Transmitter for Beam Forming Applications

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Abstract -- **Efficiency is critical parameter in any transmit module as it has high impact on cooling arrangements and power generation requirements of the system. Highly efficient GaN Transistor based transmitter design not only minimises hardware required to dissipate heat but also improves system MTBF. This paper gives details of transmit chain for beam forming application. Transmit chain uses High Power GaN transistors in Class AB power amplifiers. This Transmit chain has efficiency better than 58% and has provision to adjust gain and phase for beam steering requirement. The transmitter has protection against high VSWR and against thermal burn-out. Evaluation results of Transmitter are included.**

Keywords: Radar beam forming, Transmit receive module, GaN, Electronic beam steering

I. INTRODUCTION

RADAR beam forming is an essential requirement of AESA radars. Usually high power transmitters were used in old radar designs and beam steering was done through ferrite based phase shifters. This makes the whole system very bulky and complex. Now, with latest technological advancements, wide range of chip phase shifters and digital attenuators with low range resolution and wide adjustable range are available. Hence it becomes easier to control the gain/phase of individual transmit receive module to steer the beam over scanning area.

GaAs MMIC amplifiers and LDMOS are commonly used with typical low output powers of 5W to 10 W [1, 2] and Low gain T-R module applications. Amplifiers based on AlGaN/GaN are very promising, HPAs with higher output power compared to GaAs are already verified [3, 4] for similar applications.

GaN has higher breakdown voltages compared to GaAs and has increased power added efficiency (PAE) values and higher operating voltages w.r.t. traditional GaAs transistors. Bipolar RF Power amplifier designs given in [5, 6, 7] are less efficient. Class C design given in [7] shows limitations with signal level input variations as transmitter moves out of Class C mode. Hence variation in input affects power output drastically.

The design of transmit and receive module becomes easier and subsequently scanning of electronic beam by combination of different patterns of patch. The beam steering required very bulky hardware in old systems but due to recent advancement of technology, electronic beam steering is very convenient. Design and developmental details of Transmitter chain with variable phase and gain is discussed in detail in this paper. Developed transmitter chain uses 7-bit digital attenuator and 6-bit digital phase shifter to have multiple gains and phase variation steps as per requirement. In chain various GaN based power and driver amplifiers were used.

II. DESIGN APPROACH

This chain is capable to handle Mode-S with high duty cycle (6.4%) requirement for different ATC radars. Figure 1 shows detailed schematic of transmitter chain used as a part of Quad Transmit Receive Application.

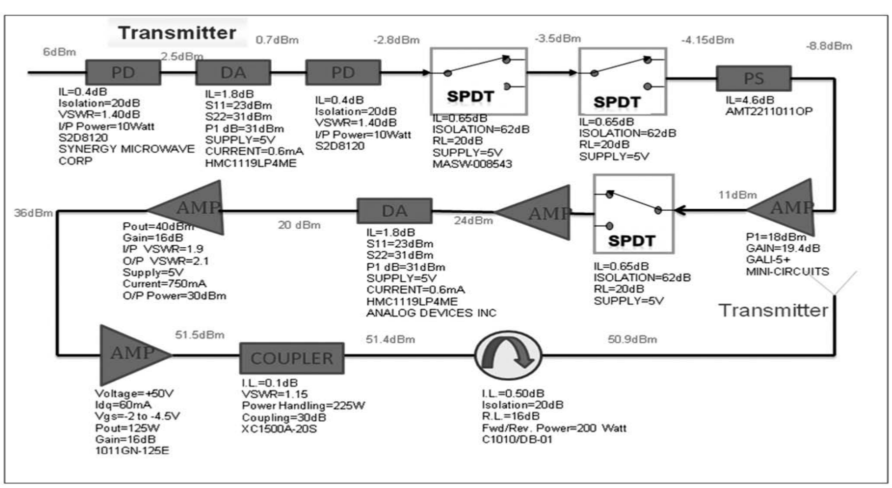

Figure 1. Transmitter chain.

Plurality of amplifiers was used to achieve required gain of Tx chain. Multiple SPDT has been used to isolate Transmit & receive path as per requirement. Phase shifter, digital attenuator and few amplifiers were made part of common leg for enhanced application. Coupler has been used to monitor RF output and Circulator was used to protect transmitter device and isolate receive path during reception.

III. DESIGN METHOD

Transmit chain is part of Quad TR module project. Complete transmit chain is divided in 3 RF PCB's namely power distribution PCB, Common leg PCB and Power Amplifier PCB. RF PCB uses Rogers 6006, 5880 and 4350 B substrates [8, 9]. The bias card for all four transmitters is common and is a multilayer FR-4 PCB. Pulsed RF signal as per ICAO / STANAG was fed to the input of RF Chain and output of 45 watt was achieved which can be reduced to 10Watt with control of digital attenuators. Variable power with adjustable phase is possible as 6-bit phase shifter and 7-bit digital attenuator are used in design. Beam steering will be possible with command and control from Radar controller. FPGA card has been used to provide command line interface, sequencing of GaN devices, and control to attenuators & phase shifters. Power and driver amplifiers are GaN based transistors and are used in Class AB to achieve high efficiency with desired input dynamic range. SPDT switches provide proper isolation among transmit mode and receive mode with least components. GaN transistors operate in Class-AB mode having excellent thermal efficiency. Fewer amplifiers at low power with SPDT switches and phase shifter are being used as common design part of Tx and Rx chain for least number of components.

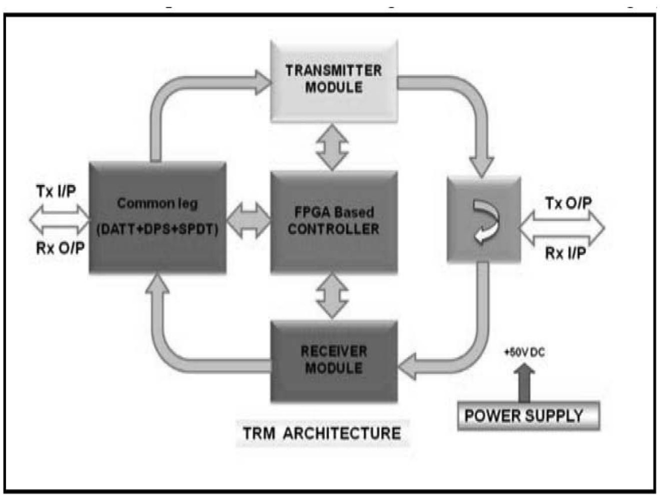

Figure 2. TRM architecture.

Figure 2 shows basic architecture of Quad TRM. It also shows interconnectivity of FPGA control card with transmit, receive and power supply portions.

IV. DESIGN OUTPUT

Developed protomodule of Quad Transmit and Receive Module is shown in Fig 3. QTRM was tested at room temperature and 48.2dBm output power was achieved at each transmit chain (min). The current consumption of QTRM was 0.42 Amp @ 50V for 0.1% duty cycle. Gain and phase-variation of each chain was measured with parallel control of attenuator and phase shifters on RF PCB's and it was as per data sheets. In integrated Quad-TRM assembly, it was tested with serial control data and meeting same specifications. Monitoring of health status has been made through 20 dB directional coupler which is used for forward power detection in terms of voltage using envelope detection method, hence fault diagnosis method of each chain has been given.

All parameters like pulse rise (<100nS), fall time (<200nS) droop (<0.5dB) was as per ICAO & STANAG [10,11].

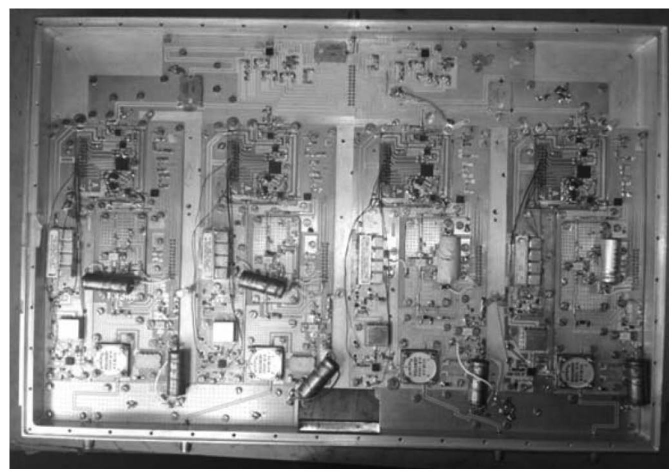

Figure 3. Developed proto-module of QTRM.

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