Barium Ferrite Tuned-Indium Phosphide Gunn Millimeter Wave Oscillators

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Abstract

Two barium ferrite (BaFe) sphere tuned InP Gunn diode oscillators are described. One oscillator's output power is 6-13 dBm from 40.5 GHz to 50 GHz while the second oscillator tunes from 42 GHz to 55 GHz with -5 dBm to 2 dBm output power. These results are compared to those obtained with a YIG sphere tuned InP Gunn diode oscillator which tunes from 34.5 GHz to 50 GHz. This work represents the first reported results for BaFe sphere tuned InP Gunn diode oscillators.

Introduction

Oscillators tuneable over broadband widths at frequencies below 40 GHz are made routinely by using a magnetically tuned YIG sphere as the tuning element and either a GaAs FET or GaAs Gunn diode as the active device. Above 40 GHz there are several major disadvantages to this type of oscillator:

1. The power dissipated in the magnet coils used to tune the YIG sphere becomes prohibitive.

2. GaAs Gunn diodes suffer degraded DC to RF conversion efficiency.

3. The power output of GaAs FETs falls off quickly.

4. The best electromagnet pole tip materials saturate at ~22 kG which sets the absolute upper limit at ~60 GHz for the use of YIG as a tuning element [f_r= 2.8 MHz/oe (H_0+ H_{anis}) with H_{anis} small for YIG].

To address these problems in building wideband tuneable oscillators, it is necessary to find more suitable tuning elements and active devices. As has been reported previously, BaFe spheres of the appropriate phase and composition have been used to tune oscillators over the 62.5-65.7 GHz region (1) and bandpass filters over waveguide bandwidths in the 26.5-90 GHz region (2,3) using their built-in anisotropy field to reduce the external magnetic field needed to bias the ferrite sphere to resonance at millimeter wave frequencies. A more suitable active device for broadband millimeter wave oscillators is the InP Gunn diode which has demonstrated broadband gain with high efficiencies from 30 GHz to 110 GHz (4).

Oscillators were built with BaFe spheres as the tuning elements and InP Gunn diodes as the active devices. Their performance is compared to the previously published results of a BaFe tuned Gunn oscillator as well as a YIG tuned InP Gunn diode oscillator.

Component Description

Barium ferrite spheres of the appropriate phase and composition were grown and processed into polished spheres of .3-.4 mm in diameter. The line width of these spheres was measured using the technique described by I. Bady (5) and was found to be about 29 oe. at 57 GHz giving a nearly constant Q of 700 over the 40- 60 GHz region. The spheres were then mounted on ceramic rods so that they could be positioned correctly in the oscillator structure.

The InP Gunn diode developed by Varian's III-V Group was used as the active device for these oscillators. The packaged diodes were tested and characterized in oscillator and amplifier test fixtures. The data (see Fig. 1 and 2) taken was then used to construct the lumped element device oscillator. The InP diodes with the flatter output power vs. frequency were chosen for the broadband application.

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CAVITY FREQ.(GHz).	Vbias (V)	Ibias (mA)	Pout (MW)	EFF. (%)
36.3	11.0	168	175	9.47
44.0	11.0	155	115	6.74
50.9	8.0	151	70	5.79

Fig. 1. Output Power vs. Frequency, Fixed Tuned InP Diode Oscillator.

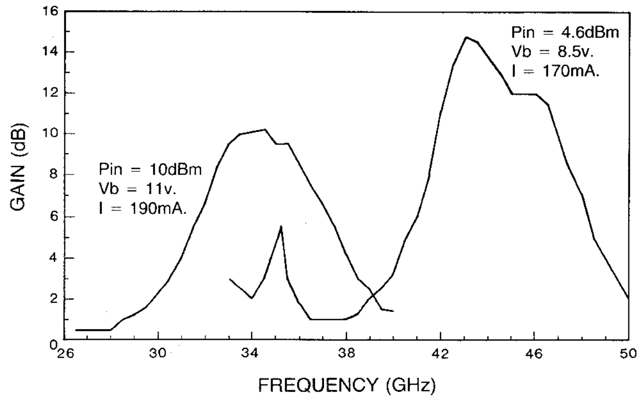

Fig. 2. Reflection Gain vs. Frequency, InP Amplifiers.

Oscillator Design

Fig. 3 shows the essential features of the oscillators. The RF circuit which houses the Gunn diode and the sphere is embedded in the air gap between the magnet pole tips. We utilized the same approach to couple the RF power out as in lower frequency GaAs Gunn oscillators. The sphere acts as a transmission type of resonator and as a bandpass filter rather than a purely reactive element as in most YIG tuned bipolar and GaAs FET oscillators. The diode loop and the output loop are orthogonally located so that the coupling between the two loops is possible only at the sphere's resonant frequency.

The first approach to oscillator design was to take the existing lower frequency GaAs Gunn diode RF circuit used by Varian (6) and scale it to operate at Q band (33-50 GHz). To insure that this oscillator does not produce any spurious frequencies, the RF circuit is designed so that the cavity formed between the magnet pole tips and the heat sink has a resonance frequency greater than 80 GHz. To provide a proper heat sink for the Gunn diode, the RF circuit is constructed with OFHC copper. Half of a double ended nonmagnetic center conductor semirigid coax to WR-28 waveguide transition was used to connect the output loop.

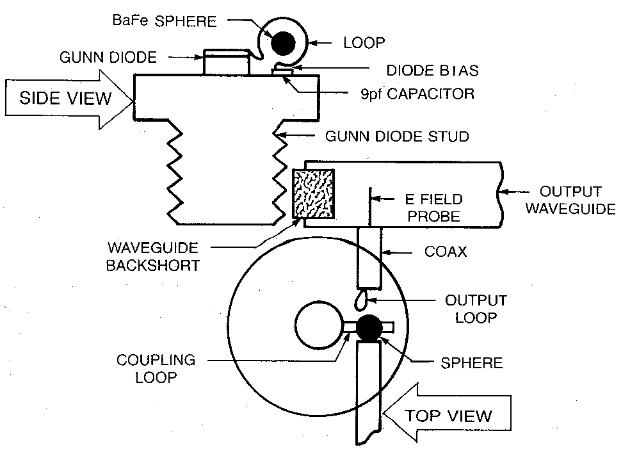

Fig. 3. Oscillator Schematic.

Modification to the transition was required to eliminate oscillation discontinuity between 40.5 and 42 GHz and beyond 47 GHz.

The second approach to oscillator design was a more open structure (no cavity formed) so that the oscillator output coupling could be adjusted while it was operating. This oscillator was designed to operate in U band (40-60 GHz). The output was coupled out by extending the center conductor of a small (.2 mm O.D.) coaxial waveguide to form a .4 mm diameter loop to couple the ferrite spheres magnetic field into the coax. To optimize the transition from coax to 40-60 GHz waveguide, two transitions were set up back to back (Fig. 4), and after adjustment for best performance (Fig. 5), the optimized values of E field probe length and backshort spacing were used to build the single waveguide to coax transition. From Fig. 5, which shows that the insertion loss for two

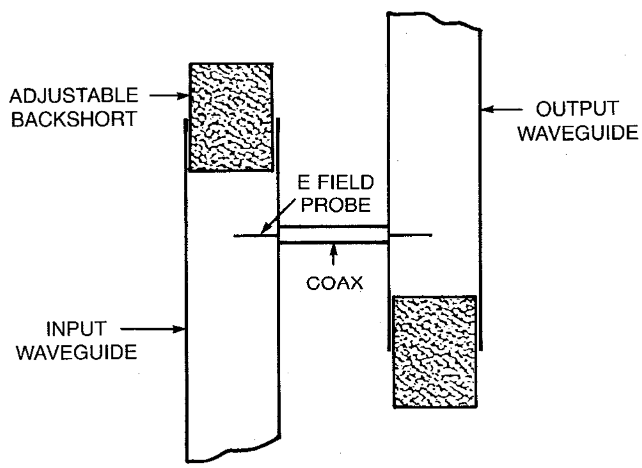

Fig. 4. Coax to Waveguide Transition Schematic, Second Oscillator.

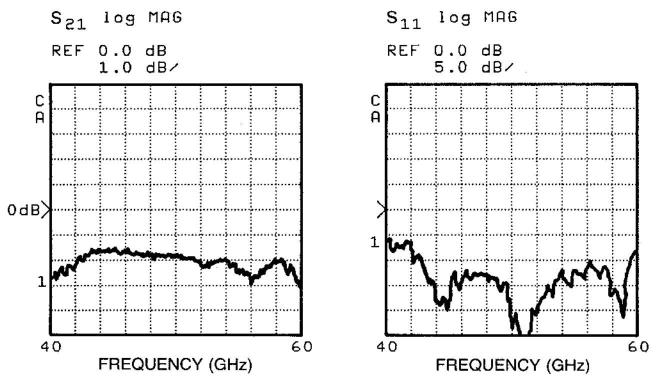

Fig. 5. Coax to Waveguide Transition Performance, Second Oscillator.

transitions is ~2 dB, it can be seen that 1 transition will have an insertion loss of ~1 dB across the band.

Results

The darker line in Fig. 6 shows the results achieved by the first BaFe oscillator. The diode was biased at 10 volts with an operating current of 198 mA. Oscillations below 40.5 GHz were not achieved due to the sphere falling out of saturation. A pure YIG sphere was substituted for the BaFe in the oscillator, and the lighter line in Fig. 6 represents its results. The output power variation is high due to the coax to waveguide transition not being optimized for Q band (Fig. 7). Fig. 8 shows the results achieved by the second BaFe oscillator. The tuning linearity of this second oscillator is shown in Fig. 9.

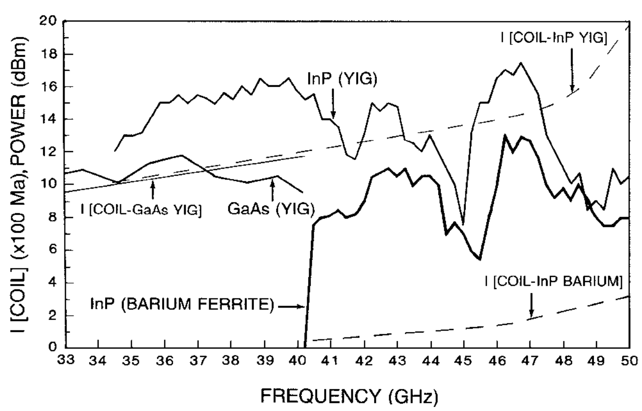

Fig. 6. Power vs. Frequency, First InP Oscillators.

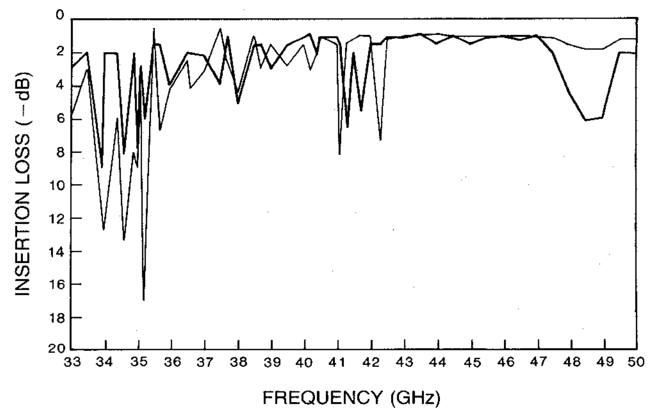

Fig. 7. Coax to Waveguide Transition Performance, First Oscillator.

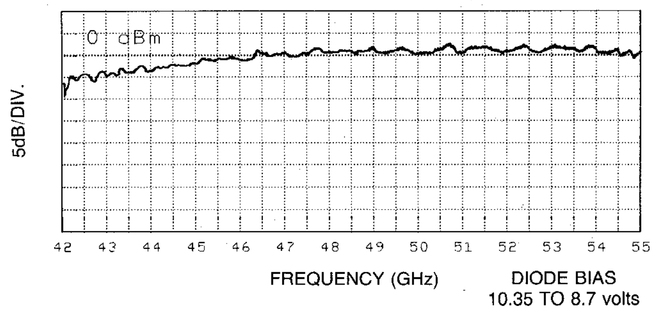

Fig. 8. Power vs. Frequency, Second InP Oscillator.

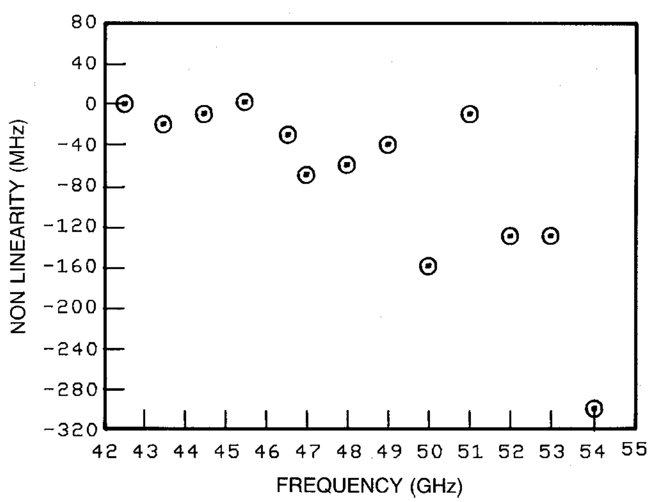

Fig. 9. Second InP Oscillator Linearity.

Discussion

The power output of the second BaFe oscillator is much lower than the first oscillator, probably due to inadequate output loop coupling in the second oscillator. The first oscillator utilized a filter coupling method whereby the loop goes around the sphere instead of using a closed loop to one side of the sphere as in the second oscillator. The higher output power obtained when using the YIG sphere in the first oscillator compared to the BaFe sphere is due to the YIG's higher Q_u.

The ferrite tuned InP diode oscillator has a higher and more constant output power vs. frequency than either a GaAs diode or a GaAs FET (Fig. 6 and 8). For similar output coupling structures the efficiency of the InP diode is higher than the GaAs diode.

Although the YIG tuned oscillator delivers higher output power than the BaFe tuned oscillator, the disadvantage is, of course, the high magnet coil currents required to tune the YIG to these frequencies (Fig. 6).

In comparison to previously reported BaFe tuned oscillators , the first oscillator has greater bandwidth (21% vs. 5.5%), higher output power (~10 mW vs. ~6 mW) and better linearity while the second oscillator has much greater bandwidth (27% vs. 5.5%), lower output power (~1 mW vs. 6 mW) and better linearity. These oscillators thus represent the present state of the art in barium ferrite tuned Gunn oscillators.

Conclusion

BaFe tuned InP Gunn oscillators have been built with tuning bandwidths greater than 20% and high output power (up to 13 dBm). These oscillators represent the best results yet achieved by BaFe tuned Gunn oscillators.

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