## Proposal Format

| 1. | **Title of the research proposal** | Development of tools for hybrid-PolSAR data analysis. |
| 2. | **Summary of the proposed research**<br>A Simple concise statement about the investigation, its conduct and the anticipated results in no more than 200 words. | The project will investigate the potential and efficacy of hybrid-polarimetric (Pol) SAR sensors. In this project work, algorithms for the analysis of hybrid-Pol data will be developed. Information extraction through decomposition of hybrid-Pol covariance matrix will be investigated. Also this project will investigate the Stokes parameter based information extraction techniques. Secondly, as hybrid-Pol data do not occupy a Euclidean space, its analysis in non-Euclidean geometry would be of major concern of this project. Third, information extraction from the hybrid-Pol images as per the remote sensing applications will be considered. Particularly, new algorithms for landcover classification/ vegetation biomass retrieval by using hybrid-Pol data will be developed. These algorithms will be implemented on RISAT datasets to evaluate their performances. |
| 3. | **Objectives**<br>A brief definition of the objectives and their scientific, technical and techno-economic importance. | **Objectives:**<br>1. **To develop tools for the analysis of hybrid-Pol data**<br>As far as the analysis of hybrid-Pol data is concerned, there have been quite a few approaches reported in the open literature. These studies have demonstrated the rich potential of hybrid-Pol system for further quantitative analysis. This gives us the motivation to develop new algorithms for the analysis of hybrid-Pol data in order to extract information from its images. Information from hybrid-Pol data may be extracted through decomposition theory. New decomposition techniques for hybrid-Pol data will be developed. Also Stokes parameter based information extraction will be investigated.<br>2. **A differential geometric approach for the analysis of hybrid-Pol data.**<br>A new geometric approach based on the notion of the information geometry of covariance matrices may be developed to extract information from hybrid-Pol data. As the hybrid-Pol covariance matrices are Hermitian positive definite matrices and the positive definite matrices do not form a Euclidean space, it becomes necessary that the hybrid-Pol data should be analysed based on non Euclidean geometry such as differential geometry. Also the Stokes vector originating from hybrid-Pol data are located on a sphere which is a manifold, so the analysis starting from Stokes vector should be based on non Euclidean geometry concept.<br>3. **Landcover classification/Biomass scattering property modeling using hybrid-Pol data.** |
Full polarimetric SAR have been well accepted as an indispensable tool for geo-science applications in agriculture, forestry, oceanography, land use-land cover, hydrology, flood plain etc. Researchers in radar community have successfully demonstrated the potential of full polarimetric SAR in various remote sensing applications. However, Hybrid-PolSAR which is a new concept and very recently introduced in literature, its usefulness in various remote sensing applications is yet to be exploited.

In this project, we will be working on either landcover classification or vegetation biomass retrieval modeling using hybrid-Pol data. The successful carrying out of this phase of the project will depend on the availability of RISAT data and ground truth. (Possibly bottleneck for the project)

The thrust of current research and development in radar community is in applying the polarimetric concept to radar based remote sensing. The polarimetric radar field started a new era with the acquisition of polarimetry data from the airborne SAR flown by the jet propulsion laboratory in the spring of 1985. Presently, the polarimetric radar field has reached its golden period of time. Complete polarimetric information helps in better target decomposition and hence better scene or target classification. Despite of these advantages, fully polarimetric radar system (quad-Pol) suffers from an increase in the pulse repetition frequency (PRF) by a factor of two and increase in the data rate by a factor of four in comparison to conventional radars (single-Pol) [1,2].

As the PRF is increased by a factor of two, the swath coverage is halved to maintain the performance with respect to range ambiguities and the average transmitted power becomes doubled. The reduced swatch coverage of the fully polarimetric radar system has an adverse impact on revisit time, which is always an important factor for the Earth-observing community. A trade off between these two systems is dual-polarimetric (dual-Pol) systems that transmits a single polarization wave and coherently receives two orthogonal polarized waves. Dual-Pol offers more target information than a single-Pol system, and simultaneously overcomes some of the drawbacks of quad-Pol system.

Recently there has been a growing interest in dual-polarimetric (dual-Pol) systems, especially in hybrid-Pol mode. The Mini-SAR on Chandraayan-1 is the first practical radar that is based on this hybrid-Pol architecture. Also, the radar imaging satellite (RISAT), the first SAR satellite from Indian Space Research Organisation (ISRO) supports this hybrid-Pol configuration [RISAT] [3]. It is a series of Indian radar imaging reconnaissance satellites being built by ISRO to provide all-weather and day-night surveillance using SAR. The SAR onboard RISAT will have the ability to acquire hybrid polarimetric data at C-band. RISAT is expected to enhance the scope of remote
sensing applications using radar data. It can be stated that India is one of the pioneering nations in implementing this type of radar systems. A hybrid-Pol system transmits circular polarization and receives two mutually orthogonal coherent linear polarizations. This configuration is the optimum choice when there is a requirement for wider swath coverage with constraint of limited average transmitted power and bandwidth [4]. It has been accepted that information content in hybrid-Pol SAR image is comparable to that of fully polarimetric (FP) SAR [1, 2]. Hence it is of utmost important to develop algorithms to analyze hybrid-Pol data and extract information from its images.

**Present state-of-art of the subject:** Souyris et al. have demonstrated that dual-Pol SAR systems can reproduce aspects of fully polarimetric data based on few simple assumptions [5]. They have introduced a radar scattering model to construct pseudo quad-Pol data from pi/4 mode data. However these models make two assumptions which limit their applicability to azimuthally symmetric scatterers only. However, the advantage with this method is that all the polarimetric tools developed for quad-Pol SAR image analysis can be applied to any dual-Pol modes by generating the corresponding pseudo quad-Pol data. A comparison of the information content between any dual-Pol mode and the corresponding pseudo quad-Pol data generated by using scattering model is carried out in [2]. In that work, it is reported that the classification accuracy of the pseudo quad-Pol data is the same as the classification accuracy obtained directly from the underlying dual-Pol data. A modified version of the radar scattering model is proposed in [1], which shows improvement over the original result in the construction of pseudo quad-Pol data. In the above work, a study of different dual-Pol modes was carried out to determine which dual-Pol configuration allows for superior reconstruction of the fully polarimetric data. Raney in [4,6] has stated that hybrid-Pol mode is the optimum configuration among different dual-Pol modes. In his work [4, 6], he has shown that the analysis of hybrid-Pol data can be started from the Stokes parameters of the backscattered field for hybrid-Pol system. Many secondary parameters, such as degree of polarization (DoP), relative phase, and circular polarization ratio can be derived from the Stokes parameters. In order to extract information from hybrid-Pol data, a DoP–Realitive phase decomposition of hybrid dual-Pol data is proposed by Raney in [4]. An unsupervised classification algorithm based on DoP–Realitive phase decomposition technique is developed in [7], which is capable of distinguishing the three basic scattering mechanisms, viz. single bounce, double bounce and volume scattering. Chen et al. further improved the DoP–Realitive phase classification results by combining DoP–Realitive phase with span and Wishart based classifiers [8]. In another work, Loi et al. provide an estimation of soil moisture and Faraday rotation from bare surface using hybrid-Pol data [9]. In their work [9], they have also introduced a new coefficient, known as conformity coefficient, which can also be used to discriminate between surface, volume and double bounce scattering by setting two threshold values.

There can be broadly three ways by which we can analyze the hybrid-Pol data. First, we can develop decomposition and classification techniques specific to hybrid-Pol architecture. The second method of analyzing the hybrid-Pol architecture is to reconstruct the full polarimetric information from dual-Pol data by employing the polarimetric scattering models. Then the well developed decomposition and classification techniques of polarimetric SAR can be directly applied to the so called pseudo quad-Pol data. Third, we can analyze the hybrid-Pol data if we can extend the full polarimetric decomposition and classification algorithms to hybrid-Pol data. With the lack of hybrid-Pol data set, we are generating the hybrid-Pol data from the quad-Pol data. However, it does not generate pure circular transmission. If ISRO can provide some RISAT datasets to us for scientific study purposes, it would be of great help. This project will mainly deal with the first and third method of analyzing hybrid-Pol data.

Secondly, analysis of hybrid-Pol data based on differential geometric approach will be undertaken to extract information from hybrid-PolSAR data. Usually, hybrid-PolSAR data analysis starts with the knowledge of Stokes vector of the received signal. It is a well known fact that Stokes vector located on a manifold known as Poincare sphere. Hence most of the techniques developed by assuming Euclidean space geometry may be incorrect. Therefore a differential geometrical approach to hybrid data analysis will be analysed in this project.

5. **Deliverables to ISRO on successful completion of the project**
   
   Project Reports, Hybrid polarimetric SAR tools.

6. **Approach**
   
   A clear description of the concepts to be used in the investigation should be given. Details of the method and procedures for carrying out the investigation with necessary instrumentation and expected time schedules should be included. All supporting studies necessary for the investigation should be identified. The necessary information of any collaborative arrangement, if existing with other investigators for such studies, should be furnished. The principal Investigator is expected to have worked out his collaborative arrangement himself. For the development of balloon, rocket and satellite-borne payloads it will be necessary to provide relevant details of their design. ISRO should also be informed.
whether the Institution has adequate facilities for such payload development or will be dependent on ISRO or some other Institution for this purpose.

For each pixel, there is a Stokes vector. As Stokes vector is a point on Poincare sphere, indirectly it can be stated that each pixel is a point on Poincare sphere. Therefore the popular data clustering techniques which assumes Euclidean space is no longer applicable for the analysis of hybrid-Pol data. So either we can extend the existing techniques to operate on data lying in non-Euclidean space or we can develop new data clustering techniques based on non-Euclidean geometry to analyse the data.

Also the PolSAR covariance matrices are Hermitian positive definite matrices and positive definite matrices do not form a Euclidean space. Therefore the analysis starts with polarimetric covariance matrices should also be based on non-Euclidean geometry. For hybrid-Pol data the covariance matrix is a 2x2 Hermitian positive definite matrix. Therefore, we may conclude that the analysis of hybrid-Pol data should be based on non-Euclidean geometry.

Third, the usefulness of hybrid-Pol data will be evaluated for various remote sensing applications. We have NASA JPL’s AIRSAR and SIR-C quad-Pol datasets for crop classification, forest type classification, ice type classifications and land cover classification. Therefore presently, we are working in these applications areas of remote sensing. First, Hybrid-Pol datasets are generated from quad-Pol datasets and then these hybrid-Pol data are used to extract information as per the remote sensing applications.

All algorithms that we are going to develop in this project will be delivered as tools to ISRO. The operating system may be Windows/Linux based and the platform may be VC++/JAVA/Matlab based (Incase of Matlab, GUI will be developed).

**Project progress plans** : The project can be viewed in terms of quarters (Q) of a year (3 months). Following is the planned activities per quarter.

Q1: Literature survey: Procurement of computing equipments, appointment of SRF (leading to PhD).
Q2: Literature survey, Obtaining RISAT dataset from ISRO. Choosing an Indian site which covers a large geographical area or agricultural area for which the ground truth and RISAT data is available.
Q3: Development of algorithms for Objective 1
Q4: Development of algorithms for Objective 1 and submission of 1st year report.
Q5: Development of algorithms for Objective 1.
Q6: Development of algorithms for Objective 2.
Q7: Development of algorithms for Objective 2.
Q8: Development of algorithms for Objective 2 and submission of 2nd year report.
Q9: Development of algorithms for Objective 3 and appointment of JRF. (The job of JRF is to develop tools from the algorithms)
Q10: Development of algorithms for Objective 3 and development of tools.
Q1: Development of algorithms for Objective 3, development of tools.
Q12: Development of tools from all the algorithms and delivering it to ISRO with the final project report.

7. **Data reduction and analysis**
   A brief description of the data reduction and analysis plan should be included. If any assistance is required form ISRO for data reduction purposes, it should be indicated clearly.

   RISAT datasets for land applications with relevant ground truths are required. The hybrid-Pol (RISAT) multi-look processed data in form of covariance matrix and Stokes vector is needed. Also if the datasets are provided in standard format such as .ceos, .stk, .dat or .pp, then it would be easier for the users of RISAT data to work on.

8. **Available Institutional facilities**
   Facilities such as equipments, etc, available at the parent Institution for the proposed investigation should be listed.

   Laboratory space; High speed Internet connection; subscription to most of the scholastic journals; library facility; UPS based power system.

9. **Fund Requirement**
   Detailed year wise break-up for the Project budget should be given as follows:

   *Note: Please specify the designation and the rate of salary per month for each category.*

<table>
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<tr>
<th>Degree</th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>Total</th>
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<tr>
<td>Research Scientist</td>
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<tr>
<td>Research Associate</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Research Fellows (SRF(P))</td>
<td>2,37,600 (18,000 Rs per month+10% HRA)</td>
<td>2,37,600 (18,000 Rs per month+10% HRA)</td>
<td>2,64,000 (20,000 Rs per month+10% HRA)</td>
<td>7,39,200</td>
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<td>Supporting Technical Staff</td>
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<tr>
<td>Other staff, if any (JRF)</td>
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<td>1,44,000 (12,000 Rs per month)</td>
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<td>Equipment *</td>
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<td>1,70,000</td>
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* (To procure high-end computing system with...*
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<th></th>
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<td>20,000</td>
<td>60,000</td>
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<td>Good graphics tool+20,000(for a printer)</td>
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<td><strong>Travel</strong></td>
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<td>50,000</td>
<td>50,000</td>
<td>1,50,000</td>
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<td>50,000(This will be spent in travelling for conferences and respond workshops)</td>
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<td><strong>Contingency</strong></td>
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<td>10,000</td>
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<td>63,520</td>
<td>97,600</td>
<td>2,16,400</td>
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<td><strong>Total</strong></td>
<td>5,85,120</td>
<td>3,81,120</td>
<td>5,85,600</td>
<td>15,51,840(Total Budget)</td>
</tr>
</tbody>
</table>

*Please specify various individual items and indicate foreign exchange requirement, if any*

| 10. Whether the same or similar proposal has been submitted to other funding agencies of Government of India. If Yes please provide details of the institution & status of the proposal. | No. |
1. **Broad subject area**: (Life Sciences, Physical Sciences, Chemical Sciences, Earth & Atmospheric Sciences, Mathematical Sciences, Engineering Sciences): **Engineering Sciences**.

2. **Specialization**: Radar based remote sensing, SAR image segmentation and classification.

3. **Title of the proposed project**: Developing supervised and unsupervised classification algorithms using polarimetric synthetic aperture radar data for landcover mapping and crop discrimination.

4. **Name and address of the Investigator**: Rajib Kumar Panigrahi,
   
   #224, Married Scholar Hostel,
   
   Indian Institute of Technology Guwahati,
   
   Guwahati-781039

   Email: p.rajib@iitg.ac.in, rajibpanigrahi@yahoo.com
   
   Ph. No.: 919707458093

5. Details of the proposed project to be undertaken:
   
   - **Origin of proposal**: Anthropogenic changes in landcover is one of the alarming factors affecting global ecological changes. Therefore the importance of acquiring complete, accurate and timely landcover information has grown over the years with the increasing concern about the ecological changes. That leads to evolution of optical radar to polarimetric radar through real aperture radar followed by synthetic aperture radar (SAR). A fully polarimetric radar system, which alternately transmits two orthogonal polarized waves and measures the scattered wave by dual coherent orthogonal polarized channels, contains all the information about the scattering process in the backscattered wave. Therefore, using such a system, the characterization of different land features can be significantly improved. Discrimination of earth surface types is one of the major remote sensing applications of radar polarimetry and has been a subject of recurring interest for the last few decades. The aim of landcover classification process is to categorize all pixels in a digital image into one of the several landcover classes. Many such classification techniques are supervised in the sense that training data sets is used to do the signature analysis and based on that a statistical decision is taken to determine which class a pixel belongs. When the ground truth is not available, it is often difficult to obtain useful training data sets. Therefore, several unsupervised techniques have been developed which classify the image automatically by finding clusters based on a given strategy. Also, combinations of the supervised and unsupervised classification techniques have been reported in literature. However, presently none of the existing algorithms are able to correctly classify all types of landcovers. This suggests that further investigations are required to develop classification techniques for accurate landcover classification using polarimetric SAR images.

   - **Research work engaged in at present**: The research works, I presently involve in are radar based remote sensing, radar image processing and information extraction from polarimetric SAR images.

   - **Objectives of the proposed project**: To develop efficient and effective landcover classification techniques using polarimetric SAR images. This research project will
mainly deal with two major applications of remote sensing, viz. landcover mapping and crop classification.

- **Review of R&D in the proposed area** (National & International Status, Importance, patents etc.): The thrust of current research and development in radar community is in applying the polarimetric concept to radar remote sensing. Presently, the polarimetric radar field has reached its golden period of time.

**National Status:** Presently ISRO has already developed and operationalised two airborne C-band imaging SAR systems. The Mini-SAR on Chandrayaan-1 is the first practical radar which was based on a new hybrid-Polarimetric architecture. RISAT (Radar Imaging Satellite)-1, expected to be launched during the last quarter of 2011, is a fully polarimetric C-band SAR mission of ISRO. RISAT also supports the hybrid-Polarimetric SAR configuration. It is a series of Indian radar imaging reconnaissance satellites being built by ISRO to provide all-weather and day-night surveillance using SAR. The SAR onboard RISAT will have the ability to acquire polarimetric data at C-band. RISAT enhances the scope of remote sensing applications using microwave data. The RISAT-1 will be useful for various land applications such as landcover mapping and crop discrimination.

**International Status:** The polarimetric radar field started a new era with the acquisition of polarimetry data from the airborne SAR flown by the jet propulsion laboratory in the spring of 1985. AIRSAR has been the primary imaging polarimetry for last 25 years. There has been a growing interest in radar polarimetry due to the high quality data produced by various airborne missions (NASA/AIRSAR(1987), DLR/ESAR(1988), DCRS/EMISAR(1995), ONERA/RAMSES, JAXA/PI-SAR(1996), NASA/UAVSAR(2007)), and spaceborne missions (NASA/SIR-C(1994), ESA/ENVISAT-ASAR(2002) CSA/ RADARSAT-2(2007), DLR/TERRASAR-X(2007), JAXA/ALOS-PALSAR(2006)). The many advances in these different polarimetric spaceborne platforms were developed to respond to specific needs for radar data in remote sensing applications such as oceanography, sea-ice monitoring, crop monitoring and conditioning, disaster management, oil spill detection, snow monitoring, hydrology, landcover mapping, geology, agriculture, soil moisture and forest sensing.

- **Work plan** (including detailed methodology and time schedule):
  Detailed methodology: A thorough investigation of the existing literatures and the reason why they failed to correctly classify different landcovers may throw some light to develop new effective algorithms. Secondly, different bases to analyze the polarimetric data may be considered. An adaptive basis can be selected depending on the statistical properties of the data. Third, Information geometry may be used for polarimetric SAR classification.

  Time schedule: From Jan 2012 to June 2014 (2years 6 months)

- **Future plans**: The project can be viewed in terms of quarters (Q) of a year (3 months). Following is the planned activities per quarter.

Q1: Literature survey, Obtaining RISAT dataset from ISRO.
Q2: Literature survey: Procurement of computing equipments
Q3: Choosing an Indian site which covers a large geographical area or agricultural area for which the ground truth and RISAT data is available.
Q4: Processing of RISAT data.
Q5: Implementation of existing popular and efficient algorithm on RISAT data.
Q6: Any new problem formulation and RISAT data analysis.
Q7: Testing of chosen algorithms on RISAT data.
Q8: Developing new algorithms for landcover mapping and crop discrimination.
Q9: Developing new algorithms for landcover mapping and crop discrimination.
Q10: Writing journal papers and submitting the final project report.

- Details of the research funding received in the past and/ongoing projects
  (mention Ref. no., title, duration, cost, funding agency, and brief achievements). N/A

6. Name and address of the institution where the proposal will be/likely to be executed:
   National Institute of Technology Rourkela, Orissa.

7. Facilities provided/to be made available at the host institute: Laboratory space; High speed Internet connection; subscription to most of the scholastic journals; library facility; UPS based power system.

8. Name(s) and address(es) of Indian expert(s) in the proposed area: there is a guy in IIT Roorkee; and also the IITB professor.

   Dr. Tapan Misra, FNAE
   Group Head, Microwave Remote Sensing Area,
   Space Application Centre (SAC), ISRO
   Ahmedabad 380015
   misratapan@sac.isro.gov.in

   Dr. Dharmendra Singh,
   Associate Professor,
   Deptt. of E&CE,
   IIT Roorkee, Roorkee-247667,
   India

   Dr. Y.S. Rao
   Senior Research Scientist
   Centre of Studies in Resources Engineering (CSRE)
   Indian Institute of Technology, Bombay
   Powai, Mumbai-400 076, India
   Ph. +91-22-2576-7683, Fax: +91-22-25723190
   Email: ysrao@csre.iitb.ac.in
9. **Details of financial requirements for three years (with justifications) and phasing for each year:** (All amount are in Lakhs)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Head</th>
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<th>2nd Year</th>
<th>3rd Year (6 months)</th>
<th>Total</th>
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<td>4.2</td>
<td>2.1</td>
<td>10.5</td>
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<td>2.</td>
<td>Manpower**</td>
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<tr>
<td>3.</td>
<td>Consumables</td>
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<td>0.2</td>
<td>0.1</td>
<td>0.6</td>
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<td>4.</td>
<td>Travel (within India) 0.5(This will be spent in travelling for conferences)</td>
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<td>0.2</td>
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<td>1.2</td>
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<td>5.</td>
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<td>0.3</td>
<td></td>
<td>1.5</td>
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<tr>
<td>6.</td>
<td>Equipment (Generic Name with minimum required accessories, make &amp; model &amp; Cost in Indian Rupees) 1.5(Apple laptop(Macbook): Need to have high performance computer with good visualisation tools)</td>
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<td>0.3</td>
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<td>7.</td>
<td>Overhead Costs (max. up to 20% of project cost)</td>
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<td>3.12</td>
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10. **Have you ever applied before under this Scheme or Women Scientist Scheme? If yes, give details** (Name of the scheme, Title, subject area, reference number, if any, year and the decision): N/A

11. **Any other information in support of the proposed project:** No

12. **Statement from the Present Employer as per Annexure-I** (In respect of person holding regular position): N/A
**Detailed Biodata**

1. **Name of the Applicant**: RAJIB KUMAR PANIGRAHI

2. **Mailing Address**: S/o Sri. Chiranjiba Panigrahi, 
   Braja Nagar 1st lane, Bramhapur, Orissa, Pin Code: 760001
   Email: p.rajib@iitg.ac.in, rajibpanigrahi@yahoo.com
   Ph. No.: 919707458093

3. **Date of Birth & Gender**: 14.05.1979 & Male

4. **Educational Qualifications** (Starting from Graduation onwards):

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Exam passed</th>
<th>University/Board/Institution</th>
<th>Month/Year of passing</th>
<th>Specialization</th>
<th>% of Marks/CGPA</th>
<th>Division</th>
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<td>1</td>
<td>B.E.</td>
<td>Bangalore Univ.</td>
<td>July 2001</td>
<td>E&amp;C</td>
<td>65.6</td>
<td>First Class</td>
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<tr>
<td>2</td>
<td>M. Tech</td>
<td>CUSAT, Cochin</td>
<td>June 2006</td>
<td>Microwave</td>
<td>8.62 (CGPA)</td>
<td>First Class with Distinction</td>
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<tr>
<td>3</td>
<td>PhD</td>
<td>IIT Guwahati</td>
<td>Thesis is submitted on June 2(^{nd}) 2011</td>
<td>Polarimetric SAR based remote sensing</td>
<td>9 (CGPA)</td>
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- Details of professional training and research experience, specifying period.

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<tr>
<th>Sl No</th>
<th>Scientific/Engineering Discipline</th>
<th>Name &amp; address of employer/inst</th>
<th>Designation</th>
<th>Field of Specialization</th>
<th>Length of Experience</th>
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<td>Microwave</td>
<td>SAMEER-CEM, Chennai</td>
<td>M.Tech project Trainee</td>
<td>Analysis and Design of multiple ridged waveguide and Horn antenna</td>
<td>1 year (from July 2005 to June 2006)</td>
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<td>2</td>
<td>Radar based remote sensing</td>
<td>IIT Guwahati</td>
<td>PhD Research Scholar</td>
<td>Information extraction from PolSAR images</td>
<td>3 years</td>
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- Details of employment (past & present).

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<th>Name &amp; address of employer/inst</th>
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<td>UCP Engg. School, Bramhapur</td>
<td>01.07.03 to 30.12.03</td>
<td>Part-time Lecturer</td>
<td></td>
<td>Teaching</td>
<td>6 Months</td>
</tr>
<tr>
<td>DSCE, Bangalore</td>
<td>18.07.06 to 15.03.07</td>
<td>Lecturer</td>
<td>18000</td>
<td>Teaching</td>
<td>9 months</td>
</tr>
<tr>
<td>NIST, Bramhapur</td>
<td>19.03.07 to 25.07.08</td>
<td>Sr. Lecturer</td>
<td>22000</td>
<td>Teaching &amp; Research</td>
<td>16 months</td>
</tr>
<tr>
<td>IIT Guwahati (ISRO RESPOND program)</td>
<td>01.01.10 to Till date</td>
<td>Research Associate</td>
<td>23000</td>
<td>Research</td>
<td>18 months</td>
</tr>
</tbody>
</table>

- **List of publications during last five years** (with complete details such as Journal name, all the author’s name as appeared in the journal, volume number, page number and the year of publication).

Research Papers in Journals:

**Accepted**

**Under review**


Conference Publications:


5. Professional recognition, awards, fellowships received: GATE Fellowship, PhD fellowship, NRTS scholarship and SRF fellowship.
6. Any other information: No.

Place: Guwahati. Signature of the applicant
Date: 1.08.2011