포락선 검파를 통한 이중 바이어스 조절과 PBG를 이용한 도허티 증폭기 전력효율과 선형성 개선

(Research on the Improvement of PAE and Linearity using Dual Bias Control and PBG Structure in Doherty Amplifier)

김형준*, 서철현**

(Hyoungjun Kim and Chulhun Seo)

요 약

본 논문에서는 이중 바이어스 조절과 PBG 구조를 이용하여 Doherty 증폭기의 효율과 선형성을 개선하였다. PBG 구조를 출력 정합회로에 구현하였으며, 이중 바이어스 조절을 Carrier Amplifier에 적용하여 낮은 입력레벨에서도 Doherty 증폭기의 효율을 개선할 수 있었다. 제안된 구조를 이용한 Doherty 증폭기는 기존의 전력증폭기에 비해 PAE는 8 %, IMD3는 -5 dBc 개선하고, 모든 입력전력레벨에서 30 % 이상의 고효율을 가질 수 있었다.

Abstract

In this paper, the PAE (Power Added Efficiency) and the linearity of the Doherty amplifier has been improved using dual bias control and PBG (Photonic BandGap) structure. The PBG structure has been used to implement on output matching circuit and dual bias control has applied to improve the PAE of the Doherty amplifier at a low input level by applying it to a carrier amplifier. The Doherty amplifier using the proposed structure has improved PAE by 8% and 5dBc of IMD3 (3rd Inter-Modulation Distortion) compared with those of the conventional class AB amplifier. In addition to, it has been evident that the designed the structure has showed more than a 30% increase in PAE for flatness over all input power level.

Keywords: Dual bias control, Doherty amplifier, power added efficiency, power amplifier, PBG

I. Introduction

The significance of high-output amplifiers in wireless communication has been emphasized due to the rapid distribution of mobile communication systems. The current HPA require high power added efficiency and linearity[1]. In a solution for the linearity of conventional power amplifiers, various methods, such as back-off, feedback, predistortion, feedforward, and PBG, have been used. Among these methods, feedforward and predistortion methods have exhibited the disadvantage of requiring additional elements. Thus a PBG based method has been used to implement linearization[2, 3]. In general, a Doherty amplifier has used two different classes of amplifiers in which if a main amplifier is designed as a class-A or class-B amplifier, an auxiliary amplifier will be applied as a class-B or class-C amplifier. In the case of the class-B and class-C amplifier, they may have a linearity problem. Furthermore, a class-A and class-AB amplifier in Doherty amplifier increase distortion elements due to saturation because the input
signal in the operation of a class-B, C amplifier is high. Thus a Doherty amplifier has exhibited problems in linearity although it improves the power added efficiency\(^4\).\(^6\)

There are three kinds of using bias control to obtain high PAE in HPA\(^7\).\(^9\). This paper has implemented a DC voltage control for drain and gate and PBG structure on the output matching circuit of a Doherty amplifier. The circuit has been based on a dual bias control method under the conditions that a class-A or class-AB carrier amplifier had certain degradations in linearity due to saturation when a class-B or class-C peaking amplifier was operated. It is possible to improve the problem of the PAE and the IMD\(_3\) in the power amplifier and characteristics occurring in non-linearity simultaneously. In addition, there is a possibility that it may improve performance by more than 32% on all bandwidth for input signals.

II. Theory and design of dual bias control

PAE can be expressed as Eq. (1)

\[
PAE = \frac{(RF_{outputpower}) - (RF_{inputpower})}{(V_{gs} \times I_{gs}) + (V_{ds} \times I_{ds})}
\]  

(1)

In this paper, both voltages of gate and drain have been controlled by input power level. This paper has been used a dual bias control circuit that controlled both drain and gate voltages in which an envelope detector using an AD8313 Analog Device with an excellent linearity and temperature insensitivity.

As shown in Fig. 2, although the output voltage

(DC) was produced according to the scale of input signals (RF) through an envelope detector, the bias voltage was adjusted with OP-Amps. As shown in Fig. 3, corresponding to increasing in input power, a bias control circuit has been fabricated in this research using a directional coupler due to the decrease in the gate bias voltage value from a class-AB to class-B and finally class-C.

III. Theory and design of PBG

Using a PBG structure, the forming of a stop band could be estimated based on the frequency that corresponded to \(2\Lambda\) in the Bragg lattice principle\(^10\). It was possible to form a stop band at a desired point based on this PBG structure. The lattice phase \(\Lambda\) can be noted as Eq. (2)

\[
\Lambda = \frac{\lambda_0}{2}
\]  

(2)
where $\lambda_g$ is the wavelength of the wave induced from a microstrip line structure and calculated using the effective permittivity and center frequency of a desired stop band as expressed as Eq. (3)

$$\lambda_g(f) = \frac{\nu_p(f)}{f} = \frac{c}{f\sqrt{\mu_r \varepsilon_{r,eff}(f)}}$$ (3)

where $\varepsilon_{r,eff}(f)$ is the effective permittivity index of the center frequency of a stop band in a microstrip structure. HFSS by Ansoft has been used as a simulation tool in order to design the PBG.

As shown in Fig. 4, the PBG was designed to obtain a minimum signal decreasing at a center frequency of 2.14GHz that was exhibited as $S_{21} = -1.2\text{dB}$. In addition, it was designed to obtain $S_{21} = -39.4\text{dB}$ levels at a secondary harmonic frequency of 4.28GHz in order to decrease a harmonic frequency that affects the nonlinearity of HPA.

IV. Design of a Doherty amplifier using a dual bias circuit and PBG structure

Teflon board with a permittivity of 3.2 has been used in this research. In addition, ATF34143 of Agilent has been used in power amplifier. A loadpull simulation using ADS2005A was applied to determine an output matching point. Then, a Doherty amplifier has been designed using output matching according to this output matching point. Fig. 5 shows the implementation of an output matching circuit including the PBG in an offset-line when the output matching circuit was produced by determining the loadpull matching point of the power amplifier. Based on processes, a Doherty amplifier was designed to using the PBG in order to improve the linearity.

At first, a class-AB power amplifier has been designed as a reference amplifier in order to compare it with this research. As shown Fig. 6, an output power of 19.45dBm was obtained from the 1-tone measurement in this reference amplifier in which the power added efficiency and IMDs characteristic were 27.12% and -27.45dBc from 2-tone measurement, respectively.

This paper proposes a structure that improves the PAE of a Doherty amplifier by applying dual bias

(239)
Table 1. Bias voltage variation according to the input power.

<table>
<thead>
<tr>
<th></th>
<th>Bias Voltage</th>
<th>Input power Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>0V~0.5V</td>
<td>0~10dBm</td>
</tr>
<tr>
<td>Drain</td>
<td>2V~4V</td>
<td></td>
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</tbody>
</table>

Table 2. Comparison of measured data for each power amplifier.

<table>
<thead>
<tr>
<th></th>
<th>Reference (class-AB)</th>
<th>Doherty (classical)</th>
<th>Doherty (with PBG)</th>
<th>Proposed Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power (dBm)</td>
<td>19.45</td>
<td>21.14</td>
<td>22.24</td>
<td>24.09</td>
</tr>
<tr>
<td>PAE (%)</td>
<td>27.12</td>
<td>30.18</td>
<td>32.85</td>
<td>36.28</td>
</tr>
<tr>
<td>IMD3 (dBc)</td>
<td>-27.45</td>
<td>-28.24</td>
<td>-31.84</td>
<td>-32.26</td>
</tr>
</tbody>
</table>

The proposed dual bias control circuit and PBG structure exhibited an output of 24.09dBm, PAE of 36.25%, and IMD3 characteristic of -32.47dBc. Fig. 8 shows the comparison of the PAE of the conventional Doherty amplifier with that of the Doherty amplifier using the proposed dual bias control circuit and PBG structure. As shown in Fig. 8, the Doherty amplifier using the proposed dual bias control circuit and PBG structure showed a roughly 6% increase in output compared to that of the reference power amplifier.

In this research, this research has achieved the flatness in PAE for all input power level. It has been to obtain more than 30% PAE at low input power level with controlling dual bias point by changing the bias voltage of the gate and drain.

Table 1. shows the voltage variation in gate and drain bias voltage corresponding to the input power level with a value 0 to 10dBm. Table 2. notes the comparison between output power, PAE and IMD3 for each power amplifier.

V. Conclusion

In this paper, the dual bias control and the PBG structure has been employed to improve the PAE and
the linearity of the Doherty amplifier. The controlling of the gate and the drain bias voltage corresponding to input power level has been done to improve the PAE of the Doherty amplifier. The PBG structure has been employed on the output of the Doherty amplifier to improve the linearity. The PAE and the linearity has been improved 8% and 5dBc compared with those of the conventional class-AB power amplifier, respectively. Our Doherty amplifier has been very good flatness of output power over all input power range.

参考文献


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