Design and Testing of 10W SSPA based S band Transmitting Module

Divya B N[1], Mrs. Shakunthala C[2]

[1]M. Tech CAID, Dept. of Electrical & Electronics Engineering, The National Institute of Engineering, Mysuru, Karnataka, India

[2]Assistant Professor, Dept. of Electrical & Electronics Engineering, The National Institute of Engineering, Mysuru, Karnataka, India.

---***---

ABSTRACT:-*Future of weather radar lies in Phase Array Technology with its advanced multifunction capability and performance. Solid State Power Amplifier (SSPA) using GaN apparently presents many benefits including reliability over Travelling Wave Tube Amplifier (TWTA). The SSPA forms an integral unit of a phased array antenna used in Multifunction Phase Array Radar (MPAR). This paper describes the design and testing of SSPA based transmitting module consisting of pre-driver, driver and power amplifier stage to deliver 10W output power at 2.85GHz(S band frequency range) .Simulation is carried out using Agilent ADS software for impedance matching. S parameters measurements are carried out in the laboratory with fabricated components using Vector Network Analyzer.*

Key words:-Solid State Power Amplifier, S band, S parameter, impedance matching

I. INTRODUCTION

Radar technology is one of the most advanced methods used to measure the position of an object at point where radar is Located, and the distance between the objects. A radar system usually consists of a transmitter that generates electromagnetic signals emitted by an antenna in space. An active electronically scanned and computer controlled phased array antenna is used by radar, in antenna theory. Without moving the antenna, the radio waves can be sent in different direction by means of electromagnetic control. Each antenna element is connected to a small solid state transceiver module under the control of computer that performs the function of transmitter of antenna.

Multifunction Phase Array Radar (MPAR) is an active phased array radar having the main features such as Electronic steering , rapid scanning and capable to simultaneously perform weather surveillance ,aircraft surveillance with a single phase array radar operating at the frequency range of S band. The transmitter module consisting power amplifier is designed for S-band MPAR system which is used to provide sufficient energy for radar signals before transmitting and generating from the antenna for the implementation of long way communication and to achieve lower attenuation [2].The Gallium Nitride (GaN) HEMT is a strategic component for high performance, wideband transceiver modules and high performance semiconductor transmitters [3]. High power density is the important feature of GaN and high voltage feature decreases the need of voltage conversion, leading to higher efficiency operation [1].

The radar transmitter generates the high power short duration RF signals that are radiated into space by the antenna and having significant characteristics such as suitable RF bandwidth, high stability to signal processing, easily modulated to required waveform design, high efficient and reliable .

Radar transmitter is classified into two types:

- High–Power Oscillator transmitter
- High–Power-Amplifier transmitter

Power Amplifier Transmitter (PAT) is an active antenna where each antenna element or group is designed with an own amplifier such as Magnetron, Klystron or Solid State Amplifier. Radar with PATs is fully coherent.

Solid State Power Amplifier (SSPA) is significantly beneficial over the Travelling Wave Tube Amplifier (TWTA) with parameters such as size, weight, power, linearity, efficiency, reliability, output distribution losses and RF output power.

This paper describes the design and testing of 10W SSPA based S band transmitting module. The block diagram of the transceiver module is as shown in the figure 1. It consists of transmitting and receiver chain. Transmitting chain consists of 3 stages namely:

- Pre-driver
- Driver
- Solid State Power amplifier

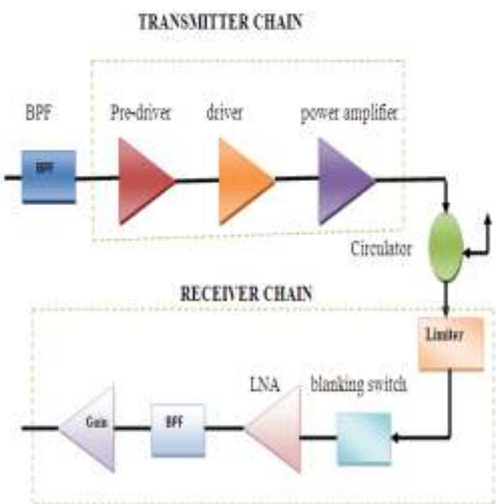

Figure.1. Block diagram of Transceiver Module

RF Power Amplifier is DC consuming power circuit that delivers the maximum output power. It mainly consists of an active device and the matching circuit at input and output side required for the transformation of impedance and biasing.

Combination of pre-driver, driver and amplifier stage forms the transmitting chain .Transmitting chain forms integral part transceiver module and aims at achieving the higher efficiency and linearity and maximum power transfer.

Transmitting module is integral part of Radar for S band multifunction phase array radar (MPAR). It is operating at the 2.85 GHz frequency. In order to compromise between the better efficiency and linearity the device is biased in class AB through transmission lines using microstrip line. Stability analysis is carried out to ensure the circuit is marginally stable. Load pull technique is applied to check the optimal load for increasing delivered power. Impedance Matching is achieved by matching circuitry to ensure the maximum power transfer. Optimization is carried out for suppressing the harmonics to ensure the linearity of amplifier.

Vector Network Analyzer is used for the analysis of signal behavior described in terms of gain, return loss and reflection coefficient and also for the measurement S-parameters.

The electrical behavior of the linear electrical networks can be described by the S-parameters. S11 and S22 are the input and output reflection Coefficient S-parameter. S21 is the transmission coefficient scattering parameter. S11 and S22 represents the return loss and S21 represents the gain which plays an important role in the impedance matching.

The two port network S-parameters can be easily modeled with the software such as Agilent Advanced Design System (ADS). Advanced Design System is a type electronic circuit design software which supports at every step of schematic and layout capture, frequency and time domain circuit simulation and also electromagnetic simulation.

Testing and measurement of the fabricated component is carried out in laboratory to meet the desired value using the Vector Network Analyzer.

II. DESIGN

A. DESIGN INDEX

- The operating frequency range of 2 to 4 GHz
- The transmitter Input Power of -5dBm
- Peak transmitting power of 10W

B. THE CHOICE OF COMPONENTS

Design of pre driver, driver and power amplifier stage should choose the suitable RF gain block, transistor or FET through access to relevant specification and considerations. Finally choose the ADL5545 RF gain block for pre driver stage, providing the broadband operation from frequency range 30MHz to 6GHz and providing a gain of 24dB.

The Hetero-junction Field Effect Transistor XF1001-SC providing a gain of 10dB and suitable for the application up to 6GHz frequency operation is chosen for the driver stage.

The high electron mobility transistor (HEMT) CREE transistor CGH40010 with the capability of high gain efficiency is chosen for the power amplifier stage operating up to 6GHz and providing a gain of 14dB.

III. SIMULATION

Simulation of the transmitting module consisting of 3 stages of amplifiers are carried out using the ADS software, which provides the unified environment to RF electronic device designers and also supports the designers at each step to characterize and optimize the RF design ,allowing the design schematic capture ,circuit simulation and highly accurate and versatile models.

A.STABILITY ANALYSIS

Transistor is operated in the active region by DC biasing so that the power amplifier performance is improved. Instability of the device can damage or destroy transistor. Stabilization circuit is designed to avoid the power amplifier entering the oscillations causing the decrease of the gain at lower frequency side. In order to overcome the stability issue stabilization circuit is designed where parallel RC circuit is connected to gate side of the CREE transistor. Stability test is carried out and simulation results for the stability are shown in figure 2-3.

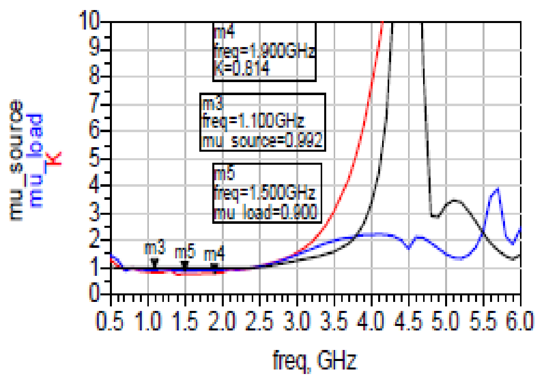

Figure.2. Stability factor before adding the RC circuit at 1.9 GHz

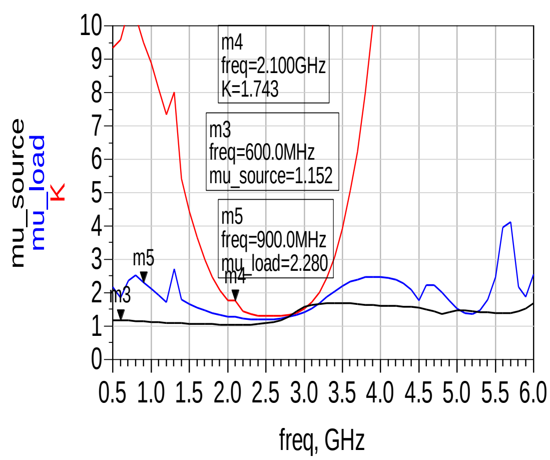

Figure.3. Stability factor after adding the RC circuit at 2.1GHz

B. MATCHING NETWORKS

For impedance transformation, matching networks are designed usually between the transistor and the terminations on the input and output side of the amplifier. In this paper load pull technique is carried out using the ads software providing the platform to analyze and to find out the optimum values of source and load impedance required for design of matching circuits [1]. Impedance matching technique ensures the maximum power transfer.

Optimum impedance is obtained by load pull test used for the Matching Network design. In pre driver design ADL5545 is used .It is found optimum source and load impedance are 24.321+j2.073 and 34.889-6.919. The matching circuit output result with the gain of 21dB and other s parameter at 2.85 GHz is as shown in figure 4.

In driver design XF1001-SC transistor is used. It is found optimum source and load impedance are 71.746+j30.531 and 10.793-j7.527. The matching circuit output result with the gain of 9.957dB and other S parameter at 2.85 GHz is as shown in figure 5.

In power amplifier design CGH40010F CREE transistor is used. It is found optimum source and load impedance are 2.95+j*2.29 and 10.79+j*2.29. The matching circuit output result with the gain of 15.259dB and other S parameter at 2.85 GHz is as shown in figure 6.

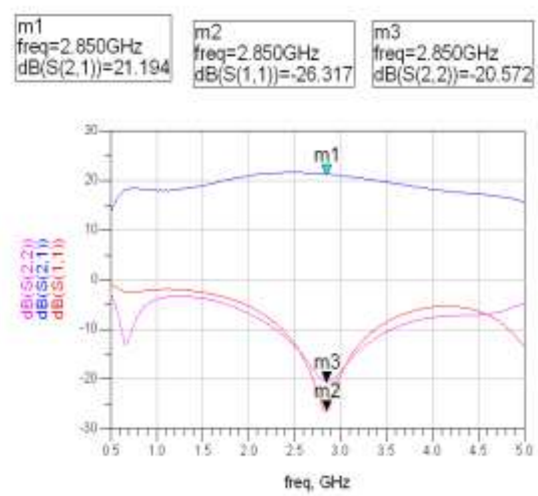

Figure.4. Matching circuit output with the gain of 21.194dB at 2.85GHz

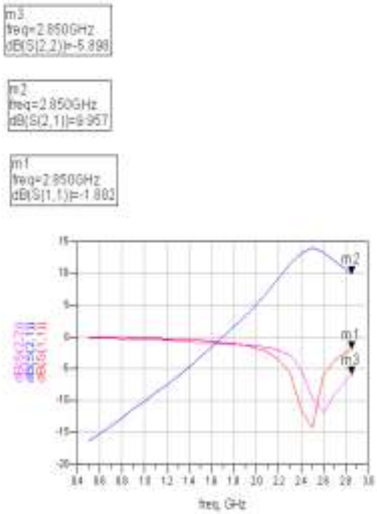

Figure.5. Matching circuit output with the gain of 9.957dB at 2.85GHz

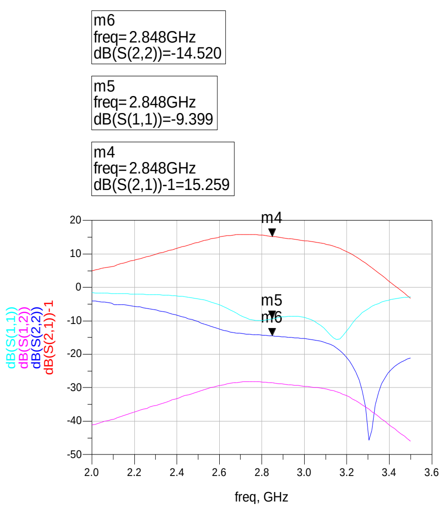

Figure.6.Matching circuit output with the gain of 15.259dB at 2.85GHz

C. FABRICATION

Fabrication is carried out on F4 substrate. The fabricated components of pre –driver, driver and amplifier forming the transmitting chain are as shown in the figure 7.

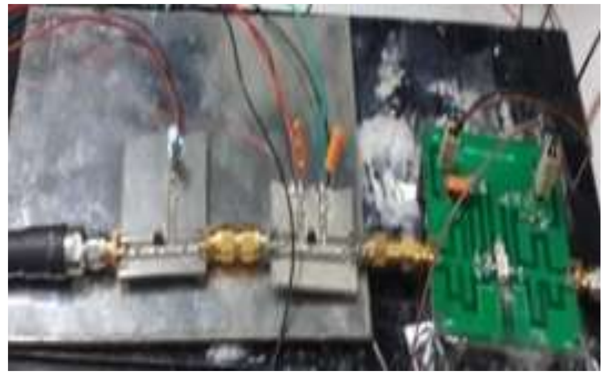

Figure.7. Fabricated transmitting chain

IV. TESTING

D. MEASUREMENT RESULT

In this paper the measurements are made with the fabricated pre-driver, driver and power amplifier component to obtain the desired result using the network Analyzer. The experimental setup is as shown in the figure 8.

Figure.8. Experimental setup for testing the transmitter chain

The test result of the fabricated ADL5545, pre-driver is as shown in figure 9. Gain (S21), S11 and S22 parameters of 18.1dB, -14.5dB and -23dB is obtained respectively at the frequency of 2.85GHz.

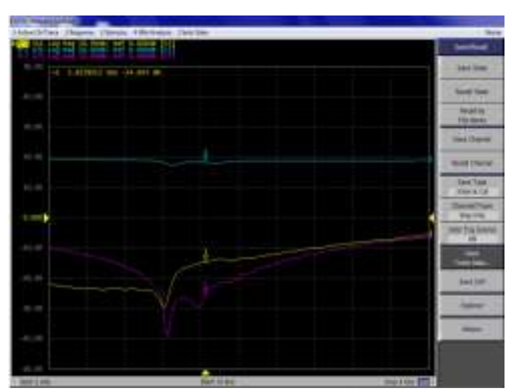

Figure.9. Network analyzer of ADL5545

The test result of the fabricated XF1001-SC, driver is as shown in the figure 10. Gain (S21), S11, S22 parameters of 9.4dB, -8.89dB and -5.1dB are obtained respectively at the frequency of 2.85GHz.

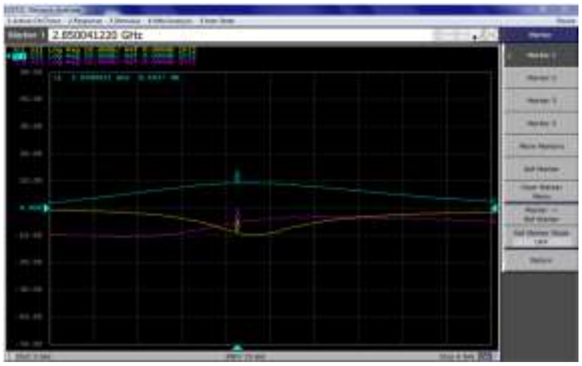

Figure.10. Network Analyzer of XF1001

The test result of fabricated CGH40010, power amplifier is as shown in figure 11.Gain (S21), S11, S22 parameters of 13.2 dB, -5.7 dB and -11.0dB is obtained respectively at frequency of 2.85GHz.

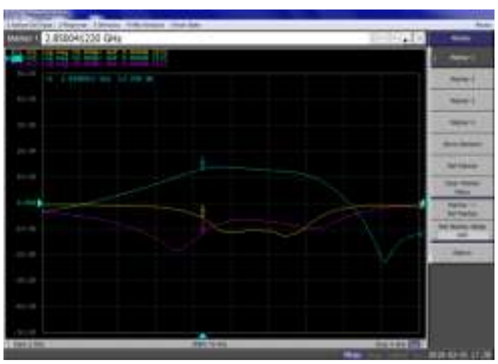

Figure.11. Network Analyzer of CGH40010

The test result of transmitter chain is as shown in the figure 12. Gain (S21), S11, and S22 parameters of 41.2 dB, -20dB, -9dB are obtained respectively at frequency of 2.85 GHz.

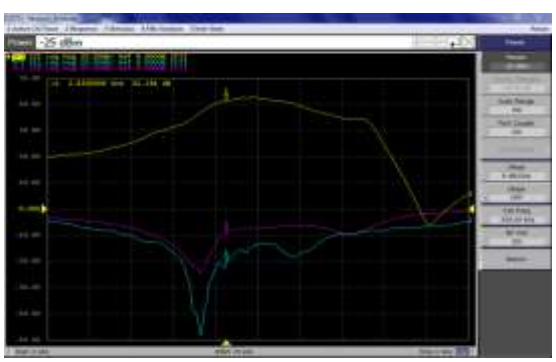

Figure.12. Network Analyzer of ADL5545+XF1001+CGH40010

V. CONCLUSION

In this paper design, simulation and testing of 10W SSPA based S band transmitting module is carried out. Simulation and testing results were found to be satisfactory. The test result of transmitter chain shows the gain of 41.2 dB at the frequency of 2.85GHz. Better gain, efficiency, linearity and reliability of transmitting module are achieved.

REFRENCES

[1] Muhammed Hakan Yilmaz, “Design of a wideband 10W GaN power amplifier,” Thesis for the degree of Master of Science, Norwegian University of Science and Technology, Trondheim, July 2011.

[2] Doan Van Truong, Linh Mai, Van-Su Tran, “ 0.5 W S-band Two-stage Power Amplifier: Research, Design and Implementation,”2nd International conference on Recent Advances in Signal Processing, Telecommunications & computing, IEEE Trans. May. 2018

[3] Gan Shujian, Pei Chen, Chu Ran, “Design of a High-Efficiency Doherty GaN Power Amplifier,”IEEE Trans.March 2016

[4] Lianmei Wang, Dong Chen, “Design of Broadband Power Amplifier based on ADS,”IEEE Trans. March.2016

[5] Congjie Wu, Yalin Guan, “Design and Simulation of Driver Stage Power Amplifier,” IEEE workshop on advanced Research and technology in industrial applications, IEEE Trans. 2014.

[6] R. Gilmore and L.Besser, “Practical RF Circuit Design for Modern WirelessSystems,” Volume II Active Circuits andSystems, Artech House, 2002