Ultra Wideband Power Amplifier Design for Active Antenna Applications

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ABSTRACT-An ultra-wideband power amplifier is designed, simulated and tested in this work. The frequency of operation ranges from 700 MHz to 3 GHz with average gain of 17.5 dB over entire band. Maximum power handling capacity of +22 dBm maintains average power gain over the band of operation with gain variation up to 3 dB tolerable. Peak gain of 22 dB is observed at 1.9 GHz. Input and output matching networks are designed to provide wideband impedance matching with tolerable impedance variation of 5 ohm. The matching networks also provide good isolation through shunt feedback topology. Finally, simulation and measurement results are compared and discussed.

KEYWORDS- *ultra-wideband power amplifier, wideband impedance matching, shunt feedback topology.*

I. INTRODUCTION

Recently, many authors have utilized MESFET semiconductor devices for power amplifier design with common applications being aerospace, military systems and digital TV broadcast[1]. Such devices have very high internal resistance[2]. This can simplify design of matching networks to achieve wider bandwidth and efficient power coupling[3][4][5].

In the RF amplifier design, the input and output matching network are used to provide the stability, small signal gain, and bandwidth [6][7]. The high frequency transistor amplifier design is the matching of the input and the output network at high frequencies using S-parameters at a DC-bias point with source and load impedance of Z0. The input and output matching networks are fundamental to reduce the undesirable reflection of signal and to improve effectiveness of the transmission from source to load [8][9].

In this paper, one such design is completed and discussed. Section II discusses the power amplifier design procedure that includes two major points: DC bias tee design and wideband matching networks design. DC bias circuit discussed here is separates DC and RF signals flowing through the circuit. This mainly includes selection of RF choke for wideband performance and tuning range as per frequency variation. It also includes selection of ringing and DC blocking capacitors. Also, design of wideband matching networks involves appropriate Q value selection over the band of operation. Shunt feedback network was also designed as part of matching networks for obtaining wideband operation from 700 MHz to 3 GHz. In Section III, simulation and test results are compared and discussed. Section IV concludes the design and findings. It also mentions the future scope of this work.

II .PROPOSED AMPLIFIER DESIGN PROCEDURE

Design of any power amplifier starts with the selection of a transistor that matches with the targeted specifications. For this work, targeted frequency range is from 700 MHz to 3 GHz. The selected device for such range is MGA83563. This device offers considerably flat response over the band of interest. Next step is to design DC bias circuit design. Major application of DC bias circuit is to isolate DC current and voltage from RF signal. There are two main components to DC bias tee. First component is RF choke design. This inductor value is lower at higher frequency components and higher at lower frequency components. To get wideband performance with RF choke, high value choke is needs to be selected. Scattering parameters S11 and S22 provide circuit performance after putting RF choke at work. Figure 1 shows circuit under test with RF choke at work. Internal equivalent circuit is shown in Figure 2. In some of the power amplifier designs, multiple tantalum capacitors are connected between DC supply line and ground to prevent ringing and memory effects that occur in RF power amplifiers. In this design, two capacitors are kept for preventing memory effects.

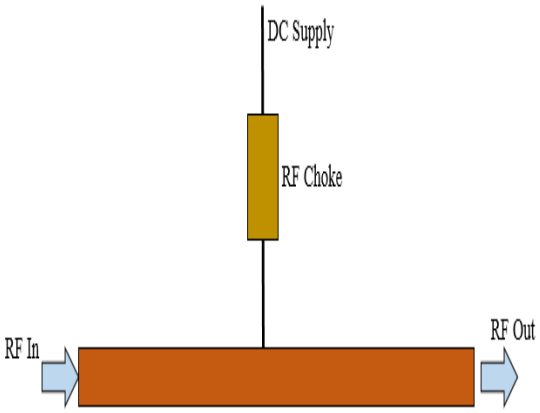

Figure 1 Circuit schematic with RF choke

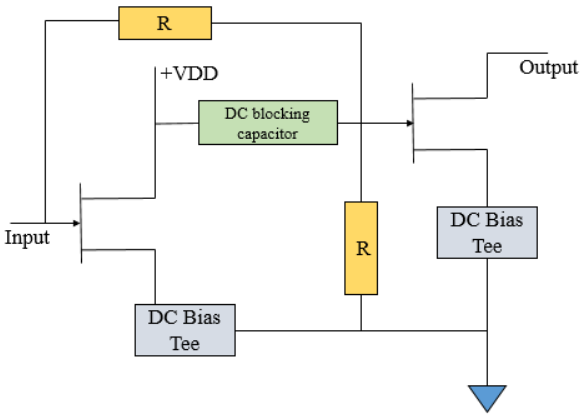

Figure 2 DC bias tee equivalent circuit

Next step in the design is wideband matching network design. Matching networks act as filtering networks with high Q values. However, matching network design process varies widely that filter design. In case of wideband matching networkdesign, shunt feedback technique is most common. This technique deploys feedback resistance R_F and feedback capacitor C_F. Both of these components values are related to scattering parameter as,

$$R_F=Z_0\ (1+|S_{21}|)$$

This equation holds true in case of $|R_F|>Z_0$. Feedback capacitor bypasses RF signal and this capacitor works as DC blocking capacitor between gate and drain. Its value can be calculated by treating this capacitor as Miller's capacitor for small signal operation. Unconditional stability for Rolle's factor can be obtained by adding series impedance at gate side of amplifier. Impedance matching circuit at input and output side of the amplifier provide the stable amplifier for the frequency range of interest. For any power amplifier design of matching networks have several targets; few of them being: maximum power delivery to load, maximum power added efficiency and maximum load balancing. In this design case, maximum power delivery to load is the target while designing the matching networks. Microstrip equivalent matching network was designed and simulated using AWR Microwave Office. The schematic diagram of amplifier is shown in Figure 3. For Microstrip components design substrate considered was FR4 with thickness of 0.8 mm and dielectric constant of 4.4.

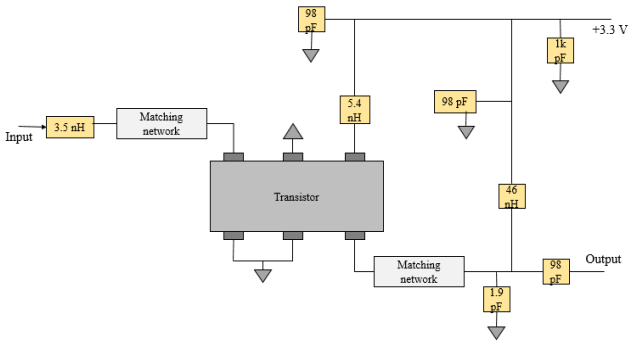

Figure 3 Power amplifier schematic diagram

Figure 4 shows IV characteristics of device which is suitable for selection of dc bias. Figure 5 shows the Load pull data contour of the device.

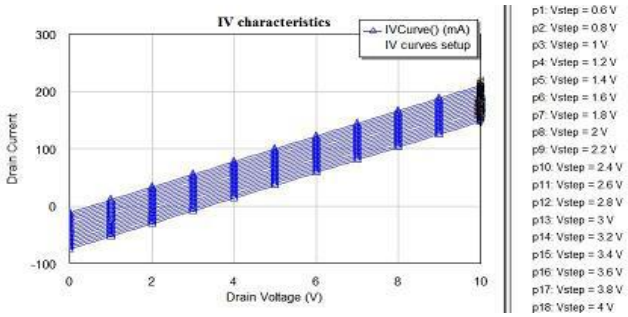

Figure 4 IV characteristics of the device

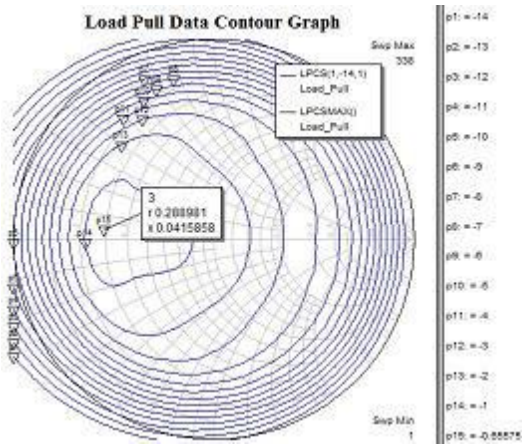

Figure 5 IV Load pull data contour of the device

This section directly gives comparison between simulated and measured results. Small signal scattering parameters are measured at 3.3 V and 160 mA bias point using vector network analyzer. The comparison for scattering parameters is given in Figure 4 and 5.

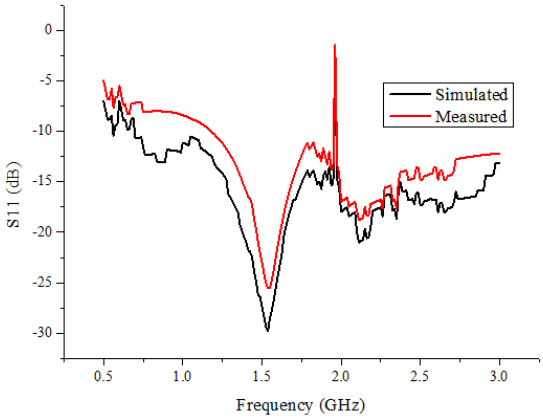

Figure 6 Comparison for simulated and measured values of S11

However, maximum deviation range of 2 dB is observed in case of small signal gain and such deviations are acceptable over the wide band of operation. Maximum small signal gain

is achieved at 1.9 GHz as observed from figure 5. Amplifier design maintains the return loss lesser than -10 dB over 700 MHz to approximately 3.1 GHz; which is in agreement with design targets. Forward and reverse return losses are measured and simulated and are shown in Figure 6 for reference.

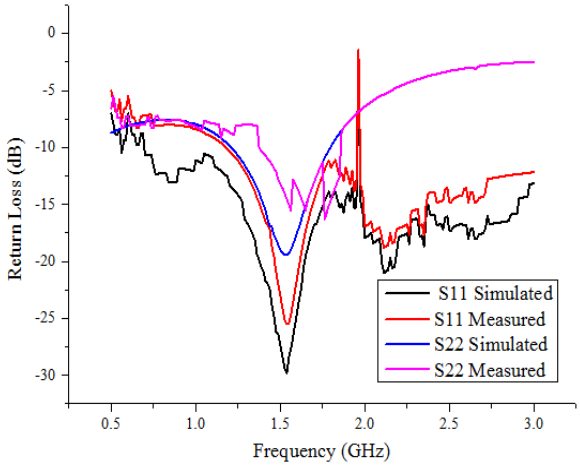

Figure 7 Forward and reverse return loss measurement

For power measurement, setup was done with RF continuous wave signal generator connected to amplifier under test through the high gain pre amplifier. The output of the amplifier under test is connected to spectrum analyzer through the series of attenuators circuits which can be tuned to desired attenuation levels. PAE, amplifier power output and power gain are plotted in same graph and shown in Figure 8. Power amplifier designed here provides peak power of +22 dBm and its compression point is found to be at +26 dBm. Margin of +4 dB is kept in order to accommodate any back-off phenomena in case it is used with modulated source rather than continuous wave.

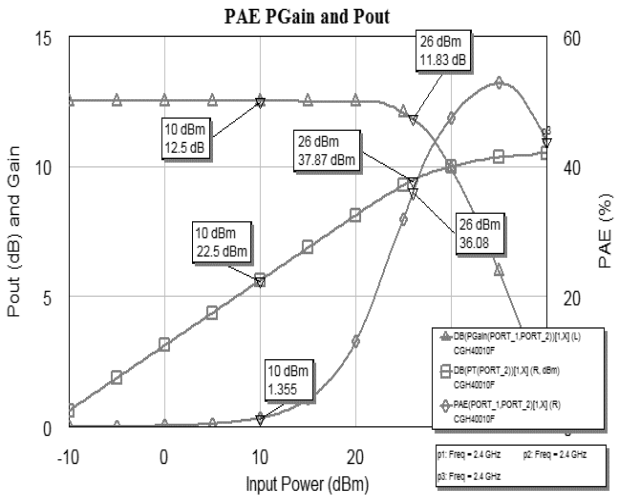

Figure 8 PAE, power gain and power output plots

The proposed amplifier is fabricated and tested. Figure 9 shows photos of the fabricated wide band amplifier.

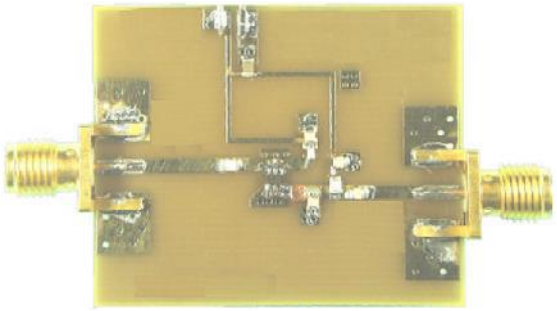

Figure 9. Photos of the amplifier PCB

V. CONCLUSION AND DISCUSSION

A wideband power amplifier that operates from 700 MHz to 3 GHz is designed, simulated and tested in this work. Over such wide band this amplifier offers gain flatness with 2 dB fluctuations which is tolerable. Small signal scattering parameters are measures at 3.3 V and 160 mA operating point and found to be in agreement for frequency band of interest. Maximum gain of 22 dB is obtained at 1.9 GHz with PAE of 37 %. The results were discussed and good agreement found with simulated and measured values. Future scope of this work includes connecting multiband antenna to this amplifier and uses the complete unit as active antenna. Active antennas are power amplifier output directly coupled into antenna input, for better power output. The work is in progress.

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