RADAR TRANSMITTERS

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Abstract

Radar transmitters are one of the major sub-systems of the mainstream RADAR System and the transmitter must be of adequate power to obtain the desired Radar range and also satisfy other requirements imposed by the system application. The special demands of various functionalities such as pulse Doppler, phased array Radar, ECCM and MTI applications influence the type of transmitterselected and its method of operation. This paper reviews one particular type of transmitter developed by HAL as part of the Multi Mode Radar(MMR) program .

I. CONTENTS

- Airborne radar transmitter – a brief
- Challenges in the development
  a) High Voltage deck development
  b) Collector module development
  c) Cathode module development
  d) Testing of Transmitters
- Energising of the Transmitter and different modes of operation
- Conclusion

II. Airborne radar transmitter

The transmitter discussed in this paper, also called as Power Amplifier Unit(PAU) , is the Line Replaceable Unit(LRU) of a Multi Mode Radar (MMR). The uniqueness in the Transmitter design is the generation of High Voltages that are required for biasing the TWT . Also is the special attention given to make the mechanical design in a robust manner so as to withstand the vibrational environments of fighter aircraft engines. The transmitter amplifies the small R.F. input signal (7 to 13 dBm) given from the Exciter unit to the high power microwave signal of the order of more than 5 KW(around 66 dBm) in the X-band . It is an assembly of several sub-modules and components. The main microwave power source in the PAU is the Travelling Wave Tube(TWT). TWT is chosen as power amplifier because of wide bandwidth apart from having good stability that is required for MTI applications. The other sub-modules and components cater to either source power or to protect the TWT. Built in test(BIT), signal monitoring are incorporated within the system for fault analysis and display of alarms.

Brief Specifications of the Transmitter

Frequency of operation	: X-band
Maximum duty cycle	: 10%
Pulse width	: 0.2 to 40 us
Output peak power	: 67 dBm (5.4 KW)
Spurious noise outside desired range	: less than -57 dBc
Spectral purity	: less than -60 dBc
VSWR	: 1.3 : 1 max.
DC input power	: +28 VDC, 100W max
AC input power	: 115 VAC/400 Hz,3phase
Forced air cooling(for sub modules)	: 30 g/s
Forced liquid (for the TWT)	: 14 lit/min
Length of the unit	: 795 +/- 5 mm
Width of the unit	: 560 +/- 5 mm
Height of the unit	: 200 +/- 5 mm
Weight of the unit	: 75 kg

The block diagram of the Transmitter is given below:

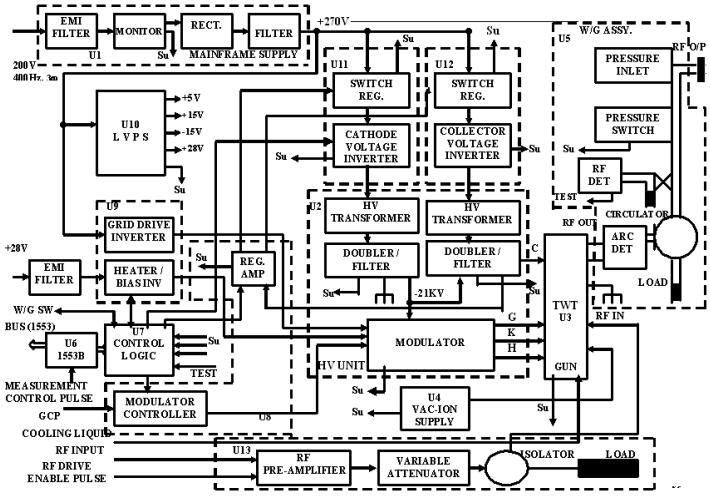


Fig.1 Transmitter Block diagram

The PAU has following main modules which are further divided into sub-modules whose functions are described below:

1. Main frame supply
2. Power line filter
3. Low Voltage deck
4. High Voltage Tank containing Collector ,Cathode, modulator submodules
5. Driver amplifier
6. Travelling Wave Tube(TWT)
7. Waveguide assembly
8. VAC-ION supply

Functioning of the various modules

The input to the main frame supply is the aircraft's prime power 115V, 400Hz,3 phase supply. The input of the main frame supply is provided through 3 phase EMI filter. The input supply is rectified and filtered to a 270 VDC. This will be the input to all the sub-units. Low voltages and High voltages are generated in separate sub-modules. The high voltages are employed in biasing the TWT for generating the high power output of order of KW. The low voltage circuits are used to feed the high voltage generation circuits as well help in powering supervisory and protection circuits. The low power RF input is given to the TWT from Exciter module . The amplified high RF output power from the transmitter is transferred to the antenna for transmitting out of the Radar using suitable waveguide network.

In addition to abovementioned main functionalities the tight regulated output voltages that are required for the TWT are achieved using a module called Regulating amplifier along with special linear regulator circuits. The heater voltage required for the generation of electrons by the TWT are generated using a module called Heater Grid module.

The status and fault signals from the different sub-modules are processed by a module called Control Logic Module which with the help of PAU –RT module sends the alarms to Signal Data Processor outside the transmitter.

III. Challenges faced in development of airborne radar transmitter

High Voltage deck development

Developing High Voltage modules involves lot of challenges, since the modules should not arc due to corona discharge. Also sufficient care to be taken to avoid shock hazards. Proper insulating materials were chosen to avoid high voltage arcings. Usage of silicon rubber compound as material for potting High Voltage deck is an example. Also highly insulating PAO oil was used to keep the high voltage generating modules immersed. Care was also taken in choosing proper high voltage components.

Collector and Cathode modules development

The cathode of the TWT is biased with -21KV and the collector is biased with -14KV. Such high voltages are generated in three stages. The input to the module is 270 VDC from the main frame unit. This is converted to intermediate 200VDC by the switch regulator followed by the inverter circuit which generates 200 V p-p AC supply . Finally this AC voltage is fed to the High Voltage multiplier cum rectifier circuit for generating the required high voltages. Special precautions are taken while designing PCB layout so that heavy currents can be handled. Similarly specially insulated high voltage transformers are made and care taken such that there are no inter winding arcings. The portion of the supply which generates the high voltage, is kept immersed in the insulating liquid called PAO oil and this separate portion is called as High Voltage Deck.

Environmental Testing

Transmitter being used in radars of fighter aircraft, have to undergo extensive environmental testing. Testing include Vibration, Acceleration , Shock, High temperature, Low temperature and Altitude tests.

Testing of the Transmitters

Testing of High Voltage circuits is an art in itself. High voltage probes along with heavily insulated high voltage wires are used to make the interconnections while making test set ups. Battery operated Oscilloscope to be used to avoid arcing. Proper caution sign board to be kept to warn people while doing high voltage testing. Test jigs are used to indicate fault alarms and statuses after getting inputs from fault sensing circuits within the transmitter.

Following is the list of faults and their classification :

A faults : Highest priority faults. Transmitter pulsing off. High Voltages are made off

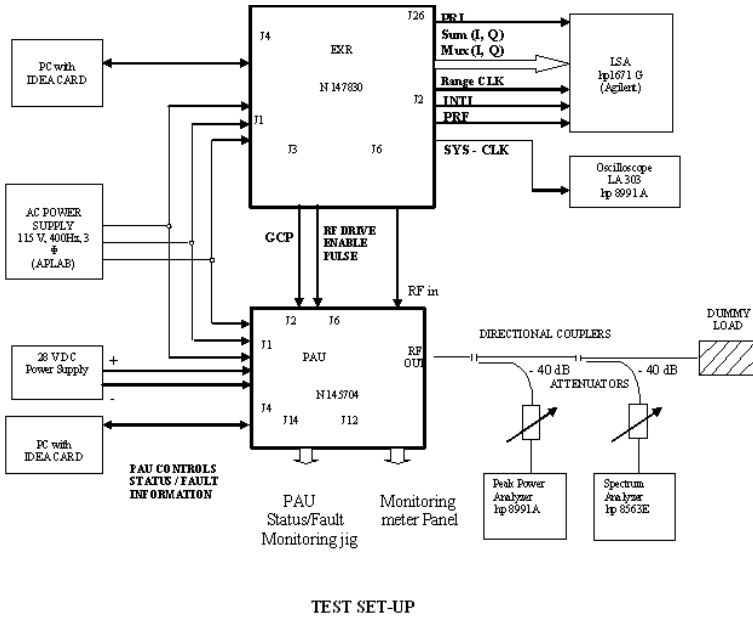
B faults : Lesser than A; Can be over ridden. Transmitter goes to stand by mode. High voltages are off.

C faults : Transmitter pulsing off. High voltages are ON.

D faults : least priority faults. Transmitter function not affected.

In all the cases the fault information is sent to SDP(Signal Data Processor) through the MIL-bus for analysis. MIL-1553B is the preferred mode of communication.

The test set up diagram is shown below:



TEST SET-UP

Fig.2 Test SET-UP

IV. Energising the Transmitter and different modes of operation

There are three stages of Transmitter energisation:

1. Heater Ready stage
2. High Voltage Ready stage
3. Radiation stage

Heater Ready stage

Once the 115VAC and 28 VDC from the aircraft is applied the heater voltage is generated and applied to the TWT heater element. All supervisory circuits are activated. Bus communication established between PAU and SDP. VAC-ION supplies ion pump voltage to the TWT. After 300s lapses heater ready status signal is given to the SDP.

High Voltage Ready stage

Now the unit is capable of going into High Voltage generation mode. When the PAU ON command comes from the SDP high voltages of Cathode and Collector are generated and applied to the TWT.

Radiation Ready Stage

Once the heater is ready and high voltages are developed then during radiation stage the control pulses and RF drive pulses are applied. The transmitter generates full output power.

During any of the above stages if any fault occurs then the transmitter shuts down automatically so that protecting the high value components from being damaged.

Modes of operation

The transmitter presented here used in three Different Modes of Radar operations which help in detection of long range targets, fast moving targets, ground terrains etc

Low PRF mode

Medium PRF mode

High PRF mode

V. CONCLUSION

This paper dealt with Transmitters used in Multi Mode Radar which is an improvement over olden day Radars .Accomplishing detection of multiple targets, simultaneous tracking and ranging , helping the pilot to fire missiles(fire control) are advantages of modern day radars. They also help in detecting ground based targets, ship based targets against noise created by rough sea waves. Recently AESA radars have emerged which have combination of Transmitter and Receiver called as T/R module where the beam steering is done electronically.

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Ramesh Jayaraman received his B.E. in Electronics & Communication from Bharathidasan University,Tiruchirappalli and presently working as Senior Manager(design) in Strategic Electronic Research and Design Centre(SLRDC),HAL,Hyderabad since 2006. He has been involved in design,testing of Transmitters for Multi Mode radar(MMR). Prior to joining HAL he worked in various organizations designing and testing power supply units for telecom related equipments.

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P.S.Krishnakumar received his M.Tech. in Radar Systems from I.I.T.Kharagpur and he retired as General Manager of SLRDC,HAL,Hyderabad. He has rich experience in Multi Mode Radar design. He also has expertise in insallation of Radar RIGs.He has also worked in PARs,ARSRs etc.