GSAT Program
Communication Payload

Request For Proposal
for
Ku-Band Linearized TWTA

(RFP No.: SAC/GEOSAT/DEC/2016/02)

December 2016

Government Of India
Indian Space Research Organisation
Space Applications Centre
Ahmedabad-380015
INDIA
REQUEST FOR PROPOSAL (RFP)
200W/195W/190W Ku-Band Linearized Traveling Wave Tube Amplifiers (LTWTAs)

INTRODUCTION
Indian Space Research Organisation (ISRO), Department of Space, Government of India requests your company to submit quotation for space-qualified Ku-band Linearized TWT Amplifiers (LTWTAs) as described in this document. These will be used in the Flight Models of the Communication Payloads of spacecraft under GEOSAT program of ISRO. This document consists of five Exhibits:

EXHIBIT-A: Provides general background / end use and scope of the document. This also contains general guidelines and conditions, which should be carefully studied and followed by all the vendors, before submitting the bid.

EXHIBIT-B: Provides electrical, mechanical and other interface requirements of LTWTA.

EXHIBIT-C: Provides reliability and quality assurance requirements.

EXHIBIT-D: Provides details of additional information, which vendor shall enclose in the proposal.

EXHIBIT-E: Provides details on quantity, delivery schedules and warranty.
1.0 **Background:** Indian Space Research Organization (ISRO) is planning to build and launch new generation high capacity communication satellites to meet the bandwidth demand from telecom operators, private and government users. The communication satellites will be used to provide broadband services, connectivity to VSAT networks for data communication, TV broadcasting applications etc.

2.0 **Request for Proposal (RFP):** Your Company is requested to submit detailed proposal against this request for proposal for supplying Linearized TWTAs (LTWTAs) for these communication satellites.

3.0 **SCOPE OF THE DOCUMENT**

This document covers the requirement of Flight & Proto Flight Model of LTWTAs, required mainly for the communication payload of GSAT series of Satellites. Unless otherwise specified, all performance requirements shall apply simultaneously and shall be fully met over the specified temperature range and other environmental conditions, R & QA provisions and with interface characteristics as detailed in subsequent sections. The document will be treated as a baseline specification document (Technical) and will be taken as a reference in future. The contents of this document will be mutually agreed by SAC/ISRO and vendor, and will be binding on both. The contents of this document can be refined after the Design Review (CDR). These changes will be incorporated in the present document to evolve FINAL SPECIFICATION DOCUMENT (TECHNICAL).

4.0 It is very important that your proposal includes sufficient technical data for proper evaluation of your product. If this technical data is not in public domain, we request that you apply in advance to your Government for a license to export this technical data.

5.0 **GENERAL GUIDELINES AND CONDITIONS**

Your offer must contain sufficient data and material to prove that your company has at least ten years of experience in manufacturing space qualified LTWTAs. Your Ku-band LTWTAs must have successful heritage of flying on board the communication spacecrafts in geostationary orbit.

It is desirable that the product offered by the vendors against tender is compliant to all specifications. All offers shall be evaluated against requirements and specifications given in this RFP. Vendors are advised that their offer needs to be at least fully compliant to key specifications related to parameters such as: **Rated Power Output, Large Signal Gain, DC Power Consumption, Inter-Modulation Product, Operating Frequency Band and compatibility to the specified primary Spacecraft Bus. Otherwise, their offer shall not be accepted.**

SAC (ISRO) also understands that LTWTA technology is very complex and that various performance parameters are interrelated and sometimes their values have to
be traded among themselves. Therefore, SAC (ISRO) does not expect that the product offered against this RFP will exactly match all the requirements given later in the RFP, in totality. Due to this, vendors are advised to submit their best expected performance even when they are not fully compliant against other supplementary (other than the key specifications related to parameters mentioned in previous paragraph) specifications. The technical part of the offers shall be evaluated by SAC (ISRO) against overall system performance and shall be considered, even with minor deviations in the supplementary specifications, in case it is found that overall system objectives are achievable in spite of these deviations. The decision of SAC (ISRO) will be final in this respect. Only the offers of technically compliant vendors will be considered for further evaluation.

SAC reserves the right to award contract to more than one vendor.

Vendors may further note that SAC (ISRO) also reserves the right to decline an offer, if there is a large deviation in delivery-schedule, commercial and/or general terms and conditions offered against the requirements, even if the offer is technically suitable.

Vendors are free to seek any clarification or may point out any error or omission in the proposal, so that requirements projected in this RFP are met correctly and adequately.

In case of receipt of a bid against this tender, it will be assumed by SAC (ISRO) that all the guidelines and conditions mentioned above, have been carefully read and accepted by the bidder.

Non-submission of offers by the vendors shall be taken and noted as “no bid” for this tender.
TECHNICAL SPECIFICATIONS for LTWTAs

1. SCOPE

This Exhibit contains the Technical specifications of the Ku-band Radiation Cooled LINEARISED TRAVELING WAVE TUBE AMPLIFIERS (LTWTAs) required for the Communications Satellite payloads of the GSAT series Satellites of ISRO. The LTWTAs should include Ku-Band TWT, Electronic Power Supply Module (Electronic Power Conditioner – EPC) and the Linearizer.

2. GENERAL REQUIREMENTS

Unless and otherwise specified, all performance requirements shall apply simultaneously and shall be fully met over the operating range of Bus voltage, specified frequency range, operating temperature range and other environmental conditions. Interface requirements are also provided in the subsequent sections. While taking up the design, the manufacturers shall devote special attention and efforts to achieve the following:

a) Highest possible DC to RF efficiency and proper thermal design
b) Unconditionally stable performance ensuring long term stability
c) Minimum mass and volume
d) Provide adequate protections for the units and the Spacecraft Bus,
e) Meet all the provisions of R&QA, as detailed in this document for high reliability.
f) Ensure useful life in space of unit to be more than 15 years

3. GENERAL DESCRIPTION

The LTWTAs under consideration shall deliver minimum output power at saturation at the below mentioned frequency bands.

<table>
<thead>
<tr>
<th>Band</th>
<th>Operating Frequency</th>
<th>RF O/P Power @ Sat (EOL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band-1</td>
<td>10.70 GHz to 11.70 GHz</td>
<td>200W min (desired 210W)</td>
</tr>
<tr>
<td>Band-2</td>
<td>11.70 GHz to 12.75 GHz</td>
<td>200W min (desired 210W)</td>
</tr>
<tr>
<td>Band-3</td>
<td>10.70 GHz to 12.75 GHz</td>
<td>190W min # (desired 205W)</td>
</tr>
</tbody>
</table>

# Note: Manufacturer offering higher power will be given preference for band-3.

The LTWTAs will primarily operate with the following Satellite Bus and Tele-command:

<table>
<thead>
<tr>
<th>Bus Description</th>
<th>Regulated Variable Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Type</td>
<td>70±5V (65V to 75V) DC</td>
</tr>
<tr>
<td>Telecommand Type</td>
<td>+29±1V, 64ms pulse</td>
</tr>
</tbody>
</table>
The LTWTA shall include TWT, suitable EPC, Linearizer and all necessary cables for inter connecting above components. DC voltage required by Linearizer shall be connected directly from EPC to the Linearizer. They shall meet the performance requirement in the full operating band as given in sections of Para 4 & Table No 4.0.1 of Exhibit B. Incase of discrepancy the Table No 4.0.1 to be treated as requirement. Vendor should also provide saver connectors for DC and RF.

Note: All the components used in a given LTWTA, including SMA attenuator (along with its value of attenuation) used for tuning of Linearizer & TWT should be assigned with unique Sr no (vendor may use their own Sr no also) for proper record keeping and easy identification.

3.1 TRAVELING WAVE TUBE (TWT)
Radiation Cooled TWT shall provide necessary and sufficient RF gain (Ref: Sec 4.4), with minimum RF output power at EOL at saturation as per Table- 3.1 below. (The small change in the rated power, if any, shall be communicated later). The TWT in the transponder will be driven through a Channel Amplifier with Commandable attenuator to control the input drive of the LTWTA.

<table>
<thead>
<tr>
<th>Freq. band</th>
<th>Operating Bandwidth</th>
<th>Output Power (EOL) @ Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band-1</td>
<td>1.00 GHz</td>
<td>200W min (desired 210W)</td>
</tr>
<tr>
<td>Band-2</td>
<td>1.05 GHz</td>
<td>200W min (desired 210W)</td>
</tr>
<tr>
<td>Band-3</td>
<td>2.05 GHz</td>
<td>190W min (desired 205W)</td>
</tr>
</tbody>
</table>

3.2 ELECTRONIC POWER CONDITIONER (EPC)
The required DC power for the TWT shall be provided by the EPC. The EPC shall operate on 70V spacecraft bus with voltage range from 65V to 75V.

The EPCs should also process the On/Off tele-command signals, which control the operation of LTWTA and provide appropriate telemetry signals for monitoring the health of TWT and EPC. The EPC should also have built-in protection mechanisms to safeguard the unit and the spacecraft DC-bus against any failure from inside the unit. The RF performance of Units should not be affected due to any failure in TC/TM circuits.

3.3 CHANNEL AMPLIFIER (CAMP) POWER SUPPLY
The EPC shall also be able to provide auxiliary DC supply (available on DC interface connector of EPC) for CAMP, which are used to drive LTWTA.

3.4 LINEARIZER
- The Linearizer shall be an integral part of the unit. DC supply for the Linearizer shall also be derived from the EPC.
- The suitable RF cable connecting Linearizer output and TWTA input should be provided along with LTWTA. The typical length of the cable will be about 40 to 60 cm, however exact length of the cable shall be specified for each individual unit before RF testing LTWTA.
- Vendor shall also provide separately, full technical details about the Linearizer, along with the offer.

4.0 SPECIFICATIONS OF LTWTAs

The electrical requirements given in this section shall be met over the entire operating conditions of bus voltage, temperature and environment.

Consolidated electrical specifications have been tabulated as below in **Table No. 4.0.1.**

**Table 4.0.1: Specifications of LTWTA**

*Note: The Small-signal (SS) is defined as 20dB IBO from Saturation point.*

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>DETAILS</th>
<th>SPECIFICATIONS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Frequency Band</td>
<td>Band-1: 10.70 GHz to 11.70 GHz</td>
<td>Ref Para 4.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-2: 11.70 GHz to 12.75 GHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-3: 10.70 GHz to 12.75 GHz</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Bandwidth</td>
<td>Band-1: 1.00 GHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-2: 1.05 GHz</td>
<td>Ref sr.no.-1 (above)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-3: 2.05 GHz</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>RF Power Output at saturation (Po)</td>
<td>Band-1: 200W minimum (EOL)</td>
<td>Ref. Para 4.2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-2: 200W minimum (EOL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-3: 190W minimum (EOL)</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Output power stability over 24 hours at 25°C</td>
<td>0.1 dB (p-p) max</td>
<td>Ref Para 4.5</td>
</tr>
<tr>
<td></td>
<td>At saturation</td>
<td>0.25 dB (p-p) max</td>
<td></td>
</tr>
<tr>
<td></td>
<td>At 20 dB IBO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Output Power stability over 20° temp. change:-</td>
<td>Pin Sat.</td>
<td>Ref Para 4.5</td>
</tr>
<tr>
<td></td>
<td>-15 to + 5 deg C</td>
<td>0.3 dB max p-p</td>
<td>##: EPC up to +65°C</td>
</tr>
<tr>
<td></td>
<td>+5 to +25 deg C</td>
<td></td>
<td>TWT up to +80°C</td>
</tr>
<tr>
<td></td>
<td>+25 to +45 deg C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+45 to +65 deg C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+65 to +80 deg C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Output Power Variation at Saturation; over freq.-band.</td>
<td>&lt; 0.4dBpp</td>
<td>Ref. Para 4.2.2</td>
</tr>
<tr>
<td>7.</td>
<td>Input Drive (Pin)</td>
<td>-2 dBm max.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Overdrive Capability</td>
<td>20 dB</td>
<td>See Para 4.2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without any damage or degradation in performance when overdrive is removed.</td>
<td></td>
</tr>
<tr>
<td>Sr. No.</td>
<td>DETAILS</td>
<td>SPECIFICATIONS</td>
<td>REMARKS</td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>----------------</td>
<td>---------</td>
</tr>
</tbody>
</table>
Band-3: 353W max. | Ref Para 4.3 |
| 10.    | DC-RF Efficiency  
At saturation. | ≥ 55 % | Ref Para 4.3 |
| 11.    | RF Gain (at single carrier  
Saturation) | > 55dB | Ref. Para 4.4.1 |
| 12.    | RF Gain at Small Signal | Not exceeding 4dB w.r.t. gain at Sat. | Ref. Para 4.4.2 |
| 13.    | Gain Response at  
Saturated output power | 0.5dB max p-p over full band (Band-1 & 2)  
0.7dB max p-p over full band (Band-3)  
0.2 dB max p-p over any 40 MHz | |
| 14.    | Gain Response at Small Signal | 2.5dB max p-p over full band (Band-1 & 2)  
3.5dB max p-p over full band (Band-3)  
0.5dB max p-p over any 40 MHz | |
| 15.    | Gain Slope at Saturated  
output power | ≤ 0.02dB/MHz | Ref Para 4.4.4  
& 4.4.5 |
| 16.    | Gain Slope at Small Signal | ≤ 0.03dB/MHz (Band-1 & Band-2)  
≤ 0.04dB/MHz (Band-3) | Ref Para 4.4.6 |
| 17.    | Gain Stability with time  
24 Hrs. | Pin sat. 0.1 dB p-p  
Pin-6dB 0.15 dB p-p  
Pin-20dB 0.25 dB p-p | |
| 18.    | Noise Figure | 40dB max | |
| 19.    | AM/PM Conversion  
Coefficient  
At Saturation  
At 3 dB IBO  
At 20 dB IBO | 3.0 deg/dB  
2.0 deg/dB  
0.8 deg/dB | Ref Para 4.7 |
| 20.    | Total Phase Shift | 15 deg. max p-p | Ref Para 4.8 |
| 21.    | AM/PM Transfer  
Coefficient  
0 dB IBO  
-3 dB IBO  
-6 dB IBO  
-9 dB IBO  
-12 dB IBO  
-14 dB IBO | Desirable: 7 deg/dBmax  
Mandatory: 12(Band-1&2)/15(band-3) deg/dBmax  
Desirable: 5.5 deg/dBmax  
Mandatory: 7 deg/dB max  
5 deg/dB max  
4 deg/dB max  
2 deg/dB max  
2 deg/dB max | Ref Para 4.9 |
| 22.    | Third Order IMD  
3 dB IBO (Each Carrier)  
6dB IBO  
10dB IBO  
17 dB IBO | -11.5 dBc max (goal of -12dBc)  
-16.5 dBc max  
-26.5 dBc max  
-32 dBc max | Ref Para 4.10 |
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>DETAILS</th>
<th>SPECIFICATIONS</th>
<th>REMARKS</th>
</tr>
</thead>
</table>
| 23.    | Spectral Purity, Non-Harmonic Related | a) In-band spurious other than due to EPC ripple $<-60$ dBc (Goal: $-70$ dBc)  
b) Out of Band Spurious $<-45$ dBc  
c) In-band spurious due to EPC ripple $<-55$ dBc (Goal: $-70$ dBc)  
d) In-band spurious due to heater supply frequency $<-55$ dBc (Goal: $-60$ dBc)  
e) Spurious in CS test of 3 V p-p amplitude $<-60$ dBc | |
| 24.    | Spectral Purity, Harmonic Related | Total Harmonic Power $<-15$ dBc  
2nd Harmonic $<-18$ dBc  
3rd Harmonic $<-25$ dBc | Refer Para 8.13 of Exhibit-C |
| 25.    | RF Emission | At carrier frequency: $<100$ dBµV/m  
For lower than 100 MHz and carrier harmonics: $<85$ dBµV/m  
All other frequencies: $<45$ dBµV/m | |
| 26.    | Noise Power Density at TWTA Output | Within the operating frequency band $<70$ dBm/Hz at no RF condition | |
| 27.    | Noise Power Ratio NPR | 3 dB OBO  
4 dB OBO  
6 dB OBO  
9 dB OBO  
12 dB OBO  
15 dB OBO | 14 dB  
17 dB  
23 dB  
25 dB  
25 dB  
25 dB | Refer Para 4.15 |
| 28.    | Group Delay | Linear – 0.02 ns/MHz maximum  
Ripple – 1.2 ns (p-p) maximum | |
| 29.    | Insertion loss | $>70$ dB | Refer Para 4.17 |
| 30.    | VSWR, Input/Output | Input Hot 1.7: 1.0 max  
Output Cold 1.5: 1.0 max  
Output Hot 3.0: 1.0 max | Refer Para 4.18.1 |
| 31.    | Load VSWR | -Unit shall meet all requirement when in-Band VSWR up to 1.5: 1.0 (any phase) and out of band VSWR up to infinity (any phase)  
-No degradation of performance when operated 24 hours with input drive corresponding to saturation to a load that has in-band VSWR 1.5 any phase & out of band VSWR up to infinity (any phase). | Specify the duration for which Unit operated in:  
Case-1: In & Out of Band VSWR 1.5.  
Case-2: In-band VSWR 1.5 & Out of band VSWR up to infinity.  
as standard drive condition without any damage or degradation. |
| 32.    | RF Impedance (In/Out ports) | Input port Coaxial SMA 50 Ohm  
Output Port WR 75 Waveguide | |
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>DETAILS</th>
<th>SPECIFICATIONS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.</td>
<td>Spurious Phase Modulation</td>
<td>As per para 4.19 and Fig. 4.19.1</td>
<td></td>
</tr>
<tr>
<td>34.</td>
<td>Stability</td>
<td>Unit shall be unconditionally stable and shall not oscillate or get damaged,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>even if input/output terminal are open/short circuited Under no drive</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>condition</td>
<td></td>
</tr>
<tr>
<td>35.</td>
<td>Electrical Interface</td>
<td>-DC interface through Standard D-type Connector (s)</td>
<td>Refer Para 4.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RF Input connector shall be coaxial and output through suitable waveguide</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>interface (WR-75) Additional mating D type connectors and D type and RF savers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to be provided.</td>
<td></td>
</tr>
<tr>
<td>36.</td>
<td>Bus Supply voltage</td>
<td>70±5V (65V to 75V) DC</td>
<td>Refer Para 3.0</td>
</tr>
<tr>
<td>37.</td>
<td>Primary DC Input Power</td>
<td>Band-1 &amp; Band-2 : 362W max.</td>
<td>Refer Para 4.24.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Band-3 : 353W max. under any operating condition of bus voltage</td>
<td></td>
</tr>
<tr>
<td>38.</td>
<td>In-rush Current Transients</td>
<td>Less than twice the nominal input current</td>
<td>Refer Para 4.25</td>
</tr>
<tr>
<td>39.</td>
<td>Under Voltage</td>
<td>When the input voltage falls below 63±0.5V, the unit shall not draw more</td>
<td>Refer Para 4.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i/p DC power and shall not be damaged.</td>
<td></td>
</tr>
<tr>
<td>40.</td>
<td>Tele command</td>
<td>Detailed specification as per Para 4.23</td>
<td>Refer Para:4.23.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vendor should also indicate the maximum duration of the Telecommand pulse</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>which could be applied causing no damage</td>
<td></td>
</tr>
<tr>
<td>41.</td>
<td>Telemetry outputs</td>
<td>Bi-level telemetries:-</td>
<td>Refer Para 4.23.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0V to 0.5V for ‘Low’ level, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5V to 5.0V for ‘high’ level.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>a) EPC ON/OFF Status:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) HOCPC Enable/Disable status</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Spurious Switch Off / ARU</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analog telemetries:-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output shall be analog voltage from 0V to +5V.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Helix Current monitoring</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Anode Voltage monitoring</td>
<td></td>
</tr>
<tr>
<td>Sr. No.</td>
<td>DETAILS</td>
<td>SPECIFICATIONS</td>
<td>REMARKS</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>----------------</td>
<td>---------</td>
</tr>
<tr>
<td>f)</td>
<td>Input DC Bus Current / Input DC Power consumption monitoring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 42. | Protection Circuit | As per detailed specification in Para 4.27.  
   a) Under voltage 63±0.5V  
   b) Fuse  
   c) Over Current/Power  
   d) Helix over-current protection  
   e) Spurious Shut-off / Automatic restart. | Refer Para 4.27 |
| 43. | Voltage Ripple From Main Bus | As per para 8.13 of exhibit “C” | |
| 44. | Voltage Transients | No degradation when transient described in figure 4.28.1 of peak volt = 100 % of the DC supply voltage is applied with pulse width t=10 µs +/-20 %. | Refer Para 4.28.2 |
| 45. | Main Bus Impedance | As per description given later | Refer Para 4.29 |
| 46. | EMI/EMC Requirements | As per para 8.13 of exhibit “C” | |
| 47. | Auxiliary Output Voltages | (a) Positive Output: +6.7V +/-0.2V with nominal current value between 300 mA to 700 mA. It shall be > 6.5V under all operating conditions.  
   (b) Negative Output: -7.1V +/-0.2V with nominal current value between 30 mA to 100 mA  
   (c) The return of the auxiliary output shall be isolated from input bus return, TC return. | Additionally vendor shall provide data of Ripple and Spike/PARD for these outputs.  
   Note: Exact output specifications will be finalized at the time of placement of order. |

**Mechanical Requirements**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>DETAILS</th>
<th>SPECIFICATIONS</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>48.</td>
<td>Mass</td>
<td>Mass of the unit shall be as small as possible and should be &lt; 3 kg (desired: &lt; 2.8kg) Excluding HV Cable &amp; RF Cable</td>
<td>Refer Para 4.32</td>
</tr>
<tr>
<td>49.</td>
<td>Mounting Details</td>
<td>LTWTA shall be mounted on honeycomb deck plate in satellite and all the details like mounting lug positions, surface accuracy, provision for thermal grease application, mounting torque of unit &amp; connectors shall be provided by the vendor.</td>
<td>Refer Para 4.32</td>
</tr>
<tr>
<td>50.</td>
<td>Size/Shape</td>
<td>The vendor shall specify LTWTA size and shape. Size should be as small as possible. ICD should be provided by the vendor. Thermal profile of the bottom surface should also be provided by the vendor.</td>
<td>Refer Para 4.32</td>
</tr>
<tr>
<td>51.</td>
<td>Venting</td>
<td>The equipment shall be vented sufficiently to meet space requirement given in R &amp; QA requirement</td>
<td>Refer Para 4.32</td>
</tr>
</tbody>
</table>
4.1 FREQUENCY BAND OF OPERATION
The LTWTA is required to operate anywhere in the frequency bands specified in the table-3.0/Table 4.0.1.

4.2 RF OUTPUT and INPUT POWER
4.2.1 RATED RF POWER OUTPUT (P₀)
The RF power output of LTWTA, measured with single carrier, shall be as per Table-3.1/Table 4.0.1 in saturated condition over the specified operating frequency band, operating temperature, and all other operating conditions. Power output shall be achievable immediately after turning HV ‘ON’.

Any minor change in the rated power output requirement shall be communicated to the vendors before placement of the order. The BOL output power shall have adequate margin to account for degradation due to ageing, radiation and other long-term effects. LTWTA shall be optimized for adequate power output and maximum DC-RF efficiency in the entire respective frequency bands.

At the time of submitting the offer, vendor shall also furnish the following details:

(a) Minimum RF output power at worst-case operating condition over the frequency range, operating temperature range, bus voltage variation range and environmental condition.
(b) Maximum output power delivered under any operational conditions.
(c) Estimated degradation of output power over life, due to aging, radiation and other long-term effects.

Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life, at the time of Design Review.

Note: The vendor has to ensure (by calculation and by test data) that at the end of life the power output would not be less than rated power under all operating conditions.
4.2.2 OUTPUT POWER VARIATION
The output power variation in full frequency band shall be less than value specified in Table 4.0.1 at saturation over all specified environmental conditions.

4.2.3 INPUT DRIVE (Pin)
The maximum input level required to drive the LTWTA to saturation shall be as per Table 4.0.1.

4.2.4 OVERDRIVE CAPABILITY
The units shall be capable to withstand overdrive, as specified in Table 4.0.1, beyond the drive level required for rated saturated output, for prolonged period without any degradation in the performance and life. Over drive shall be demonstrated for 24 Hrs in PFM unit and for 2 Hrs in FM units.

4.3 DC TO RF EFFICIENCY
The DC-RF efficiency of the Units at rated output power level should be as high as possible. However, it should be as per value specified in Table 4.0.1. under all operating conditions. Total DC input power consumption shall not exceed the value specified in the Table 4.0.1.

The vendor also shall specify the DC-RF efficiency in tabulated format at zero to 20dB input back off, in 1dB steps.

The vendor shall give power dissipation in TWT & EPC for different drive levels.

Vendor shall provide power consumption and efficiency test data for the LTWTAs along with the End Item Data Package (EIDP).

Vendor shall furnish estimated degradation in the Gain, efficiency and power consumption over life due to aging, radiation and other long-term effect on Linearizer, TWT and EPC at the time of submitting offer.

Vendor shall also provide analysis that various parameters like IMD will not degrade beyond the specified levels due to long-term variations in Gain etc.

Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life at the time of design review.

Note: The efficiency figure should be met over the complete operating range of the input bus voltage.

4.4 RF GAIN
The RF-gain, defined as the ratio of output power to input power, shall be measured at saturated power and at small signal.

4.4.1 RF GAIN AT SATURATION (SINGLE CARRIER)
The gain of the LTWTAs at room temperature shall be as per Table 4.0.1 specification to produce single carrier saturation at the center frequency at nominal
input level. Vendor shall furnish estimated degradation in the saturated gain over life due to aging, radiation and other long-term effects at the time of submitting offer. Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life at the time of Design Review.

4.4.2 SMALL SIGNAL GAIN
The small signal gain shall be as per Table 4.0.1 specification. The Pin/Po curve should be smooth. Vendor shall furnish estimated degradation in the small signal gain over life due to aging, radiation and other long-term effects at the time of submitting the offer. Vendor shall also provide detailed worst-case analysis accounting for the total variation over the life at the time of Design Review.

4.4.3 GAIN RESPONSE
The gain response of Units shall not exceed the requirements specified in the Table 4.0.1.

4.4.4 GAIN SLOPE
The gain slope specified in Table 4.0.1 is absolute and not the relative change. The sign ± indicates the positive/negative slope only and not the variation.

4.4.5 GAIN SLOPE AT RATED OUTPUT POWER
The gain slope measured at any point within full operating frequency band shall not exceed the value specified in Table 4.0.1, at saturated power output (Po)

4.4.6 GAIN SLOPE AT SMALL SIGNAL
The gain slope shall be less than the value specified in Table 4.0.1, at any point over the full frequency range after adjusting the input drive level corresponding to small signal.

4.4.7 GAIN RIPPLE
The Peak-to-Peak small signal gain ripple shall not exceed 2.5 dB, over full bandwidth.

4.5 OUTPUT POWER STABILITY WITH TIME/TEMPERATURE
The output power stability for LTWTAs shall be better than the values given in Table-4.0.1
Power Stability will also be measured in 4 hours period at temperature of –15 to 5, 5 to 25, 25 to 45, 45 to 65 and 65 to 80 (EPC up to +65°C and TWT up to +80°C) deg C at nominal bus voltage on PFM in thermal vacuum condition.

4.6 PHASE CHARACTERISTICS
The phase characteristics shall include the following measurements.

4.7 AM/PM CONVERSION COEFFICIENT
AM/PM conversion coefficient for the Units shall not exceed values specified in Table 4.0.1. when the RF input level is swept from Pin(saturation) to Pin(small-signal). Discrete values are given in Table 4.0.1.
4.8 PHASE SHIFT
The total phase shift shall not exceed values specified in Table 4.0.1., when input drive is varied from Pin(saturation) to Pin(small-signal).

4.9 AM/PM TRANSFER COEFFICIENT
This can be computed from the I/O curve of the Unit. Values are specified in Table 4.0.1.

4.10 THIRD ORDER IMD
The Third Order Inter-mod distortion, measured with two carriers separated by 1 MHz, shall be less than the values given in Table-4.0.1. The curve for input drives (from small signal to saturation) versus single carrier, two carriers and inter-mod shall be provided.

4.11 NOISE FIGURE
As per value specified in the Table No 4.0.1

4.12 SPECTRAL PURITY
As per value specified in the Table No 4.0.1

4.12.1 NON HARMONIC SPURIOUS LEVELS
As per value specified in the Table No 4.0.1

4.12.2 HARMONIC SPURIOUS LEVEL
As per value specified in the Table No 4.0.1

4.13 RF EMISSION
As per value specified in the Table No 4.0.1

4.14 NOISE POWER DENSITY AT TWTA OUTPUT
As per value specified in the Table No 4.0.1

4.15 NOISE POWER RATIO (NPR)
The Noise Power Ratio for the multi-tone signal shall be as per Table 4.0.1
Note: The manufacturers are requested to quote best achievable NPR @ 4 dB OBO.

4.16 GROUP DELAY
As per value specified in the Table No 4.0.1

4.17 INSERTION LOSS
The Insertion loss in non-operating condition, when measured from input to output, shall be more than value specified in Table 4.0.1, over the entire frequency band of operation.

4.18 VSWR

4.18.1 INPUT/OUTPUT VSWR
Over the specified bandwidth and under all operating conditions, the input and output VSWR shall not be greater than that given in Table- 4.0.1
4.18.2 LOAD VSWR  
As per Table No 4.0.1

4.19 SPURIOUS PHASE MODULATION
1. The periodic phase modulation generated by the unit shall not exceed the limits as given in fig. (4.19.1) when driven by the TDMA signal (duty cycle 1:1) from 0 to 20 dB IBO. The maximum phase modulation shall not exceed 20 degrees peak to peak.
2. Vendor shall describe the exact method for characterization of the unit under TDMA operation.

![Fig. 4.19.1 Limits for Spurious Phase Modulation](image)

4.20 RF IMPEDENCE  
Reference Impedance for Input port: 50 ohm (Coaxial, SMA),  
Reference Impedance for out port: WR 75 waveguide

4.21 STABILITY  
The Units shall be unconditionally stable and shall not oscillate or get damaged, even if the input/output terminals are open/short circuited under no drive condition.

4.22 ELECTRICAL INTERFACES  
The Bus voltage, TC and TM interface shall be through multi-pin D-Type DC connector(s) (low out gassing qualified as per GSFC spaces or NASA/ESA specs preferably general D-sub type Rectangular DC connector). The input RF connector should be coaxial SMA and output should be through WR-75 waveguide interfaces.
4.23 TELE-COMMAND / TELEMETERY INTERFACES

4.23.1 TELE-COMMAND SIGNALS
The Units shall be able to switch ON and OFF, and also accept other commands applied to EPC of the unit through tele-command subsystem of the spacecraft. The units will have provision for the following tele-command:

a) **TWTA ON:** For turning-on the unit. (High Voltage should be turned ON automatically after the pre-determined filament warm-up delay).

b) **TWTA OFF:** For Turning-Off the Units. (Both H.V and Heater should Turn-Off)

c) **Helix Over Current Protection Circuit (HOCPC) Enable/disable:**
   For enabling or disabling helix over-current protection using tele-command. There can be one pin (toggle type function) or two separate pins for receiving these commands (enable and disable). Vendor shall describe the wake-up mode.

All the telecommand (ON, OFF, HOCPC) live and return lines from the spacecraft will NOT be ground-referenced, but can have a common-mode voltage. Therefore, the telecommand input pins (live and return) of the unit shall be fully isolated from chassis and from any other point in the unit.

Vendor shall provide the current drive requirement by the telecommand lines.

The nature of the tele-commands signal will be \(+29V \pm 1V\) with nominal pulse width of \(64 \pm 2\) ms. However, pulse width may be up to \(128\)ms. Vendor also shall submit the Tele-
command circuit diagram along with proposal. Vendor should also provide value of maximum duration of the Telecommand pulse which could be applied causing no damage.

4.23.2 TELEMETRY OUTPUTS
It is required to monitor Filament status, Helix current, HOCPC Enable/Disable status, Anode voltage and Spurious Shut Off activation status in the Units with following characteristics:

**Bi-level telemetries:** the output of these bi-level telemetries shall be 0V to 0.5V for ‘Low’ level and shall be 4.5V to 5.0V for ‘high’ level.
   a) Filament Status / EPC On-Off Status:
      ‘Low’ meaning absence and ‘high’ meaning the Filament voltage is applied.
   b) HOCPC Enable / Disable status:
      It shall indicate the enable/disable status for helix-over-current-protection feature.
      Vendor shall provide interpretation of ‘high’ and ‘low’ levels.
   c) Spurious Switch Off / ARU:
      ‘Low’ meaning absence and ‘high’ meaning Spurious HV shut-off.

**Analog telemetries:** the output of these analog telemetries shall be analog-voltage from 0V to +5V. Vendor shall provide their calibration curves in end-item-data-packages.
   d) Helix current monitoring
   e) Anode Voltage monitoring
   f) Input DC Bus Current / DC Input Power consumption monitoring

4.23.2.1 Following are the interface circuits for the telemetry lines

a) For Analog Telemetry Lines

![Figure: 4.23.1 Analog Telemetry interface](image)

b) For Digital Telemetry line

![Figure: 4.23.2 Digital Telemetry interface](image)

Note 1: The internal circuit should be able to deliver signal to a load of TTL circuit or equivalent.

Note 2: In case of malfunction in telemetry circuits, the units shall continue to operate normally without any degradation in performance.

Note 3: The interface resistors values could be changed after mutual discussions.
**Note 4:** Telemetry return shall be isolated from the input Bus return and Tele-command return.

**Note 5:** TM voltage level shall be restricted to 5.1 V maximum by suitable clamping circuit. Clamp should be effective during all conditions including turn on/off etc.

### 4.24 PRIMARY POWER

#### 4.24.1 DC INPUT VOLTAGE

The input power to the Units shall be supplied directly from the spacecraft bus. Bus input shall be 70 ± 5 V DC i.e., +65V to +75V. The input voltage variation in the specified range should not cause any degradation in performance.

#### 4.24.2 INPUT POWER

The maximum input power drawn by the LTWTA from the spacecraft bus, shall not exceed the value specified in Table 4.0.1 under the worst case operating condition of bus voltage, temperature and RF drive.

Vendor shall specify the power requirement for TWT and EPC and LTWTA separately for saturation condition, No-drive condition and over drive condition and worst-case dissipation condition. Vendor should provide the information in the attached POWER-EFFICIENCY DATA TABLE as per given in Table 4.24.1 at the end of this RFP.

Vendor shall also furnish estimated increase in the input DC power over life, due to aging, radiation and other long-term effect on TWT, EPC and Linearizer, at the time of submitting the offer.

### 4.25 IN-RUSH CURRENT TRANSIENTS

During Bus Voltage Plug-in, Heater on and HV-On conditions, Vendor shall specify

(a) The peak value of inrush current
(b) Rate of change inrush current
(c) Total charge delivered to the circuit expressed in coulomb
(d) Wave shape of the inrush current transient
(e) Front-end circuit seen by the bus including the capacitors values.

The current inrush at switch-on shall be limited to twice the nominal input current during Heater and HV turn-on.

### 4.26 OVER/UNDER VOLTAGE

In case the input voltage variation exceeds the specified limits, the units shall be protected from damage.

### 4.27 PROTECTION CIRCUITS

a) The provision shall be made for the units to turn “OFF” in case the input voltage falls below the under voltage trip point, which shall be set at value specified in Table 4.0.1.

b) The provision for disconnecting the units from the bus shall be incorporated in case of malfunction. The fuses (one fuse in parallel with a fuse in series with a resistor of TBD ohms) should be the very first elements encountered by the raw bus line entering the
EPC. The fuse rating should be consistent with inrush current transients. Vendor shall provide fuse clearing characteristics, I and $I^2t$ rating of the fuses.

c) Provision shall be made to turn-off the units within shortest possible time (desirable: 4ms to 20ms) in the event of any malfunction causing input power to exceed the 150% to 200% of the nominal input power.

d) Provision shall be made for the helix over current protection in case of helix current exceeding a certain safe limit. Provision for disabling this protection by telecommand shall be incorporated.

e) Any fault in the TWT/EPC causing excessive helix current or transient over current in input bus should turn off the high voltage (Heater should remain on) within 10 to 40 milliseconds. High voltage restore must occur within 300 ms maximum after a shut off caused by transient fault (except Bus under voltage). In case of another fault within 5 minutes, units shall be completely switched off (high voltage and filament). If the second spurious shut off does not occur within the specified time, the automatic restart capability should be enabled again.

ESD Protection: Bleed path of $<10^6$ ohms between center conductor of Co-axial RF ports to ground to be ensured.

Notes: The units can be turned-on again only through the execution of ON command in the event of complete shut down due to any fault. The vendor shall also provide the time taken for actuation of all protection circuits.

4.28 BUS CHARACTERISTICS
The spacecraft bus voltage will be Regulated DC 70 ± 5 V (65V to 75V).

4.28.1 VOLTAGE RIPPLE FROM THE MAIN BUS
The units shall meet the performance requirements with main-bus voltage ripples as specified in Table 4.0.1 / Exhibit-C. The vendor must specify the maximum allowed power level in this frequency range without stress on the unit.

4.28.2 VOLTAGE TRANSIENT
The units shall not exhibit any degradation of performance when the transient, shown in figure 4.28.1, of peak voltage, $V_{\text{peak}} = 100\%$ of the DC supply voltage, pulse width $t=10$ micro sec ± 20 %, is applied to the DC power input leads. Such voltage transient could occur any time during the operation. Unit shall be capable to withstand such transients without any degradation and in any case, the unit performance also shall not be degraded.

This transient could get applied with positive polarity at the highest DC supply voltage. The transient could get applied for duration of up to 15 minutes at a repetition rate of 10 pps.

Testing for transient performance shall be carried out in accordance with MIL-STD 461C/462C, and as per CS06 test method.
4.29 MAIN BUS IMPEDANCE

The typical bus impedance shall be assumed to have the characteristics as shown in Figure 4.29.1 & 4.29.2. Changes, if any, in bus impedance will be communicated before contract finalization.

Vendor shall provide the information about the interaction margin between the input impedance of EPC and the input filter (including the spacecraft input harness and bus impedance). Vendor should clearly mention the tolerable input bus and spacecraft harness impedance for proper functioning of the LTWTA.
Figure No. 4.29.1 Bus Impedance Eclipse Condition.
4.30  EMI/EMC REQUIREMENTS  
The Units shall be designed and tested to meet conducted/radiated emission and susceptibility limits specified in para-8.13 of Exhibit-C.

4.31  EPC SPECIFICATIONS  
Vendor shall provide the typical performance data of the EPC, proposed to be used in the units, along with the offer. It should include the following:
(a)  Typical output Voltage and current applied to each electrode.
(b)  Typical voltage regulation against line, load and temperature variation.
(c)  Typical variation in output voltage due to aging and other long-term effect.
(d)  Ripple in each output expressed in time and frequency domain
(e)  Efficiency
(f)  Typical curve for Turn On/Turn Of performance of high voltages applied to each electrode in TWT.

Figure No. 4.29.2 Bus Impedance Sunlit Condition.
(g) Switching frequency.
(h) Vendor shall also furnish the data of voltages, currents and other performance requirements of each TWT and provide the detailed EPC test data package along with End Item Test Data.
(i) The EPC shall be unconditionally stable under all operating conditions.
(j) Loop gain characteristic of main regulation loop, helix regulator and cathode current control loop (bode plots), input filter damping characteristics against transient, input filter converter interaction margins and the results of practical stability test data shall be made available at the appropriate design review (PDR/CDR) stages.

4.32 MECHANICAL REQUIREMENTS

4.32.1 MASS
The Mass of LTWTA (Linearizer + TWT +EPC+ all interconnection cables) shall be specified by the vendor and should be as small as possible. However, it shall be as per specified in Table 4.0.1. Vendor shall provide mass-breakup.
Note: Manufacturer shall offer best minimum mass of their qualified-design.

4.32.2 MOUNTING DETAILS
The Units will be mounted on Honeycomb panel in the satellite. The vendor should provide mounting lug positions and mounting surface accuracy requirements etc.

Note: Normally Units will be mounted in horizontal position; however, there should not be any constraint for mounting it in vertical plane.

4.32.3 SIZE/SHAPE
The vendor shall specify the size and shape of the units. Size should be as small as possible.
Note: The vendor shall provide complete Interface Control Drawing (ICD) with the Proposal.

4.32.4 VENTING
The equipment shall be vented sufficiently to meet space use requirements as per the R & QA requirements.

4.32.5 SURFACE FINISH
All the external surfaces except the bottom-mounting surface shall be black using: black thermal paint or Alternative; with emissivity of 0.85 or better. The bottom surface shall be left unpainted, but the collector radiator shall be anodized.

Note: The vendor shall provide the thermal profile of the bottom surface, so that the heat distribution is known.

4.33 Ground Isolation Requirements
1 Primary ground i.e. 70V Bus ground and the secondary ground/chassis should be isolated from each other with a minimum of 1 M ohm resistance at the unit level.
2 TC return should be isolated from primary, secondary and Chasis returns. TM return should also be isolated from Primary return. The TM & TC returns should be brought out separately on to a connector. The EPC design should be able to tolerate potential difference of around 1 V between any combination of TM, TC, Secondary / Chassis ground. All internal circuit and circuits powered by the EPC such as CAMP and Linearizer etc should not get affected.

3 Primary ground will be nominally at the same potential as TM /TC/secondary ground in the spacecraft. However, EPC should function properly even under non-nominal conditions where a non-zero potential exists between primary ground and secondary returns. (The primary return could float in a range of +1 to –70 volts with respect to secondary returns under severe fault conditions). Vendor shall submit the ground isolation scheme at the time of proposal.
RELIABILITY AND QUALITY ASSURANCE (R & QA)

INTRODUCTION

This section provides the details on R & QA requirements, which shall be assured by the vendor for this program. The final assembly is referred as ‘Unit’ in this exhibit.

1.0 RELIABILITY

1.1 Life

a) The Units shall meet all the design requirements for use on board spacecraft with a minimum life for 15 years, with a cathode life of 18 years.

b) The Units shall be capable of meeting all the functional requirements at various stages of spacecraft assembly and storage as follows.
   - 3 years’ storage and life at various levels of spacecraft assembly
   - 5 years in controlled environmental conditions.

The vendor shall specify exact method of storage and retest criteria in case of longer storage.

1.2 Reliability analysis

The units shall be designed and fabricated to achieve an estimated reliability figure of 0.99 at the end of 180 days and better than 0.85 after 15 years at maximum operating temperature. However, vendor to specify exact reliability figure at the end of 15 years. As a part of CDR, vendor shall give exact failure rate and reliability figure for 15 years in orbit of TWT, EPC, Linearizer (LIN) and integrated LTWTA, calculated at maximum operating temperature.

The manufacturer shall provide de-rating analysis and derating criteria followed for all the parts used in LTWTA, including EPC, Linearizer and TWT. The maximum junction/ channel temperatures of all solid-state devices shall not exceed +110°C under any operating and environmental conditions.

The reliability calculation shall be carried out as per MIL-HDBK-217-FN2. The vendor should also specify in analysis report, the methodology used in arriving at the failure rate of TWT and other components not mentioned in MIL-HDBK-217-FN2. Manufacturer shall supply analysis, test data / test reports taken as reference for arriving at the failure rate values of such parts.

Manufacturer shall provide following detailed analyses reports as a part of CDR documentation.

(i) Detailed reliability analysis consisting of
   a) Reliability estimation
   b) Stress analysis
   c) FMECA
d) Worst case drift & tolerance analysis. (also taking into account of radiation effects, aging and temperature drift for 15 years)
e) Confirmation that the circuit designs are compliant to the ESA/NASA parts usage guidelines and alerts. Detailed justification along with risk assessment shall be provided for components that are used beyond the recommended configurations/limits.

(ii) Thermal analysis under worst case operating conditions.
(iii) Mechanical / Structural analysis.
(iv) Radiation analysis.
(v) EM analysis/ Test report from heritage program
(vi) Venting analysis

1.3 Safety
The unit design shall be failsafe, so that any failure within unit shall not degrade or affect the performance of other subsystems in the spacecraft. This shall be assured through adequate usage of protection mechanisms/ circuitry and shall be detailed in CDR.

2.0 ENVIRONMENTAL CONDITIONS
2.1 Non-operating environment

The Units shall be capable of withstanding the following environmental conditions:

a) Temperature range : -35 °C to 85 °C
b) Pressure : Ambient to 10⁻⁶ Torr or better
c) Relative humidity : Up to 70% without condensation of water at +40°C
   (Short duration)
   (Applicable for ground storage during transportation and handling only)

2.2 Operating environment

a) Turn-on
The Units shall be capable of being turned-on without any damage at following temperature The unit however, need not meet the performance specifications at this temperature. The test should be conducted at following temperature

<table>
<thead>
<tr>
<th>Unit</th>
<th>TWT</th>
<th>EPC &amp; LIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>QM/PFM</td>
<td>-35 °C &amp; +85°C</td>
<td>-35 °C &amp; +65°C</td>
</tr>
<tr>
<td>FM</td>
<td>-30 °C &amp; +80°C</td>
<td>-30 °C &amp; +60°C</td>
</tr>
</tbody>
</table>

b) Temperature range

<table>
<thead>
<tr>
<th>Unit</th>
<th>TWT</th>
<th>EPC &amp; LIN</th>
<th>Radiator</th>
</tr>
</thead>
<tbody>
<tr>
<td>QM/PFM</td>
<td>-15°C to +85°C</td>
<td>-20°C to +65°C</td>
<td>-180 to +110°C</td>
</tr>
<tr>
<td>FM</td>
<td>-10°C to +80°C</td>
<td>-15°C to +60°C</td>
<td>-180 to +110°C</td>
</tr>
</tbody>
</table>
**Note**: EPC temperatures is referred to the base plate, near to EPC. The TWT collector temperature at lug, shall be given by vendor. Vendor shall ensure that operation with TWT collector temperature up to 80°C at lug will not affect the life, operation and specifications of the LTWTA. The TWT collector temperature shall be measured in this condition.

c) **Pressure**

The unit shall be capable of operating at any pressure, i.e. 1 atmosphere as well as vacuum conditions of $10^{-6}$ torr or better. The design shall allow quick depressurization during launch ascent.

2.3 **Space radiation**

The unit shall be designed and fabricated to operate without any degradation in performance or life for the following:

a) $1.5 \times 10^7$ Rads Ionizing dose absorbed in silicon.

b) $6.0 \times 10^{14}$ elec. / cm$^2$ (3 MeV bulk damage equivalent)

c) Immunity against SEE (including SEL/SEGR/SEB/SEU etc) : LET 75 MeV /mg/cm$^2$

The manufacturer should ensure reliable operation of the units in the presence of cosmic Radiation, while considering the shielding offered by satellite structure as 0.5 mm.

The design and shielding applied should be such that RDM (Radiation Design Margin of 1.2) shall be demonstrable.

Vendor shall provide Radiation analysis considering 0.5 mm shield offered by Satellite structure, for a life of 15 years in Geo-stationary orbit.

Note: The dose in silicon at the center of spherical aluminum shield for the mission is as given in Figure –1

![Dose at Center of Spherical Aluminium Shield](image)

**FIGURE-1 : DOSE AT CENTER OF SPHERICAL ALUMINIUM SHIELD**
<table>
<thead>
<tr>
<th>Thickness (mm Al)</th>
<th>Thickness (gm/cm²)</th>
<th>Total dose (rads/15 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.0135</td>
<td>696 M</td>
</tr>
<tr>
<td>0.10</td>
<td>0.027</td>
<td>423 M</td>
</tr>
<tr>
<td>0.20</td>
<td>0.054</td>
<td>223 M</td>
</tr>
<tr>
<td>0.50</td>
<td>0.135</td>
<td>52.2 M</td>
</tr>
<tr>
<td>1</td>
<td>0.27</td>
<td>13.8 M</td>
</tr>
<tr>
<td>2</td>
<td>0.54</td>
<td>2.17 M</td>
</tr>
<tr>
<td>3</td>
<td>0.81</td>
<td>542.0 K</td>
</tr>
<tr>
<td>4</td>
<td>1.08</td>
<td>161.0 K</td>
</tr>
<tr>
<td>5</td>
<td>1.35</td>
<td>64.8 K</td>
</tr>
<tr>
<td>6</td>
<td>1.62</td>
<td>29.0 K</td>
</tr>
<tr>
<td>7</td>
<td>1.89</td>
<td>18.6 K</td>
</tr>
<tr>
<td>8</td>
<td>2.16</td>
<td>12.1 K</td>
</tr>
<tr>
<td>9</td>
<td>2.43</td>
<td>9.98 K</td>
</tr>
<tr>
<td>10</td>
<td>2.70</td>
<td>8.71 K</td>
</tr>
</tbody>
</table>

Total dose at the center of spherical shield at geostationary orbits

**Note:** To calculate equivalent thickness of any other material, divide column two by the density of material.

2.4 **Vibration / shock**

The unit shall be designed and fabricated to meet the vibration (sine and random), and mechanical shock, as per the test plans given.

3.0 **PARTS / MATERIALS:**

Parts / materials proposed to be used in the unit shall be selected from qualified parts / material list (QPL/QML) and through a qualified sub-vendor, normally associated with long life communication satellite hardware. Quality level of parts used shall meet the following quality level requirements.

3.1 (a) Parts

Parts to be used in Flight Model shall meet the following minimum quality requirements, given in Table-1 below. In general, the Quality of components for the actual flight deliverable units shall be S-level (minimum).

All components proposed to be used in the unit shall have previous space flight history, which shall be verifiable, through reference documents. The Parts Approval Document (PAD) sheets shall be provided as a part of CDR.
### Table-1 Parts quality level

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Part Type</th>
<th>Quality Level</th>
</tr>
</thead>
</table>
| 1       | RF semiconductors | (i) ESA / SCC level B  
          |           | (ii) Non QPL / QML devices – equivalent to JANS procured with full screening and quality conformance tests & DPA and shall have space flight history.  
          |           | (iii) JANTXV with 240 hrs. Burn-in and quality conformance tests. |
| 2       | General Semiconductors | (i) JANS or ESA / SCC level B  
          |           | (ii) JANTXV with quality conformance tests. |
| 3       | Passive Parts | (i) ESA / SCC level B or MIL-ER failure rate ‘S’  
          |           | (ii) MIL-ER failure rate ‘R’ only for the part types where ‘S’ is not available  
          |           | (iii) Non QPL / QML parts – with manufacturer’s in house screening program equivalent to ‘R’ level with group A testing. |
| 4       | Micro – Circuits (Including ASIC memory etc.) | (i) ESA / SCC level B or MIL-PRF-38535 QML class V.  
          |           | (ii) ESA approved parts with LVT.  
          |           | (iii) Processed & screened to S level with QCI (Manufacturer’s specs) |
| 5       | RF passive parts (attenuators, terminators, isolators etc.) | (i) ESA / SCC level B  
          |           | (ii) ESA approved part with LVT tests.  
          |           | (iii) With adequate screening & LAT as per manufacturer’s Hi-Rel program. |
| 6       | RF connectors | (i) ESA / SCC level B  
          |           | (ii) MIL-PRF-39012 qualified with group A & B testing. |
| 7       | Multipin connectors (Only miniature D-type connectors shall be used) | (i) ESA / SCC level B  
          |           | (ii) Connectors as per NASA – GSFC requirements |
| 8       | MMICs | As per 3.1 (b) |

**Note:**  
(i) For all the parts, quality level listed as (a) is preferred. Other quality levels are acceptable only if parts with quality level (a) are not available.  
(ii) A copy of Parts Approved Document (PAD) containing details of parts, their quality levels, etc. shall be supplied as part of CDR

#### 3.1 (b) Quality requirements for MMICs:  
(i) Manufacturer shall have obtained ESA capability approval, for fabrication of MMICs or Qualified as per MIL-PRF-38535.  
(ii) Foundry shall have capability for fabrication & testing requirements as per ESA-9010 and shall have delivered MMICs for space use with testing as per ESA-9010 level B or equivalent space grade.

MMICs procured with the above quality level shall undergo following testing prior to their use in the units:  
1) Visual inspection as per MIL–STD–883C, method 2010, Condition–A on 100 % of lot.  
2) DC probing on 100 % of lot.  
3) RF probing on 10 % of lot.  
4) WLAT on 5 samples.
**In the case of bare die usage**, following tests on packaged samples from each lot
(a) RF & DC electrical test over operating temperature range.
(b) Burn – in 240 hrs; followed by life test 1000 hrs on 10 samples.
(c) Bond pull & die – shear on 5 samples.

**In the case of packaged device usage**, the devices shall be screened per the requirements of ESA 9010 level B or equivalent space grade, with quality conformance testing to LAT-2 or equivalent VOQ testing.

PAD sheet for MMIC shall be provided as a part of CDR documents.

### 3.2 Materials

Ferrous and non-ferrous material used shall be of corrosion resistance type or suitably treated to resist corrosion caused by atmospheric conditions existent in storage or normal operational conditions. Non-magnetic materials shall only be used for parts, except where magnetic materials are essential. Materials, which are nutrients for fungus, shall not be used.

Organic and inorganic materials shall be stable under atmospheric and high vacuum conditions. These materials shall have a Total Mass Loss (TML) of less than 1% and Collectable Volatile Condensable Materials (CVCM) of less than 0.1% when subjected to test condition of \(+125^\circ\text{C}\) and \(1\times10^{-06}\) torr pressure for 24 hrs. Only space qualified epoxies, potting materials, etc. shall be used, within their shelf life and with cure schedule as specified by the vendor. However, their use shall be restricted and failure due to these shall be recorded and analyzed as and when detected.

The selection and use of dissimilar materials shall be avoided, where it is impractical to avoid dissimilar metals in direct contact with each other, suitable protection shall be provided by space proven coating / plating etc.

As a part of CDR, a detailed list of materials to be used shall be provided to SAC for review; along with their Quality and Out-gassing specifications.

### 4.0 Processes

The unit shall be built to the standards normally associated with long life communication satellite hardware. Particular attention shall be paid, as a minimum, in respect to the following:
- All the processes used should be qualified for space use,
- Neat, clean, smooth, and fully welded homogeneous solder joints,
- Eliminate bubble entrapment in coatings / epoxies where ever used,
- All components including torroidal / bead inductors / coils shall be suitably supported on PCB by RTV etc.
- Wherever wires are attached to casing for grounding etc., a higher melting point solder than that used for lid (cover) soldering, shall be used,
- The input / output connections on pins form the PCB etc. shall also be made with high melting point solder to avoid detachment of these
connections while soldering the pins to external system using SN-63 solder.

➢ The marking and plating etc. shall be permanent and should not get damaged during normal cleaning process using Isopropyl Alcohol and other recommended cleaning solvents.

All tolerances not specified shall be consistent with the best engineering practices. Units shall be uniform in quality and free from blemishes and defects.

5.0 MARKING AND IDENTIFICATION:

The unit shall be identified by assigning unique serial number on the exterior surface by a suitable process applicable for space use. Marking shall not degrade the performance of the unit. In addition to functional markings like input / output, frequency etc. following marking shall appear on each unit:

a) Part name
b) Part Number
c) Specification Number / Contract Number
d) Serial Number
e) Name of the Manufacturer
f) Date of Manufacture
g) PFM / FM as applicable.

The permanency of the marking shall be sufficient to withstand the specified environmental conditions and normal cleaning operations using Isopropyl Alcohol and other cleaning solvents. The test method to demonstrate the same shall be specified by the manufacturer.

6.0 TRANSPORTATION:

Suitable packaging shall be provided for the transportation of the unit by air, ship or road without any degradation / damage. The transportation package shall protect the unit from rough handling test as specified in MIL-P-116. Wherever required the transportation container shall have nitrogen purging facility so that whenever required the unit before shipment is purged with dry nitrogen to prevent contamination and corrosion.

Each unit shall be packaged in individual ESD protective package. This package shall protect the unit from environmental conditions during transportation like heat, humidity dust. This individual container shall then be placed in a transportation container. More than one individual unit packages may be placed in transportation container. The transportation container shall protect the units from heat, humidity, dust, mechanical shock & vibrations during transportation.

Individual unit package and transportation containers shall be clearly marked with following instructions, along with other mandatory markings. Humidity & shock sensor shall be mounted in transportation container.

“ESD sensitive units”
“To be opened under clean environment with ESD precautions only”
“High Reliability Space usage systems”

Note: LTWTA shall be fitted with metric unit size screws / nuts only on their carrier plate.

7.0 Model philosophy

Proposed unit should have,
   a) Sufficient flight history / heritage for use in Communication payload in GEO orbit,
   b) Qualification successfully completed.

Following test philosophy will be applicable.
   - Proto Flight Model (PFM)
   - Flight Model (FM)

Vendor shall provide following details / documents to SAC for establishing qualification by similarity.
   a) List of space program, wherein the proposed design has been used, test philosophy followed for that program. (Separate details to be provided by Vendor for TWT, EPC and Linearizer)

   b) Qualification test report / summary report, clearly indicating LTWTA withstood test severity as specified in following para.

Only previously qualified designs are acceptable. However, SAC reserve right to add requirement of Qualification Model (QM) based on review of above documents.

In case minor design changes are incorporated at module level (i.e. EPC, LIN or TWT level) for this program, that individual module shall be subjected to qualification level testing as per mutually agreed plan. After successful qualification of individual module, the design may be implemented in the actual FM Units.

7.1 Qualification Model (QM) : (If applicable)
The QM shall incorporate final electrical & mechanical design and configuration using electronic parts, materials and processes of final type and quality standard that are adequate to pass successfully the qualification testing. One QM unit shall be subjected to full qualification test as per Table-2.

7.2 Proto Flight Model (PFM)
Wherever qualification by similarity is established, the first FM unit shall be subjected to PFM level testing. The PFM unit shall undergo testing as per Table-2 at Qualification level severity. However, the duration of the tests shall be restricted to acceptance levels.

7.3 Flight model (FM)
The flight model units represent the final electrical and mechanical design and configuration using screened Hi-Rel parts, materials and processes of qualified standard and workmanship.
The unit fall-out during Acceptance (screening) tests shall state the number of times that each test parameter failed and quantity of units failed in one or more test parameters. This shall identify all catastrophic, degradation failures and failure modes observed.

Any failure observed, shall be reported to ISRO immediately. This shall be followed by a detailed failure analysis, clearly identifying the type of failure (random or design). Any modifications required in electrical, mechanical or process related aspects shall be approved by ISRO. In case of mechanical or electrical design related failure, a retest plan or modification in the test plan may be necessary. Based on failure analysis, such retest plan / modified test plan shall be decided and implemented after approval by ISRO.

8.0 TEST PLAN

Vendor shall provide ATP / QTP as supplied for previous program at the time of CDR. Tests to be performed on QM/ PFM and FM units are shown in Table-2. All electrical testing including Burn-in, EMI, Thermovac, shall be carried out with LTWTA in power ON condition.

Suitable buffer connectors shall be provided to minimize the mating / de-mating during testing.

Table – 2 : LTWTA Test plan

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Test</th>
<th>QM</th>
<th>PFM</th>
<th>FM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical Measurements (Note 1)</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>2</td>
<td>Visual Inspection (External)</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>3</td>
<td>Leak test (at TWT level)</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>4</td>
<td>Magnetic Field Measurement (Note 2)</td>
<td>T</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>Initial Functional Tests</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>7</td>
<td>Temperature Tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) Temperature Storage</td>
<td>T</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(b) Temperature Operational</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>8</td>
<td>Vibration Test (Note 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a) Sine Vibration</td>
<td>T</td>
<td>T</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>(b) Random Vibration</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>9</td>
<td>Mechanical Shock</td>
<td>A &amp; T</td>
<td>A &amp; D</td>
<td>--</td>
</tr>
<tr>
<td>10</td>
<td>Corona check</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>11</td>
<td>Thermal – vacuum</td>
<td>T</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Thermo-vacuum cycling</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td></td>
<td>b) On/off cycling</td>
<td>T</td>
<td>T</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>c) Multipactor</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>Humidity storage Test</td>
<td>T</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>13</td>
<td>EMI/EMC</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>14</td>
<td>Final Functional Tests</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>15</td>
<td>Final Visual Inspection</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
</tbody>
</table>
T denotes Test to be performed.
D denotes compliance by PREVIOUS TEST DATA and
A denotes compliance by ANALYSIS.

At the end of each environmental test, visual inspection and electrical performance check will be carried out.

Note:
1. CoG by analysis
2. Magnetic field measurement data of representative program shall be provided by Vendor at the time of Design review.
3. Vibration shall be done separately for TWT and remaining assembly.
4. EMI test will include RE (sniff test) and RS tests (spray test).

8.1 Test parameter
The test parameter in each functional environmental test to be measured are given in Annexure-1

8.1.1 Carry Forward Data (CFD) requirement:
Following CFD shall be provided as a part of Data package

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Test to be performed</th>
<th>LIN</th>
<th>TWT</th>
<th>EPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I/O transfer Curve (Amplitude and phase)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Over-drive</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>Gain / Power</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>O/P Power stability</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>Input / Output VSWR</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>Harmonics/Spurious</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Noise Power Density</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>DC Consumption vs Drive</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>SSO &amp; Auto-Restart</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>Cathode Activity, including burn-in logs</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>11</td>
<td>Cathode operating Point</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Vacuum check</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>Gain/Phase margin, switching frequency, synchronization details</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>14</td>
<td>Transient response</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>TM Calibration</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>16</td>
<td>Helix/Over-current Protection/Limits</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>17</td>
<td>UV/OV Protection</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>18</td>
<td>Input In-rush Current</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
8.2 Physical measurement
The unit shall be examined for Mass & Dimensions and analyzed for Moment of Inertia & Centre of gravity. The vendor shall provide the measured data of mass and dimension of all the units.

8.3 Visual inspection
The UNIT shall be inspected for surface finish, mechanical, process & workmanship related defects. Each unit shall be examined visually before and after each environmental test is carried out.

8.4 Leak test
Vacuum characterization shall be performed before TWT integration with EPC. The vendor shall give the details of leak test carried out on each TWT.

8.5 Magnetic field measurement
Magnetic field measurement data of the test performed on representative TWT during previous Qualification/ development program shall be provided by the vendor as a part of design review data package and along with the test results.

8.6 Initial functional test
All the electrical parameters as shown in Annexure-1 shall be measured during Initial functional tests, and taken as reference for all the other environmental tests and final functional tests.

8.7 Burn-in test:
Each TWT shall be subjected to burn-in for a minimum of 750 Hrs at 50 °C during which cathode activity test shall be carried out.

**LTWTA level:**
QM/PFM unit shall undergo cumulative 240 Hrs of operation during various tests (minimum 168 Hrs in TVAC). All FM units shall undergo cumulative 168 Hrs of operation during various tests (minimum 96 Hrs in TVAC).

Logging of time duration during various phases of testing should be recorded in support of cumulative operating time and provided in data pack.

Pre and post-burn-in electrical measurements shall be carried out. During the burn-in, the electrical performance measurements shall also be carried out and critical parameter shall be monitored & recorded.

8.8 Temperature operational test
This test shall be performed on all FM & QM/PFM units in TV, to check the performance specifications of the units at the specified high and low operating temperatures.

All parameters as specified under ‘Thermal Test’ shall also be measured during thermo vacuum as per Annexure-1.
### Table – 4  operational temperature test

<table>
<thead>
<tr>
<th>Test</th>
<th>Temperature</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Operational</td>
<td>FM: -10 °C for TWT and -15 °C for EPC</td>
<td>24 hours</td>
</tr>
<tr>
<td></td>
<td>QM/ PFM: -15 °C for TWT and -20 °C for EPC</td>
<td></td>
</tr>
<tr>
<td>Hot Operational</td>
<td>FM: 80 °C for TWT and 60 °C for EPC</td>
<td>24 hours</td>
</tr>
<tr>
<td></td>
<td>QM/ PFM: 85 °C for TWT and 65 °C for EPC</td>
<td></td>
</tr>
</tbody>
</table>

### 8.9 Vibration
Vibration shall be done separately for TWT and remaining assembly, as per specified level. Vibration levels given below are tentative. Levels may be changed depending upon mechanical configuration.
Vendor shall provide first fundamental resonance frequency and amplitude. It is suggested that vendor shall generate the vibration test report in standard format as shown in Annexure-2.

#### Resonance search (LLS):
Pre & Post Sine and Random vibration, resonance search shall be carried out in all the three axes as per following levels. Natural resonance frequency shall be greater than 120 Hz.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 2000</td>
<td>0.5 g</td>
</tr>
<tr>
<td>Sweep rate</td>
<td>2 Oct / Minute</td>
</tr>
</tbody>
</table>

Resonance search success criteria shall be as under,

a)  $< 10\%$ in frequency shifts for modes with effective mass >10%

b)  $< 20\%$ in amplitude shifts for modes with effective mass >10%

#### Vibration test sequence:
1. For QM/PFM Unit (all axis) : LLS, Sine Vibration, LLS, Random Vibration, LLS
2. For FM Unit (all axis)          : LLS Random Vibration, LLS

### 8.9.1 Sine vibration
This test is applicable for QM/ PFM. The unit shall be in non- operating condition.
The following test level shall be applied separately along the orthogonal axes. (X, Y & Z)

<table>
<thead>
<tr>
<th>Normal to mounting plane</th>
<th>Amplitude</th>
<th>Parallel to mounting plane</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td></td>
<td>Frequency (Hz)</td>
<td></td>
</tr>
<tr>
<td>5 - 20</td>
<td>12.4 mm (0-peak)</td>
<td>5 - 18</td>
<td>11.5mm (0-peak)</td>
</tr>
<tr>
<td>20 - 70</td>
<td>20 g</td>
<td>18 - 70</td>
<td>15 g</td>
</tr>
<tr>
<td>70 - 100</td>
<td>15 g</td>
<td>70 - 100</td>
<td>8 g</td>
</tr>
<tr>
<td>Sweep rate</td>
<td></td>
<td>Sweep rate</td>
<td></td>
</tr>
<tr>
<td>PFM</td>
<td>4 octave / min</td>
<td>PFM</td>
<td>4 octave / min</td>
</tr>
<tr>
<td>QM</td>
<td>2 octave / min</td>
<td>QM</td>
<td>2 octave / min</td>
</tr>
</tbody>
</table>

Documents / report shall be submitted at the time of quotation, demonstrating that unit will meet the above sine level.
8.9.2 Random vibration
The random vibration test shall be conducted for QM / PFM and all FM units. The unit shall be in non-operative condition.

(a) For QM/PFM units:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>PSD (g²/Hz)</th>
<th>Normal to mounting plane</th>
<th>Parallel to mounting plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-100</td>
<td></td>
<td>+3dB / oct</td>
<td>+3dB / oct</td>
</tr>
<tr>
<td>100-700</td>
<td></td>
<td>0.33 g² / Hz</td>
<td>0.1 g² / Hz</td>
</tr>
<tr>
<td>700-2000</td>
<td></td>
<td>-6 dB / oct</td>
<td>-3 dB / oct</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>19.1 grms.</td>
<td>11.8 grms.</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
<td>1 min (PFM)</td>
<td>1 min (PFM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 min (QM)</td>
<td>2 min (QM)</td>
</tr>
</tbody>
</table>

(b) For FM units:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>PSD (g²/Hz)</th>
<th>Normal to mounting plane</th>
<th>Parallel to mounting plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-100</td>
<td></td>
<td>+3 dB/octave</td>
<td>+3 dB/octave</td>
</tr>
<tr>
<td>100-700</td>
<td></td>
<td>0.15</td>
<td>0.044</td>
</tr>
<tr>
<td>700-2000</td>
<td></td>
<td>-6 dB/octave</td>
<td>-3 dB/octave</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>12.7 g</td>
<td>7.9 g</td>
</tr>
<tr>
<td>Duration</td>
<td></td>
<td>60 sec.</td>
<td>60 sec.</td>
</tr>
</tbody>
</table>

8.10 MECHANICAL SHOCK TEST:
Vendor shall provide qualification data of design similarity showing that mechanical shock test conducted on similar units and it has successfully survived the levels mentioned below.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Normal to mounting plane</th>
<th>Parallel to mounting plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 600</td>
<td>15 dB / octave</td>
<td>15 dB / octave</td>
</tr>
<tr>
<td>600 - 5000</td>
<td>700g</td>
<td>400g</td>
</tr>
<tr>
<td>5000 - 10000</td>
<td>-6 dB / octave</td>
<td>-6 dB / octave</td>
</tr>
</tbody>
</table>

No. of shocks: 2 pulse per axis

8.11 Corona check test
The unit shall be designed to be free from corona or arc discharge. The corona cycling shall be carried under no RF drive condition, as shown in Table below, TVAC chamber will be pumped down from ambient to vacuum within 15 minutes,
thus passing the critical pressure region. The reverse process is done at the end of TVAC with a transition from vacuum to ambient pressure, again passing through the critical pressure region within 15 minutes.

<table>
<thead>
<tr>
<th>Table – 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressure (in torr)</strong></td>
</tr>
<tr>
<td>a.</td>
</tr>
<tr>
<td>b.</td>
</tr>
</tbody>
</table>

8.12 Thermo Vacuum Test:
Thermo vacuum test shall be carried out on the final assembled configuration as specified, consisting all the elements like TWT, EPC & Linearizer.

8.12.1 Thermal vacuum cycling
Thermo vacuum testing shall be conducted on all units under vacuum conditions of $10^{-6}$ torr or better. The number of cycles shall be five minimum. The first cycle shall include stabilization at the Cold & Hot Turn-on temperature. All the remaining cycles shall include stabilization at the extreme Cold and Hot operating temperatures. The PFM unit shall be subjected to Qualification level testing and the FM units shall be tested at acceptance level.

Measurements during cycles may be limited to monitoring of important parameters for all units. Measurements for all specified parameters shall be carried out in the first and last cycle of operating temperatures as shown in Annexure-1. The Thermo vacuum test profile is shown in Figure – 2.

**Figure-2 : Thermo vacuum test profile**
Test temp. for PFM unit:

<table>
<thead>
<tr>
<th></th>
<th>CNO</th>
<th>CS</th>
<th>CO</th>
<th>HO</th>
<th>HNO</th>
<th>HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWT</td>
<td>-35°C</td>
<td>-35°C</td>
<td>-15°C</td>
<td>+85°C</td>
<td>+85°C</td>
<td>+85°C</td>
</tr>
<tr>
<td>EPC</td>
<td>-35°C</td>
<td>-35°C</td>
<td>-20°C</td>
<td>+65°C</td>
<td>+85°C</td>
<td>+65°C</td>
</tr>
</tbody>
</table>

Test temp. for FM unit:

<table>
<thead>
<tr>
<th></th>
<th>CNO</th>
<th>CS</th>
<th>CO</th>
<th>HO</th>
<th>HNO</th>
<th>HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWT</td>
<td>-30°C</td>
<td>-30°C</td>
<td>-10°C</td>
<td>+80°C</td>
<td>+80°C</td>
<td>+80°C</td>
</tr>
<tr>
<td>EPC</td>
<td>-30°C</td>
<td>-30°C</td>
<td>-15°C</td>
<td>+60°C</td>
<td>+80°C</td>
<td>+60°C</td>
</tr>
</tbody>
</table>

8.12.2 ON/OFF Cycling

For units that undergo PFM Level Testing, manufacturer shall also conduct 200 RF ON/OFF cycles test (100 ON/OFF cycles, at both extreme temperature extremes).

8.12.3 Multipactor

The manufacturer shall provide results of Multipactor analysis as well as results of any previous tests carried as a part of previous Qualification, demonstrating a 6 dB margin over operating power level.

8.13 EMI / EMC

EMI / EMC test including RE, RS, CE & CS tests shall be conducted on PFM unit and in-band RE (Sniff) and RS (Spray) test shall be performed on all FM units.

This test shall be conducted as per and to meet the requirements as specified MIL-STD-461E with the exceptions as mentioned below:

- CE102 test on power lines. Positive and Return lines
  - 10 KHz to 10 MHz
- CS101 test on power lines. Ripple of:
  - 30 Hz to 100 KHz: 3V pk-pk,
  - 100KHz to 400 MHz: 1Vpk-pk or 1W
- CS06 Transient on Power lines as per MIL-STD 461C: Vpeak = 100% of the DC supply voltage, pulse width t=10 micro sec ± 20 %
- RE as per MIL-STD-461E, in band emission up to 100 dB µV/m at carrier frequency. For lower than 100MHz and carrier harmonics: < 85 dBµV/m and all other frequencies: < 45dBµV/m.
- RS as per MIL-461-E subjected to 10V/m radiated field. Test shall be conducted at LTWTA level.
- In band RE (Sniff) and RS (Spray) testing shall be performed on all FM units.
8.14 Final functional tests
The final functional test shall be conducted for both PFM as well as all FM units. Parameters as shown in Annexure-1 shall be measured.

8.15 Final visual inspection
Visual inspection shall be carried out to confirm that there is no degradation after FM/PFM level testing on the assembly. This test shall be carried out as per para 8.4.

9.0 MAXIMUM ALLOWABLE TOLERANCE IN TEST CONDITIONS

Table–10: Maximum Allowable Tolerance in Test Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>±1°C Amb. Pressure \n±3°C under vacuum</td>
</tr>
<tr>
<td>Atmospheric Pressure</td>
<td>±5% \n±50%</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>±5%</td>
</tr>
<tr>
<td>Acceleration</td>
<td>±10%</td>
</tr>
<tr>
<td>Sine Vibration Amplitude</td>
<td>±10% \n± 2% above 25 Hz &amp; \n0.5 Hz below 25 Hz \n5% \n± 1%</td>
</tr>
<tr>
<td>Random Vibration Power Spectral Density</td>
<td>± 1.5 dB for 20-300 Hz &amp; \n±3 dB for 300-2000 Hz \n±10% \n+ 10% / - 0%</td>
</tr>
<tr>
<td>Shock Response Spectrum Test Amplitude</td>
<td>-3dB / +6dB</td>
</tr>
</tbody>
</table>

Note: The instrument shall be capable of measuring at least 10 times better than tolerance limit.

10.0 MEASUREMENT ACCURACY
The accuracy, calibration etc., of the test instruments shall be verified and the factors shall be stated in the test plan and procedures submitted by the vendor.

11.0 TEMPERATURE STABILIZATION
Temperature stabilization shall be considered reached when all the temperature readings are within ± 1 °C (± 3 °C for thermo-vac test) of the specified temperature for at least three consecutive readings taken at fifteen minutes intervals.

12.0 NON-CONFORMANCE CONTROL
The vendor shall follow an effective non-conformance procedure for preventing any non-conforming items to be used in the deliverable units. In case of failure during any stage of optimization and testing, the same shall be reported to SAC, along with cause of failure and necessary modification in the
design/fabrication required to overcome the problem shall be identified, the rejection criteria being deviations from the specifications mentioned in Sec. 2.

13.0 CONFIGURATION CHANGE CONTROL
The manufacturer shall follow an effective configuration change control procedure during the design and fabrication of units.

14.0 LIST OF DOCUMENTS TO BE SUPPLIED

(a) The following documents shall be provided.
   - Space History, Space Program, Qualification status details etc.
   - List of important parts proposed to be used for this program. Quality level of the parts proposed to be used for flight model units.
   - Qualification Report of previously qualified designs.
   - Reliability Analysis Summary.
   - Configuration change control plan.
   - Tests Details, wherever specified.

(b) Apart from above the documents / reports as given below, but not limited to, shall be supplied later after the award of contract. These have to be full reports (not the summary reports) :
   - List of parts, materials, their quality levels, derating, criterion followed, traceability data, purchase history etc. in PAD sheets
   - Failure reports (for catastrophic failures), mechanical or handling failures, malfunctioning or operative deviations from the specifications along with corrective actions.
   - Failure Mode, Effect & Criticality Analysis (FMECA) report.
   - Worst case analysis.
   - Radiation design margin analysis
   - Non-conformance parts and material test reports.
   - Documents containing test procedures, test and calibration facilities, environmental facilities and relevant operation details, as supplied in previous program.

(c) Complete QM/PFM and all FM units test data reports and list of approved drawings
   (soft copies – in CD)
### PARAMETER TEST MATRIX FOR LTWTA

<table>
<thead>
<tr>
<th>SR NO.</th>
<th>PARAMETERS</th>
<th>BURN-IN</th>
<th>IFT</th>
<th>THERMAL TEST</th>
<th>VIBRATION</th>
<th>POST VIBRATION</th>
<th>CORONA</th>
<th>THERMO VAC</th>
<th>FINAL FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saturated RF output</td>
<td>Fo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>RF input-output transfer data Curve (s. s. to 3 dB over drive) Gs, Gls, Psat, Compression, All Telemetries, Tele-command, DC input current, input power</td>
<td>Flhc</td>
<td>Flhc</td>
<td>Fo (No I/o)</td>
<td>Flhc</td>
<td>Flhc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DC input current, input power, Efficiency, Telemetries</td>
<td>Fo</td>
<td>Flhc</td>
<td>Flhc</td>
<td>Fo (DC)</td>
<td>Flhc</td>
<td>Flhc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Camp power supply, Voltage, Current</td>
<td>Yes</td>
<td>CFD</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>TM-helix current, Anode voltage (Warm up, no drive, sat. s.s.)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Off state current,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>pre heating time, inrush current.</td>
<td>Yes</td>
<td>CFD for Hot</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Gain response, gain slope, Gain ripple. (Saturation &amp; S.S.)</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Output power stability with time &amp; temperature.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Output Phase v/s input RF drive, AM-PM Conversion data curves. (s. s. to 3 dB over drive)</td>
<td>Flhc</td>
<td>Flhc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>IMD 3rd order</td>
<td>Flhc</td>
<td>Flhc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>AM-PM transfer</td>
<td>Flhc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flhc</td>
</tr>
<tr>
<td>13</td>
<td>Over drive ( in TV, hot, 30min) PFM only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes (Hot)</td>
<td>Yes</td>
</tr>
<tr>
<td>14</td>
<td>Harmonic</td>
<td>CFD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Non harmonic Spurious</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Spurious Phase Modulation, PFM only</td>
<td>Fo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fo</td>
</tr>
<tr>
<td>17</td>
<td>TDMA, PFM only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fo</td>
</tr>
<tr>
<td>18</td>
<td>Noise figure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>RF emission in-band (Also done at TWT level)</td>
<td>Fo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fo</td>
</tr>
<tr>
<td>20</td>
<td>Noise power density at no drive. ( out of band ), PFM only</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Group delay</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Insertion Loss, PFM only</td>
<td>CFD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>VSWR Input / output</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Stability : PFM only a) Under Open &amp; Short at input and output ports under no drive. b) 2.5 VSWR at full drive</td>
<td>CFD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Input Under voltage Protection</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CFD for hot</td>
</tr>
<tr>
<td>SR NO.</td>
<td>PARAMETERS</td>
<td>BURN-IN</td>
<td>IFT</td>
<td>THERMAL TEST</td>
<td>VIBRATION</td>
<td>POST VIBRATION</td>
<td>CORONA</td>
<td>THERMO VAC</td>
<td>FINAL FUNCTION</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------</td>
<td>---------</td>
<td>-----</td>
<td>--------------</td>
<td>-----------</td>
<td>----------------</td>
<td>--------</td>
<td>------------</td>
<td>----------------</td>
</tr>
<tr>
<td>26</td>
<td>Input Over voltage protection</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>27</td>
<td>Complete EMI / EMC (PFM only)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>28</td>
<td>Radiated Susceptibility only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>29</td>
<td>Radiated Emission only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>30</td>
<td>ON-OFF cycling; PFM only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>31</td>
<td>Mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>32</td>
<td>Mechanical Dimension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Fo = Overall center of frequency band;**  
**Flhc= Low, High, Centers of respective frequency bands, CFD = Carry forward data**  
*Wherever PFM is indicated, measurement is to be done on PFM unit only. In all other cases, measurements apply to all PFM/FM units.*
### Annexure-2

### Preferable format of Vibration & SRS test report

<table>
<thead>
<tr>
<th>Company Logo</th>
<th>Name &amp; Address of Company/industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>REPORT No.</td>
<td>DATE</td>
</tr>
</tbody>
</table>

#### STANDARD FORMAT OF VIBRATION & SRS TEST REPORT FOR ISRO-SAC UNIT

- **ISRO Specification Number**
- **Subsystem**
- **Sub Assembly details**
- **Customer Part No.**
- **Model No.**
- **Serial No.**
- **Model**
- **Weight**
- **Test start date & Test End date**
- **Drawing No. and T & E clearance certificate no with date**
- **Vibration Test Equipment & calibration details**

---

Sample of Photos showing test set-up of Subsystem with control & measurement accelerometer location with Axis definition.

**Fixture Characterization in LLS**

- Parallel to mounting plane
- Normal to mounting plane
Subsystem during Vibration test in each Axis

Parallel to mounting plane  Normal to mounting plane

Test Description:

1. Vibration Test Set-up:
1.1 Fixture details [size, Material, No of mounting fasteners & torque details to shaker]
1.2 Mounting Torque: Fixture to subsystem: Size & No. of Fastener
1.3 Torque Wrench Calibration details
1.4 Accelerometer details with calibration
1.4. Axis Definition with photo graph/sketch [Parallel to Mounting Plane, Perpendicular to Mounting Plane]

2. TEST SPECIFICATIONS:

2.1 Resonance Test [LLS]

<table>
<thead>
<tr>
<th>Axis</th>
<th>(Frequency-Hz)</th>
<th>Amplitude</th>
<th>Sweep Rate Oct/Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y &amp; Z</td>
<td>10 to 2000 Hz</td>
<td>0.5 g</td>
<td>2</td>
</tr>
</tbody>
</table>

2.2 Sample of Sine & Random Test Levels:

<table>
<thead>
<tr>
<th>Axis</th>
<th>SINE TEST (Frequency-Hz)</th>
<th>Amplitude</th>
<th>Sweep Rate Oct/Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Axis</th>
<th>RANDOM TEST (Frequency-Hz)</th>
<th>PSD (g²/Hz)</th>
<th>OVERALL g.r.m.s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X &amp; Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.3 Sample of SRS Test Levels:

<table>
<thead>
<tr>
<th>Axis</th>
<th>SRS TEST (Frequency-Hz)</th>
<th>Amplitude</th>
<th>No. of Pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td>X,Y,Z</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Response of Random/SRS & Resonance search tests: Frequency (Hz) / Amplitude (g):

<table>
<thead>
<tr>
<th>Axis</th>
<th>Measurement Accelerometer Ch. No</th>
<th>Measurement Accelerometer location</th>
<th>Pre-Sine/SRS Resonance Hz/g</th>
<th>Post-Sine Resonance Hz/g</th>
<th>Random response gms</th>
<th>Post Random/SRS Resonance Hz/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. TEST SEQUENCE: For Vibration testing of QM

```
QM 1. [LLS-SINE-LLS-FUNCTION-TEST-LLS-RANDOM-LLS] in X, Y, Z Axis
PFM 2 [LLS-SINE-LLS-RANDOM-LLS] in X, Y, Z Axis
FM 3 [LLS-RANDOM-LLS] in X, Y, Z Axis
```

For SRS testing of QM [LLS-SRS-LLS] in X, Y, Z Axis

5. PASS/FAILURE CRITERIA:

- **Pass Criteria**
  - Full functionality and structural integrity of subsystem following vibration testing as verified by visual inspection during and after test.
  - Structural integrity is defined as no loose components (bolts backing out), cracking of structure, excessive buckling, or excessive displacements. Functionality is defined as full electrical and mechanical characteristics.
  - First natural frequency greater than 100 Hz
  - “Before” and “After” Sine Survey Sweeps match each other within 10% of frequency & 20% of Amplitude.

6. OBSERVATION/ ANALYSIS:

- Natural frequency of the package in each Axis above 120Hz.
- No apparent structural damage observed after & during vibration test. Pre & Post resonance signatures are matching within acceptable criteria.
- No loosening or damage found during or after Vibration test.
- Annexure should be attached for vibration test plots.

7. CONCLUSION

Sub-system withstood the specified severities of vibration / SRS tests successfully and hence, cleared for further activities.

Test carried out by

Test surveillance by
ADDITIONAL INFORMATION
In addition to the details required in Exhibits–B and Exhibit–C the vendor shall provide following details in his proposal:

a) Design approach including circuit configuration of EPC, TWT, and Linearizer.
b) Details about the input / output characteristics of LTWTAs.
c) Assessment of the loop stability for 15 year operating life in space.
d) Protection circuit configuration and its functioning under fault conditions.
e) details on HV Potting and procedures followed
f) The telecommand / telemetry circuit and interface details.
g) List of non-standard components proposed to be used.
h) Quality levels of parts for EM & FM.
i) Names of the vendors for important components.
j) The reliability figures and flight history for similar hardware supplied to any space mission.
k) Details of the line certification programme followed for fabrication.
l) Thermal design and maximum junction / channel temperatures of devices.
m) The dissipation on TWT / EPC / LTWTA during RF-OFF and RF-ON conditions.
n) Vendor may seek any clarification or may point out any error or omission in the proposal, so that requirement is met correctly and adequately.
QUANTITIES, SCHEDULE AND WARRANTY

1.0 QUANTITIES
The vendor shall quote in slab quantities for LTWTA units as mentioned below.

The requirement is primarily for Flight hardware; however one unit will go through Proto-Flight tests as discussed under Qualification and Test Philosophy.

<table>
<thead>
<tr>
<th>Slab Quantities</th>
<th>For Band-1 and Band-2 units</th>
<th>For Band-3 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 - 30</td>
<td>6 - 10</td>
<td></td>
</tr>
<tr>
<td>31 - 50</td>
<td>11 - 20</td>
<td></td>
</tr>
<tr>
<td>51 - 70</td>
<td>21 - 30</td>
<td></td>
</tr>
<tr>
<td>71 - 90</td>
<td>31 - 40</td>
<td></td>
</tr>
<tr>
<td>91 - 120</td>
<td>41 - 60</td>
<td></td>
</tr>
<tr>
<td>121 - 150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>151 - 170</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each LTWTA should be delivered as an integrated functional unit consisting; EPC, Linearizer and TWT. All the necessary interconnection RF cable(s) and Harness(es) should be part of the unit. The length of the RF cable shall be decided at the appropriate time.

Vendor should supply:
- 10% extra quantity of RF cable-assemblies and Harnesses.
- Flight worthy mating D-type connectors with Crimpable pins
- D-type DC Connector savers
- Co-axial RF savers

The above (b), (c) & (d) shall be along with ‘each’ Unit and in addition to that, 20% spare quantities.

2.0 DELIVERY SCHEDULES:
Start of delivery: T₀ + 12 months
Delivery at the rate: 10 units per 15 days.

3.0 ADDITIONAL QUANTITY OPTION
As an option SAC/ISRO can place a purchase order for additional units within one year from the date of ordering the contract at the same rates.

4.0 REVIEWS / ACCEPTANCE TESTS
The following review / Acceptance tests shall be held at the site of vendor at an appropriate time.
- Critical Design Review
b) Acceptance witness testing for qualification level testing on Proto Flight model

c) Acceptance witness testing / Pre-shipment Review on PFM / FM UNITs

5.0 **WARRANTY**

The vendor shall provide Warranty as given below:

“The units supplied here upon shall be free from any defects in material or workmanship and in accordance with the applicable specifications and drawings”.

This warranty shall run for a period of **Four** years from the date of final acceptance by SAC/ISRO at SAC premises. This warranty shall continue to be valid for corrected or replaced units until four years after the date of final acceptance.
POWER AND EFFICIENCY DATA

Worst case minimum output power at BOL = ____________
Ageing & Radiation = ____________
Temp variation = ____________
Frequency Variation = ____________
BOL power output at room temp. & Fo = ____________

Table – 4.24.1

<table>
<thead>
<tr>
<th></th>
<th>TWT</th>
<th></th>
<th></th>
<th></th>
<th>EPC</th>
<th></th>
<th></th>
<th></th>
<th>LTWTA</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO</td>
<td>RF</td>
<td>SAT</td>
<td>OVER</td>
<td>3 dB</td>
<td>OBO</td>
<td>NO</td>
<td>RF</td>
<td>SAT</td>
<td>OVER</td>
<td>3 dB</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>SAT</td>
<td>OVER</td>
<td>3 dB</td>
<td>OBO</td>
<td></td>
<td>RF</td>
<td>SAT</td>
<td>OVER</td>
<td>3 dB</td>
<td>OBO</td>
</tr>
<tr>
<td></td>
<td>DC Input power</td>
<td>Dissipation</td>
<td>Efficiency</td>
<td></td>
<td></td>
<td>DC input power</td>
<td>Dissipation</td>
<td>Efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WORST CASE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Page 51 of 51