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Synthetic Aperture Radar in Indian Remote Sensing

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ABSTRACT
India's first indigenous all-weather Radar Imaging Satellite, RISAT-1, launched successfully from Sriharikota (Andhra Pradesh), dated on April 26, 2012 (07:03 IST) by the Indian Space Research Organization (ISRO). The Synthetic Aperture Radar (SAR) technique first time used in India, hence the Risat-1 images will facilitate agriculture and disaster management because of its day-night, all-weather monitoring capability. The payload of Risat-1 weighing 1858 kg is heaviest satellite being launched yet by the PSLV-C19 and it is the country's first Microwave Remote Sensing satellite. Risat-1 satellite will enhance ISRO's potential for earth observation, especially during floods, cyclones, landslides and in disaster management in a supplementary supportive approach. Hence, the incoming SAR technique in Indian Remote Sensing growing the capability of ground truth information, especially of remote and undulating areas for variety of spatial planning and development.

Keywords
Microwave, Remote Sensing, SAR, Risat-1.

1. INTRODUCTION
India's space program developing day by day with the scientific and technological advancement approaches. Remote Sensing is the one of the activity of ISRO, which is the helpful for communication, monitoring, land information and operating on the basis of verities of satellites data. India launched first Synthetic Aperture Radar (SAR) satellite the RISAT-1 successfully dated on 26, 2012 which is in the polar circular orbit (polar Sun-Synchronous).

Fig 1: PSLV-C19's first launch Pad in left image and its lifts from Sriharikota Andhra Pradesh), dated on April 26, 2012 in right image *(Source: ISRO's Website)*.

This satellite owing to the SAR technology helpful for capturing the surface image data in unsupportive weather conditions even cloud cover, rain and storm to take images of 1m resolution. There for the Risat-1 satellite will be used to estimate the agriculture, particularly paddy monitoring in Kharif season, military applications, disaster management of natural disasters like flood and cyclone, and remote area's detail topographic information in the country. The aim of this paper is to inform the SAR technology, its system, process, and SAR data's applications with the global and Indian remote Sensing perspective.

2. REMOTE SENSING
Remote Sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information. Remote Sensing is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. From last few decade there is continues advancement in the remote sensing technology.

The synthetic aperture radar principle has been discovered in the early 50th in the Remote Sensing. After that, the fast progress took place in all over the world and in the air- and space-borne systems which are operational in now a day. Its Radar has proven to be important, because of its day-and-night ability as well as the possibility of penetrate clouds and rain systems due to the great wavelength of radar signals limits the achievable resolution in cross range direction of real aperture radar systems. The design of SAR has been transmitting the pulses and stores the scene echoes along SAR which is mostly useful for military and civilian applications.

3. MICROWAVE REMOTE SENSING
Analyzing the information collected by the sensors that operate in the microwave portion (wave lengths within the 1mm to 1m) of the electromagnetic spectrum is called as Microwave Remote Sensing, (Fig 3). These longer waves have the ability of penetrating through the clouds, soil, vegetation cover and any types of weather effects. Microwave reflection (backscattering), in active mode, and emissions, in passive mode, from earth surface are not bound by the time of data acquisition and hence microwave sensors are capturing surface data in day and night also. On the other hand, the amount and nature of backscattered electromagnetic radiation can give information about the size, shape, configuration and electrical properties of the surface objects. These advantages response of the Microwave Remote Sensing is mainly useful for timely monitoring of soil moisture, crop, vegetation, snow

cover, geological features, coastal zone, urban extent, manmade targets, ocean wind vector, wave spectra, wave height and atmospheric parameters. There for increasing the verity of applications in spatial planning due to microwave remote sensing's capability.

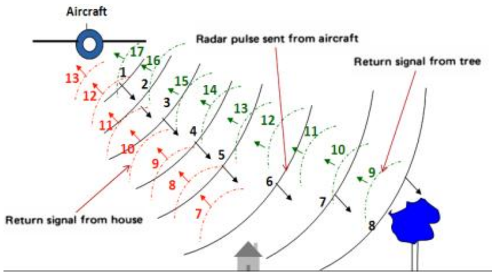

Fig 3: Microwave Remote Sensing

4. SYNTHETIC APERTURE RADAR

A Synthetic Aperture Radar (SAR) is an airborne or space borne side looking radar (SLR) system which utilizes the flight path of the platform to simulate a very large antenna or aperture electronically, which helps for generates high-resolution remote sensing imagery, (Fig 4). Synthetic Aperture Radar is originated as an advanced form of side-looking airborne radar (SLAR) which is the form of radar and it use of relative motion; between an antenna and its target region for obtain finer spatial resolution. SAR is implemented by mounting, on a moving platform of aircraft or spacecraft, a single beam-forming antenna from which a target scene is frequently illuminated with pulses of radio waves at wavelengths from 1mm to 1m. SAR images have extensive applications in remote sensing for the mapping of the surfaces of the earth. It has potential for agricultural mapping, environmental monitoring, resource mapping, disaster supervision, and military systems managements because of broad-area imaging at high resolutions. A technique closely related to SAR uses an array (referred to as a "phased array") of real antenna elements spatially distributed over either one or two dimensions across the range dimension. These arrays are truly synthetic ones, indeed being created by synthesis of a collection of subsidiary physical antennas. Their operation need not involve motion relative to targets. Image resolution of SAR in its range coordinate (expressed in image pixels per distance unit) is mainly proportional to the radio bandwidth of whatever type of pulse is used during the Remote Sensing of present topographical regions. The basic design of a synthetic-aperture radar system can be improved to gather more information. Most of these methods use the same basic principle of combining many pulses to form a synthetic aperture, but may involve supplementary antenna or significant additional processing.

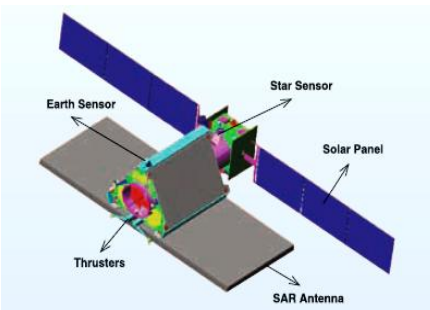

Fig 4: Structure of Risat-1 satellite

4.1 How does Synthetic Aperture Radar work?

In a given Fig (Fig 4) a detailed structure explained that the how SAR is works? The Airborne SAR imaging perpendicular to the aircraft velocity as shown in the Fig below. Typically, SARs produce a 2-D image, such has one dimension in the image is called range or cross track and is a measure of the "line-of-sight" distance from the radar of aircraft to the ground target. Range measurement and resolution are acquired in SAR as a same method as most other radars. In this system time is measured from transmission of a pulse to receiving the repeat (Echo) from a surface target. SAR, range resolution is depend on transmitted pulse width, such has narrow pulses yield fine range of resolution and long pulses yield lesser range resolution. Image resolution of SAR in its range coordinate (image pixels per distance unit) is mainly proportional to the radio bandwidth of whatever type of pulse is used. The other dimension is called azimuth or along track and is perpendicular to range and has a ability of SAR to produce relatively fine azimuth resolution. To obtain fine azimuth resolution, a large antenna is needed to focus the transmitted and received energy into sharp beams. The azimuth resolution depends on the sharpness of the beams. Likewise, optical systems, mainly telescopes, require large apertures (mirrors or lenses) to obtain grater imaging resolution. A narrow synthetic beam width results from the relatively long synthetic aperture, which yields finer resolution. The azimuth resolution of a SAR is depends on length of the antenna (not depend on platform altitude), full-coherent transmitter, an efficient and powerful SAR-processor, and flight path and the velocity of the platform. The SAR was used on board of a Space Shuttle during the Shuttle Radar Topography Mission (SRTM) which has given the earth surface data in Three Dimension (3D). It is the NASA's Shuttle Radar Topography Mission (SRTM), which covered approximately 80% of the earth's surface, with a global resolution of 90 m. and a resolution of 30 m. over the USA which covers the planet earth from 56° south to 60° North. Some time, distortions are produced during SAR remote sensing; such has slant-range distortion, Foreshortening, Layover, and shadowing effect etc are responsible for generating the distortions in SAR satellite imagery data.

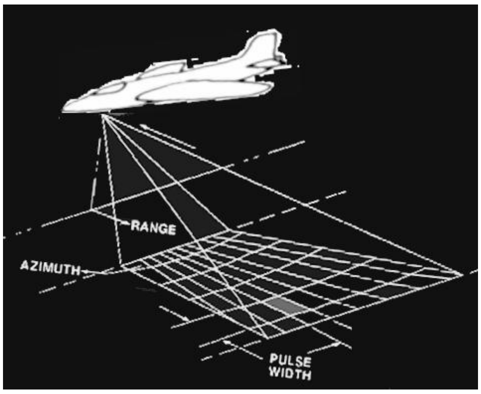

Fig. 5: Synthetic Aperture Radar Imaging

4.2 Synthetic Aperture Radar's Developments in World

Carl A. Wiley, a mathematician at Goodyear Aircraft Company in Litchfield Park, Arizona, invented synthetic-aperture radar in June 1951. In early 1952, Wiley, together with Fred Heisley and Bill Welty, constructed a concept validation system known as DOUSER (Doppler Unbeamed Search Radar). Independently of Wiley's work, experimental trials in early 1952 by Sherwin and others at the University of Illinois' Control Systems Laboratory showed results that they pointed out "could provide the basis for radar systems with greatly improved angular resolution" and might even lead to systems capable of focusing at all ranges simultaneously. During the 1950s and 1960s, Goodyear Aircraft (later Goodyear Aerospace) introduced numerous advancements in SAR technology. A more advanced focused-radar project was among several remote sensing schemes assigned in 1953 to Project Michigan, a tri-service-sponsored (Army, Navy, Air Force) program at the University of Michigan's Willow Run Research Center (WRRC), that program being administered by the Army Signal Corps.

The SAR principle was first acknowledged publicly via an April 1960 press release about the U. S. Army experimental system, which consisted of an airborne element made by Texas Instruments and installed in a 'Beech L-23D' aircraft and a mobile ground data-processing station made by WRRC and installed in a military van. SAR-Lupe is Germany's first investigation satellite system and is used for military purposes. The SAR-Lupe program related to five identical (770kg) satellites, developed by the German Aeronautics Company. SAR-Lupe's "high-resolution" images can be acquired day or night throughout all weather conditions. The first satellite was launched from Plesetsk (Russia) on 19 December 2006. Four more satellites were launched at roughly six-month intervals, and the entire system achieved full operational readiness on 22 July 2008. On 30 July 2002 a cooperation agreement between Germany and France was signed, under which the SAR-Lupe satellites and the French Helios optical investigation satellite will operate jointly. Other European Union (EU) countries have been invited to join as well as Italy has shown considerable interest for SAR implementation for finer Remote Sensing. In India first indigenous all-weather Radar Imaging Satellite, RISAT-1, launched successfully from Sriharikota (Andhra Pradesh), dated on April 26, 2012 by the Indian Space Research Organization. This Synthetic Aperture Radar technique first time used in India, hence the Risat-1 images will facilitate agriculture and disaster management because of its day-night, all-weather monitoring capability.

4.3 Synthetic Aperture Radar Applications

The increasing Synthetic Aperture Radar (SAR) principal in Remote Sensing fields in the most of the world and also in Indian Remote Sensing growing the capability of ground truth information for variety of spatial planning and its developments. Here a few of the applications of synthetic aperture radar explained. These applications increase almost daily as new technologies and innovative ideas are developed because of the SAR having the capability of Remote Sensing in all-weather and day-or-night at finer resolutions.

4.3.1 Monitoring of Environment and Resources

There is large diversity in environment in the world and also in India having the regional diversity of environment. There for the diversity is generated in the cultural resources due to physical diversity. Synthetic aperture radar is used for a wide variety of environmental applications, such as monitoring of crop characteristics, deforestation, ice flows, oil spills, Roads network density, forest fire, mining, urban growth, etc. Oil spills can often be detected in SAR imagery because the oil changes the backscatter characteristics of the ocean. Ex. Oil Spills in Arabian Sea near Mumbai in 2011. It can be noticed the presence of oil because of decreasing the radar backscatter from ocean. Thus, oil slicks appear dark in SAR images relative to oil-free areas. The change in natural phenomena can be also noticed and monitored by SAR imagery for verity of land use changes analysis and its future predictions. River is important resources for the surrounded regions developments which is useful for all biotic life. It can be also be under supervision time to time for frequent change analysis, (Fig 6).

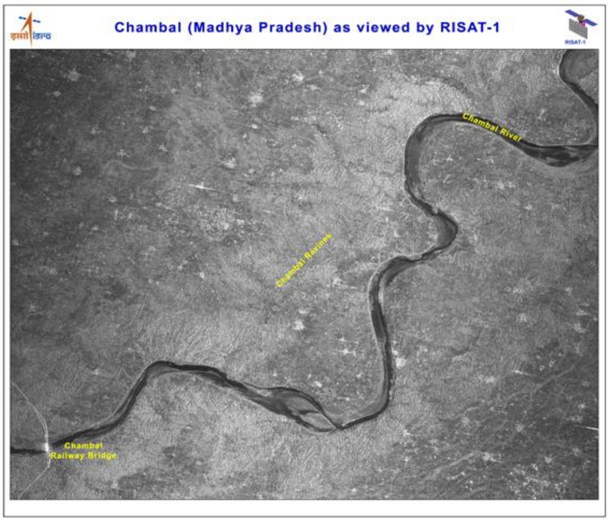

Fig. 6: Chambal River (MP) viewed by Risat-1 Satellite (Source: ISRO Website)

4.3.2 Surveying

Surveying is the main task of land measurements with surface resources mapping. Traditional surveying is time consuming and less precise. Synthetic Aperture Radar is advance sources for investigation, observation, and targeting of any objects of ground. SAR provides adequately high resolution to differentiate terrain features and to identify selected man made targets by surveying over SAR satellite imagery data.

4.3.3 Three Dimension (3D) data of Surface

We know that our earth is undulating, and having the diversity of physical feature over the earth surface on large scale. There for the 3D information is essential for monitoring of area and implementation of various planning related to topography. The Interferometric synthetic aperture radar (IFSAR) data can be acquired using two antennas on one aircraft or by flying two slightly offset passes of an aircraft with a single antenna. So the IFSAR can be used to generate very accurate surface profile maps of the terrain for several types of planning, such has dam construction, road construction, wind mill site suitability, surveying of canal site etc.

4.3.4 Ground Penetration

Owing to the most of surface barrier, such has trees, brush, and other ground cover we could not the observed or monitor the hidden targets. But Synthetic aperture radars must operate at relatively low frequencies (10's of MHz to 1 GHz) which offer the capability for penetrating materials which are optically opaque, and thus not visible by optical or IR techniques. According to few recent studies observed that the SAR may provide a limited capability for imaging selected underground targets, such as utility lines, arms caches, bunkers, mines, etc. the penetration depth depend on soil conditions, its moisture content, conductivity, and target size. For example in dry sand, penetration depths of 10 meters are possible to SAR.

4.3.5 Moving Object Information

SAR not only detect the static object but also giving the moving objects information which is in motion over the ground such as a car, truck, or military vehicle etc. Sandia is one of the parts of the world who has developed these types of techniques to automatically notice surface based moving or dynamic targets and to extract target information such as location, speed, size, and Radar Cross Section (RCS) from these target signatures. In these types of applications is mostly useful for unexpected change analysis and predictions of disaster.

4.3.6 Navigation

SAR provides the day and night as well as all-weather data, there for it provides the capability for autonomous navigation and guidance. It is done by forming SAR reflectivity images of the terrain and then correlating the SAR image with a stored reference (previous SAR image), hence, the navigation update can be obtained to us. SAR may also be used to guidance applications by pointing the antenna beam in the direction of motion of the airborne platform. In this approach, the SAR may image a target and guide for navigation with high accuracy.

4.3.7 Change Detection

SAR having the capability to change detection between imaging passes. By analyzing the imagery can be detect whether or not a change has occurred between two images. Here only same areas image are required or the same scene of area, but at different times. These are observed after the rectification process in GIS software. The images are geometrically registered so that the same target pixels in each image align or similarly superimposed over one another. Then the change is observed between the various types of same areas image. The SAR satellite data can be comparing with the other satellite data also for understanding the differentials features or changes in ground, (Fig 7).

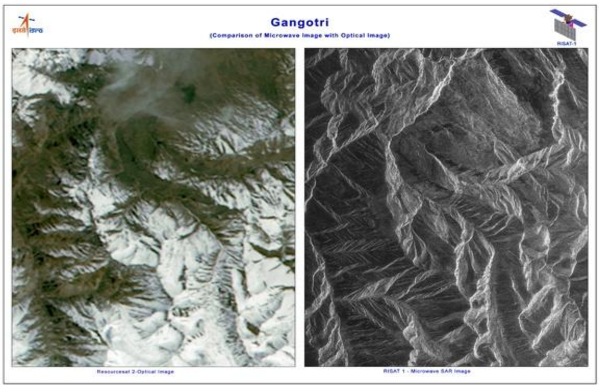

Fig 7: Comparison of Microwave and Optical Image of Gangotri's same Area (Source: ISRO)

4.3.8 Other Applications

SAR having the verity of applications for the detail spatial planning, such has the classify the kind of vegetation, military context (aircrafts and high flying unmanned platforms carry sensors for wide area observation and miniaturized SAR equipment is used for integration into drones for battle field observation), to monitor a ground area, high resolutions satellite images of surface. Synthetic aperture radar technology has provided terrain structural information to geologists for mineral exploration, oil spill boundaries on water to environmentalists, sea state and ice hazard maps to navigators, and investigation and targeting information to military operations. There are many potential applications for civilian, administration, industry. In last few decades this technology has not yet been adequately explored because of higher coast and maintenance. But now a day it become useful because of the lower cost electronics are just beginning to make SAR technology economical for smaller scale uses.

5. DISCUSSION

An Indian Remote Sensing technology is becoming the leading in the world due to the day by day advancement in space borne applications program. The Synthetic Aperture Radar (SAR) is an all-weather imaging tool that achieves fine along-track resolution by taking the advantage of radar motion to synthesize a large antenna aperture. India consists with sub-tropical climatic zone where the diversity of clouds, rains, day-night phenomena, seasons and physical structure also. Hence, the normal Remote Sensing could not useful for all seasons and day-night monitoring. There for the first time implementation of SAR techniques in RISAT-1 satellite will open the new gate way of research, educations, business, spatial planning as far as agricultural monitoring, military strategy, and disaster management.

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