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High 1dB gain compression and harmonic suppression octave bandwidth Power Amplifier

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Abstract. This paper describes the design, implementation, and measurement results of a 1GHz to 2.5 GHz high harmonic suppression octave power amplifier (PA). The fabricated PA provides the harmonic suppression higher than 20dBc at the 1dB gain compression point, which is up to 47dBm, and the minimum saturation output power is up to 50dBm. Compared with the other works, the PA presented in this letter has a better performance in terms of 1dB gain compression point, saturation output power and harmonic suppression, which is to be an optimum selection device in EMC test field.

Index Terms. high harmonic suppression, 1dB gain compress point, octave bandwidth, power amplifier (PA).

1. Introduction

Electromagnetic Compatibility systems require high harmonic suppression PA to support octave bandwidth. The pure signal is needed to add on the DUT to get the accurate data, but the spurious signal especially the harmonic signal is inevitably created as the transistor's nonlinearity. There are many achievements output based on the wideband and octave PA. The input and output matching techniques and parallel feedback topology was used to increase bandwidth is proposed ^[1], but the harmonic compression isn't involved. An output power of 200 W using a 90-degree power combiner is achieved ^[2], but this PA can't support octave work, as the output capacitance C_{ds} of the high-power transistor limits the bandwidth and efficiency. The digital predistortion technology and Doherty structure was used to improve the linearity of the power amplifier ^[3], but only can work in narrowband. Until now, the PA, which can work for the octave bandwidth with the high harmonic compression, isn't proposed.

After decades of development, two key factors are overcome. How to expand the bandwidth and how to improve the PA's performance, such as harmonic, 1dB gain compression point, output power, and efficiency ^{[6]-[7]}. This paper is got excellent results based on the basic principles and work experience, the specific implementation form is as follows.

2. Design procedure

The desired specifications in this letter are as follows: a frequency bandwidth of 1GHz to 2.5 GHz, an output power greater than 100W, the harmonic suppression higher than 20dBc at 1dB gain compression point, which is up to 47 dBm. To fulfill these requirements, a Cree CGH40120 GaN power transistor is used.



2.1. Relationship between quiescent current and harmonic

Theoretically there is no waveform distortion in class A with the 50% conversion efficiency. Class B and Class C was used to get high efficiency, but the distortion is very significant. In order to get the balance between efficiency and linear, the class AB is widely used.

It is assumed here that the conduction angle is α , the normalized maximum swing current $I_o=1$, I_q is the normalized static operating point. According to the working principle of the power amplifier, the relationship between the current waveform and the static working point and conduction angle is as Fig.1:

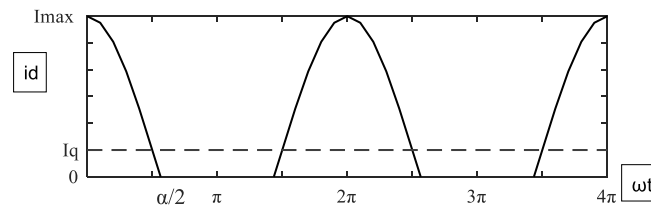


Fig.1. Relationship between quiescent current and conduction angle

As can be seen from the above figure:

$$i_d(\theta) + I_q + I_p \cdot \cos\theta, \quad -\alpha/2 < \theta < \alpha/2 \quad (1)$$

$$i_d(\theta) = 0, \quad -\alpha/2 < \theta < \alpha/2 \quad (2)$$

$$\cos(\alpha/2) = -I_q / I_p \quad (3)$$

$$I_p = I_{\max} - I_q \quad (4)$$

Can be derived:

$$i_d(\theta) = I_{\max} \cdot (\cos\theta - \cos(\alpha/2)) / (1 - \cos(\alpha/2)) \quad (5)$$

Integrating in one signal period also yields the current of the nth harmonic:

$$I_n = 1/\pi \cdot \int_{-\alpha/2}^{\alpha/2} I_{\max} \cdot (\cos\theta - \cos(\alpha/2)) \cdot \cos n\theta (1 - \cos(\alpha/2)) d\theta \quad (6)$$

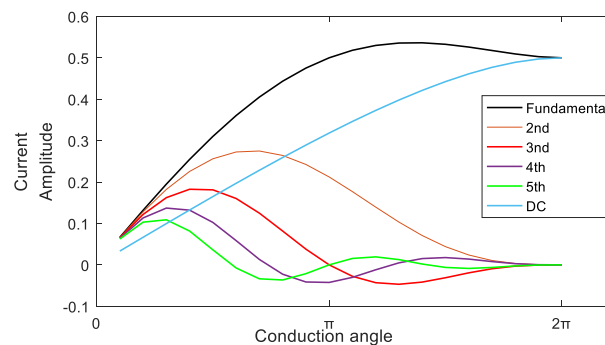


Fig.2. Relationship between conduction angle and harmonics

It can be seen from the above figure that when the conduction angle $\alpha=2\pi$, the nth harmonic is 0, which provides a strong theoretical guidance for solving the harmonic problem. However, the efficiency of PA will drop when it works in class A, which brings great challenges to the thermal design of the power amplifier, especially for systems with high volume requirements. Therefore, in this paper, the appropriate I_{dq} will be explored to balance the harmonic and efficiency.

2.2. Matching technique

The design of the matching circuit is the key technology of the power amplifier. Impedance of the power amplifier transistor varies with frequency, resulting in different gain and efficiency at each frequency point. It is difficult to achieve an ideal match for the entire working band. Therefore, the impedance can be matched according to the actual needs between linear and efficiency.

The 2nd harmonic of the low frequency is in the working bandwidth, so it will be amplified. The method of harmonic compression can be started from two aspects: On the one hand, adjust output impedance matching points to reduce harmonics without affecting the output power of high frequency points. On the other hand, the gain of high frequency is sacrificed, but need to meet the whole requirements. The final output matching circuit design is shown in Fig.3.

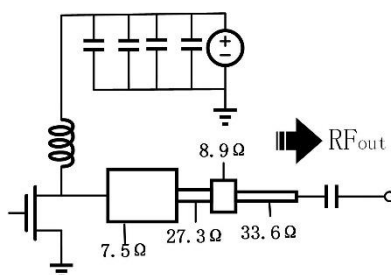


Fig.3. Output matching circuit

Based on the above research, this paper uses two CREE's cgh40120F power amplifier transistors to get the output power. A broadband high harmonic compression octave PA is designed (Fig.4).

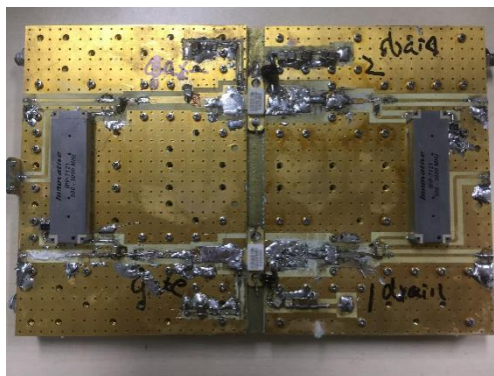


Fig.4. Fabricated PA with two power amplifier transistors

3.Results and comparison

Fig.5 shows the amplifier 1dB gain compression point and saturation output power of measured and simulated. These two results have some deviation due to the loss of the microstrip and the simulation is an ideal model. The 1dB gain compression in all frequency bands is higher than 47dBm. The saturation output power of single amplifier transistor in all frequency bands is higher than 50dBm.

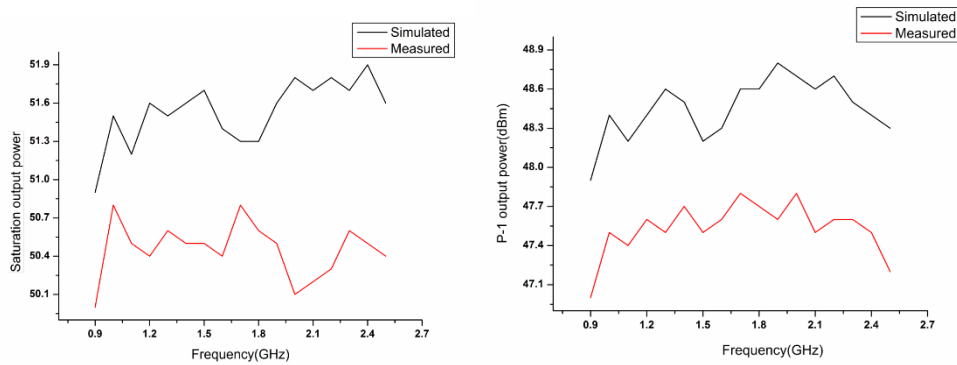


Fig.5. Simulated and measured P-1 output power and saturation output power.

Fig.6 shows the harmonic and IMD3 of the fabricated PA. The harmonic suppression is higher than 20dBc and the IMD3 is up to 15dBc at 1dB gain compression point 47dBm.

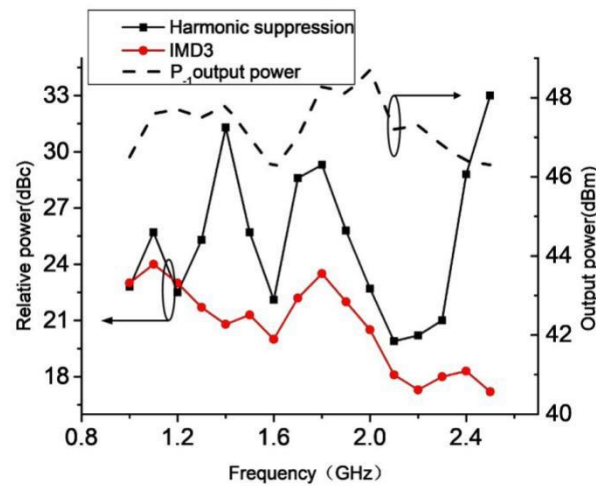


Fig.6. The measured results of the PA.

Table 1. Comparison of the most advanced broadband linear pas

Year [Ref.]	BW [GHz]	FBW [%]	Linearity	P _{sat-out} [dBm]
2018[3]	1.8-3.8	71.5	/	44.3
2018[5]	0.85-5.4	160	Harmonic suppression>14dBc	43.5
2018[4]	1.5-3.8	87	/	42.3
This work	1-2.5	85	P _{-1 out} >47dBm; Harmonic suppression>20dBc	50

Finally, the proposed PA is compared with the most advanced broadband linear PAs in terms of bandwidth, bandwidth, linearity, saturated output power. Table1 shows the comparison results, which clearly indicate that this work has more significance in application value than other design before.

4.Conclusion

This letter presented an octave bandwidth, high harmonic suppression, and high P₋₁ output power amplifier. Impedance broadband matching is used and the transistor conduction Angle is controlled. The 1dB gain compression point output power is higher than 47dBm, the harmonic suppression is

higher than 20dBc, and the output power is up to 50dBm was achieved in the frequency band of 1GHz to 2.5GHz.

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