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Ground Penetration Radar

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1.Abstract:

Ground penetrating radar is a geo-physical method that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum and detects the reflected signals from sub-surface structures. GPR can be used in variety of media including rock, soil, ice, pavements and structures. It can detect objects, changes in material voids and cracks.

GPR has enormously wide range of applications from planetary exploration to the detection of buried mines. The selection of a range of frequency operations, a particular modulation scheme, and the type of the antenna and its polarization depends on the number of factors, including the size and shape of the target, the transmission properties of the intervening medium, and the operational requirements defined by the economics of the survey operation, as well as the characteristics of the surface. The specification of a particular type of system can be prepared by examining the various factors which influence the detectivity and resolution.

To operate successfully, GPR must achieve:

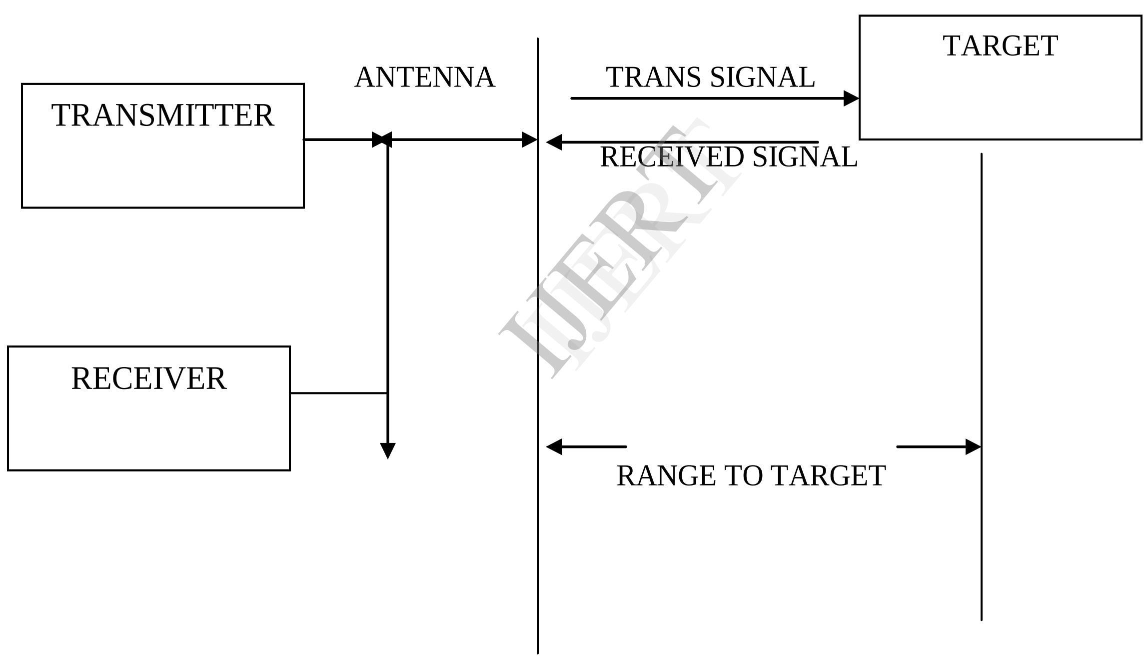
* An adequate signal to clutter
* An adequate signal to clutter
* An adequate signal to noise ratio
* An adequate special resolution of the target
* An adequate resolution of the target

In this paper we have done the Simulation of signal processing block of GPR using a stepped frequency waveform of bandwidth 3GHz is successful. We have concentrated to resolve 3 targets on pulse repetition frequency, maximum ambigious range,successfully.

2.Introduction:

The Word radar is an abbreviation for radio detection and ranging. In general, radar systems use modulated waveforms and directive antennas to transmit electromagnetic energy into a specific volume in space to search for targets. Objects (targets) within a search volume will reflect portions of this energy (radar returns or echoes) back to the radar. These echoes are then processed by the radar receiver to extract target information such as range, velocity, angular position, and other target indentifying characteristics. Radar can perform its function at long or short distances and under conditions impervious to optical and infrared sensors. It can operate in darkness, haze, fog, rain and snow. Its ability to measure distance with high accuracy and in all weather is one of its important attributes.

2.BASIC PRINCIPLE OF RADAR



The transmitter shown generates an electromagnetic signal that is radiated into space by an antenna. A portion of the transmitted energy is intercepted by the target and re-radiated in many directions. The re-radiation directed back towards the radar is collected by the radar antenna, which delivers it in a receiver. There it is processed to detect the presence of the target and determine its location. A single antenna is usually used on a time-shared basis for both transmitting and receiving when the radar waveform is a repetitive series pulses. The range, or distance, to a target is found by measuring the time it takes for the radar signal to travel to the target and return back to the radar. The target's location in angle is found from the direction the narrow-beam width radar antenna points when the received echo signal is of maximum amplitude. If the target is in motion there is a shift in the frequency of echo signal due to Doppler effect. This frequency shift is proportional to the velocity of the target relative to the radar also called: radial velocity".

The Doppler frequency shift is widely used in radar as the basis for separating desired moving targets from fixed unwanted "clutter" echoes reflected from the natural environment such as land, sea, or rain. Radar can also provide information about the nature of the target being observed.

3.RANGE TO A TARGET

The most common radar signal, or waveform, is a series of short duration, somewhat rectangular shaped pulses modulating a sine wave carrier (sometimes called a pulse train). The range to a target is determined by the time Tr it takes for the radar signal to travel to the target and back. Electromagnetic energy is free space travels with the speed of light, which is c=3*10^8 m/s. The time it takes a pulse to travel to a target and back is, in formula form:

$T=2R/c$

The range to a target is then

$Range=ct/2$

4.PULSE REPETITION FREQUENCY:

Pulse repetition frequency (PRF) is the number of pulses per time unit (e.g. Seconds). It is mostly used within various technical disciplines (e.g. Radar technology) to avoid confusion with the unit of frequency hertz (Hz) mainly used for waves.. There is however no clear or formal boundary for when to use the one or the other. Waves are thought of as more or less pure single frequency phenomena while pulses may be thought of as composed of a number of pure frequencies. The reciprocal of PRF is called the Pulse Repetition Time (PRT), Pulse Repetition Interval (PRI), or Inter-pulse period (IPP), which is the elapsed time from the beginning of one pulse to the beginning of the next pulse. Within radar technology PRF is important since it determines the maximum target range (Rmax) and maximum Doppler velocity (Vmax) that can be accurately determined by the radar.

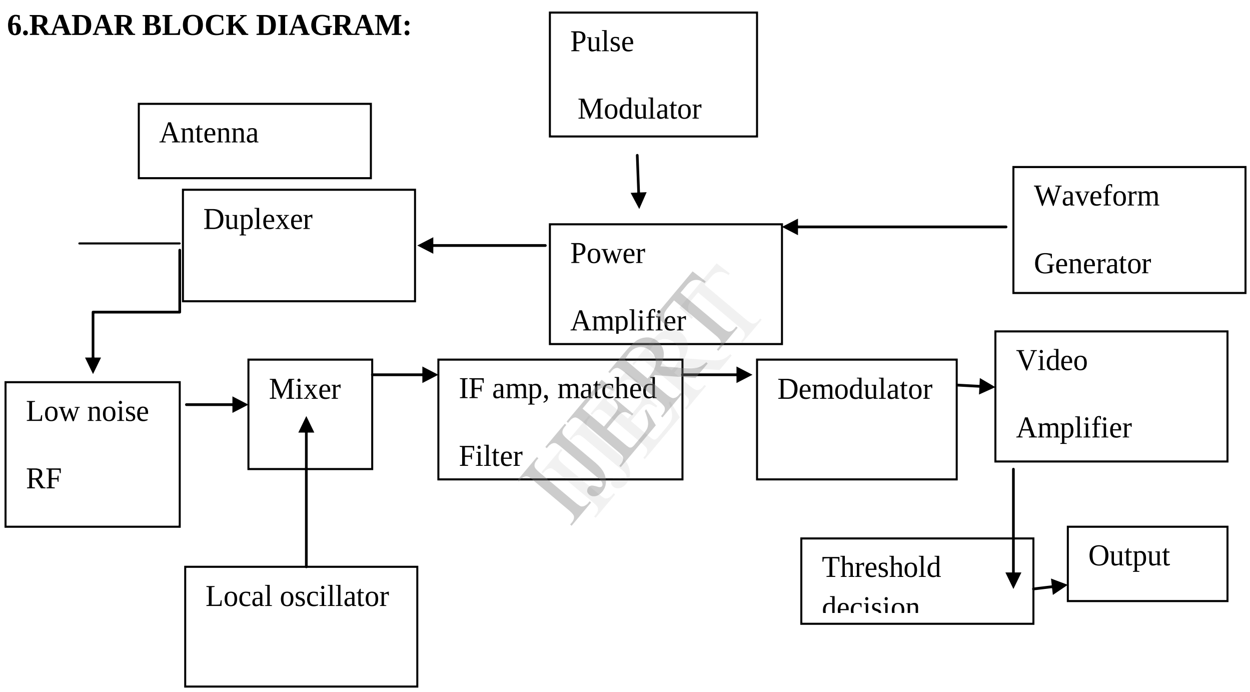
5.MAXIMUM UNAMBIGOUS RANGE

Once a signal is radiated into space by a radar, sufficient time must elapse to allow all echo signals to return to the radar before the next pulse is transmitted. The rate at which pulses may be transmitted therefore is determined by the longest range at which targets are expected. If the time between the pulses Tp is too short, an echo signal from long range target may arrive after the transmission of next pulse and be mistakenly associated with that pulse rather than the actual pulse transmitter earlier. This can result in an incorrect or ambiguous measurement of range. Echoes that occur after the transmission of next pulse are called second-time around echoes. The range beyond which targets appear as a second-time around echoes is the maximum unambiguous range Run and is given as

Max Range=CTprt/2=C/2PRF { Tprt=1/PRF

Where PRF=Pulse Repetition Frequency

6.RADAR BLOCK DIAGRAM:



The TRANSMITTER may be a power amplifier, such as the klystron, travelling wave tube, or transistor amplifier. It might also be a power amplifier such as magnetron oscillator.

The radar signal is produced at low power by WAVEFORM GENERATOR which is then input to the power amplifier. In most power amplifiers, a modulator turns transmitter on and off in synchronism with the input pulses. When a power oscillator is used it is also turned on and off by PULSE MODULATOR to generate a pulse waveform. The output of the transmitter is delivered to the ANTENNA by a waveguide or other form of transmission line, where it is radiated into space. Antennas can be mechanically steered parabolic reflectors mechanically steered planar arrays or electronically steered phased arrays.

The DUPLEXER allows a single antenna to be used on a time-shared basis for both transmitting and receiving. The duplexer s generally gaseous device that provides a short circuit (an arc discharge) at the input to the receiver when transmitter is operating, so that high power flows to the antenna not the receiver. On reception, the duplexer directs the echo signal to the receiver and not to the transmitter.

The receiver is almost always a superhetrodyne. The input or RF stage can be a low-noise transistor amplifier. The mixer and local oscillator convert the RF signal to an intermediate frequency (IF) signal where it is amplified by an IF amplifier. The IF amplifier is designed as a MATCHED FILTER. The matched filter maximizes the delectability of weak echo signals and attenuates unwanted signals.

The IF amplifier is followed by a crystal diode, which is also called the second detector or demodulator. Its purpose is to assist in extracting the signal modulation from the carrier. The combination of IF amplifier, second detector and video detector act as ENVELOPE DETECTOR to pass the pulse modulation and reject the carrier frequency. The combination of IF amplifier and video amplifier is designed to provide sufficient amplification, or gain, to increase the level of input signal to a magnitude where it can be seen on a display, such as a cathode-ray tube (CRT).

At the output of receiver, decision is made whether or not a target is present. The decision is based on the magnitude of the receiver output. If the output is large enough to exceed a pre-determined threshold, the decision is that a target is present. If it does not exceed the threshold, only noise is assumed to be present.

7.RADAR RANGE EQUATION:

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

Pr=PtGtAr F^4/(4pi)^2 Rt^2Rr^2

Where

Pt-------transmitter power

Gt-------gain of the transmitting antenna

Ar--------effective aperture (area) of the receiving antenna

F----------pattern propagation factor

Rt--------distance from the transmitter to the target

Rr-------distance from the target to the receiver

8.CLASSIFICATION OF RADARS:

Radars can be classified as ground based, airborne, space borne, or ship based radar systems. They can be classified into numerous categories based on the specific radar characteristics, such as the frequency band, antenna type, and waveforms utilized. Another classification is concerned with the mission and/or the functionality of the radar. This includes: weather, acquisition and search, tracking, track-while-scan, fire control, early warning, over the horizon, terrain following, and the terrain avoidance radars.

Radars are most often classified by the types of waveforms they use, or by their operating frequency. Considering the waveforms first, radars can be continuous wave (CW) or pulsed radars (PR). CW radars are those that continuously emit electromagnetic energy, and use separate transmit and receive antennas. Unmodulated CW radars can accurately measure target radial velocity (Doppler shift) and angular position. Target range information cannot be extracted without utilizing some form of modulation. The primary use of unmodulated CW radars is in target velocity search and track, and in missile guidance. Pulsed radars use a train of pulsed waveforms (mainly with modulation). In this category, radar systems can be classified on the basis of the Pulse Repetition Frequency (PRF), as low PRF, medium PRF, and high PRF radars. Low PRF radars are primarily used for ranging where target velocity (Doppler shift) is not of interest. High PRF radars are mainly used to measure target velocity. Continuous wave as well as pulsed radars can measure both target range and radial velocity by utilizing different modulation schemes

GROUND PENETRATING RADAR:

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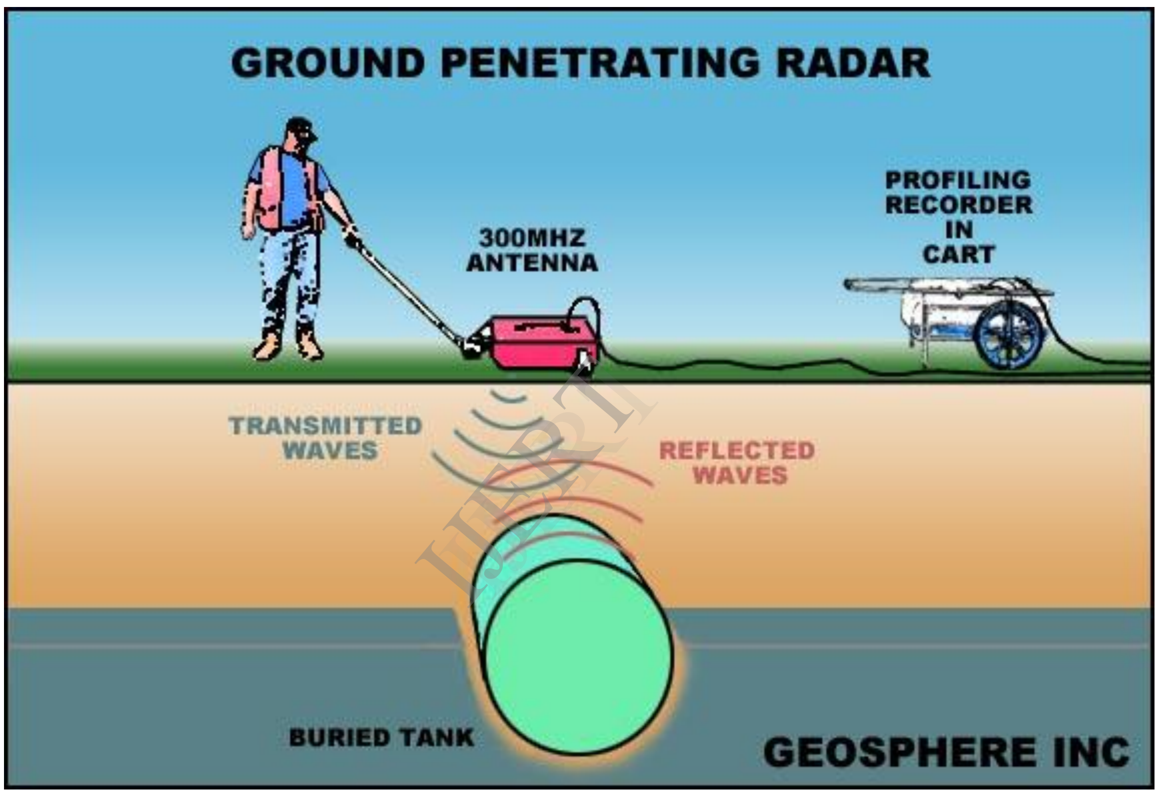
BLOCK DIAGRAM:

A block diagram of GPR is as below:



The source of energy can be amplitude, frequency or phase modulated waveform or noise signal, and the selection of bandwidth, repetition rate and mean power will depend upon the path loss and target dimensions. Targets can be classified according to their geometry: Planar interfaces, long thin objects or localized spherical or cuboidal objects. GPR uses transmitting and receiving antennas or only one containing both the functions. The transmitting antenna radiates short pulses of high-frequency (usually polarized) radio waves into the ground. When the wave hits a buried object or boundary with different dielectric constants, the receiving antenna records variations in the reflected return signal.

The depth range of radar is limited by the electrical conductivity of ground, the transmitted center frequency and the radiated power. As the conductivity increases, the penetration depth also decreases. This is because the electromagnetic energy is more quickly dissipated into heat, causing a loss in signal strength at depth. Higher frequencies do not penetrate as far as lower frequencies, but give better resolution. Optimal depth penetration is achieved in ice where the depth of penetration can achieve several hundred meters. Good penetration is also achieved in dry sandy soils or massive dry materials such as granite, limestone, and concrete where the depth of penetration could be upto 15m. In moist and/or clay-laden soils and soils with high electrical conductivity, penetration is sometimes only a few cm.

GPR antennas are generally in contact with the ground for the strongest signal strength; however, GPR air launched antennas can be used above the ground. The radiation pattern required for GPR applications must be unidirectional, this means that power radiated must be more focused at a narrow angular direction rather than spread evenly around the antenna.The need for this characteristics is to eliminate ambiguous target detection.

The following antenna specifications required:

- Operating bandwidth of between 400-800MHz, i.e. ultra wide-bandwidth, bandwidth greater than 20% of center frequency.
- Directive antenna with maximum energy projecting into the ground
- Antenna will need to be robust and mobile for active GPR testing.

Antenna’s input impedance will have to be balanced and transformed to 50 to minimize mismatch between antenna and radar.

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The technique used is no different from that of a conventional free-space radar, but of the factors that affect the design and operation of any radar system the four requirements indicated earlier take on the additional significance in ground penetration work. Specifically propagation loss, clutter characteristics and target characteristics are distinctly different.

APPLICATIONS:

GPR has many applications in number of fields. In the earth sciences it is used to study bedrock, soils, groundwater, and ice. Engineering applications include non destructive testing (NDT) of structures and pavements, locating buried structures and utility lines, and studying soils and bedrock. In environmental remediation, GPR is used to define landfills, contaminant plumes, and other remediation sites, while is archeology it is used for mapping archaeological features and cemeteries. GPR is used in law enforcement for locating clandestine graves and buried evidence. Military uses include detection of mines, unexploded or dance, and tunnels. GPR technology is being used to reduce the false alarm rates and providing improved detection of low metal content mines.

Borehole radars utilizing GPR are used to map the structures from a borehole in underground mining applications. Modern directional borehole radar systems are able to produce three-dimensional images from measurements in a single borehole. One of the other applications fro ground penetration radars is to locate underground utilities. They can generate 3D underground images of pipes, power, sewage and water mines. While most GPR are used in close proximity to the ground, air borne systems have been able to map ice transformations through a thick forest canopy.

CONCLUSION:

Simulation of signal processing block of GPR using a stepped frequency waveform of bandwidth 3GHz is successful. We were able to resolve 3 targets successfully. We have also proved that SFW is giving good output as compared to LFM since the generation of LFM with such a high sweep bandwidth is not possible so we have used a stepped frequency waveform.

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