HIGH POWER MICROWAVE TRANSISTOR OSCILLATOR

by

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Abstract

The design of a microwave transistor oscillator with the unique combination of low noise, high output power and extremely linear modulation capability vital to a new generation of simplified, high performance telecommunication transmitters is described.

Introduction

The design of a microwave oscillator capable of operation from 1.5 to 2 GHz which combines the often conflicting parameters of high power, low FM noise and linear modulation characteristic is described below. Realization of this oscillator has led to a new generation of simplified, high performance solid state radio relay transmitters.

Circuit Design

A schematic of the oscillator is shown in Figure 1. Use of a grounded collector coaxial transistor simplifies mechanical design and allows optimum heat removal from the device active area. The package configuration used (emitter and base interchanged from the usual amplifier form) increases collector-emitter capacity and produces a wideband negative resistance between collector and base (with emitter open circuited).

The oscillator output matching circuit utilizes a silverplated invar coaxial cavity for low loss and good temperature and mechanical stability. This circuit was carefully chosen over other possible configurations since it is inherently simple yet simultaneously performs the following functions: 1- Matches the oscillator transistor to the desired 50 ohm output load, 2- Provides a high loaded Q for good FM noise performance, and 3- Presents the proper out-of-band impedances to prevent undesirable oscillations. The measured oscillator loaded Q is approximately 100, giving a residual FM noise deviation of less than 1 Hz rms in a 1 kHz bandwidth for baseband frequencies where shot noise predominates (above about 500 kHz).

At frequencies close to the carrier 1/f noise predominates. Mueller[1] has proposed a transistor model, describing the mechanism for 1/f noise generation, which predicts that 1/f noise can be substantially reduced by connecting a low impedance (at low frequencies)between transistor emitter and base. Low frequency noise measurements have confirmed this. Figure 2 qualitatively illustrates this same effect at the RF output frequency with curves of system (transmitter plus receiver) low frequency FM noise for a resistance of 630 ohms between the oscillator transistor emitter and base (Curve 1) and for this resistance shunted by a 300 μf capacitor (Curve 2).

A novel circuit is utilized to obtain excellent frequency modulation linearity with a typical loss in oscillator output power of less than 0.8 dB. It consists of a coaxial transmission line with a tuning varactor shunting one end and with the other end capacitively coupled to the oscillator output circuit. The simplified numerical example illustrated in Figure 3 gives some insight into circuit operation. Here an abrupt junction varactor whose impedance varies approximately as the square root of reverse bias voltage is assumed. This means that as the bias voltage is increased linearly, diode impedance increases but at a continually decreasing rate. Two varactor impedance values differing by a factor of 2 are plotted in Figure 3. After transformation by a 0.282 λ transmission line, the resultant impedance change is very close to 16, the proper factor for linear modulation. In addition, the transformed impedance increases at a continuously increasing rate as the varactor voltage is increased, the desired characteristic to compensate the varactor diode.

Actual modulator design was facilitated with computer analysis of a simplified model (Figure 4) of the actual modulator-oscillator. Measured diode and oscillator cavity parameters were used and ℓ_1, Z_0, and C_1 were varied for optimum modulation linearity. The modulation linearity realized in practice is quite close to that predicted theoretically. The measured derivative $\frac{df}{dv}$ of a typical frequency-voltage characteristic for $f_o \pm 5$ MHz is shown in Figure 5.

Conclusion

A picture of the complete modulator-oscillator is shown in Figure 6. Typical performance obtained over a 1.64 - 1.72 GHz band is:

Power Output---	>1.8 Watts
Modulation Nonlinearity--	<0.2% ($f_o \pm 5$ MHz)
FM Noise-------	<1 Hz rms (1 kHz BW, 500 kHz - 10 MHz)
Frequency Stability-----	<$\pm$0.08% (-30 to +65°C)

Realization of this oscillator, which combines high output power with low FM noise and excellent modulation linearity, has allowed the design of radio relay transmitters with greatly simplified rf circuitry, in some cases completely eliminating the need for rf power amplifiers. In addition, the performance, reliability and long term stability is excellent, exceeding the most stringent requirements for high channel capacity systems.

[1] O. Mueller, "Thermal Feedback in Power Semiconductor Devices", IEEE Transactions on Electron Devices, September 1970.

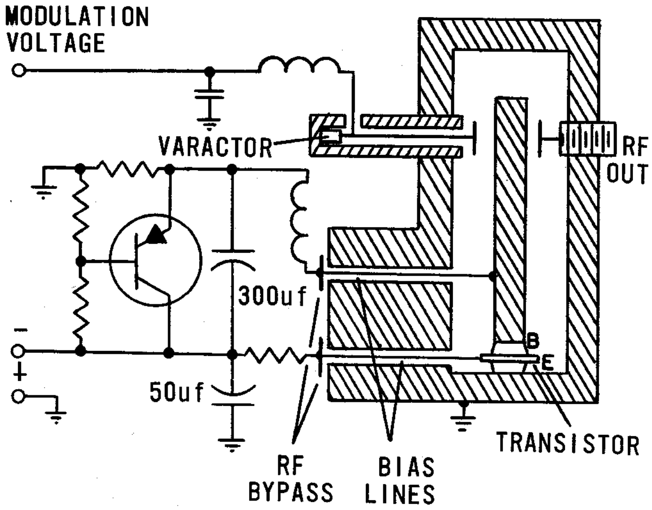

FIG. 1 – OSCILLATOR CIRCUIT

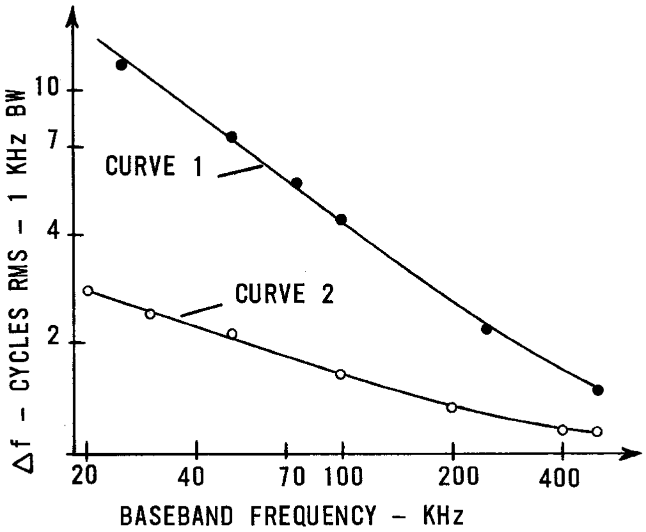

FIG 2 – SYSTEM FM NOISE SPECTRUM
FREQ = 1.74 GHz, POWER OUT = 1.25 W.

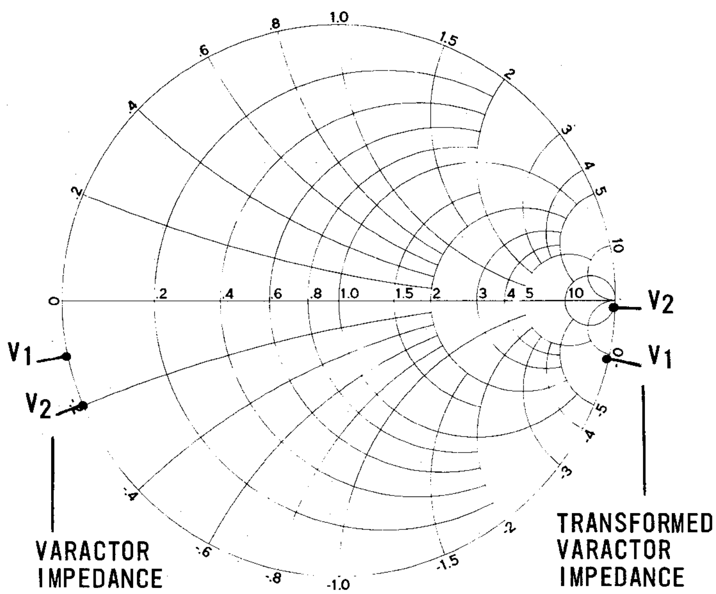

FIG 3 – IMPEDANCE OF VARACTOR DIODE TRANSFORMED BY 0.282λ TRANSMISSION LINE.

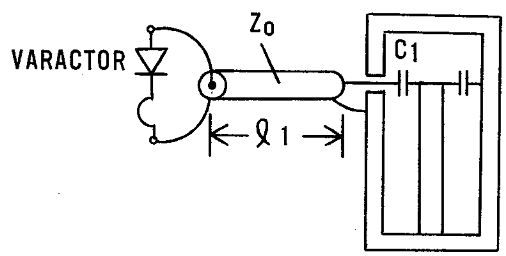

FIG 4 – OSCILLATOR MODEL USED FOR COMPUTER SIMULATION

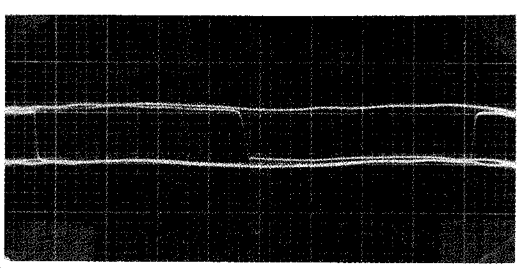

FIG. 5 – MEASURED DERIVATIVE OF VOLTAGE-FREQUENCY CHARACTERISTIC 1% CALIBRATION SPACING ±5 MHz SWEEP

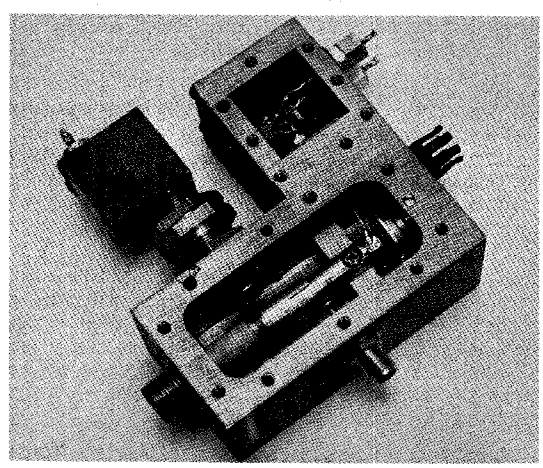

FIG. 6 – PHOTOGRAPH OF COMPLETE OSCILLATOR/MODULATOR