# CLASS F POWER AMPLIFIER INTEGRATED WITH CIRCULAR SECTOR MICROSTRIP ANTENNA

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## *ABSTRACT*

*A high efficiency class F power amplifier integrated with a circular sector microstrip antenna is reported. To obtain the class F operation, the second and third harmonics are shaped through the input impedance of the antenna. At the operating frequency of 2.55GHz, a power added efficiency of 63% is demonstrated.*

## INTRODUCTION

In recent years, there has been a strong demand to increase the power added efficiency (PAE) of transmitter in mobile communication systems. One of the techniques for improving PAE is to tune the output circuit of the amplifier of the harmonic frequencies. In [1] the PAE is increased by short circuiting the impedance of the output circuit at even harmonics. In [2] the first three harmonic load terminations are controlled independently using the active load pull technique. There are many more examples which use additional circuitry to tune harmonics.

In active antenna design, the harmonics can be shaped using the radiator. This method does not require any additional circuitry, and can give more compact and simpler design. In [3]-[4] the rectangular patch antenna was shaped in two different ways to provide the optimum impedance at the second harmonic. Unfortunately, the rectangular patch antenna does not provide the ideal termination for the third harmonic. Therefore, we investigated the annular, annular sector, and circular sector antennas [5], which offer additional degrees of freedom. In this paper the circular sector microstrip antenna is used, but this is not the only structure that can provide the desired terminations at the second and third harmonics.

## ANTENNA DESIGN

The circular sector microstrip antenna used is shown in Fig. 1. The input impedance of the antenna is measured using a network analyzer, and is shown in Fig. 2. The operating frequency is 2.55 GHz, which is slightly off the first resonance, and allows easier power matching. The real part of the input impedance at the second and third harmonic frequencies is almost zero. The measured radiation pattern of the antenna is shown in Fig. 3. The E-plane co-polarization pattern exhibits ripples due to the finite ground plane. The relative cross-polarization levels for both the E- and H-planes are below -16 dB in all directions.

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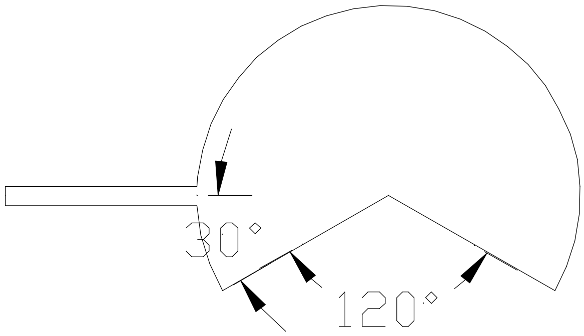


Fig. 1: The circular sector microstrip antenna used as the radiator and harmonic tuner.

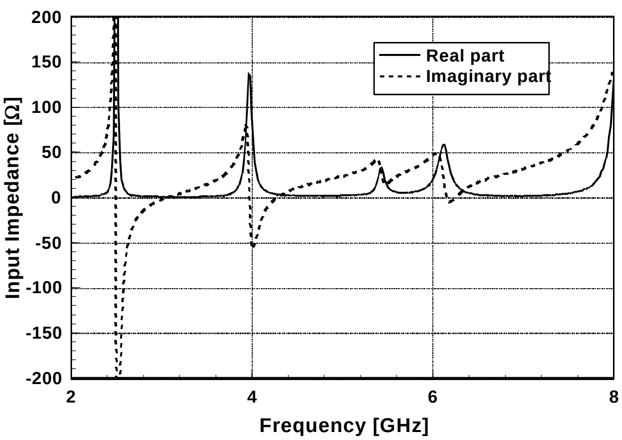


Fig. 2: The measured input impedance of the antenna shown in Fig. 1.

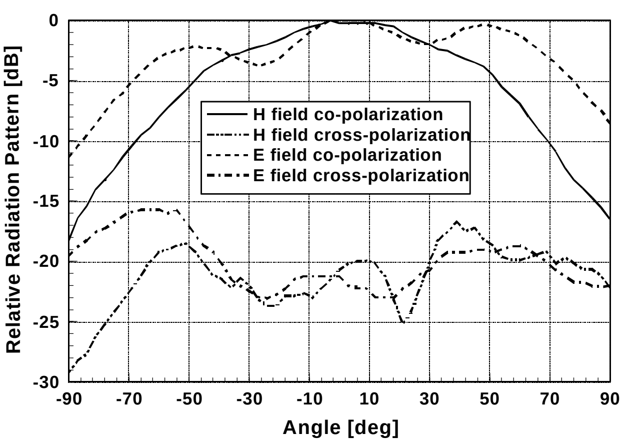


Fig. 3: The radiation pattern of the antenna shown in Fig.1.

## POWER AMPLIFIER DESIGN

The device selected is the MicroWave Technology MWT-8HP GaAs FET, having the 1200 micron gate width. The drain bias voltage is 5 V, while the gate bias voltage is set so that the DC drain current is 10% Idss. A nonlinear model of the device and harmonic balance simulation including the first four harmonics are used in the design. The simulator used is Hewlett Packard's Microwave Design System (MDS) [6]. The antenna is incorporated in the simulation as an one port device containing the S-parameter data from 0.13 to 14GHz.

## RESULTS AND DISCUSSION

The antenna only and the amplifier integrated with antenna (see Fig. 4) were fabricated on RT/Duroid 5870 ($\varepsilon_r$ = 2.33, tan$\delta$ = 0.0012). The measurements were done in the anechoic chamber using the Friis free space formula [7]. First, the gain of the passive antenna was measured at the broadside and it was 5.8 dB. Then, the passive antenna is substituted with the power amplifier integrated with antenna. This measurement method eliminates any systematic errors. The results are shown in Fig. 5, 6, and 7. The output power and PAE in Fig. 5 and 6 were calculated based on the amplifier gain only (and do not include the antenna gain). The maximum measured PAE is 63% at an output power of 24.4 dBm. MDS predicted the maximum PAE of 61% at 24.2 dBm. Fig. 7 shows the increase in the average DC drain current due to the self-biasing effect. Fig. 8 shows the simulated drain voltage waveform. It deviates from the "ideal" square voltage waveform due to the parasitics in the device package and more accurate device model than in [8]. Similar drain voltage waveform for the class F amplifier was reported in [2].

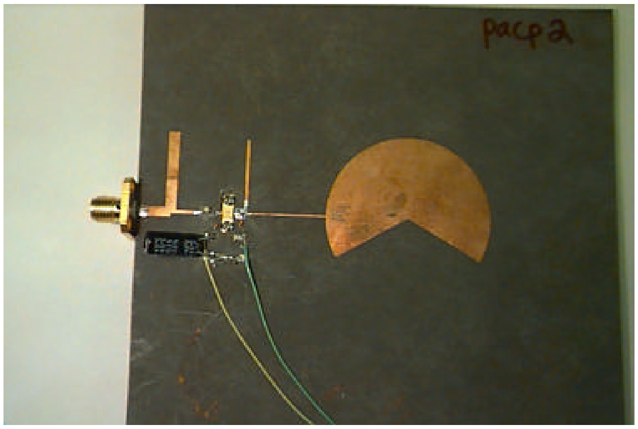


Fig. 4: The picture of the power amplifier circuit integrated with antenna.

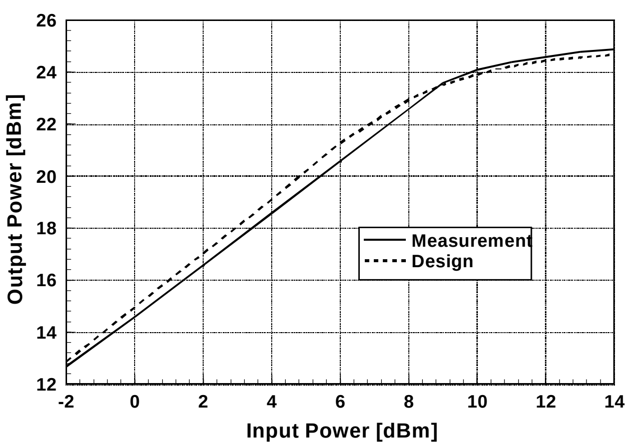


Fig. 5: Measured and simulated (MDS) output power of the amplifier versus the input power.

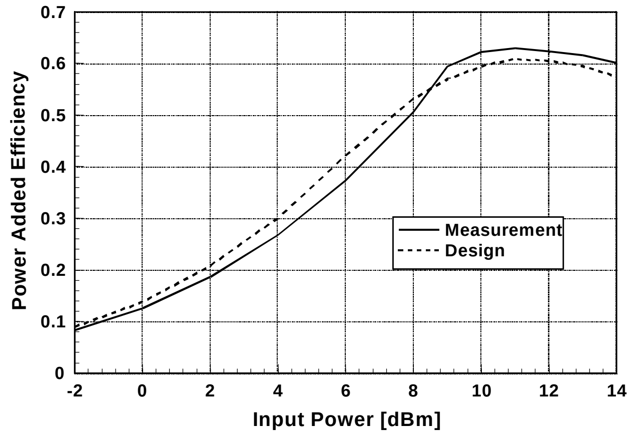


Fig. 6: Measured and simulated (MDS) power added efficiency of the amplifier versus the input power.

## CONCLUSION

A class F GaAs FET power amplifier integrated with a circular sector antenna was presented. The maximum PAE of 63% was measured at the operating frequency of 2.55 GHz and an output power of 24.4 dBm. The tuning of the second and third harmonics is achieved through the input impedance of the antenna.

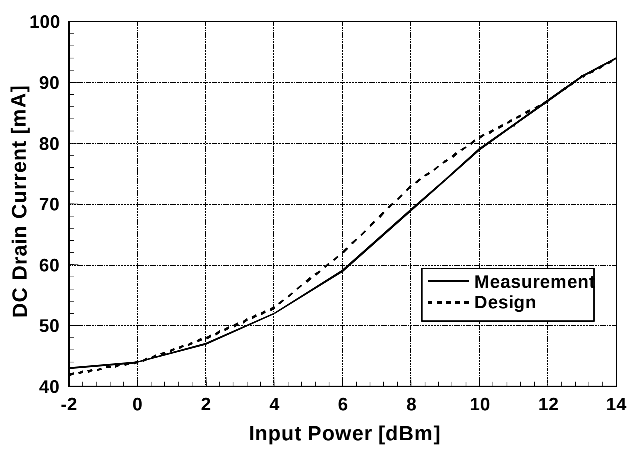


Fig. 7: Measured and simulated (MDS) DC drain current of the amplifier versus the input power.

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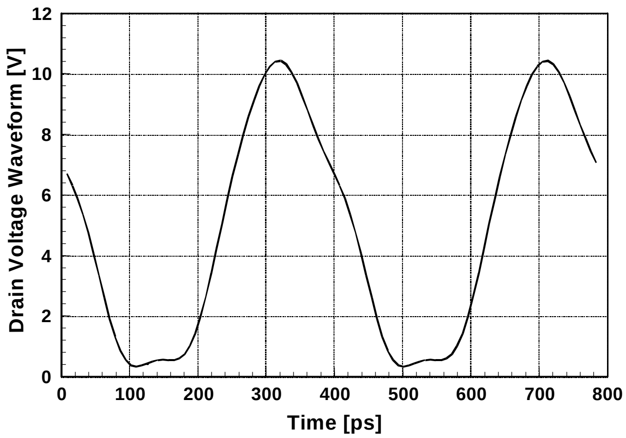


Fig. 8: Simulated (MDS) drain voltage waveform.

## ACKNOWLEDGMENT

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