A COMPREHENSIVE CHARACTERIZATION OF FET POWER AMPLIFIER MODULES

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ABSTRACT

This paper reports on an investigation of the pertinent parameters of X-band GaAs FET power amplifier modules operating in both CW and pulse mode. Power compression, efficiency, AM/PM, bias sensitivities, output VSWR, AM and FM noise, IMD, harmonics, temperature, pulsewidth, duty cycle, intrapulse and interpulse data are presented.

INTRODUCTION

To characterize FET power amplifiers the effects of input power, bias voltages, output mismatch, duty cycle, pulsewidth and temperature on amplifier performance are of interest. Data on AM and FM noise, IMD, harmonics, pulse to pulse deviations and module reproducibility would also be significant. Previous studies touched upon important parameters such as AM/PM, bias sensitivities, IMD, harmonics, duty cycle and pulsewidth[1-6]. The purpose of this paper is to report on a comprehensive investigation of these and other parameters mentioned above leading to a more complete characterization of FET amplifiers.

The specific data for a four-stage FET amplifier with 33 dBm peak output power corresponding to 26 dB gain in the 8.75 to 10 GHz frequency range is presented. Statistical data covering a larger sample of amplifiers is cited where appropriate. The amplifier consists of three single-ended driver stages and a balanced power stage. The FET's are MSC 88101 and MSC 88104 flip-chip devices.

CW DATA

Swept frequency transfer characteristics for various input power levels are shown in Figure 1. The power added efficiency at center frequency with 7 dBm input power is 13 percent. Details of phase variation with varying input power (AM/PM) is shown in Figure 2 where it is observed that the AM/PM is sensitive to frequency with a worst case of 3.5 deg/dB at 9.8 GHz but much less elsewhere. Since these

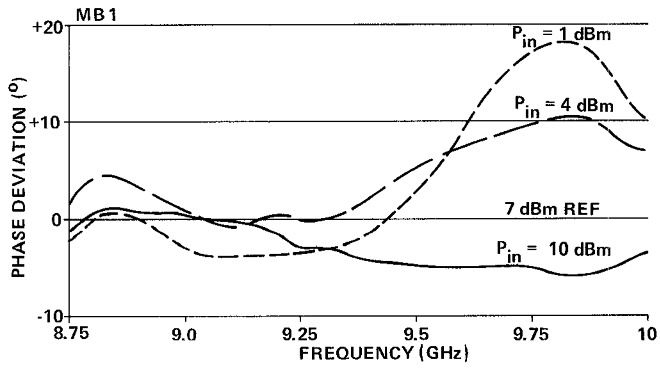

Figure 2 - CW Mode AM/PM

amplifiers are tuned for power only, redesign for minimum AM/PM[7] will result in improved performance. A worst case value of less than 1-2 deg/dB is likely. More important, testing of additional modules indicates that for amplifiers of the same design, the AM/PM dependence on frequency is similar and therefore appears to be predictable.

Swept frequency data was taken with varying bias voltages and output mismatch. The amplitude and phase sensitivities to power supply voltage variations are 0.6 dB/V and 4 deg/V for the 8 V drain supply, and 0.7 dB/V and 23 deg/V for the -2 V gate supply.

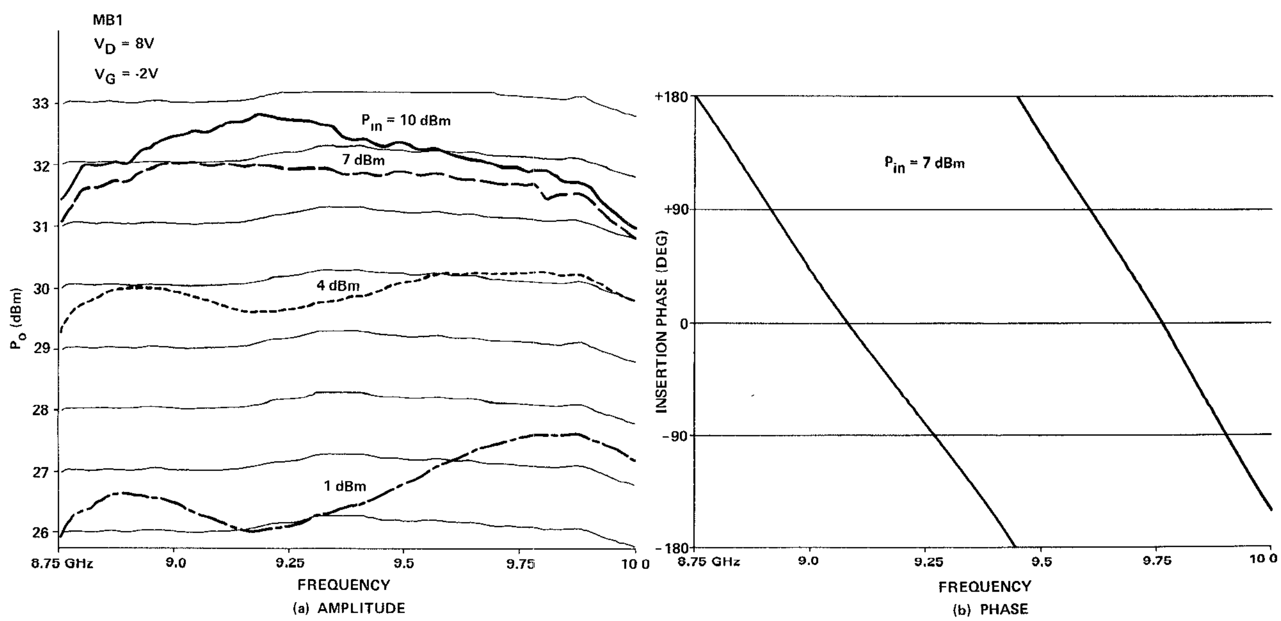

Figure 1 - CW Mode Transfer Characteristics

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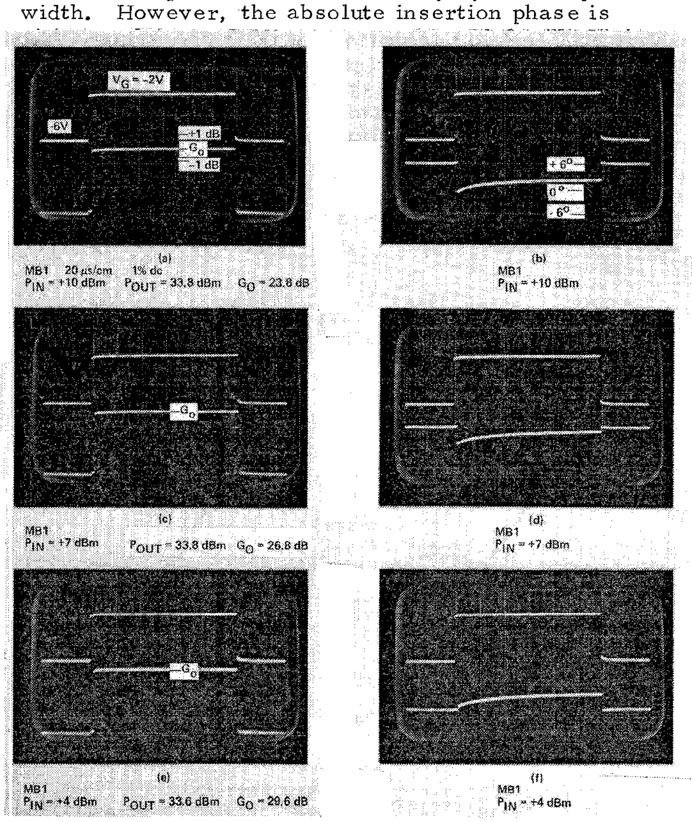
By regulating the voltages to within 0. 1 V for the drain and 0. 05 V for the gate, the deviations can be kept to approximately 0. 1 dB in amplitude and 1 deg in phase. The contribution to amplitude and phase errors for a 2. 5:1 mismatch rotated through 360 deg is found to be 0. 8 dB and 6 deg.

The measured IMD level is -15 dBc at 7 dBm total input power, and is not well behaved as previously predicted[2, 3]. The second harmonic is -38 dBc, the AM noise is -127 dBc at 10 kHz from the carrier in a 1 kHz band, and the FM noise is below the noise floor of the test set which is 0. 2 Hz in a 1 kHz band up to 500 kHz from the carrier, all at 7 dBm input power (approximately the 1 dB compression point).

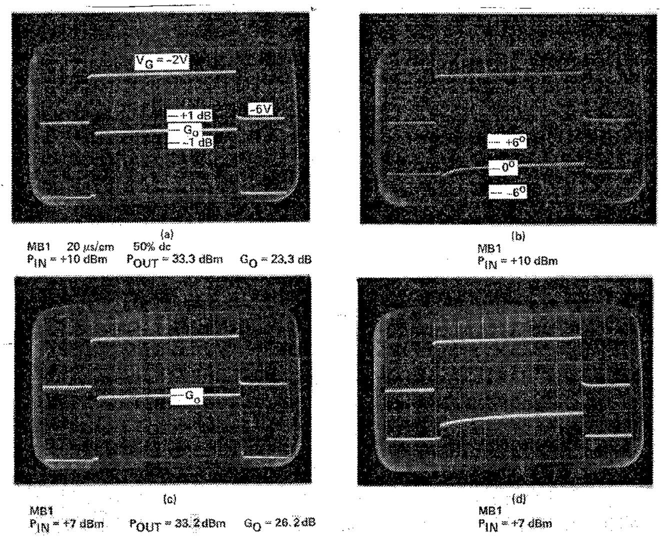
PULSE DATA

Pulse data at 9. 5 GHz taken with gate pulsing technique are presented for 120 μsec and 0. 4 μsec pulses at 1 percent and 50 percent duty cycles. At 1 percent duty cycle, the average drain current is approximately 30 percent of the CW value. In this case, reduced thermal dissipation enhances amplifier gain/power resulting in 1 to 2 dB improvements (Figures 1 and 3). There is reasonable correlation for the AM/PM data between the CW and pulse measurements as shown in the following example. Using the transfer phase at 7 dBm power input as reference, CW data at 9. 5 GHz shows +3 deg, +5 deg and -5 deg phase deviations at +1 dBm, +4 dBm and +10 dBm power input respectively (Figure 2). The corresponding deviations are +2 deg, +5 deg and -3 deg for the 120 μsec pulsewidth, 1 percent duty cycle pulse measurements (Figure 3). Equally good correlation is found for other amplifiers. AM/PM is found to be quite insensitive to duty cycle and pulsewidth. However, the absolute insertion phase is sensitive to duty cycles. Changing from 1 percent to 50 percent duty cycle results in a 6 deg phase change (Figures 3 and 4). These figures also show the drop in output power with increasing duty cycle. The risetime for these amplifiers is on the order of 50 nsec as shown more clearly in narrow pulse data in Figure 5. Note that MB2 represents a second module of the same design. At 7 dBm input, intrapulse phase deviation is typically 2-3 deg for both narrow and wide pulses with negligible amplitude droop.



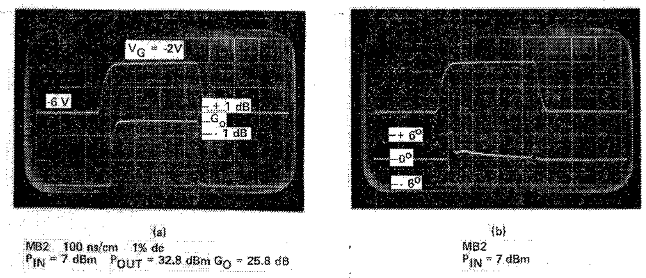
RF Amplitude RF Phase

Figure 3 - Pulse Mode Response, 120 μsec Pulsewidth, 1 Percent Duty Cycle, F_o = 9. 5 GHz, V_G = Gate Voltage



RF Amplitude RF Phase

Figure 4 - Pulse Mode Response, 120 μsec Pulsewidth 50 Percent Duty Cycle



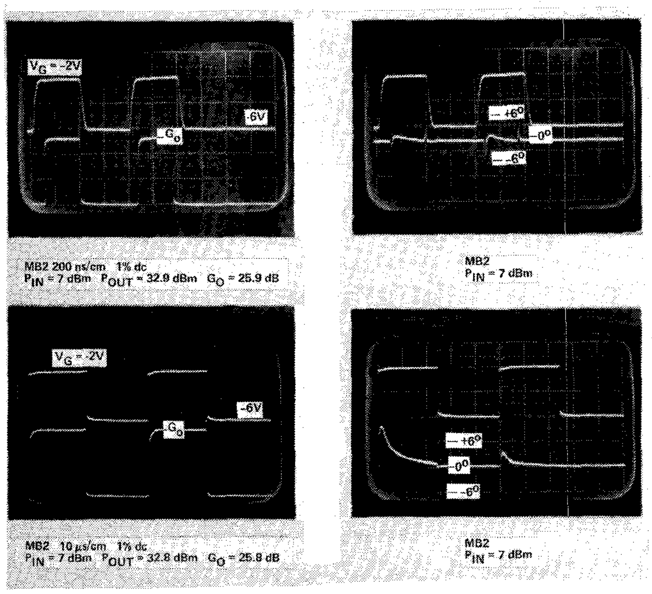
RF Amplitude RF Phase

Figure 5 - Pulse Mode Response, 0. 4 μsec Pulsewidth, 1 Percent Duty Cycle

However, some modules show as much as 5-7 deg phase deviations. Double-pulse measurements indicate significant (6 deg) interpulse phase deviations but only for wide pulses (Figure 6).

TEMPERATURE EFFECTS

At the 1 dB compression point, the power output was found to vary by 0. 75 to 1 dB over the 25°C to 40°C temperature range indicating the necessity for temperature compensation for operation over an extended temperature range. It would also be advantageous to design amplifiers to operate further into saturation and hence become less temperature sensitive.



RF Amplitude RF Phase

Figure 6 - Pulse-to-Pulse Deviations

CONCLUSIONS

FET power amplifier performance under a wide range of operating conditions has been studied. It was demonstrated that such amplifiers can be designed to meet stringent performance requirements.

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