Broad-Band Power Amplifier Using Dielectric Photonic Bandgap Structure

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***Abstract*— Two class AB GaAs field-effect transistor (FET) power amplifiers have been designed and fabricated in the 4.4–4.8 GHz range. In the first case, a dielectric PBG line was incorporated in the design to tune the second harmonic. In the second case, a 50-Ω line is used with no harmonic tuning. The PBG structure allows broad-band harmonic tuning and is inexpensive to fabricate. A 5% improvement in power-added efficiency was achieved at the design frequency of 4.5 GHz, in both simulation and measurement.**

***Index Terms*—Class AB, FET, PBG, power amplifier.**

I. Introduction

HIGH-EFFICIENCY power amplifiers have beneficial effects on an amplifier's size, weight, output power, and reliability. Many different types of high-efficiency power amplifiers have been reported, e.g. class AB [1], B [2], E [3], and F [4]. Henderson *et al.* have reported a class AB SiGe BJT power amplifier with 53% power-added efficiency (PAE) at 1.88 GHz with no harmonic termination [1]. However, load impedances for the fundamental and harmonics are typically optimized to maximize the PAE and/or output power.

Several conventional techniques exist for harmonic termination. The tuning of the second harmonic is usually done by adding a short-circuited stub approximately one quarter-wavelength long at the fundamental frequency at the output [2], [5]. A similar stub is used for tuning the third harmonic. Alternatively, chip capacitors with a self-resonance near the second harmonic can be used [6]. In the active antenna approach, harmonics can be tuned using the input impedance of the antenna [4], [7]. Unfortunately, all of these techniques are narrowband.

We propose a broad-band matching technique that incorporates photonic bandgap (PBG) materials [8] into microstrip circuits. PBG's are periodic structures in which certain bands of frequencies cannot propagate. Because their stopband is wider than that of quarter-wavelength stubs, they can be used to design broad-band high-efficiency amplifiers. Here we concentrate on two-dimensional (2-D) PBG structures compatible with microstrip transmission lines [9].

II. PBG Design

The PBG structure selected is a 2-D honeycomb lattice with circular holes around 50-Ω microstrip line, shown in Fig. 1.

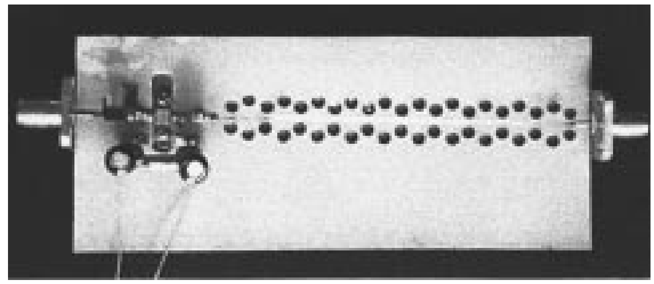

Fig. 1. Photograph of power amplifier showing the PBG structure incorporated at the output.

The substrate used is RT/Duroid 6010 with dielectric constant of 10.5 and 50 mil thick. The period is 250 mil and hole radius is 50 mil. This is a 2-D PBG structure, but because the fields in the microstrip line are concentrated near the line only one row of cells is necessary. It was fabricated by drilling the holes through the substrate and then adding copper tape onto the ground plane. This technique for incorporating PBG into microstrip circuits is simple and inexpensive. This structure is compared to 50-Ω microstrip line without PBG holes. Both structures were fabricated and measured using HP 8510 Network Analyzer. Fig. 2 shows (a) finite-difference time-domain (FDTD) simulated and (b) measured results for reflection (S_{11}) and transmission (S_{22}) coefficients for PBG microstrip line. A relatively broad stopband is observed in both FDTD simulation and measurement. The peak of the stopband is at 9.07 GHz for FDTD and at 8.91 GHz for measurement.

III. Power Amplifier Design

Two class AB amplifiers were designed using Hewlett Packard's Microwave Design System (MDS) [10]. The device used was the MicroWave Technology MWT-8HP power GaAs FET. The large-signal model of this device (which was in the MDS's nonlinear library) and harmonic balance simulation including the first three harmonics were used in the design. The drain voltage is 5 V, while the gate is biased so that the quiescent drain current is 10% I_{DSS}. The microstrip line with and without the PBG were incorporated into MDS simulation as two-port devices containing the measured S-parameter data from 0.13 to 26 GHz. The input matching consists of double stub tuner and chip capacitor. The output match has a transmission line, chip capacitor and either PBG or 50-Ω transmission line.

IV. Results

Fig. 1 shows the amplifier with PBG structure. A comparison amplifier was also fabricated, and a simple 50-Ω microstrip

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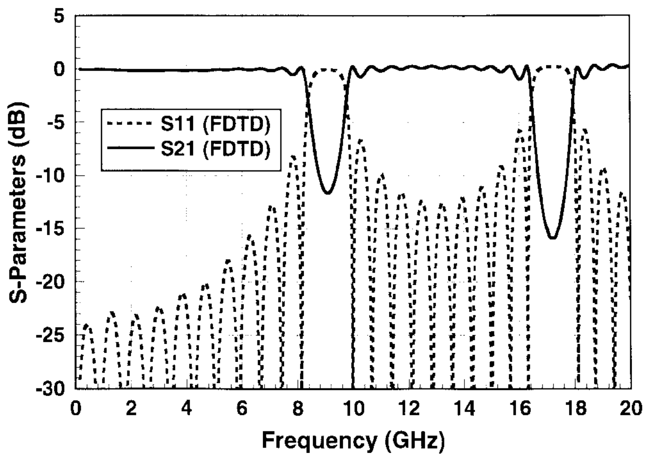
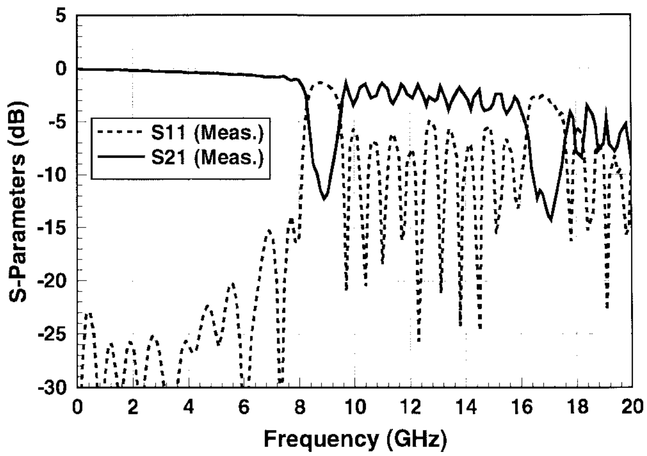


(a)



(b)

Fig. 2. (a) FDTD simulated and (b) measured S-parameters for the PBG line shown in Fig. 1.

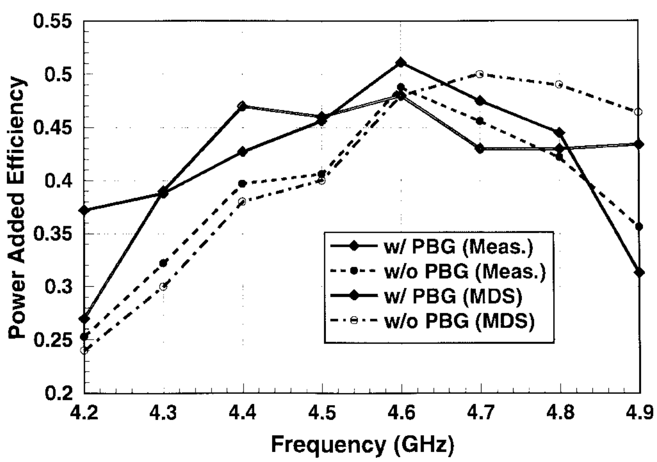


Fig. 3. Measured and theoretical (MDS) PAE efficiency versus frequency for both amplifiers. "w/pbg" means that the second harmonic is tuned using the PBG structure shown in Fig. 1.

line of the same length as the PBG line was connected at the output. Fig. 3 shows the measured and simulated (MDS) PAE for both amplifiers. The measured PAE is above 40% from 4.4 to 4.8 GHz (9% bandwidth) for the PBG amplifier, and 4.5 to 4.8 GHz (6% bandwidth) for the reference amplifier.

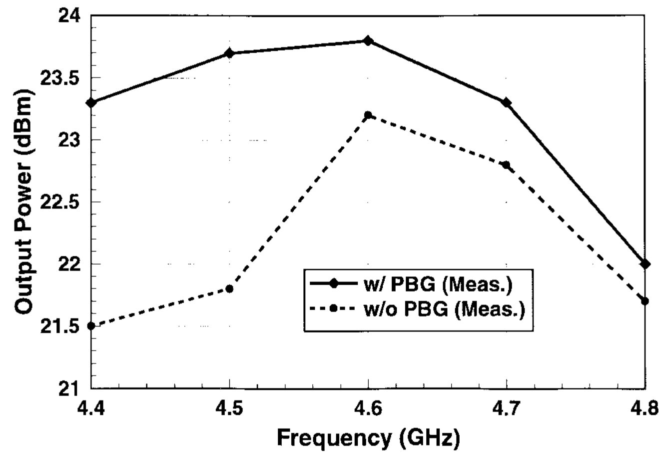


Fig. 4. Measured output power versus frequency for both amplifiers. "w/pbg" means that the second harmonic is tuned using the PBG structure shown in Fig. 1.

The maximum measured PAE is 51% for output power of 23.7 dBm at 4.6 GHz for the PBG amplifier. Fig. 4 shows the measured output power for both amplifiers. An increase of at least 0.3 dB in the measured output power throughout the frequency band of interest is demonstrated.

V. Conclusion

We have demonstrated a novel class AB GaAs FET power amplifier which incorporates PBG structure to terminate the second harmonic. A 5% improvement in PAE was measured at the center frequency of 4.5 GHz compared to the reference amplifier. Increase of over 0.3 dB in output power was measured over 9% frequency bandwidth.

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