PR No. YS/PD-IP/2021/318

A Project Proposal

On

UAV-Aided Weather Radar Calibration

In collaboration with

National Institute of Technology, Tiruchirapalli / SRM Institute of Science and Technology

April 2022

Group / Division Centre / Laboratory / Unit Name

UR Rao Satellite Centre

Indian Space Research Organisation

Department of Space

Proposal ID: YS/PD-IP/318

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|  | Name, Designation | Signature | Date |
| --- | --- | --- | --- |
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| Chairperson, JMC, S-TIC/ JPMC, RAC-S |  |  |

Group / Division Centre / Laboratory / Unit Name Indian Space Research Organisation Department of Space

Contents

1. PD/IP Proposal Code - YS/PD-IP/318
2. Title of the Proposal - UAV-Aided Weather Radar Calibration
3. Detail of students working for this project - Mentioned Below
4. Scope - Mentioned Below
5. Objectives - Mentioned Below
6. Scientific / Technical Need Aspect with respect to Indian Space Programme - Mentioned Below
7. Brief summary of basic literature survey for relevant execution of project - Mentioned Below
8. Brief outline of the project including envisaged approach / methodology - Mentioned Below
9. Available Institutional facilities - Mentioned Below
10. Expected supports / facilities requirements from ISRO side for execution of project - Mentioned Below
11. Expected Deliverables / Outcomes - Mentioned Below
12. Project Duration - 2 years
13. Budget detail - Mentioned Below
14. Milestones - Mentioned Below
15. The societal application part of the outcome of this project - Mentioned Below
16. Product / Service marketability including start-up / business potential - Mentioned Below
17. Describe how it will help students to become future entrepreneurs - Mentioned Below

3. Details of the students:

| SNo | Name | College Name | Course and Department | Roll Number | Email | Contact Number |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | Pushpal Das | SRM Institute of Science and Technology | Btech , Electronics and Communication Engineering(ECE) | RA1911004010565 | [pd7000@srmist.edu.in](mailto:pd7000@srmist.edu.in) | 8910497557 |
| 2 | Ved Prakash Dubey | SRM Institute of Science and Technology | BTech Computer Science and Engineering with a Specialisation in Software Engineering | RA1911033010043 | vd8413@srmist.edu.in | 9674990810 |
| 3 | Abhishek Sarkar | Jadavpur University | B.E. in ETCE | 001910701027 | abhisrkr007@gmail.com | 6290782054 |
| 4 | Suriya Devalan AR | SRM Institute of Science and Technology | B.Tech,Mechanical | RA1911002010176 | as5539@srmist.edu.in | 8072137976 |
| 5 | Debangan Mandal | Vellore Institute of Technology, Vellore | B.Tech, Computer Science and Technology | 19BCE0688 | debangan.mandal@gmail.com | 6291855524 |
| 6 | Sayak Sanyal | Vellore Institute of Technology, Vellore | BTech , Electronics and Communication Engineering(ECE) | 19BEC0682 | sayak.sanyal2019@vitstudent.ac.in | 9123782678 |
| 7 | Arkadeep Mukherjee | Vellore Institute Of Technology, Vellore | B.Tech, Mechanical Engineering | 19BME0494 | arkadeep.mukherjee2019@vitstudent.ac.in | 7595932726 |
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4. Scope

• Unmanned aerial vehicle (UAV) consisting of GPS module & Metal sphere.

• Software for processing the data for Antenna pattern.

• Data processing for Radar constant.

5. Objective

Atmospheric observation is made possible through weather radar, which provides data regarding the conditions of the atmosphere phenomena at a large volume within a short time. There is a requirement of weather radar data with sufficient measurement accuracy for accurate estimation of Weather Radar products. Radar system bias can be introduced from any radar F components, which adds uncertainty in radar measurements. This system bias should be quantified through a radar calibration process, which aims to identify the unknown system error caused by the transmitter, receiver and antenna. The radar calibration can be divided into two parts: the internal calibration and the external Calibration. It is a more practical approach to evaluate and characterise the radar system as a whole using the external calibration. The external calibration involves the measurement of backscattering of a calibrator with known radar cross section, such as a metal sphere.When conducting the external calibration, the calibrator needs to be positioned in the far field, which is difficult as some radars are located at the top of high buildings or towers.The proposal is to use an unmanned aerial vehicle as the platform to carry a metal sphere to achieve the external radar calibration.

6. Scientific / Technical Need

Aspect with respect to

Indian Space Programme

ISRO has provided a lot of solutions in the department of UAV development and its applications. In comparison to traditional aerial surveys, which are quite expensive when a study requires a number of periodic surveys, UAVs have been successfully employed for real-time mapping, surveying, and monitoring activities with high spatial and spectral resolution data.

North Eastern Space Application Centre, has taken up the responsibility of UAV development in India. NE-SAC designed and built a Hex Copter that can carry a payload of up to 2.5 kg of various sensors such as thermal, multispectral, optical, hyperspectral, or LIDAR. Moving forward on this design and working upon it would be an aim for our team. The flights were carried out in two test sites located in the Ri Bhoi district of Meghalaya and one test site in Morigaon district of Assam of India.

Weather radar is a well-known sensor for measuring the microphysical and dynamical aspects of precipitation with high spatial and temporal resolution. One of the most crucial criteria for reliable observations is radar calibration. Unmanned aerial vehicle (UAV)-aided radar calibration is presented in this article as a portable, cost-effective, and reproducible radar calibration approach.

ISRO AND IMD carried out a calibration experiment on new X-band radar which was installed at NIOT, Pallikaranai using a drone, it was the first time in the country that a drone was used to carry out calibration experiments on a weather radar. Hence this methodology can help the existing project by improving its efficiency like time of flight, power consumption and also their aerodynamics.

7. Literature Survey

From the dissertation submitted by Arturo Yoshiyuki and Umeyama Matsumoto at University of Oklahoma Graduate College named “Unmanned Aerial Vehicle-Based Far-Field Antenna Characterization System For Polarimetric Weather Radars” (identifying URL: https://hdl.handle.net/11244/326678), UAV-based weather radar solutions are hypothesised to be able to replace conventional outdoor ones due to low cost and flexibility of operations. It describes necessary RF instrumentation to perform accurate measurements of a typical weather radar.

The radiation characteristics of the probe antenna are degraded due to scattering and diffraction effects from the interaction of the antenna and the UAV. Hence, to effectively and accurately perform calibration, proper steps need to be taken to compensate for the above mentioned impact on the radiation characteristics.

From the paper written by Aswath and Jeevak Raj, we could find that a particular type of UAV namely VTOLs (Vertical Take-Off and Landing) could be efficient as it does not require any runaway to get airborne and that these types of drones are used a lot in agricultural fields, swarm-based collaborative robots, warehouse management etc. From the paper it was understood which type of controllers would be best fitted for such a heavy payload.and the most common among them would be PID controllers which can be used to achieve basic hovering and attitude control.

Based on the results provided from Digital Object Identifier 10.1109/ACCESS.2020.3027790 - the error metrics for the UAV calibrator - namely co-polarization mismatch and cross-pollination mismatch are comparable to that of an external calibrator on a pedestal at an elevated level. This proves that a UAV-based antenna characterization method can be as effective as an elevated range, provided that the accuracy of the navigation and tracking system are sufficient.

Probe correction techniques can be applied, which would further improve the error levels.

It is recommended to use a probe antenna with as narrow a beam-width as possible while still being physically realisable, and to prioritise the altitude accuracy over the x-y accuracy to keep the error levels at a minimum. A point to be noted in DOI: 10.1109/TGRS.2019.2933912 is that measurements at higher altitudes were not performed due to lawful restrictions on drone flight, specifically values of range resolution should be 30m not 3m. Hence, we can try making more observations in operational mode and take the necessary observations.

Based on the paper written by Jiapeng Yin , Student Member, IEEE, Peter Hoogeboom, Christine Unal, Herman Russchenberg , Fred van der Zwan, and Erik Oudejans, We can get a conclusion that using a UAV to carry a metal sphere with an external GPS box underneath the sphere, the proper flying modes, namely horizontal and vertical zigzag movements, are designed to intercept the antenna gain pattern at several points. With the GPS coordinates obtained from the UAV and the external GPS box, it is possible to obtain the positions of the sphere and output its azimuth and elevation angles. Then, the antenna pointing calibration can be conducted. The S Band TARA is placed 350m at 12 degree angle to receive the signals from the GPS.

Hence we need to provide a proper chassis that is metal sphere like or an airfoil shape to improve the aerodynamic performance. We place a powerbank, MCU,Receiver and antenna in the 3d printed object. Small gap must be made in the 3d printed object so that the antenna can transmit the signals with the S band. Although the hole can change the direction of the air trivially we need to try to maintain the centre of mass of the object which is a bit complicated but can be achieved to an extent. Reference IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 57, NO. 12, DECEMBER 2019

8. Methodology

8.1 UAV and Hardware requirements

Covering the mechanical requirements first and creating a prototype of the UAV will be conducted as follows. Six motors are mounted to the frame with arms and rotate the propeller at extremely high rates to provide propulsion in a hexacopter. Two landing gears are used to provide stability while landing and must be flexible to face any sudden jerk and prevent the toppling of the UAV

Three motors rotate in clockwise (CW) and counterclockwise (CCW) orientations to achieve stability. It is possible to cancel the net moment about the drone's yaw axis with this setup.

BLDC motors are utilised in multi-rotors, and the rotational speed is controlled utilising three different phases of current. With the help of an ESC, the motors' programmed rotation speed is maintained (Electronic Speed Controllers). ESCs constantly monitor the motor's feedback current and make minute adjustments to the motor's input current. Batteries are used to power the on-board computer, sensors and motors. Based on these mentioned components, a physical model of the hexacopter will be designed in Solidworks and the final 3D CAD(Computer Aided Design) model is exported The whole weight distribution of the hexacopter must be evaluated; this enables for component analysis and highlights the relevance of each portion, as well as tracking its performance with past and future iterations of the Multi-rotor designs.

As the first step we need to collect all the components and sensors based on our requirements and choose the best sensors possible providing the most accurate results. Assemble the BDLC in the frame and connect the electronic speed controllers to it . Attach all these to the Pixhawk flight controller accordingly. Attach the gps module also to the flight controller. After assembling the drone we need to place the raspberry pi in such a manner that the drone can be balanced. Attach a camera module also to the raspberry pi and program the pi.

8.2 Software Requirements

To finish the calibration procedure, a UAV acts as a steady aerial platform holding a metal sphere that flies over the radar illumination zones. The UAVs flight routine may be pre programmed, allowing the antenna pattern to be retrieved for various elevation and azimuth angles. A real-time single-frequency exact point positioning-type global navigation satellite system solution is being developed to determine the sphere's position. Furthermore, the radar constant is computed in the range-Doppler domain, and only the data where the metal sphere distinguishes itself from clutter and other objects is chosen. The calibration effort employs the S-band polarimetric Doppler transportable atmospheric radar (TARA). The following are the outcomes of the experiments:

1. antenna pointing calibration can be completed,

2. antenna pattern can be retrieved and weather radar constant can be accurately calculated.

9. Available Institutional Facilities

**Infrastructure Faculties available at the host institution**

| **Sl.**  **No** | **Name of the Lab** | **Name of the Equipment** | **Specification** | **Nos.** |
| --- | --- | --- | --- | --- |
| 1 | IPT Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 30 |
| 2 | Embedded Systems Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 30 |
| 3 | Cyber Forensics Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 30 |
| 4 | RDBMS Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 30 |
| 5 | OST Lab | DELL Workstation | Dell Precision Tower 5810  Intel Xeon E5-2630 V4 2.2GHz 10core 20logical processor  32 GB Memory  1 TB SCSI Disk  22” LED Monitor | 13 |
| 6 | OST Lab | Dell Desktop Optiplex 390 | Dell Optiplex 390SF Intel core i5 Processor 4 GB RAM  500 GB HDD | 8 |
| 7 | OST Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 12 |
| 8 | OOPS Lab | HP Elite Desktop | HP Elite Desk 800G1 SFF core i5 3.2 GHz 4 GB RAM  500GB HDD | 55 |
| 9 | VP Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 30 |
| 10 | WST Lab | Dell Desktop Optiplex 9020 | Dell Optiplex 9020PC  Intel Core i5 3.2 GHZ Processor  4 GB DDR3 RAM 500 GB HDD | 32 |
| 11 | Cisco Academy Lab | Dell Desktop Optiplex 5040 | Dell Optiplex 5040PC  Intel Core i7 6700 Processor  8 GB DDR3 RAM  500 GB HDD | 40 |
| 12 | Data Structures Lab | Dell Desktop Optiplex 5040 | Dell Optiplex 5040PC  Intel Core i7 6700 Processor  8 GB DDR3 RAM 500 GB HDD | 20 |
| 13 | Digital Communications Lab | Trainer Kit | | 50 |
| 14 | Microwave and Optical Communications Lab | Microwave Measurements Setup  3-30 GHz | | 10 |
| 15 | Research Lab | VNA Measurements for Antenna, HFSS Software, ADS Software | | 1 |

| **Sl. No.** | **Infrastructural Facility** | **Yes/No** |
| --- | --- | --- |
| 1. | Workshop Facility | Yes |
| 2. | Water & Electricity | Yes |
| 3. | Laboratory Space / Furniture | Yes |
| 4. | Power Generator | Yes |
| 5. | AC Room or AC | Yes |
| 6. | Telecommunication including e-mail & fax | Yes |
| 7. | Transportation | Yes |
| 8. | Administrative / Secretarial Support | Yes |
| 9. | Information facilities like Internet / Library | Yes |
| 10. | Computational Facilities | Yes |

10. Expected Support/Facilities Requirements From ISRO for Project

1. Intellectual and guidance support
2. Permission to access related experimental data
3. Need of radar data for testing
4. Permission to validate results at their labs

11.Expected Deliverables

* A cost-effective, mobile, in-situ UAV-based far-field antenna characterization system for polarimetric weather radar applications. A means for accurate in-situ polarimetric calibration.
* Able to figure out one of the best aerodynamic shapes from a metal sphere leading to better ergonomics. Work on evenly balancing the centre of gravity in UAV. Controlling the flight endurance of 30 to 40 mins or more, based on material, size, weight or any other factors to be considered. Working on the frame design, to make the UAV more aerodynamic in nature thus providing ingenious solutions to tackle wind problems.
* Obtain position of the calibration sphere using the GPS unit and output its azimuth and elevation angles. With this the antenna pointing calibrations can be conducted. To finish the calibration procedure, a UAV acts as a steady aerial platform holding a metal sphere that flies over the radar illumination zones. The UAV’s flight routine may be pre programmed, allowing the antenna pattern to be retrieved for various elevation and azimuth angles. A real-time single-frequency exact point positioning-type global navigation satellite system solution is being developed to determine the sphere's position. Furthermore, the radar constant is computed in the range-Doppler domain, and only the data where the metal sphere distinguishes itself from clutter and other objects is chosen. The calibration effort employs the S-band polarimetric Doppler transportable atmospheric radar (TARA).
* Finally, with the measurements complete, the interpolated 2-D antenna pattern can be received and depicted using appropriate software and weather constant can be correctly calculated.

12. Project Duration - 2 Years

13. Budget Details

| **Item** | **Amount in (Rs.)** | | |
| --- | --- | --- | --- |
| **Total Cost** | **1st Year** | **2nd Year** |
| Equipment | 11,76,800 | 11,76,800 | 0 |
| Manpower | 11,70,000 | 5,85,000 | 5,85,000 |
| Consumables | 1,20,000 | 80,000 | 40,000 |
| Contingencies  / Other Costs | 50,000 | 25,000 | 25,000 |
| Travel | 1,50,000 | 75,000 | 75,000 |
| **Total** | **26,66,800** | **19,41,800** | **7,25,000** |
| Institutional Overhead Charges (10% of Total) | Rs.2,70,000 | 1,35,000 | 1,35,000 |
| **Overall Total (6+7)** | **29,36,800** | **20,76,800** | **8,60,000** |

**Budget Summary:**

**Proposed cost: Rs.29,36,800.00**

**Duration: 2 Years**

**Details of Costs of Various Components and Justification**

1. **Cost of Equipment:**

| **Sl. No.** | **Name of the Equipment along with make & model** | | **Units** | **Estimated Costs in Rupees** |
| --- | --- | --- | --- | --- |
| 1  . | Hardware Specifications | * Bosch Sensortec BME280 * Silicon Laboratories SI1145 * Raspberry pi * Readytosky 80A * Pixhawk 32 Bit Flight Controller * U-BLOX NEO-M8N * FLY SKY FS IA6B * Propellers * Frame * Landing Gears * Lipo Batteries * Brushless DC motor | 1  1  1  6  1  1  1  10  1  1  1  6  - | **5,88,400/** |
| 2 | Workstation Requirement (Dell/HP)   * Processor Intel Xeon E5- 3.14GHz16core * 2133Mhz, 64GB DDR4 RDIMM SDRAM * NVIDIA Quadro Display Adapter(6GB) * Power (SMPS) Needs single CPU system with 950W PSU * 4. ATA SCSI Disk 2TB * 22' LED Display Screen * Operating System: Windows 10 server OS   (5,88,400@per equipment) |  | 1 | **5,88,400/** |

2) **Manpower Cost**

| **Sl.**  **No.** | **Designation**  **/Numbers** | **Amount in Rupees** | | | |
| --- | --- | --- | --- | --- | --- |
| **1st**  **Year** | **2nd**  **year** | **3rd**  **year** | **Total** |
| 1. | Junior Research Fellow (JRF)  (Rs.26,200+HRA (24%)  –Rs.32,500 / month)  Rs. 3,90,000/ year)  **\*As per DST Norms** | 3,90,000/ | 3,90,000/ | 3,90,000/ | 11,70,000/ |

14. Milestones

|  | **Year 1** | | | | **Year2** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity | **1-3M** | **4-6M** | **7-9M** | **10-12M** | **13-15M** | **16-18M** | **19-21M** | **22-24M** |
| 1. Updating the Literature Survey 2. Mathematical modelling and simulation 3. Purchase of components |  |  |  |  |  |  |  |  |
| 1. Prototype Development. 2. Experimentation, Validation, Testing of the prototype. |  |  |  |  |  |  |  |  |
| 1. Paper publication 2. Patent Filing and Commercialization. |  |  |  |  |  |  |  |  |

15. Societal Application of the Project

The societal application of this project is as simple as that that in many of the scenarios we often face a glitch or an error in the live forecasting of the weather based on the atmospheric layer as a result of it to study and grow more in deep with the results and outcome and give as much as efficiency and accuracy as it can be will be the best output for everyone has a hole when it’s live weather forecasting and the need of people to know about weather detail.

16. Business/Product Potential of the Project

Start up or business potential as we can see is to unlimited offset into a particular set of market the particular set of market can only be targeted into sectors owning satellites and when the word satellite comes today forecasting is what we human beings are updated to so the market capability for its growth its extended to news channels and not only that even for perfect accuracy as a measurement instruments to various sorts of lab for carrying out many such research works so if we view this as a start-up or a business model the growth is where enormous as the inside layer of it rather than not outside or we can say that people will not be exposed to it directly but indirectly that is what it potentially have a gravity towards it.

17. Inspiration to students in pursuing entrepreneurship

Today India our country as we know is on the verge of start-ups and many such business plans but if we see things very technically then we the engineering student can make it happen with the support of organisations all we need is a bit of patience hard work and vision that we all carry in the commencement of the project in today’s generation there is not a single leader in the team what we believe is we are our own leaders we are our own master we are our own captain of the ship so it’s us who decide in what direction we want the product to grow when it’s too accurate to perfect and up to the market so it is asked the entrepreneurs who knows the limit of the product all we need is a chance and sacrifices to to prove what our words mean.