Global Navigation Satellite Systems and Applications
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Lecture - 12
Real-Time Kinematic (RTK)

Hello everyone and welcome to new discussion which is on the RTK. This is 12th lecture of Global Navigation Satellite Systems and Applications course. And in this RTK that is Real-Time Kinematics, we are going to discuss that first of all, it is different than our differential GNSS and how this technique works and what are the other options available with this technique.

One thing I can definitely say at this stage that compared to DGNSS that is Differential GNSS system, here this RTK is developing at a very fast rate and things are becoming very you know, common and popular among the users. And very soon with the introductions of SBAS that is the Satellite Based Augmentation System.

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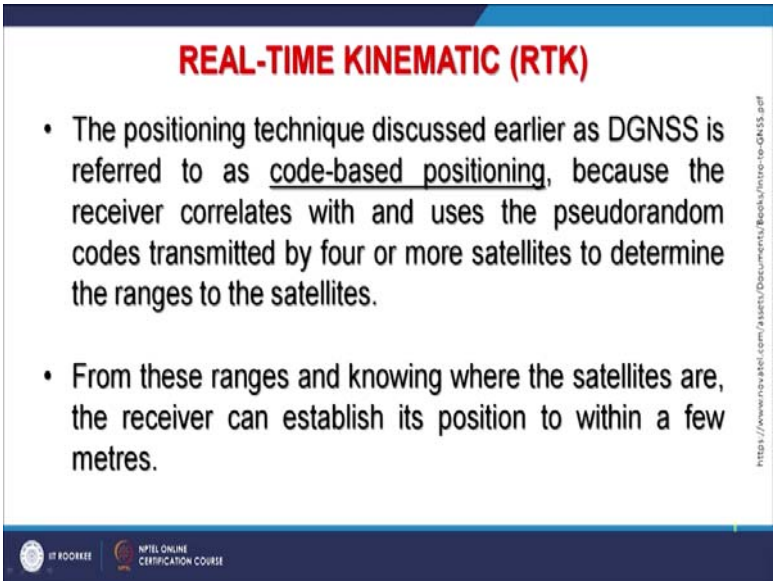

This RTK can become so useful and so easy that using a single handheld GPS receiver or GNSS receiver and even in your smart mobile can give you accuracy of few centimetres. So, that is the real future of this technique compared to DGNSS which is now it is already established that is there but you require different things setup for that.

So, the position technique which we have already discussed with DGNSS is referred as code-based positioning but in case of this RTK, we are going to discuss technique which is a carrier-based technique. So, it uses the carrier signals instead of code-based signals. So, here in the DGNSS, the receivers correlates with and uses the pseudo random codes transmitted by four or more satellites to determine the ranges to the satellites.

Whereas from these ranges DGNSS by knowing where the satellites are, the receiver can establish its position within a few metres.

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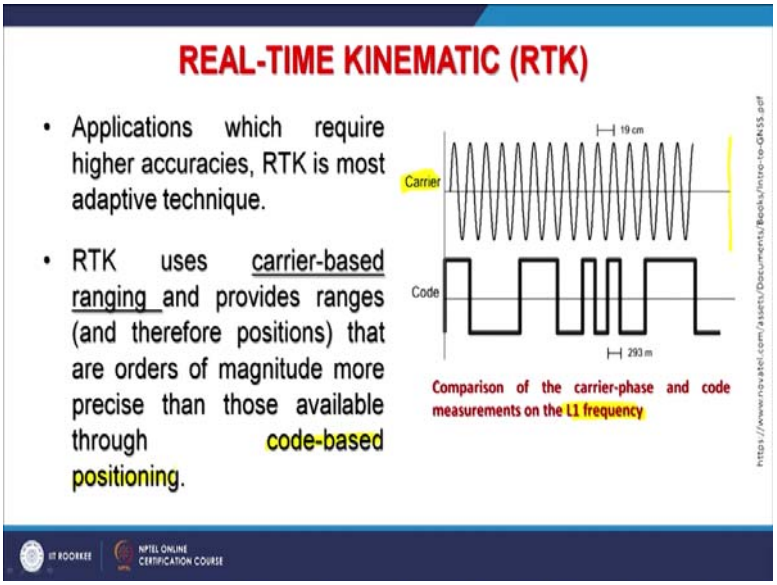

Application of which require higher accuracy; there are several applications. For example; might be application in Crustal Deformation studies where we would like to know that how these different tectonic plates of the earth are moving? What is the speed? What is the direction velocity all those things? And there might be a many other RTK applications which are coming where you want to use a driverless vehicle and so on so forth.

So, in such applications, one requires a very high accurate position and therefore the RTK can play a very good role there. So, that is why now instead of DGNSS, lot of development is taking place in case of RTK. As I mentioned that in the DGNSS, it was a code-based technique whereas this RTK is the carrier-based technique. And this is working on the L1 band or frequency which is being transmitted by the satellites of various navigation systems.

So, RTK uses carrier-based ranging instead of code-based ranging and provides ranges and therefore positions that are orders of magnitude more precise than those available through the code-based that is your differential positioning system.

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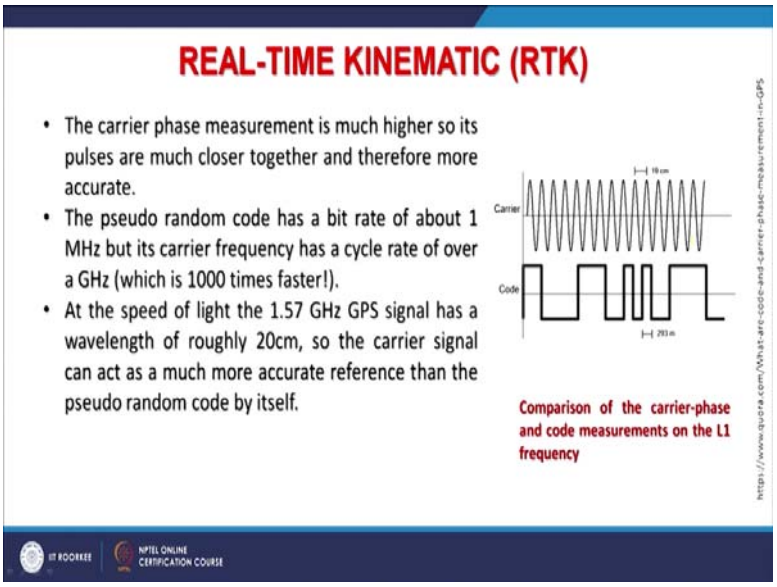

And carrier phase measurement is much higher. So, its pulses are much more closer as you can also see here and therefore more accurate it can give the position and the pseudo random code has a bit rate of about 1 mega Hertz but its carrier frequency has a cycle rate of over a Hertz which is about 1,000 times faster.

And also at the speed of light, the 1.57 giga Hertz GPS signals has a wavelength of roughly 20 centimetres. So, the carrier signals can act as much more accurate reference then the pseudo random code by itself. So, code-based technique may not give such kind of accuracy. So, carrier phase measurements are able to provide a precision at a millimetre level and this is what it is being exploited in case of RTK. As you can see here again you are having a roving station and of course, base station.

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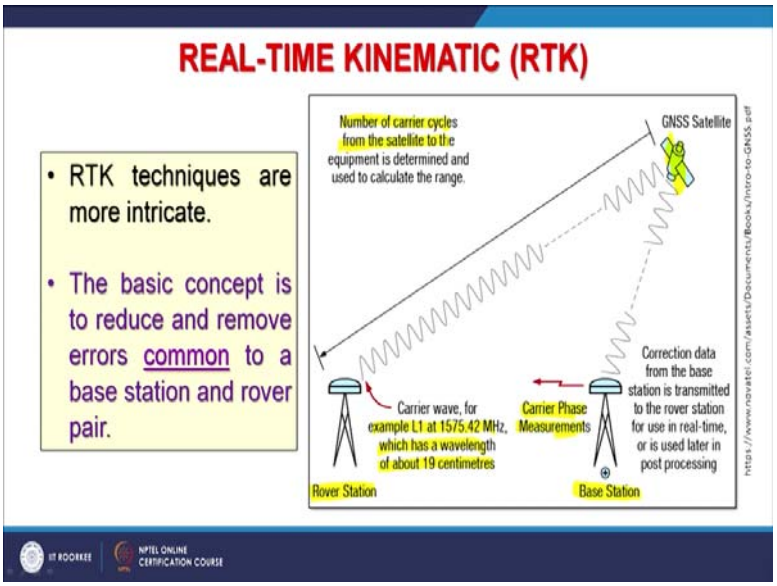

And these are the carrier phased measurements are being done by the base station which may be transmitted to the roving station in real time or a GNSS satellites can also transmit or a geostationary satellite can also transmit these errors signals to the rover receiver.

So, the carrier waves for example; here L1 at 1575.42 mega Hertz which has a wavelength of about 19 centimetres as you know schematically it has shown here. And the correction data from the base station is transmitted to the roving station for use in real time or used later in post processing. This is similar in that sense with compared to differential GPS. So, number of carrier cycles from the satellites to the equipment or receiver is determined and used to calculate the range.

So, RTK technique is more intricate because the basic concept here is to reduce and remove errors common to base station and rover pair. So, the errors are removed here in that way and as in case of DGNSS but the accuracy part is much more because instead of code-based ranging here we are using carrier-based ranging.

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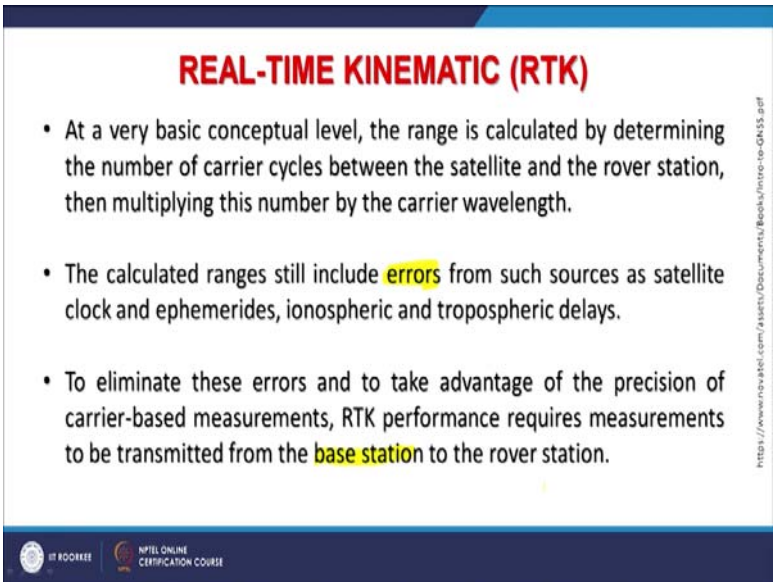

And the very basic conceptual level, the range is calculated by determining the number of career cycles between the satellite and the rover station and then using these carrier cycles to multiply this number by a carrier wavelength. And the calculated ranges still include errors which can be removed by using the base station data from such sources as satellite clock and ephemerides, ionospheric delays and tropospheric delays.

To eliminate these errors and to take advantage of precision of carrier-based measurements, in RTK; the performance requires measurements to be transmitted from the base station to the roving station. As I am saying that there is a possibility that instead of directly transmitting to rovering station, a base station can first transmit the data to a geostationary satellite and then that satellite can transmit data for a larger footprint or for a larger area where do not 1 or 2 but 1000's of roving receivers might be there and these receivers will directly receive signals from there.

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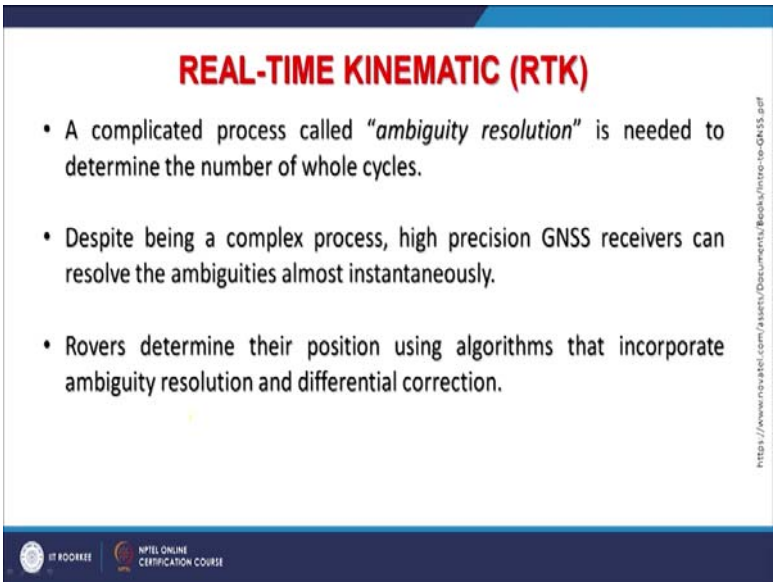

So, this is what is going to be or it is already happening in case of RTK. So, the complicated process called ambiguity resolution. It needed to determine the number of whole cycles and despite being a complex process compared to DGNSS or simple GNSS receiving position, this high precision GNSS receiver can resolve the ambiguities almost instantaneously and rovers determine their position using algorithms that incorporates ambiguity resolution and differential correction. So, that is why both receivers are required here also.

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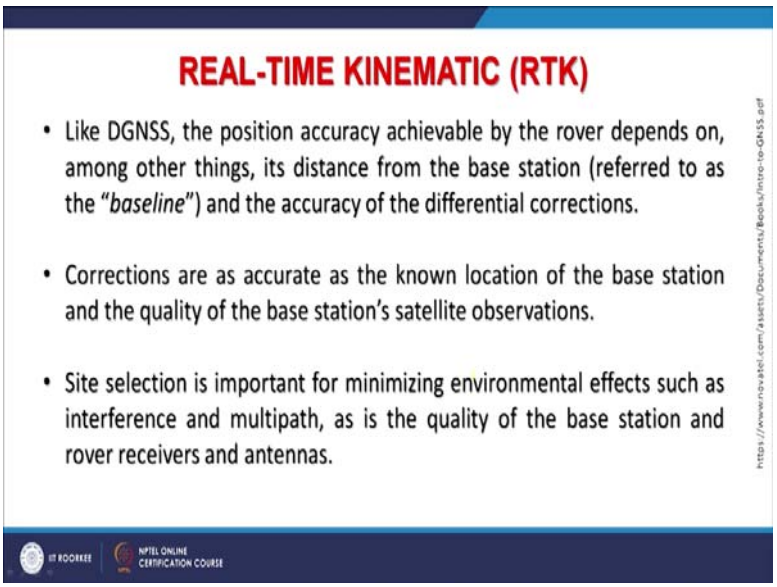

But if there is a SBAS signal which are transmitting errors then this problem can be solved. So, like DGNSS, the position accuracy achievable by rover depends on among other things, its distances from the base station that is a baseline and the accuracy of the differential corrections. Corrections are as accurate as known location of base station and the quality of base stations satellite observations and site selection is important for base station always.

For minimising environmental effects such as interference and multipath that means the base station should not be surrounded by building or a mountain in open area and should have minimum interferences from other signals also because nowadays having a lot of mobile towers and high density of mobile towers sometimes there might be some interference from these signals as well. So, the quality of base station and rover receivers and antenna, they will determine basically the accuracy part; how accurate the data is.

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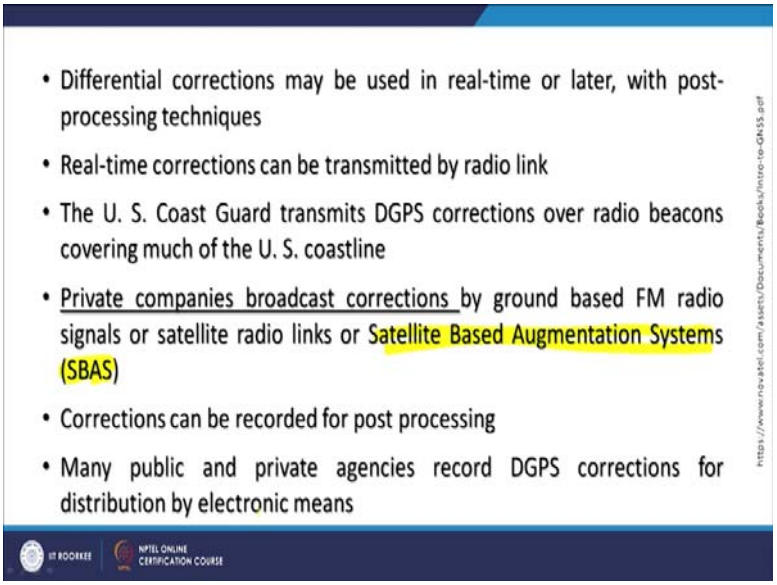

And differential corrections may be used in real time or later with post processing. Through post processing technique if at real time it is not possible to transmit errors or data from base station to rover station. Real time correction can be transmitted by a radio link and there is example in case of differential GPS U.S. Coast Guard transmit DGPS corrections over radio beacons covering much of the US coastline. In India also it was introduced through using GAGAN which is Ground Based Augmentation System and

these differential signals bare being transmitted or errors bare being transmitted and those who were in the coastal areas were getting the data.

But if we involve a geostationary satellite then it is called SBAS. So, in future very soon, we will be discussing this SBAS as well. So, if we involve that one then we do not require a base station. A common base station can serve you know, lot many surface or lot many people by transmitting data to a geostationary satellite and then the satellite back transferred to the various rovering stations all the time.

So, private companies are now coming here, they are broadcasting corrections by Ground Based FM radio signals or satellite radio links or Satellite Based Augmentation Systems as I have been mentioning that is SBAS. Then roving receiver needs corrections. Now these corrections can come from a base station, we ourselves might have installed or a base station installed by some government agency or base station installed or established by a private company.

That's the only requirement for a roving station to get the correction data. If I want to use in real time that in the field I should get. So, getting signals or errors from this Satellite Based Augmentation Systems, this makes much easier because suppose one satellite over India having this SBAS concept can transmit errors all the time for a large footprint which will not only cover India but surrounding countries as well and in that way, a single receiver as a roving receiver can give you the very high accuracy of few centimeters very easily.

And corrections can be also done through post processing if real time corrections are not available. Many public and private agencies as I have already mention record DGNSS corrections for distribution by electronic means. So, through internet and others, these differential connections can also be made available but if somebody is intending for post processing. But the techniques have now developed so much that it is really now possible to do RTK in near real time or exactly maybe real time.

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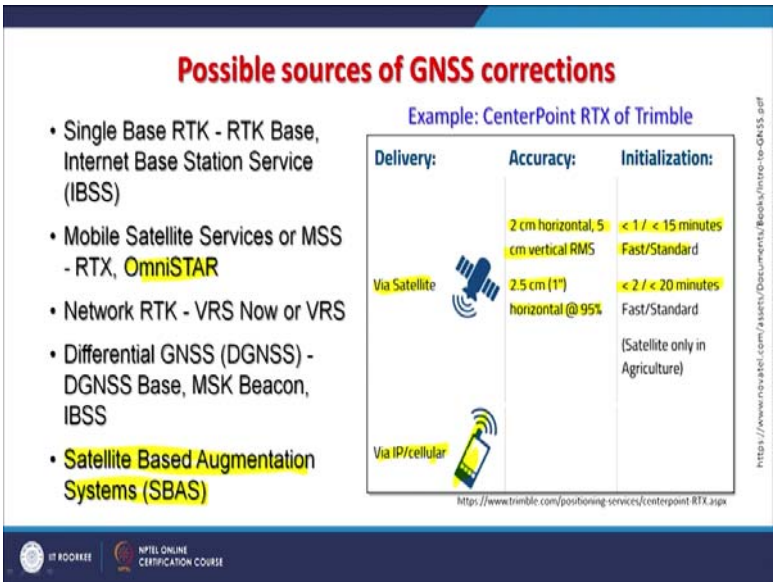

So, single based RTK: RTK Base, Internet Base Services are there that is IBSS. Mobile Satellite Services or MSS that is RTX, OmniSTAR, these are the providers of these errors data. Network RTK: VRS Now or VRS. And by Differential GNSS or DGNSS: so that you are having data through beacons along the coastal areas. Satellite Based Augmentation System that is the future; already some satellites are coming. Over India also with using your smart mobiles and appropriate app, you can also locate at least one SBAS satellite over India.

And if app or software is capable of using SBAS data then your mobile receiver can give you much better accuracy. Earlier without SBAS, it might have been giving best accuracy of say 3 or 4 meters. Now the same receiver will start giving you the accuracy of 10-20 centimetres. So, it is a huge development by using SBAS data, only thing you have to make sure that your application is using SBAS data to give you a RTK as a solution. So, by satellite as we can see that accuracy 2 centimetres horizontal, 5 centimetres vertical root mean square is possible and 2.5 centimetres horizontal at 95 percent confidence.

And initialization that might take 1 to 15 minutes fast in standard or in case of 2.5 centimetres that 2 to 20 minutes. So, initially sometimes it may take some time but once your roving receiver has established the links with the different satellites including SBAS then you start getting very good accuracy or it is also possible via your mobile

network but again because mobile network is not available in all parts of the, say in country of from the same company. So, a mobile network may be better of a company in a hilly terrain, but in a coastal area that network may not be there.

Whereas, if we get the signals these error data from the SBAS technique that is Satellite Based Augmentation then these data will be available everywhere around the clock. So, that is what it is coming now.

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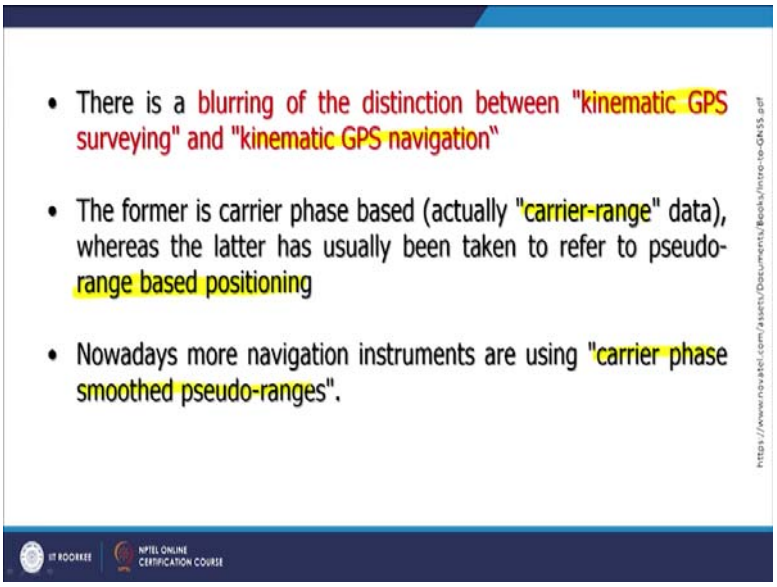

Now there is a blurring of distinction between kinematic GPS or GNSS surveying and kinematic GPS navigation. The former is the kinematic GPS navigation is a carrier phase based which is carrier ranged data which uses the carrier range data whereas the later the usually has taken the pseudo random based.

So, this range data is the pseudo range based data that is code-based data. So, nowadays more navigation instruments are using carrier phase smoothed pseudo-ranges. So, rather than code-based signals, they are moving towards a carrier phase signals. So that, more accuracy can be achieved by these receivers.

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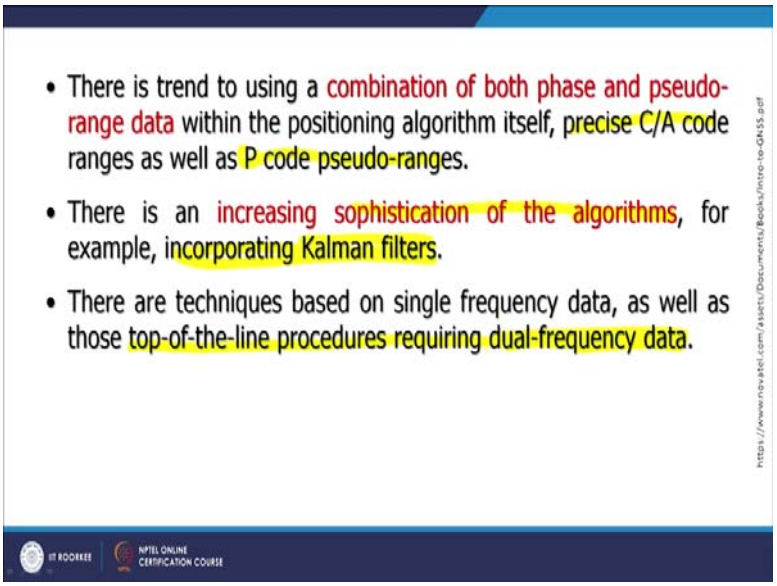

There is a trend of combination of phase and pseudo range data within the position algorithm itself, precise Course Acquisition code ranges as well as Precision code of pseudo-ranges. And there is increasing sophistication as I have been already mentioning through these applications or programs that increasing sophistication of algorithms.

For example, incorporating a Kalman filters. So, if they are capable of using that you get further improvements in the position accuracy and there are technique based on single frequency data as well as those top of the line procedure requiring dual frequency data. Now if we go for this option accuracy can further be improved instead of single frequency data, dual frequency data.

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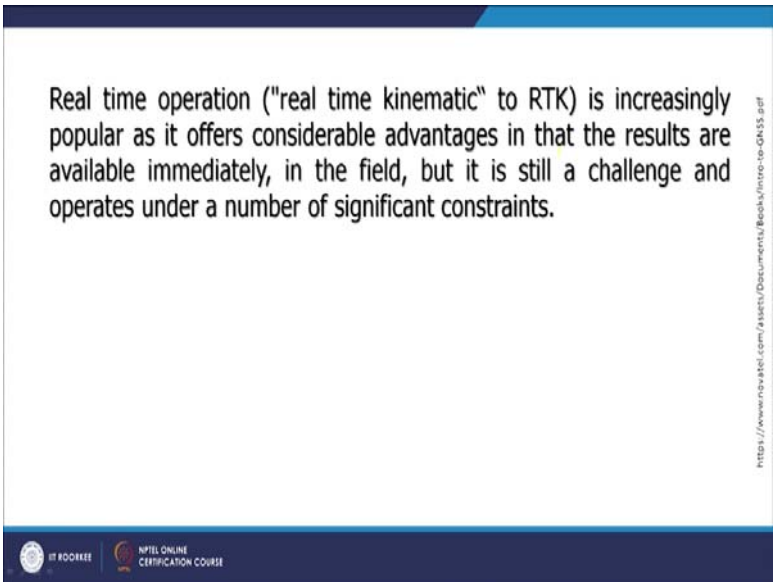

So, real time operations or RTK or Real Time Kinematic is increasingly popular because the error data is becoming available through various sources. So, it offers considerable advantages in that the results are available immediately in the field and during the survey but it is still a challenge and operates under a number of significant constraints. But very quickly, these constraints are getting removed and we are going to have on a regular basis in a normal conditions, RTK positioning that is of centimetre accuracy. Currently because sometimes if you get the signals, these error data from some private agencies then you have to subscribe to their services, so, they will charge.

But if some free networks are available then it becomes little cheaper. Of course, these carriers phased or carrier signal based receivers are currently expensive but in future they too, will become cheaper and then accuracy part will improve compared to what currently we are having or normally which our receivers are.

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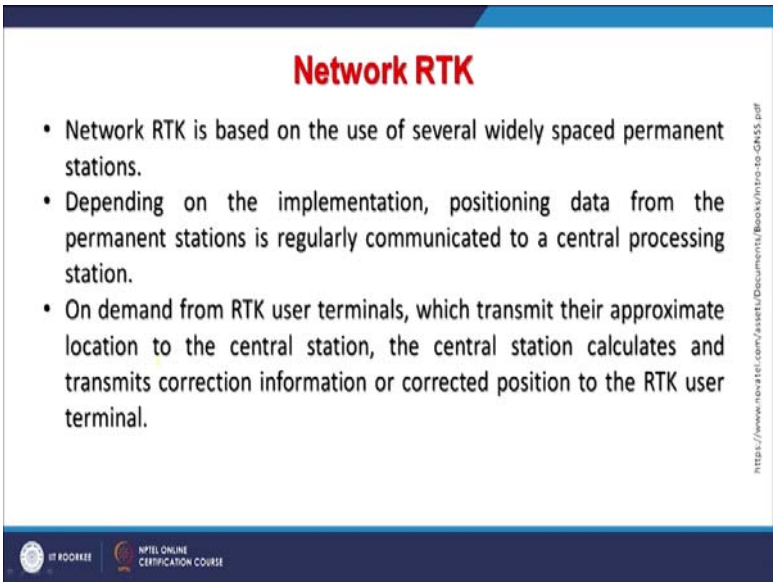

So, network RTK is based on the use of several widely spaced permanent stations maybe mobile towers, similar kind of situation. Depending on the implementation, positioning data from permanent station is regularly communicated to a central processing station. And on demand if you provide the subscription or get the permission then on demand from RTK user terminals, which transmits their approximate location to central station, the central station calculates and transmits correction information or corrected position to the RTK users terminal or to the receiver in the field for which you require of course, a network.

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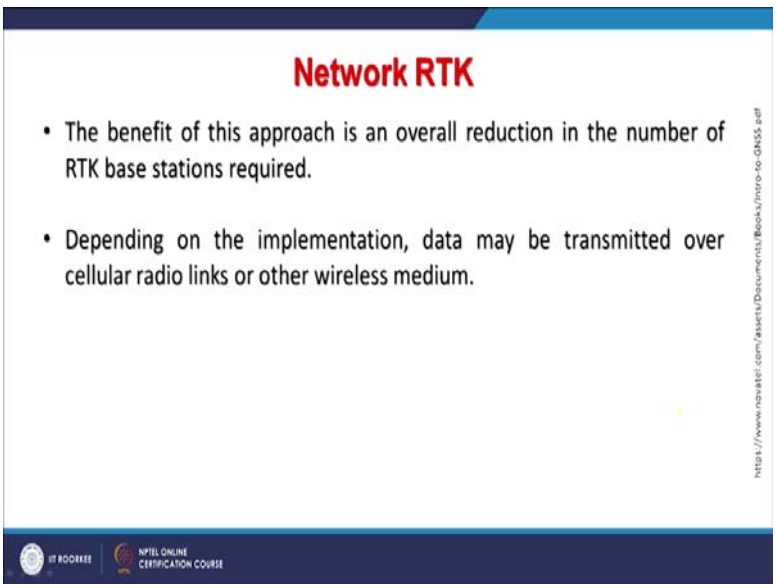

So, the network may be internet connections or through mobile network and the benefits of this approach is an overall reduction in the number of RTK base stations required. That is what people are targeting even a single Satellite Based Augmentation System can get better accuracy for you. So, depending on the implementation, how all this setup has been implemented, data may be transmitted over a cellular radio links or other wireless mediums.

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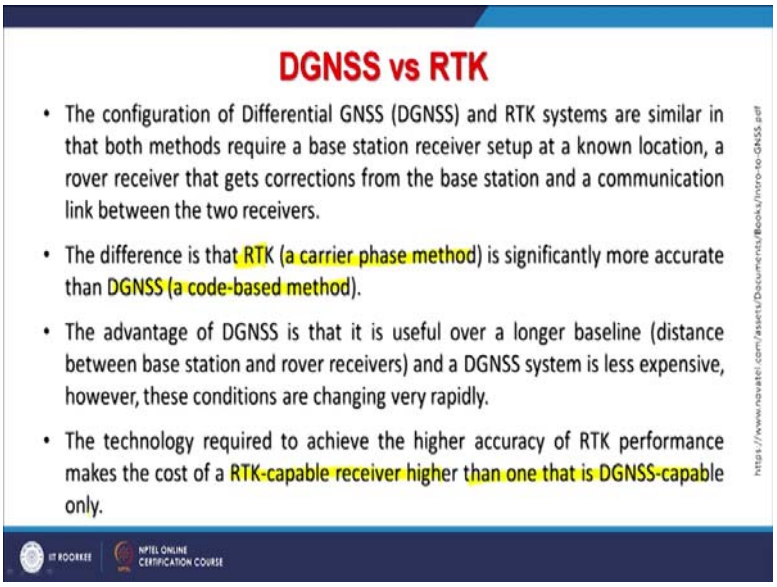

Now, we will quickly go through the comparison between DGNSS and RTK that the configuration of DGNSS and RTK systems are similar in that sense that both requires your base station as well as your roving station and if we want to do real time then you require error data in the real time through a communication link between these two receivers. And the main difference as have been also mentioned earlier in the beginning that the RTK is a carrier phased method and whereas your DGNSS is a code-based method.

That is the major difference here because this carrier phase method is much more accurate and then your code-based method. So, there are some advantages with DGNSS is also that the advantage with DGNSS is that it is useful over a longer baseline that is the distance between base station, base receiver and roving receivers and a DGNSS system is less expensive; currently it is less expensive and whereas as also mentioned

earlier indicated that RTK will also become less expensive once people start using and more companies are there.

So, more competition if there then this carrier phase method will become popular and cheaper also; cost keep changing. Now technology required to achieve the higher accuracy of RTK performance makes the cost of RTK capable receiver higher than one that is in the DGNSS because this code-based receivers have been there since about 25 years in civilian domain or more than that but these carrier phase based methods or receivers are recent introduction of only few years.

So, once they also pass through the time, I am sure that such receivers will become also cheaper. So, this brings to the end of this discussion about Real Time Kinematics and also comparison between real time Kinematics RTK and this DGNSS. We have also discussed about how post processing can be done. And if somebody is does not have this that link in the real time then post processing is possible and if error data is available in the real time then in the field itself, a high accurate position can be achieved.

But the future is have as also discussed that our future is in towards RTK and slowly-2 many countries are getting including India the signals from SBAS and which will make our receivers which would be of course, carrier phase method receivers which will give you much better accuracy and the applications because we started discussion on this RTK based application requirements.

Because now in many applications like you know this driverless cars or maybe driverless train services or many other applications where we require very high accuracy through these receivers or position accuracy and for which RTK can be one of the best solution available.

Thank you very much.