FOUR GIGABITS PER SECOND MILLIMETER-WAVE EXCITER-MODULATOR-AMPLIFIER MODULE*

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Abstract

This paper describes a solid-state oscillator-quadri-phase modulator-amplifier module operating at four gigabits per second data-rate in V-band frequency range.

Introduction

Recent advance of solid-state devices for millimeter-wave communication has been developing rapidly. Fast signal modulation was achievable with solid-state small junction devices such as PIN diodes.[1,2,3] Previous work[4] of an all solid-state oscillator-bi-phase modulator-amplifier module for PSK-PCM (phase-shift-keyed pulse-code modulation) operation achieved one gigabit per second data-rate in the V-band frequency range. This paper describes an extension of that work to QPSK (quadri-phase-shift-keying) pulse-code modulation to achieve four gigabits per second data-rate.

Module Configuration and Detection

The module consists of an IMPATT diode oscillator as the power source operating at 57 GHz followed by a high speed PIN diode quadri-phase modulator and a two-state IMPATT diode reflection amplifier. Fig. 1 shows a photograph of the complete module. Fig. 2 shows the block diagram of the module and the differential phase bridge circuit for pulse-code modulation detection. The quadri-phase modulator consists of two circulator coupled PIN diode modulators, one for the 0^o-180^o phase modulation and the other for the 0^o-90^o phase modulation. The two-state circulator coupled cascaded amplifier was operated in the stable amplification mode. A broadband isolator was also used between the amplifier and the modulator. Detection of the quadri-phase modulated signal was accomplished by the phase bridge circuit as shown in Fig. 2. The modulated signal was compared with the two reference phases set at $+45^o$ and -45^o by the phase shifters in the reference arms of the bridge. Two sets of data trains were detected and monitored on a sampling scope.

Phase Modulators and Amplifiers

The silicon PIN diode used in the phase modulator consists of 5 μm diameter planar junction fabricated on a thin epi-layer of about 1 μm in thickness. The diode was mounted in a Sharpless type wafer in a reduced height waveguide and contacted by a thin AuNi whisker. Transition between the modulator and the circulator was done through a tapered transformer. Fig. 3 shows the transfer characteristics of the 0^o-90^o and 0^o-180^o phase modulation. Phase modulation was determined by adjusting the distance between the PIN diode and a tuning short placed behind the diode. The diode whisker length was used for inductive tuning to balance the insertion loss between the forward bias and the reverse bias state of the diode. Phase transitions were abrupt with 90% of the phase shift occuring between 1 volt reverse bias and 0.2 mA forward bias. Maximum insertion loss of the quadri-phase modulator was 5.8 dB including the losses in the two circulators. The maximum loss imbalance was determined to be 1 dB between the 0^o and 270^o phase state.

The two-state circulator coupled IMPATT amplifier was selected so that the first stage had higher gain and lower power saturation and the second stage had lower gain and higher power saturation. A broadband isolator was used for isolation between the two stages. Fig. 4 shows the two-stage amplifier output power vs. input power. The amplifier gain-bandwidth product was measured to be 20 GHz. Power output of 180 mW at 14.1 dB gain was achieved.

Module Operation

Fig. 5 shows the pulse-code data output from the modulator without the amplifier stage. With each bit length of 0.5 nsec, the two sets of pulse train detected by the $\pm 45^o$ reference phase detectors constituted a high-data-rate of four gigabits per second. The detected pulse transition time was about 0.4 nsec with no apparent pulse form degradation associated with amplitude modulation. Fig. 6 shows the four gigabits per second data pulses pattern after going through the two-stage cascaded amplifier. Pulse form distortion was small and the 0.4 nsec phase transition time was preserved by the amplifier. The module was also linked to a balanced broadband hybrid-coupled IMPATT amplifier to deliver 500 mW output power.

Conclusion

In conclusion, a solid-state millimeter-wave module consisting of an IMPATT oscillator, a quadri-phase modulator, and a two-state cascaded IMPATT amplifier has been constructed and demonstrated the feasibility of four gigabits per second data-rate QPSK transmission.

References

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3. W.J. Clemetson, N. D. Kenyon, K. Kurokawa, B. Owen and W.O. Schlosser, "An Experimental MM-Wave Path Length Modulator," Bell System Technical Journal, Vol. 50, pp. 2917-2944, Nov. 1971.

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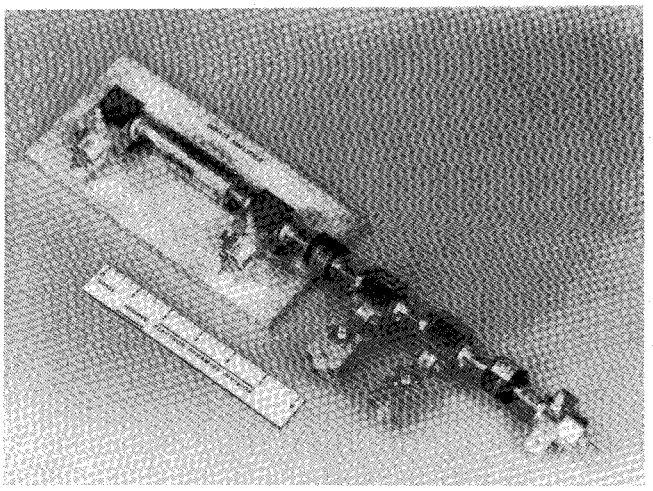


Fig. 1 Photograph of the solid-state exciter-quadri-phase modulator-amplifier.

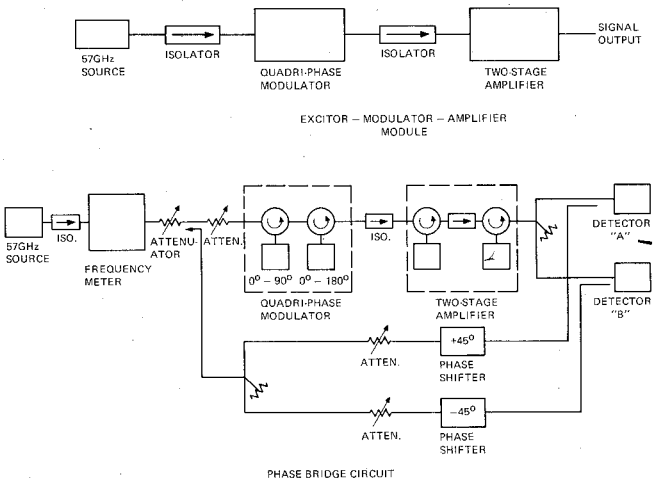
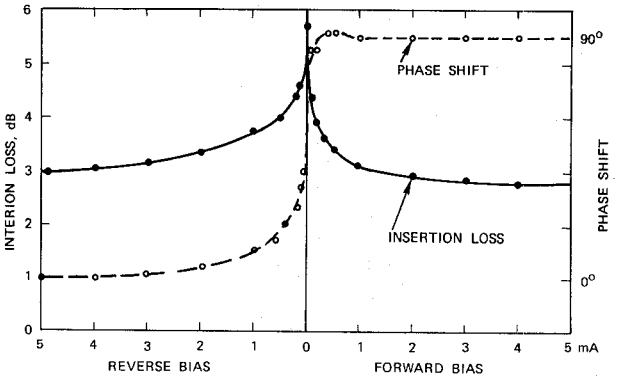


Fig. 2 Phase bridge circuit for millimeter-wave quadri-phase modulation detection.



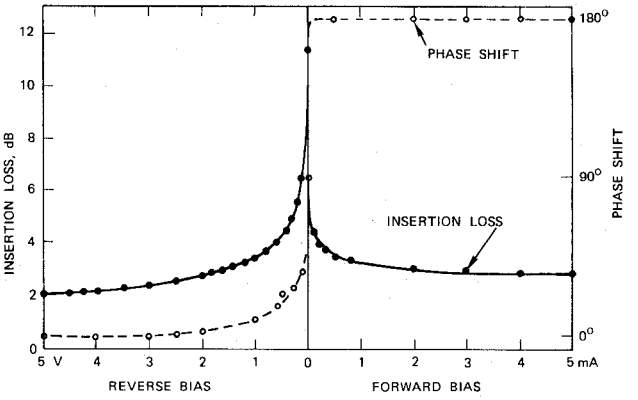


Fig. 3 Transfer characteristics of the PIN diode quadri-phase modulator.

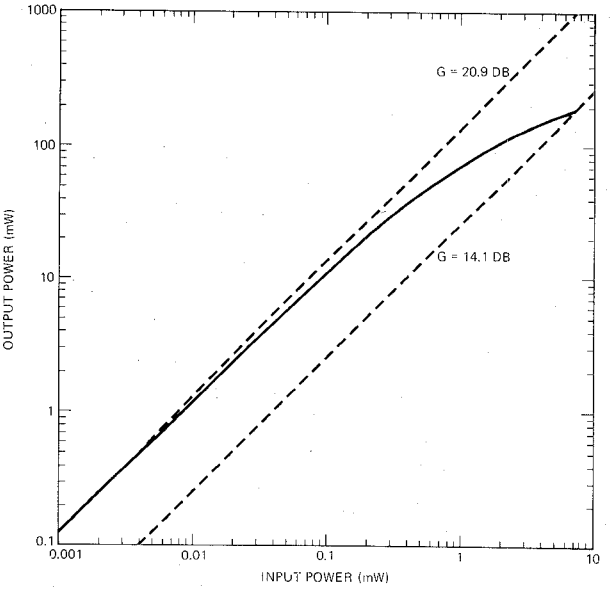
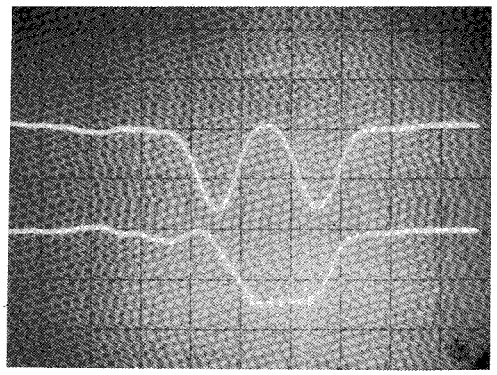
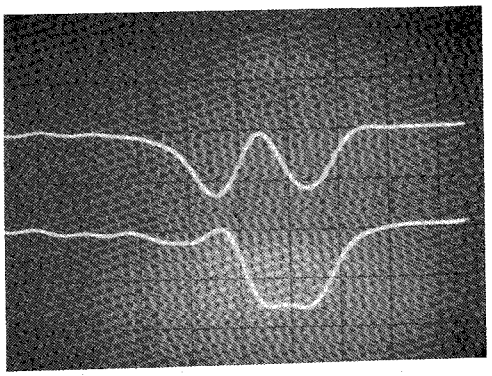


Fig. 4 Input/output characteristics of the two-stage IMPATT amplifier.



"A"	0	1	0	1	0	0
"B"	0	0	1	1	0	0
PHASE	0°	+90°	−90°	180°	0°	0°

Fig. 5 Detected four gigabits per second data-rate pulsed-coded output of the quadri-phase modulator.



"A"	0	1	0	1	0	0
"B"	0	0	1	1	0	0
PHASE	0°	+90°	−90°	180°	0°	0°

Fig. 6 Two-state amplifier output at the four gigabits per second data-rate.