Dual Channel Transmitter for Medium Range Secondary Surveillance Radar

Amit Tiwari, FIETE
Development & Engineering, Microwave Components Division,
Bharat Electronics Limited, Ghaziabad 201010 UP India
amittiwari@bel.co.in

Abstract -- **A Gallium Nitride High Electron Mobility Transistor based solid-state light-weight highly reliable and compact dual channel Identification Friend or Foe (IFF) transmitter is developed and presented in paper. It can give 1KW output power. Module supports MSK, DPSK, PAM modulation which makes it suitable for ICAO Mode S, Mk XII(A) application as well as for Mode 1, 2, 3/A, C, 4, 5. The module generates a fault for high pulse width, high VSWR and high duty cycle. Complete design and measurement results of the transmitter are presented.**

Keywords: Identification Friend or Foe Interrogator, *Secondary surveillance radar, Transmitter, International Civil Aviation Organization, Standardization Agreement*

I INTRODUCTION

LATEST advancements in materials lead to design of highly efficient high power transmitters to meet existing and future demands. Systems that use S-Mode capabilities are often used for surveillance systems for air traffic control. Additionally, some ATC applications may use Mode-S transmitters, for example, vehicle-surface surveillance, or surveillance system for fixed-target detection [1]. This paper discusses design of dual channel 1KW transmitter using latest efficient Gallium Nitride HEMT amplifiers, featuring advantage of higher collector [2, 3] and thermal efficiencies.

Since power transistors operating at radio frequencies dissipate substantial power, appropriate cold plate, or heat sink is needed as per the cooling technique available. Low junction temperature is desirable for ensuring high reliability [4]. Developed module by the author maintains temperature inside the housing below 80°C.

II. DESIGN APPROACH

Author's design approach to realize compact high-power transmitter is depicted in Fig.1. Here signals for MSK, PAM, DPSK and power supply are routed through the 'monitor and the protection card' in transmitter design. This particular card protects transmitter from high VSWR, large pulse width, large duty cycle, high temperature and besides generating fault (TTL) for system level applications.

1030 MHz signal is obtained from gated crystal oscillator when TTL mode pulse (PAM Signal) is applied to it. Crystal output drives DPSK/MSK modulator which is controlled by signals received externally. This modulator drives 20Watt dual output driver amplifier, that in turn drives 1200W HEMT. A high power coupler with detector diode is used to monitor forward power. To be cost effective and reliable, RO4350B has been used in design.

As transmitter has to meet ICAO rise/ fall-time criteria, it is designed using capacitors as close as possible to drain of transistors. Tantalum capacitors were chosen for suitability of the transmitter for airborne application in design. Surface finish of the mounting location of the high power transistor also plays important role, therefore silver pre-form is planned to use at that point.

Transmitter is designed to meet thermal dissipation requirement of Mode-S/5 pulse characteristics and can be used with conduction, forced air convection and liquid cooling of transmitter.

In case of high VSWR,Circulator is put at final output pointfor protectinghigh-power transistors from reflected power. For this purpose,a detector diode is put at the third port of Circulator, is used to counter High VSWR fault &protection. The forward &reflected outputso detectedare compared with respect to threshold, generating indication for monitor & protection card. The module uses 50 volts DC power supply.

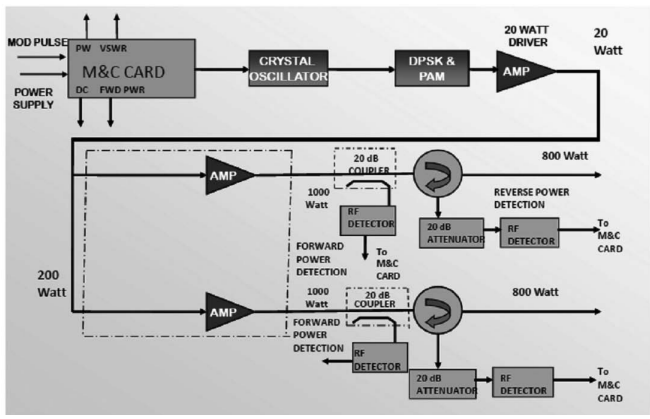

Figure 1. Design schematic of compact dual channel 1KW IFF Interrogator Transmitter.

III. DESIGN METHOD

Design uses broadband, 50 ohm matched, TTL Control DPSK modulator based on SPDT and Hybrid. Output of DPSK modulator fed to 20W LDMOS driver, which drives 1200W GaN Transistor of microsemi. At the Output of 1200W transistor, coupler for forward power and circulator for reverse power detection & protection were implemented. Rogers RT Duroid 6010, 6006 &5880 substrates &FR-4 substrate of two ounce & one ounce were used. Design and simulation tools like ADS, App-cad, Altium, Solid Work, Flowtherm etc have been used in calculations for the development

For providing power-supply sequencing and filtering, FR-4 substrate is used to design the 'Bias card'. It has a capacitor bank, which is needed by FET devices of both channels to ensure faster charging and discharging. Figure 2 shows the schematic.

Monitor and Control Card doesn't allow pulses more than 33 μs width and greater than 2% duty cycle.

IV. DESIGN OUTPUT

Figure 3 depicts designed Prototype S SPA. The module has one SMA connector and one 25 pin Mini D connector. Later has DC power supplies besides BPSK & Mode Pulses, ground connections, faults indication (in form of TTL High logic) and control signals on it, while the former has RF output power. RS232 Communication is used to display Fault and power. The module can work up to 32microsecond alongwith 2% duty cycle pulse width.A single housing of 216mm x 170mm x 35 mm encapsulatesthe complete Transmitter.

The transmitter housing is securely screwed on to the liquid cooled cold-plate, providing acceptable cooling with cover efficiency by cooling underneath each of the power devices of the transmit chain. By using external heat sink, the same module works with forced airflow cooling.

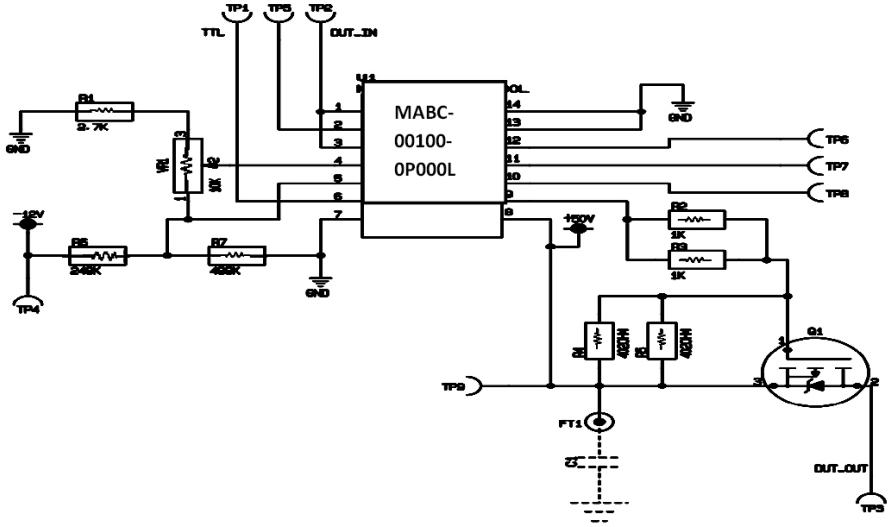

Figure 2. Bias sequencing card schematic used for dual channel IFF transmitter.

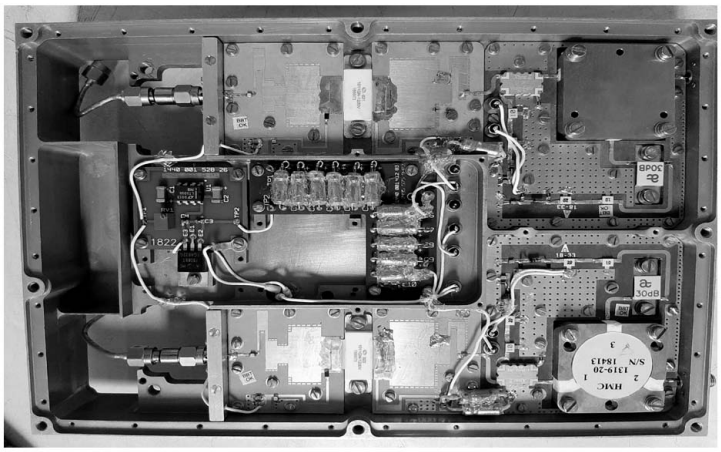

Fig 3: Developed prototype of dual channel 1KW IFF Interrogator Transmitter.

V. MEASUREMENTS

Developed system has been evaluated at temperatures as well. At 60^{0}C after 4 hour operation with fan of C F M 90, the currents are as follows: 0.35 Amp (32µs, 1.0% duty cycle), current 12V: 0.12A, current @5V: 50mA. Measured power was 60.21 and 60.1 dBm in both channels with droop of 0.32 & 0.3 dB respectively (Fig. 4). Pulse characteristics are measured as power 60.21dBm Pulse droop of 0.32dB, harmonics -33dBc; rise time < 70ns and fall time < 100ns.

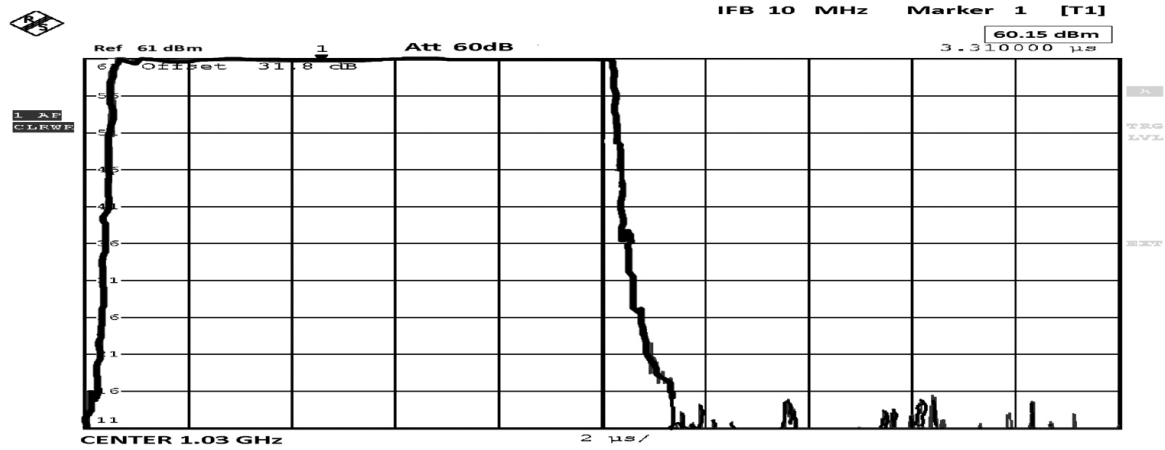

Figure 4(*a*). Measured output power.

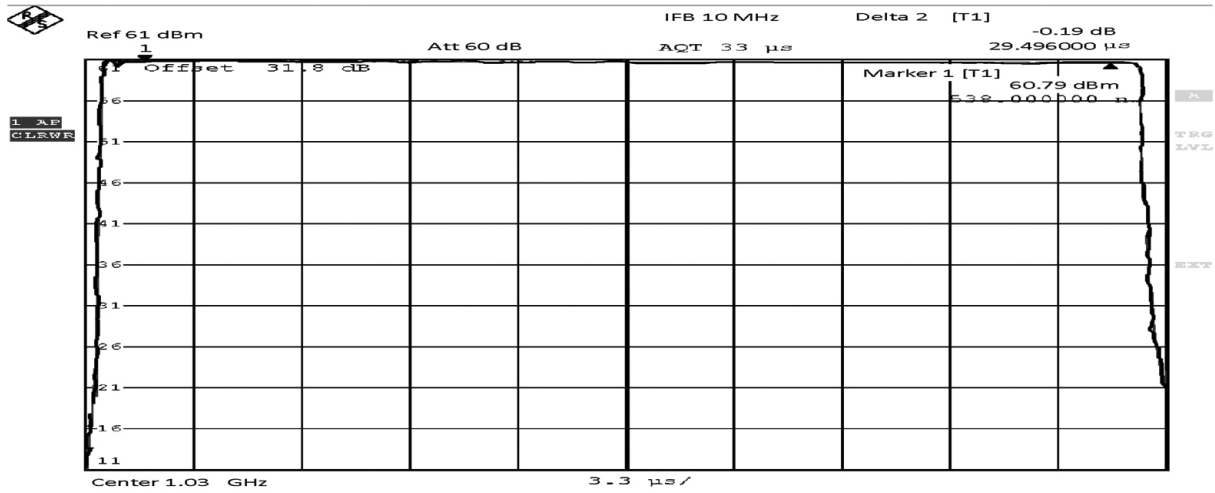

Figure 4 (*b*). Measured output power and droop.

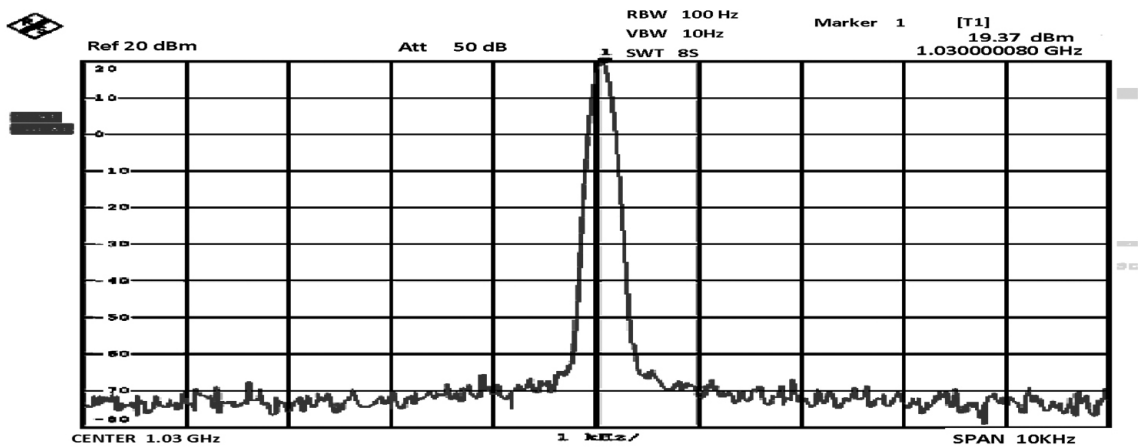

Figure 5. Measured carrier frequency.

VI. CONCLUSION

ICAO & STANAG standards [1, 5], namely frequency stability, rise time < l00 ns and fall time < 200 ns are met by the Compact dual channel SSPA realized in this paper. Additionally, it also satisfies environmental MIL standards 810E & EMI/EMC MIL STD of 461 E (with EMI Filter at supply). Features like compact size, light weight, transmitter protections, high thermal efficiency make it suitable for various IFF interrogator transmitters.

REFERENCES

[1] Annex 10 to The Convention on International Civil Aviation, Volume IV *Surveillance Radar and Collision Avoidance Systems*, pp. 3-1 to 3-13.

[2] Steve C. Cripps, *RF power amplifiers for wireless communications,* Artech House publishers, ISBN 0-89006-989-1.

[3] Mihai Albulet, *RF Power Amplifiers,* Noble Publishing Corporation, Atlanta, GA.

[4] R.G. Harrison, "A non linear theory of class C transistor amplifier & frequency multiplier", *IEEE Journal Solidstate Circuits*, vol. SC-2, Sept 1967, pp. 93-102.

[5] Technical characteristics of IFF MK-X(A) and MK XII Interrogators and Transponders – Part IV, pp. A-20.

Amit Tiwari, FIETE obtained Bachelor in Engineering in Electronics and Communication & Master of Technology in Microwave Engineering from ITBHU. He has 20 years of R & D experience. He also served MITS & Institute of Engineering, Jiwaji University Gwalior as an assistant professor.

Currently working as Manager, in Development & Engineering-Microwave Components of Bharat Electronics Limited, Ghaziabad. Designed & developed C-Band Airborne RF Transceivers, IFF Tx-Rx Unit & IFF Transmitters. Received various excellence awards for his innovative efforts. He has 3 IPR's in his name and 3 patents are under evaluation. His exemplary 'Make in India' work was awarded with IETE Sh. Devi Singh Tyagi memorial award 2018-19.