6.1 Introduction

MIL radar works for 24x7 operations continuously in all weather conditions. This requires very stringent design measures with little scope for tolerances. Radar design is carried out using different simulation software for thermal analysis, structural analysis, reliability and maintainability analysis etc. Printed circuit board layout is also planned with MIL grade components. Design precautions are taken in printed circuit board layout for EMI/EMC. Optical system also requires dust control and safety of operator. Calculations are required for mean time between failure and mean time to repair. As radar is considered mission critical equipment, its project management requires overhaul and periodic maintenance plan, spare stock inventory management etc. Normally radar is planned to work in unmanned situation. This necessitates the availability of all control and operation commands remotely. Conventionally radar uses ruggedized Cat 6 LAN cable for antenna remoting. This cable can be used upto a short distance of 100 meters. This puts a limitation on antenna remoting. In contrast optical systems can run for long distances without depreciable loss of the signal. Hence MWP is rapidly applied in different applications of radars. This will also improve bandwidth and field reliability of system.

AESA radars have large antenna array. The size of antenna depends on mainly two aspects. The first is beam width requirement. This is governed by azimuth resolution specification of the target. For fine azimuth resolution the beam should be narrow. As radar cannot distinguish between two targets if they fall in the same beamwidth. The size of array is inversely proportional to beam width. So, for achieving narrow beamwidth of 2-3° the array is kept large. Second requirement is transmit power. The transmit power is directly proportional to the number of transmit elements in the array. If radar
is designed for medium range say 250 km, it requires hundreds of transmit module. Presently with
GaN based transmit module, transmit power of the order of 125W max is available per module.
Hence this defines the number of T/R module are generally 1000 or 2000 in nos.
To beat enemy infiltration, radar changes its operational frequency regularly. This change in
frequency either happens on pulse to pulse basis or on burst of pulses. Pulse Doppler processing is
based on coherent processing interval. In this scheme, series of pulses are sent towards the target
with same pulse width, duty cycle, frequency etc. The received echo is processed for measurement
of Doppler frequency. This information is then utilized to know radial speed of target, classification
of target etc. Hence the proposed MWPN is also required to have large bandwidth identical to radar
bandwidth of 2-4 GHz. The performance of MWPN is required to be identical for this bandwidth.
Microwave components are primarily nonlinear in nature and also their performance varied piece to
piece. This has emerged as challenge for this design.
Radars are deployed in difficult terrain with different temperature region. Hence the equipment is
required to be operational from -20°C to +55°C. The storage temperature requirement is -30°C to
+70°C. The design of MWPN also takes care of this aspect and all the components are carefully
chosen to match this specification.
Fig. 6.1 shows the block diagram of proposed MWPN.
MIL environment calls for safety of equipment and safety of personnel. Safety of equipment is established by various means such as safety loop, audio horn, emergency power shutdown etc. Safety of personnel is ensured by keeping radar operational shelter away from radar Tx. Enemy targets RF radiation hence it is important to keep air situation picture display away from radar. This is proposed with antenna remoting.

The system has been realized for one current radar using three modules and its cabling. The system is designed for rugged operation with features like standby operation, faithful degradation etc. First module receives four RF and four digital signals. RF signals are received through signal conditioning card. Each RF channel has one signal conditioning card dedicated to it. Though all signal conditioning cards are identical in design, but tuning is done appropriate to each input. Four digital signals are RS 422 signals sent to WDM multiplexer. The output of this module is single optical fiber carrying all 8 channels. This is sent to rotary joint. The signals are then amplified with the help of EDFA. As EDFA has narrow bandwidth, these channels are de-multiplexed and amplified separately. Receiver module receives multiplexed channel. It de-multiplexes and converts optical energy into electrical energy.

The requirement of optimum performance over full temperature range has one constraint. Laser diode’s performance degrades at higher temperature due to power – current relationship. Due to rise in temperature, wavelength increases. The refractive index also increases along with the length of active zone. Laser does not resonate beyond a certain temperature. The threshold current of laser diode increases exponentially with rise in temperature given by (6.1).

\[ I_{th} = I_o \exp \left( \frac{T}{T_o} \right) \]  

(6.1)
where, $I_0$ is injection current and $T_0$ is characteristic temperature expresses temperature sensitivity of threshold current.

Spontaneous emission is dominant for current below the threshold. For the strong increase above the laser threshold stimulated emission is responsible. Optical power of laser is zero below threshold output. Any photon emission in the laser’s semi conducting material is due to spontaneous transition. The variation of threshold with temperature is low in case of DFB lasers. Hence same is proposed in this work. Laser beam widening effect happens with increase in temperature. Cooling of laser is required in DWDM as separation of channels is 2 nm. In case of CWDM channel separation is 20 nm hence cooling is not required.

Pulse Doppler radar’s performance greatly varies with the change in reference phase. All the performance parameters such as accuracy, resolution, radial velocity etc. are dependent on phase stability. Radars are calibrated in NFTR prior to field installation to test phase relationship of antenna array elements. In this testing, phase of all T/R modules are set to zero by appropriate weight functions. The radar is then tested in far field for beam formation.

MIL application demands high level of robustness and ruggedization. All the equipment supplied to defence services, may it be Army, Navy or Air force should meet specific MIL standards. These standards are upgraded from time to time by different agencies. The quality of equipment’s performance is governed by these standards. Defence services require 24 x 7 all weather operation for its electronic equipment. US MIL STD 810 G is generally taken as a base reference for environmental engineering testing guidelines for induction of equipment in MIL services. These tests create identical harsh weather conditions in test chambers to simulate the effect of environment on the equipment under test. It’s equivalent environmental test prescribed for Indian operation is JSS 55555.
6.2 Environmental testing

Radars are designed to work for 24 x 7 operations, deployed in the rough terrain and exposed to harsh weather. Thus application of MWP in MIL requirement calls for ruggedization of all subsystems which are being used with radar. The MWPL which is proposed to be used for RF and digital signals distribution in AESA radar is also subjected to temperature testing from -20 °C to +55 °C. This is as per MIL standard 851. The MIL standard gives guidelines for ground MIL application. All the test setups are also planned as per the recommendations of standard.

6.3 Design challenges

As part of ECCM techniques, radar works on different spot frequencies. This is done to prevent any electronic attack to jam radar frequencies. In this regard frequency can be changed on pulse to pulse basis. There is dynamic loading of frequency depending upon the least jammed frequency. This puts lots of difficulty in design as it is to perform for large bandwidth.

Another design challenge was to maintain the amplitude of output RF signals to be 0 dBm ± 1 dBm. The performance of digital receiver depends on the flatness of this value for different spot frequency.

6.4 Test criteria

Fig. 6.2 shows temperature gradient followed for temperature cycling.
Initially environmental chamber is at ambient temperature of 25°C. The chamber is programmed for a gradient of 5 °C per minute temperature decrease till it reaches -20 °C. The chamber is allowed to stabilize at this low temperature for 45 minutes. Then MWPL is powered on and checked for different frequencies. During basic checks all spot frequencies are tested for full band and performance is verified on known criteria. The system is switched OFF. After 15 minutes, temperature is programmed to rise up to +55 °C at same temperature gradient. The MWPL is again turned ON after stabilization of chamber. The system is turned OFF after basic testing for full frequency band. A snapshot of environmental chamber is shown in Fig. 6.3.
The MWPL is connected to a remote computer to monitor the health and status of link inside the environmental chamber. Fig. 6.4 shows the screen shot of the remote computer.

![Fig. 6.4: Reading of temperature sensors of MWPL on remote computer](image)

### 6.5 EMC requirements

Radars are installed with other electronics and communication equipment. Radars are expected to perform when all other electronic equipment are working. It is also expected that radar functioning should not disturb functioning of other equipment. This is called EMC of radar. MWPN along with its subsystems are designed to comply EMC tests as per MIL STD 461F. As optical systems are immune to EMI, one subsystem of MWPN i.e. touch input panel computer is tested for EMC compliance.

The air situation picture (ASP) is available on display console. This provides interface to operator and equipment. It is also used for health and status monitoring and control. Radar can be operated from display console. Site adaptation parameters such as antenna tilt, sector threshold, runway position etc. are entered through display console only. Conventionally keyboard and track ball are
used to control display machine. Due to increased use of smart mobile phones nowadays, touch screen are gaining popularity. It provides ease of operation along with zoom functions. It also saves space and power of system. There are mainly four types of touch panel namely capacitive, resistive, surface wave acoustics and infrared. Capacitive touch panels can also be classified as surface capacitive and projected capacitive. Highest level of ruggedization is available in resistive and infrared screens in spite of some limitations. So they dominate MIL world. Resistive touch screens require hard pressing on the screen unlike feather touch of smart mobile phones. Resistive screens does not have multi touch feature. The screen of infrared enabled system is highly sensitive. This gets activated even by a small insect sitting on it. As radars are deployed in rough field conditions, its use is limited to cockpit operation of aircrafts. Surface acoustic wave is scratch proof but it is sensitive to water droplets. Surface capacitive screen also has a drawback. It restricts the operator to use hand gloves. Considering harsh MIL climatic conditions, this technology is also not recommended. Hence projected capacitive touch based panel computer is used in MWPN. Projected capacitive screens offer scratch resistance, excellent image clarity, feature touch operation, use of gloves and multi touch operation along with space and power saving features. Map areas can be zoom in/out in capacitive based touch display. As this is relatively new field not much research is available for EMC aspects of PCT based panel computer.

6.6 Test procedures

EMC analysis and testing is carried out to understand the effect of MWPN on other subsystems and surrounding electronic equipment. This is done as per guidelines given in MIL STD 461F. This is mandatory requirement for induction of any electronic equipment in defence services. In this work, device under test (DUT) is a PCT based panel computer. It has been rigorously tested to check its compliance with respect to MIL STD 461F. It has resolution of 1024x768 pixels in 12.1
inch touch screen. It has three USB port, two LAN connectors, two com ports and one connector for AC supply. The PC is based on PCT screen for touch functions. Out of several tests, seven tests are mandatory for display system when used in ground army application. Table 6.1 presents seven mandatory tests as applicable for PCT based PC. This is as given on page number 26 of MIL STF 461F in Table V Requirement Matrix (release date 1 Dec 2007).

<table>
<thead>
<tr>
<th>S.N.</th>
<th>MIL STD 461F</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CE102</td>
<td>To test the electromagnetic emissions from the DUT for power input leads including returns.</td>
</tr>
<tr>
<td>2</td>
<td>CS101</td>
<td>To verify the ability of the DUT to withstand signals coupled onto power leads.</td>
</tr>
<tr>
<td>3</td>
<td>CS114</td>
<td>To verify the ability of the DUT to withstand RF signals coupled onto DUT associated cabling.</td>
</tr>
<tr>
<td>4</td>
<td>CS115</td>
<td>To verify the ability of the DUT to withstand impulse signals coupled onto DUT associated cabling.</td>
</tr>
<tr>
<td>5</td>
<td>CS116</td>
<td>To verify the ability of the DUT to withstand damped sinusoidal transients coupled onto DUT associated cables and power leads.</td>
</tr>
<tr>
<td>6</td>
<td>RE102</td>
<td>To verify that electric field emissions from the DUT and its associated cabling</td>
</tr>
<tr>
<td>7</td>
<td>RS103</td>
<td>To verify the ability of the DUT and associated cabling to withstand electric fields.</td>
</tr>
</tbody>
</table>

6.7 EMC tests

Radars are deployed in remote areas along with other electronic equipment. The functioning of radars should not disturb other equipment. Similarly functioning of other electronic equipment should not disturb radar performance. This requirement is measured with MIL standard tests called MIL 461E. These tests are performance of any subsystem or system to work in polluted RF environment.
The tests are conducted for following conditions

i. Conducted Susceptibility (CS)

ii. Conducted Emission (CE)

iii. Radiated Susceptibility (RS)

iv. Radiated Emission (RE)

The tests are also based on specific application of DUT. Fig. 6.5 shows actual photograph of CS116 test setup. Fig. 6.6 shows actual photograph of RE102 test setup.

![Fig. 6.5 Actual picture of CS116 test setup](image-url)
6.8 Conclusion

Military radars require harsh environmental and electromagnetic compliances. MWPN’s requirement in terms of temperature and EMC is defined. The system is tested for ruggedization with the help of tests listed in Table 6.1.