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Radar Satellites: Concept, Applications and Challenges

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ABSTRACT: In this paper the technological concept and instrumental function of RADAR satellite payload is reviewed. RADAR satellite uses and process radio waves to determine objects and its conditions a technology termed as active remote sensing. This is differentiated from optical system technology that naturally uses reflected energy from the targets and is termed as passive system. Synthetic Aperture RADAR(SAR) principle permits RADAR systems to acquire images of fine spatial detail at high altitudes than real aperture remote sensing systems. SAR have the ability to acquire images in darkness and through cloudy weather conditions, a feature making it a powerful remote sensing instrument than optical systems. The social and economic applications of SAR systems in Nigeria are discussed in this paper. SAR is characterised with the capability of artificially illuminating targets and collecting information via radio frequency, the image processing and interpretation challenges is one aspect presented in this paper.

KEYWORDS: SAR, Concept, Applications, Challenges.

I. INTRODUCTION

RADAR is an object detection system that uses radio waves to determine the range, angle or velocity of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formation and terrain [1]. A RADAR transmits radio waves or microwaves that reflect from any object in their path. A RADAR receiver which is typically the same system as the RADAR receiver processes the reflected waves to determine properties of the object. The limitation of optical sensors for operations during dark and cloudy weather conditions necessitated the use of RADAR active sensors which operate in all weather conditions. The modern uses of RADAR are highly diverse including air and terrestrial traffic control, RADAR astronomy, air defense systems, anti missile systems, marine RADARs to locate landmarks. These applications are not adequately addressed by optical systems including high resolution sensors such as Nigeriasat2 and UK-DMC2. However, the employment of RADAR satellite will resolve and improve in Nigeria challenging security and industrial applications. There are number of challenges associated with RADAR technology and data interpretation as discussed in section X. This paper is organized in twelve sections. Apart from section I which is introduction the remaining sections II-XII discuss on Radar Concept and Principles, Geometry of Radar Imaging System, Radar Resolution, Synthetic and Real Aperture System, SAR Imaging Techniques, SAR Hardware and Software Components, Inverse SAR, Radar Applications, SAR Challenges and Limiting Factors, Conclusion and references respectively

II. RADAR CONCEPT AND PRINCIPLES

A RADAR system has a transmitter that emits radio waves called RADAR signals in predetermined directions. When these come into contact with an object they are usually reflected or scattered in many directions. RADAR signals are reflected especially well by materials of considerable electrical conductivity—especially by most metals, by seawater and by wet ground. Some of these make the use of RADAR altimeters possible. The RADAR signals that are reflected back towards the transmitter are the desirable ones that make RADAR work. If the object is moving

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either toward or away from the transmitter, there is a slight equivalent change in the frequency of the radio waves, caused by the doppler effect. RADAR receivers are usually, but not always, in the same location as the transmitter. Although the reflected RADAR signals captured by the receiving antenna are usually very weak, they can be strengthened by electronic amplifiers. More sophisticated methods of signal processing are also used in order to recover useful RADAR signals. The weak absorption of radio waves by the medium through which it passes is what enables RADAR sets to detect objects at relatively long ranges—ranges at which other electromagnetic wavelengths, such as visible light, infrared light, and ultraviolet light, are too strongly attenuated. Such weather phenomena as fog, clouds, rain, falling snow, and sleet that block visible light are usually transparent to radio waves. Certain radio frequencies that are absorbed or scattered by water vapour, raindrops, or atmospheric gases (especially oxygen) are avoided in designing RADARs, except when their detection is intended.

RADAR relies on its own transmissions rather than light from the Sun or the Moon, or from electromagnetic waves emitted by the objects themselves, such as infrared wavelengths (heat). This process of directing artificial radio waves towards objects is called illumination, although radio waves are invisible to the human eye or optical cameras[2]. Figure 1 describes the basic functions of a RADAR imaging activity. If electromagnetic waves travelling through one material meet another material, having a very different dielectric constant or diamagnetic constant from the first, the waves will reflect or scatter from the boundary between the materials. This means that a solid object in air or in a vacuum, or a significant change in atomic density between the object and what is surrounding it, will usually scatter RADAR (radio) waves from its surface. This is particularly true for electrically conductive materials such as metal and carbon fibre, making RADAR well-suited to the detection of aircraft and ships. RADAR absorbing material, containing resistive and sometimes magnetic substances, is used on military vehicles to reduce RADAR reflection. This is the radio equivalent of painting something a dark colour so that it cannot be seen by the eye at night. RADAR waves scatter in a variety of ways depending on the size (wavelength) of the radio wave and the shape of the target. If the wavelength is much shorter than the target's size, the wave will bounce off in a way similar to the way light is reflected by a mirror. If the wavelength is much longer than the size of the target, the target may not be visible because of poor reflection. Low-frequency RADAR technology is dependent on resonances for detection, but not identification of targets. This is described by Rayleigh scattering, an effect that creates Earth's blue sky and red sunsets. When the two length scales are comparable, there may be resonances. Early RADARs used very long wavelengths that were larger than the targets and thus received a vague signal, where as some modern systems use shorter wavelengths (a few centimetres or less) that can image objects as small as a loaf of bread. Short radio waves reflect from curves and corners in a way similar to glint from a rounded piece of glass. The most reflective targets for short wavelengths have ninety degree angles between the reflective surfaces. A corner reflector consists of three flat surfaces meeting like the inside corner of a box. The structure will reflect waves entering its opening directly back to the source. They are commonly used as RADAR reflectors to make otherwise difficult to detect objects easier to detect. Corner reflectors on boats, for example, make them more detectable to avoid collision or during a rescue. For similar reasons, objects intended to avoid detection will not have inside corners or surfaces and edges perpendicular to likely detection directions, which leads to odd looking aircraft. These precautions do not completely eliminate reflection because of diffraction, especially at longer wavelengths. Half wavelength long wires or strips of conducting material, such as chaff, are very reflective but do not direct the scattered energy back toward the source. The extent to which an object reflects or scatters radio waves is called its RADAR cross section [3].

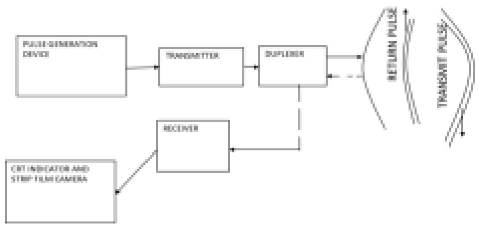

Figure 1: Block of a RADAR Functional Imaging System

A. RADAR equation

The power Pr returning to the receiving antenna is given by the equation:

$$Pr = \frac{PtGtAr\sigma F^4}{(4\pi)^2 R^2 t R^2 r} \quad (1)$$

where P_t = transmitter power, G_t= gain of the transmitting antenna, A_r = effective aperture (area) of the receiving antenna which is also expressed as $G_r\lambda^2/ 4\pi$ where λ= transmitted wavelength , G_r = gain of receiving antenna, σ = RADAR cross section, or scattering coefficient of the target, F = pattern propagation factor, R_t = distance from the transmitter to the target and R_r = distance from the target to the receiver.

Doppler RADAR and Pulse-Doppler RADAR frequency shift is caused by motion that changes the number of wavelengths between the reflector and the RADAR. That can degrade or enhance RADAR performance depending upon how that affects the detection process. As an example, Moving Target Indication can interact with Doppler to produce signal cancellation at certain radial velocities, which degrades performance. Sea-based RADAR systems, semi-active RADAR homing, active RADAR homing, weather RADAR, military aircraft, and RADAR astronomy rely on the Doppler effect to enhance performance. This produces information about target velocity during the detection process. This also allows small objects to be detected in an environment containing muchlarger nearby slow moving objects. Doppler shift depends upon whether the RADAR configuration is active or passive [4]. Active RADAR transmits a signal that is reflected back to the receiver. Passive RADAR depends upon the object sending a signal to the receiver. The Doppler frequency shift for active RADAR is given by the relation $F_D= 2 \times F_T \times (V_{R/} C)$ where $F_D$is Doppler frequency, $F_T$is transmitting frequency, $V_R$is radial velocity, and C is the speed of light. Passive RADAR is applicable to electronic countermeasures and radio astronomy is given as $F_D F_T \times (V_{R/} C.)$.Only the radial component of the speed is relevant. When the reflector is moving at right angle to the RADAR beam, it has no relative velocity. Vehicles and weather moving parallel to the RADAR beam produce the maximum Doppler frequency shift. Doppler measurement is reliable only if the sampling rate exceeds the Nyquist frequency for the frequency shift produced by radial motion. As an example, Doppler weather RADAR with a pulse rate of 2 kHz and transmit frequency of 1 GHz can reliably measure weather up to 150 m/s (340 mph), but cannot reliably determine radial velocity of aircraft moving 1,000 m/s (2,200 mph).In all electromagnetic radiation, the electric field is perpendicular to the direction of propagation, and this direction of the electric field is the polarization of the wave. In the transmitted RADAR signal the polarization can be controlled for different effects. RADARs use horizontal, vertical, linear and circular polarization to detect different types of reflections. For example, circular polarization is used to minimize the interference caused by rain. Linear polarization returns usually indicate metal surfaces. Random polarization returns usually indicate a fractal surface, such as rocks or soil, and are used by navigation RADARs.

B. RADAR Wavelength

Wavelengths are used to designate various RADAR systems velocity and changes as radiation passes through media of different density. Hence the choice of a particular wavelength, depend on the RADAR specific mission application. Equation (1) shows the relationship among wavelength and frequency.

$$C = \lambda f \qquad (2)$$

Where ƛ, C and f represent the wavelength, speed of light and frequency respectively. Table 1 shows the ƛ and frequency used in radar remote sensing.

TABLE 1: RADAR WAVELENGTH AND FREQUENCIES

Band Designation	ƛ(cm)	Frequency (Ghz)(10 Cycles/S)
Ka	0.8 – 1.1	40 – 26.5
k	1.1 – 1.7	26.5 – 16.0
Ku	1.7 – 2.4	18 – 12.5
X	2.4 – 3.8	12.5 – 8.0
C	3.8 – 7.5	8.0 – 4.0
S	7.5 – 15	4.0 – 2.0
L	15 – 30	2.0 – 1.0
P	30 – 100	1.0 – 0.3

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III. GEOMETRY OF RADAR IMAGING SYSTEM

One significant characteristic of RADAR system is the depression angle (α). α is defined as the angle between a horizontal plane and a beam from the antenna to a target on the ground as in figure 2 α is steeper at the near-range side of an image strip and shallower at the far-range side.

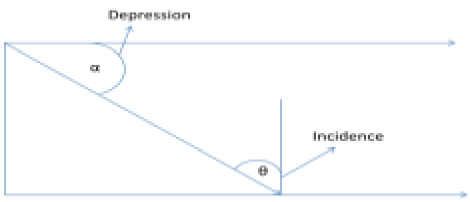

figure 2RADAR signal depression and incidence angles

An average depression angle of an image is measured for a beam to the middle of an image. Another geometric featured taken is the incidence angle (θ) and is defined as the angle between RADAR beam and a line perpendicular to the surface. In RADAR imaging for a horizontal surface α is complement of θ, but for inclined and high topographic area, the correlation between α and θ don't exist. The incidence angle θ more precisely describes the relationship of a RADAR beam and the imaging surface than does from the depression angle α. However, in practice the surface is assumed to be horizontal and the incidence angle is regarded as the angle between the RADAR beam and a vertical plane passing through the antenna. Look angle and off-RADAR angle are other terms that have been applied to the incidence angle. The spatial resolution of a RADAR image is determined from a combination of range and azimuth resolution discussed in section IV[3][4].

IV. RADAR RESOLUTION

The range and azimuth resolution determine the spatial resolution capacity of the RADAR imaging system. Range Resolution is basically determined by the depression angle and is equal to one-half the pulse length. Pulse length which is measured in micro second is the duration of the transmitted pulse. It can be converted from time in to distance by multiplying by the speed of electromagnetic radiation and the resulting distance is measured in the direction in which energy propagates from the antenna to the imaged target. However, range resolution is expressed in ground range which is the distance measured on the terrain. A Ground Range Resolution is obtained when the slant range distance is divided by the cosine of θ/2 of the depression angle (α).

For a given depression angle α_1 and α_2 the corresponding range resolutions are calculated as follows:

$$Rr1 = r1C/2\cos\alpha1 \quad (3)$$

$$Rr2 = r1C/2\cos\alpha2 \quad (4)$$

Hence for a depression angle of α1 and α2 and a pulse length of 0.2 sec, r1 and r2 are the corresponding range distances for α1 and α2 respectively. The target must be separated by Rr1m and Rr2m resolution to be resolved. Range resolutions improve at lower depression angle α2. This is because α2 is obtained at far-range (k-m target). This is shown in Figure 3 for target I-J located in the near range and target K-M located in the far range.

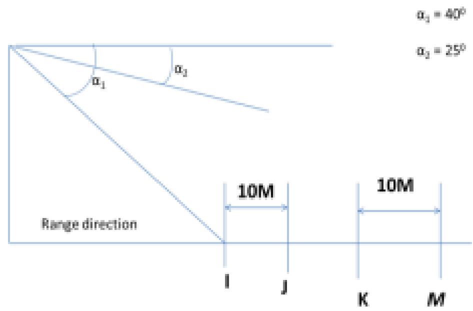

Figure 3: Range resolution at lower and far depression angle

Range resolution can be improved by a technique which employs shortening the pulse length and hence the total amount of the transmitted signal per energy per pulse is reduced. However, the energy and pulse cannot be reduced below the required level to generate a sufficient strong return from the target. Electronic method can be developed for shortening the apparent pulse length while providing adequate and required signal strength. This technique can be embedded within the receiver functionalities.

Azimuth resolution (Ra) in the azimuth direction is determined by the width of the target terrain illuminated by the RADAR beam. For target terrain to be resolved, target must be separated in the azimuth direction by a distance greater than beam width as measured on the ground. The RADAR beam is narrow in the near range than in the far-range resulting in the azimuth resolution

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being smaller in the near range portion of the image. Azimuth resolution is high in the short wavelength since angular beam width is directly proportional to wave length of the transmitted energy. However, the short wave length lack the capability desired for weather penetration. Also, angular beam width is inversely proportional to antenna length hence resolution improves in the longer antenna although there are practical limitations to the maximum antenna length. The equation for Ra is express as

$$Ra = 0.7S\lambda/D \quad (5)$$

Where S is the slant range distance, D is the antenna length. For t-band antenna system with ƛ = 3cm and D =500.3cm, at the near range position, the slant range is 10KM and therefore, Ra is calculated to be (10KM × 3cm)/5.3cm = 41.9m.

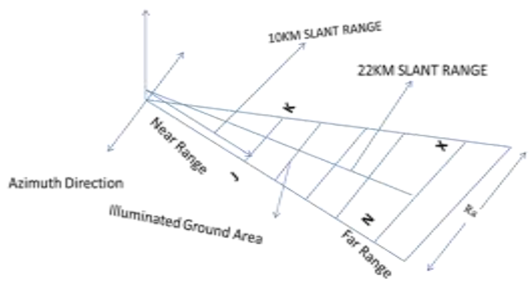

Figure 4: azimuth resolution at near and far range

This is shown in **Error! Reference source not found.**for target J-K and target Z-X. The target Z-X at far range is calculated to be 0.7 × (20km × 2cm) / 500.3cm = 83.9m hence the system could not be resolved. However in modern SAR technology, values greater than these in equation (5) are obtained[3][4].

V. SYNTHETIC AND REAL APERTURE SYSTEM

SAR and real Aperture (RA) primarily differ in the technique each employ to achieve resolution towards azimuth direction. The RA system uses a maximum practical length antenna to produce and receive a narrow angular beam width in the azimuth direction. The SAR uses small length antennas that transmits and receive a relatively broad beam. Special data processing techniques and the doppler principle are employed to synthesize the resolution in the azimuth direction of a very narrow beam. The SAR employs the principles of doppler to resolve the resolution produces by the very narrow beam of the small antenna length. Doppler principles state that the pitch (frequency) of a sound heard differs from the pitch of vibrating source whenever the listener and the source are in motion relative to one another. This is illustrated in Figure 6.

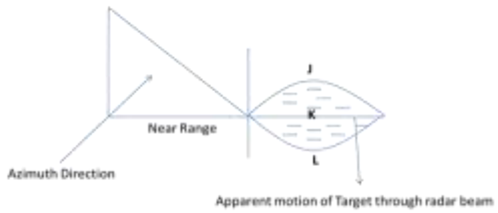

Figure 5 Apparent motion of target through RADAR beam

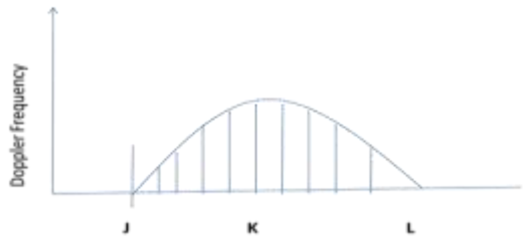

Figure 6: Doppler Frequency

The apparent motion of a target through the successive RADAR beams from point J-L as illustrated in Figure 5. This is as a consequence of the forward motion of the aircraft. The frequency and the energy pulse returning from the target increases from a minimum at point J to a maximum at point K normal to the RADAR system. As the target recedes from K-L the frequency decreases.

The return pulse data from target is recorded by a laser system that produces a holographic film record of the amplitude and phase history of the return from each target as the repeated RADAR beams pan across J to L of the target. The holographic film is then played to generate an image film. The record of the doppler frequency changes enables the target to be resolved on the image film though it had been observed with an antenna of length L as in **Error! Reference source not found.**. However, the range resolution is determined from pulse length and depression angle for both real aperture and SAR systems. The depression angle is shallower for the real aperture image which can result in longer shadow on images acquired in similar condition with SAR. In SAR image, spatial resolution is constant from the near to the far range while in real aperture resolution becomes purer at far-range.

SAR are more complicated in design and require sophisticated data recording and processing while the real aperture systems are simple in design and the coverage in the range direction is relatively limited and only shorter wavelength can be employed if high resolution is required. SAR systems maintain high azimuth resolution at long distance in the range direction at both long and short wavelength. The additional complexity and cost of SAR design are the main trade-off for these benefits[3][4][5]

VI. SAR IMAGING TECHNIQUES

The resolution and imaging capability of a RADAR system can be improved with a particular imaging technique design. The three major techniques are employed based on mission objectives and the design considerations. SAR strip map mode is a conventional mode which assumes a fixed pointing direction of the RADAR antenna broadside to the platform track. Strip mode measures the width of the SAR swath and then continues on the length contour of the flight line of the platform itself. This mode allows maximum coverage of the target rather than concentration on an improved resolution.

SAR- spot light mode operation allow the system to obtain a light resolution by steering the beam to keep the subject within the beam for a longer time and hence produce a longer synthetic aperture (SA). The employment of this technique allows improving the system images to better resolution. In this mode more pulse are used and therefore the azimuth resolution (section) is significantly improved. The longer time used to electronically steer the beam to one side of the target is usually at the expense of spatial coverage given a smaller swath than the strip mode.

SAR-scan mode operation has the capability to illuminate several sub-targets by pointing its antenna off-nadir into variable positions. This method can be used to improve the temporal resolution of a particular target of interest [3]

VII. HARD/SOFT WARE COMPONENT OF SAR

The hardware configuration depends on the capability and complexity of the system. It actually depends on the amount of pulse to be generated and the specified wavelength and frequency. However, the major and important hardware components consist of the RADAR antennas which transfer the transmitter energy to signals in space with the required distribution and efficiency. The transmitter component produces the short duration high-power radio frequency pulses of the energy that are into space by the antenna while the receiver component amplifies and demodulates the receive radio frequency signal. A duplexer is an alternative component that switches the antenna between the transmitter and receiver. This switch technique allows both the receiver and transmitter to be composed in a single component and disallow the high pulse of the transmitter to destroy the receiver.
The major and important software component of a RADAR system consists of the radiometric correction, geometric correction, modeling/inversion of the raw out of the SAR. Other components include post processing application such as image enhancement for better recognition, image transformation and image interpretation application [6] .

VIII. INVERSE SYNTHETIC APERTURE RADAR (ISAR)

ISAR is a technique using RADAR imaging to generate a two dimensional high resolution image of a subject. It is analogous to conventional SAR, except that ISAR technology utilizes the movement of the target rather than the emitter to generate the synthetic aperture. ISARRADARs have a significant role aboard maritime patrol aircraft to provide them with RADAR image of satisfactory quality to allow it to be used for target detection purposes. In situations where other RADARs display only a single unidentifiable bright moving pixel, the ISAR image is often sufficient to discriminate between various missiles, military and civilian aircrafts.

IX. RADAR APPLICATIONS

The modern uses of RADAR are highly diverse, including air and terrestrial traffic control, RADAR astronomy, air-defence systems, antimissile systems, marine RADARs to locate landmarks and other ships, aircraft anti-collision systems, ocean surveillance systems, outer space surveillance and rendezvous systems, meteorological precipitation monitoring, altimetry and flight control systems; guided missile target locating systems, ground penetrating RADAR for geological observations; and range controlled RADAR for public health surveillance[3]. High technology RADAR systems are associated with digital signal processing, machine learning and are capable of extracting useful information from very high noise levels. Other systems similar to RADAR make use of other parts of the electromagnetic spectrum. One example is "lidar", which uses ultraviolet, visible, or near infrared light from lasers rather than radio waves. RADAR technologies have potential and great impact in addressing needs in the areas of transportation and asset management, security, environmental monitoring, aviation and marine industries, geological survey and agriculture.

RADAR data can support Asset Management a major activity of transportation managers in which large volumes of data must be collected frequently. Evaluating the condition of assets allows managers to set priorities and estimate costs.

Surface roughness of roads and the mapping of road corridors can be done with SAR. Topographic data from ISAR sensors can provide high spatial resolution road maps. A better temporal resolution is achievable from RADAR technology which can provide coherent detection, which identifies surface changes over time, can be used to map pothole changes and areas where roads are sinking.

Ground Moving Target Indicator (GMTI)RADAR has practical applications for estimating vehicle counts, movements and speed. GMTI can help transform Intelligence, Surveillance and Reconnaissance (ISR). This technology is a mission area which can especially be used to arrest challenging security issues in Nigeria including Boko-Haram movements and activities around the country border and territories. The RADAR can depict enemy forces and their vehicular movements in near-real time mode over a large area of the country regardless of weather and day conditions. The asymmetrical advantage modern GMTI technology provides United State forces results from its unique ability to distinguish targets moving on land or water from surface clutter over a large area. This is possible even in bad weather and darkness conditions. The GMTI image shows moving vehicles as dots overlaid on a digital map. There are two types of GMTI RADAR: snapshot/static RADAR and continual observation or dynamic RADAR. Static RADAR provides an instantaneous picture of what was moving at a point in time with infrequent updates depicting moving target density. The Army OV-1 Mohawk's RADAR was an example of a static GMTI RADAR. Development of RADAR capable of continual observation was key to the immense operational value of GMTI information. The E-8C Joint STARS RADAR is an example of a dynamic GMTI RADAR system that provides periodic updates and allows precise tracking of a moving vehicle. A RADAR system's ability to provide detailed, near-real time information on vehicular movement depends on its ability to reliably detect, accurately locate, and precisely track slow moving ground targets. GMTI can provide vehicle information, such as the length and the configuration of specific vehicles within a freeway, even when RADAR returns are temporarily interrupted by terrain screening or aircraft turns. To provide precise, near-real time information on vehicles moving within a given area, a GMTI system must be able to generate and maintain numerous automatic tracks. The ability to do this depends on the system's performance in terms of the following metrics:

a) Probability of Detection – the probability of detecting a given target at a given range any time the RADAR beam scans across its path.
b) Vehicle Location Accuracy – a function of platform self-location performance, RADAR pointing accuracy, azimuth resolution, and range resolution..
c) Minimum Detectable Velocity – the minimum rate of movement that can be detected by the sensor.
d) Vehicle Range Resolution – the fidelity determining whether two or more targets moving in close proximity will be detected as individual targets.
e) Stand-off Distance – the distance separating a RADAR system from the area that it is observing.

Error! Reference source not found. is an example map from Ground Movement Tracking RADAR showing dots indicating vehicles along road networks. Ground Penetrating RADAR(GPR) can detect subsurface problems and buried utilities which can alleviate not only geological survey functions but security issues inclusively. GPR uses electromagnetic wave propagation and backscattering to image, locate, and identify changes in electrical and magnetic properties in the ground. GPR has the highest resolution of any geophysical method for subsurface imaging, approaching centimetres. Depth of penetration varies from meters to several kilometres depending upon the materials' properties. Detection of a subsurface feature also depends upon contrast in the dielectric electrical and magnetic properties. Interpretation of Ground Penetrating RADAR data can lead to information about depth, orientation, size, and shape of buried objects. GPR has utility for a variety of transportation applications These include: location of underground pipes, wires, fibre, soil types, and water. During operation of a GPR,

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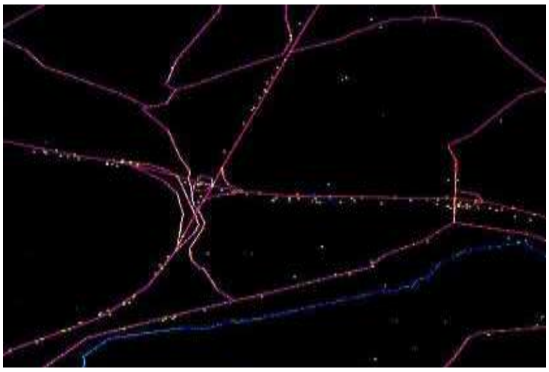


Figure 7:output map from a GMTI RADAR - ERS

A RADAR pulse is modulated at frequencies from 100 to 1000 MHz, with the low frequency penetrating deeper than the high frequency, while the high frequency has better resolution than the low frequency. Basic pulse repetition rates are up to 128 Hz on a RADAR line profiling system on a sled or airborne platform. RADAR energy is reflected from both surface and subsurface objects, allowing depth and thickness measurements to be made from two-way travel time differences.

SAR data is significant in detecting oil slicks. Petroleum from the ocean floor causes a thin film of petroleum floating on the ocean surface that creates a locally smooth water surface that in turn induces conditions that promote specular reflections over that region of the ocean. oil slicks occur when molecules of oil reach the sea surface to form a thin layer of petroleum that dampens the ocean-surface capillary waves. SAR is sensitive to differences in surface roughness, so it can easily discriminate between the smoother oil slick and surrounding water. Thus oil slicks are regions of little to no backscatter characterized by distinct areas of darkness on the RADAR image. Hence the dark returns assist in identifying regions where such slicks might originate and this can function of the RADAR can be provided in all weather and time conditions.

In the aviation industry, aircraft are equipped with RADAR devices that warn of aircraft or other obstacles in or approaching their path, display weather information, and give accurate altitude readings. Such aircrafts equipped with RADAR devices can land in fog at airports equipped with RADAR-assisted ground controlled approach systems in which the plane's flight is observed on RADAR screens while operators radio landing directions to the pilot.

Marine RADARs are used to measure the bearing and distance of ships to prevent accident with other ships, to navigate, and to fix their positions at sea when within range of shore or other fixed references such as islands, and light ships. In harbor, vessel traffic service RADAR systems are used to monitor and regulate ship movements in busy waters. ISAR is utilized in marine surveillance for the classification of ships and other objects. In these applications, the motion of the object due to wave action often plays a greater role than object rotation. For instance a feature which extends far over the surface of a ship such as a mast will provide a high sinusoidal response which is clearly identifiable in a two dimensional image. Images sometimes produce a strange similarity to a visual profile with the interesting effect that as the object rocks towards or away from the receiver the alternating doppler returns cause the profile to cycle between upright and inverted. **Error! Reference source not found.** shows ERS SAR image indicating a ship discharging oil into the sea while

Figure 9 shows identification of ships in a busy port from a RADAR image.

Meteorologists use RADAR to monitor precipitation and wind. It has become the primary tool for short-term weather forecasting and watching for severe weather such as thunderstorms, tornadoes, winter storms, precipitation types, etc. Geologist use specialized ground penetrating RADARs to map the composition of earth crust.

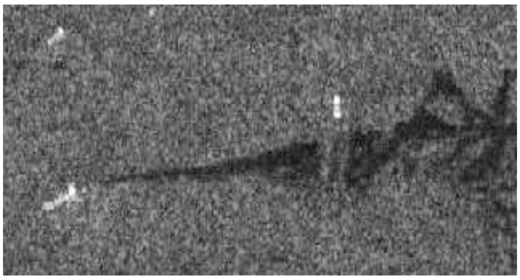
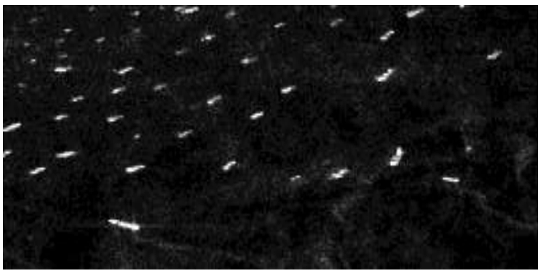


Figure 8 :A ship (bright target near the bottom left corner) is seen discharging oil into the sea in this ERS SAR image



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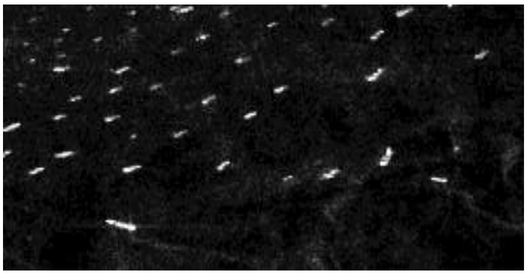


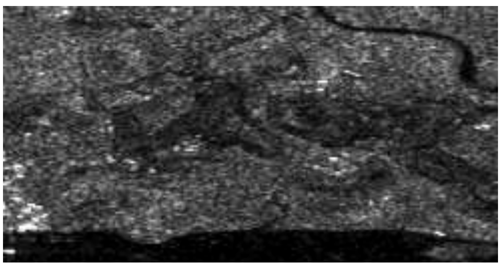
Figure 9 : This SAR image shows an area of the sea near a busy port. Many ships can be seen as bright spots in this image due to corner reflection. The sea is calm, and hence the ships can be easily detected against the dark background.

X. CHALLENGING AND LIMITING FACTORS

Several number of challenges are found in RADAR images which are not present in optical images. The RADAR sensor collects back its emitted radiation and the emitted radiation is scattered within the target and this will introduce noise. Hence this will also affect the RADAR data processing requirements in terms of filtering techniques and rectification for the correct image of the target. Other limiting and challenging factors include residual sensor error which considerably blurs the SAR image. This is removed by autofocus techniques. The effect of translational motion in ISAR causes the images to be blurred and is required to be removed. section C to E discuss some of the major challenges.

C. Noise

Contrary to optical images, RADAR images are created by coherent interaction of the transmitted microwave with the targets. Hence, it experiences the effects of speckle noise which arises from coherent summation of the signals scattered from ground distributed randomly within each pixel. A RADAR image appears more noisy than an optical image. The speckle noise is sometimes suppressed by applying a speckle removal filter on the digital image before further analysis. **Error! Reference source not found.** A and B is a RADAR image with speckle and removed speckle noise respectively.



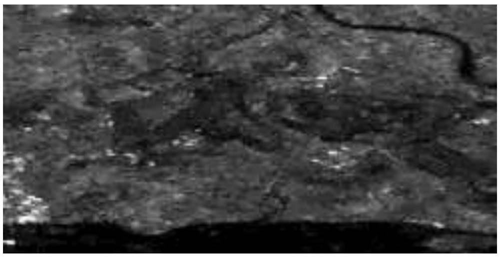


Figure 10 A : Left RADAR image with speckle noiseB:right same image with speckle noise removed

D. Interpreting RADAR Images

Interpreting a RADAR image is not an uncomplicated task. It regularly requires some familiarity and knowledge with the ground conditions of the targets imaged. As a valuable rule of thumb, the higher the backscattered intensity, the rougher is the surface being imaged. Flat surfaces such as paved roads, runways or calm water normally appear as dark areas in a RADAR image since most of the incident RADAR pulses are specularly reflected away.

From **Error! Reference source not found.**, a smooth surface acts like a mirror for the incident RADAR pulse. Most of the incident RADAR energy is reflected away according to the law of specular reflection, allowing little energy to be scattered back to the RADAR sensor. With diffused reflection a rough surface reflects the incident RADAR pulse in all directions. Part of the RADAR energy is scattered back to the RADAR sensor. The amount of energy backscattered depends on the properties of the target on the ground. Calm sea surfaces appear dark in SAR images. However, rough sea surfaces may appear bright especially when the incidence angle is small. The presence of oil films smoothen out the sea surface. Under certain conditions when the sea surface is sufficiently rough, oil films can be detected as dark patches against a bright background. This is shown in **Error! Reference source not found.** and **Error! Reference source not found.**.

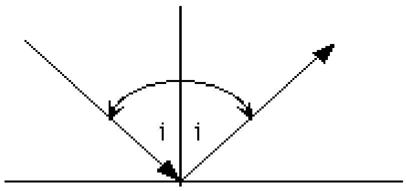
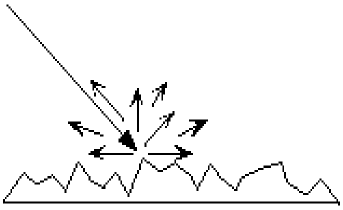


Figure 11 : A-left Specular Reflection



B- right diffuse reflection

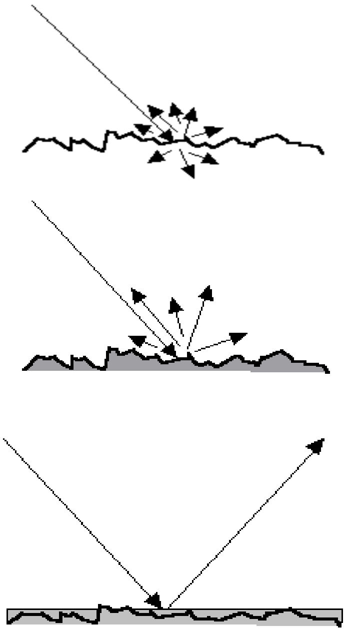


FIGURE 12 A: DRY SOIL , B: WET SOIL, C : FLOODED SOIL

In Figure 12A, Some of the incident RADAR energy is able to penetrate into the soil surface, resulting in less backscattered intensity while in B,the large difference in electrical properties between water and air results in higher backscattered RADAR intensity and in C RADAR is specularly reflected off the water surface, resulting in low backscattered intensity. The flooded area appears dark in the SAR image [3][4][5[6]].

E. Interference

RADAR systems must overcome unwanted signals in order to focus only on the actual targets of interest. These unwanted signals may originate from internal and external sources in both passive and active imaging systems. The ability of the RADAR system to overcome these unwanted signals defines its signal-to-noise ratio (SNR). SNR is defined as the ratio of a signal power to the noise power within the desired signal; it compares the level of a desired target signal to the level of background noise (atmospheric noise and noise generated within the receiver). The higher a system's SNR, the better it is in isolating actual targets from the surrounding noise signals[7]8][9].

XI. CONCLUSION

In this paper, the technology of RADAR techniques is reviewed. It is also discovered that RADAR remote sensing is an important tool in the area of security and environmental monitoring aspects which supersedes that provision with the optical sensors. The RADAR output data is involved with a number of challenges including interference issues, interpretation ambiguities which require expert knowledge and techniques for proper rectification and interpretation.

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