THE YIG-TUNED GUNN OSCILLATOR, ITS POTENTIALS AND PROBLEMS

by

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The YIG-tuned Gunn oscillator has the capability of achieving broadband tuning with low residual FM noise, as good as or better than that of a reflex Klystron. Our approach to YIG-tuning a Gunn diode is shown in Fig. 1. The uniform precession mode of the YIG sphere acts as a magnetically tunable transmission type resonator. The diode and output loops are orthogonally located so that the coupling is null in the absence of the YIG sphere or magnetic field. The capability of achieving smooth, broadband tuning with medium power output with this approach is illustrated in Fig. 2. The diode was fabricated from Varian-grown, n-type, epitaxial GaAs. The carrier concentration in the solution-grown active layer was 2.5×10^{15} cm $^{-3}$. The thickness of the epitaxial layer was about 9 m. The Gunn diode was mounted in a 0.76 mm o.d. x 0.3 mm high ceramic package. The YIG sphere had an outside diameter of 1 mm, saturation magnetization of 1780 G, and a linewidth of 0.5 Oe. The capability of achieving low noise oscillation, which is comparable to that of a Varian Gunn effect oscilla-

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tor mounted in a waveguide cavity, is illustrated in Fig. 3. The data was taken from a diode which was oscillating at a frequency of 10.25 GHz with 40 mW of output power. Note that for modulation frequencies greater than 1 KHz from the carrier, the FM noise is as good as or better than that of an ordinary reflex Klystron. This rather good FM noise performance was achieved through circuit optimization and through improvements in the Gunn diode fabrication. The YIG-tuned Gunn oscillator was built for use with a small electromagnet having a gap of 2.8 mm. The entire oscillator, including magnet, weighs 445g and is pictured in Fig. 4.

Using this approach to tune a Gunn diode, the starting frequency of the tuning is limited by the circuit resonance of the diode and the diode loop. This circuit resonance couples to the uniform precession mode of the YIG sphere so as to split the degenerate mode at the crossover point as shown if Fig. 4. Therefore, the diode oscillates at the circuit resonant frequency, f_d, when the H_{dc} is zero. As the H_{dc} is increased, the oscillating frequency follows along the upper branch of the dispersion curves. For linear tuning, the lowest tuning frequency should be somewhat above the diode circuit resonant frequency. For smooth, reciprocal tuning, the couplings from the diode to the YIG resonator and from the YIG resonator to the output circuit should be such that the diode matches well to the output circuit. The required coupling coefficients can be calculated from

$$\beta_1 = \frac{Z_o}{Z_d} (1 + \beta_2) \quad ,$$

where β_1 = coupling coefficient between the diode circuit and the YIG resonator,

β_2 = coupling coefficient between the YIG resonator and the output circuit,

Z_o = characteristic impedance of the output circuit,

Z_d = characteristic impedance of the diode circuit.

When this condition is not met, the tuning becomes non-reciprocal as illustrated by arrows (1) and (2) in Fig. 4. Non-reciprocal tuning can also be caused by inhomogeneties in doping of the active layer of the Gunn diode.

Coupled modes between 1) a higher order mode of the YIG resonator and the diode resonance, 2) a higher order mode and the uniform precession mode of the YIG resonator, and 3) a circuit spurious resonance and the YIG uniform precession mode may also be present in this system. Their effects on the tuning are illustrated in Fig. 5. They all introduce non-reciprocal frequency jumps as well as power jumps in most cases. The higher order modes in the YIG resonator are excited by non-uniform dc and rf magnetic fields. The coupling between the higher order mode and the uniform precession mode is caused by the BeO YIG holder which destroys the orthogonal relationship among the normal modes of the YIG sphere resonator.

In addition to the spurious responses mentioned above, the shift of the oscillation frequency away from the uniform precession frequency[1] may be of importance in some applications. This frequency shift is caused by the diode active capacitance, as well as the package capacitance and inductance which are connected in series in an equivalent resonant circuit. When the capacitance is dominant, the oscillating frequency is higher than that of the uniform precession mode, and when the inductance is dominant the oscillating frequency is lower. This effect will introduce a small non-linearity in this tuning which is otherwise linear. Experimentally, these frequency shifts are observed to be from 2 to 20 MHz at 10 GHz. This effect can, however, be utilized to fine tune the frequency by a varactor diode. An initial experiment achieved a maximum of about 3 MHz peak-to-peak modulation.

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[1]M. Omori, "Octave Electronic Tuning of a CW Gunn Diode Using a YIG Sphere," Proc. IEEE (letters), Vol. 57, p. 97, January 1969.

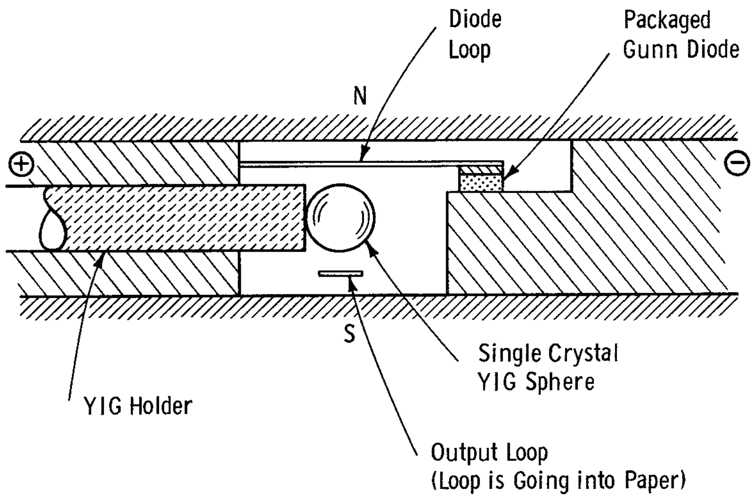

Fig. 1 Cross Sectional View of YIG-Tuned Gunn Oscillator Circuit

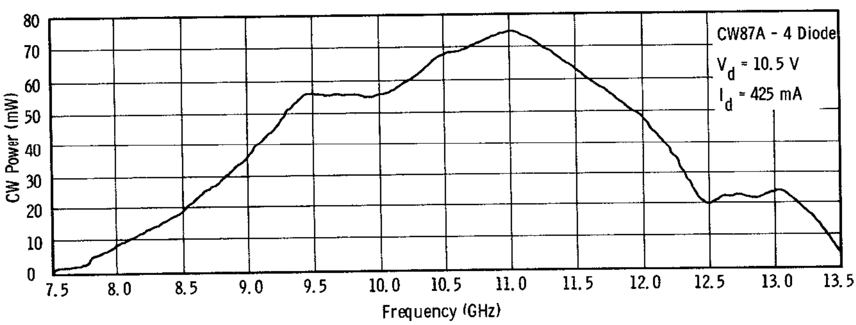

Fig. 2 X-Y Recorded CW Power Output as a Function of Frequency

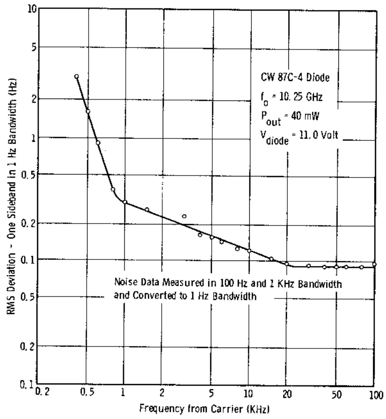

Fig. 3 Measured FM Noise Spectrum of a YIG Tuned Gunn Oscillator

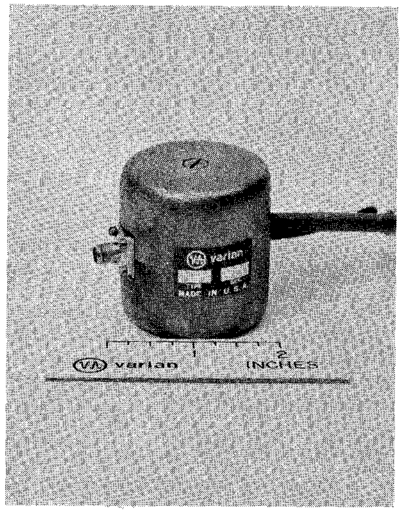

Fig. 4 Complete YIG-Tuned Gunn Oscillator

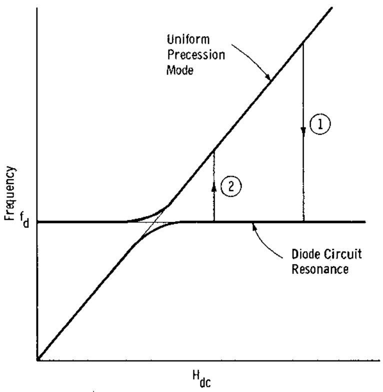

Fig. 5 Fundamental Coupled Mode in YIG Tuned Oscillator

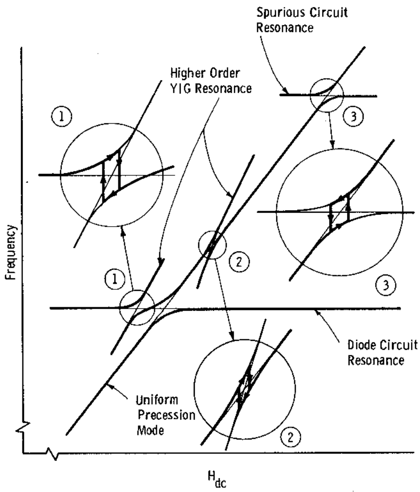

Fig. 6 Higher Order Coupled Modes in YIG Tuned Oscillator