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A WATT-LEVEL 2.3-GHz GaAs MESFET POWER AMPLIFIER WITH GAP-COUPLED MICROSTRIP-LINE MATCHING TOPOLOGY

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ABSTRACT: *A one-stage hybrid power amplifier integrated with gap-coupled microstrip lines for impedance matching is demonstrated in this work. The gap-coupled microstrip line amplifier module realized here can provide 15-dB power gain, 33.5-dBm output power, and 42% power-added efficiency (PAE) at 2.3 GHz. The demonstrated topology is suitable in monolithic IC technology, especially in the millimeter-wave frequency because the gap-coupled microstrip lines can be easily compacted into small size.* © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 41: 346–348, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20137

Key words: *MESFET; power amplifier; microstrip lines*

1. INTRODUCTION

Recently, demand for high-level integration in microwave monolithic integrated circuits (MMICs) has increased and become more important. The off-chip band-select filters are often too bulky for integrated-circuit technology. Typical microwave and millimeter-wave transceivers still consist of MMIC chips and off-chip filters to achieve maximum performance. The potential of integrating devices and filters in integrated-circuit technology is thus attractive for cost reduction [1]. In this work, a GaAs MESFET power amplifier with gap-coupled microstrip-line matching structures has been developed. The gap-coupled microstrip lines serve as impedance transformations and also provide DC blocking. Chip capacitors are inserted into the gaps to optimize the matching design for the desired band-pass amplifier response. The amplifier demonstrated provides 15-dB gain and 33.5-dBm output power at 2.3 GHz. The power-added efficiency (PAE) at maximum output power is 42%. The gap-coupled microstrip lines can be easily compacted into a serpentine shape and thus the amplifier topology demonstrated here is very suitable for millimeter-wave monolithic integrated circuits.

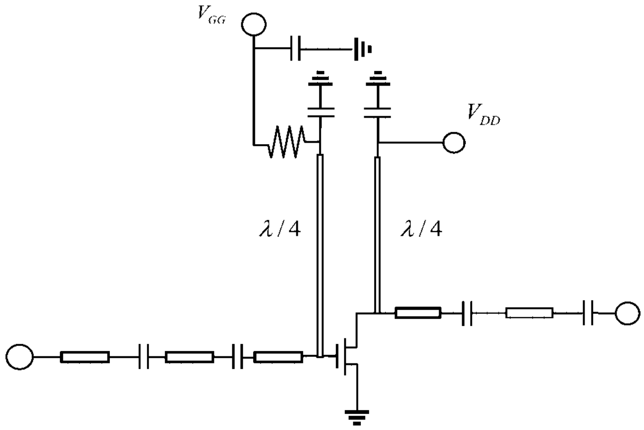

Figure 1 Schematic of the gap-coupled microstrip-line power amplifier

2. CIRCUIT DESIGN

Figure 1 illustrates the schematic of a one-stage GaAs MESFET power amplifier with gap-coupled microstrip lines for impedance matching and transformation. A load-pull measurement is used to obtain the optimum load impedance for maximum output power and the packaged device's S parameters are also measured for power-amplifier design. A gap-coupled microstrip-line topology is simple and thus used for impedance matching. In other words, the gap-coupled microstrip lines not only have band-pass characteristics, but also provide the input and output impedance matching of a power amplifier. The band-pass nature of a gap-coupled matching network also helps increase the stability of a power amplifier because such a device is prone to low-frequency oscillation and the gain mismatch at low frequency increases the stability. There are two design parameters in gap-coupled 50Ω microstrip lines: the lengths of the microstrip lines and the capacitors inserted in the gaps. A conventional power-amplifier design methodology is adopted here; the input impedance matching is optimized for power gain and the output impedance matching is optimized to obtain maximum output power [2, 3]. The input equivalent-circuit of a MESFET device is close to a series-RC circuit and thus the capacitor is absorbed into the gap-coupled microstrip line-matching circuit [4, 5]. The output equivalent-circuit for maximum power-impedance matching is close to a parallel-RC circuit and the effect of the parallel capacitor is negligible at the frequencies of interest. Quarter-wavelength RF chokes are used at bias gate and drain terminals. The stability factor K is large than 1 and the B factor is larger than zero for all the frequencies in order to prevent undesired oscillation in the amplifier design.

3. EXPERIMENTAL RESULTS

A photograph of the fabricated power amplifier is shown in Figure 2. A standard microwave ceramic package is used to package the

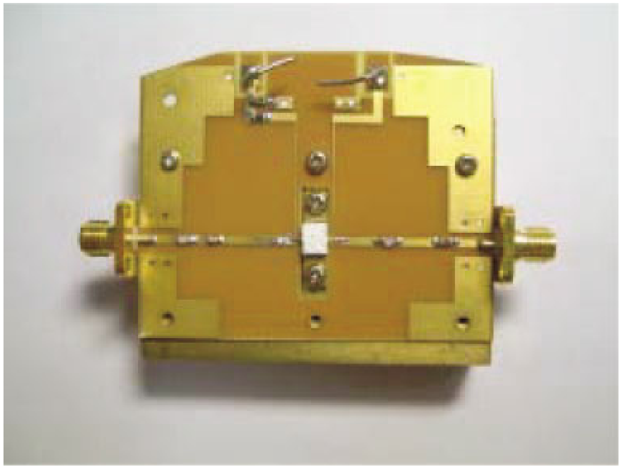

Figure 2 Photograph of the fabricated gap-coupled microstrip-line power amplifier. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

GaAs power MESFET device. The device has 6-mm gate width and 0.7-μm gate length. The FET has via holes for grounding and the backside of the die attaches to the bottom of the package by Au-Sn solder. A brass heat sink is used to dissipate heat and the case of the device package contacts directly to the heat sink for better thermal resistance and electrical grounding, as shown in Figure 2. Multiple bond wires are used to connect the FET gate (drain) to the gate (drain) lead for reducing gate (drain) inductance. The gate lead and drain lead of the packaged device are connected to the input and output gap-coupled microstrip lines by soldering, respectively. The microstrip lines are fabricated on FR4 PC board. The FR4 material has high dielectric loss in the RF frequency and will influence the performance of the circuit. The device is biased at V_{ds} = 10 V and I_{ds} = 0.6 A. The amplifier power gain and input return loss as functions of frequency response are illustrated in Figure 3. The input return loss S_{11} is -13 dB and the small-signal gain S_{21} is 15 dB at the frequency of 2.3 GHz. The output power, power gain, and PAE measurement results are shown in Figure 4. The maximum saturation output power is 33.5 dBm, the linear power gain is 15 dB, and PAE is 42% at maximum output power. The two-tone intermodulation measurement results are shown in Figure 5 and the OIP_3 is 40 dBm.

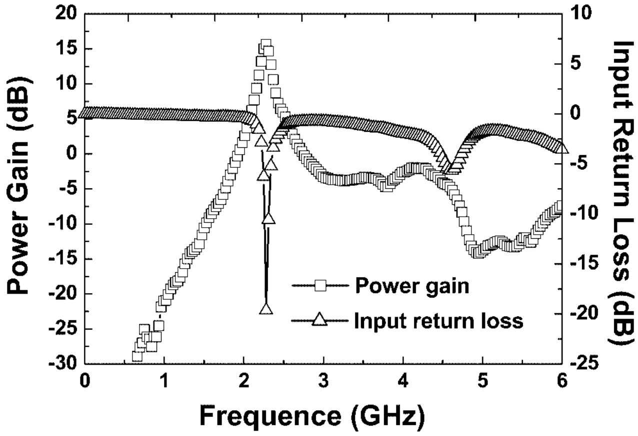

Figure 3 Measured power gain and input return loss of the gap-coupled power amplifier

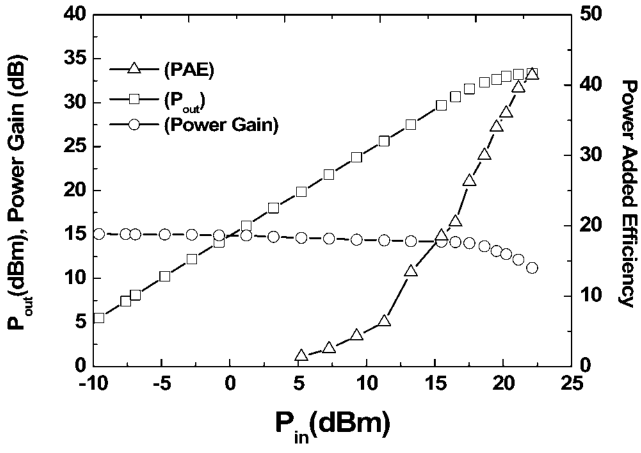

Figure 4 Output power, gain, and PAE of the gap-coupled power amplifier at 2.3 GHz

4. DISCUSSION AND CONCLUSION

We have demonstrated a Watt-level band-pass amplifier operating in the center frequency of 2.3 GHz. The gap-coupled microstrip line power amplifier provided 15 dB gain, 33.5 dBm output power, and 42% PAE. The performance has not been optimized in this work as yet. The gap-coupled microstrip-line filters have been well established for 50Ω to 50Ω microwave band-pass filter design [6]. The gap-coupled microstrip lines should be able to perform impedance transformation by extending the filter design theory to unequal source and load impedances. Thus, standard microwave filter design theory can be conveniently applied to design gap-coupled band-pass transformers at both input and output to further optimize the band-pass frequency response. Moreover, the structure of gap-coupled microstrip lines is very simple and can be compacted into a serpentine shape for size reduction. Thus, the demonstrated topology is suitable for monolithic integration, especially in the millimeter-wave frequency range.

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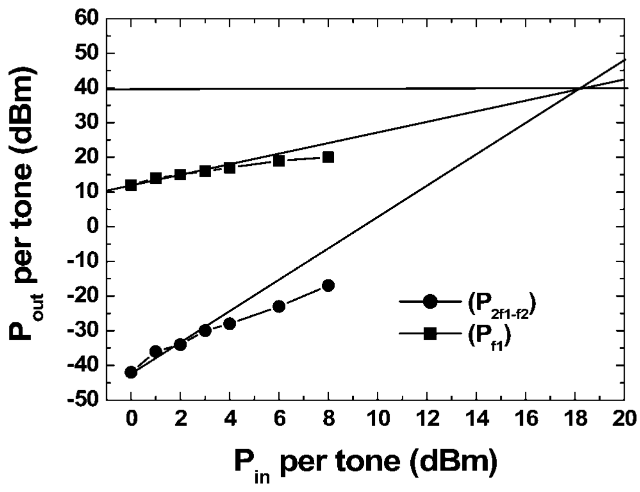

Figure 5 Two-tone intermodulation measurement results of the gap-coupled power amplifier at 2.3 GHz

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EXPERIMENTAL CHARACTERISTICS OF A PRINTED OPEN-SLOT ANTENNA WITH REFLECTOR FOR PCS, DCS, AND IMT-2000

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ABSTRACT: *In this paper, we investigate a new rectangular-fed printed open-slot antenna (POSA) with reflector, which has the advantages of improved radiation-pattern properties along with broad-bandwidth characteristics. The measured bandwidth of the proposed POSA with reflector is approximately 47.6% (-10 dB $\geq S_{11}$), thus, it can be used for PCS, DCS, and IMT-2000. But the measured bandwidth of the PCSA with reflector is approximately 46% (with VSWR $\leq$ 2.0). The tilt angle at maximum gain is enhanced by using a modified POSA with reflector for practical applications. The radiation pattern null and distortion of the open-slot antenna exhibited better performances than those of the closed-slot antenna. The back-lobe level of the POSA with reflector also presented much better results than the PCSA with reflector. The proposed antenna obtained not only wider bandwidth but also better radiation patterns characteristics than the PCSA with reflector.* © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 41: 348–350, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20138

Key words: *printed open-slot antennas; etching ground-plane effects; antenna feeds*

1. INTRODUCTION

The slot antenna has been investigated since the 1940s at least [1], and is treated in many electromagnetic textbooks. The major drawback of the microstrip antenna in its basic form is its inherently narrow bandwidth. The narrow bandwidth of these antennas is a major obstacle that restricts its wider application. In general, transverse or slanted slots are cut in the ground plane of a microstrip line and present series impedance to the feed line. Y. Yoshimura [2] and D. M. Pozar [3] have demonstrated simple techniques of narrowband matching (a few percent of the bandwidth [4]) of the slot radiator. Recently, an operational bandwidth of approximately 40–50% for the microstripline-fed slot antenna is investigated [5, 6]. Unfortunately, these antennas have low gain. Moreover, the radiation patterns of these antennas also have many nulls and distortion at high frequencies. Therefore, a vast amount of techniques for widening the microstrip antenna's bandwidth has been proposed. Widening bandwidths of 24% for the cavity-backed radiator [7], and 30% broadband for the triangular microstrip antenna with U-shaped slot antenna [8] have been observed. But the radiation pattern of these antennas also has many nulls at higher frequencies, which restrict wider application of these antennas. Therefore, many techniques to enhance the radiation patterns of microstrip antennas have been proposed [9, 10]. But the narrow bandwidth of these antennas is major obstacle.

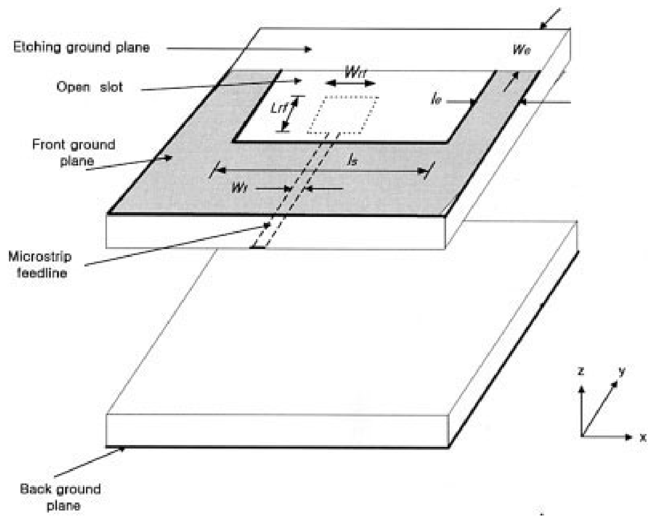

Figure 1 Structure and design parameters of the POSA with reflector

In this paper, we propose a new structure for a rectangular-fed printed open-slot antenna with reflector, which has the advantages of improved radiation-pattern properties along with broad-bandwidth characteristics. The printed open-slot antenna (POSA) is designed to be etched on the horizontal side of the ground plane of a rectangular slot, while the printed closed-slot antenna (PCSA) is designed not to be etched on the horizontal side of the ground plane of a rectangular slot. In this case, the proposed antenna not only obtained wider bandwidth, but also better radiation patterns characteristics than the antenna not etched on the ground plane. The measured bandwidth of the proposed POSA with reflector is approximately 47.6% (-10 dB $\geq S_{11}$); thus, it can be used for PCS, IMT-2000, and WLL with an antenna at the same time. But the measured bandwidth of the PCSA with reflector is approximately 46% (with VSWR $\leq$ 2.0). The radiation-pattern null and distortion of the POSA with reflector exhibited better performance than those of the PCSA with reflector. The back-lobe level of the POSA with reflector also presented much results better than the PCSA with reflector. The proposed POSA with reflector obtained not only wider bandwidth but also better radiation-pattern characteristics than the POSA with reflector. The offset and other design parameters of the antenna lead to good impedance matching in a wide-frequency band. Etched the ground plane lead to the wider bandwidth and fewer null-radiation patterns. As discussed in this paper, this antenna can be easily implemented at microwave frequencies and exhibits broadband performance and good radiation patterns.

2. ANTENNA STRUCTURE AND EXPERIMENTAL RESULTS

Figure 1 shows the structure and design parameters of the POSA with reflector, which consists of an open slot, a rectangular feed line, and a reflector, where l_s is the slot length, W_s is the slot width, *offset* is the gap from the y-directional slot center to the center of cross-shaped feed line, W_{rf} is the horizontal-feed-line length, L_{rf} is