Mine Automation and Data Analytics

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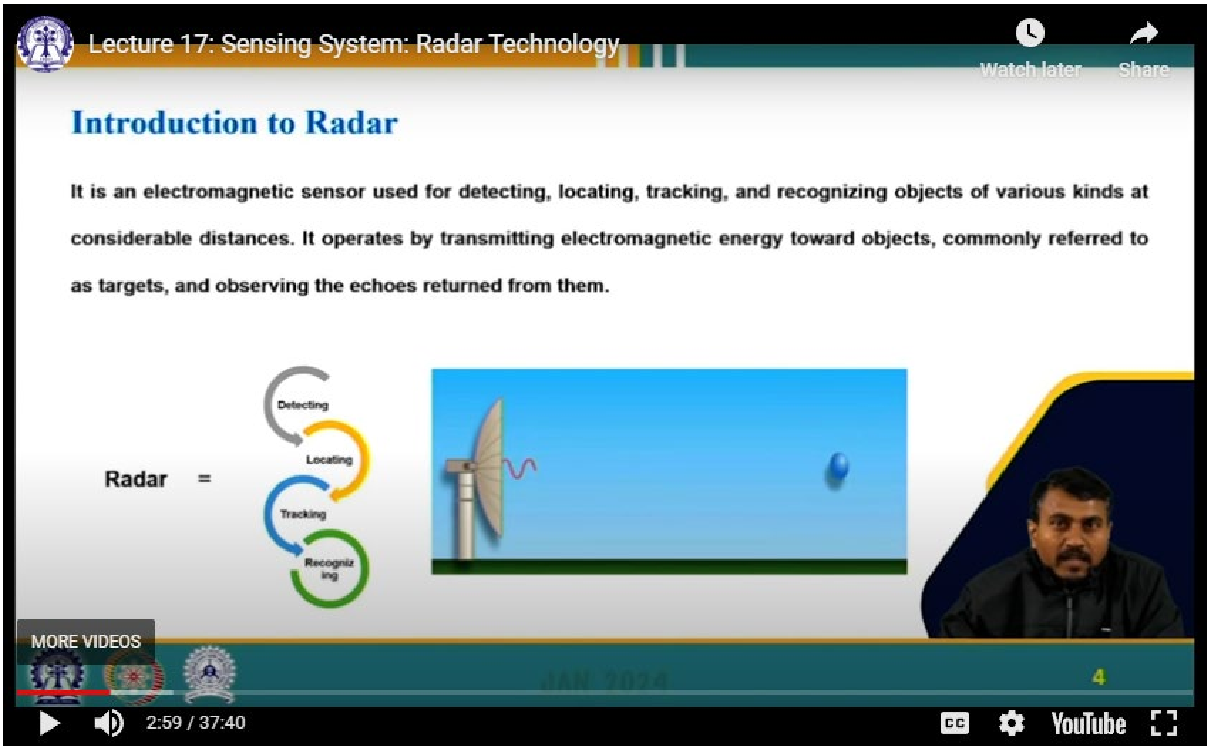
Week-4

Lecture-17

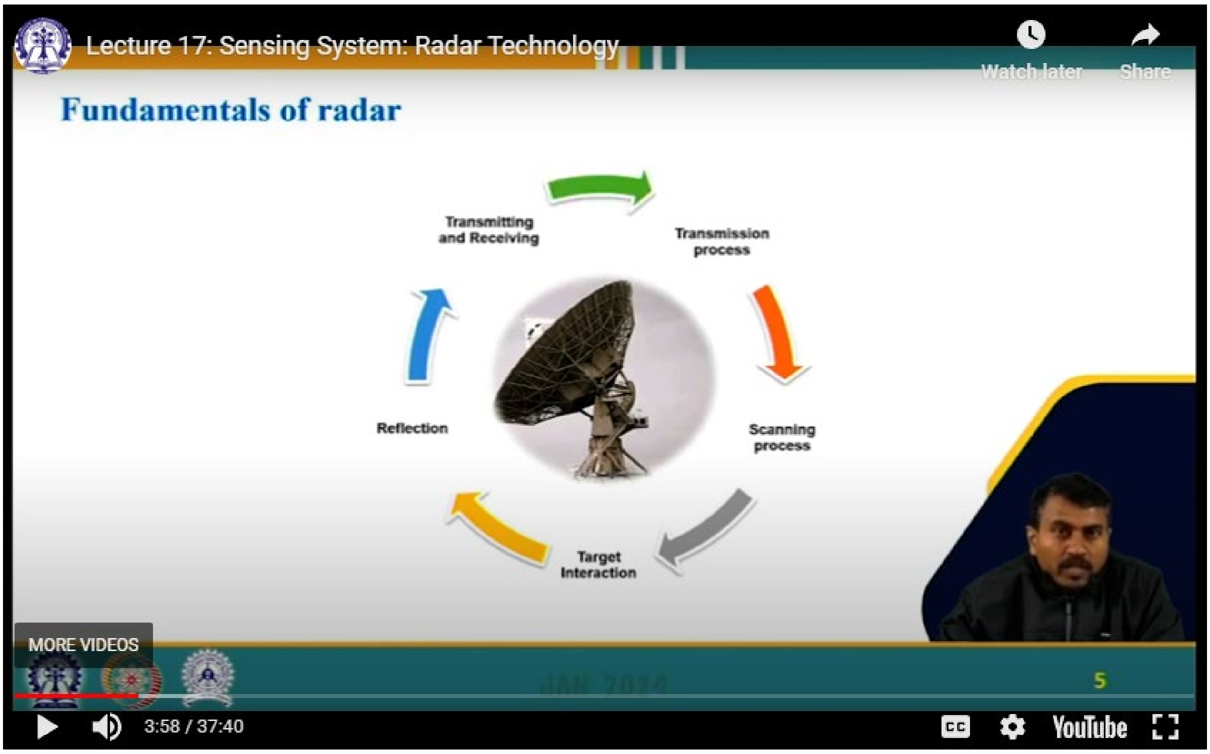
Sensing System: Radar Technology

Welcome back to my course, My course mine automation and data analytics. Today, we will discuss on sensing technology and we will use the radar technology in the mine for detecting object, detecting movement more particularly the in mine slope. So, we need to discuss different aspect of the radar technology. So, in this lesson we are going to discuss the following introduction to radar, fundamental of radar technology, the types of different radar, basics of radar technology, principle of measurement using the radar technology, introduction to the slope stability radar or in abbreviation SSR, risk management with the slope stability radar and a case study using the radar technology in the mine. So, what is radar? So, radar is an electromagnetic spectrum basically. So, it is an electromagnetic sensor used for detecting, locating, and recognizing objects of various kinds at considerable distances.

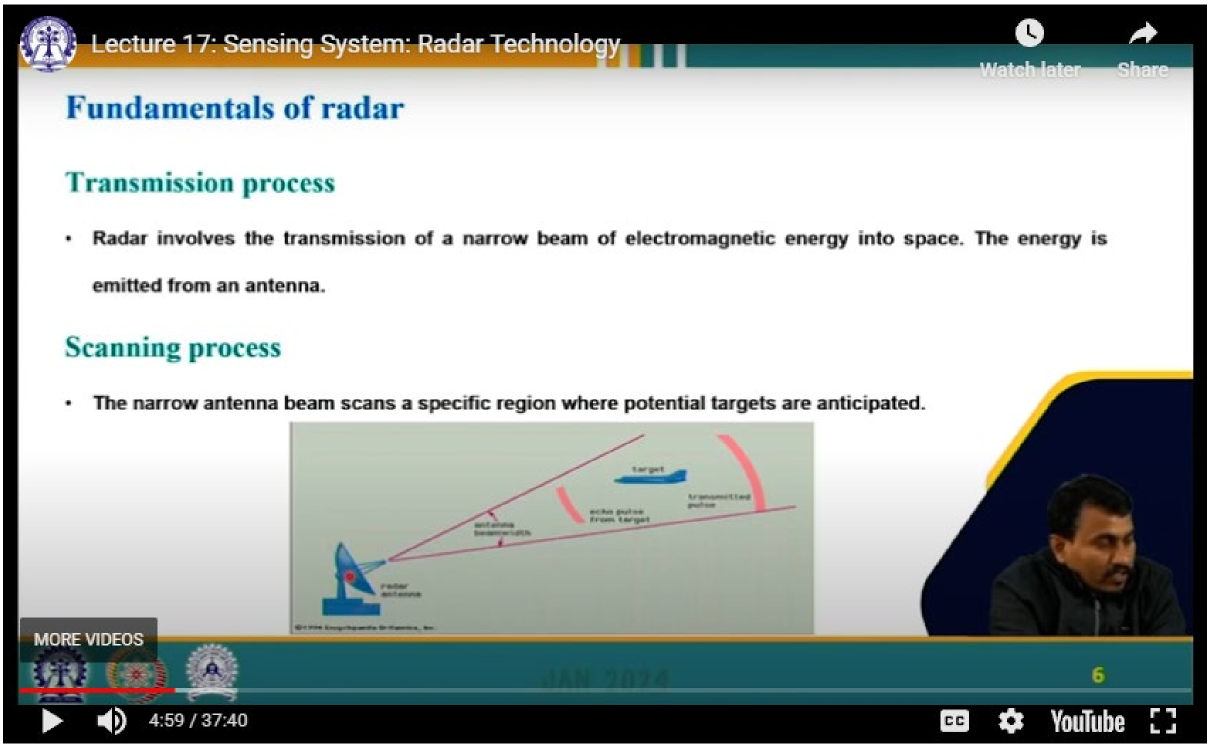
So, it operates by transmitting electromagnetic energy towards objects. Basically, it is a radio frequency wave commonly referred to as target and observing the echoes returned from the object. So it detects, it locates, it tracks, means when there is a movement it also tracks and recognizes the object. So this is a typical way how radar basically works.



It emits a signal and signal hits the object and part of the pulse return back at the receiver. Receiver receives the signal and process the signal and identify the object, location, distance, and different aspect of the object. So the fundamental of radar technology, it has the transmission process, it has scanning process, more particularly the scanning process is used for monitoring the mine slope. The scanning process is also used in the defense technology as well as in aviation. Target interaction, then reflection, then transmitting and receiving.



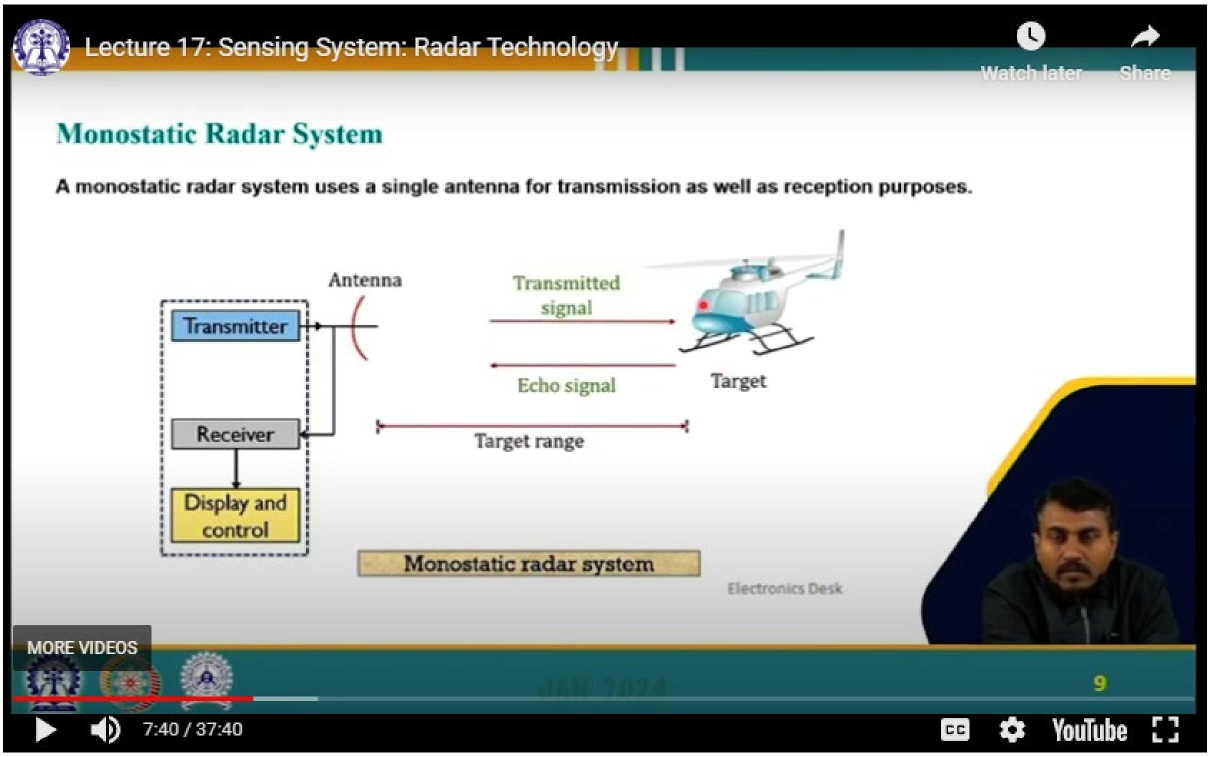
So these are the process continuously goes on in the radar technology and from that basically by the processing we get the information about the object, about object movement and the locations. Transmission process. So the radar involves the transmission of an narrow beam of electromagnetic energy into the space. The energy is emitted from an antenna. Scanning process. The narrow antenna beam scans a specific region where potential targets are anticipated. This is an example here that the transmitter radar transmitter send the signal in narrow band and here is the object and after beam hit the object part of that energy return back and it also received and based on that it basically process and get an decision about the target and objects. Target interaction. When a target is within this scanned region it intercepts a portion of the radiated energy.



Reflection. The target reflects a part of the intercepted energy back to the radar system and by that only radar process the information and gets the information about the object. Transmitting and receiving. Most radar systems do not transmit and receive simultaneously. A single antenna is commonly used on a time-seared basis for both transmitting and receiving. Let us see the different types of radar systems.

So one is the monostatic radar system. Another is bi-static radar system. So what is monostatic radar system? A monostatic radar system uses a single antenna for transmission as well as reception purposes. So here a single antenna serves both the purpose. Transmitting the energy as well as receiving the return pulses that is echoes.

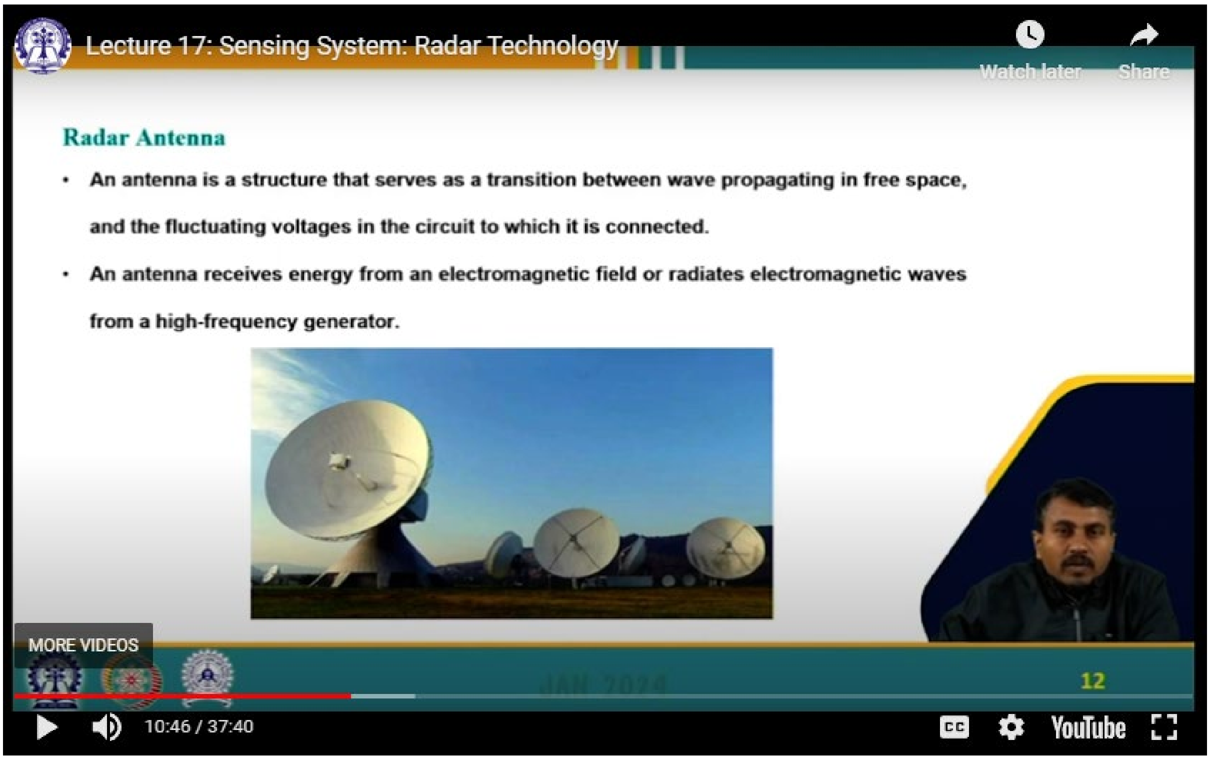
So this is a typical image schematic image of a monostatic radar. So here within these antenna we have the transmitter as well as the receiver and there is a display and control system is attached to that. So antenna emits the signal and objects it hits the object and the return signal that is echo signal received by the antenna and by the receiver. So based on that information it basically identify the distance of that particular target when it was hit the target. So monostatic radar is a simplified system.



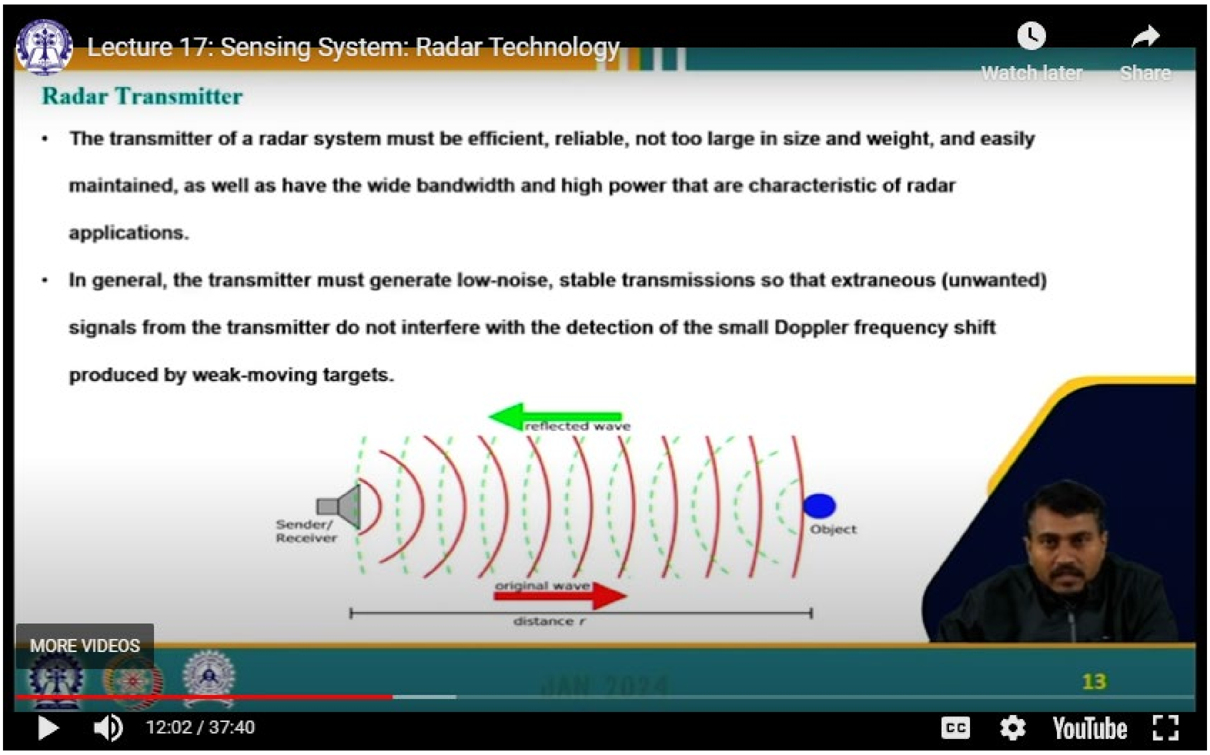
There are another system that is bi-static radar system. So, a bi-static radar system utilizes independent antennas for the transmission and reception of the signal. So when the purpose is to achieve a very high level of accuracy and very sensitive cases. For example, for defense purposes for aeronautical engineering purposes, they use bi-static radar. So transmitter and receiver are basically located in a geographically separate area.

In mostly in missile technology also we use the bi-static radar system. So here the receiver and the emitter is basically located in a separate area or a separate location and there is a distance between these receiver and the transmitter and rest of the process and rest of the algorithm is same by for identifying the object and their locations and the distance. So this is basically the technology of the radar. So here we have the system control and in this system control it established control over the transmitter how much energy to be emit and there is a duplexer and duplexer is basically attached to the antenna and this antenna also received the return echoes and there is a receiver and here after receiving the signal it basically process there is a signal processor. So based on the signal processing it reached to a decision and about the objects and there is a data processor and by that process it basically displays what is the status.

So this is basically the basic technology of the radar that is being used in different purposes. Radar antenna. An antenna is a structure that serves as a transmission between wave propagating in free space and fluctuating voltages in a circuit to which it is connected. So an antenna receives energy from an electromagnetic field or radiates electromagnetic waves from a high frequency generator. So this is a typical image of the radar.



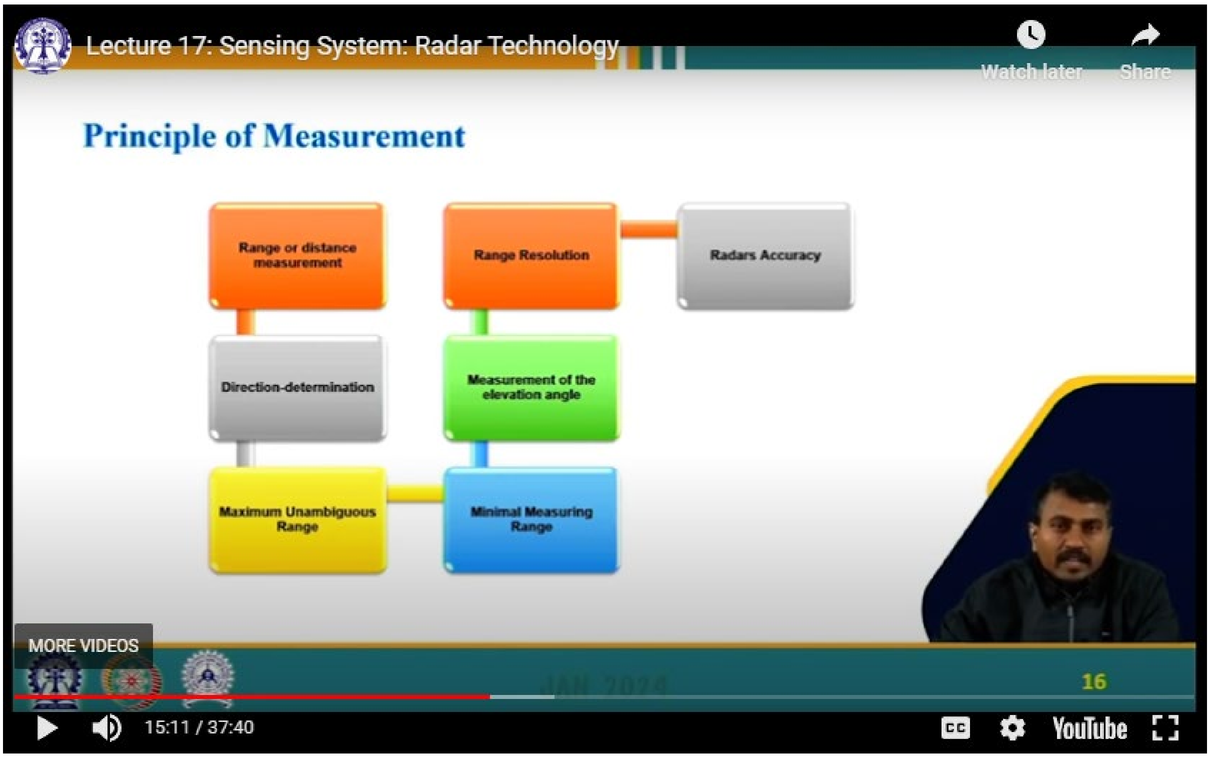
So these are the big big radars are used for defense and aerospace applications. Radar transmitter. The transmitter of a radar system must be efficient, reliable and not too large in size and weight and easily maintained as well as have the wide bandwidth and high power that are characteristics of a radar applications. So in general the transmitter must generate low noise and there is a stable transmission so that extraneous or unwanted signals from the transmitter do not interfere with the detection of small Doppler frequency shift produced by weak moving targets. So this is a typical diagram that the sending receiver and there's a reflection wave there should be a sensitivity in the transmitter about detecting the small movement in the in the objects.



Radar receiver. The function of a receiver is to take the weak echoes from the antenna system and amplify them sufficiently and detect the pulse envelope and amplify the pulses and feed them to the indicator. The receivers used in radar can accept weak echoes and increase their amplitude by a factor of 20 to 30 million. Since radar frequency are not easily amplified a super heterodyne receiver changes the radio frequency to an intermediate frequency for amplification. Radar signal processor. The signal processor is a part of the receiver that extract the desired target signal from the unwanted clutter.

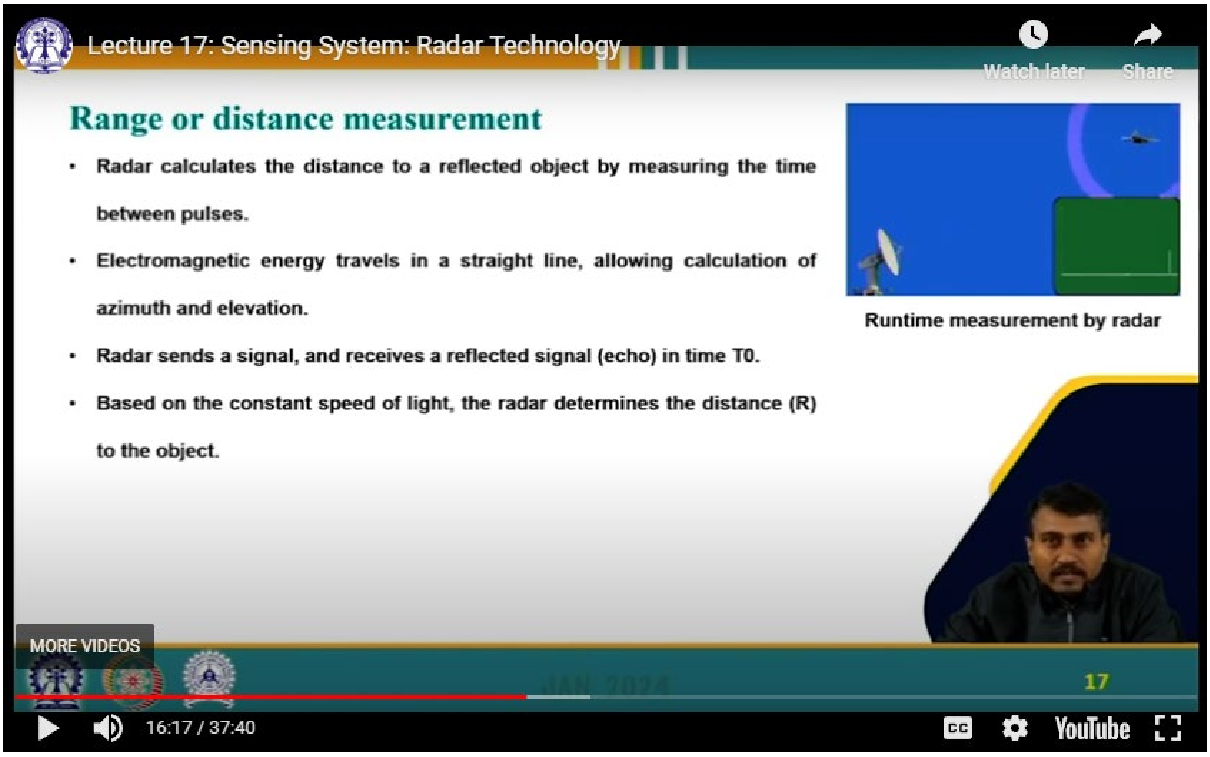
It is not unusual for these undesired reflections to be much larger than the desired target echoes. In some cases more than 1 million times larger. Large clutter echoes from stationary object can be separated from small moving target echoes by noting the Doppler frequency shift produced by the moving targets. Most signal processing is performed digitally with computer technology and digital processing has significant capabilities in signal processing not previously available with the analog methods.

Principle of measurement. So there is a measurement for the distance range by this radar. We can also estimate the direction of the object or the target. It has a maximum unambiguous range of the pulse. Also it has minimal measuring range and it can also measure the elevation angle. The angle above the surface and radar also have the resolution based on the necessity these resolution will be fixed based on the purpose and sensitivity of the case study and the radar accuracy.



So radar accuracy is pretty high and it is a very portable technology and a very reliable technology also and that is why for the sensitive applications we use the radar. Range or distance measurement. Radar calculates the distance to a reflected object by measuring the time between the pulses. The electromagnetic energy travel in a straight line allowing calculation of azimuth and elevation. Radar sends a signal and receives a reflected signal echo in time T0.

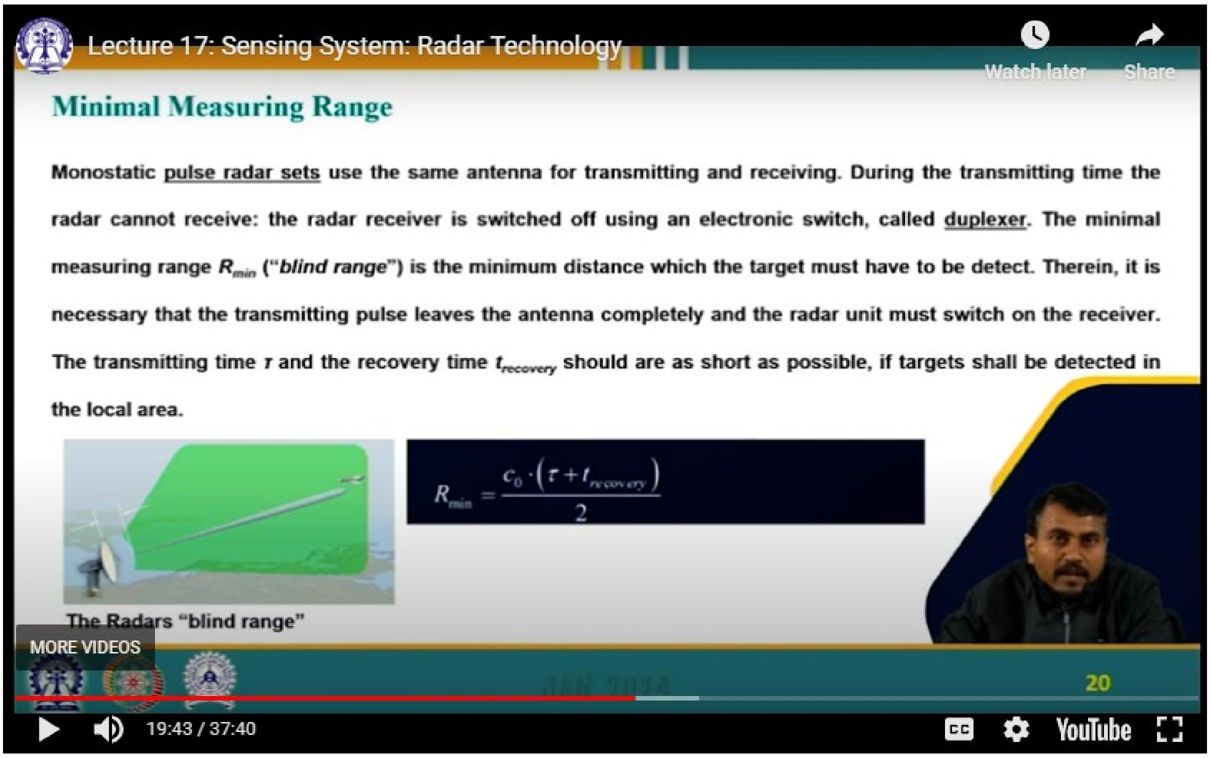
So based on the constant speed of light the radar determine the distance to the object. So this is basically the radar antenna emits a signal then hits the object and based on that it basically generate the pulse. So based on that it basically calculates the distance R0. Direction determination. Angular determination of the target relies on the directivity of the antenna.



So directivity is also known as directive gain and it concentrate transmitted energy in a specified direction. An antenna with high directivity is termed a directive antenna. By measuring the antennas direction when receiving the echo azimuth and elevation angle to the object are determined. The accuracy of angular measurement depends on the directivity linked to the antenna's size. So this is basically the principle of estimating the direction from the radar system.

Maximum unambiguous range. The maximum unambiguous range that is R max is the longest range to which a transmitted pulse can travel out to and back again between consecutive transmitted pulses. So in other word Rmax is the maximum distance radar energy can travel round tree between pulses and still produce reliable information. So therefore, maximum unambiguous range Rmax is maximum range for which Ţ is less than the T0. So Rmax is basically equals to C0 multiplied by T minus tau divided by 2. So as the tau is basically length of the transmitted pulse.

Minimal measuring range. The monostatic pulse radar sets use the same antenna for transmitting and receiving. So during the transmitting time the radar cannot receive. So the radar receiver is switched off using an electronic switch called duplexer and the minimal measuring range R min that is a blind range is the minimum distance which the target must have to be to detect. So therein it is necessary that the transmitting pulse leaves the antenna completely and radar unit must switch on the receiver. So the transmitting time tau and the recovery time t recovery should are as short as possible if targets shall be detected in the local area.

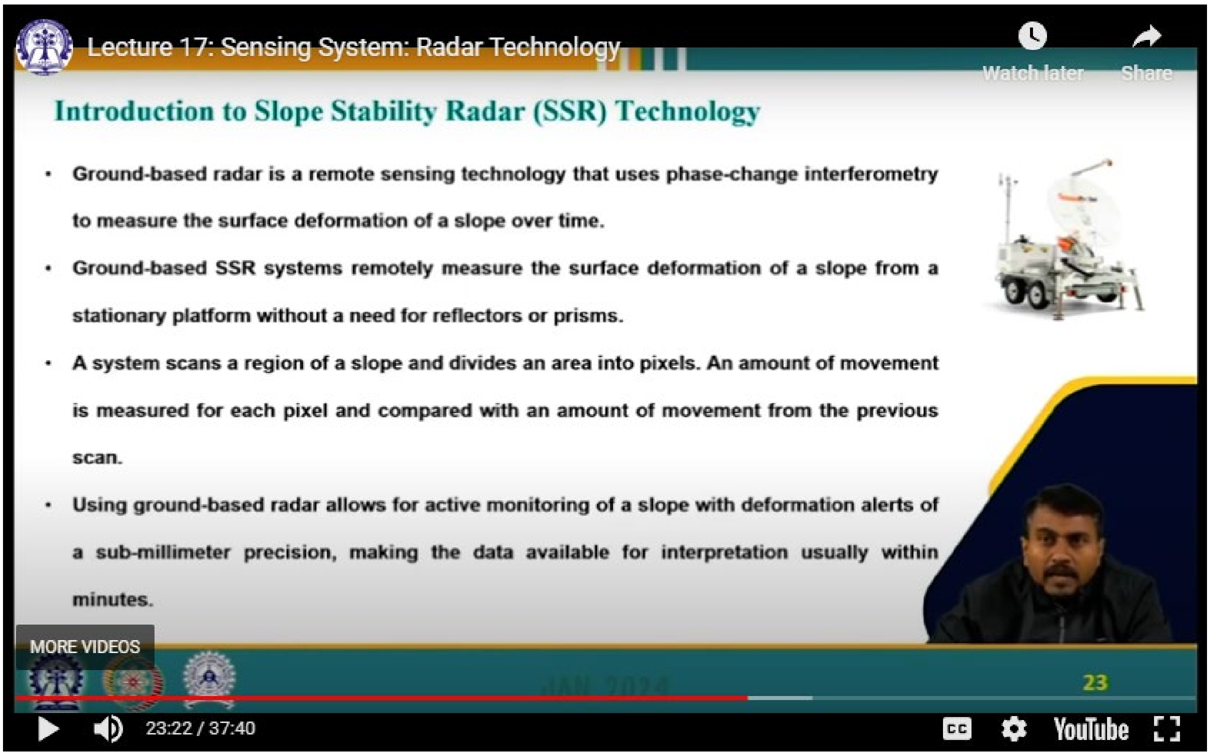


So the R min is equal to C0 multiplied by tau plus t recovery divided by 2. So this is basically the minimal distance radar can detect the object. Measurement of the elevation angle. The elevation angle is the angle between the horizontal plane and the line of sight measured in the vertical plane. The reference direction that is an elevation angle of 0 degrees is a horizontal line in the direction to the horizon and starting from the antenna.

The elevation angle is denoted by Greek letter epsilon mostly and it is positive above the horizon but negative below the horizon. So this is how the elevation angle is measured. So altitude and height finding radars mostly for defence purposes radar use a very narrow fan beam in vertical plane. Height finding radar systems that also determine bearing must have a narrow beam in the horizontal plane in addition to one in vertical plane. The beam is mechanically or electronically scanned in elevation to pinpoint targets.

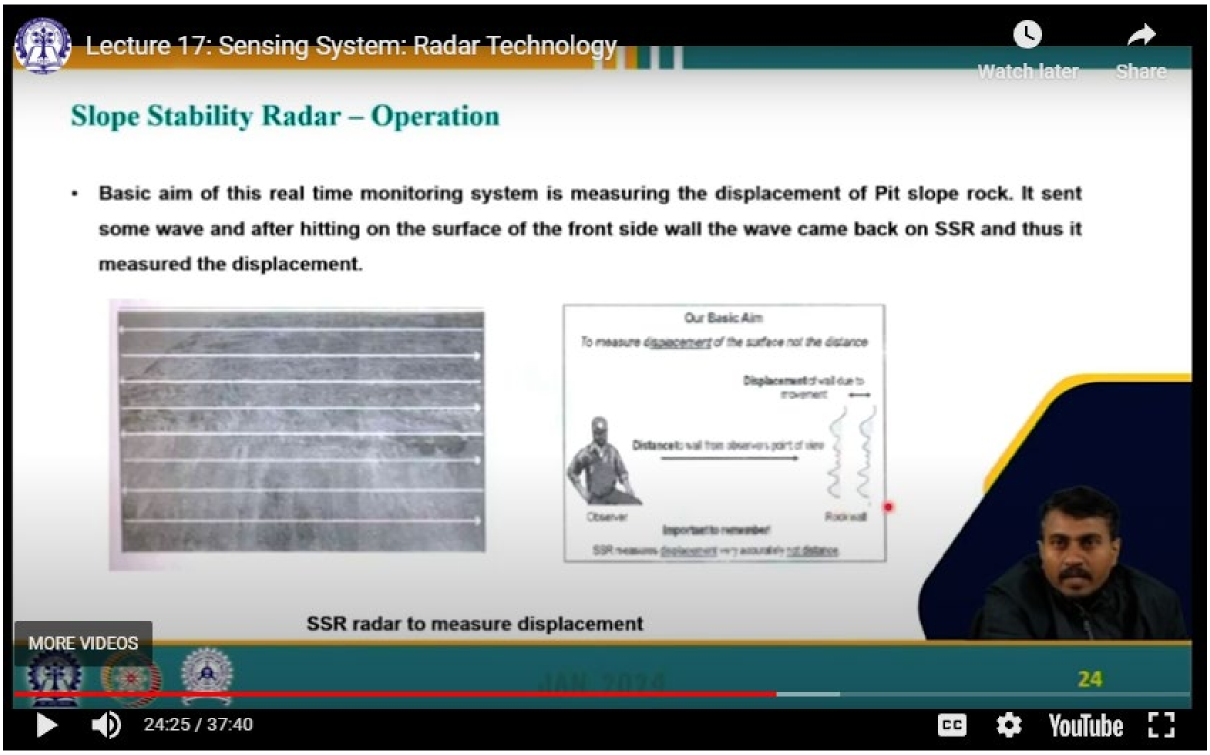
If an echo signal is detected in the receiver then the current elevation angle is equal to the direction of the antenna pattern. So let us see how we can use this slope stability radar technology using the radar technology in the mines for monitoring the mine slope. So ground based radar it is a ground based radar is a remote sensing technology that uses phase changing interferometry to measure the surface deformation of a slope over time. So ground based slope stability radar system remotely measures the surface deformation of a slope from a stationary platform without a need for reflectors or prism. A system scanner region of a slope and divides an area into pixel.

An amount of movement is measured for each pixel and compared with an amount of movement from this previous scan. Using ground based radar allow for active monitoring of a slope with deformation alerts of a submillimeter precision making the data available for interpretation usually within minutes and that is basically the advantage of slope stability radar technology using the mines for monitoring the movement of the mine slope in high wall, bend slope as well as in mine dumps. And this technology can also be used for monitoring the landslides in a very susceptible zones where sensitivity is very high and safety requirement is there. So this technology can also be used there. So this is a typical image of the slope stability radar by the ground probe.

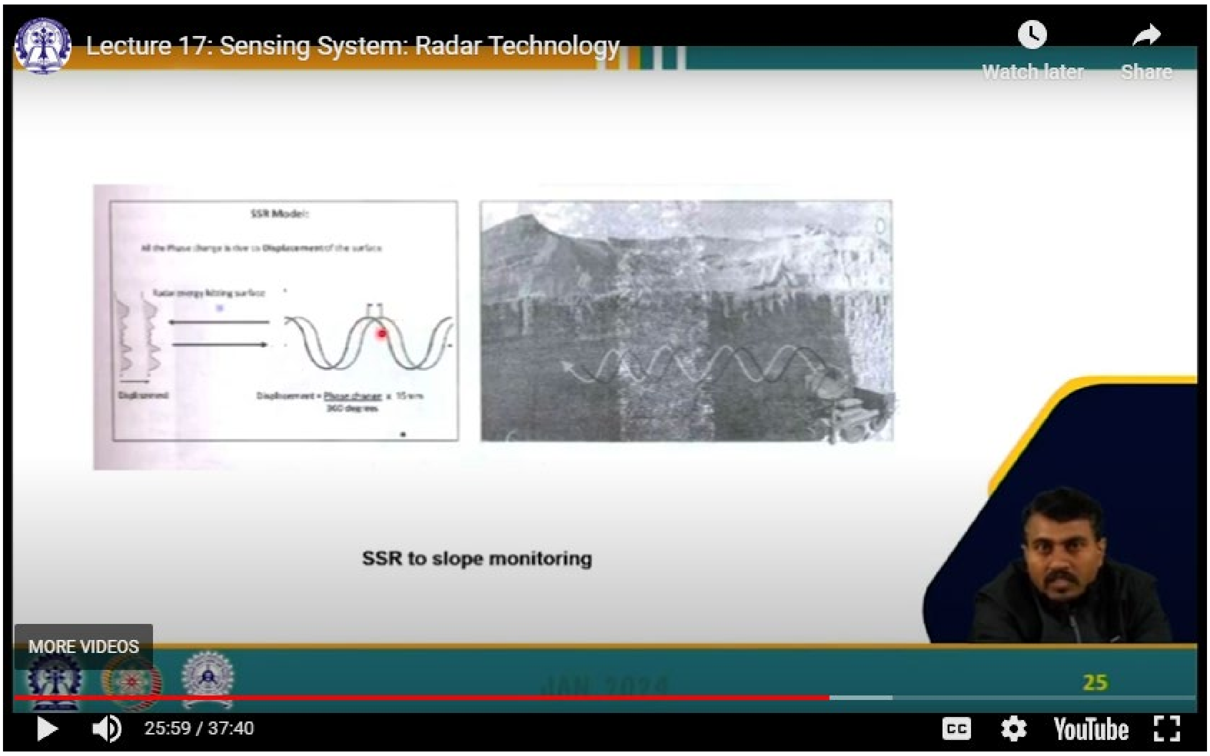


So slope stability radar operates in real time so the basic aim of this real-time monitoring system is measuring the displacement of the pitch slope rock. So we are not measuring here the distance we are measuring the displacement of the mine rock or the rock in the mine slope. So it sent some wave and after hitting on the surface of the rock slope on the on the front there is a wave return back to the SSR and by that we measure the displacement from the previous scan comparing with the previous scan. So this is basically a typical image. This is basically the rock slope the rock surface.

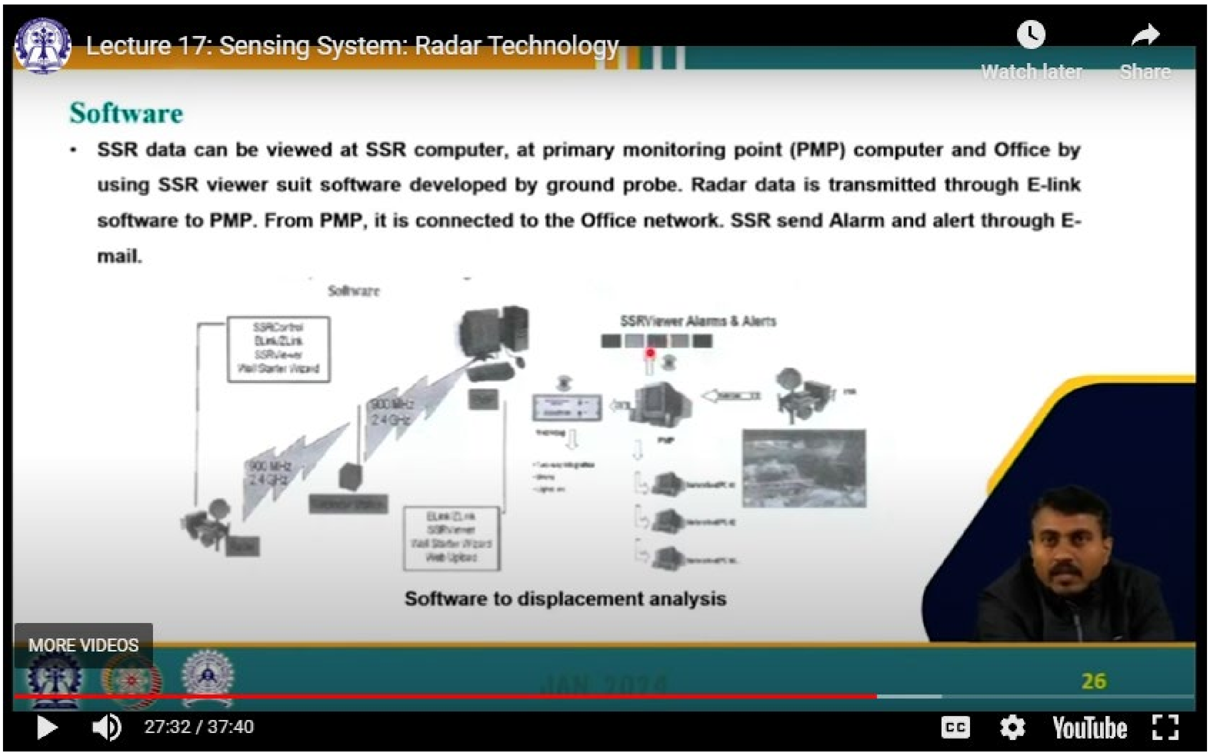
Here we are sending the pulses radar wave and we are basically trying to measure the displacement. Suppose we have scanned on 24th January 2024 so there is a data about this particular mine slope and we are again scanning that this particular phase on 31st January okay. So in seven days time for the same rock slope how much amount of deformation is there for a particular area and different areas within this mine slope. This is the purpose for installing the slope stability radar in the mine slope. So this is basically the way slope stability radar function it measures the displacement and compare with the previous scan and basically finds the amount of deformation concentrated on in different areas of this particular rock slope.



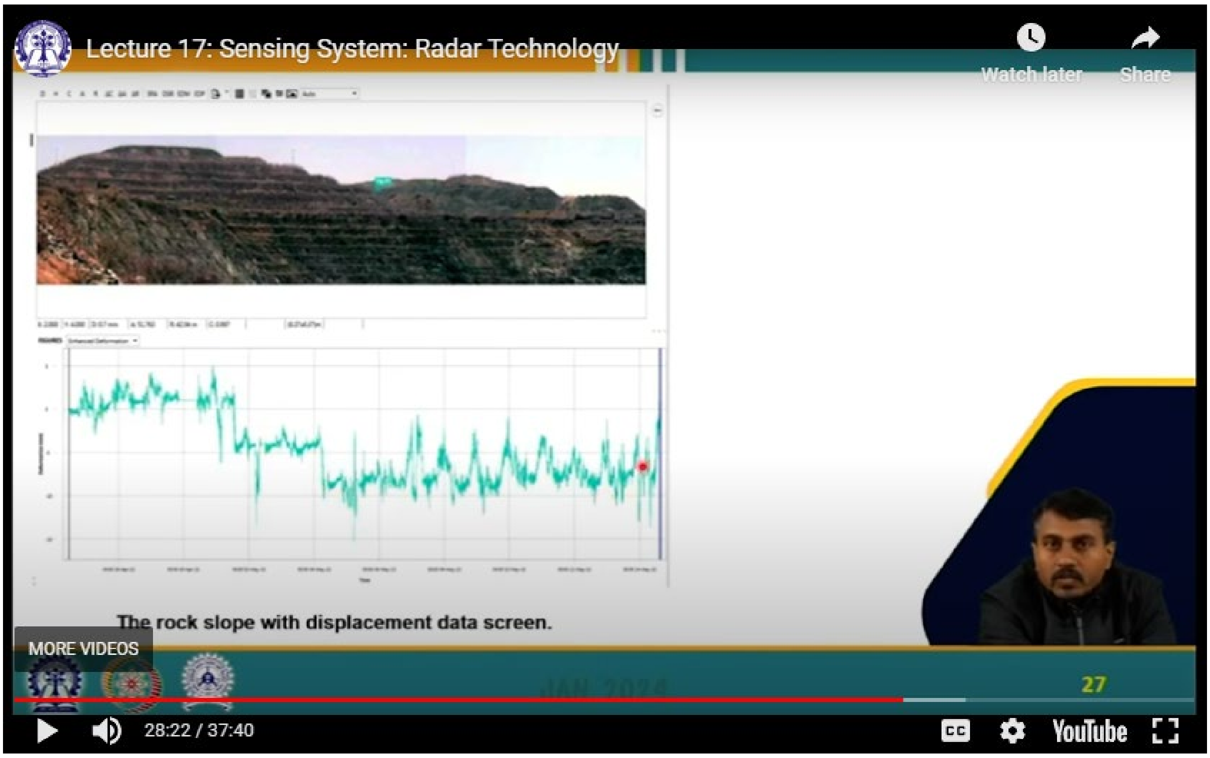
So we are not measuring the distance we are measuring the displacement of different part of this rock slope. So this is basically works on the principle of interferometry. So when there is a change when there is a displacement in a particular part of a mine slope so it basically produce some phase it basically change the phase of the pulse. So based on that change in phase of the pulse we are basically measuring the displacement. So relying on this particular algorithm we basically detect the amount of change precisely to the sub millimeter accuracy in a particular terrain or particular area of the mine slope.



So we require a number of softwares for that. So SSR data can be viewed at SSR computers on the station of that particular machine at primary monitoring point PMP computer and office by using SSR viewer suit software developed by ground probe and the radar data is transmitted through E-Link software to PMP. So from PMP it is connected to the office network and SSR sends alarm and alerts through the e-mail. So this is a particular way of how it is work this is the field so this is the radar. Radar basically send the pulse and get the receiving pulse and based on that it basically send that particular data to PMP and PMP is basically connected with the other softwares as well in the network and it analyze based on that analysis is basically generates the different alerts okay whether it is okay to say whether there is some action to be needed whether the displacement is so high so alarm will be a blinking so that it can advise the superintendent of that particular site please evacuate there is an possibility of imminent failure. So this is basically the advantage of installing the slope stability data and in different mine site and we have seen the good use of this particular technology and by that we safeguard the manpower from the accidents.



So this is a particular rock slope okay and in this particular rock slope these data these data pattern is shows the different displacement over time so this is the particular target this is the particular pixel of this particular slope and different occasion we basically scanned different time so this basically shown the profile of the displacement of that particular area. So this is basically the advantage of this particular technology so we can have the information about different pixels in that particular area how much amount of deformation takes place over the time and based on that we can develop an algorithm that what is the change or the rate of change or the rate of displacement so whether the rate of displacement is well within the limit or it is proportionally increasing so that we can go for an alert system to so that there would be an imminent failure and we can evacuate the personnel that is working in the particular vicinity and we can avoid the accident. So SSR is one of the best advanced monitoring system to monitor pit slope stability and can be easily used for monitoring open pit slopes. SSR enables mines managers and geotechnical engineers to make informed decisions to relate and evacuate people and equipment before slope fail.



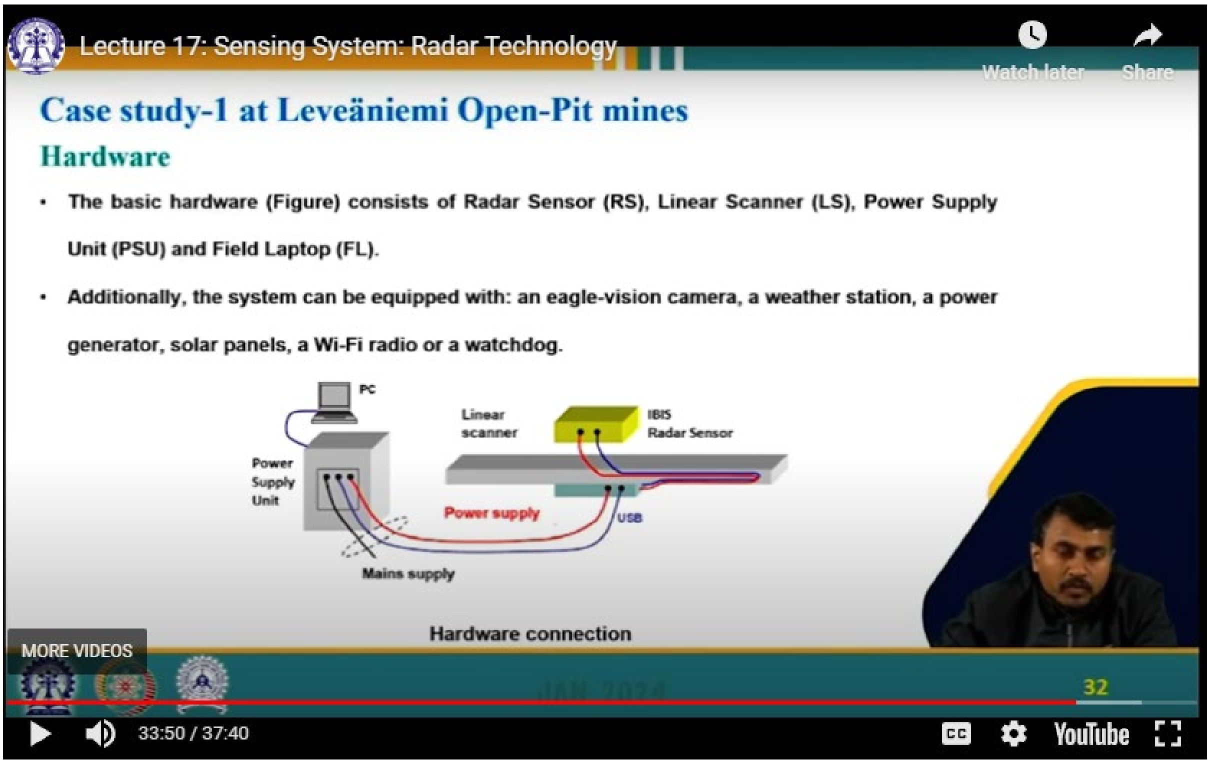
Risk management with SSR. The slope stability radar can be used as an early warning system and that is basically the good point of using the SSR. So in general an early warning system has a few main aims such as monitoring which consists of data collection and it transmission as well as maintenance of the equipment a prediction and analysis. An evacuation alarm is one of the alarm type the mines mostly are using four alarms. Green alarm a small system failure during which SSR is closed down and the SSR program has to be restarted according to the procedures. Yellow alert a radar system failures which cause that a pit superintendent to receive an information about the unavailability of a radar and a geotechnical department is informed to determine a problem with the help of an equipment producer.

Orange alarm in other words a geotechnical alarm is an announcement of a ground movement development which should make a geotechnical department conscious of possible dangers. Red alarm serious situation in which a pit superintendent must evacuate an area of concern or a whole pit when we identify that rate of displacement is going beyond the safe limit.

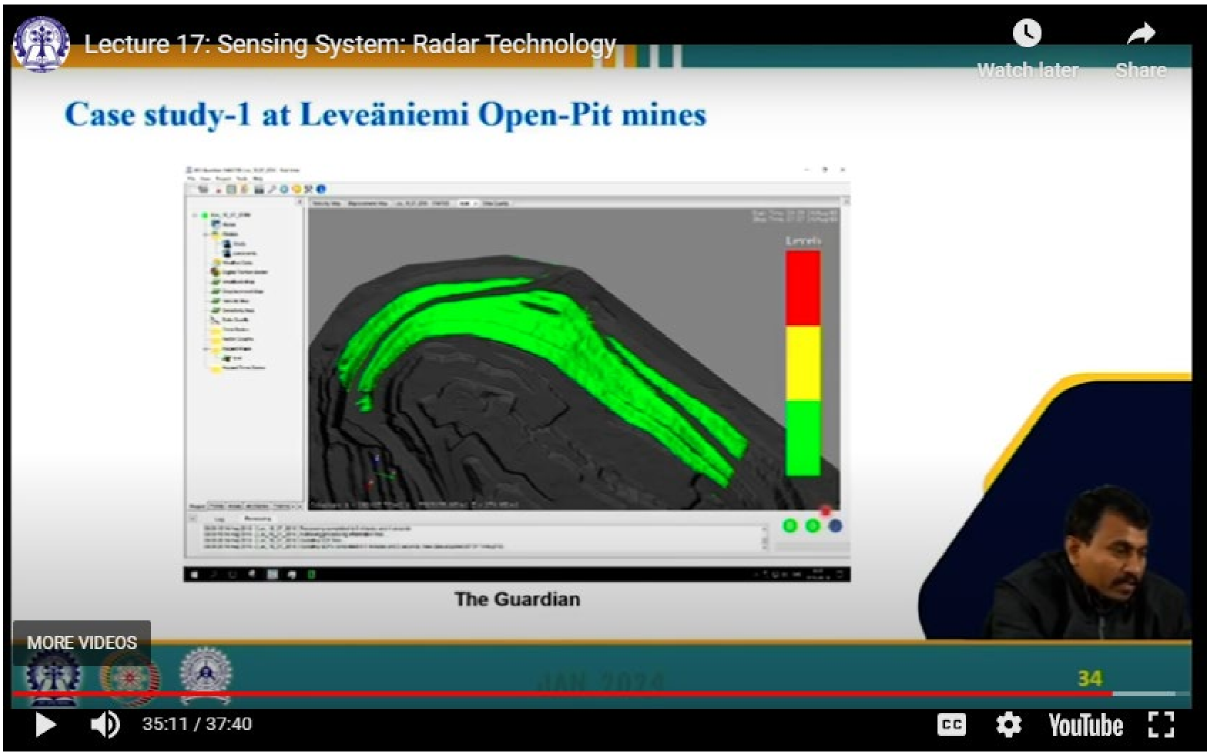
So let us see one case study of deploying the SSR in an open pit mines in Levenmi. The SSR unit is employed at Levenmi open pit mines from the Italian company IDS Geo radar. This is another manufacturer of the radar carries an overview of its different technical features.

Detection capabilities it has a very remarkable capacity of detecting small movements and a high spatial resolution in an one-kilometer distance away it has a pixel dimension of 0.5 meter by 4.4 meter. Monitoring area it covers an expansive area up to 5 square kilometers it is having the quick data acquisition system approximately within two minutes for a single data acquisition at a range of two kilometers. Power options solar power is there also diesel generator is used for battery charging so versatile option is there for the power options.

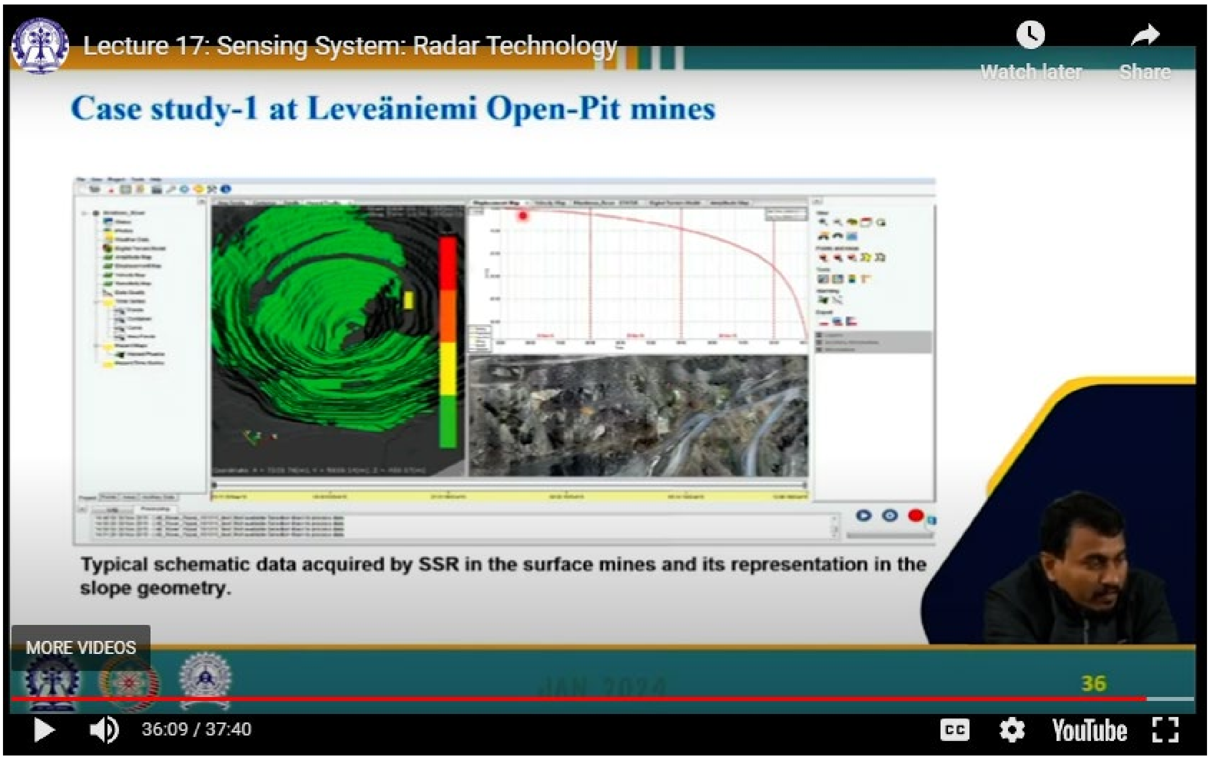
Resilience to weather conditions it can operate in all weather conditions fog mist rain it does not hinder the process that is why it is very robust technology and it can operates in a diverse temperature regime as well minus 25 degrees Celsius to 50 degrees Celsius and all the mine site condition is well within this particular limits.



Hardware the basic hardware consists of the radar sensor and linear sensor then there is a power supply unit and there is a field laptop so additionally system can be equipped with an Eagle vision camera for a better coverage and better data acquisition and weather station for predicting the weather. A power generator for emergency condition and regularly recharging the batteries solar panels and Wi-Fi radio and a watchdog so this is basically their system so this is the radar sensor linear scanner it is attached with the power supply system and there is a PC okay so this is basically the total hardware of the system so there is also some softwares. A software of the radar system consisting of two connected between each other program IBS controller and guardian so this is basically the controller on the radar station it has different control features about the instrument and it basically initially received the data and then data sends to the guardian for display for analysis showing to the end customer or the mine authority that how much amount of deformation is this for example here we are seeing the different level of displacement and this is basically the control map and this is the different legends of the amount of displacement took place in the mine downslope or mine slope.



The IBS controller has three type of files during each scan this is a raw data file GBD then MSK selection of mask and PSB pre-process file so that received by the controller and that sent to the IBS guardian and by using the MSK and the PSB file it basically produced the final process result about the amount of displacement took place in the mine slope so that would be looks like this so this is basically the complete representation using the guardian software here is the DM of the mine down and the contour and as well as a point particular point the amount of displacement that took place over the time so at different point the cursor can be moved and amount of displacement you can observe so this is basically have that particular facility.



So these are the references.

so let us summarize what we learn in this particular lesson. We have provides an initial overview of radar technology we have explored the foundational principle underlying the radar systems. We have examined the various categories and applications of radar technology. We have introduced the fundamental concept and working principle of radar system. We have discussed the methodologies involved in the measurement processes of radar technology.

We have introduced the specific application of slope stability radar in the ambit of the radar technology. We have explored how slope stability radar contributes to risk management particularly in slope stability scenarios in open pit mines as well as in landslide conditions. We have examined a real-world case study illustrating its application and the outcome of the radar technology in a specific context.

Thank you.