LINEARIZATION OF MMIC POWER AMPLIFIER

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Abstract- Power amplifier plays a very important role in transmitter in order to generate and transmit sufficient power signals. The main objective of the work is to detail out the basic design of MMIC power feed forward amplifier by using 0.15μm GaAs pHEMT technology gate width of 100 μm and 10 fingers at 2.4 GHz for wireless applications and to analyze power amplifier function, performances and applications. For 2.4 GHz power amplifier, with 3.0 V bias voltage, amplifier has achieved linear gain is 8.580dB, input return loss is 11.164dB and output return loss is 10.150dB and output power of 14.579dBm at 1dB compression point (P1dB) with 12.318% power-added efficiency (PAE). The 2.4 GHz power amplifier is linearized using feed forward technique. Good Linearization has been achieved which improves the output power and inter modulation distortion cancellation

Index terms- PHEMT, MMIC, Efficiency, Power-added efficiency, Inter modulation distortion, Feed forward Linearization.

I. INTRODUCTION

A power amplifier design has to meet the system requirements for high gain, high efficiency and desired output power while the device and process technology of choice plays a crucial role in realizing the performance of the power amplifier. Power amplifiers are a key component for the digital cellular Phones with ever increasing linearity and efficiency requirements. These amplifiers consume much of the total battery DC power and occupy significant area. DC power consumption has to be reduced for High-efficiency power amplifiers. High-efficiency operation is required as an important factor for reducing the prime power and cooling requirements for advanced microwave and millimeter wave radar, communication and electronic warfare systems. A power amplifier (PA) is a circuit for converting DC input power into a significant amount of RF/microwave output power. The PA, which is the most important element in a transmitter system which is required to provide suitable output power with a very good gain, high efficiency and linearity. All these requirements make a tradeoff and an optimization is needed for typical power amplifier design.

II. TRANSISTOR SELECTION

The MESFET or GaAs FET is a high performance field effect transistor used in microwave applications and in semiconductor RF amplifiers. The main reasons for GaAs FET to be considered are as follows,

- Higher mobility of the carriers in the channel as compared to the MOSFET, as the devices are constructed with very small gate lengths (as low as 0.1 μm).
- Smaller Parasitic resistance which makes the device faster.
- The Schottky junction in MESFET serves to lower the input capacitance, making the device easier to drive at high frequencies.
- The resistivity of GaAs is very high to $10^8$, which fits for the microwave passive components substrate.
- An improvement on the MESFET structure came with the pseudomorphic high-electron Mobility transistor (pHEMT). pHEMTs has higher gain and extended frequency performance-applications well into the 200GHz range.
III. BASIC FEED FORWARD LINEARIZATION

A power amplifier has to be operated in the linear region where the average output power is much smaller than the amplifier's saturation power (i.e. larger output back-off). But this increases both cost and inefficiency as more stages are required in the amplifier to maintain a given level of power transmitted which results in high DC power is consumed. An approach to reducing nonlinear distortion is the linearization of the power amplifier.

The aim of linearization techniques is to cancel the distortion modifying the input signal or directly subtracting it from the output signal.

The feed forward configuration consists of two circuits, the signal cancellation circuit and the error cancellation circuit. The purpose of the signal cancellation circuit is to suppress the reference signal from the main power amplifier output signal, leaving only amplifier distortion, both linear and nonlinear, in the error signal. Distortion from memory effects can be compensated by the feed forward technique, since these effects will be included in the error signal. The values of the sampling coupler and fixed attenuation are chosen to match the gain of the main amplifier. The variable attenuation serves the function of precisely matching the level of the PA output to the reference. The variable phase shifter is adjusted to place the PA output in anti-phase with the reference. The delay line in the reference branch, necessary for wide bandwidth operation, compensates for the group delay of the main amplifier by time aligning the PA output and reference signals before combining. The purpose of the error cancellation circuit is to suppress the distortion component of the PA output signal, leaving only the linearly amplified component in the linearizer output signal. In order to suppress the error signal, the gain of the error amplifier is chosen to match the sum of the values of the sampling coupler, fixed attenuator, and output coupler so that the error signal is increased to approximately the same level as the distortion component of the PA output signal.

IV. SINGLE-Stage 2.4 GHZ POWER AMPLIFIER DESIGN WITH WIN COMPONENTS

MMIC power amplifier with 0.15µm GaAs power Pseudomorphic High Electron Mobility Transistor (PHEMT) with unit gate length (UGW) of 100µm and 10 fingers with centre frequency of 2.4 GHz is designed.

Simulation Analyses

The following analyses are used to simulate the parameters of 2.4 GHz power amplifier

S-Parameter Analyses

Linear Gain

Input and Output Return Loss (S11, S22)

Power Gain at 1dB compression point

Power Added Efficiency (PAE)

Two-tone Harmonic Balance simulation

Inter modulation Distortion

The S-parameter analyses is performed between the frequencies of 1 GHz to 6 GHz. Harmonic balance simulation is performed at centre frequency of 2.4 GHz. Stability of the power amplifier is verified by checking Rollet factor K value (K>1).

![Figure 2. Schematic of the 2.4 GHz power amplifier with WIN components](image)

Layout Design

Transmission lines are the basic elements used in the design of microwave components, circuits, and subsystems. Transmission lines capable of achieving very high and very low impedances with large operating bandwidths and compatible with (MMIC)/miniature hybrid-microwave integrated-circuit (MHMIC) technology. The transmission line is represented by MLIN_D, MTEE and MCORN. The 2.4 GHz power amplifier is constructed using distributed components and simulated.
Figure 3. 2.4 GHz single stage power amplifier with distributed component

**Feed forward Linearization**

The Feed forward linearizer is constructed with power splitters, coupler and 2.4 GHz power amplifier. The output signal is an amplified and time-delayed replica of the input signal with the distortion from the main amplifier removed. The feed forward linearization technique is suited in satellite applications due to its ability to operate with unconditional stability over the large bandwidths. Feed forward system of proper design will enhance the efficiency and linearity.

Figure 4. Circuit schematic of Feed forward linearizer with 2.4GHz power Amplifier

**V. SIMULATION RESULT AND DISCUSSION**

From the simulation of circuit as shown in fig.2. The supply voltage Vds is 3V, and the drain current Id is 438mA. The small-signal performance of the single stage amplifier is shown over 1 to 10 GHz frequencies. Linear gain S(2,1) is 8.580dB, input return loss is 11.164dB and output return loss is 10.150dB. The 2.4GHz power amplifier has an output power of 14.579dBm at 1dB compression point (P1dB), a power gain of 5.888 dB and power added efficiency (PAE) of 8.313% for an input power Pin of 6 dBm, exhibits a maximum PAE of 16.453% for input power 12dBm. Figure 5, 6, 7 shows performance of 2.4GHz power amplifier.

Figure 5. Gain, Input and output return loss

Figure 6. Output power, power-added efficiency and power gain versus input power.

Figure 7. Linear gain and output power in amplifier circuit.

**Two-tone Test**

The two-tone test is performed for power amplifier and simulated results are shown in Figure 2. The two tone frequencies are chosen to be f1=2.404 GHz and f2=2.414GHz.

Figure 8. Output spectrum of power amplifier at f1=2.404GHz and f2=2.414GHz for 2.4GHz power amplifier.
Simulation results of 2.4GHz distributed power amplifier

Figure 3 shows the distributed power amplifier output power, power gain and power added efficiency. The 2.4GHz power amplifier has an output power of 13.654dBm at 1dB compression point (P1dB), a power gain of 5.888 dB and power added efficiency (PAE) of 8.313% for an input power Pin of 6 dBm, exhibits a maximum PAE of 16.453% for input power 12dBm.

VI. CONCLUSION

In summary, 2.4GHz power amplifier has been linearized using feed forward technique and implemented using WIN Semiconductor components. The following results has been achieved with achieved linear gain is 8.580dB, input return loss is 11.164dB and output return loss is 10.150dB and output power of 14.579dBm at 1dB compression point (P1dB) with 12.318% power-added efficiency (PAE). Linearization reduces the, intermodulation components are reduced and cancellation is achieved around 30dBc when compared to unlinearized power amplifier.

REFERENCES

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