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Research Paper

DESIGN AND SIMULATION OF MULTIBAND POWER AMPLIFIER

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As inferred from the name, the main job of a "Power Amplifier" (also known as 'large signal amplifier'), is to deliver power to the load and it is mathematically given by the product of the voltage across the load and current flowing through the load, with the output signal power being greater than the input signal power. In other words, a power amplifier amplifies the power of the input signal which is why these types of amplifier circuits are used in audio amplifier output stages to drive loudspeakers. For successful mobile phone communication, the job of the power amplifier is to boost the small digitally modulated input signal to an adequate output power level before it is radiated by the antenna. It is the most power consuming device in the whole transmitter chain, and hence, the performance of complete system, is mainly dependent on the performance of the power amplifier. The main concerns of power amplifier design are higher linearity, efficiency, bandwidth, lower manufacturing cost, and so on.

Keywords: Power amplifier, Reflection coefficient, S_{11}, S_{21}, Spectrum, Harmonics, 1-dB compression point

INTRODUCTION

An efficient linear power amplifier is required in all the battery-operated radio systems. Some examples of these battery operated devices are Wide-band Code-Division Multiple-Access (W-CDMA), GSM, portable handsets etc. Since the bias-point and the load line of amplifiers are optimized for the maximum value of 1-dB compression point, in order to achieve high power amplification, a conventional power amplifier has highest efficiency at the maximum output power and drops to a lower value as the output power level is reduced. The power usage efficiency is defined as the ratio of average output power over the supplied dc power.

The power amplifier works on the principle of converting the DC power drawn from the power supply into an AC voltage signal delivered to the load. Although the amplification is high, efficiency of conversion of DC power input to the AC power output is usually poor.

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An ideal amplifier would give an efficiency rating of 100% or at least the power "IN" would be equal to the power "OUT". However, in practicality, this can never be attained, as some of the power is lost in the form of heat and also, the amplifier itself consumes power during the amplification process. Then the efficiency of an amplifier is given as:

$$Efficiency = P_{out}/P_i$$

Ideal Amplifier: The characteristics of an Ideal Amplifier are:

- The amplifiers gain (A), should remain constant for varying values of input signal and across all frequencies.
- The amplification process must not add noise to the output signal.
- The amplifier gain should not be affected by changes in temperature, thus, giving good temperature stability.
- The gain of the amplifier must remain stable over long periods of time.

Amplifier Classes: Classification of an amplifier is made by comparing the characteristics of input and output signals, by measuring the amount of time, in relation to input signal, for which current flows in the output circuit. For a transistor to operate within its "Active Region" some form of "Base Biasing" is required. This small Base Bias voltage added to the input signal allows the transistor to reproduce the full input waveform at its output with no loss.

Power amplifiers are classified in an alphabetical order according to their circuit configurations and mode of operation. Amplifiers are designated by different classes of operation such as class "A", class "B", class "C", class "AB", etc. These different Amplifier Classes range from a near linear output with low efficiency to a non-linear output with a high efficiency. No class of operation is "better" or "worse" than any other class. The type of operation is determined by the use of the amplifying circuit.

For the purpose of multiband operation, linearity, being the main concern, we intend to use a Class A amplifier.

Class A Amplifier—has low efficiency of less than 40% but good signal reproduction and linearity.

Amplifier Design: The proposed amplifier is designed and verified using the tool – ADS (Advanced Design System), by Agilent. The transistors and components used are available on the library file of the simulation tool.

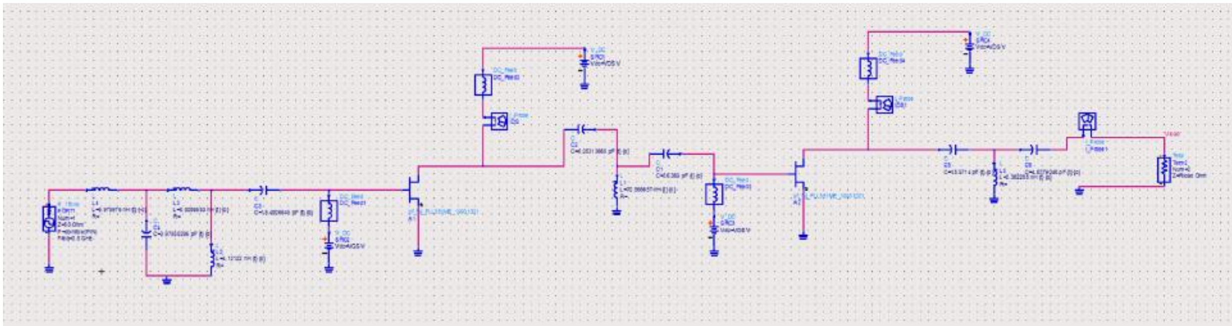
The power amplifier is a two-stage amplifier circuit with the input and output matched to 50 ohm. The circuit of the power amplifier is as shown in Figure 1. The specifications for the designed amplifier are given in Table 1.

The amplifier circuit uses separate biasing circuits for the drain-source junction and the gate source junction. The inter-stage coupling for the amplifier, and the input and output matching circuits use only inductors and

Table 1: Specifications

V_{ds}	10
V_{gs}	–1
P_{out}(max)	28 dBm-32 dBm (1 W)
P_{in}	10 dBm (10 mW)
Frequency of Operation	800 MHz and 1.1 GHz
$\|S_{11}\|$	>30 dB
S_{21}	20-25 dB

Figure 1: Power Amplifier Circuit



capacitors which can be replaced by equivalent distributed networks, because the performance of resistors at such high frequencies is poor.

RESULTS

The parameters measured to determine the performance of the amplifier are:

- S_{11}
- S_{21}
- Output power vs Input power.
- Gain vs Input power.
- Output power spectrum.
- Power spectral density.

The results obtained were:

The resultant S-parameters agree with the multiband tag used to define the power amplifier. The S_{11} value obtains a low at all resonant frequencies.

Figure 2: S_{11} and S_{21}

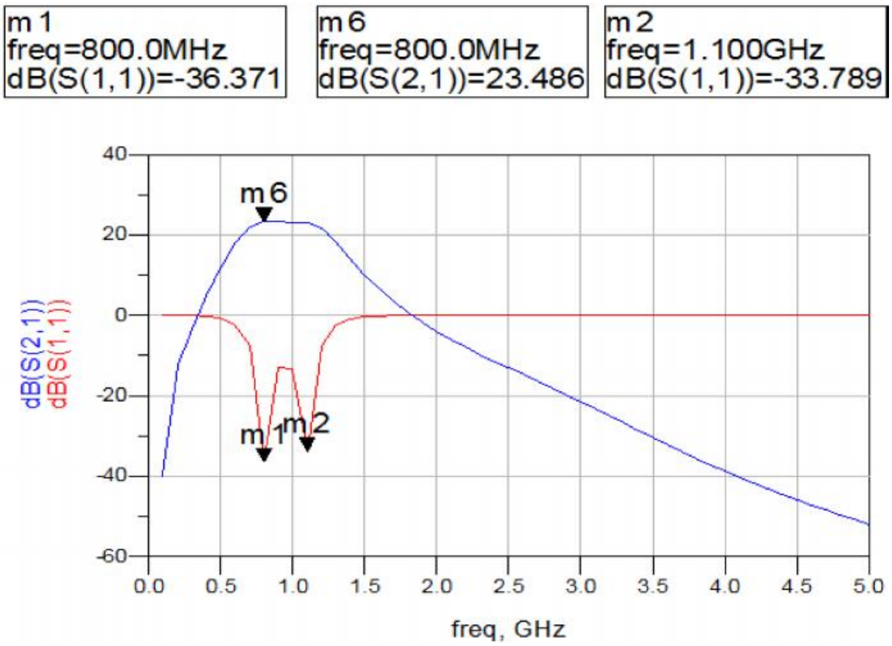
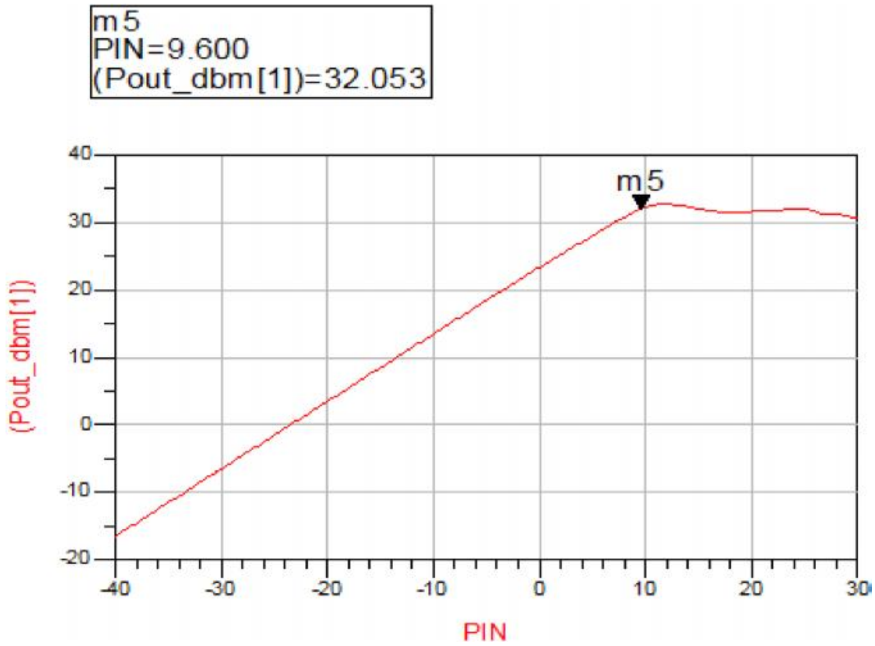
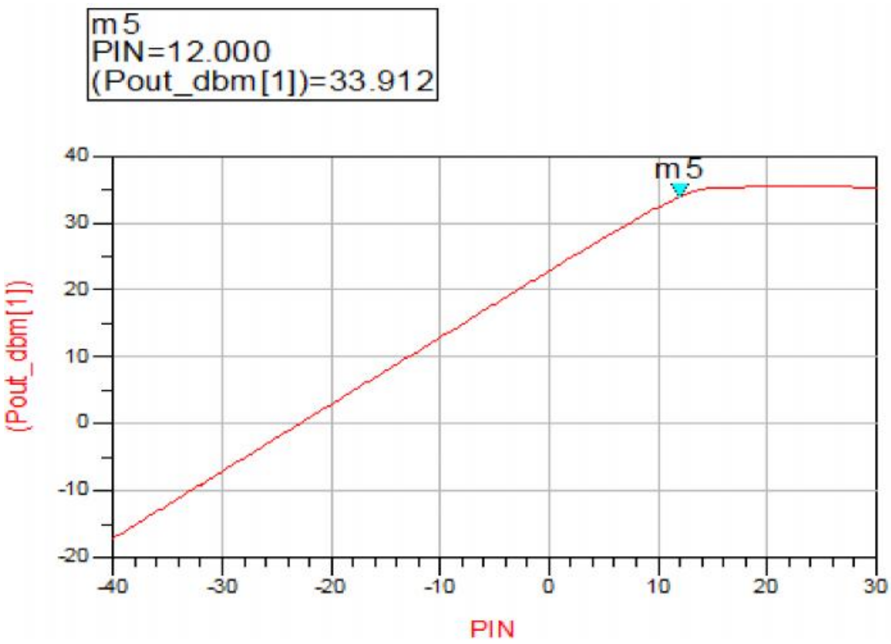


Figure 3: Output Power vs Input Power at 800 MHz



The graph of output power vs input power, at a particular frequency suggests the maximum allowable input power. The maximum allowable input power is the power at 1-dB compression point. 1-dB compression point is the point at which the gain of the amplifier falls 1dB below its maximum gain.

Figure 4: Output Power vs Input Power at 1.1 GHz



Figures 3 and 4 show the plots of output power vs input power at 800 MHz and 1.1 GHz respectively.

Figures 5 and 6 show the plots of Gain vs Input power at 800 MHz and 1.1 GHz respectively.

Figure 5: Gain vs Input Power at 800 MHz

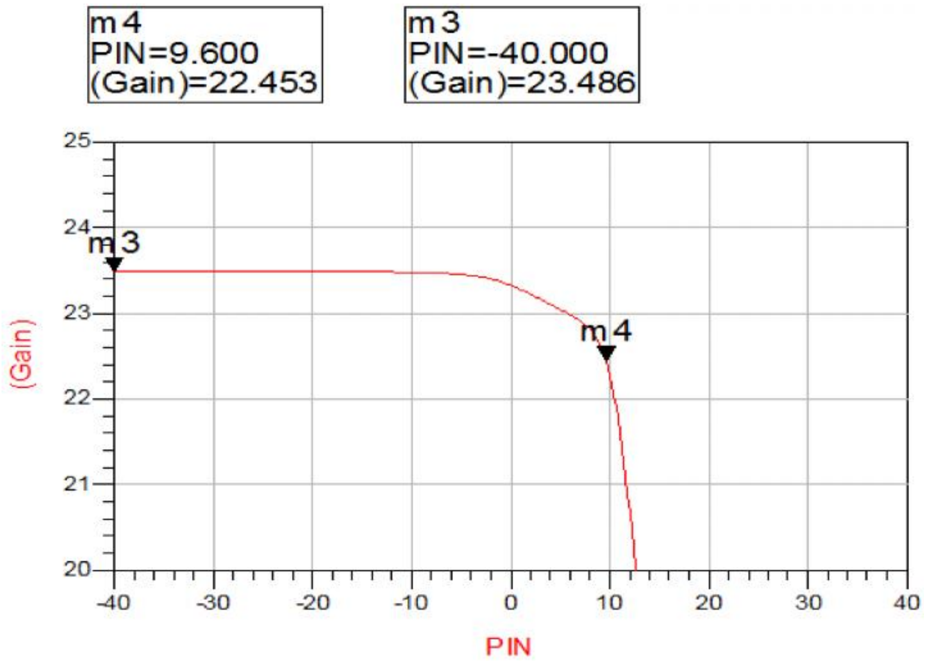
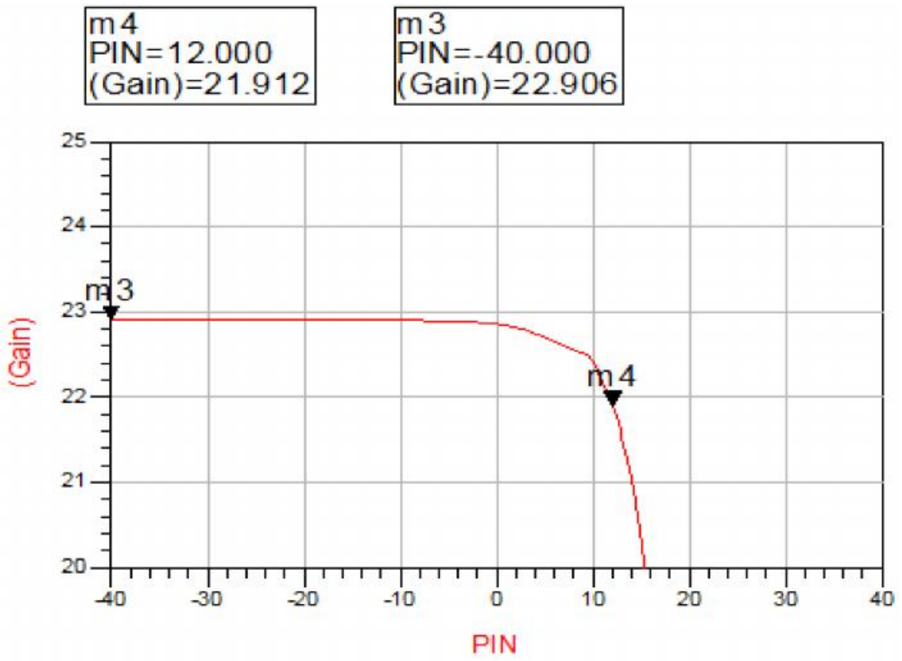


Figure 6: Gain vs Input Power at 1.1 GHz



The 1-dB compression point can be obtained from both the Output power vs Input power plot as well as the Gain vs Input power plot. Gain is given by the difference between the Output power and Input power in dB or dBm.

Figure 7: Power Spectral Density at 1.1 GHz

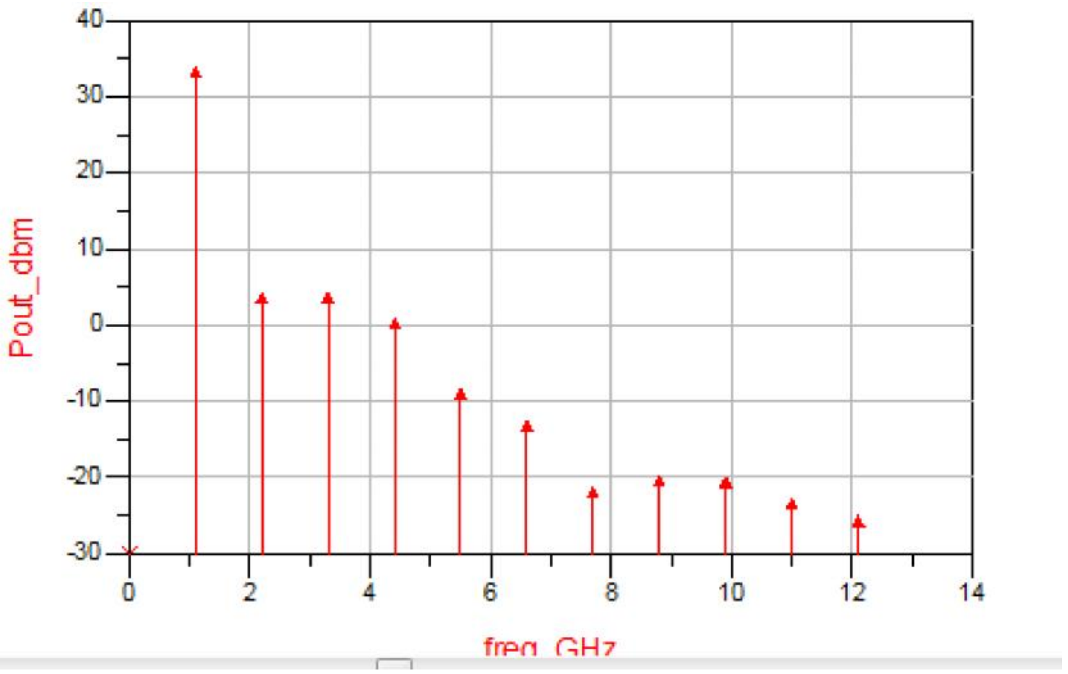
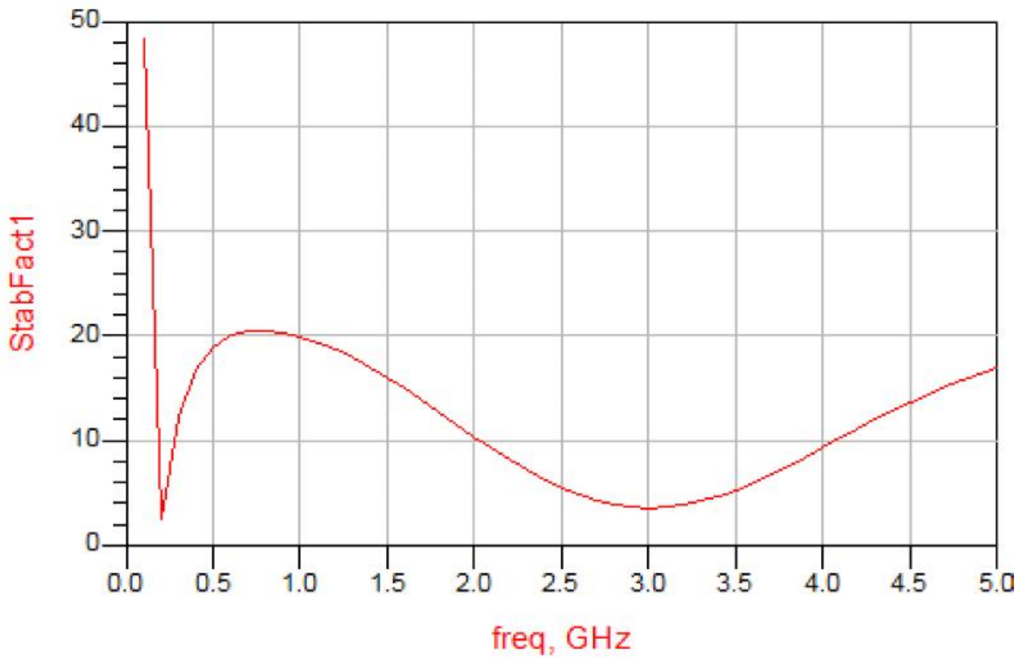


Figure 8: Stability Factor |k|



The power spectral density plot can be used to determine the strength of the harmonics. The harmonics should have a strength below 30dB of the parent signal.

The stability factor |k| should always be greater than one. The plot shows that the amplifier is stable for all frequencies after 0.2 GHz.

SUMMARY

Table 2 provides a summary of the results obtained for the designed power amplifier.

Table 2: Summary of Results

Frequency	800 MHz	1.1 GHz
S_{11}	–36.371 dB	–33.789 dB
S_{21}	23.486 dB	22.906 dB
Input Power at 1 dB Compression Point	9.6 dBm	12 dBm
Output Power at 1 dB Compression Point	32.053 dBm	33.912 dBm
Gain at 1dB Compression Point	22.453 dB	21.912 dB

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