12 GHz 1W GaAs FET AMPLIFIER FOR SHF TV SIGNAL TRANSMISSION

by SHIGENOBU AIHARA, YOSHINORI FUJIKI, SACHIRO FUKUDA, SEIZO AKASAKA, ISAO HAGA

Microwave and Satellite Communications Division
Nippon Electric Co., Ltd.
4035 Ikebe-cho, Midori-ku, Yokohama, 226 Japan

ABSTRACT

An all-solid-state RF amplifier using GaAs Schottky barrier gate FETs for use as SHF-band TV broadcast power amplifiers has been recently developed. The amplifier is composed of five unit amplifiers and designed to operate with 40 dB gain, and +24 dBm output.

Introduction

A number of significant developments and improvements in the fabrication technology and in electrical performance of GaAs FETs for C-band, or X-band solid-state power amplifying devices have emerged from various research organizations and manufacturers during the past several years.(1)

As the result, GaAs FET has now established a firm position as an amplifying element that can supersede the conventional IMPATT diode.

New technical difficulties to be solved have arisen, however, such that with the utilization of X-band, circuit elements, such as inductors and capacitors, tend to become too small and their ohmic losses too large. To overcome these difficulties, one or two FET chips are housed together with the internal matching circuitry in a hermetically sealed metal package for each unit amplifier. The newly developed amplifier consists of five unit amplifiers interconnected in cascade with 50-ohm microstrip lines.

The amplifier can be used mainly as SHF-band TV broadcast transmitting power amplifiers with 40 dB gain and +24 dBm operating output at the 6 dB backoff point.

This paper presents a brief summary of the design, construction, and electrical performance of the 12 GHz 1W GaAs FET amplifier.

Design Considerations

For X-band amplification, newly developed V110 series power FETs are employed. Those gate lengths are 0.5 μm and gate width are shown in Table 1.

In designing the amplifier, the small-signal S parameters of V110B power FET were referenced.

For the S parameters of V110C and V110D power FETs, the parallel parameters of V110B were substituted. In the chart of Fig. 1, measured values for the S11 and S22 parameters of V110B are plotted.

On the basis of these S parameters, each unit amplifier was first designed for maximum gain with the aid of computer. Then the initial circuit pattern was modified experimentally to obtain maximum output power. The final circuit pattern provides several bonding lands for adjustment by taking into considerations the variations in FET parameters.

Measured 1 dB gain compression point and the gain of each FET are shown in Table 1.

FET types	V110A	V110B	V110C	V110D for Unit Ⅳ	V110D for Unit Ⅴ
Gate width	750 μm	1500 μm	3000 μm	6000 μm	6000 μm
Gain	5 5dB	5 5dB	4 5dB	4dB	4dB
1dB-Gain Compression Point	+19dBm	+22dBm	+25 5dBm	+28.5dBm	+29dBm

TABLE 1: GaAs FET Types vs Gate Width, Gain and 1 dB Gain Compression Point

Although the intermodulation distortion of power FETs can not be expressed merely in terms of the third order distortion, the values at the 1 dB gain compression point well exceed 20 dB, as reported in several papers.(2)

Accordingly, the intermodulation distortion $IMD_{(2)}$ between two equal-level signals at +24 dBm rated output of the amplifier with a structure shown in the block diagram of Fig. 2(a) is calculated to be in excess of -22.8 dB, assuming that all FETs distortions be added in terms of the voltage sum.

Now, with color television signals conforming to the National Television System Comittee, the 920-kHz beat component f_D the intermodulation distortion for the three independent signals, i.e., video signal f_V, subcolor signal f_S, and audio signal f_A, needs reduction to a degree of no practical impediment.

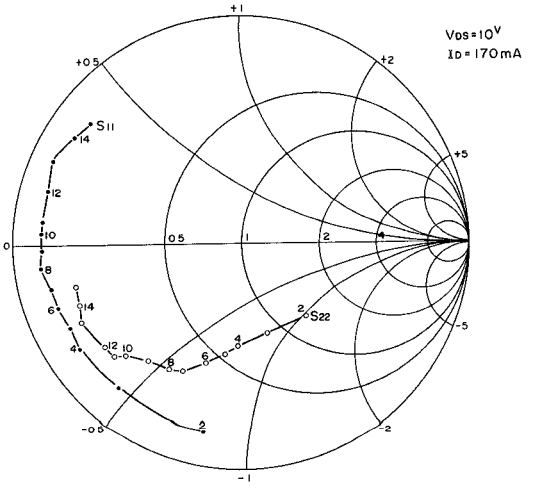

FIG. 1: V110B S-Parameters

In this TV broadcasting system, the relative levels of f_V, f_S, and f_A for the red equivalent signal were respectively chosen as f_V: -4.3 dB, f_S: -16.3 dB, and f_A: -10 dB with respect to the three-signal peak power as illustrated in Fig. 3.

Therefore the intermodulation distortion component for f_S, $IMD_{(3)}$, can be expressed as

$$IMD_{(3)} = IMD_{(2)} - 8.3 \quad [\text{ dB }]$$

The distortion radio f_D/f_S for the color television signals with the circuit configuration shown in Fig. 2(a) is estimated as -31.1 dB which meets the specified value of -30 dB for TV transmitters. As a result of such theoretical and experimental investigations, the amplifier composed of five unit amplifiers as illustrated in Fig. 2(a) was constructed.

Circuit Configuration

The photo of Fig. 2 shows an internal view of the 12 GHz 1W GaAs FET amplifier composed of five unit amplifiers interconnected with 50-ohm microstrip lines and isolators. Each unit amplifier consists of one- or two-stage FET(s) equipped with internal matching circuitry.

All FETs employed for the fabrication are power FETs of V110 series developed by NEC Central Research Laboratories. Two V110A are used in unit I and II, V110B and V110C in unit III, and V110D in unit IV and V, respectively.

The photo of Fig. 4 shows an internal view of unit V. Each unit amplifier is composed of $A\ell_2O_3$ substrates (0.254 mm in thickness), distributed constant circuitry formed thereon, and several bypass chip capacitors. Both the FET chip and the $A\ell_2O_3$ substrates are soldered onto the carrier. After checking electrical performance of each unit amplifier, the air within every unit package was replaced with He gas and the package was hermetically sealed with solder.

Since the source of FET is grounded through metallization on the side surfaces of the chip, two kinds of voltage power source +12V and -18V, are employed for drain and gate bias with current consumption of 2.6 amperes and 30 milliamperes, respectively.

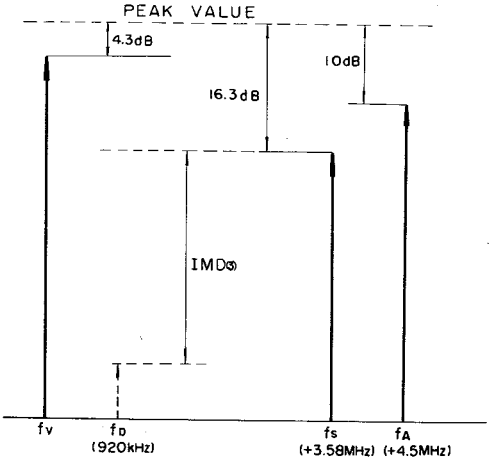

FIG. 3: NTSC Color Television System Power Spectrum with red-color Signal

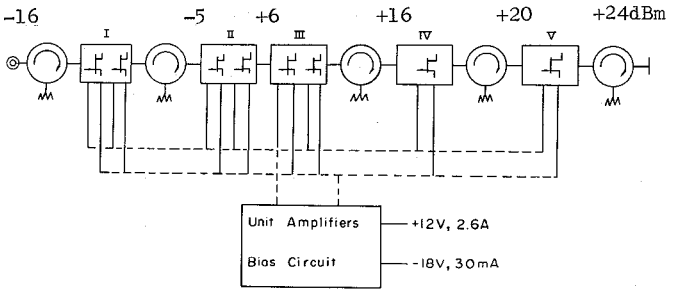

FIG. 2(a) 12 GHz GaAs FET Amplifier Block Diagram

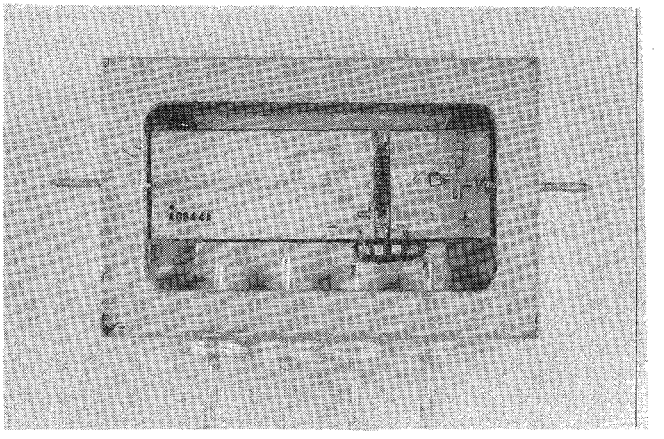

FIG. 4: Unit Amplifier V Inside View

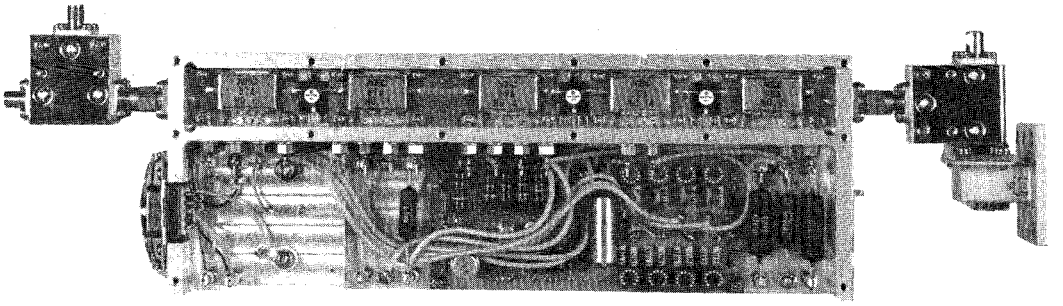

FIG. 2(b) 12 GHz RF Amplifier Inside View

Use of two poralities in DC voltage has necessitated the provision of an overcurrent protector in the FET bias circuit, designed to turn off the drain power source for the fall of gate voltage. The overall size of the amplifier is only 55 x 80 x 300 mm.

Figure 5 shows the SHF TV broadcasting Transmitter furnished with eight 12 GHz 1W GaAs FET Amplifiers.

Performance

Typical performance data are shown in Figs. 6(a) and 6(b).

Fig. 6(a) is the frequency response of the amplifier, indicating the gain of 40 dB and the 3 dB bandwidth of 500 MHz or 1 dB bandwidth of 350 MHz. Fig. 6(b) shows the input/output and the intermodulation distortion characteristics of the amplifier.

The intermodulation distortion was measured 6 dB better than the estimated value. This improvement is attributable mainly to the selection of each FET bias voltages for minimum distortion over the entire amplifier. The bias voltages for each FET were as follows: V_{DS} 6 ~ 10 volts and V_{GS} -1 ~ -3 volts. Each unit amplifier exhibited variations in the gain and saturated output power by ±1 dB approximately.

Ten amplifiers have been manufactured for the SHF TV broadcasting system. Variations of IMD(3) and gain were -37 ±3 dB and 40 ±2 dB respectively.

Acknowledgment

The authors wish to thank Dr. Y. Kaito and Mr. S. Yokoyama of Microwave & Satellite Communications Division for invaluable advices in the course of development of this amplifier. They are also grateful to Drs. Ayaki and Hasegawa and Mr. Y. Aono of NEC Central Research Laboratories, and many other personnel of Semiconductor Division for the development and supply of GaAs FETs intended for use in the present amplifier.

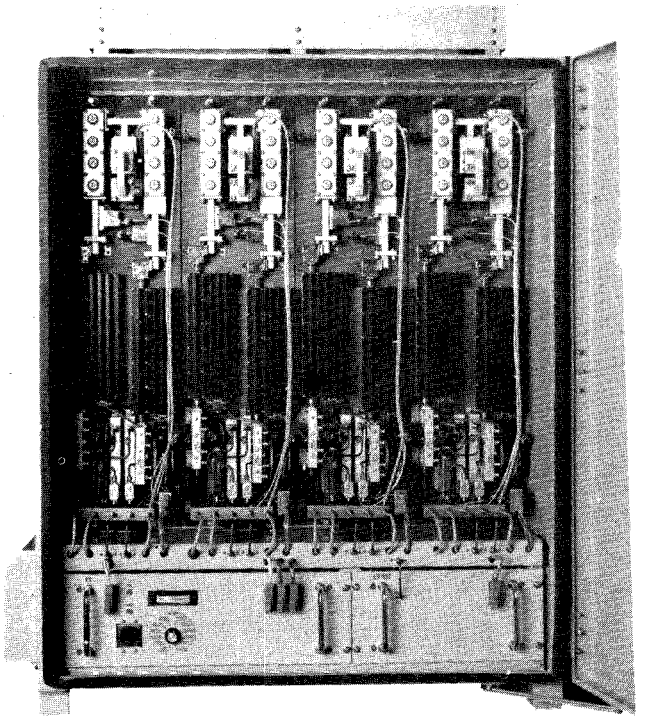

FIG. 5: SHF TV Broadcasting Transmitter Inside View

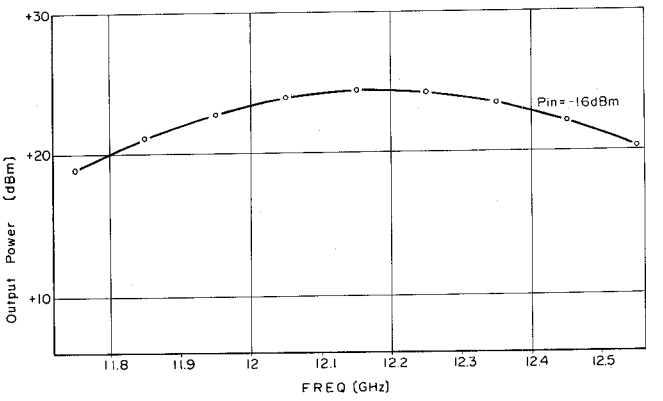

FIG. 6(a) Amplitude Frequency Response

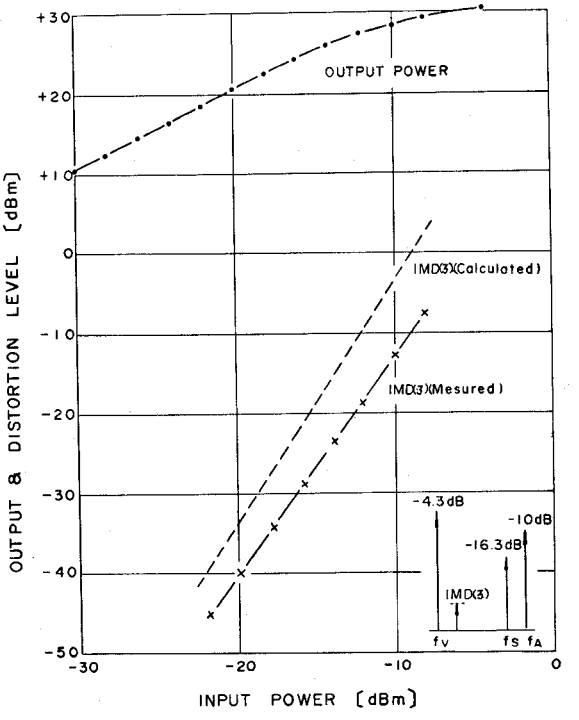

FIG. 6(b) Input/Output & Distortion Characteristics

References

(1) T. Furutsuka, T. Tsuji, and F. Hasegawa, "Improvement of the Drain Breakdown Voltage of GaAs Power MESFET's by a Simple Recessed Structure", IEEE Trans. ED - 25, 6, pp. 563 ~ 567, June 1978.

(2) E. W. Strid and T. C. Duder, "Intermodulation Distortion Behavior of GaAs Power FETs", Proceedings of 1978 IEEE MTT-S, June 1978, pp. 135 ~ 137.