THE EFFECT OF A VARIATION IN TONE SPACING ON THE INTERMODULATION PERFORMANCE OF CLASS A & CLASS AB HBT POWER AMPLIFIERS

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Abstract

The first investigation into the effect of frequency separation on the intermodulation distortion performance of Heterojunction Bipolar Transistor (HBT) power amplifiers is reported. The measured results show that the frequency spacing between the two input tones affects the intermodulation distortion performance of Class AB power amplifiers, but not Class A power amplifiers.

1. Introduction

HBTs are becoming a very popular choice of device for use in microwave power amplifiers [1,2] owing to characteristics such as high gain, linearity, and high output power. The intermodulation distortion performance of these devices has been investigated [3] and it has been proposed that they offer superior intermodulation distortion performance [4].

Highly linear power amplifiers are a vital requirement in multi-carrier communication systems where the carrier signals may be closely spaced in frequency, and it has been suggested that HBT power amplifiers may be able to address this requirement [5]. The thermal performance of power HBTs is known to limit device operation [6,7] and it has been further proposed that the thermal aspects of HBT operation can affect the intermodulation distortion performance [8]. The frequency spacing between the two input tones can affect the intermodulation distortion of an HBT biased in Class AB [8], and this paper extends the work on intermodulation distortion performance in power amplifiers by examining the role of bias conditions and their interaction with thermal operation. The work presented here examines for the first time the effect of a variation in frequency separation of the two input tones on the third order intermodulation distortion (IM_3) performance of a Class A and a Class AB HBT power amplifier. The frequency spacing (Δf) used for IM_3 measurements is usually between 1 MHz and 10 MHz. This work uses a range of different Δf in measurements and simulations to fully characterise the IM_3 performance of HBT power amplifiers.

2. Theoretical Background and Power Amplifier Simulations

The work discussed in [8] has shown that the non-linearity of the Class AB operation results in mixing products that fall within the thermal frequency response of the device causing a change in the thermal operation which results in an increase in the power of the IM_3 products. This means that HBT power amplifiers where Δf falls within this thermal frequency response have to be characterised carefully and this paper examines the intermodulation distortion performance of both Class A and Class AB HBT power amplifiers with values of Δf between 2 kHz and 1 MHz.

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Isothermal power amplifier simulations using an equivalent circuit model [9] which does not contain a thermal model have been carried out on a Class A power amplifier. This model describes a power HBT and a simulated load-pull was carried out to determine the optimum reflection coefficients to give maximum power gain. The IM_3 performance of this circuit was simulated using two different input tone frequency spacings. The first simulation was carried out with a spacing of 1 MHz and the second with a frequency spacing of 2 kHz. The results are shown in **Figure 1** and demonstrate that in the absence of any thermal effects the power of the IM_3 products does not change with a variation in input tone frequency spacing until the amplifier is driven well into the power gain saturation region.

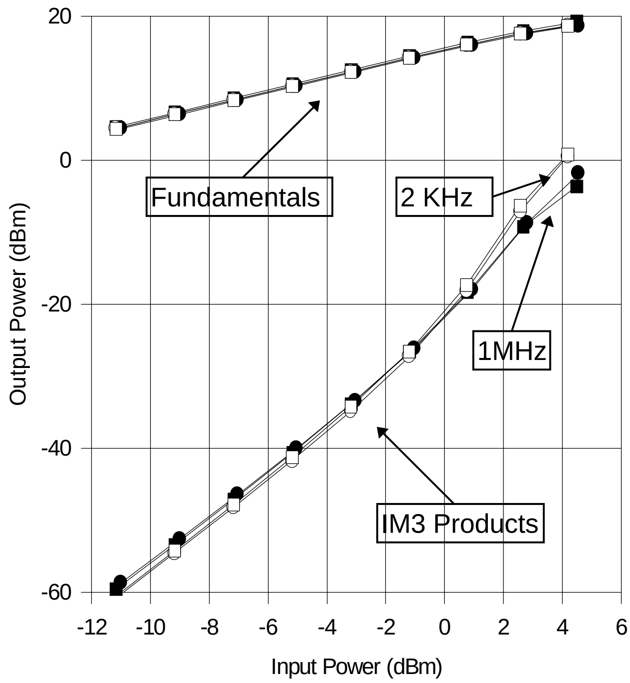

Figure 1 Class A Power Amplifier Simulations with a Variation In Frequency Spacing of the Two Input Tones.
□ ○ Δf = 2 kHz, ■ ● Δf = 1 MHz

3. Amplifier Design And Intermodulation Distortion Measurements

The two HBT power amplifiers used in this work were designed using load-pull measurements. A TRL calibration technique [10] was used to allow the measurements to be de-embedded to the plane of the devices used. The load-pull measurements were performed under Class A and Class AB bias conditions at 1.8GHz and from the results the power amplifiers were designed for maximum power gain. Each power amplifier was fabricated on microstrip and external bias Tees were used to provide the power supplies to the transistor. The P_{in}/P_{out} characteristics were measured and using the test setup shown in **Figure 2** the IM_3 performance of each amplifier was measured.

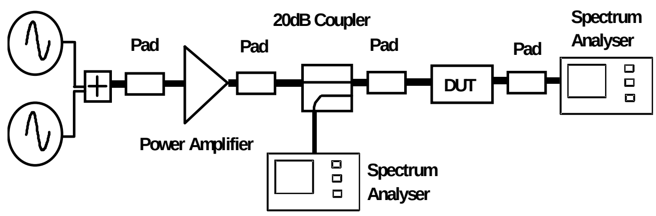

Figure 2 Two-Tone Intermodulation Distortion Measurement Setup

The frequency spacing (Δf) between the two input tones in the first measurement was set at 1 MHz and in the second measurement Δf was reduced to 4 kHz. **Figure 3** shows a typical spectrum analyzer output obtained during the measurements where the IM_3 products can be clearly seen.

4. Measurement Results

Figure 4 shows the output power level of each of the fundamentals and all of the 3rd order products resulting from the non-linear mixing of the two input tones for both the Class A and AB power amplifiers.

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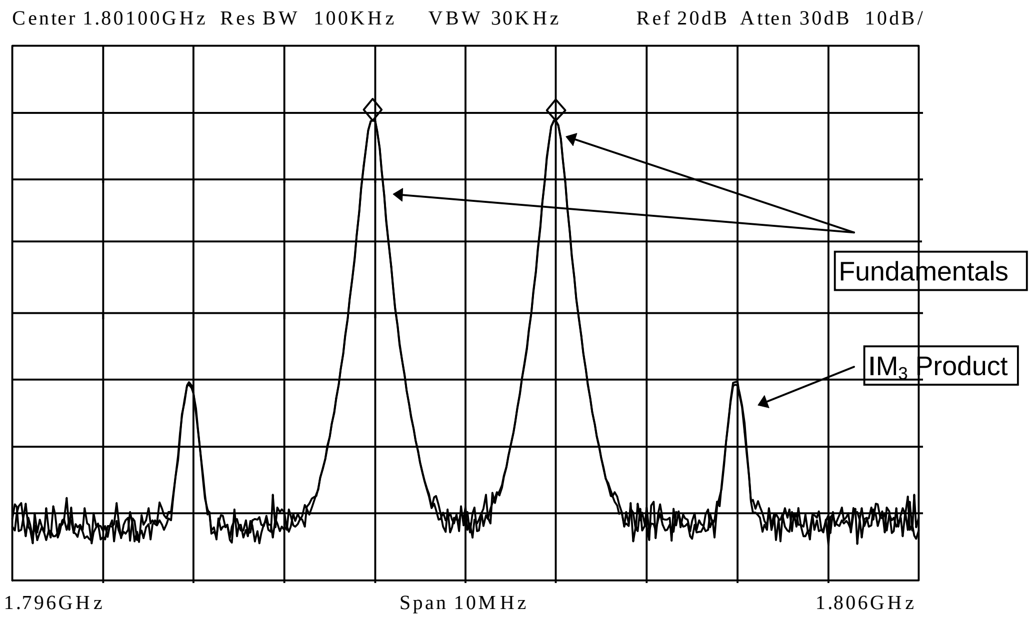
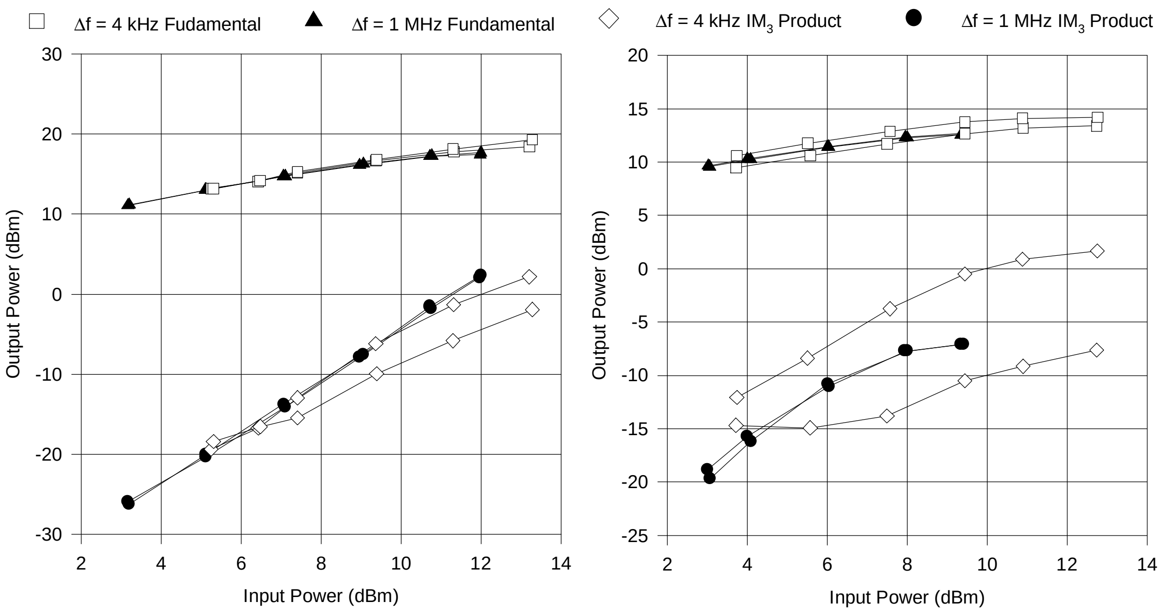


Figure 3 Typical Power Amplifier Spectrum



Class A **Class AB**

Figure 4 IM_3 Results For The Class A and Class AB HBT Power Amplifier. Fundamentals and all 3rd Order Products are Shown

In the Class A case the variation in Δf does not cause an increase in the power of the third order products. This is probably due to the linear operation of the power amplifier which although generating intermodulation distortion products that fall within the thermal frequency response of the circuit such as (f_2-f_1) product they are not of sufficient power to affect the intermodulation distortion performance. There is some variation in the power of the IM_3 products, but no increase. The variation is likely to be due to simultaneous phase and amplitude distortion[11]. The Class AB results contrast strongly with the Class A case results and show that when Δf is reduced to 4 kHz the power of the third order products can be increased by between 4 dB and 6.5 dB. This is a significant deterioration in the amplifier's performance and can be attributed to the f_2-f_1 product which falls within the thermal frequency response of the power amplifier causing the bias point to be modulated. This affects the thermal performance of the power amplifier increasing the non-linearity of operation and degrading the IM_3 performance. The comparison between the Class A and AB operation also shows that this change must be device rather than measurement equipment related since it has been seen in one Class of operation, but not in both when an identical test equipment setup has been used.

5. Conclusions

The results show that intermodulation distortion measurements where Δf may be anything between 1 MHz and 10 MHz may not be sufficient to fully describe the IM_3 performance of a Class AB HBT power amplifier which is a common Class of operation chosen by many circuit designers for mobile communications systems. Measurements presented here show that the IM_3 performance of a Class AB amplifier may be up to 6.5 dB worse when the f_2-f_1 product falls within the amplifier's thermal frequency response causing a change in the thermal performance of the power amplifier. There was no reduction seen in the IM_3 performance of a Class A HBT power amplifier showing the linear operation of this Class and demonstrating that the use of a frequency spacing between 1 MHz and 10 MHz in two-tone intermodulation distortion measurements is sufficient to describe the Class A power amplifiers IM_3 performance. The Class A and AB results also show that the change in IM_3 performance is device related rather than test equipment related.

6. Acknowledgments

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7. References

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