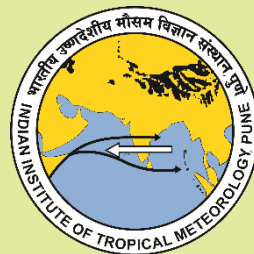
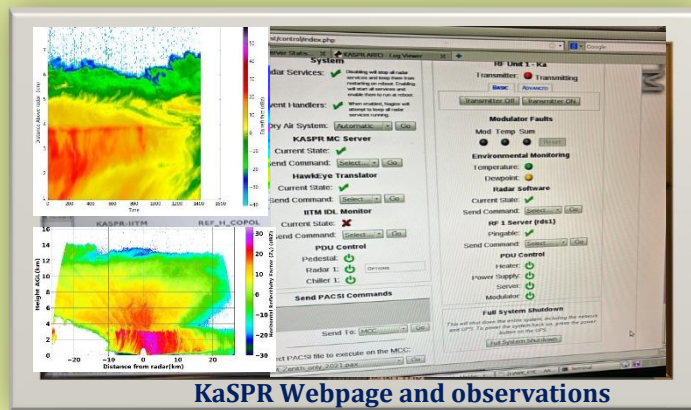


Indigenous Revival of PSM-EIKA Cloud Radar for Core Monsoon Zone Cloud Observations

Harikrishna Devisetty*, Yogesh Kolte, Abhijit Kumar, Navneet Ranjan, Muralikrishna UV, and Kalapureddy MCR*



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<http://www.tropmet.res.in/>

Technical Report

On

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DOCUMENT CONTROL SHEET
Ministry of Earth Sciences (MoES)
Indian Institute of Tropical Meteorology (IITM)

ESSO Document Number

ESSO/IITM/ART/TR/02(2026)/208

Title of the Report

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Type of Document

Technical Report

Number of pages and figures

20, 15

Keywords

Cloud Radar, Monsoon Core Zone, Klystron, Modulator, DC-DC Power Supply, Ka-band Radar

Security classification

Open

Distribution

Unrestricted

Date of Publication

April 2026

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ABSTRACT

In 2013, the Indian Institute of Tropical Meteorology deployed an EIK/Klystron tube-based 2.2 kW Ka-band Scanning Polarimetric Radar (KaSPR) (35.29 GHz, 8.5 mm wavelength) at Mandhardev (18.04°N, 73.86°E, ~1.3 km above MSL), a high-altitude location in the Western Ghats. The radar operates in three modes: Plan Position Indicator (PPI), Range Height Indicator (RHI), and Height Time Indicator (HTI), with a maximum range of ~26 km. KaSPR provides high-resolution vertical profiles (spatial: 25 m, temporal: 1 second) and highly sensitive measurements (-45 dBZ at 5 km), capabilities unmatched by solid-state radars.

To support cloud studies in the core monsoon zone of Central India, the KaSPR was relocated to ART-CI, Bhopal. However, for the past three years, it was non-operational due to a malfunction in the Power Supply Modulator (PSM) of the Extended Interaction Klystron Amplifier (EIKA). M/s. ProSensing, the original equipment manufacturer (OEM) and Supplier, confirmed that the PSM and EIKA parts are obsolete and irreparable. But the IITM Radar team tried for repairs with Indian organizations & Private companies. After the PSM was dismantled for troubleshooting, it was tested with the Control Monitoring Unit (CMU) at SAMEER, Mumbai, but the exact issues were not found. Further diagnostics at IITM, supported by Grow Controls Pvt. Ltd., revealed that a faulty isolated DC/DC converter (VIPJ622-IXX), which failed to supply -15V to the circuit. By bypassing the PSM logic and applying a -15V supply externally, the modulator was found to be operational, and all desirable outputs were provided to EIKA (such as Filament voltage, Cathode voltage, Focus beam voltage, and collector voltage). The PSM was reinstalled with radar and tested on August 10, 2024. Despite initial setbacks, all issues were resolved, and the KaSPR was fully restored to operation.

The data collected from KaSPR will provide critical insights into the microphysical and macrophysical properties of clouds during their formation and evolution over Central India, addressing a current research gap.

1. Introduction

The Ka-band Scanning Polarimetric Radar (KaSPR, 35.29 GHz), a high-sensitivity klystron-based cloud radar system, has been non-operational for the last three years due to a failure in the Power Supply Modulator (PSM) of the Extended Interaction Klystron Amplifier (EIKA). The OEM confirmed that the EIKA and PSM parts were obsolete and irreparable, posing a critical operational challenge. Under the Atmanirbhar Bharat initiative, the IITM Radar team successfully performed indigenous diagnosis and repair, identifying a faulty, isolated DC/DC converter (VIPJ622-IXX) as the cause of the failure of the -15V supply. By implementing an innovative bypass method and applying -15V externally using an AC-DC supply, the modulator output voltages were restored, and the radar returned to full operation on 10 August 2024. This restoration enables real-time monitoring and high-resolution observation of cloud evolution over the Core Monsoon Zone (CMZ) in Central India, strengthening national capability for monsoon research and cloud microphysics studies. The radar operated on different days (2024 & 2025) and uploaded data into IITM's Atmospheric Research Data Center (ARDC) for the scientific community.

The figures below (1.i-iv) present a photograph of the Ka-band radar and system-level block diagrams of the KaSPR, illustrating the overall architecture and interconnections of the major subsystems required for radar operation. The diagrams include the cooling and dry-air distribution layout, the logical network configuration, and the integrated electrical, power, and communication interconnections between the RF enclosure, pedestal, shelter equipment, and auxiliary components such as air dryer, compressor, chiller, UPS rack, and mission control computer. Together, these schematics provide a clear understanding of the radar infrastructure and support systems, and serve as essential reference material for troubleshooting, maintenance, and operational validation of the Ka-band radar system. Credit: M/s. ProSensing Inc., USA.



Figure 1. i. 1.2 m antenna cum RDS mount on Pedestal, 20 ft Container, and KaSPR on wheels photographs

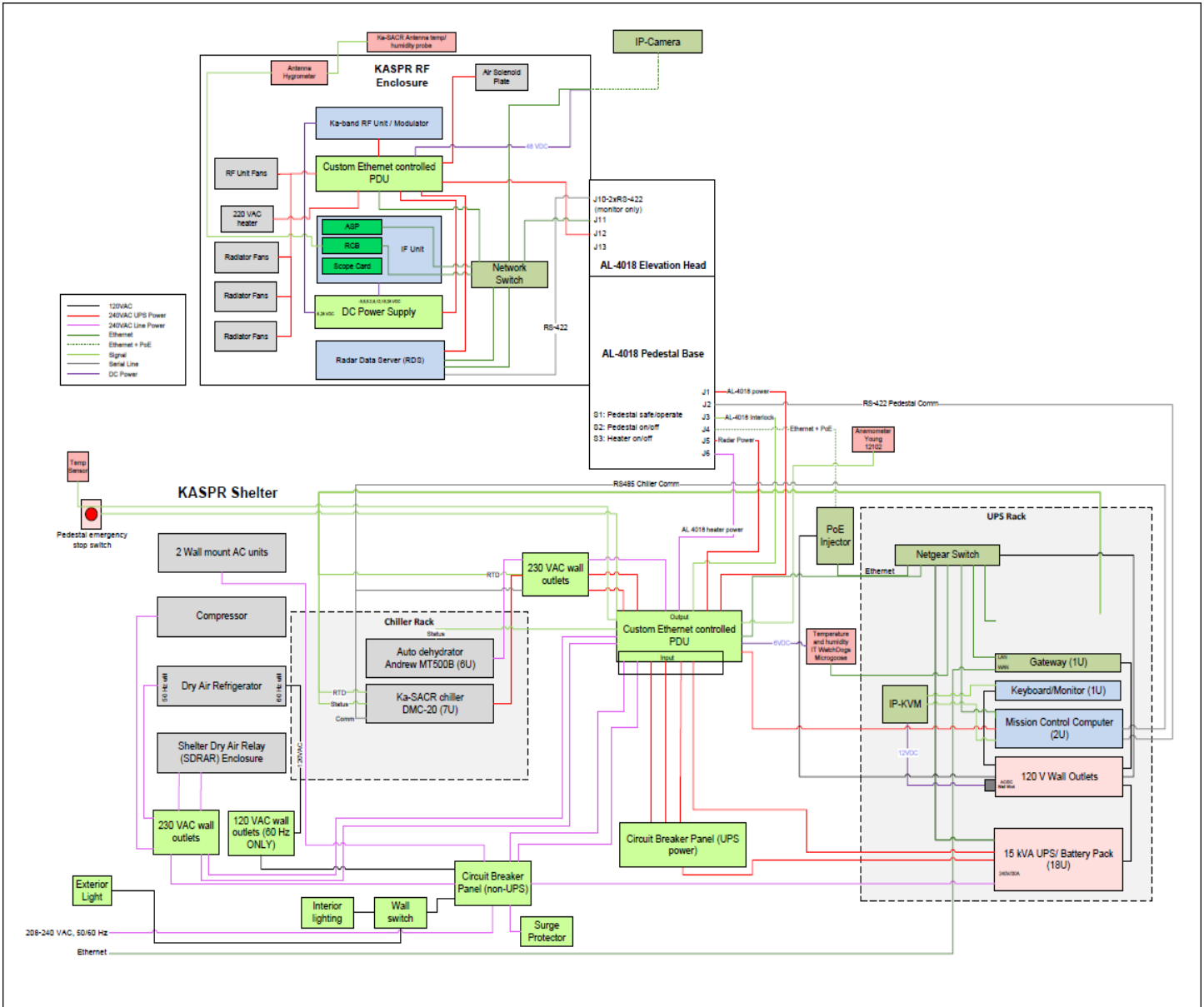


Figure 1. ii. System-level block diagram of KaSPR.

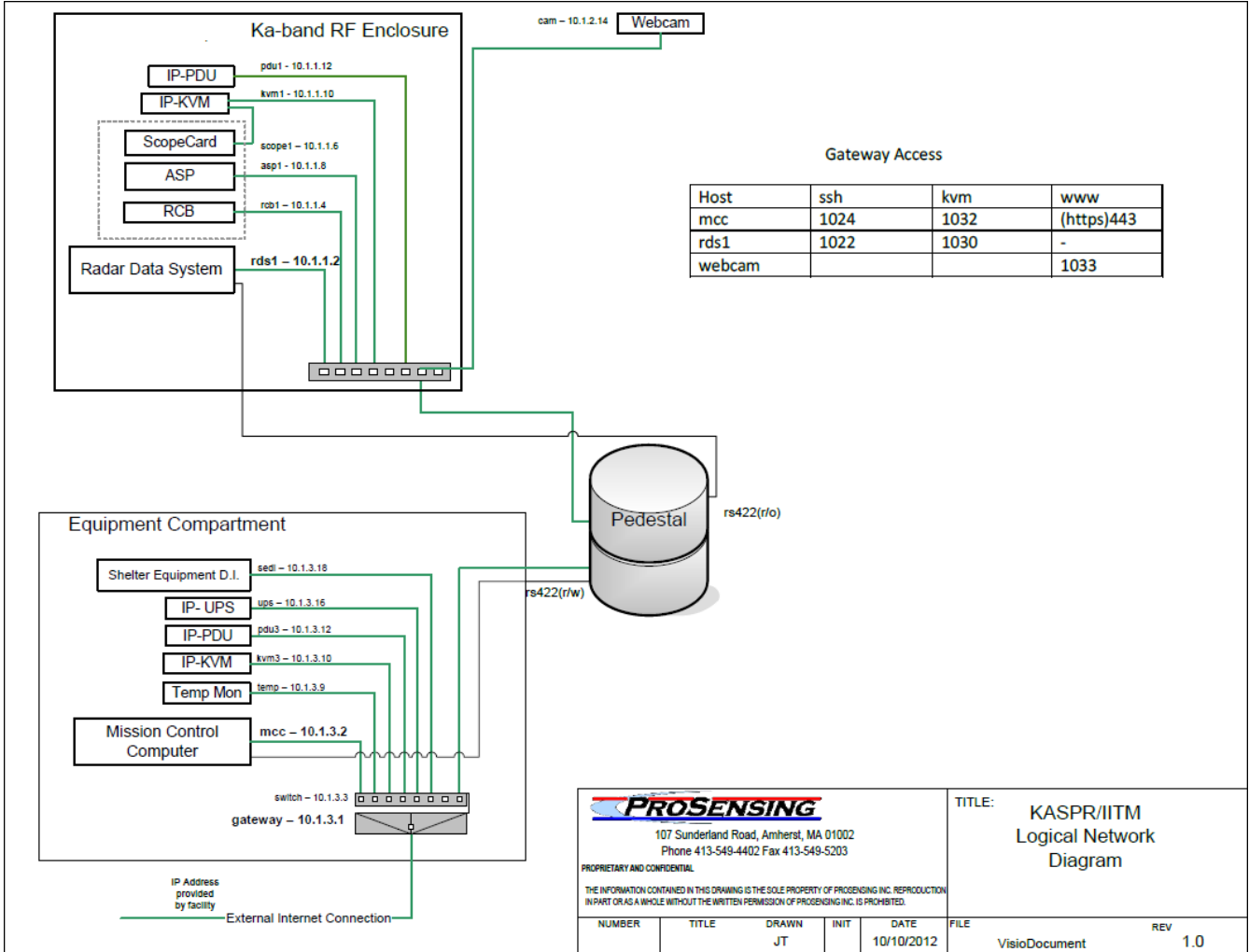


Figure 1. iii. KaSPR logical network diagram.

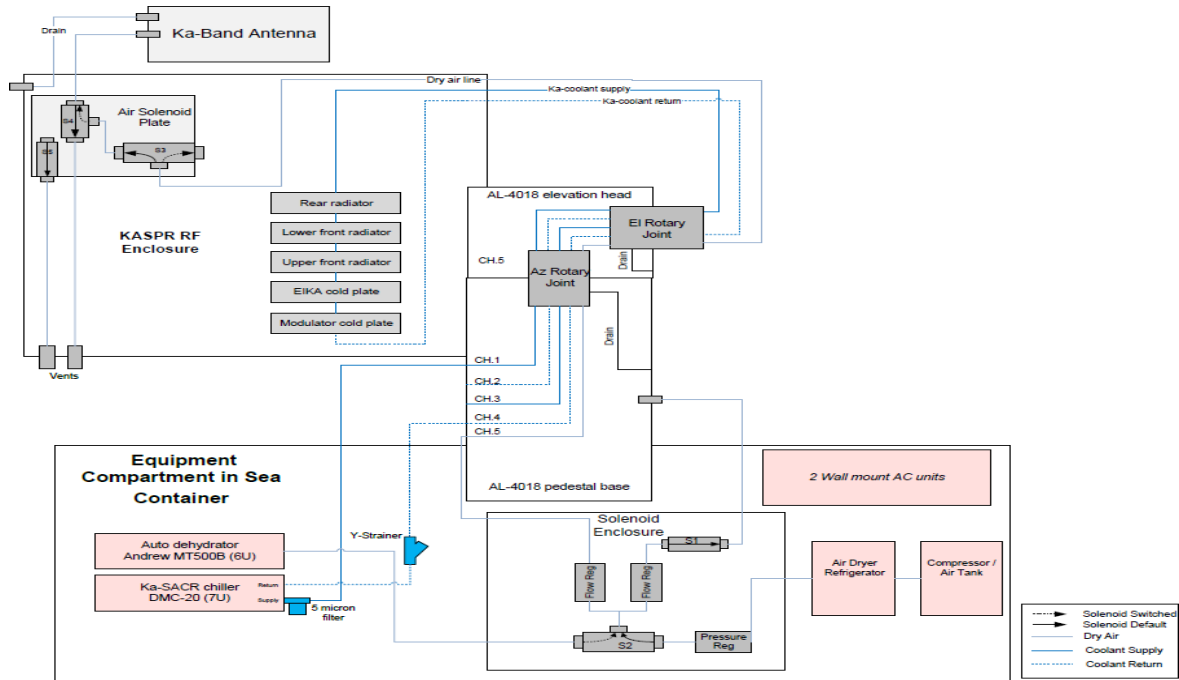


Figure 1. iv. KaSPR cooling/air-flow schematic.

2. Background and System Description

2.1 KaSPR Radar Overview

KaSPR is a klystron-based Ka-band (35.29 GHz; 8.5 mm wavelength) scanning polarimetric radar deployed by IITM in 2013. It provides highly sensitive, high-resolution measurements that are not achievable with many conventional solid-state radars.

Key Radar Specifications

Frequency: 35.29 GHz

Wavelength: 8.5 mm

Peak Power: 2.2 kW (klystron-based)

Maximum Range: ~26 km

Measurement Sensitivity: ~ -45 dBZ at 5 km

Modes of Operation: Plan Position Indicator (PPI), Range Height Indicator (RHI), Height Time Indicator (HTI / Zenith Mode)

Resolution: Spatial: 25 m

Temporal: 1 second

2.2 Scientific Need

To enhance cloud monitoring and monsoon process studies over the Core Monsoon Zone of Central India, KaSPR was relocated from Mandhardev (Western Ghats) to ART-CI, Bhopal. After relocation, the Ka-band radar is unable to transmit due to a modulator fault. We have taken up this issue to get the radar back into operation.

3. Problem Statement

3.1 Failure Summary

KaSPR became non-operational due to a malfunction in the Power Supply Modulator (PSM) of the Extended Interaction Klystron Amplifier (EIKA).

3.2 OEM Status on this problem

The OEM and supplier confirmed: PSM and EIKA parts are obsolete. Hardware is not repairable through the OEM route. The OEM is requested to send the entire system to the USA for diagnosing the problem and troubleshooting, which is not a feasible option economically. The IITM Radar Team tried with Indian organizations and private companies for resolve the issue indigenously with the online support from OEM.

4. Indigenous Troubleshooting Strategy (Atmanirbhar Approach)

4.1 Repair Attempts and Collaborative Diagnostics

The IITM Radar team initiated multi-stage diagnostics with Indian institutions and private industry support:

Step 1: External Facility Testing. The dismantled PSM was tested with the Control Monitoring Unit (CMU) at SAMEER, Mumbai.

Observation: The Issue could not be isolated precisely during CMU testing.

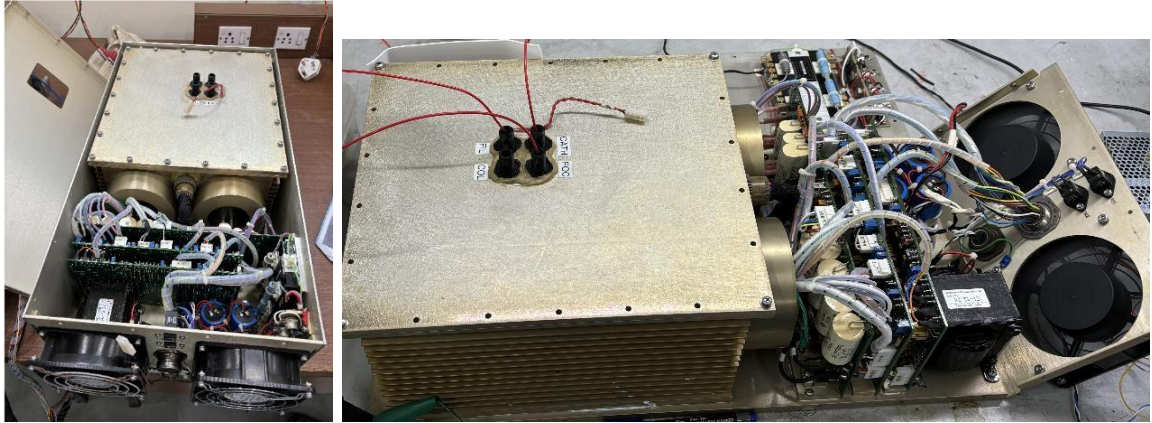


Figure 3. The PSM PCB & IC level testing at IITM, Pune, and M/s. Grow Controls Pvt. Ltd, Hyderabad.

5. Root Cause Identification

5.1 Fault Location

- The fault was traced to a failed isolated DC-DC converter: VIPJ622-1XX, as shown in Figure 4 below.

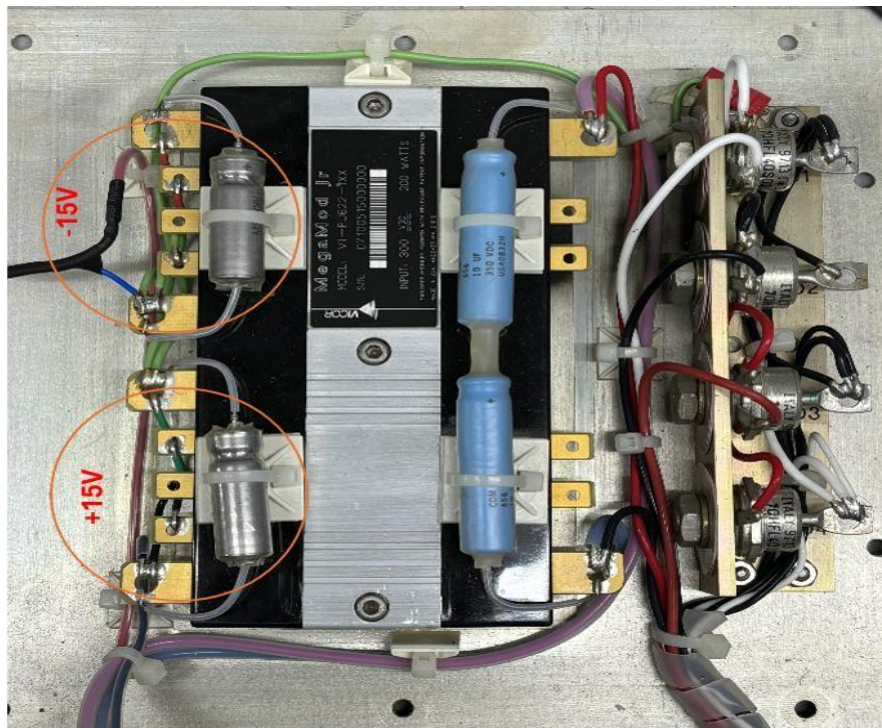


Figure 4. The Isolated DC-DC converter: VIPJ622-1XX (Circle marks indicate $\pm 15V$ supply outputs)

- The DC-DC converter will provide a $\pm 15V$ supply for other PSM power modules to activate the high-power system, which will generate voltages for Filament, Cathode, Focus beam, and Collector.
- Identified that the DC-DC converter is giving out only +15V supply and 0V supply instead of -15V supply; measured with Digital Multi-Meter (DMM) as shown in Figure 5 below.



Figure 5. Isolated DC-DC converter outputs testing with DMM. The positive output power supply shows +15V, and the Negative output power supply shows 0V as marked in circles.

- An isolated DC–DC converter is a power conversion device that converts one DC voltage to another while keeping the input and output electrically isolated. This separation (galvanic isolation) is commonly achieved using a high-frequency transformer, which improves safety and reduces the transfer of unwanted electrical noise between circuits. Such converters are widely used in systems where isolation is essential, including industrial automation, medical electronics, communication equipment, and sensitive instrumentation power supplies. A major benefit of isolated DC–DC converters is that they allow the power source and the load to operate independently, helping to minimize the impact of faults and improving overall system stability. Isolation also helps protect circuits from issues such as ground potential differences and ground loops, which can otherwise lead to unstable performance or equipment damage. With modern developments in semiconductor devices and control methods, these converters now offer higher efficiency, compact size, and greater power density, making them suitable for a broad range of advanced electronic and industrial applications.

5.2 Failure Impact

The converter failed to supply the -15V output required to enable modulator control and sequencing.

Due to this failure:

- PSM logic and gating controls were disrupted.
- EIKA did not receive the required operational voltages.

6. Repair Methodology and Restoration Process

6.1 Corrective Action (Indigenous Repair)

Since replacement part availability was limited, an indigenous workaround was implemented: the PSM logic path was bypassed, and -15V was applied externally using an AC-DC power supply, as shown in the Figure 6 below. This approach enabled validation of the system response and successful recovery of modulator outputs with a negative power supply of -14.96V.

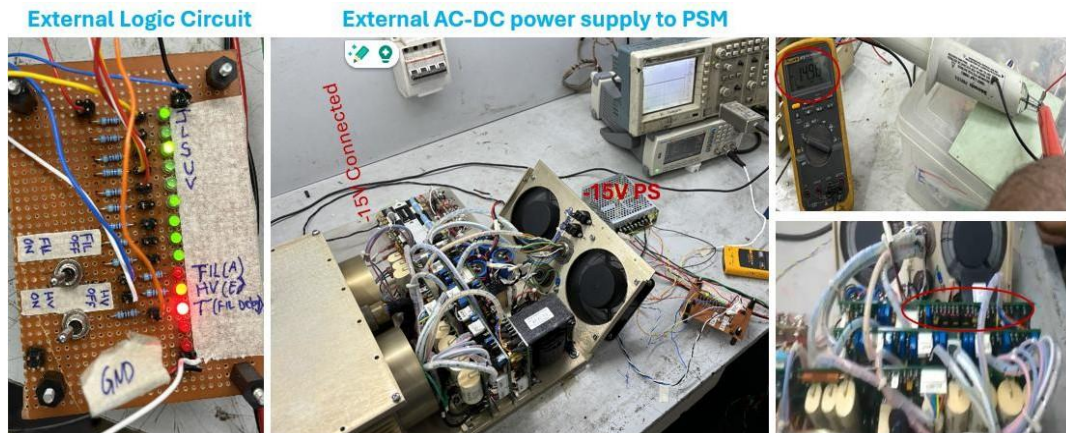


Figure 6. External powering and validation of the PSM logic circuitry using an external AC–DC supply (–15 V). The DMM verifies a stable –14.96 V input (top-right) and illuminated LEDs on the PSM PCB (bottom-right) confirm successful power delivery and logic activation.

6.2 Verification Outputs Achieved

After restoration, desirable outputs required for EIKA operation were confirmed, including

- Filament voltage,
- Cathode voltage,
- Focus beam voltage, and
- Collector voltage.
- Output performance matched expected operational characteristics.

The EIKA used in the KaSPR Ka-band radar requires multiple regulated high-voltage and auxiliary bias supplies from the PSM to ensure safe and stable RF operation. As per CPI (Canada) manufacturer specifications, the typical operating voltages include cathode voltage in the range of -12.5 to -21.0 kV (w.r.t. ground), heater voltage of -5.5 to -6.5 V (w.r.t. cathode), and a grid voltage of -3.0 to -3.5 kV (w.r.t. cathode) during OFF/blanking conditions. The cathode current (~ 750 mA) and body current (~ 40 mA) are also key indicators for ensuring proper beam formation and stable tube operation. These values serve as baseline reference limits during PSM health checks and transmitter validation. The CPI datasheet also provides absolute maximum ratings for safe operation of the EIKA system. Exceeding these limits may lead to catastrophic damage to the klystron. Critical limits include cathode voltage up to approximately -21 kV, collector voltage up to about -6 kV, and grid voltage around -3.5 kV (w.r.t. cathode). In addition, heater voltage must be maintained within safe bounds, and the system duty cycle and current rise/fall times must remain within specified values to prevent excessive thermal and electrical stress. Hence, during KaSPR revival, all modulator outputs were verified against CPI reference limits before reintegration with the radar transmitter chain.

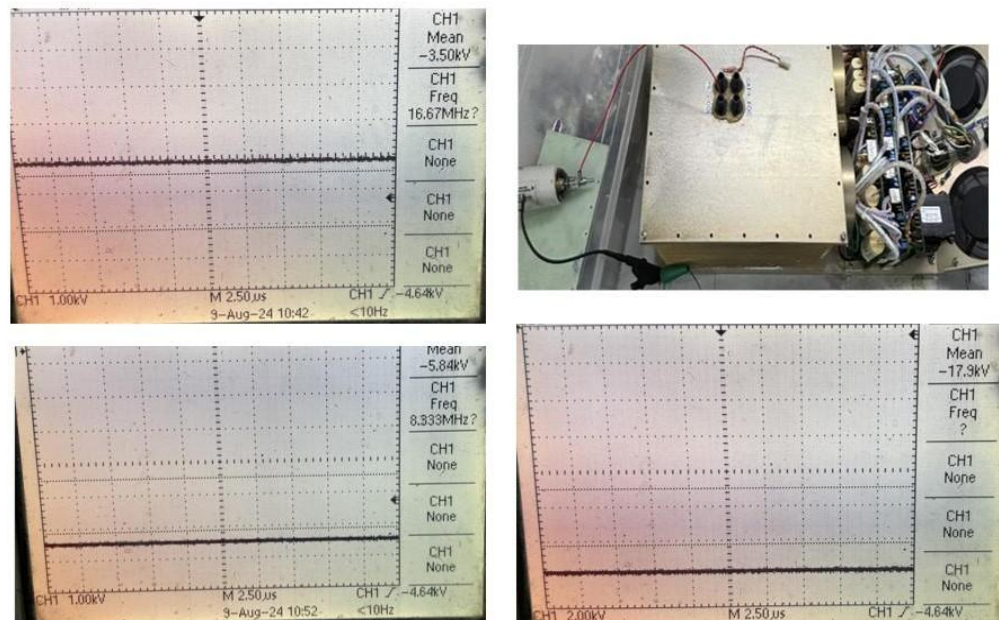


Figure 7. Measured PSM output voltages with an external DC power supply using an oscilloscope.

During indigenous troubleshooting and restoration at IITM, the PSM output voltages were checked using appropriate high-voltage probing and oscilloscope monitoring. The measured values were within expected operational levels, with grid voltage ~ -3.5 kV and collector voltage ~ -5.8 kV, indicating that the modulator was generating the correct bias. The cathode-related high-voltage output was also observed within the expected operational range during testing (e.g., ~ -17.9 kV in the recorded waveform), as shown in Figure 7 below, confirming that the restored PSM was capable of delivering the required voltages for EIKA operation, as given in Table 1. These measurements, consistent with CPI's typical operating values, helped validate that the transmitter power supply chain had returned to a safe and functional state suitable for KaSPR field deployment. The troubleshooting process is documented in the flowchart as shown in Figure 8 below.

Table 1: PSM output measured voltages compared with CPI's Typical and Absolute values

Parameter / Output	CPI Operating (Reference)	Typical Value	CPI Absolute Maximum Rating (Limit)	Measured during Testing IITM (Aug 2024)	Remarks
Cathode Voltage (w.r.t. ground)	-12.5 to -21.0 kV		-21 kV	Approx. -17.9 kV	Cathode HV generated; value close to operating region (ensure within safe envelope during operation).
Collector Voltage (w.r.t. ground)	Factory set (collector depression)		-6 kV	Approx. -5.84 kV	Within the absolute max rating, collector depression output is healthy.
Grid Voltage (OFF blanking) / (w.r.t cathode)	-3.0 to -3.5 kV		-3.5 kV	Approx. -3.50 kV	Matches CPI reference; confirms proper grid bias during blanking.

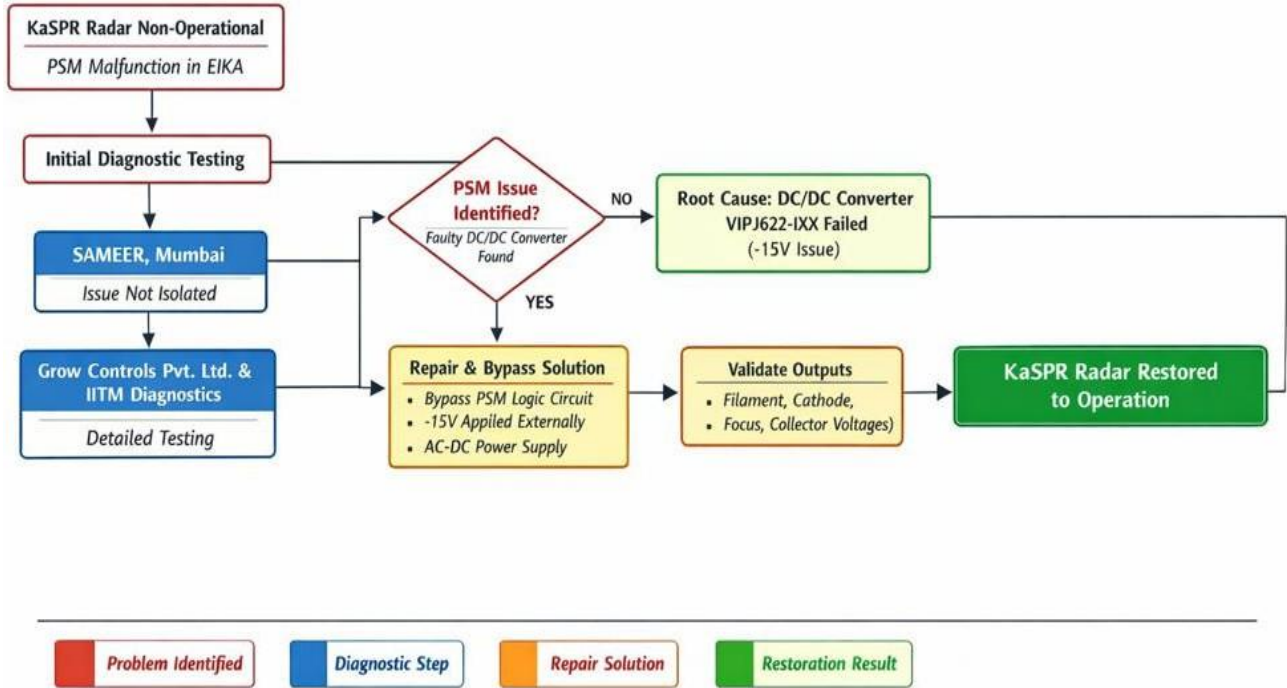


Figure 8. Flowchart: The revival process of KaSPR-Indigenously.

The indigenously troubleshooted PSM at M/s Grow Controls Pvt. Ltd, Hyderabad, with the IITM Team (Figure 9 shown below, photograph), packed and brought back to ART-CI, Silkheda, Bhopal, for further testing with KaSPR.



Figure 9. IITM with M/s. Grow Controls Pvt. Ltd team at a Hyderabad firm.

7. System Re-Integration and Field Testing

7.1 Reinstallation

Due to the prolonged non-operational condition of KaSPR, the dry-air pumping and humidity control inside the RF enclosure remained inactive for an extended period, resulting in moisture accumulation and visible water formation within the RF box, as shown in Figure 10 below. As an immediate preventive measure, the RF enclosure was opened, and all condensed water and humidity traces were carefully removed and thoroughly cleaned before applying electrical power, ensuring that no electronics or RF subsystems were exposed to the risk of short circuit. Following this safety cleanup, a systematic electrical health check was conducted to verify all power distribution and supply lines for PDU-1 (shelter power distribution) and PDU-2 (RF box power distribution). A spare 230V output from PDU-2 was used to connect an external AC–DC power supply (used to support modulator logic during troubleshooting), and all major subsystems, including RF electronics, antenna-related connections, dry air system components, and control modules, were inspected and validated step-by-step. After confirming stable power integrity and subsystem readiness, the repaired EIKA and PSM assembly was finally remounted into the KaSPR system, completing the physical restoration and preparing the radar for operational testing and revival. Figure 10 shows photographs documenting the condition of the KaSPR Ka-band radar RF enclosure and the restoration activities carried out during the revival. (a) KaSPR RF box showing installed RF modules and internal layout, (b) moisture/water accumulation inside the RF enclosure due to prolonged shutdown and stoppage of dry-air pumping, (c) RF and electronics sub-systems interface leading to the antenna section, (d) transmitter section highlighting the PSM and EIKA integration region, (e) standalone view of the Extended Interaction Klystron Amplifier (EIKA) unit, (f) PDU-1 power distribution unit in the shelter compartment, and (g) PDU-2 power distribution unit inside the RF enclosure used for subsystem power verification and connecting external AC–DC supply during troubleshooting.

The repaired PSM was reinstalled into KaSPR and integrated with the radar subsystems.

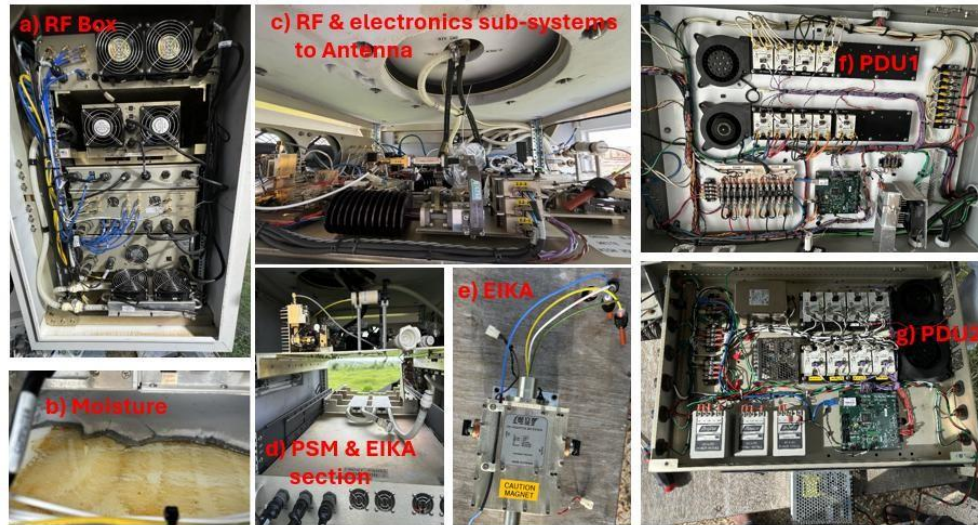


Figure 10. KaSPR Ka-band radar restoration overview showing RF box layout, moisture observed due to dry-air stoppage, RF-to-antenna subsystem connections, EIKA–PSM transmitter section, and power distribution verification using PDU-1 (shelter) and PDU-2 (RF box).

7.2 On-Site Testing

Field testing was conducted on 10th August 2024. Despite initial setbacks, System stability checks were passed; radar successfully returned to operational condition; Real-time zenith cloud echo observations were recorded.

- Following the reintegration of the KaSPR subsystems, the initial power-up attempts revealed multiple setbacks, primarily due to the PDU outlets not being enabled for critical loads such as the heater, RF power supply, computer/server, and modulator (as indicated in the PDU control/turn-ON sequence screen shown in Figure 11).

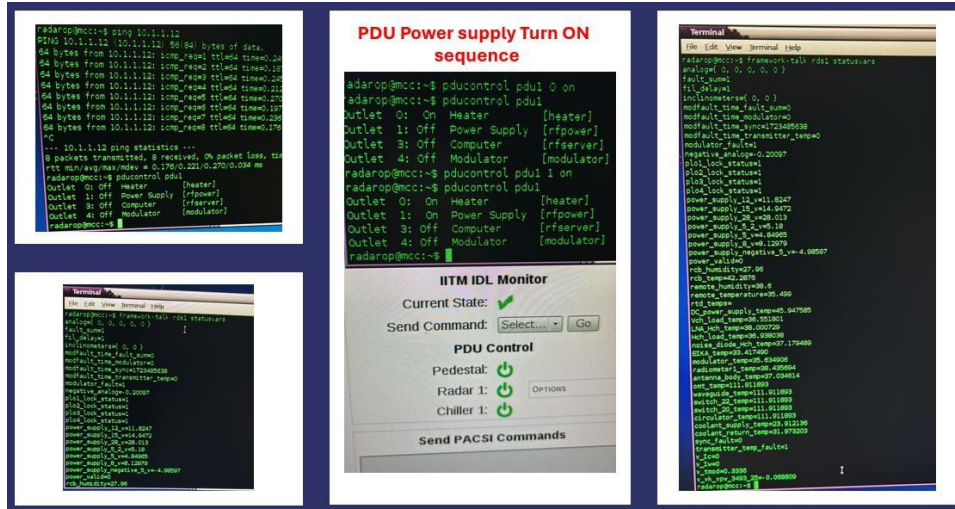


Figure 11. The attached screenshots show the PDU power supply turn-on sequence for enabling power to the heater, RF power, Computer, and Modulator.

- To resolve this, both PDU-1 (shelter) and PDU-2 (RF box) were systematically verified, and stable mains availability of ~230 V AC was confirmed during testing (Figure 12 showing multimeter and PDU testing). After successful power validation, the EIKA was remounted and connected using the four high-voltage probes (cathode, filament/heater, grid, and collector connections) as shown in the transmitter section images. During this stage, a DC centrifugal fan malfunction was also identified (fan shown in Figure 12) and rectified to ensure proper thermal management. Subsequently, a communication issue occurred due to faulty network cable/network switch connectivity, which was resolved by reconnecting and externally validating the network path to establish stable communication between the Master Control Computer (MCC), Radar Data Server (RDS) and RF enclosure modules (network cable indication Figure 12).

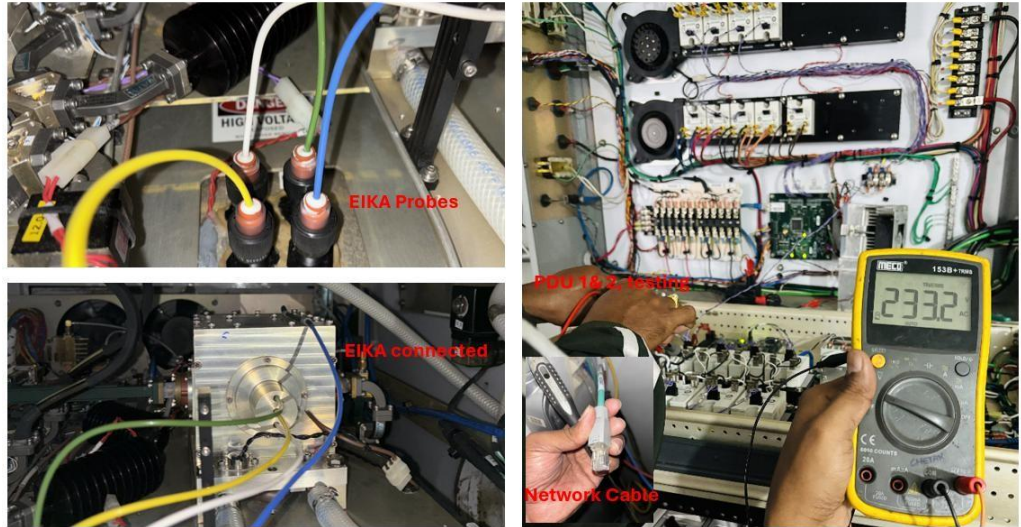


Figure 12. EIKA reintegration showing high-voltage probe connections (cathode, filament/heater, grid, and collector) and verification of transmitter section readiness before system power-up. Electrical validation of PDU-1 (shelter) and PDU-2 (RF box), including ~233.2 V AC supply verification, prior to enabling KaSPR subsystems. Network communication restoration between MCC–RDS and RF modules.

- With all hardware, power, cooling, and network links restored, the complete system was started up with online support from M/s ProSensing Inc., USA. Immediately after boot-up, the system displayed a FAULT SUM condition due to a dew point exceeding the permissible limit (web control interface figure). The team waited ~1–2 hours for the dry-air system to reduce humidity, after which the dew point returned to within limits, and the EIKA sequentially transitioned to Warm-up mode and then to the READY state for transmission (status screenshots shown in Figure 13).

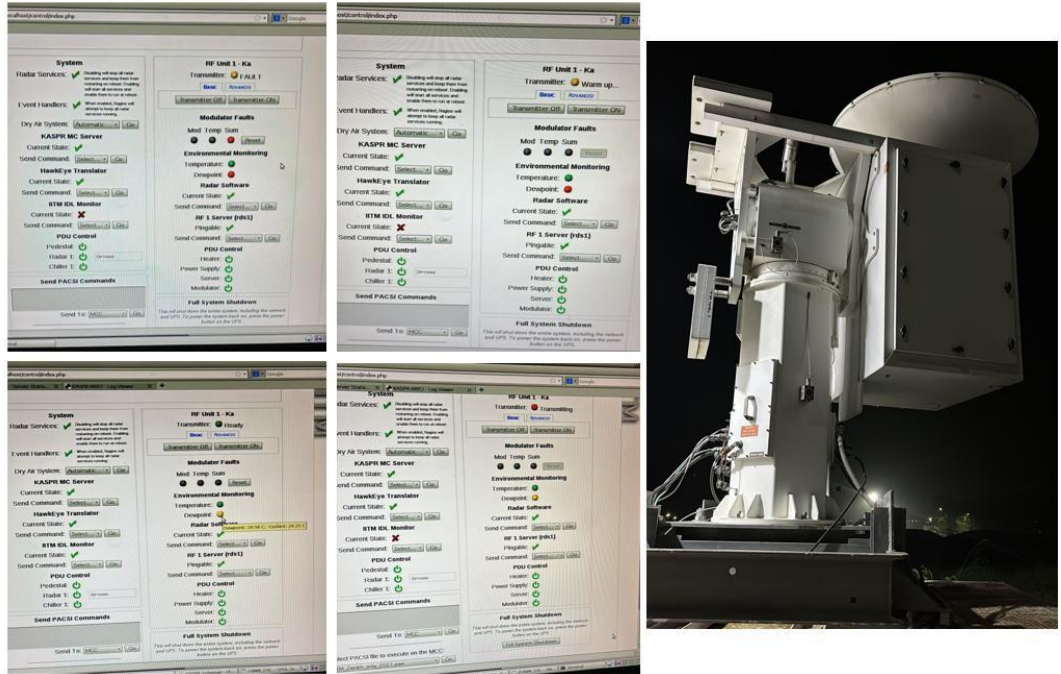


Figure 13. Dew point exceeded, triggering FAULT SUM, EIKA warm-up, and a READY state transition, confirming stable modulator outputs and transmitter readiness for radiation.

8. Results and Operational Outcome

8.1 Operational Status

KaSPR radar was successfully revived from a non-operational state to an operational state.

8.2 Observational Capability Restored

Finally, the transmitter was enabled, and successful radiation was confirmed as the first return signal appeared in the ScopeView display, with the zenith-pointing mode clearly showing cloud layers as shown in Figure 14, demonstrating the successful revival of KaSPR from a non-operational to fully operational state for ISM cloud research over Central India (ART-CI). The engineers from M/s ProSensing Inc., USA, appreciated the indigenous efforts of the IITM team in restoring the radar system to operational condition. Post-revival, radar is capable of High-resolution vertical profiling of clouds, Continuous monitoring in HTI (zenith) mode, scanning observations in PPI/RHI modes, and capturing cloud evolution and microphysical signatures during ISM conditions.

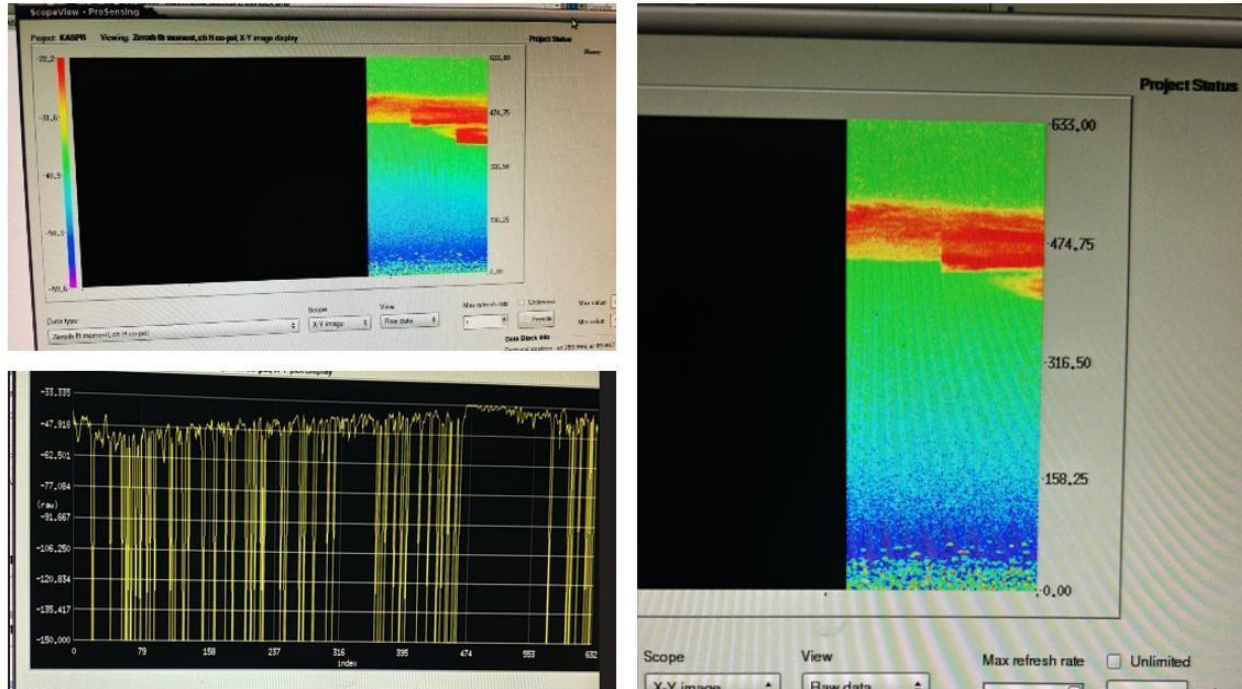


Figure 14. The screenshots show the ScopeView first-signal detection after revival and a Zenith-pointing mode (HTI) observation showing layered cloud echoes after the KaSPR system was brought back to transmitting condition, demonstrating operational cloud-monitoring capability.

8.3 National Benefit (Atmanirbhar Significance)

This work demonstrates: Indigenous repair capability for obsolete critical radar components, reduced dependence on foreign OEM support, Cost and time savings via in-house troubleshooting, and strengthened operational readiness for national monsoon research infrastructure.

9. Permanent Solution Plan and execution

The current restoration uses an ad hoc external -15V arrangement to enable the logic supply during testing. For long-term robust operation, the following is recommended and implemented by the IITM Radar Team:

- Replace faulty converter with a suitable chassis-compatible component: VIPJ622-IXX (DC-DC converter for $\pm 15V$ supply).
- Develop a permanent in-chassis regulated $\pm 15V$ supply module: Perform extended continuous operation testing under real field conditions.

- M/s Grow Controls Pvt. Ltd, Hyderabad, successfully developed the VIPJ622-IXX (DC/DC converter for $\pm 15V$ supply) indigenously under the support and guidance of IITM ART Radar Team. The top view and isometric view of the Indigenous developed DC-DC converter for the $\pm 15V$ supply VIPJ622-IXX as shown in Figure 15 below.

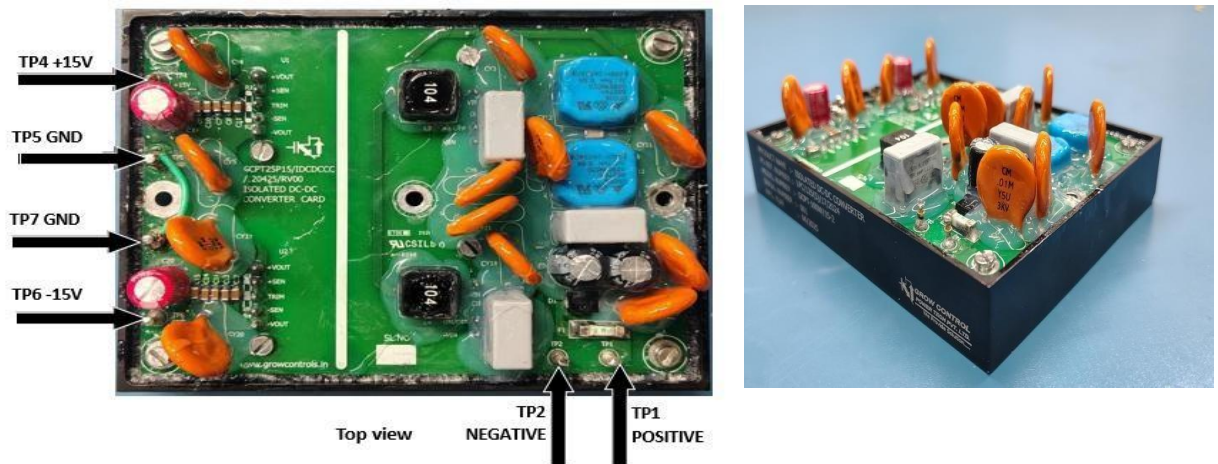


Figure 15. The top view and isometric view of the Indigenous developed DC-DC converter for the $\pm 15V$ supply VIPJ622-IXX.

- The indigenously developed Power module has been tested successfully and reinstalled in KaSPR, and it is working fine.

Conclusion

The Ka-band cloud radar (KaSPR), a critical high-sensitivity system for cloud microphysics research, was successfully revived using an indigenous troubleshooting and repair approach. The failure was identified at the DC-DC converter level, and the modulator was restored by providing an external supply and bypassing the failed sections during testing. The radar became operational on 10 August 2024 and is now enabling real-time cloud observations over Central India. This achievement directly supports the Atmanirbhar Bharat initiative by demonstrating national capacity to repair and restore obsolete high-value radar systems using local expertise and Indian industry collaboration.

ACKNOWLEDGEMENT

We sincerely express our heartfelt gratitude to the **Director, Indian Institute of Tropical Meteorology (IITM), Pune**, for the encouragement and support in the indigenous revival of IITM's Ka-band Scanning Polarimetric Cloud Radar (KaSPR).

We convey our gratitude to **Dr. G. Pandithurai, former Project Director, ART-CI**, and all members of the **Radar and Satellite Meteorology group** for their constant encouragement, motivation, and technical support throughout this work. We are especially thankful to the **Radar team at ART-CI, Bhopal**, for their continuous care and commitment right from radar relocation, site-level coordination, maintenance, troubleshooting, and operational testing. Their cooperation and assistance were crucial for successful system re-integration and field-level validation.

We also acknowledge the professional involvement of Industry **M/s Grow Controls Pvt. Ltd., Hyderabad**, whose expertise and timely assessment on Power Supply Modulator (PSM) cum EIKA testing contributed immensely to diagnostics and repair execution, particularly during troubleshooting of the PSM-EIKA and to the development of the required form-fit isolated DC-DC converter for the KaSPR PSM. We also acknowledge **M/s ProSensing Inc., USA**, for providing online support during the revival process, the KaSPR system documentation, reference block diagrams for system understanding, and reporting. We also acknowledge the support provided by **SAMEER, Mumbai**, for providing the Control Monitoring Unit for initial testing of PSM.

Further, we thank all individuals and teams involved, directly or indirectly, in this restoration, including the technical and engineering staff who assisted with testing, verification of output voltages, and the successful reinstallation of the recovered PSM with KaSPR assembly. With the collective support from all above, the KaSPR system was successfully revived from a non-operational to an operational state, and this work has strengthened our confidence and capability to independently handle radar operations, maintenance, and troubleshooting in a more effective and self-reliant manner.