Laboratory Practices in Earth Sciences: Landscape Mapping
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Week- 08
Lecture- 34

Welcome back. So, in this lecture we will talk about the GPR, Ground Penetrating Radar and various applications of that. Now, initially I will come to that history also why we should start using GPR for various applications like archeology and mainly to map the subsurface structures. Even we did for the utility mappings mapping and also for mostly for the geology subsurface or near surface stereography. So, in this lecture of course, the title that I have given is the GPR application for archeology and cultural heritage, but that does not limit to this. So, let us look at what exactly the GPR is, how it works and what all information we can extract using this application.

So, GPR by Taiti Kanpur we are having different units. This unit what you see is 350 megahertz. This unit what you see is 350 megahertz. This is the antenna here of 350 megahertz.

So, what is the importance of the frequency of different antennas that also we will discuss in this actually. Now, all the units that we are having are all shielded units and so, they avoid catching the surrounding noise of the area. Now, brief details about the GPR, then we will talk about the working principle, the initial aim using the GPR. So, the initial aim of using GPR when we had this was to use for the near subsurface mapping or at the archeological sites. And the results from the geological investigations and we will discuss this also in a few results from the archeological sites.

So, we have different units like the model name that is 3000, we also have 4000 and we have 350-megahertz antenna. Now, this is a 100-megahertz antenna and when we connect this in parallel, then this becomes like a 50-megahertz antenna. And this one what we are having here is the 200 megahertz. This is a 200-megahertz antenna and this is, as I said, the 100-megahertz antenna. And when we connect this to and then this becomes a 50-megahertz antenna and this one is your 400-megahertz antenna.

Now, there is a thumb rule which we usually take into consideration is that if you have lesser frequency and greater penetration depth. This is the unit on which we usually collect the data. So, transmission and collection are through the same unit. You see this is what I was talking about: that single antenna you are having 100 megahertz and when you connect in parallel, then you reduce the frequency that is 50 megahertz. So, if you are having 100 the depth will be comparatively lesser to what we will get then the penetration depth in the 50-megahertz antenna.

So, as I said, we have mainly for utility scan and all that we have 350-megahertz CPR antennas, then we have 400, 200, 150 and then 100-megahertz antennas. So, this is what we are having the 100-megahertz antenna and then we also use the odometer. This is also an important part of that because this measures the distance and, in this cart, we have the odometer which has been already connected in one of the wheels of this one. So, we have a GPR system and then we have a control display unit, antenna, then survey encoder and we have a power unit. So, basically we use the batteries for both of these units. One is here and another battery we use in this one is actually in this unit.

So, we have two batteries which have been connected and then this is with the tough pad and in 400 megahertz again we are having a similar unit which has not been shown here, but a similar unit as SIR 3000 that is our control unit. And the control unit has and like we can use for different modes even we can have the 3D mode of mapping and in 2D mapping you can do in a single line or the transect in the same direction. And you have the options in this to tweak with the parameters and what are those parameters I will come across in the few slides. So, this is a 200-megahertz antenna. Now, looking at the principal propagation and reflection of the electromagnetic, basically it uses the electromagnetic waves.

So, usually we know that most of the earth 's material is magnetic even though most of it is non-magnetic. So, propagation of the electromagnetic wave will be in this fashion which will be perpendicular to one another that is electrical and magnetic waves which will travel and depending on the dielectric properties of the material it will be reflected back and that is what we are actually scanning. So, depending on the property of the material the dielectric constant will be different for different earth materials. So, if you are having dry soil or sand or wet sand and saturated sand. So, the transmission will vary and that is what has been shown here.

So, in dry material the transmission will be faster and it will penetrate to a greater depth whereas here it will be slower as compared to that whereas in saturated material it will be quite slow. So, this is one point which we have to keep in mind and usually we try to look at this propagation with respect to the transmission or we compare usually with the speed of light in vacuum which is around 0.3 meter per nanosecond. So, I will also explain why we are talking about this. The propagation velocity of the EM wave is governed by two major factors : your frequency of the applied signal, that is your antenna and what is the frequency you are taking and then dielectric permittivity.

So, dielectric permittivity plays an important role there and dielectric permittivity will be affected because of the property of the material. So, usually what we do is we try to move our unit on the surface as it has been shown here. So, it will transmit and it will collect. So, this is giving you two-way travel time. So, once one travels another travels.

So, two-way travel time is usually seen here. Now the reflection received depends upon the dielectric contrast or we can say the permittivity of the subsurface material. So, this is what I have been emphasizing is the most important. The material with different dielectric constant either you say K or ER will have different travel time and that is what we are looking at the two-way travel time. So, this is one and then it is taken back here.

So, this is two-way travel time we usually measure and reflections recorded provide a high resolution profile. So, this will exactly not give you the picture of the subsurface, but it will give you the reflections that are coming on to the surface and this is what usually we have. We take the sinusoidal pattern positive and negative signals and that will be you. So, this is negative, this is positive. So, that has been recorded here. So, this has been what we call wiggle.

So, this lower picture or the figure it shows wiggle and exactly this is the line scan. So, the reflections that have been shown are the way of presenting what we are getting the data from. So, exactly it shows the similar pattern over here, but one is in the line scan with different colors and here mostly the blue and blue red and white, but here we are looking at the wiggle as I have shown here. So, it is very common if we are collecting the data in continuous mode as it is shown in this picture here. So, GPR is used for non-invasive scanning.

So, you do not need to dig it, but you can also get the information without digging the material. So, the dielectric constant of this material that is your pipe will be different as compared to what you are having the soil in surrounding. So, this material will have different dielectric constant that can be easily picked up and that is why it can be easily picked up and mostly if when the utility mapping is done you come across this type of hyperbolas, because the pipe is sitting here and that will give you the reflections here. So, this will come in the form of the wiggle here and that you can have representation in terms of the line scan also. So, this will produce a typical signal that has been shown here.

So, this is the wiggle here you are having and so pipe which is sitting here even you can calculate the diameter of the pipe and also the depth at which it has been seen or it is encountered. So, this is exactly what we are looking at. So, we can identify the subsurface object as well as the depth at which it is lying and similarly it goes for the structures also. The dielectric constants if you take the soil rocks and many other earth materials are non-magnetic. I do not say all materials are non-magnetic, but some materials are non-magnetic, but are electrically conductive and have relative permittivity.

So, it will not allow all the signal which has been going or the energy has been transmitted down it will be reflected back and that is exactly what we are talking about the permittivity. So, permittivity of the medium E is compared to the permittivity of the free space and that is what I was talking about the velocity of the light. A value for the relative permittivity that is your E r is obtained which is known as your dielectric constant. So, this is your E r is your dielectric constant of any given material. So, the equation is very simple here.

So, directly the constant here is that you have E that is the permittivity of your medium and the permittivity of the in the free space. And where k or E r there is a dielectric constant of the medium and that is known as the relative permittivity E 0 is the permittivity of your free space that is your in air. And E is finally, what we are looking at is the permittivity of the medium. Now if we take the working principle of the relation between the velocity of the wave and the material properties, dielectric constant of permittivity is the fundamental basis for using GPR to investigate the subsurface. And the velocity of the electromagnetic wave in air is above 10 to 10, raised to 10 to the power 8 meter per second or you can say around 0.

3 meters per nanosecond is the velocity of electromagnetic waves in air. So, the velocity of the red out propagation in a medium is proportional to the inverse square of your permittivity of that material where V is your velocity of the medium and of the electromagnetic wave in a medium. C is the velocity of light and E r is your dielectric constant where V again will be the frequency by lambda that is your wavelength. So, to find the depth of the buried object is a very simple equation where we know that the travel time will be taken into consideration like it is two-way travel time. So, what we need is that if we want to calculate the depth of a given object, then we need the velocity and the two-way travel time of that particular reflection.

And that can be given as which is like V into T by 2 here. So, what we see is that further that you are having the V is your further we can if you put this C by square root of because we have seen here this is your V. So, this what you are putting an input here. So, we have input here of V which is also given as D is equal to. So, this becomes because we know the velocity of the light that is your C and that gives you 0.

15. So, this will be your final equation. So, once you know what this travel time is then you can easily talk about an E r then you can easily talk about the depth actually. So, since the permittivity of earth material is greater than the permittivity of air. So, the permittivity of earth material is greater than the permittivity of the air. The travel time of the wave in a

material other than air will always be greater , which means it will actually delay.

It will not be as fast as what we see in the air because the permittivity is greater. So, the travel time of the wave in a material other than air is always greater than 3.3. This is the velocity of the in air or velocity of the light we are taking up. So, these are some basic points which one can take into consideration as I call, but told that we need to calculate the depth.

So, depth also you can obtain once you know the Er and you know the velocity and two-way travel time. So, the depth of the radar energy can penetrate depends largely upon two factors, that is frequency of the antenna and another is the dielectric constant that is a permittivity. So, the frequency again is if we say it is almost inversely proportional to the wavelength. So, that we will also have in the coming slide I will just explain that part also. So, this is the chart which is been given based on the different experiments conducted across the globe and depending on that this is the relative dielectric permittivity is been set out that what will be of the dielectric constant or dielectric permittivity of different material like dry sand and then granite and coal, shale, clay and etcetera.

So, moisture content and its distribution will affect the bulk density, porosity, physical structure and the temperature and that will also affect the overall property of the material. So, more electrically conductive material less penetration energy gets attenuated at the shallower depth. So, this is what we were looking at in the slides ahead in that if you are having like the more conductive material and even if you are having the saturated material the penetration will be slower. So, higher high electrically conductive material examples, saline water, clay and wet soil restrict the penetration of radar waves. Also, the higher the magnetic permittivity permeability more electromagnetic energy will be attenuated during the transmission will affect the further transfer penetration.

So, these two original points can be kept in mind when we are conducting the survey. Now radar energy if we take in GPR application the frequencies are ranging right from this. So, antennas we have from 10 megahertz to 1500 megahertz and that is again as I said that this energy occupies the same spectrum of television and FM radio broadcast, cellular phones and other personal communication devices. So, mostly when we are performing this survey we ask our team to switch on the mobiles because that can create noise and that can be recorded into the data which we are requiring. Low frequency antennas generate long wavelengths and the penetration depth will be more accurate.

So, it penetrates to 50 meters and depending on the site conditions. And then high frequency will produce shorter wavelength and it penetrates shallower. So, mostly if we have to do a very detailed high-resolution subsurface mapping then we use a 400-

megahertz antenna. So, that the penetration depth is shallower and we acquire good information in this case ok. Whereas, if you want to go deeper then we use a low frequency antenna.

So, for example, if we are using 100 or 50 then we are able to go much deeper. So, it is a thumb rule that higher the frequency, shorter the wavelength resulting in lesser penetration depth. Whereas, where as I said that velocity is almost like in, we can say that the frequency and the lambda we can say it is inversely proportional to each other. So, frequency is inversely proportional to your wavelength or you can say the wavelength is directly proportional to your depth actually. So, reflections in terms of as I said that we can have several traces and that can produce a sort of a reflection profile that has been seen here and this is what we are looking at the line probe is the line scan and where we are looking at the positive pulse.

So, we are having the sinus that is what I was talking about. So, if you take this line and you are having negative positive, negative positive and so on. So, this is what we call wiggle and this one is the representation of the way where we are having the line scan with the red and blue pulses. So, further if we as we discussed that if you are looking at the utilities in subsurface for example, if you are having pipes we will be looking at typical hyperbolas. And as I said that if you know the two-way travel time and the dielectric constant you can calculate the depth also of this.

So, for example, this is a 3D scan of an area where you can clearly see these two hyperbolas. This is one and this is another. Now, what does this imply? This implies that at this depth there is a utility from the surface and this is this one and then you can also talk about the diameter of your pipe. And this you can now see very clearly. So, this is a broader pipe here you are having and this one is the with the smaller diameter and that will give you the depth also.

So, this is what is the advantage of GPR and also, I would say that the advantage of taking the GPR survey in 3D. So, that helps you slice down at various locations in terms of the depth and then understand how the pipe even you can trace out because you are having the data collected in a horizontal way also and then you are having the vertical profile. So, you can also trace out in which direction your utility or the pipe has been aligned that also you can do with this. So, I will end up here and we will continue with this further showing you more examples of what we have done in the archaeological sites and all that and also in the geological investigations in the next lecture. Thank you so much. Thank you.