Remote Sensing: Essentials and Applications

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Abstract— Remote sensing has been developed from earlier technologies such as surveying, photogrammetry, cartography, mathematics and statistics. In 1970s, first remote sensing satellite Landsat -1 was launched which provided continuous observation of Earth's land areas. In early decades of 21st century, owing to internet availability, public access to remote sensed data was available when Google earth was first launched. Today, remote sensing has become a very sophisticated procedure to monitor Earth's environment. This paper briefly covers the remote sensing basics, types of the methodologies adopted for the procedure and its applications. As a concluding remark, a history of Indian remote sensing is tabulated.

Key words — Radar clutter, Airborne radar, Spaceborne radar, backscattering, sea clutter, Light detection and ranging, Synthetic aperture radar, Swath

I. INTRODUCTION

Remote sensing, if interpreted by literal meaning, states to sense something remotely (without being touched, from distance). Technically, it is the field of science that deals with gathering information about various targets (e.g. Earth's surface, atmospheric conditions, etc.). Figure 1 shows the process of remote sensing paraphrased. The energy sources can be widely distributed as active or passive sources.[1] Active sources do not require light sources where as passive sources do require other light sources to capture the target details..
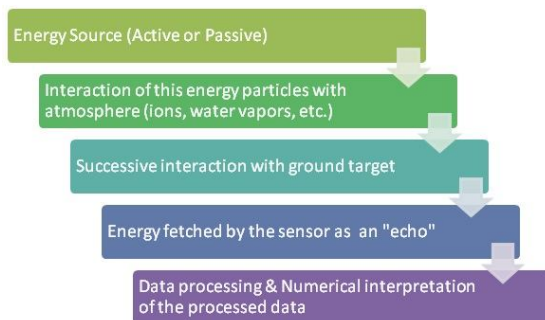

Figure 1 Remote Sensing Process

Figure 2 Active and passive sources[6]

Radiations from the passive sources (like Sun) or active sources (like camera on sensor) will strike the target and pass through atmosphere again before reaching sensor. This two way distance that radiation travels is called path length Microwave radiation is the longest wavelength used for remote sensing. The relationship between energy and wavelengths has connections with remote sensing.

$$Q = \frac{hc}{\lambda}$$

The above equation states that for the detection of the low energy microwaves (with large wavelength), sensor needs to remain fixed over site for comparatively long period of time. Low energy microwaves detection is done by viewing larger area. Using Wein and Stephan Boltzmann laws one can relate temperature, wavelength, frequency and intensity of energy as follow:

$$Lm = \frac{A}{T}$$

where Lm = Maximum wavelength , A = 2898 μm Kelvin, T = temperature emitted by body (°K).

$$M = \sigma T^4$$

where M = radiant surface energy (Watts), σ = Stephan Boltzmann constant = 5.6697 X 10^{-8} W/m^{2}K^4

Using this relation, ocean water temperature distribution can be mapped by measuring emitted radiation. Also the surface temperature of distant solar system can be estimated.
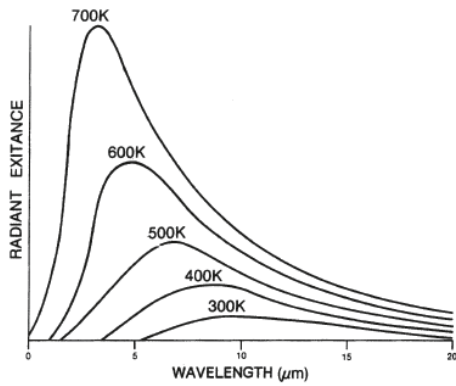
Figure 3 Wien's displacement law

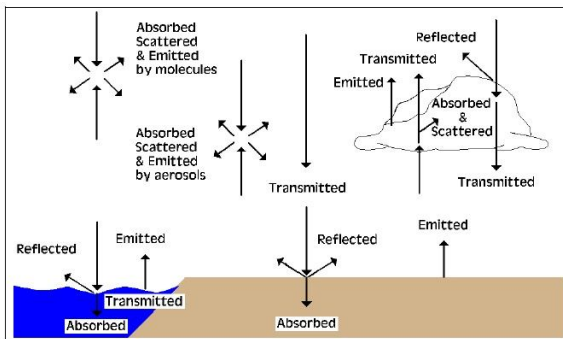Energy that reaches the target will be
a) Absorbed
b) Transmitted
c) Reflected

Figure *4* Radiation obstacles and scatter paths
(*http://orbit-net.nesdis.gov/arad/fpdt/tutorial/12-atmra.gif* and
http://rst.gsfc.nasa.gov/Into/Part2_4.html)

As seen in the figure 3 owing to the interactions with the atmosphere, three types of scattering occur mainly. Scattering and absorption in the atmosphere affect the intensity, direction as well as the wavelength of the radiations.[2] Rayleigh scattering dominates if the diameter of the particles in atmosphere is much smaller than incoming radiation wavelength (ф<λ). If the diameter of the climatic particles is equal to wavelength of radiation then Mie scattering occurs. It dominates in humid conditions. When the diameter of aerial particles gets much larger than incoming radiation, it results in white appearance in the sky and is known as non selective scattering.

Echo is the energy that is reflected back to the sensor from the target. This is required to be converted to digital form and processed well to be interpreted by operator. This processed data stored in sensor of the satellite and is sent to the Earth station through line-of-sight communication. It is similar to that of transmitting radio signals.

Final block of figure 1 denotes satellite receiving stations. Satellites can transmit the data only when in the range of the receiving station, else they keep storing the data. Received data is decoded and recorded on ROM.

II. SOURCES OF ERRORS

The errors that occur during acquisition can be random and non random. Major sources of errors are:
i)   Geometric effects: Errors due to sensor angle, path length, etc.
ii) Sea clutter & ground clutter: Reflections from the non uniform sea surface or from ground(other than target echo)

Geometric corrections can be made by re-sampling an image with the use of image processing tools or special softwares. Overall, data corrections are required for computation of reflectance & radiance values. Also, the correction is required for the reducing positional distortions. There is a record of the empirical data of the ground at the time the sensor passes overhead. This data is used to compare with the image data obtained and necessary correction is applied accordingly.

Another way is to use a mathematical model instead of an empirical model to correct the values received. A set of mathematical models have been developed recording the atmospheric conditions and this is then used as a reference to compare the data obtained. Consequently, the changes are applied.

III. RADAR IMAGES AND BACKSCATTERING

Radar images are formed of many pixels. These pixels represent radar backscatter for that area on ground. Low backscatter is represented by darker areas in image and high backscatter is represented by brighter areas. Bright areas correspond to large amount of energy reflection back to radar. While dark areas correspond to little energy reflections. Hot surfaces that reflect very minute microwave energy towards radar will always seem dark in radar images. Vegetation tends to appear rough on scale of most radar spectrum so it is captured as grey or light grey in radar image. Backscatter is dependent on target's electrical characteristics; wetter objects appear brighter though smooth water body acts like flat surface and hence appear dark.

Various observation angles have some impact on backscatter. Incidence angle causes variation in backscatter (low incidence angles leads to high backscatter). Low incidence angle corresponds to perpendicular to the surface.

A captured image is subdivided into small pixels and representing the brightness of each pixel with some number (digital). The computer displays each of these numbers as different levels of brightness. Hence the energy sensed by the sensor is recorded as an array of numbers in digital format. The information gathered from narrow wavelength range is stored in a channel. This information is combined digitally and can be displayed using three primary colors (red, green and blue)[6].
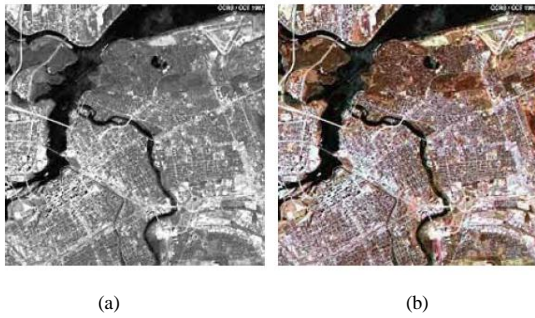
(a)   (b)

Figure 5 a) black and white image from a single channel and b) color image from the combination of channels

As shown in figure5a the image is being displayed using the single channel. And figure 5b denotes the image that has been displayed by the combination of three channels of RGB to form a color image.

IV. REMOTE SENSING INSTRUMENTS

The instruments used for the remote sensing are classified on the basis of the mode of their operation whether they belong to an active source system or passive source system. Though in this paper, it is listed in generalized overall types that have been widely used for the remote sensing. These are:

a) Aerial photography: Black and white photography which records grey shades in visible spectrum. Must operate in day light.

b) Color Infrared Film (CIR): Detects longer wavelengths around and beyond red end of the light spectrum. Can also detect the minute details of vegetation.

c) Thermal Infrared Multispectral Scanner (TIMS): Used to detect ancient Anasazi roads in Chaco Canyon, NM. Can be used for archaeological research.[2]

d) Airborne Oceanographic Lidar (ADI): It is laser device that gets the details about Earth's surface. Lidar helps to get the details about the heights of the forest. Also used to detect oil farms, water clarity and organic pigments like chlorophyll.

e) Synthetic Aperture Radar (SAR): Most common method of remote sensing. Can be airborne as well as space borne. It is sensitive to vegetation and ground surface phenomena.

f) Microwave radar: Widely used to find buried artifacts in arid regions.

Remote sensing methods when classified as passive and active then we can list them as radiometer and spectrometer as passive methods whereas radar, scatteroemter and lidar as active methods. Radiometer is a tool which is designed to measure electromagnetic radiation. It is equipped with various electromagnetic wavelength detectors. Spectrometer is a tool to observe and explicate spectral components of electromagnetic spectrum. Scatterometer's concept is similar to that of radar. It basically operates at high frequency especially to determine wind direction and speed over ocean surface. Lidar is LIght Detection And Ranging. It uses laser to transmit a light pulse and receiver to sense echo light. Lidars are normally used to provide an outline of atmospheric components like aerosols, clouds, etc.
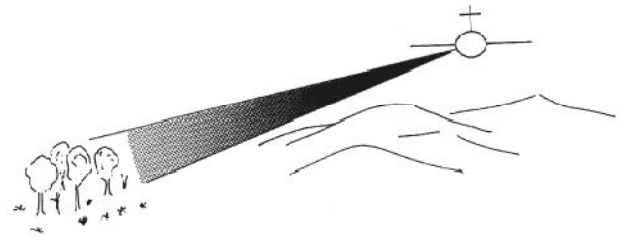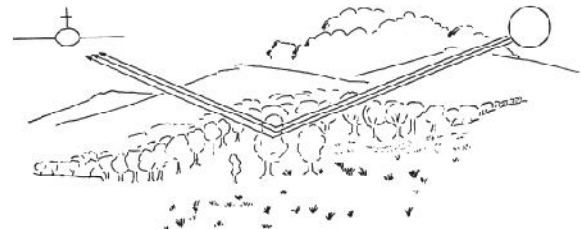

Figure 6 Active remote sensing

Figure 7 Passive remote sensing

V. DECIDING FACTORS OF PROPER RADAR PARAMETERS

In order to design a healthy remote sensing system, we need to keep the radar parameters to be properly chosen as radar plays the vital part in remote sensing. Following are the few important parameters of radar that will affect the quality of remote sensing.

a) Wavelength: Radar wavelength better be matched with target size. E.g. for sensing ice details (small details) it is preferable to use X- band; for geology mapping, L-band is used. In general C- band is good compromise.
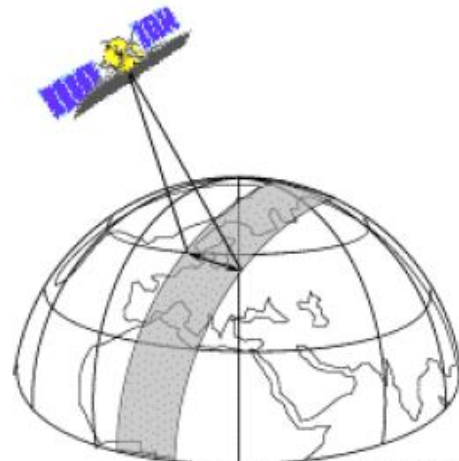

Figure 8 Swath: the area imaged on the Earth's surface[6]

a) Polarization: Basically SAR have one polarization viz. HH or VV. Though research shows that multiple polarization aid in distinguishing physical structure of targets. E.g. HV – vegetation, HH or VV phase angles – corner structures and VV – Ocean (Bragg scattering).

b) Swath width: This is widely dependent upon the data handling capacity and range obscurities.

VI. AIRBORNE AND SPACE BORNE REMOTE SENSING

In airborne remote sensing, an aircraft is equipped with downward or sideward sensors. Owing to the proximity to earth's surface, it has an advantage of providing very high spatial resolution (size of the smallest object that can be resolved on the ground) images in order of tens of centimeters. Analog aerial photography wherein the photographs are digitized by a scanning device for computer assisted analysis. Digital photography allows real time transmission of the data being sensed by the sensor to the Earth station providing immediate access to data analysis.
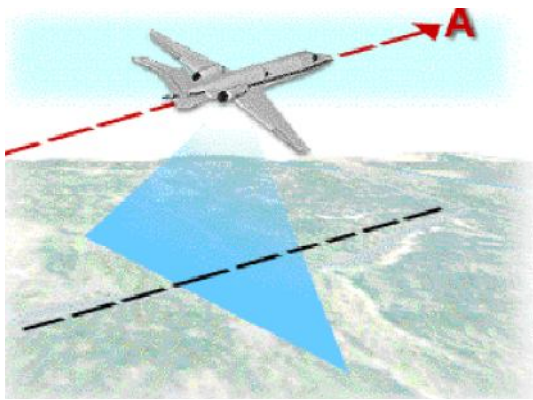

Figure 9 Airborne remote sensing (courtesy Canada centre for Remote Sensing)

In addition to the above mentioned methods, SAR also uses the airborne platform. Airborne remote sensing is a good choice for high resolution data, but at the cost of low coverage area and cost.

In Space borne remote sensing, sensors are mounted on board a satellite orbiting around the Earth. As an obvious reason of being at a higher altitude, the coverage area is quite more than that in airborne systems. But it comes with the compromise in resolution. The latest research has shown resolution of about 1m[8].

Space borne systems have other advantages of being cost effective for the coverage of large area, continuous monitoring of the target, semiautomated processing and analysing over airborne systems which are basically one time operation based. Few of the examples of space borne systems are SPOT – 1, 2, 4; OrbView -2 (SeaStar); NOAA – 12, 14 ,16; RADARSAT series, ERS series.repeated
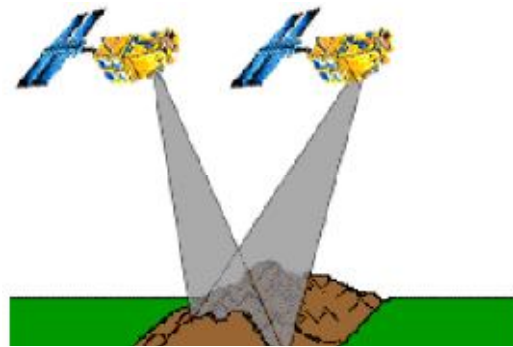

Figure 10 Space borne remote sensing (Courtsey: Canada centre of remote sensing)

VII. INDIAN REMOTE SENSING

Theoretically, the idea of the remote sensing was put forward by Dr. Sarabhai influenced by the experimental stage of the satellite application in US. Dr. Sarabhai was certain that it would not be wise to wait till our own satellites to be used for the applications. Instead, he thought of using other countries' satellites in order to develop necessary ground system and by the time our own firm of satellites gets developed, our scientists are well trained of the technology to be used for satellite design, launch and working. Practically, remote sensing started with an infra-red aerial survey to study root-wilt disease of coconut trees in Kerala in 1970. India requested the access to the America's Landsat before it was even launched. So India became one of the preliminary users of Landsat by mid 1972. After launching the initial satellites like Aryabhata and Bhaskara, India moved forward with IRS – series. Table 1 shows the summary of the history of the Indian remote sensing satellites. Launch of experimental satellites like TES made India the second country after US to offer images with 1 m resolution.

Satellite	Launch – date	Launch – site	Features & functions	Mission life
Bhaskara - I	7th June 1979	(Russia)	Experimental satellite On – board TV cameras.	1 year
RS-D1	31st May 1981	SHAR (India)	Experimental satellite	Failed
Bhaskara – II	20th Nov 1981	(Russia)	Improved payload compared to Bhaskara – I	1 year
Rs-D2	17th Apr 1983	SHAR (India)	Experimental mission	17 months
IRS- 1A	17th Mar 1988	Kazakhstan	Carried two cameras Swath width – 140km	8 years, 4 months
SROSS – 2	13th Jul 1988	SHAR (India)	Experimental	Failed
IRS – 1B	29th Aug 1991	Kazakhstan	Gyro referencing for better orientation sensing time tagged commanding	12 years, 4 months
IRS – 1E	20th Sep 1993	SHAR (India)	Monocular electro-optical stereo	Failed

			scanner	
IRS – P2	15th Oct 1994	SHAR (India)	Operational remote sensing	3 years
IRS – 1C	28th Dec 1995	Kazakhstan	Second generation operational remote sensing satellite Better spatial resolution	11 years, 8 months
IRS – P3	21st Mar 1996	SHAR (India)	Carries two remote sensing payloads – wide field sensors (WiFS) Modular Opto – electronic Scanner (MOS)	9 years 10 months
IRS – 1D	27th Sep 1997	SHAR (India)	Operational remote sensing	12 years, 3 months
Oceansat (IRS-P4)	26th May 1999	SHAR (India)	First satellite built primarily for ocean applications	11 years, 2 months
TES	22nd Oct 2001	SHAR (India)	Experimental satellite Helped US army with high resolution images during 9/11 counter terrorism offensive against Taliban	Success
Resources at-1 (IRS-P6)	17th Oct 2003	SHAR (India)	Most advanced remote sensing satellite of ISRO as of 2003	In service
CARTOS AT – 1	5th May 2005	SHAR (India)	First Indian remote sensing satellite providing in-orbit stereo images used for cartographic applications	In service
CARTOS AT -2	10th Jan 2007	SHAR (India)	Operational remote sensing	In service
CARTOS AT – 2A	28th Apr 2008	SHAR (India)	13th satellite of IRS series	In service
IMS -1	28th Apr 2008	SHAR (India)	Low cost microsatellite imaging mission	In service
RISAT – 2	20th Apr 2009	SHAR (India)	India's first dedicated reconnaissance satellite	In service
Oceansat - 2	23rd Sep 2009	SHAR (India)	Three payloads: OCM, Ku band Pencil Beam scatteroemter (SCAT) and Radio Occultation Sounder for atmosphere ROSA	In service
CARTOS AT – 2B	12th Sep 2010	SHAR (India)	Swath – 9.6km with resolution better than 1m	In service
Resources at – 2	20th Apr 2011	SHAR (India)	18th remote sensing satellite built by ISRO Enhanced spatial coverage	In service
Megha – Tropiques	12th Oct 2011	SHAR (India)	Indo – French Joint satellite mission For water cycle	In service
RISAT – 1	26th Apr 2012	SHAR (India)	With SAR payload Imaging of surface features during day and night under all weather conditions	In service
SARAL	25th Feb 2013	SHAR (India)	Indo – French satellite mission For oceanographic studies Marine meterology and sea state forecasting Climate monitoring	In service

Table 1
(Courtsey: http://www.isro.org/satellites/earthobservationsatellites.aspx)

VIII. CONCLUSION

Remote sensing has become a vital part of the space missions. Globally, researches are carried out in this field on large scales. Experimental missions aid the successive launch of commercial satellite missions. Remote sensing offers services that are useful for ocean monitoring, to detect the harmful contents in environment, to forecast weather, to study irrigation needs, fisheries, natural disasters like flood, drought management, polar ice studies, etc. Lots of advances are yet to come in this field which would facilitate to control several aspects to save "Mother Earth".

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