A NEW MICROWAVE AMPLITUDE LIMITER USING GaAs FIELD EFFECT TRANSISTOR

Sachiro Fukuda, Mikio Kitamura, Youichi Ara and Isao Haga

Microwave and Satellite Communications Division

Nippon Electric Co., Ltd.

4035 Ikebe-cho, Midori-ku, Yokohama, 226 Japan

Abstract

This paper describes a new microwave amplitude limiter with low AM-to-PM conversion using a class A GaAs FET amplifier. It has been experimentally established that this limiter is applicable for use with 200 Mbits/sec 4-phase PSK signals or 2700-channel FDM-FM signals.

Introduction

Gallium Arsenide Schottky-barrier gate field effect transistors (GaAs FETs) have inherently excellent high-frequency and low-noise capabilities and have a wide range of applications including their use in low-noise amplifiers.

This paper describes a new application of GaAs FETs in a microwave amplitude limiter by utilizing the output power saturation of a class A GaAs FET amplifier. Microwave amplitude limiters are required for signal processing under constant amplitude conditions, for suppressing AM components before direct demodulation of the microwave FM signals, or for keeping the burst signal level constant in TDMA type satellite communication receivers. In these cases, wide dynamic ranges, adequate AM suppression, and low AM-to-PM conversion are required.

The 1.7 GHz, 4 GHz, and 7 GHz limiters developed by using GaAs FETs had as low an AM-to-PM conversion as 1.5 degrees/dB or less and provided excellent performance for the transmission of 1.7 GHz 200 Mbits/sec 4-phase PSK signals or 7 GHz 2700-channel FDM-FM signals. The limiter characteristics of a silicon bipolar transistor amplifier and a tunnel diode amplifier are also shown for the purposes of comparison.

Limiting Action of GaAs FETs

When a class A GaAs FET amplifier undergoes saturation, the output drain current or voltage, which varies along the load line and reaches the saturation region or cutoff region of the FETs, receives amplitude limitation within a range determined by the drain current or voltage at the cross point of the load line and the saturation region or cutoff region, exhibiting a limiting characteristic. In GaAs FETs, the majority carrier flow is controlled by the input voltage applied to the Schottky-barrier gate and no such minority carrier storage effect as exhibited by bipolar transistors in the saturation region is involved. In both the cutoff region and the active region, the Schottky-barrier junction is reversely biased and the gate-source capacitance which varies with the input level is essentially very small. Accordingly, the rise time delay and fall time delay are basically determined by the time constant of the equivalent circuit and not by input level variations.

In addition, GaAs FETs have excellent isolation, and therefore, very small leakage signals do not affect the amplitude and phase of the amplified and limited signal.

Thus the limiting characteristic can be considered good while the AM-to-PM conversion can be considered very small.

Performance

The limiter circuit discussed here forms a class A amplifier in common source operation as shown in Fig. 1. The limiter uses a packaged GaAs FET with a 1 μm gate length (V244, Nippon Electric Company) and is composed of microstrip input and output circuits on a teflon fiber glass circuit board.

The output power vs. input power characteristic, AM-to-PM conversion and high-speed waveform response of the 1.7 GHz 4-stage limiter are shown in Fig. 2(a) and (b). The dynamic range of the limiter is as wide as 35 dB from -25 dBm to +10 dBm in input power. At an input power of -20 dBm an AM suppression of more than 20 dB is obtained. The AM-to-PM conversion is less than 1.5 degrees/dB over the entire range below the input power level of 0 dBm in a 200 MHz band of 1.6 ~ 1.8 GHz. The output waveform completely follows the high-speed input waveform amplitude-modulated by 20 dB. Fig. 3 shows the measured bit error rate for a 200 Mbits/sec 4-phase PSK signal and the measuring system used. The degradation due to the use of 1.7 GHz GaAs FET limiter is 0.2 dB in C/N. C/N degradation caused by a conventional 2-stage reflection type tunnel diode limiter and that caused by a limiter using a 5-stage bipolar class A amplifier in the saturation are also given for the purposes of comparison. The AM suppression of the tunnel diode limiter was about 10 dB and that of the bipolar transistor limiter was about 15 dB. Although the C/N degradation of the tunnel diode limiter was nearly equal to that of the GaAs FET limiter, the C/N degradation of the bipolar transistor limiter was as bad as 1.7 dB at a bit error rate of 10^{-7}.

Fig. 4 (a) and (b) show the characteristics of the 2-stage GaAs FET limiter and 3-stage bipolar transistor limiter in the 4 GHz band for comparison. Of the limiters using saturated output amplifiers, the GaAs FET limiter is found to be much better than the bipolar transistor limiter for AM suppression, dynamic range, and AM-to-PM conversion.

Fig. 5 (a) and (b) show the noise figure vs. input power and output power vs. input power characteristics of a 8-stage 7 GHz limiter. The small signal gain of this limiter is about 75 dB and the output power variation in the -50 dBm ~ 0 dBm input power range is less than 0.2 dB. The noise figure of the limiter is less than 5 dB at an input power level below -20 dBm, which demonstrates that the limiter is a low-noise limiter. The FM signal transmission characteristic of the limiter having the output vs. input power characteristic shown in Fig. 5 is shown in Fig. 6 (a) and (b). The variation of 2 MHz differential gain over a -50 dBm ~ 0 dBm range is about 0.05% /MHz, which shows that the AM-to-PM conversion is extremely small. When an input of -20 dBm is applied, the AM-to-PM conversion measured by using the dynamic method,[1,2] is 0.6 degree/dB. The noise loading test of 2700 channels shows that the intermodulation noise due to the limiter is 4 pW at the top channel (11700 kHz) for a relative loading level of 0 dB.

A continued test conducted over 1000 hours for 4 GHz amplitude limiters using GaAs FETs (V244) showed no characteristic deterioration. It can thus be concluded that there is no problem in the reliability of the amplitude limiter using the output saturation of a class A amplifier.

Conclusion

A microwave amplitude limiter which utilizes the output saturation of a class A GaAs FET amplifier is recommended. It has been proven that this limiter is applicable for high quality transmission of 200 Mbits/sec 4-phase PSK signals or 2700-channel FDM-FM signals.

Acknowledgement

The authors wish to express their appreciation to Mr. T. Furuya, Mr. S. Yokoyama and Mr. K. Sakamoto of NEC for their encouragement and useful advice.

References

1. Koyama, K., Private communications.

2. IEC 12E (Central Office) 40
"Methods of measurement for equipment used in terrestrial radio-relay systems"

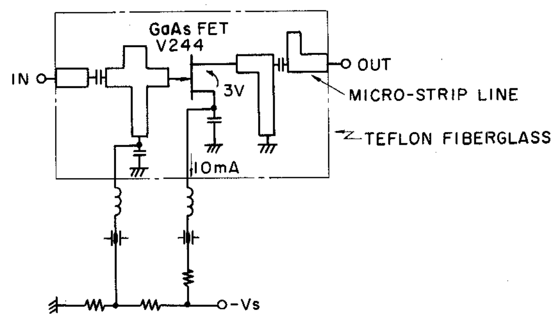

Fig. 1 Construction of GaAs FET Limiter

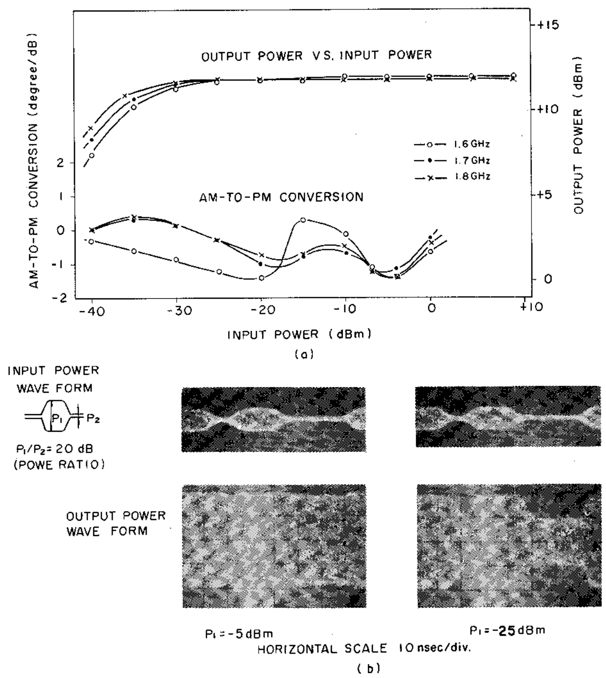

Fig. 2 Characteristics of 1.7 GHz GaAs FET Limiter
(a) Output Power vs. Input Power and AM-to-PM Conversion
(b) High-Speed Waveform Response

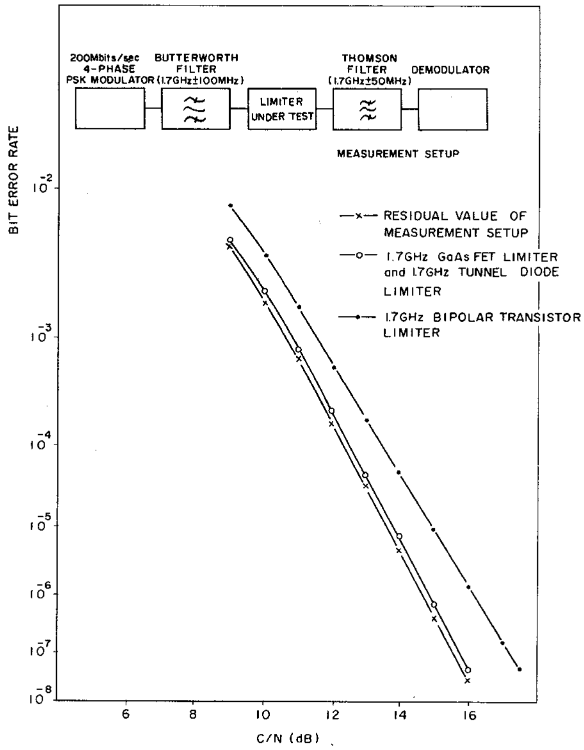

Fig. 3 Bit Error Rate vs. C/N

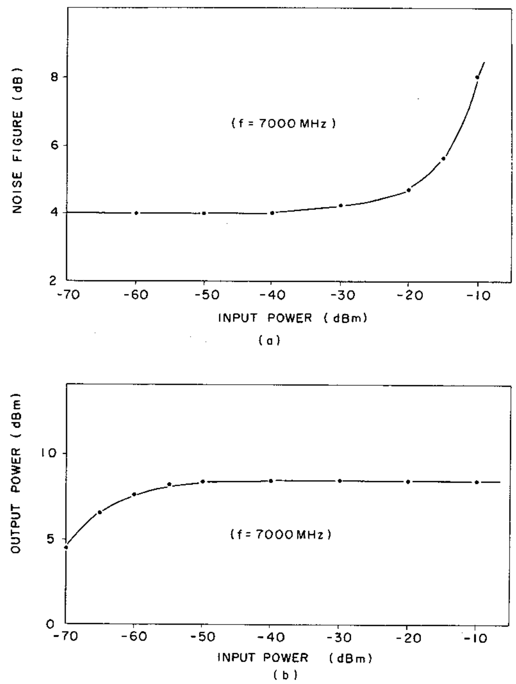

Fig. 5 Characteristics of 7 GHz GaAs FET Limiter
(a) Noise Figure vs. Input Power
(b) Output Power vs. Input Power

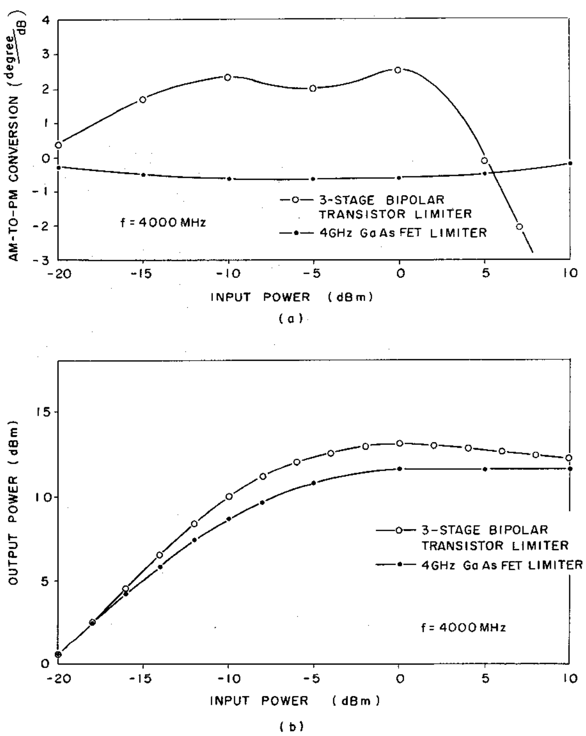

Fig. 4 Characteristics of 4 GHz GaAs FET Limiter and 4 GHz Bipolar Transistor Limiter
(a) AM-to-PM Conversion vs. Input Power
(b) Output Power vs. Input Power

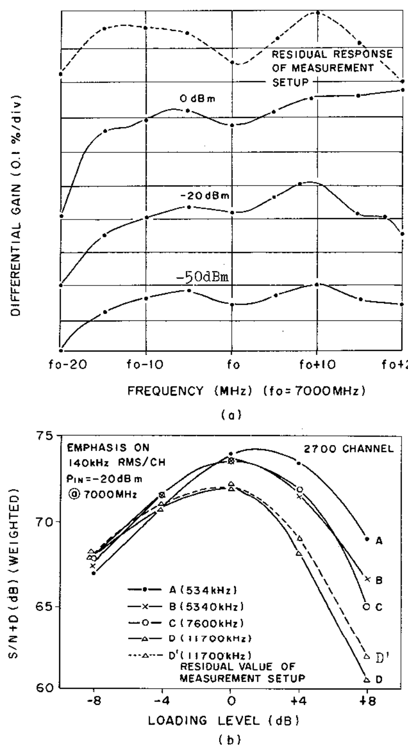

Fig. 6 Characteristics of 7 GHz GaAs FET Limiter
(a) Differential Gain vs. Frequency
(b) Noise Loading