A Novel Design of High Power Amplifier Employing Photonic Band Gap in Millimeter Wave Band

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Abstract

In this paper, we have designed and fabricated the high power amplifier employing PBG(Photonic Band-Gap Structure) to improve the linearity of the amplifier in the millimeter wave band. The fabricated amplifier using MMIC(TGA1073G) has operated about 24 GHz band and the PBG has resulted in 35 dB suppression about 49 GHz where the second harmonic occurs due to the amplifier. As a result, the output power has been 24.43 dBm and 13.2 dBc of the IMD has been improved. Also, the PAE is obtained to 14.96 % of the amplifier employing the PBG structure in Ka band.

Key words : PBG, IMD, Output Power, Ka-band, HPA.

Ⅰ. Introduction

The PBG structure that is using the periodic discontinuous structure has the suppression characteristics on some frequency band. This is originated from the research on the bragg lattice of the optical science. Later, many researches to improve micro-strip circuit of microwave band have been performed by employing PBG on the ground of these circuits. For example, these researches have been on antenna with better radiation pattern[1]~[3], broadband attenuator[4], and power amplifier with better PAE and linearity[5],[6]. There has been considerable of interests within the communication industry in producing high power amplifiers with the power efficiency. There have been many kinds of researches on amplifier employing the PBG structure performed on relatively low RF frequency like 2.4 GHz and 5.8 GHz. But there have been no reports about the PBG structure amplifier operated in millimeter frequency band.

In this paper, we designed the PBG structure and fabricated it on the ground of the output line of the high power amplifier in millimeter wave band. The PBG structure was optimized to suppress the second harmonic of the amplifier. The designed PBG structure has better the stop band characteristics and occupies smaller area than the conventional PBG. As a result, we improved the IMD of 3.8 dBc with the same output power.

Ⅱ. PBG Design

Generally, the PBG structure has been designed to satisfy Eq. (1). The Λ is period of lattice and λ is the wavelength of corresponding frequency which is to be suppressed

$$\Lambda = \frac{\lambda_g}{2} \tag{1}$$

In references [7], [8], various lattices were located in series and parallel, respectively so that can obtain the broadband suppression characteristics. However, when we consider the PBG structure for the linearization of amplifier, we must regard the second harmonic of amplifier as the most important factor to improve the third IMD. Therefore, we can reduce the PBG size, if we can design the PBG suppressing only the second harmonic of the amplifier and having shorter lattice period than conventional PBG instead of having broadband suppression characteristics.

Fig. 1 shows the change of stop band characteristics with various widths W of the PBG. Two lattices were located on the ground of micro-strip 50 Ω line. The allumina substrate having dielectric constant of 9.8 and thickness of 10 mil (0.254 mm) was used for simulation. Simulation tool has been used to the HFSS of Ansoft. PBG lattices are simplified to minimize the parasitic effects in millimeter wave band. As the width W of the PBG has been increased, the suppression band has shifted to the lower frequency. It has determined the suppression characteristics of band. But the wide width W center conductor has resulted in increasing the ripple and the loss in pass band.

Fig. 2 shows the stop band characteristics of the conventional and the proposed PBG. In case of the

Manuscript received December 30, 2005 ; revised May 22, 2006. (ID No. 20051230-050J)
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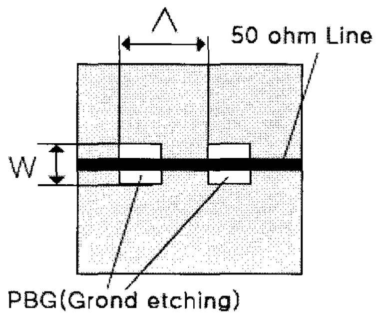
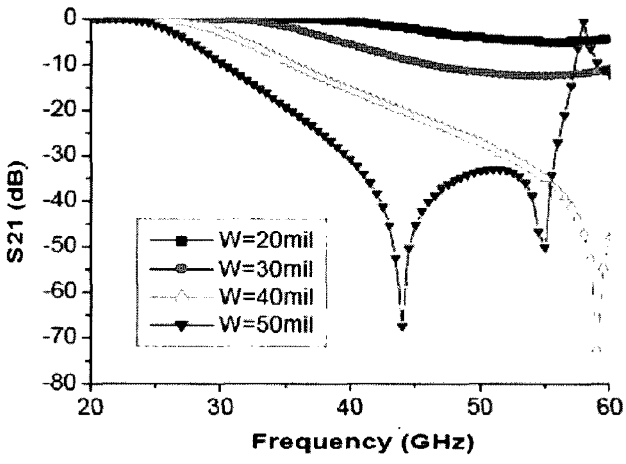
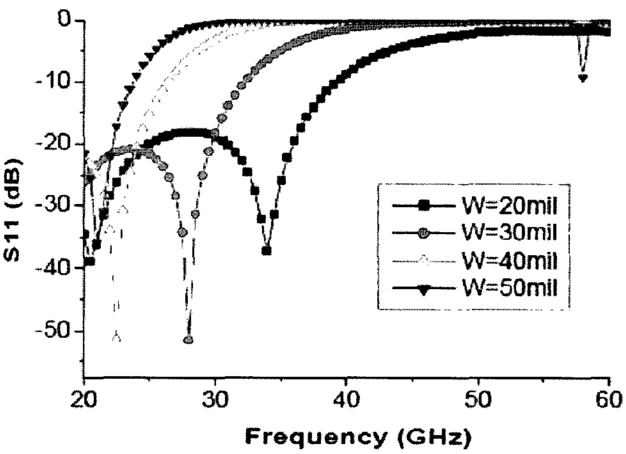


(a) Simulated PBG structure

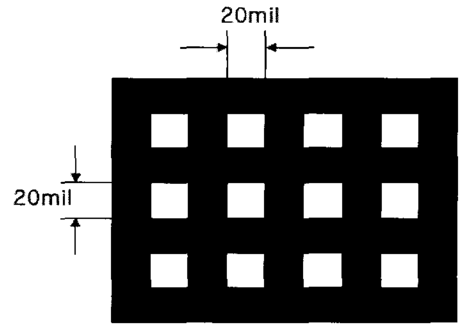


(b) Simulated S_{21}

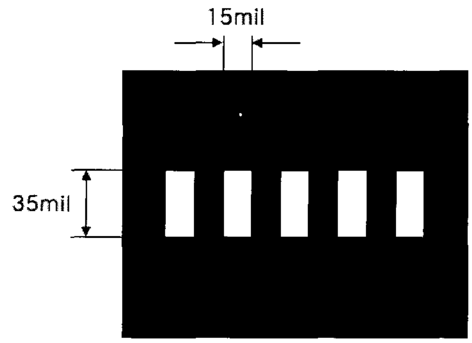


(c) Simulated S_{11}

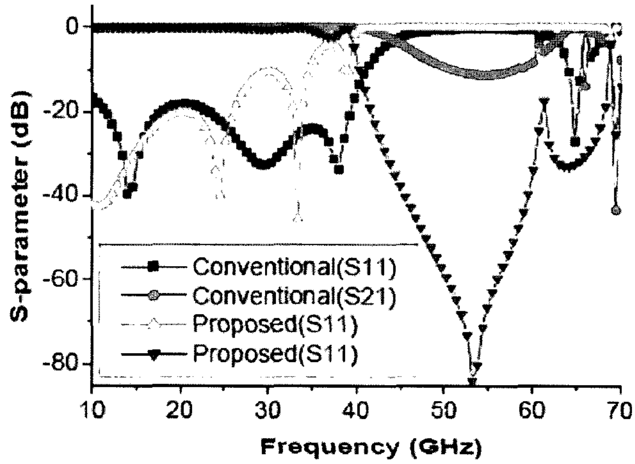
Fig. 1. PBG with various width W.



(a) Conventional PBG(20×20 mil)



(b) Proposed PBG(15×35 mil)



(c) Simulated result

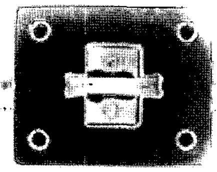
Fig. 2. Comparison of conventional and proposed PBG.

proposed PBG shown in Fig. 2(b), we increased the width W of the PBG and shorten the period so that the proposed PBG has same stop band as the conventional PBG structure. Fig. 2 implies the proposed PBG suppressed the second harmonic more effectively, if we want to eliminate only the second harmonic of the amplifier.

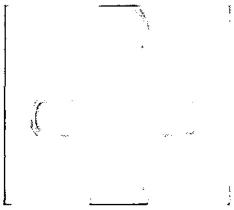
Fig. 3 shows the frequency response of the fabricated PBG. It shows 35 dB or more suppression over 49 GHz that is the second harmonic band of the amplifier. The insertion loss and the return loss at 24.5 GHz have been 27 dB and 0.927 dB, respectively. The insertion loss is rather bigger compared with the simulation results. This comes from the connector loss, the ribbon bonding loss and the loss of the PBG itself.

Ⅲ. Millimeter Wave High Power PBG Amplifier

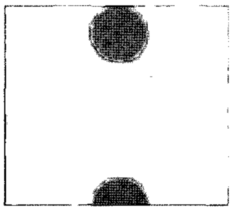
We fabricated the Ka-band millimeter wave high power amplifier. TGA 1073G MMIC having 22 dB of



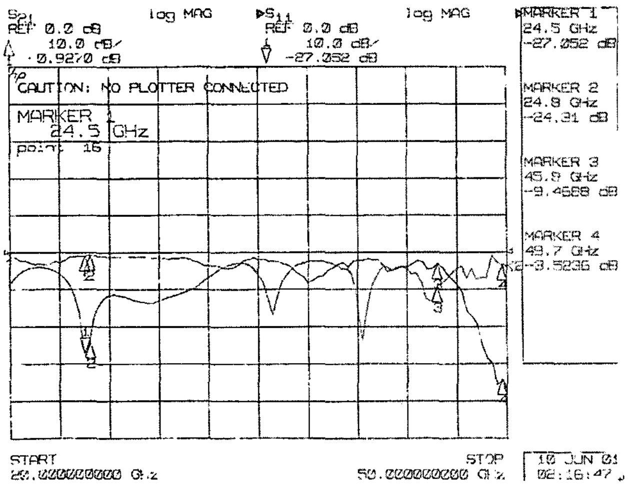
(a) Top view with jig



(b) Bottom view

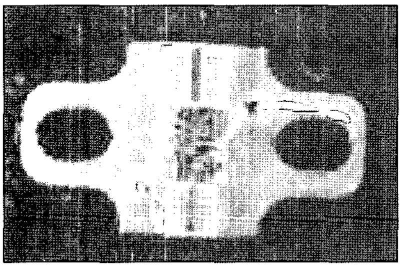


(c) Top view

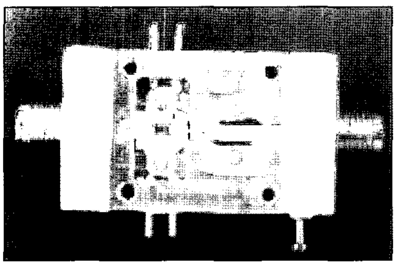


(d) Measured response

Fig. 3. Fabricated PBG and frequency response.



(a) S_{21} and S_{11}



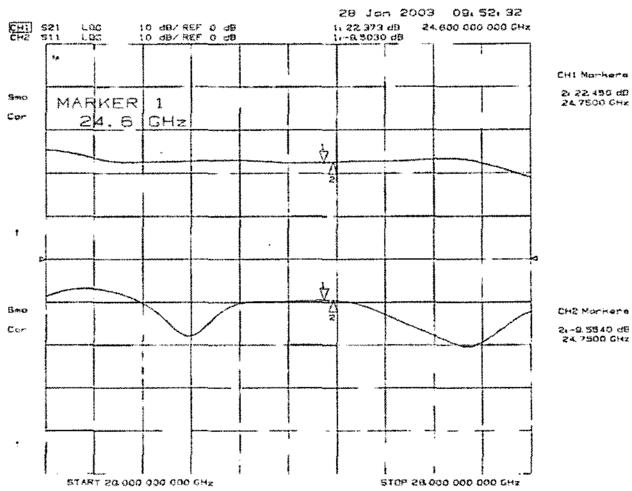
(b) S_{22} and S_{12}

Fig. 4. The fabricated amplifier.

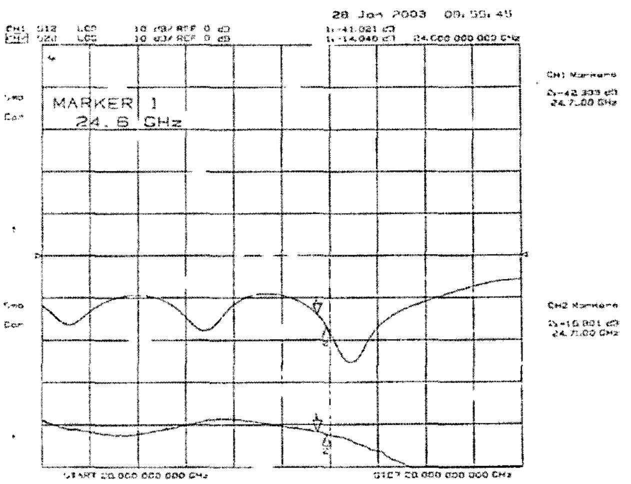
gain and 25 dBm of P1 dB were used. The process of measurement is as follows. First, we connected the 50 Ω line to the jig made in normal temperature, and measured the gain and the IMD of the amplifier. Second, we exchanged the 50 Ω line-width the manufactured PBG carrier, and measured the amplifier again. Third, we compared the first and the second results. We exchanged only a carrier for the precise comparison, and so any other affects are minimized.

Fig. 4 shows the fabricated amplifier employing the proposed PBG structure. The carrier right side in the jig has been for 50 ohm line or PBG. Fig. 5 shows the S-parameter of the amplifier. S parameters obtained at 24.6 GHz of millimeter power amplifier are as follows: the magnitude of S_{11}=−9.5 dB, S_{21}=22.4 dB, S_{22}=−14 dB.

Fig. 6 shows the IMD of the conventional and the proposed amplifier. The output power level has been 17 dBm per the tone. The input power level was controlled

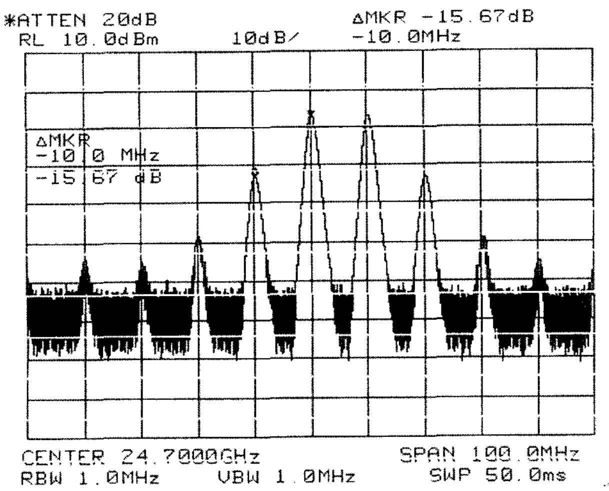


(a) S_{21} and S_{11}

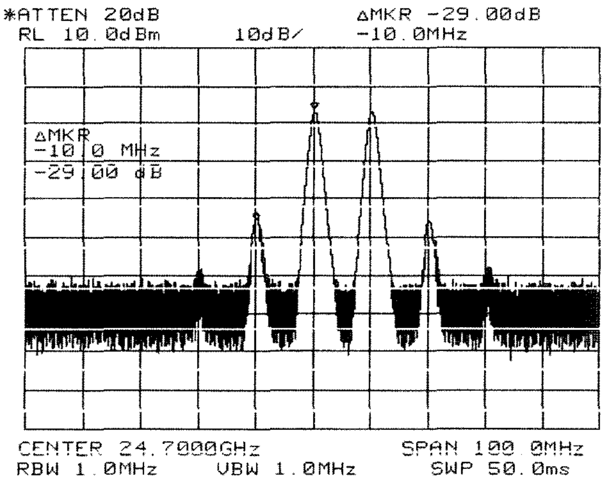


(b) S_{22} and S_{12}

Fig. 5. S-parameter of the fabricated amplifier.



(a) Conventional amplifier



(b) PBG amplifier

Fig. 6. Two tone test for IMD of amplifier.

to equalize the output power level of the conventional and the proposed amplifier. For 20 dBm output power, the input power level per the tone was 1.5 dBm for the conventional amplifier and 5.5 dBm for the proposed amplifier. The third IMD was 15.67 dBc for the conventional amplifier and 29 dBc for the proposed PBG amplifier. In conclusion, we obtained 13.33 dBc improvement of the IMD with 8.5 dBm output power level using the PBG. Fig. 7 shows the IMD of the conventional and the proposed high power amplifier with changing the input power level. Fig. 8 shows the output power level of that of the conventional and the proposed amplifier with same IMD of power level. For −36 dBm IMD power level, the output power level per the tone was 8.83 dBm for the conventional amplifier and 7 dBm for the proposed amplifier.

Table 1 is the comparisons of the PBG amplifier and the conventional one.

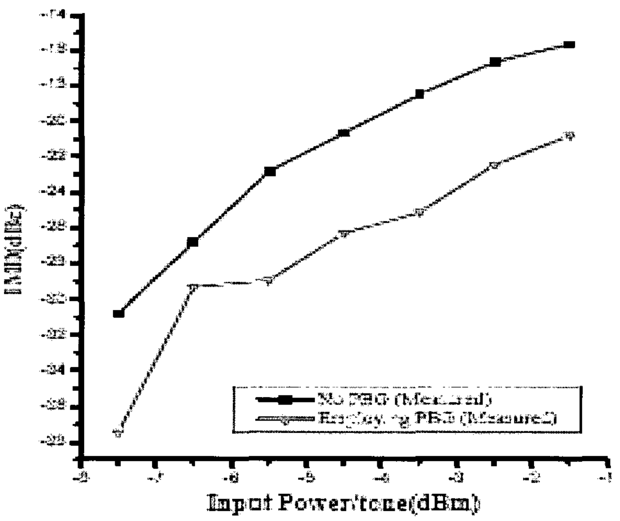
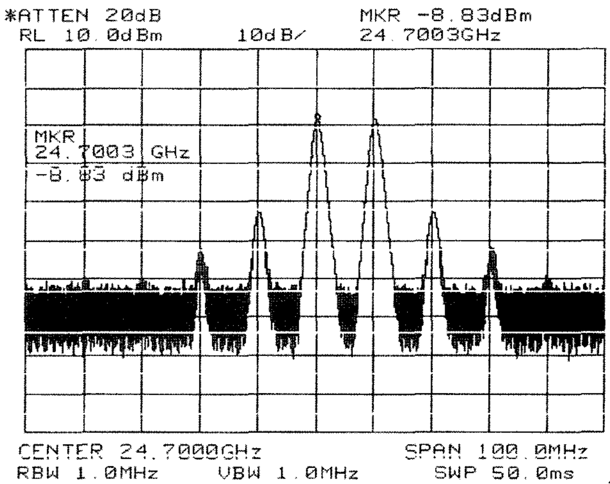
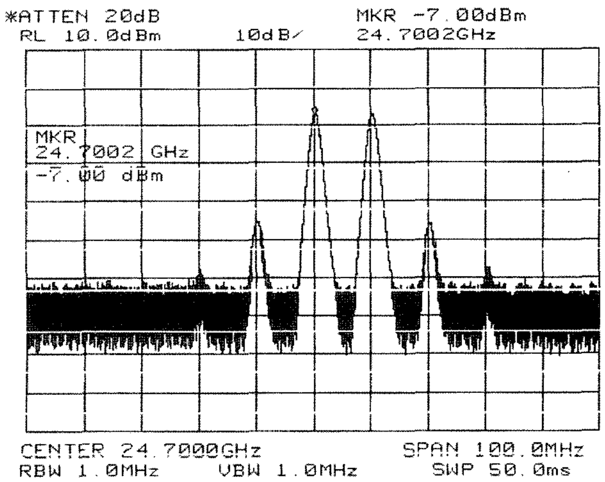


Fig. 7. IMD's power of the amplifier according to the change of the input power.



(a) Conventional amplifier



(b) PBG amplifier

Fig. 8. Two tone test for IMD of amplifier when the output power is same.

Table 1. Conventional amp consider employing amplifier.

	Conventional AMP	Employing AMP
Frequency Range	24.6~24.75 GHz	24.6~24.75 GHz
Gain	21.95 dB	22.37 dB
Gain Flatness	1.0 dB	1.0 dB
Output Power	21.43 dB	24.43 dB
IMD	−15.67 dBc	−29 dBc
PAE	7.2 %	14.96 %

Ⅳ. Conclusions

In this paper, we designed the PBG structure and fabricated the high power amplifier employing the PBG in the millimeter wave band. The PBG has been placed on the output line of the fabricated amplifier. The fabricated PBG suppress the second harmonic of the amplifier more than 35 dB. As a result, we obtained 13.33 dB improvement of third IMD at 24.43 dBm output power level. And then, the PAE of 7.76 % is improved by the PBG structure in millimeter wave band. If the PBG structure is optimized, the PAE will be very improved in millimeter wave amplifier.

This work was supported by Soongsil University Research Fund.

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