantek's nominal 0.3 micron recessed Schottky-barrier gate, gold metallization, and silicon nitride passivation. These devices have small signal gain of 6 dB and P-1 dB of >10 dBm over 2 to 22 GHz. The complete oscillator uses two separate substrates. The first substrate is 5 mils thick alumina and contains the oscillator circuit as well as an MMIC. The second substrate is a 10 mil alumina and accommodates a voltage regulator and two MMICs.

EXPERIMENTAL RESULTS

Figure 4 shows power output as a function of frequency. The power beyond 21 GHz drops down due to Si-Bipolar transistor as well as the buffer GaAs MMIC amplifier limitation. Minimum power output across most of the band was higher than 12 dBm. Figure 5 shows 2nd as well as third harmonics of the YTO at 25 deg C. A minimum of 12 dBc harmonics over the entire band, representing an excellent performance was achieved by proper selection of the buffer devices and their bias. The linearity was measured to be within $\pm$.25% over the entire band. Fig.6 represents the phase noise plot for the oscillator. Over most of the band the SSB phase noise at 10KHz from the carrier was better than 95dBc. At frequencies below 3 GHz the phase noise degrades due to the reduced quality factor of the YIG sphere and above 18 GHz the phase noise degrades due to the active device limitation. Table I provides typical measured data for the 2-22 GHz YIG tuned oscillator. Excellent pushing and pulling figures have been achieved(Table I) due to the use of a high performance voltage regulator and three MMICs respectively. Fig. 7 shows a picture of the 2-22GHz YTO.

Frequency Range (@ 25 deg. C)	1.94 - 22.3 GHz
Power Out Min. (2-22 GHz Range)	10 dBm
Linearity	+/- 0.25%
Second Harmonic	-14 dBC
Third Harmonic	-12 dBC
Pushing	.02 MHz/V
Pulling (12dB R.L.)	.1 MHz
Frequency Drift (0 to +65 deg.C)	22 MHz
Sensitivity: Main coil/FM coil	18/.48 MHz/mA
Bandwidth: Main coil/FM coil	5/500 KHz
DC Bias	+12V / 250 mA & -5V / 15 mA

Table I
Typical Measured Data

CONCLUSION

Design & Results on an industry first YIG tuned oscillator covering 2-22 GHz is presented. This oscillator represents state of the art performance in terms of frequency coverage, power output and phase noise.

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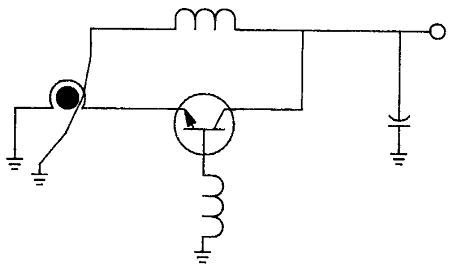

Fig.1 Composite Feedback YTO

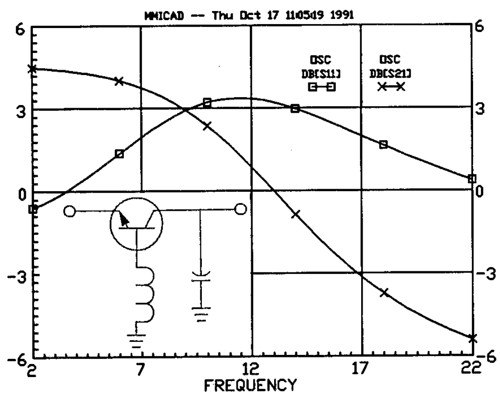

Fig.2 Principle of Composite Feedback

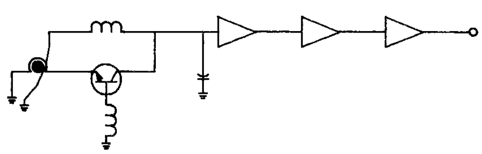

Fig.3 2-22 GHz 10 dBm YTO Block Diagram

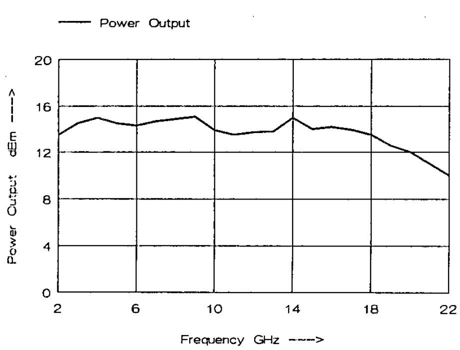

Fig.4 Power Output vs. Frequency

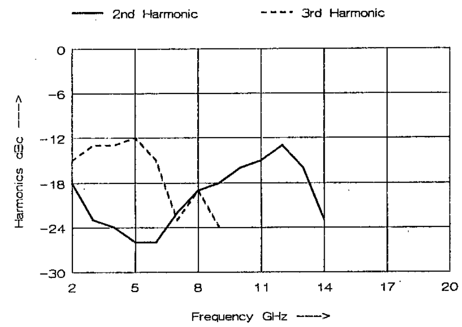

Fig.5 Inband 2nd & 3rd Harmonic

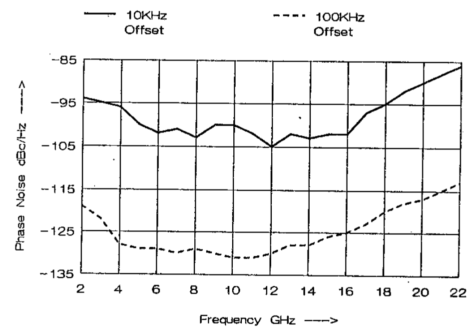

Fig.6 Phase Noise vs. Frequency

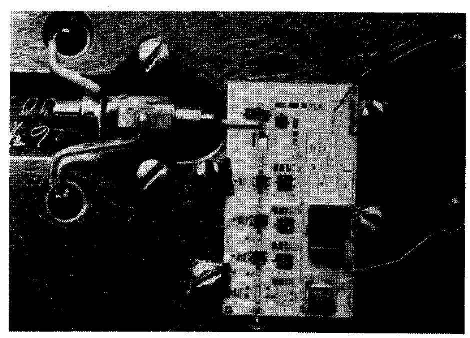

Fig.7 2-22 GHz YIG Tuned Oscillator