Improvement of Broadband Feedforward Amplifier Using Photonic Bandgap

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***Abstract*—In this paper, the photonic bandgap, the predistortion, and the secondary harmonic tuning are simultaneously employed in feedforward amplifier to maximize the power added efficiency (PAE) and the operating bandwidth for in IMT-2000 band. In this case, the secondary harmonic tuning and the predistortion linearizer can cancel the second and the third harmonics, respectively. The PBG prevented any more harmonics to appear over 6 GHz. The feedforward amplifier was improved 4%, and 15 dBc in the PAE and the IMD(Intermodulation Distortion), respectively. The operation bandwidth was achieved twice wider than the conventional feedforward amplifier.**

***Index Terms*—Amplifier, feedforward, harmonic tuning, PBG.**

I. Introduction

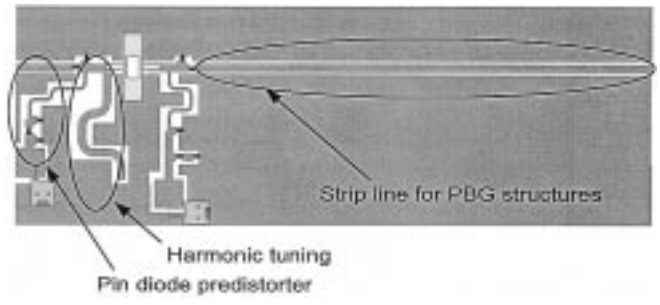
MODERN wireless communication systems are placing new demands on power amplifiers. There is considerable interest within the communication industry in producing high power amplifiers with power efficiency. Feedforward linerarization has been shown to produce amplifiers with excellent linearity [1]–[4]. However, its power efficiency is limited by the requirement for an error amplifier and compensating delay line. The combined use of feedforward and analogue predistortion has good performance on the linearity and the power efficiency, but this method has some complexity on the amp circuits [5].

Photonic band gap (PBG) structures are periodic structures in which certain bands of frequencies are not passed. The WDM system needs very sharp filters to divide the wavelengths of optical signals and uses PBG filter. Now PBG structures are used to improve radiation pattern antenna and increase power efficiency of high power amplifiers in the microwave and millimeter region [6]–[8].

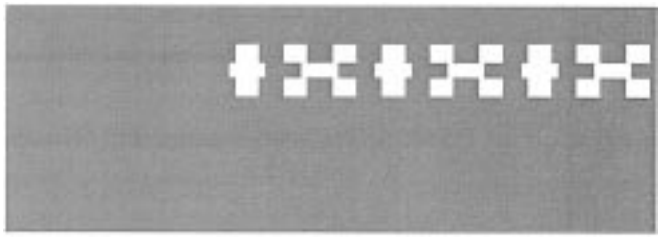
In this paper, the photonic bandgap, the predistortion, and the secondary harmonic tuning are simultaneously employed in feedforward amplifiers to maximize the power added efficiency (PAE) and the operation bandwidth for the IMT-2000 band.

II. Main Amplifier Design and Measurement

The designed and manufactured main amplifier is in IMT-2000 band. NE650 FET has been used and manufactured in order to operate the 4 W class after setting A class operation point in 8 V, 500 mA. The theoretical maximum PAE of high power FET is 45% and the linear gain of it is 11 dB and also the maximum input power of it is 26 dBm. But the PAE of the main amplifier manufactured without the PBG, the predistortion and the secondary harmonic tuning does not exceed 30% because the input to 20 dBm for satisfying the characteristics of IMD 30 dBc on the simulation. Furthermore, the linear gain of the actually manufactured amplifier is 8 dB and it brings 3 dB of attenuation. As a result, it gains the maximum 30% PAE.



(a)



(b)

Fig. 1. Schematic of main amplifier with the PBG, the predistortion, and the secondary harmonic tuning. (a) Top view; (b) bottom view.

Fig. 1 is the main amplifier with the PBG, the predistortion, and the secondary harmonic tuning. Its size increases more than two times by PBG, but the importance of the size comes to relatively decrease in case of application to feedforward. The PBG structure can be achieved in microstrip technology with the periodic pattern in the ground plane and conductor microstrip line having a width of 50 Ω on the top plane by etching, as shown in Fig. 1 [8]. We proposed to fabricate two different PBG structures in parallel on the ground plane to construct two stopband single microstrip plane. For achieving band-stop filter above 6 GHz, the two periods of 15.5 and 10.3 mm were selected.

Fig. 2 shows the simulation characteristics of output power of the main amplifier compared with the measurement ones. As a result of the single carrier level of harmonic two-tone, it can get 31.8 dBm output at the 26 dBm input, but it has to be used in 20–22 dBm input in order for IMD to exceed about 30 dBc. We got IMD from subtract third_IMD power from fundamental power.

The IMD of the main amplifier with the predistortion [9] and the secondary harmonic tuning [10] was improved 12 dBc com-

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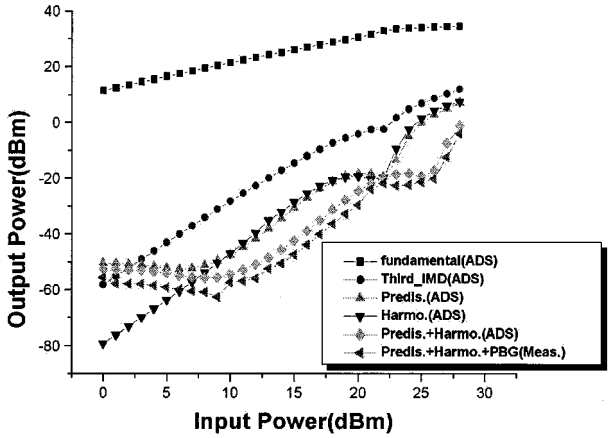

Fig. 2. Theoretical and measurement output power versus input power.

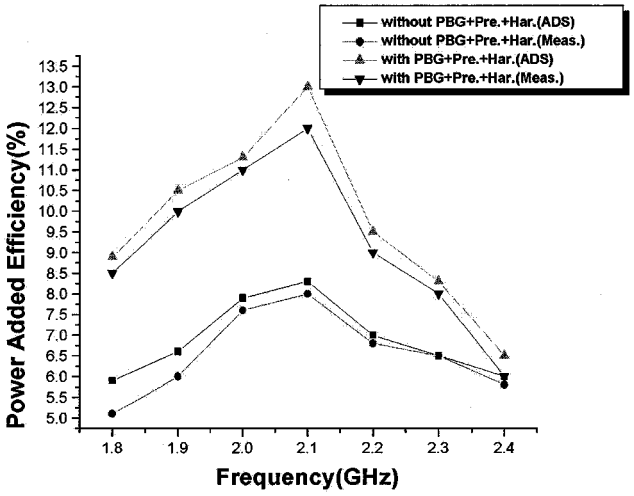

Fig. 3. Theoretical and measurement PAE versus frequency.

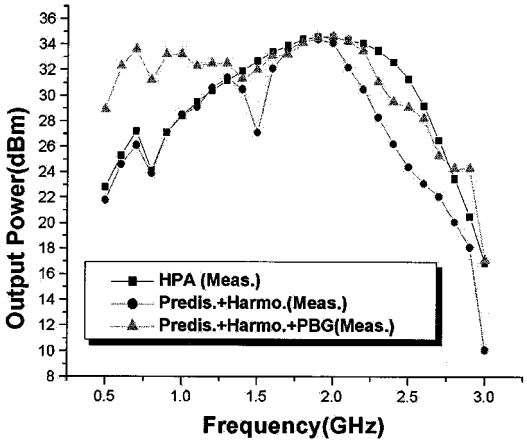

Fig. 4. Measurement of output power versus frequency.

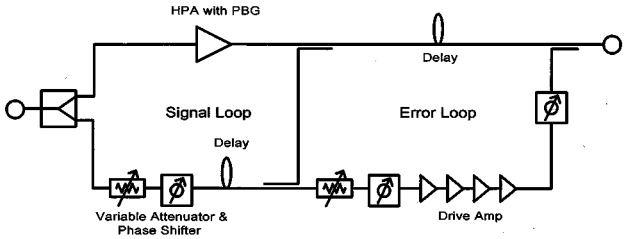

Fig. 5. Block diagram of feedforward.

pared with the conventional main amplifier and additionally increased 3 dBc with PBG. It shows that the improvement of the IMD results in increasing of the PAE because of the linearity impacted on the PAE. This predistortion linearizer utilizes a nonlinearity of a series resistance of the diode. Series pin diode provide positive amplitude and negative phase deviations with the increase of input power.

III. Feedforward Design and Measurement

The purpose of design is to get the characteristics of IMD above 60 dBc with the feedforward when IMD up to 30 dBc of main amplifier. The input power was 20 dBm below without the PBG, the predistortion, and the secondary harmonic tuning. But when the PBG, the predistortion, and the secondary harmonic tuning are simultaneously employed, the characteristics of IMD of the main amplifier get to satisfy 30 dBc, although it adds to about 26 dBm into the input. It is say that 6 dB back-off is not needed. As a result, the PAE increases. When only 20 dBm of input is employed, the IMD of feedforward amplifier becomes 75 dBc with the PBG, the predsitortion, and the second harmonic tuning.

Fig. 3 shows the measured PAE of the feedforward power amplifier. The PAE is, at most, 8% without the PBG, the predistortion, and the secondary harmonic tuning, but it is increased upto 12% with the PBG, the predistortion and the secondary harmonic tuning. Feedforward amplifier output is 26 dBm to be satisfied with IMD 70 dBc. In this case, the efficiency is 12% (total DC power 35.5 dBm for main amplifier, four drive amplifiers, two variable phase shifters, three variable attenuators).

Fig. 4 shows the measurement of 3-dB bandwidth with the PBG, the predistortion, and the secondary harmonic tuning. It has 900 MHz of bandwidth centered on 2.13 GHz, in case of the feedforward amplifier using only general power amplifier, but it shows that the bandwidth is decreased to 400 MHz, in case of using only the predistortion and the secondary harmonic tuning.

Also, in case of using PBG simultaneously, the bandwidth has been greater by two times, 1800 MHz. When only the predistortion and the secondary harmonic tuning are employed, the bandwidth is decreased according to the change of frequency, but the bandwidth and PAE are improved at the same time because it can be compensated using PBG.

Fig. 5 is the block diagram of feedforward. In the actual manufacture, four drive amplifiers with 10 dB gains, two variable phase shifters with 90° phase shift, three variable attenuators with 15 dB attenuation, one 3 dB power divider, and three coupled line couplers are manufactured. The rigid cable is used for coinciding the 6.2 ns of time delay of signal loop and error loop. Feedforward amplifiers are used only to cancel the third_IMD $(2f_1\text{-}f_2, 2f_2\text{-}f_1)$ of the main amplifier without cancellation of the main amplifier fundamental output power. In this case, the main amplifier with the photonic bandgap, the predistortion and the secondary harmonic tuning can cancel the second harmonic $(2f_1, 2f_1)$, third, fourth ... etc., therefore the third intermodulation $(2f_1\text{-}f_2, 2f_2\text{-}f_1)$ can be canceled, effectively.

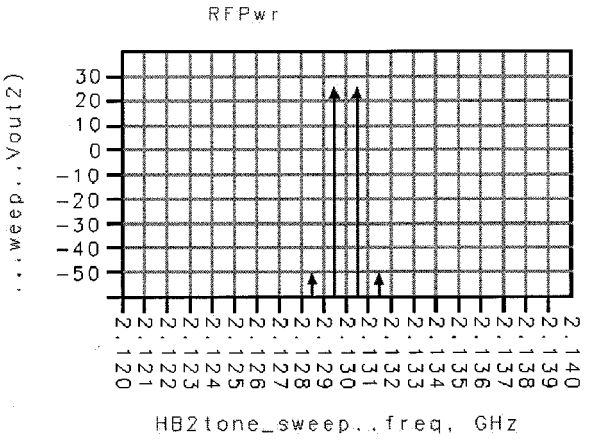

Fig. 6. Two-tone IMD characteristics of the feedforward amplifier.

Fig. 6 shows 1 MHz band harmonic two-tone measurement results with the PBG, the predistortion, and the secondary harmonic tuning to the main amplifier. It shows that the IMD of our amplifier becomes 75 dBc, which is better than 15 dBc compared with that of amplifier without the PBG, the presdistortion, and the second harmonic tuning.

IV. Conclusion

The predistortion and the harmonic tuning method has simultaneously been applied in feedforward amplifier and employed PBG structure on the ground plane to remove the broadband harmonics of the feedforward amplifier. The PAE is up to 4% with the PBG, the predistortion and the secondary harmonic tuning.

The PAE and the IMD were improved 4%, and 15 dBc in PAE and IMD, respectively, in this paper. The operation bandwidth was achieved two times wider than the conventional feedforward amplifier.

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