BROADBAND POWER AMPLIFIER INTEGRATED WITH SLOT ANTENNA AND NOVEL HARMONIC TUNING STRUCTURE

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ABSTRACT

A high efficiency class AB GaAs FET power amplifier integrated with a slot antenna has been designed and fabricated. Broadband second harmonic tuning was achieved using a microstrip line with a periodically etched ground plane. Power-added efficiency greater than 50% was achieved in the 3.7-4.0 GHz bandwidth.

INTRODUCTION

Advances in wireless communications systems require high efficiency transmitters. Since the majority of power is consumed in the output power amplifier, the emphasis is to increase its power-added efficiency (PAE). Usually load impedances of the fundamental and/or a few harmonics are controlled to achieve maximum PAE. A tuned class B power amplifier was reported in [1], where source and load second harmonic impedances are controlled using approximate short circuits. There are many other examples of tuned amplifiers that use transmission lines to optimize impedance at second, third, or both harmonics [2]. Unfortunately, most of these techniques are narrowband.

In this paper, broadband second harmonic tuning is achieved using a microstrip filter based on photonic band-gap (PBG) concept [3]. PBG is a periodic structure which prohibits wave propagation in certain frequency bands [4]. In this work, two-dimensional (2-D) structure based on etching a periodic 2-D pattern in the microstrip ground plane is used [3]. This structure has a stopband that is generally wider than the one achieved using a single or double stub. Therefore it can be used to reactively terminate second harmonic in a wide frequency range.

The active integrated antenna approach is used to design the power amplifier. In the active antenna approach, circuits and devices are efficiently combined with a printed antenna. The circuit does not have to be terminated in 50 Ω, but rather in a value that optimizes performance of the circuit. This results in reduction of size and cost, as well as improvement in circuit performance. The microstrip fed slot antenna is chosen as a radiator, because it has wider bandwidth than microstrip patch antennas.

PBG DESIGN

The periodic structure consists of 2-D square lattice of circles etched in the microstrip ground plane, as shown in Fig. 1. The substrate used is 31-mil-thick RT/Duroid 5870 (ε_r=2.33). The lattice period is 480 mil, and circle radius is 110 mil. The structure has 4×3 cells. Microstrip line width is 90 mil, corresponding to 50 Ω line for conventional microstrip. The microstrip PBG structure changes the physical properties of

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transmission line, and creates a distinctive stopband, as shown in Fig. 2.

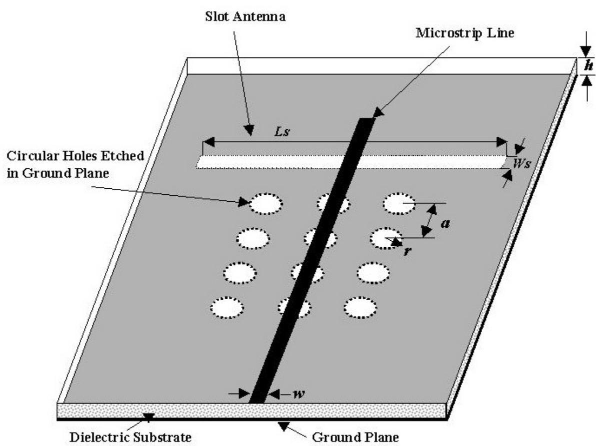

Figure 1. Three-dimensional view of 2-D periodic structure used to tune the second harmonic and slot antenna. The square lattice circles of radius *r*=110 mil are etched in the microstrip ground plane. The period *a* is 480 mil. The microstrip line width *w* is 90 mil. The slot length is *Ls*=2200 mil, and width is *Ws*=130 mil.

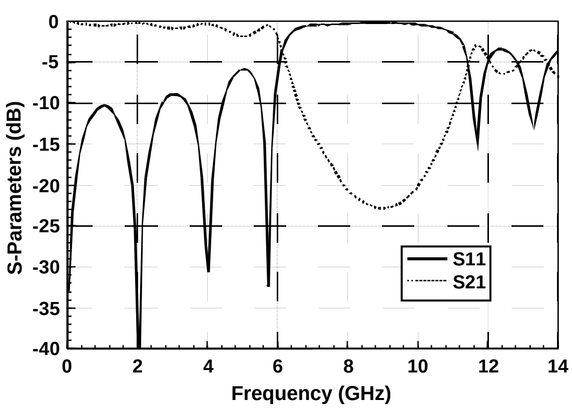

Figure 2. Measured S-parameters of the periodic structure consisting of 4×3 circles etched in the microstrip ground plane. The period is 480 mil, and the circle radius is 110 mil.

ANTENNA DESIGN

The layout of the slot antenna is shown in Fig. 1. The length and width of the slot are 2200 mil and 130 mil, respectively. The slot length corresponds to approximately one wavelength at the operating frequency. One wavelength slot typically has wider bandwidth than half-wavelength slot. The microstrip feed line extends 467 mil across the slot, which roughly corresponds to one-quarter wavelength at the operating frequency. The antenna was designed using finite-difference time domain (FDTD) method. The return loss is measured using a network analyzer. Fig. 3 shows FDTD and measured return loss of the slot antenna. The measured slot antenna radiation pattern is shown in Fig. 4. The E-plane co-polarization pattern exhibits slight ripples and asymmetry due to the finite ground plane and feed line. The relative cross-polarization levels for both the E- and H-planes are below -15 dB in all directions. The radiation field is bi-directional and causes a 3 dB gain loss, which can be undesirable for some applications. The slot antenna can be made unidirectional by using a ground plane reflector behind the circuit [5], or backing it with a cavity. These options were not pursued in this paper since the bi-directional antenna was not a problem. The antenna gain was measured in an anechoic chamber using Friis transmission formula [6], and is shown in Fig. 5.

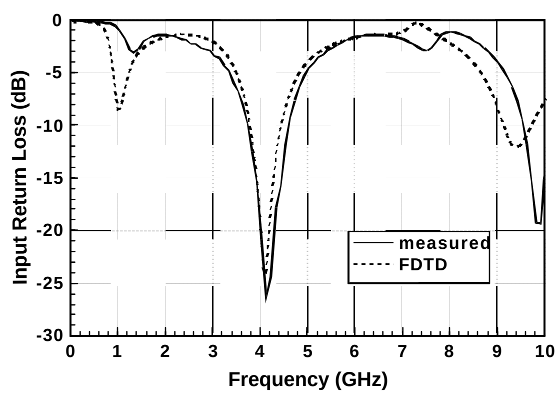

Figure 3. Measured and FDTD return loss of the slot antenna with microstrip feed. The length and width of antenna are 2200 mil and 130 mil, respectively. The microstrip feed line extends 467 mil across the slot.

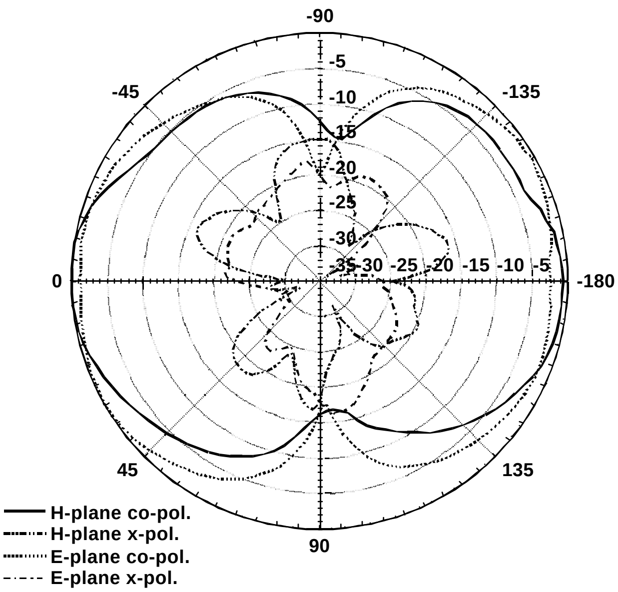

Figure 4. The relative radiation pattern of the slot antenna with microstrip feed. The antenna dimensions are the same as in Fig. 3.

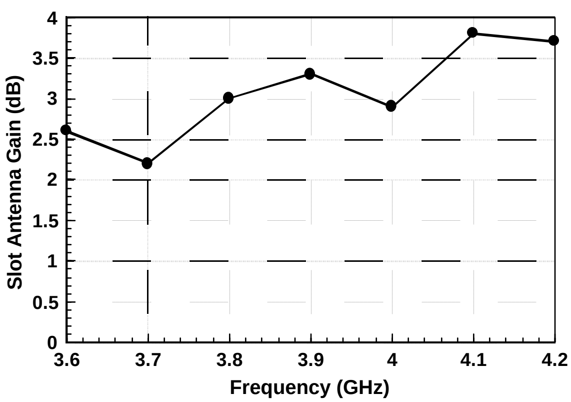

Figure 5. Measured gain of slot antenna with microstrip feed. The antenna dimensions are the same as in Fig. 3.

POWER AMPLIFIER DESIGN AND MEASUREMENTS

A class AB power amplifier integrated with the slot antenna and periodic structure was designed using Hewlett Packard's Microwave Design System (MDS) harmonic balance analysis [7]. The device selected is the MicroWave Technology MWT-8HP GaAs FET, which has 1200 micron gate width. Drain bias voltage is 5 V, while gate bias voltage is set so that quiescent drain current is 10% I_{DSS}. The antenna and periodic structure were incorporated in the simulation as one and two port S-parameter files containing data from 0.13 to 20 GHz.

The antenna alone and the amplifier integrated with the antenna and PBG were fabricated on RT/Duroid 5870. The measurements were done in the anechoic chamber using the Friis free space formula [6]. First, the gain of the passive antenna was measured at the broadside. Then, the passive antenna was substituted with the power amplifier integrated with antenna and PBG. This measurement method eliminates any systematic errors. Fig. 6 shows measured and simulated (MDS) (a) output power and (b) PAE for the power amplifier. The measured PAE is better than 50 % from 3.7 to 4.0 GHz (8 % bandwidth). The maximum measured PAE is 65% for output power of 23.9 dBm at 3.9 GHz.

CONCLUSION

C band high efficiency GaAs FET power amplifier integrated with a slot antenna was demonstrated. A PBG based periodic structure is used to tune the second harmonic. The experimental results show that this structure can be used to design broadband tuned class AB amplifiers. The measured PAE is above 50 % over 8 % bandwidth.

ACKNOWLEDGMENT

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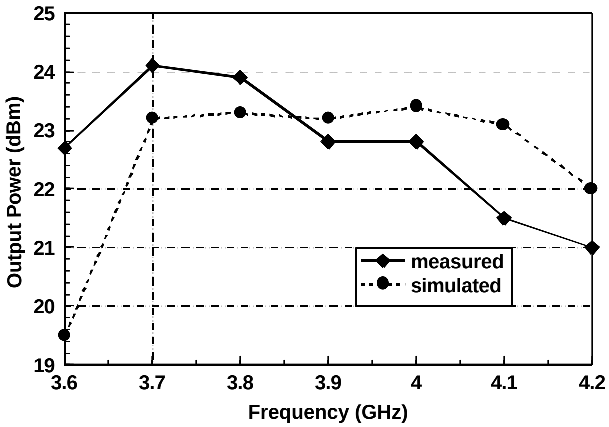
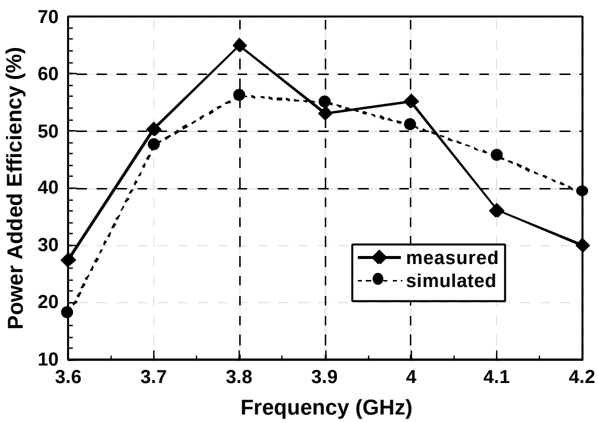


(a)



(b)

Figure 6. Measured and simulated (MDS) (a) output power and (b) power added efficiency of the power amplifier versus frequency. The operating frequency range is from 3.7 to 4.0 GHz.

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