Design and Simulation of 
3.5 GHz MMIC Power Amplifier Using GaAs Technology
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Abstract. Design of MMIC power amplifier for wireless application by mistreatment 0.3 m Ga As technology with a gate dimension of 250 μm and ten fingers at 3.5 GHz for 3.5GHz power electronic equipment, the amplifier has achieved 17.69 dB small-signal gain, input and output come loss of -13.41 dB and -9.41 dB, with 9.03 the concerns power-added potency (PAE). The 3.5 GHz power amplifiers used for WiMax base station.

Introduction
Generally, the objective of an amplifier is to increment the input power. Amplifiers detect application in all kinds of electronic contrivances designed to perform number of functions. Types of amplifiers have each with a categorical reason. For example, a radio transmitter makes utilization of an RF Amplifier such an amplifier is designed to amplify the given signal in radio frequency range.

Modern microwave and RF engineering is an exciting and dynamic field, as a result of recent advances in fashionable device technology and also the current explosion in demand for voice, data, and video communication capability. before this revolution in communications, microwave technology was the nearly exclusive domain of the defense trade and dramatic increase in demand for communication systems for such applications as wireless paging, mobile telecom, broadcast video, and confined in addition as pc networks is revolutionizing the trade. Microwave technology is of course suited to these rising applications in communications and sensing, since the high operational frequencies allow each massive numbers of freelance channels for the big variety of uses unreal in addition as vital accessible information measure per channel for prime speed communication.

Power Amplifiers are present in the transmitting chain of a wireless system. They are the final amplification stage before the signal is transmitted, and therefore must produce enough output power to overcome channel losses between the transmitter and the receiver. The design of RF and microwave amplifiers has various facets affecting their performance. The most important factors include the selection of semiconductor technology, device models, circuit architecture and design methodology, matching networks, packaging, and thermal management.
An amplifier circuit consists primarily of a gain device or devices, and input and output matching or coupling networks as shown in Fig.1. The amplifier ought to create weak signals larger while not adding an excessive amount of noise or distortion. Ideally, the amplifier would add no noise and wouldn't distort the signal in any manner. Electronic devices don't seem to be ideal but, and so degrade the signal to a point.

The amplifier style objective is to attenuate the noise extra and therefore the distortion created whereas increasing the amplitude of the signal. Style trade-offs enable one to get the simplest potential performance from a specific active device.

**Design and Implementation**

The design methodology for power amplifier design can be broken down into three main sections: biasing network, stability considerations, and matching network for optimization.

**Biasing Network**

The GaAs FET is what’s typically brought up as a “normally ON” sort device. Its basic distinction from the MOSFET is that the use of a Schottky barrier at the gate rather than associate compound layer. This is often a particularly necessary purpose. In alternative words, virtually no GaAs FET gates square measure insulated from the channels in terms of electricity. Thus, even if GaAs FETs square measure referred to as “normally ON” sort devices, the utmost gate voltage should be zero. It doesn't use stuff just like the MOSFET, therefore if a positive voltage is applied at the gate, electricity flows through it. Since the gate may be a terribly little piece of metal (0.5, µ-1.0µ-2.0µ), the gate electrodes can fuse fully in most cases. The properties of a GaAs MESFET are shown in Fig.2.

**Stability Considerations**

Two port networks may be stable or potentially unstable. It is imperative that the amplifier does not oscillate in the product environment, since such behavior leads to product malfunction. If the two-port is potentially unstable, there are conditions where oscillations can occur. Certain source or load terminations that produce the oscillations provide the conditions necessary for the unstable behavior. This type of design is called a conditionally stable design. If the conditionally stable design method is utilized, extreme care must be observed to guarantee that a source or load termination that produces an oscillation is never presented to the amplifier. This applies to all
frequencies in-band and out of band. This can be a difficult task at best in most applications. The unconditionally stable design approach allows any source or load terminations, which have reflection coefficient magnitudes between ‘0’ and ‘1’, inclusive, presented to the amplifier without the possibility of an oscillation. It is highly recommended that the two ports are made unconditionally stable at all frequencies. An unconditionally stable design guards against unexpected oscillations, which cause product malfunction.

\[
K = \frac{(1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2)}{2|S_{21}S_{12}|} > 1 \quad (\text{Eq. 1})
\]

Where: \(|\Delta| = |S_{11}S_{22} - S_{12}S_{21}| > 1

Matching Network

For linear systems, the condition for maximum power transfer is obtained when the impedance of the circuit receiving a signal has an equal resistance and an opposite reactance of the circuit sending the signal. In the mathematics of complex variables, this relationship is known as the complex conjugate. The complex conjugate of a complex number is obtained by simply reversing the sign of the imaginary part. Here \(Z^*\) denotes the complex conjugate of \(Z\); thus, for linear systems the condition for maximum power transfer is when \(Z_L = Z^*_S\).

The location of the load becomes crucial in the choice of circuit configuration for the purpose of matching. The load can have three distinct possibilities.

**Case I:** The load is located inside the \((1+jx)\) circle i.e., resistance unity circle

Solution 1: shunt L and series C
Solution 2: shunt C and series L

**Case II:** The load is located inside the \((1+jb)\) circle i.e., conductance unity circle

Solution 1: series L and shunt C
Solution 2: series C and shunt L

**Case III:** The load is located outside the \((1+jx)\) and \((1+jb)\) circle.

In this case, there are four solutions possible, as shown in Fig.3.

\[\text{Figure 3: Smith chart solution for case III}\]

Solution 1: series C and shunt C
Solution 2: series C and shunt L
Solution 3: shunt C and series C
Solution 4: shunt C and series L

Considering all three cases, case III has the highest flexibility because it has highest number of design choices to suite the designer’s needs.

**Simulation and Measurements Results**
The supply voltage, VDD for this simulation is 3.0 V and drain current, Idd is 29.47 mA. Supply input power is ‘0 dBm’. After amplification the resultant power around 4 dBm achieved. The circuit diagram as shown in Fig.4.

Figure 4: Circuit schematic of power amplifier

Figure 5: Stability factor calculation

Figure 6: Input and output matching coefficients

The stability factor (K) of the transistor is 1.298, so the transistor in unconditionally stable as shown in Fig.5. After designing the input and output matching the coefficients are S (1, 1) and S (2, 2) respectively as shown in Fig.6.
The small signal gain is calculated by using S(2,1), input and output return losses are calculated by S(1,1) and S(2,2) respectively. The all S-Parameter values are taken from the Fig.7. The final result of an amplifier is shown in Fig.8. i.e., output power is increasing as input power increases.

Conclusion

The 3.5 GHz power amplifier were designed for wireless application by using 0.30 μm GaAs technology with a gate width of 250 μm and 10 fingers has been presented. Software ADS was used in the designing process. It has been demonstrated that at a 3.0 V drain voltage, the amplifier has achieved 17.69 dB small-signal gain S21, input and output return loss of -13.41 dB and -9.41dB, with 9.03 % power-added efficiency (PAE) for 3.5GHz power amplifier. The designed PA are in unconditionally stable condition due to the stability factor for the PA are higher than 1 at the whole range of frequency. In order to improve the performance of the system and achieve a higher output power, the matching system should be designed in a specific way.
References


