MILLIMETER-WAVE SOLID-STATE EXCITER-MODULATOR-

AMPLIFIER MODULE FOR GIGABIT DATA-RATE

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Abstract

A module consisting of an IMPATT diode oscillator, a PIN diode bi-phase modulator, and an IMPATT diode power amplifier operated at a gigabit data-rate in V-band frequency range is described.

Introduction

Interest and need for solid-state devices suitable for high-data-rate millimeter-wave communication systems have been increasing rapidly in recent years. As a result much progress has been made in the development of millimeter-wave semiconductor devices for such applications. Notable among them are IMPATT diodes for power generation and amplification, PIN diodes and varactors for signal modulation and frequency translation, and mixers and detectors for demodulation[1]. This paper will present recent development achieved with a millimeter-wave solid-state module for PSK-PCM (phase-shift-keyed pulse-code modulation) operated at gigabit data rate in V-band frequency range.

Module Configuration

The module consists of an IMPATT diode oscillator as a power generator followed by a high-speed PIN diode bi-phase modulator and then by an IMPATT diode phase-locked oscillator as a wideband, high power amplifier as shown in Fig. 1. The first stage IMPATT diode oscillator can also be used as a narrow-band, high-gain phase-locked oscillator for amplification of low level reference signal. By using a phase-locked oscillator for power amplification in the last stage, the module can deliver the maximum output power with minimum undesirable amplitude modulation[2]. In addition the power amplification after the phase-modulator reduces the power handling requirement for the modulator. This makes it possible to use a diode with small junction area for the modulator. By using a PIN diode phase-modulator in which phase switching takes place in a very narrow bias range as shown in Fig. 2, very high speed phase transition and high-data-rate can be achieved with minimum phase error caused by bias voltage fluctuation or ringing.

Phase-Modulator

The PIN diode bi-phase modulator consists of a silicon PIN diode with an extremely small planar junction (5μm diameter) fabricated on a thin (1μm) epi-layer which is mounted in a Sharpless type wafer mount with a thin whisker contact. The small junction geometry minimizes the bias driver power requirement. This is specifically an important feature of the modulator to achieve a high modulation rate since the low bias power requirement makes it easy to achieve high switching speed from a bias driver. The diode was operated at bias levels of 1 mA forward current and 5 V reverse voltage. Figure 2 shows relative phase-shift and insertion loss variations of the modulator measured as a function of bias. Although the measured insertion loss of 6 dB is relatively high further improvement can be expected. The phase-modulator was operated up to 2 gigabit modulation rate by driving with an RF generator and phase switching time of 0.2 ns was measured. In Fig. 3 the phase waveform of the output of the PIN diode phase modulator is shown together with the bias voltage waveform driven by an RF generator set at a data-rate corresponding to 2 gigabit/sec. Note that due to the limiting transfer characteristics of the modulator as shown in Fig. 2, the bias voltage waveform is sharpened in the resulting phase waveform of the output signal.

Oscillator/Amplifier

It has been demonstrated that an IMPATT diode phase-locked oscillator can effectively be used for amplification of phase modulated millimeter-wave signals.[2,3] In Fig. 4 a cross sectional view of the IMPATT diode phase-locked oscillator circuit is shown. It consists of a silicon IMPATT diode mounted in a reduced height V-band waveguide section with a movable short. Coupling to the circulator is achieved through a quarter-wavelength impedance transformer. The phase-locked oscillator was operated at an output power level of about 100 mW at a free running oscillation frequency. In Fig. 5 the measured gain-bandwidth characteristics of the phase-locked oscillator are shown. The locking gain-bandwidth product of about 6 GHz was measured.

Module Operation

In order to achieve symmetrical phase transition[2] the module was operated at the free running oscillation frequency of the phase-locked oscillator. The locking bandwidth of the phase-locked oscillator was set to 3 GHz. The phase transition time of the output signal was measured to be about 0.3 ns. Figure 6 shows the voltage waveform of the bias input to the phase modulator and the waveform of the output of the module operated at data-rate corresponding to 1 gigabit per second. The module was successfully operated at data-rate corresponding up to 1.5 gigabit per second beyond which the amount of phase-shift started to deviate from 180°.

Conclusion

In summary a millimeter-wave module consisting of an oscillator which can also be used as a high gain phase-locked oscillator followed by a high speed bi-phase modulator and a wideband phase-locked oscillator as power amplifier was developed and operated at gigabit data-rate. Further improvement in the output power level of the IMPATT diode phase-locked oscillator perhapt to the level of 500 mW to 1 W can be expected by using the double-drift IMPATT diodes.[4]

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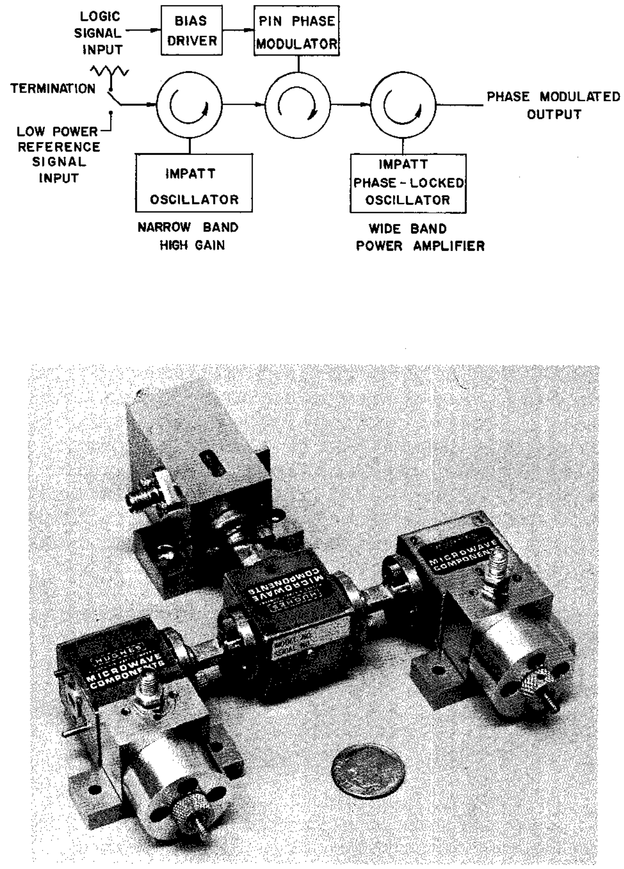

FIG. 1 Block diagram and photograph of exciter-modulator-amplifier module.

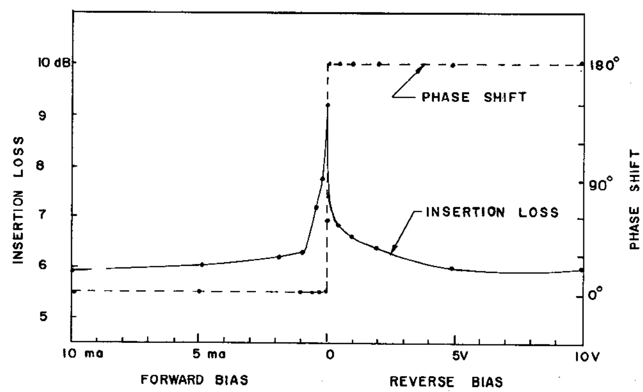

FIG. 2 Transfer characteristics of PIN diode bi-phase modulator.

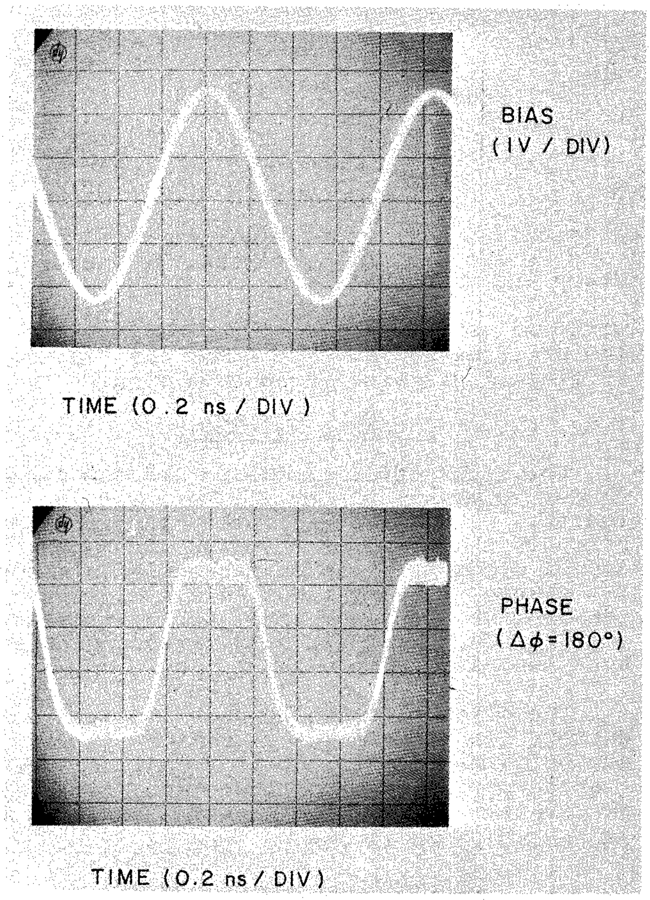

FIG. 3 Bias voltage waveform and output phase waveform of PIN diode phase-modulator operated at 2 gigabit rate.

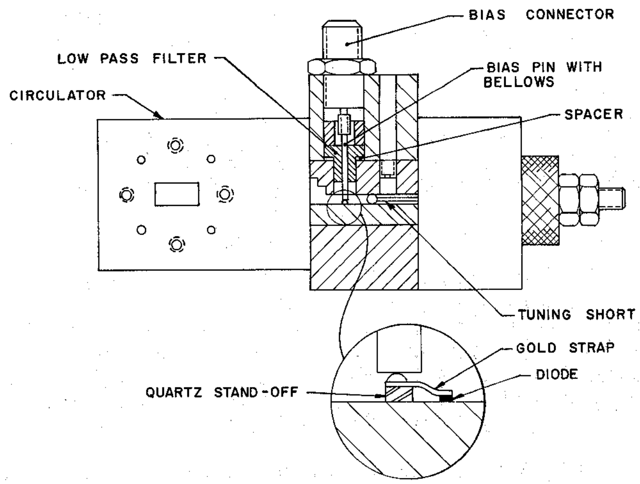

FIG. 4 Cross sectional view of IMPATT diode phase-locked oscillator.

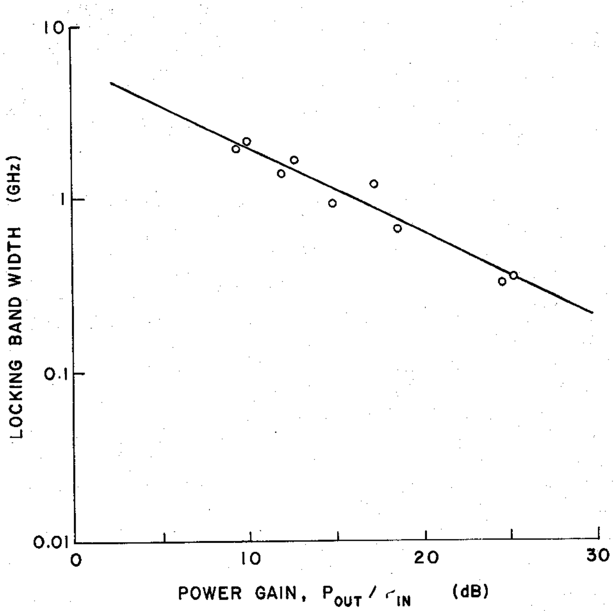

FIG. 5 Locking gain-bandwidth characteristics of IMPATT diode phase-locked oscillator.

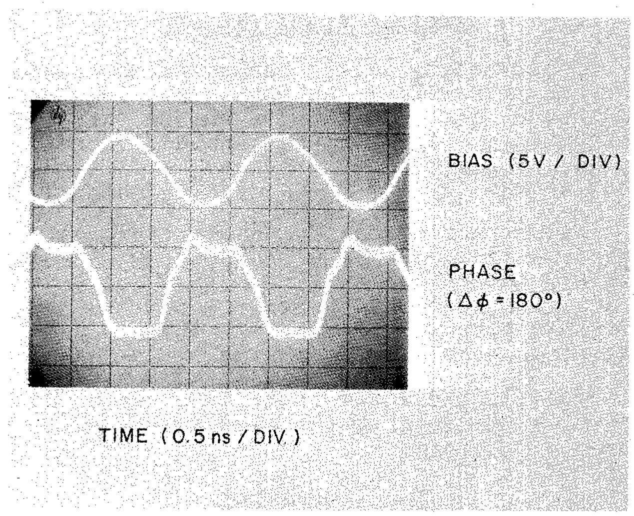

FIG. 6 Voltage waveform of phase modulator bias input and phase waveform of output signal from module operated at 1 gigabit data-rate.