BHARAT ELECTRONICS LIMITED, GHAZIABAD

SUMMER TRAINING REPORT

ON

ROHINI RADAR

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1. INTRODUCTION TO THE COMPANY

1.1 History

Bharat Electronics Limited (BEL) was set up at Bangalore, India, by the Government of India under the Ministry of Defence in 1954 to meet the specialized electronic needs of the Indian defence services. BEL is among an elite group of public sector undertakings which have been conferred the Navratna status by the Government of India.

In 1966, BEL set up a Radar manufacturing facility for the Army and in-house R&D, which has been nurtured over the years. Manufacture of Transmitting Tubes, Silicon Devices and Integrated Circuits started in 1967. The PCB manufacturing facility was established in 1968. 1972 saw BEL manufacturing TV Transmitters for Doordarshan. The following year, manufacture of Frigate Radars for the Navy began. The second Unit of BEL was set up at Ghaziabad in 1974 to manufacture Radars and Tropo communication equipment for the Indian Air Force. The third Unit was established at Pune in 1979 to manufacture Image Converter and Image Intensifier Tubes.

In 1983, an ailing Andhra Scientific Company (ASCO) was taken over by BEL as the fourth manufacturing Unit at Machilipatnam. In 1985, the fifth Unit was set up in Chennai for supply of Tank Electronics, with proximity to HVF, Avadi. The sixth Unit was set up at Panchkula the same year to manufacture Military Communication equipment. The first Central Research Laboratory was established at Bangalore in 1988 to focus on futuristic R&D. The second Central Research Laboratory was established at Ghaziabad in 1992. During 2008-09, BEL recorded a turnover of Rs.4624 crores.

1.2 Research and Development

Research and Development is a key focus activity at BEL. Research & Development started in 1963 at BEL and has been contributing steadily to the growth of BEL's business and self-reliance in the field of defence electronics and other chosen areas of professional electronics. R&D engineers are engaged in the development of new products, cutting edge technology modules, subsystem, processes & components in the following major areas:

- Radars
- Sonar & Naval Systems
- Communications
- Command Control Systems
- Electronic Warfare Systems & Avionics
- Tank and Opto-electronics
- Broadcast, Satcom & Telecom
- Other products & systems

1.3 Manufacturing Units

Its corporate office is at Bangalore. Bangalore complex is the BEL's first and largest unit and it accounts for two-thirds of both the company's turnover and manpower. This unit's product range covers over 300 Defence and Civilian products. Ghaziabad is the second largest unit of BEL and it specializes in radars, communication equipments & microwave-components.

In total BEL has got 9 units. These are distributed in all over the India as:

- BANGALORE (Corporate Office)
- GHAZIABAD
- PANCHKULA
- MACHILIPATNAM
- PUNE
- HYDERABAD
- CHENNAI
- KOTDWARA
- TALOJA

2. ROHINI RADAR SYSTEM

INTRODUCTION

Rohini Radar System consists of the following major system components:

a) Multi-beam Antenna System
b) Transmitter
c) Receiver
d) Signal Processor
e) Radar Data Extractor
f) Radar Data Processor
g) Radar Controller
h) Radar Console
i) Electronic Equipment Cabin
j) Data centre
k) Mobile Power Source
l) IFF System

ROHINI is medium range 3D-surveillance radar mounted on a mobile platform and designed to meet the operational requirements of IAF for Base radar. The radar is capable of detection, tracking and interception of air targets upto 150 kms in range. The antenna is rotated mechanically in azimuth to provide for coverage of 360°. The radar is capable of being operated at two-RPM modes. The field configuration of ROHINI system is shown in Fig.2.1.

The antenna design is such that it provides for elevation coverage of 30^0. In the receive mode, the seven beams cater for a height coverage of greater than 15 kms and elevation coverage of 30^0. This provides for an azimuth resolution of better than 3.0° and accuracy of 0.5°.

The antenna has low azimuth side lobes for first two peaks occurring within 5°. Elevation side lobes will be of the order of -25dB average. The stacking in elevation is such that response from a single target is available in multiple beams. These responses are processed to arrive at the required elevation and height of the target.

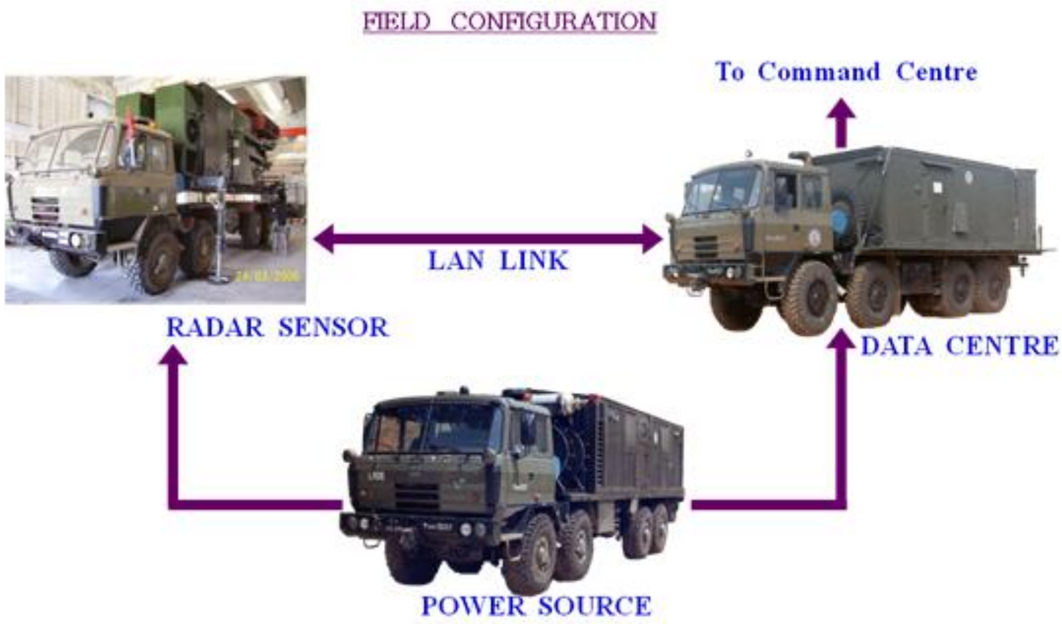

Fig 2.1 Field Configuration for ROHINI Radar System

The transmitter of ROHINI is based on TWT amplifier and generates about 100kW of peak power and an average power of 3kW. The transmitter is designed to operate with no RF transmissions [Sector Blanking] for any number of sectors covering 360°, selectable by the operator. The transmitter is also designed to transmit lower power of 10 KW (peak) as low power mode.

The Radar generates different videos viz., Analog and Digital videos at the Receiver and Signal Processor. These are interfaced to the display over dedicated lines and displayed. The bandwidth at the display restricts the full display of linear video. Hence log video is easier to distinguish and display.

The Radar Console local display is the color display that has features for monitoring of radar performance, the radar output selection for radar modes of operation. Interfaces to radar control signals are built-in. High speed data transfer of target parameters can be done. This helps in data remoting upto a distance of 500mtrs which can be extended with suitable repeaters.

2.1 ECCM Features

ROHINI utilizes Pulse Compression techniques with correlation Receiver, in the digital domain to obtain a compressed Pulse Width. The compressed Pulse Width is sufficient to achieve a great Range resolution and accuracy of the order of 100m.

The ECCM features provides for CPI to CPI Doppler filtering and automatic calculation and selection of Least Jammed Frequency.

2.2 Data Centre Cabin

The operator's workstation for ROHINI consists of two high resolution radars consoles to provide the real time aerial picture and five desktop computers connected in the network mode. In addition four VHF/UHF/R/T equipment (customer supplied) are also housed in DCV. It is shown in fig 2.2

Fig 2.2 Data Centre Vehicle (DCV)

2.3 Mobility

To have good all terrain mobility, the radar is configured in two TATRA vehicles. The first vehicle called Radar Sensor Vehicle (RSV), houses all electronic subsystems like Transmitter, Receiver, Antenna, SDP. These two vehicles are supported by Mobile Power Source of 2 x 125kVA generator sets mounted on TATRA. The design incorporates necessary features to ensure the transportation by Road, Rail and Air.

2.4 Energy System

Energy System for ROHINI consists of two DG Sets of 125kVA mounted on TATRA. One set is sufficient to cater for the operation of the radar any time and the second set is planned as standby generator. The Energy vehicle provides the power supply to the DCV and RSV. It contains two DG sets of 125 KVA rating each and a UPS of 100 KVA rating.

2.5 System Architecture

System architecture will take into account the parallel structure of the radar system. Control and data flow requirements consistent with the architecture will be provided. The radar operates in S-band and is capable of Track-While-Scan [TWS] of airborne targets up to 130 Kms, subject to line-of-sight clearance and radar horizon. The radar employs Multibeam coverage in the receive mode to provide for necessary discrimination in elevation data. It employs 8 beams to achieve elevation coverage of 30° and a height ceiling of 15 Kms.

3. MULTIBEAM ANTENNA SYSTEM

The Multibeam antenna system for Rohini is planned to be realized to have 360° Coverage in Azimuth and 30° Coverage in elevation. The antenna will have a wide beam in transmit mode and eight simultaneous narrow beams in receive mode to give 30° Coverage in elevation.

The block schematic of multibeam antenna unit is given at fig.3.1 indicating the major constituent blocks. The core elements of the antenna viz. planar array, Transmit Beam Former and Receive Beam Former, which together form the beams in space. The antenna electronics consisting of LNA’s (33 nos), Receiver (8 nos), supported by BITE system is realized and the Mechanical Engineering complement including antenna rotation and leveling system, hydraulics concerned with folding and deployment of antenna etc. is planned. Since the realization of the antenna is through different agencies, the constituents are divided as below, so that the individual constituents can be specified and qualified independently.

3.1 Constituents of Multibeam Antenna

The constituents of Multibeam antenna system are as follows:

3.1.2 Radiating Assembly

The sub-system consists of:

- Main Antenna (32 rows and 48 elements per row)
- SLB Antenna
- IFF Antenna

The passive antenna system is designed for 3D medium range radar Rohini operating in S frequency band and installed on vehicle. Elevation coverage is 30°, which is realized:

- For transmission with shaped beam
- For receive 8 pencil beams

The radiating assembly subsystems meant for Rohini includes Primary radar planar array antenna (Main Antenna composed of 32 rows, each row including 48 radiating elements (dipoles)), Side lobe Blanking Antenna and IFF antenna. Polarization of radiated electromagnetic energy is horizontal (for primary radar and SLB Antenna) and vertical (for IFF antenna). Each element of the primary antenna transmits and receives electromagnetic energy.

3.1.3.1 Main Antenna

One planar array is used both for transmit and receive of radar signals. An array composed of radiating dipoles seems to be the most suitable for this particular application. This solution has no squint and does not require application of matching loads as in wave-guide antennas. The antenna is created with 32 rows of radiating elements. Each antenna row includes 48 radiating elements (dipoles). The RF signals from and to the antenna inputs/outputs are fed through coaxial cables.

Dipoles radiating and receiving energy are arranged in 32 rows each of the row include 48 dipoles.

3.1.3.2 Side Lobe Blanking (SLB) Antenna

The Side Lobe Blanking (SLB) antenna with omni-directional radiation pattern in azimuth, which covers up the envelope of the main antenna side lobes in azimuth and in required elevation angle.

The output of SLB antenna is connected to the SLB amplification channel. This channel includes a microwave row assembly and a front-end receiver. IF signals from the front receiver are transmitted through rotary joint and they are directed to the electronic cabin for further processing.

3.1.3.3 IFF Antenna

The AFF-999 antenna is a planar array of radiating sources realized as micro-strip patches deposed on a dielectric layer. Array's radiating elements are fed through a power divider, which is also realized in the micro-strip technology.

The regular rectangular shape of the radiator assures linear polarization of the radiated field and low level of cross polarization. In order to eliminate interaction between desirable patches radiation and the spurious feeding network radiation both circuits are separated by the common ground plane. Coupling between feed line and radiating elements is realized through the slot with rectangular aperture, which is cut in the ground plane.

3.1.4 The Antenna cabin

Following are the major constituent Blocks of Antenna cabin:

- Transmit Beam Former Block (TBF Block)
- Low noise Amplifier Block (LNA Block)
- Receive Beam Former Block (RBF Block)
- Collection and Distribution Block (CDS Block)
- Receiver Assembly Block (RCV Block)
- Controller Block

High power RF signal from the transmitter is delivered to antenna cabin through a rectangular wave-guide R32. It is transmitted to the wave-guide power divider of beam forming network (TBF), located in the antenna cabin where it is divided into 32 output signals. Amplitudes and phases of which are adjusted to create shaped transmit pattern. The transmit signal from 32 rows is sent to the antenna rows through 3 port circulator which operates as TR switch and through directional coupler to power divider. In each row, transmit signal is divided in a T-junction divider for two equal parts.

Signals received by the primary antenna are feeding LNA's and then they are sent to the beam forming network (Blass matrix type) (RBF) whereby suitable adjusting of their phases and amplitudes, 8 pencil shape beams of appropriate beam widths to cover 30° elevation is formed. The network must provide high accuracy of both amplitudes and phases.

Signals from 8 outputs of beam forming network and signal from SLB feed 8 front-end receivers with double frequency conversion. The beams 6 and 7 are multiplexed to one receiver (6^{th} receiver). Signals from the SLC antenna are fed into its own microwave row assembly and then into eighth receiver and through the rotary joint are transmitted to the electronic equipment cabin for further processing.

3.1.2.1 Transmit Beam Forming Network (TBF)

The transmit signals from the rotary joint are feeding particular rows of antenna (32) through the transmit beam forming network (TBF) and through ferrite circulators.

The basic function of the 3-port circulator is to ensure transmission of high power signals from the transmit beam former (TBF) to the primary radar antenna (during transmit) and from the primary radar antenna to the low noise amplifiers (during receive). The wave-guides sections are composed of the non-symmetrical T-junctions connected in cascade. The serial divider construction assures that the signals on the wave-guides sections output ports have the same phase delay.

As a fixed phase shifter the appropriately designed wave guide sections is used. This construction assures higher power capacity and offers that the phase distribution deviation caused by the change of the operation frequency out of the middle of the band does not occur.

3.1.2.2. LNA block

LNA block consist of 33 Identical and Matched LNA units and a Collection and Distribution Network (CDN unit). Out of the 33 LNA units, 32 are used for generating eight receive beams and One LNA is for SLB channel.

The SLB channel LNA is fed from SLB antenna, which is linear array identical to one of the antenna sticks used in the main array. The SLB channel LNA is fed from SLB antenna and used in receive mode only.

Received echo signals are amplified in this unit, while maintaining low Noise figure. Signals received by the main antenna are fed to LNAs through wave-guide Pre-TR system, (a bank of high power four port ferrite circulators and limiter as first stage of LNA system). The part of the transmitted signal reflected from antenna row goes to the input of TR and further to each of the LNA unit in LNA Block. The LNA unit consists of gated attenuator - limiter and Low noise amplifiers with required selectivity. The peak power handling capability of the limiter is adequate to handle transmitter signal leak considering the worst case VSWR of antenna (2:1).

Failure of any LNA unit especially the center LNAs and degradation in gain/phase matching of these units across all the 32 elements effect the receive beam formation. Therefore, testing of the working of these units is done periodically through off-line BITE system. The BITE system for LNA testing consists of switching network, which injects and collects the test signal sequentially for all 33 LNA units. The test signal for this purpose is generated in the Exciter, amplified and routed through CDS units.

3.1.2.3. Receive Beam Forming Network

The receive beam forming network is realized using a modified Blass matrix which is composed of 7 columns (created with directional coupler connected in series) and 32 rows (connecting output of directional couplers).The TEM mode transmission lines are used for interconnections and for obtaining the required time delay.

To achieve required beam widths and their position in elevation, the particular antenna rows are supplied with signals, amplitude of which is changing with cosines square law.

3.1.2.4. Collection and Distribution System (CDS Block)

It houses eight CDS units, Antenna BITE amplification and distribution system and System BITE amplification distribution system. CDS block is situated between RBF block and RCV block and the functions of this unit are:

- To collect Beam former outputs for off-line testing
- To multiplex beams six and seven controlled by radar controller
- To Amplify and Distribute antenna BITE signal received from Rotary joint to LNA block for LNA /BFN test and also to RCV block for RCV test
- To amplify and selectively inject System BITE in to receive channels.
- The CDS block contains ten signal transmission channels (eight channels for eight receive beams, one for SLC channel).
- The beams six and seven are multiplexed. The CDS block will be realized in 5 identical plug-in modules and a motherboard catering for BITE collection & distribution.

3.1.2.5. RCV Block

The RF signals received at S-band (after beam formation), are down converted to IF using dual frequency conversion. Along with received signals, System BITE and test BITE signals are also down converted to IF.

Receiver Block consists of eight identical and matched receiver units along with LO I and LO II Power dividers and RCV test o/p collection switch. Out of the eight receiver units, six are for elevation beams and one for SLB and one for down conversion of off-line test signals from LNA and BFN tests. These eight receivers will be made as plug-in modules on the common motherboard.

It uses the SLB channel receiver as redundant back up for the elevation channels, since detection is of higher priority. In the case of failure in any of the elevation receiver channels, it is replaced with SLB channel receiver as they are identical and matched. BITE is injected at appropriate time during the PRT in selected scan, and the sample of the receiver output is collected, detected and result is sent as a diagnostic signal to the Radar controller. If the fault is detected in any of the receiver channels, the SLB channel replaces that channel through channel configuration.

The input signal spectrum of the receiver consists of one or more of the following signals:

- Radar Target Return Signal
- BITE
- Noise
- Hostile radiation and Interference.

The receiver has to extract the radar target return signals in the presence of noise and interference, amplify with minimum distortion and present the video signals to the SP at required levels. At microwave frequencies, the internal noise generated within the receiver generally dominates the external noise, which enters the receiver via antenna.

4. TRANSMITTER BLOCK

The Transmitter for 3D Surveillance radar Rohini is a Coherent Master Oscillator Power Amplifier (MOPA) type employing Traveling Wave Tube (TWT) Type as final power amplifier. The transmitter is capable of delivering RF power of more than 140 kW (peak) and 4.0KW (average.

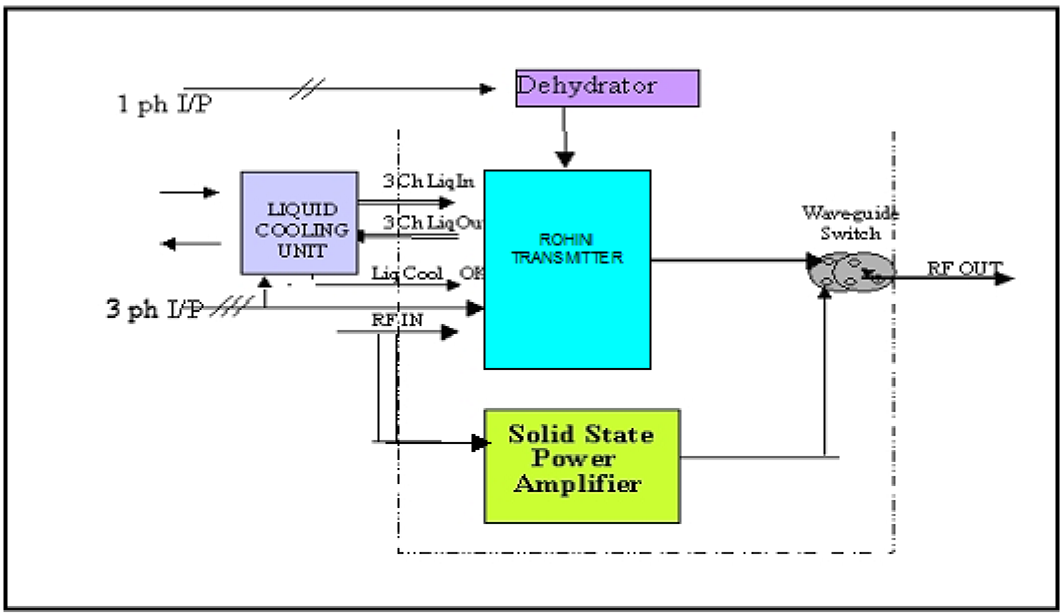

Fig. 4.1 Block Diagram of a Transmitter

4.1. Brief Description of Rohini Transmitter

The prime power to the transmitter is 3 Phase, 415V, 50 Hz from the Generator. The High Power Transmitter consists of mainly TWT, which amplifies the pulsed RF signal from 2W to a level of 120 to185 KW at the TWT output. The transmitter accepts the timing signals from SDP. It also receives the commands and sends the status to the operator console.

4.1.1. Modes of operation and control

The transmitter is designed to operate in the following modes defined as adequate controlled states

a) OFF	:	All subsystems switched OFF
b) Cold Standby	:	Only LVPSU's, TWT heater and Grid biases are switched ON. No High Voltage applied.
c) Hot Stand By	:	High Voltages applied, No RF and No grid Pulsing.
d) Transmission	:	RF power delivered to Antenna / Matched load.

i) Full Power mode	:	Full RF Power delivered to the Antenna (120KW Peak (min)
ii) Reduced Power mode	:	The transmitter is operated at 1/10 of its full power based on the selection by the user.
iii) Fail safe mode	:	A power of 1.5 KW peak at required duty is delivered to antenna through Solid State. Power Amplifier when liquid cooling fails. Mode selected by the operator.

4.1.2. General Cooling Requirements

The TWT, High Power Ferrite Isolator, dummy load and high voltage power supplies are cooled with de-ionized water and ethylene glycol mix (50:50). Liquid cooling distribution is realized in such a way that the Liquid Cooling Unit will have minimal pressure on the connections.

Forced air-cooling is employed to other components using the ambient air properly filtered to ensure dust free air. A dry air with low dew point and dust particles filtered is applied for the wave-guide channel.

4.1.3. General Mechanical Design

The transmitter consists of three metal racks containing respectively three functional units: Microwave Unit (MU), Power Supply Unit (PSU), and Control Unit (CU). All racks have front doors properly gasket for protection against EMI.

At the upper part of each unit, above the door, slip panels containing RF input, Transmitter pulse input, control and measurement connectors, control lamps, hour meters, CBs and high voltage meters are placed.

a) Microwave Rack consists of TWT, microwave plumbing components, SSPA and RF driver.
b) High voltage rack Consists of all high voltage components and FDM capacitor.
c) Control Rack Consisting of Monitoring and Diagnostics circuits, Control Circuits, Power distribution along with line filter unit and high voltage inverter unit.
d)

4.1.4. Microwave Unit

The microwave unit consists of the following functional assemblies:

(a) Low power amplifier [RF drive unit]
(b) High power TWT amplifier
(c) RF Plumbing, Wave-guide switch & dummy load
(d) Solid state power amplifier (2 kW) for low power transmission mode
(e) TWT ion pump supply
(f) Resistive TWT anode divider
(g) Microwave power measurement circuits
(h) Air cooling components

4.1.4.1. Low Power Driver for TWT (RF Driver)

Low Power amplifier stage (RF Driver) amplifies pulsed RF signal from 1mW (0dBm) to 2 – 4 W, necessary to drive the TWT amplifier. This consists of:

(a) Transistor Power amplifier - Amplifies the Pulsed signal

(b) Separating isolator - Used to protect the transistor power amplifier against excessive reflections from TWT.

(c) Directional Coupler - To monitor the power available at the input TWT.

Fig.4.2 shows the input output diagram of RF Driver

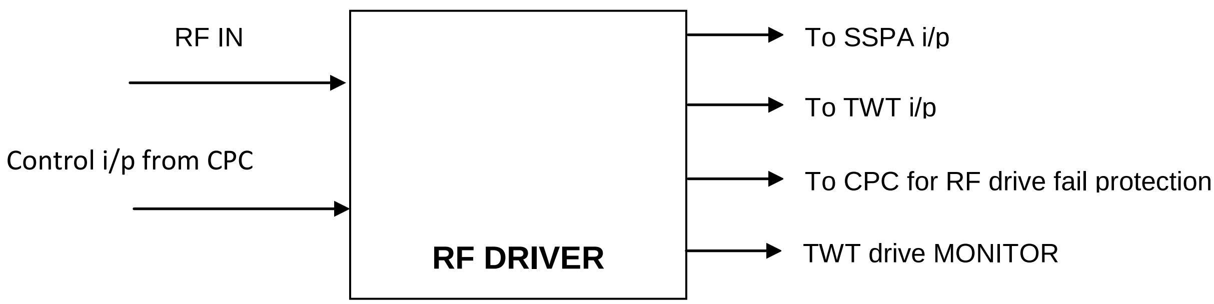

Fig. 4.2 Input/output diagram of RF Driver

4.1.4.2.High Power Microwave Stage

High Power Microwave consists of mainly TWT, which amplifies the pulsed RF signal from 2W to a level of 120-185 KW at the TWT output followed by High Power RF plumbing components. High Power RF stage consists of:

(a) Traveling Wave Tube (TWT)
(b) Ferrite Circulator
(c) Dual Directional Coupler (DDC)
(d) High Power dummy load
(e) Wave guide channel
(f) Wave guide switch

Traveling Wave Tube (TWT)

TWT is the main power amplifier used in the transmitter. A coupled cavity TWT type is selected for this transmitter

Ferrite circulator

Ferrite circulator is used to protect the microwave tube against failure / damage due to reflected power in case of excess VSWR at Antenna input port. The Four port Ferrite circulator is used as an isolator.

Dual Directional Coupler

High Power Dual Directional Coupler (DDC) is used for measuring the Transmit Power and reflected power. If reflected power exceeds the specified limit of 2:1 VSWR, video signal is generated to cut-off the RF drive through control and protection unit.

Power dissipated in DDC = 66 W [$P_{T =}$ 120KW DU = 2.4%] insertion loss of 0.1 dB.

High power dummy load

High power dummy load is used to test the transmitter without connecting the antenna during standalone testing.

Wave-guide Channel

To connect all the components in the required form, flexible sections, E-bends, H-bends and straight sections are used. Standard W/G sections are being used for this purpose.

4.1.4.3. Microwave Channel (High Power)

The microwave channel consists of high power amplifier using TWT amplifier and high power RF plumbing components.

Antenna channel matching requirements

Mismatch in the antenna channel, being the load of the transmitter, significantly decides of VSWR as seen from the TWT output. It seems to be difficult to satisfy VSWR $\leq$1.7, because the TWT should operate at VSWR $\leq$1, the isolator of proper directivity has to be applied in the wave-guide channel.

Max. RF power losses along the output wave-guide channel altogether with VSWR losses taken into consideration, were calculated for operation on the antenna. Assuming that RF pulse power at the TWT output is equal 120 kW (min), RF pulse power at the transmitter output should be contained within in the range of 90 kW in the case of operation on the antenna.

Solid State Power amplifier

This Solid-state power amplifier is used during the fail-safe mode. A power of 1.5 KW peak at required duty is delivered to antenna through Solid State Power Amplifier when liquid cooling fails. This Mode is selected by the operator.

4.1.4.4. Ion Pump Supply

Ion pump supply is a source of positive voltage about 3.3kV, intended to supply TWT ion pump, which is integral part of the TWT to maintain the vacuum level inside TWT.

4.1.4.5. Transmitter Cooling

This system is a forced liquid-to-air type, used for cooling sub systems of the F-Band Transmitter. The primary coolant used for circulation through this transmitter heat loads is Dematerialized water / Glycol for operation from -20°C to 55°C. The transmitter employs liquid cooling for TWT, high power circulator, RF dummy load and high voltage inverter and forced air-cooling for all other sub-assemblies. Independent of air-cooling, a dry air with low dew point and dust particles should be applied for wave-guide pressurizing and for TWT. General design of the cooling is worked out in such a way that the temperature rise for outlet coolant is around 10°C as compared to the inlet coolant.

4.2. CONTROL RACK

The block diagram of the Control Rack is shown in fig 4.3. The rack houses the Inverter, Control and Protection circuits, Synoptic Panel, Control Panel and Monitoring Panel. The function of various modules is as follows.

MONITORING PANEL A5
CONTROL PANEL A4
SYNOPTIC PANEL A3
CONTROL AND PROTECTION CIRCUIT A2
INVERTER A1

Fig 4.3 Block Diagram of Control Rack

4.2.1. Inverter

Phase (415V, 50Hz) mains power is converted to DC bus of 550V using AC/DC Converter employing soft start and the resulting DC is used as input to power inverters. The power inverters convert DC to high frequency AC (Pulse width controlled square wave) which is stepped up to the required level using respective HVHF transformers, rectified and filtered to derive -44KVDC and -33KVDC needed for the microwave tube.

A 3-phase rectifier is implemented as diode-thyristor bridge driven by the gate pulses from AC/DC. A capacitive bank filters the rectified DC. Since the filter capacitors draw considerable surge current, a soft start mechanism is implemented using diodes and a charging resistor 1K. The unit also incorporates its own supervisory function of checking the voltage level and ensuring that the same is within the limits. Only, when the voltage is within the limits the inverters are switched ON. In case of excess DC current, the SCR triggers are removed and fault reported to CPC.

The inverter is the main functional block of the (cathode / collector) HV Power supplies. A modified series resonant topology is selected for the basic inverter due to its inherent advantage of operation with short circuit loads.

4.2.2. Control and Protection Circuits (CPC)

The control and protection unit assures the sequential switching on the transmitter, continuous monitoring and interlocking of various parameters, detection and indication of errors, finally placing the transmitter in appropriate state, and switching off. All these are achieved by dedicated hardware and software.

The dedicated hardware consists of fast acting voltage comparators for detection of faults occurring on the high voltage side and the modulator side of the transmitter. For this, three comparator cards have been used wherein one card checks for power supply faults and the second card checks for the various faults such as Ion Pump Excess, Fil Current, Fil Voltage faults and the third card for giving the switching ON/OFF commands. The comparators are of latching type and hence the error is detected and stored immediately. The speed of the comparator latch is within 2 or 3 microseconds. The latched error activates the protection

protocol and places the transmitter in one of the following states, i.e.; hot standby or cold standby.

Under faultless condition the Cold standby signal is high and switches on the cathode voltage and collector voltages. After these are switched on the unit goes to a state called Hot standby wherein it checks for the RF drive signal. After this the grid signal and RF signal are switched on.

The Timing Card gives the necessary control pulses during standalone operation. A multiplexer allows the selection of control pulses, grid pulse, RF pulse etc. either internally or externally from unit. Pre-trigger can be adjusted by DIP-switch. With the help of the dip switch PRF from 50Hz to 4 kHz can be selected. Grid pulses and RF pulses are synthesized by programming EPROM. Another function carried out by the timing card is to blank the RF trigger during the sector blanking command received from Signal Processing unit.

4.2.3. Synoptic Panel

Synoptic panel is mounted in Control Rack, above CPC. It gives the LED indications for the fault and status signals generated by CPC. Green LEDs represent status signals while Red LEDs represent faults. Buzzer indication for faults is also provided on synoptic panel. All the LED indications and buzzer signals are directly interfaced with CPC through LED Card.

Synoptic panel also contains switches like Manual Crowbar switch, Mode1 (Full power), Mode2 ($1/10^{th}$ power transmitted) and Mode3 (SSPA mode) switches to select the mode of operation, Local/Remote control selection switch, RESET switch, Cold standby, RF and Hot standby switches. All the switches are directly interfaced with CPC through Remote Card. LCD Display is also provided on synoptic panel displaying transmitter parameters sent by Micro controller Card in CPC, for on-line monitoring. Remote card also receives the switching ON/OFF commands from operator console during remote operation. This card also sends status of the Transmitter on dedicated lines through an RS422 interface. It is shown in fig 4.8.

ANTENNA and DUMMY LOAD LED indications are also provided indicating transmitter transmitting to antenna or dummy load. LAMP test switch is provided to test the condition of all the LEDs.

4.2.4. Control Panel

The control panel consists of 6 mains powered LED Indicator Lamps, 6 Electromagnetic circuit Breakers,1 Time Delay Relay, 3 Solid State Hour Meters, one Hour Meter Box Assy, solid state relays and phase monitoring circuits.

The function of control panel is to control the power supply of various units such as Fans, Heater, LVPSU, Inverter, Modulator, RF Drive Unit and SSPA.

4.2.5. Monitoring Panel

It consists of Cathode Voltage Meter, Collector Voltage Meter and Emergency Switch. Cathode Voltage Meter and Collector Voltage Meter receive the signal from the High Voltage Rack and display the cathode voltage and collector voltage. The transmitter can be switched off under an emergency situation by pushing the emergency switch. This switch gives the required signal to the Control and Protection Circuits to switch off the Transmitter.

BNC connectors are provided on this panel for monitoring the Cathode inverter current, Collector inverter current, Cathode bridge output, Collector bridge output and Droop voltage. Pre-trigger and RF trigger signals from CPC are available on this panel. Status of liquid coolant from cooling unit is given to the CPC through the Monitoring panel.

4.2.6. Power Supply Unit

The transmitter is powered from 3 Phase AC Power Supply of 3 x 400 V $\pm$10%, 50 Hz source. The 3 Phase Power fed to the transmitter is distributed to various sub-units through Solid State relays for controlling the power and circuit breakers to protect against over current. The Power Supply Unit consists of the following sub-units.

a) TWT Cathode (body) power supply
b) TWT Collector Power Supply
c) TWT heater supply and Grid Modulator
d) HV Crowbar System

e) Probe assembly consisting of HV probes
f) Air Cooling and Heaters

4.2.7. HV Generation (Cathode Supply)

The HV is generated using DC – DC converter. The input DC voltage is converted into high voltage of –45kV using resonance bridge inverter followed by step – up transformer, HV diode bridges and filter capacity.

4.2.8. Inverter(20KHz)

General Description

The Power Supply uses resonance inverter configured in full bridge form. A Raw DC is applied to the inverter and converted to AC signal (V_{AB}) square wave in nature and is stepped up using HVHF transformer, rectified and filtered using HV capacitor. A modified series resonant topology is selected for the basic inverter due to its inherent advantage of operation with short circuit loads. Though the voltage waveform is square wave, the resulting current is near sinusoidal. For reducing the switching losses the inverter is operated in lag mode viz. resonant frequency is less than the switching frequency. By incorporating this ZVS (zero voltage switching) is accomplished.

Features of HV converter

The other features of the Power Supply are

- The operating frequency synched to common multiple PRF's
- The status of the Power supply parameter is sent to CPC.
- Single switch ON / OFF and soft start.

4.2.9. Collector Power Supply

The Collector Supply is similar to cathode supply in all-operational aspects. The HVHF transformer is designed to meet the specifications given. This Power Supply will be made to track the body supply.

4.2.10. High Voltage Circuit

The High voltage Circuit consists of:

1. High Voltage High Frequency (HVHF) Transformer with built-in rectifiers for Cathode Supply and Collector Supply.
2. HV filter capacitor
3. Voltage Dividers for regulation and HV measurements
4. Crowbar limiting resistors and crowbar system.
5. High Voltage High Frequency (HVHF) Transformer with built-in rectifiers for Cathode Supply and Collector Supply.
6. HV filter capacitor
7. Voltage Dividers for regulation and HV measurements
8. Crowbar limiting resistors and crowbar system.

4.2.11. Transmitter Cooling

The system is a forced liquid-to-air type, used for cooling systems of the S-Band Transmitter. The primary coolant used for circulation through this transmitter heat loads is Demineralised water / Glycol to catch for operation from -20°C to 55°C. The transmitter employs liquid cooling for TWT, high power circulator RF dummy load and high voltage power supplies and forced air-cooling for all other sub-assemblies. Independent of air-cooling, a dry air with low dew point and dust particles should be applied for wave-guide pressurizing and for TWT. General design of the cooling is worked out in such a way that the temperature rise for outlet coolant is around 10°C than the inlet.

4.2.12. Realization

A dedicated liquid cooling unit (LCU), employing liquid to air cooling will be used. Since liquid cooling is passing through the slow wave circuit of TWT and other sensitive electrodes, there are specific requirements for coolant.

Due to the requirement of high purity, the cooling unit is specially designed. The cooling unit consists of three channels for cooling the TWT body, collector and other electronics separately. Since the cooling unit has to work at -20°C, a 50: 50 demineralised water and Glycol mixture is used as coolant. The freezing point of the coolant is around -36°C.

5. LOW POWER MICROWAVE SUBSYSTEM

The Low Power Microwave Subsystem is a part of 3D-Surviallance Radar Receiving System. The reflected signals from the target are received by the Multibeam Antenna. These signals are amplified by the Low Noise Amplifier, down converted to IF Frequency using two-stage super heterodyne receivers. The IF Output is given as final output of the Low Power Microwave Subsystem to be further processed in the signal processor.

The Low Power Microwave Sub-System is being configured as three major subsystems, Viz. LNA Block, CDS Block and Receiver Block. The total subsystem is configured in such a way that identifiable blocks can be easily separated and health checks can be carried out. The configuration will be so chosen that servicing becomes fairly simple.

The total receiving system consists of the 33-channel LNA block, The Receiver Beam Former, the Collection and Distribution System (CDS) block, the Receiver block and the Bite Control Unit (BCU).

32 signals are received from the 32 rows of 48 element antenna arrays and one signal is from the Side Lobe Blanking Antenna. These 33 received signals are amplified by 30 dB in the Low Noise Amplifier block. The 32 amplified signals from the 32 antenna rows are fed to the Receiver Beam Former. The receiver Beam former outputs seven signals corresponding to 32 inputs. These eight signals and the SLC channel are fed to the CDS unit (Collection and Distribution System Unit).The eight inputs to CDS system are brought down to seven outputs by

switching 6 & 7 channel signals and 9th input is from SLB Channel. The 9th receiver in the receiver block is used for the measurement of the BITE / CAL signals.

The receivers are basically Double Super-heterodyne receivers. The S-Band signals are converted to 1st IF using Local Oscillator (Lo-I) and then to Local Oscillator (Lo-II). The final IF of all the receivers are given as the final output of the Low Power Subsystem.

The Low Power Microwave Sub-system is broadly divided into four sub-modules.

- LNA Block
- CDS Block
- Receiver Assembly
- BCU Block

5.1. LNA Block

The LNA module is sub-divided as follows

- Directional Coupler (DC-1)
- Limiter with Attenuator
- LNA
- Band pass filter (BPF-1)
- Amplifier (A1)
- Isolator
- Phase Shifter
- Directional Coupler (DC-2)
- SP8T Switch

The signals from the various antennas are fed to the LNA channel through phase-matched cables. A Low Noise Amplifier of 26dB Gain and 1.0dB noise figure follows the limiter. Two stage amplifiers are used with a small attenuator of 2dB in between. The first stage is a Low Noise device and the second stage is with high P_1dB point (+15dBm) device. The attenuator in between is used to avoid any mismatch oscillations.

A Band Pass Filter follows the two stage LNA. The Band Pass Filter is designed to have Image Rejection of 70dB minimum and LO rejection of 50dB minimum. An Amplifier of 10dB gain and P1dB of +15dBm follows the BPF. The Amplifier is followed by an electrical line length, which can be adjusted for phase matching between the units. A coarse adjustment of the total

NA channel phase/delay can be adjusted at the factory. An Isolator follows this line stretcher, which is of Drop-in configuration.

The Isolator is followed by a Mechanical Phase Trimmer, which is used to fine tune ($\pm 30^o$) the LNA channels externally after all the channels are mounted and cabled to the T/R switches. Finally a 30dB Directional Coupler at the output of the LNA channel is used for retrieving the BITE/CAL signals from the LNA channel.

The LNA channel hardware is housed in a aluminum housing. The Input / Output RF connections are through N-type connector. The BITE/CAL INPUT and OUTPUT connectors are of BMA type. Each LNA channel is configured as plug-in module. 33 such channels are plugged to a motherboard. All the DC Power Supply connections are made through 9-pin D-Sub connector from the Mother Board. The necessary DC Voltages (+7V, +5V and -5V) are derived from +27 Volts DC, using DC-DC converter housed in the motherboard. The Input 27V DC is passed through a series diode (Reverse Voltage protection) a shunt TRANSORB (protection against Voltage spikes) and EMI Filter. With this EMC/EMI Protection at the input the DC Voltage is fed to DC-DC Converter to generate the required voltages of +7V, +5V and -5V.

The LNA/BFN Test signals from the CDS block are fed to the LNA block mother board through SMA Connector. All the 33 LNA channels are designed and are adjusted for Gain and Phase matching of ±1.8dB and $\pm 5^o$ respectively.

5.1.1. Electrical Specifications for LNA Block

(i) It takes 27V DC Supply and derives the necessary internal supplies to LNA units and Mother Board.

(ii) It takes the following controls on RS422 and provide necessary distribution across LNA units through Mother Board

5.2.CDS Block

The CDS BLOCK is sub-divided as follows

- Isolator
- SPDT Switch
- 15dB Directional Coupler (DC-1)
- 10dB Directional Coupler (DC-2)
- Band pass filter
- 8-Way power divider
- SPST Switch
- SP8T Switch
- Amplifier
- Detector

The Collection and Distribution System (CDS) block receives the RF inputs from the 8 beams of the Receive Beam Former and RF input from the SLC channel. The 8 RF inputs are connected to 8 receivers in the Receiver block. Beam 6 & 7 are Multiplexed here.

Each of the ten CDS channels have an Isolator at the input, followed by SPDT Switch. The SPDT Switch facilitates the receiver to be either connected to the Receive Beam former input signals or to RCV Test signals. The SPDT Switches in each of the eight channels can be controlled independently. The SPDT Switch output passes through two 15dB Directional Couplers and to the Isolator at the Output. The first Directional Coupler is used to inject Radar Target BITE signals to the receivers. The second 15dB Directional Coupler is used to couple BFN Test O/Ps from each of the channels. The Isolators at the input and output of the CDS block helps in maintaining good VSWR, so that the load effects are minimal on the calibration of the system.

The Digital Controls to the LNA block are given from the BCU through differential lines. These control commands include one set of differential line control for Attenuation Control, and 12 sets of differential line controls for 4 SP8T.

The attenuation command is given simultaneously to all the 33 channels. The single differential line command is received in the Mother Board converted to single line, buffered and fed to 33 channels. All the digital control signals are given from BCU to LNA block using 37-pin D-Sub connector on the Mother Board. The DC Power Supply to the LNA block is provided through the 4-pin Circular connector.

The 10 channels of the CDS block are realized in 5 plug-in modules. These five modules are plugged to the Mother Board. Each module will be having inputs from two channels and two outputs, where in the fourth module multiplexing of 6^{th} and 7^{th} beam occurs. This CDS module will have two RF inputs and one RF Output. The other four blocks will have two RF Inputs and two RF Outputs.

The Input and Output RF connectors of the CDS blocks are SMA (F) connectors. The interconnections from this block to the Mother Board are through BMA Connectors.

The Radar Target BITE / ANT BITE Signal is fed into the Low Power Microwave Subsystem through the Rotary Joint. The second RF Input to the CDS Mother Board is the LNA Test O/Ps from the LNA Block. The two RF outputs of the CDS Mother Board are (1) The LNA/BFN Test Signals which is fed to the LNA Block (2) The Bite Output signals are taken out of the CDS Mother Board and are fed to the 8^{th} Receiver for carrying Out Vector Analysis.

5.3 Receiver Assembly Block

The RECEIVER module is sub-divided as follows

- Isolator
- STC Attenuator
- LNA
- Band pass filter (BPF-1)
- Isolator
- Mixer
- Band pass filter (BPF-2)
- Amplifier (A1)
- Amplifier (A4)
- Amplifier (A5)
- Amplifier (A6)
- Directional Coupler & Detector (DC-3)
- Directional Coupler (DC-4)
- Directional Coupler & Detector (DC-5)
- Directional Coupler (DC-6)
- SPDT Switch
- Active isolator (ISO-1)
- Active Isolator (ISO-2)
- 8-Way Power Divider (PD-1)
- 8-Way Power Divider (PD-2)
- SP8T Switch

The Receiver Assembly Block consists of 8 identical Receivers realized as Plug-in modules. These 8 receivers are plugged to the Mother Board. The 8 RF Inputs to these receivers are from the CDS Block,

Viz: Beam -1, Beam – 2, Beam – 3, Beam – 4, Beam – 5, Beam – 6/7, SLC Channel and the BITE Channel.

Each of the Receivers is a Double Super heterodyne Receiver as shown in the block diagram. The input signal frequency is first down converted to 1st IF using Local Oscillator. This first IF Signal is converted to 2nd IF by using Local Oscillator. These Local Oscillator signals to the 8 Receivers are fed from the Mother Board using BMA Connectors.

Each of the 8 Receivers consists of an Isolator at the input followed by 60 dB PIN diode Attenuator. An analog Voltage called Sensitivity Time Control (STC) controls the PIN-Attenuator. The receiver is desensitized when the target is at close range. The STC signals following different laws are generated in a digital card, for which the TOT will be given and the card will be housed inside the Receiver Housing.

The first mixer converts the RF signals to 1^{st} IF by mixing with Local Oscillator signal. The mixer is followed by BPF that is designed to have image rejection due to 2^{nd} LO of 70dB (min) and LO leakage of 50dB (min).

The IF is amplified by 16dB and the signal is down converted in the 2^{nd} mixer using Local Oscillator. A manual attenuator is provided at the 1^{st} IF stage to control the overall conversion gain of the Receiver Channel. This control is provided externally so that the overall 8 Receivers conversion gain be adjusted for equality when all the units are cabled and measured. The second IF 60 MHz signal is filtered and amplified by 16dB. The output is provided as final output to the Rotary Joint for further processing in the Digital Processor. A 10dB-coupled power is provided as Test O/P. This Test O/Ps from 9 Receivers are selected in the SP8T + SPDT Switch combination housed in the Mother Board and the selected signal is fed to the Vector Analyzer for Vector Analysis. A part of output signal is detected (Logarithmically) and is given as detected output for health monitoring. This DC Output (0.6 to 2.5 Volts DC) is provided on the D-Sub Connector.

The Mother Board of the Receiver block provides all the DC Power supplies for Individual Receivers (+7 V, +5V, -5V & +15V). The 27V DC passes through series diode (Reverse Voltage Protection), a Transorb, EMI/EMC filter and DC-DC Converters. Circular connector is used for 27V DC input. The Two LO signals are connected to the Receiver Block Mother Board from Rotary joints through SMA (F) connector. The LO Signals are amplified and 9-way Power Divided to feed to the Individual Receivers.

5.4 Exciter

Rohini Exciter generates the Coherent high stability signals.

The following are the coherent signals generated

- ‘S’ band, Coded Stable Master Oscillator signal to drive TWT amplifier (Long pulse)
- ‘S’ band, Stable Master Oscillator signal to drive TWT amplifier (Short Pulse)
- Fast switching, frequency agile, ‘S’ band STALO for 1^{st} down conversion in receivers
- UHF band, Fixed STALO for 2^{nd} down conversion in receivers.
- RF and IF Built-In-Test (BITE) signals for On-line performance monitoring of the system
- CW ‘S’ band Signal for as Antenna BITE

All the above signals will have the required spectral purity to ensure the performance of the radar against clutter.

Constituent units of Exciter

The Exciter System consists of mainly following four functional blocks:

1. STALO generation
2. Coded Waveform generation
3. STAMO generation
4. IF/RF BITE generation

1. S- Band STALO (STALO 1) Generation

S - band STALO frequencies are generated in the S-band. STALO 1 is used in the Exciter to up convert the radar waveform to STAMO frequencies in the S-band. The waveform is generated by up conversion of waveforms generated at IF frequency by first up conversion using fixed STALO.

STALO signal is very critical to the performance of the Exciter and in turn to the radar system.

- It possess very good Phase noise performance for achieving MTI improvement factor & detects low velocity targets in the presence of heavy clutter
- It provides large number of spot frequencies over the band as an ECCM feature
- It switches the frequencies at fast rate for LJF analysis and selection of suitable frequency of operation
- It produces very low Spurious and Harmonic signals

2. STAMO Generation

The phase coded long pulse waveform centered, generated using WGM is up converted to S-band in two stages using UHF LO and Variable frequency S-band LO. The final transmit drive will be in the frequency range of S-band. Double balanced mixers with good inter port isolations are used for up conversion. Further, isolators and filters are used to suppress the leakages of signals in to adjacent ports. At the output of IInd up converter, switched bandpass filters with 200MHz bandwidth each are used to remove the LO leak sufficiently even from the last selected frequency. STAMO signal is passed through a high isolation switch before feeding to transmitter.

3. IF/ RF BITE Signal generation

Target like features in terms of Doppler (phase shift for consequent PRF) and signal amplitude is given to pulse signals at IF frequencies generated using DDS. These characteristics can be built in to the generation scheme without physically using a phase shifter and attenuator.

4. ANTENNA BITE signal

To test the LNAs, BFN and receivers an S-band CW signal in the radar band is required. This is generated using the same hardware in the exciter for up conversion. OCXO output is used for this purpose. The Antenna BITE is sent to rotating platform through the same cable carrying RF BITE. Thus depending on the mode of radar switches is controlled to select input waveforms for up conversion and routing.

Exciter Unit consisting of the following modules

- Multiplier Module
- Frequency Synthesizer
- Up converter Module
- UHF synthesizer & Clock Module
- Waveform Generator Module
- Power supply module

5.5 Wave form generator module

Overview:

- Waveform generation module will generate up converted composite Radar waveform.
- It will also give radar sub system timings like CPI, PRT, NORTH, MSTC TRIGG, TX Timings, RX Timings for RF Exiter, SDP, Radar console and IFF on RS 422 differential lines.
- Depending upon commands from RC on LAN or RS 422 and SP on RS422, it sends tuning words for DAS and DDS.
- Generates RF BITE

5.6 Up Conversion Module

Here the ‘S’ band STAMO is generated in two stages of Up-conversion. First, the radar waveform which is a chirp around carrier from the WGM is Up-converted in UHF Up-converter using the second LO (Upper side band selected). To reduce the requirement for amplification at ‘S’ band, it is preferable to work with higher modulating input levels & here modulation signal level is kept at 0 dBm. This Up-converter requires +10 dBm of LO. The RF to LO isolation is of the order of 40 dB for this unit. The Up-converted signal passes through the filter before translation to `S ‘band. The output at UHF up-converter is + 5 dBm.

The 1 dB compression point of the mixer is +5 dBm. It is decided to work with +4 dBm modulating signal (1 dB below compression point). The spurious generated above (LO + 2IF) and suppressed sufficiently in the filters following the Up converter. The mixer requires LO level of +12 dBm. The ‘S’ band LO sample from amplifier and filter module is amplified and filtered to provide +12 dBm LO drive to the Mixer. The mixer has about 40 dB RF to LO isolation. Two Isolators in the `S’ band LO path, and the coupler isolation will bring about 100 dB isolation between STAMO and ‘S’ band at receiver.

The STAMO signal generated at Up converter is cleaned for the LO leak using two stripline filters of 200 MHz bandwidth connected in parallel. The filters are switched using SPDT switches at input and output depending on the `S’ band frequency selected for transmission. The STAMO signal is passed through RF switch open only for time duration of transmitter pulse amplified to provide -3 dBm drive to the driver amplifier at the input of transmitter Unit. A high power isolator as last stage component is used to protect the Exciter from accidental reflections from the driver amplifier. The gain of the STAMO amplifier takes care of the plumbing loss from Exciter to transmitter unit. IF BITE, and Field BITE are also generated in this module. The two LO signals will be sent to RCV Block of Antenna cabin through Rotary joint Assembly.