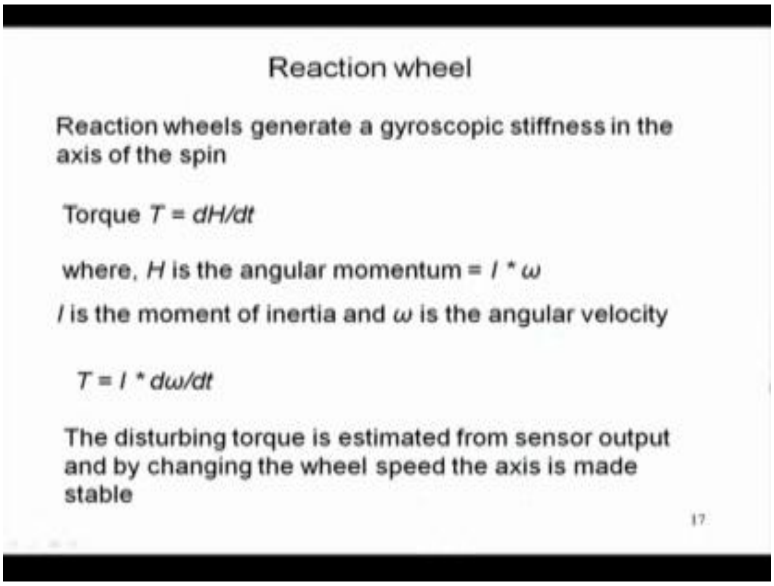
Satellite Communication Systems
Prof. Kalyan Kumar Bandyopadhyay
Department of Electronics and Electrical Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture – 07
Space Segment-2

Welcome back, to our Space Segment discussion.

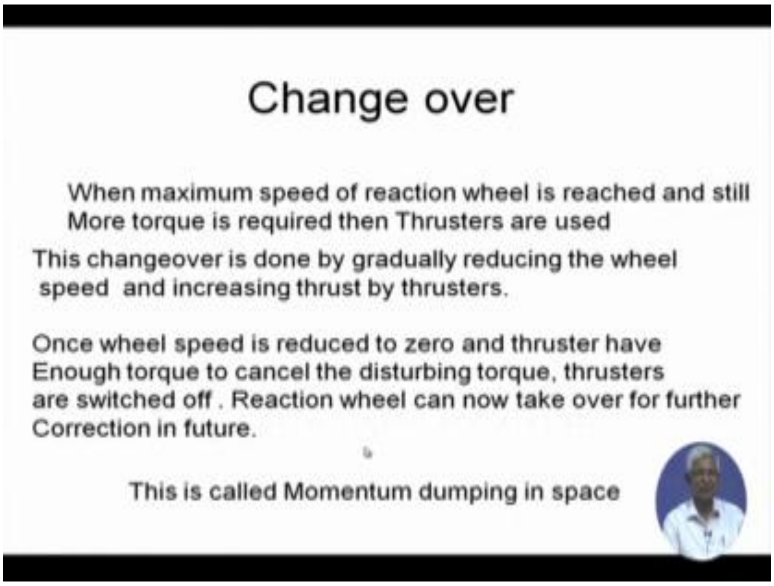
(Refer Slide Time: 00:23)



We stopped last at this particular slide which talks about reaction wheel. And this reaction wheel we are using to generate some stiffness, that means we run a wheel with a motor and its speed has increase the stiffness of the axis is adjusted, so we are continue to run this motor. The disturbing torque can be adjusted and further disturbance may come, so that is slightly difficult.

What is done is we have to stop this motor and let this talk be taken over by something else and get into the natural phenomena. So, that is done by some technique is changeover.

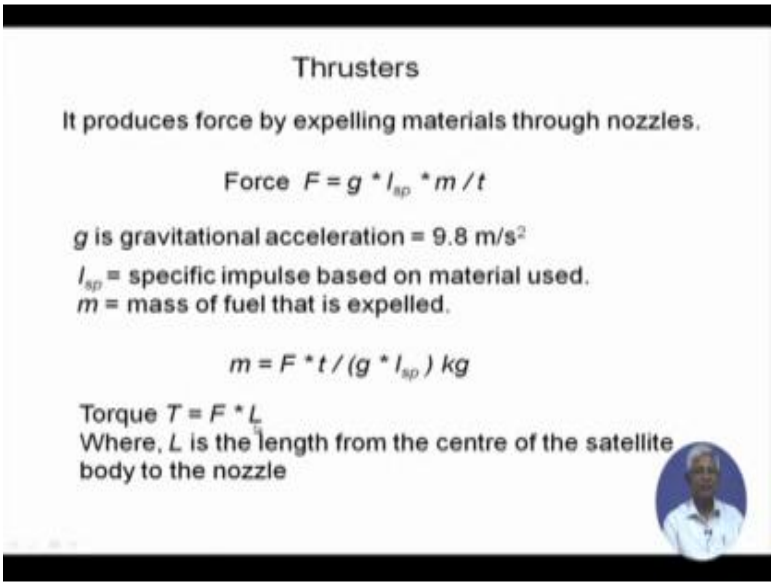
(Refer Slide Time: 01:10)



When the maximum speed of the reaction wheel is reached and still more torque is required then the thrusters are used. Thrusters are just the principle is just like a rocket proportion. So, this change over from the reaction will to the thrusters is done gradually. As you increase the thruster's thrusts the reaction wheel speed is reduced gradually. And at some point of time reaction wheel speed will be 0 and thrusters had achieved that particular thirst and thrust can be switched off of the thrust is already given.

So, this enough torque to cancel the disturbing torque the thrusters are switched off and reaction wheel can now take over for further correction in future that is reaction wheel is set to 0 now. So, this is called a momentum dumping in space technique.

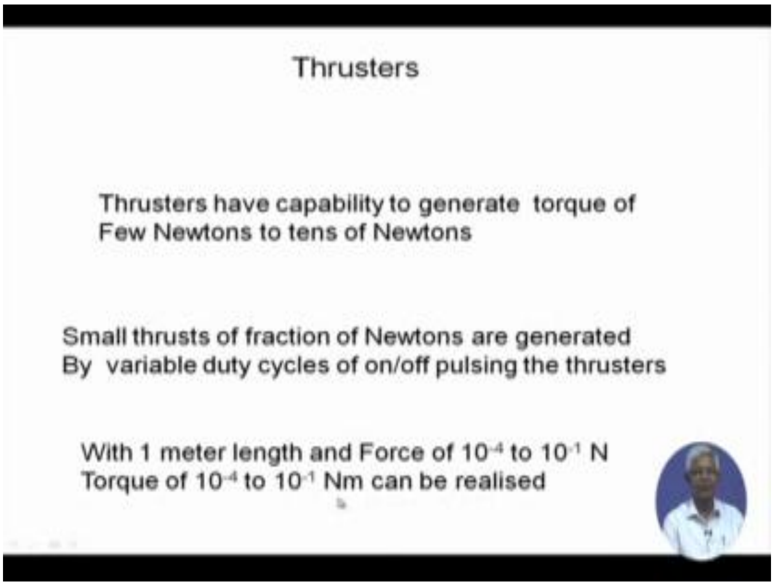
(Refer Slide Time: 02:13)



What is a thruster? Let us get into a very brief description of that. It produces force by expelling material through a nozzle. And that force obviously is equal to F is equal to capital of acceleration, then a something called specific impulse and mass of the fuel per unit time. So, amount of fuel that is (Refer Time: 02:38) the mass is you can slight change that is equal to m is equal to force into the time divided by gravitation acceleration and the specific impulse that is in kg.

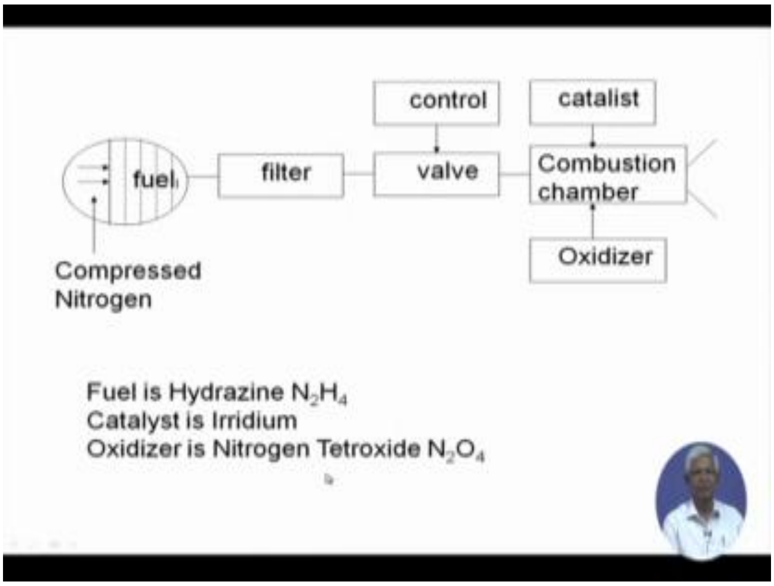
Now this force is given at the nozzle point. So, the torque is generated it dependence on the centre body of the satellite centre point to that particular nozzle the length. So, this force into the length will be torque; torque is F into L. Where, L is a is a length from centre of the satellite to the satellite body to the nozzle. That is the thrusters.

(Refer Slide Time: 03:21)



And how it is done? Thrusters have capability how to generate torque of the order of few Newton's to tens of Newton's. And very small thrust if is required a fraction of a Newton that can be generated by variable duty cycle of expelling the fuel or on of pulsing of the thrusters. And with approximate calculation could be with 1 meter length and the force of 10 to the minus 4 to 10 to the power minus 1 Newton a torque of 10 to the power of minus 4 to 10 to the power of minus 1 Newton meter can be realize simple.

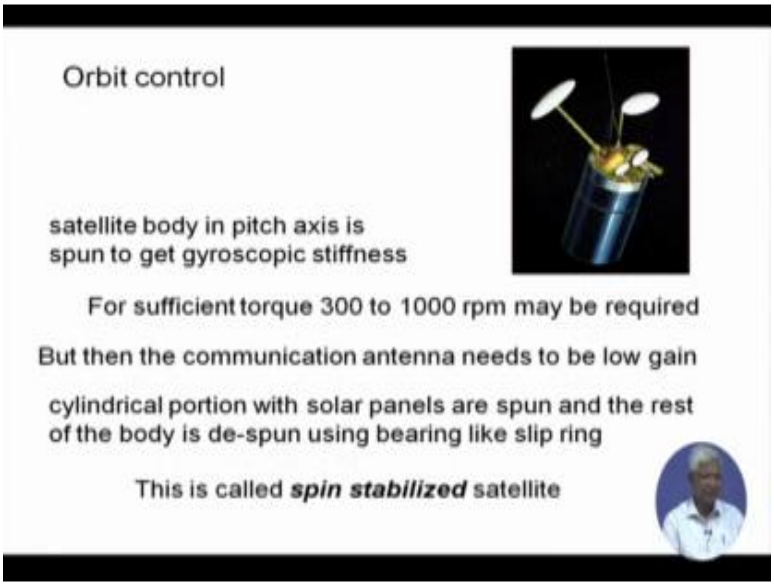
(Refer Slide Time: 03:59)



Now, brief block diagram of that; that is the fuel is there in a tank and compress nitrogen is pressing the fuel out that goes through a filter and then it gets into a wall which is controlled how much fuel has to expelled. And then there is a combustion chamber where this fuel is mixed with a Catalist and Oxidizer and it goes out to the nozzle.

Generally this Fuel is Hydrazine chemical name is Hydrazine the chemical compound is N 2 H 4 and the Catalist is iridium and Oxidizer is Nitrogen Tetroxide. This is a typical arrangements there many other combination. This are falling under the propulsion system, we would not discuss much about this several chemical things. Just for brief information for you.

(Refer Slide Time: 04:55)



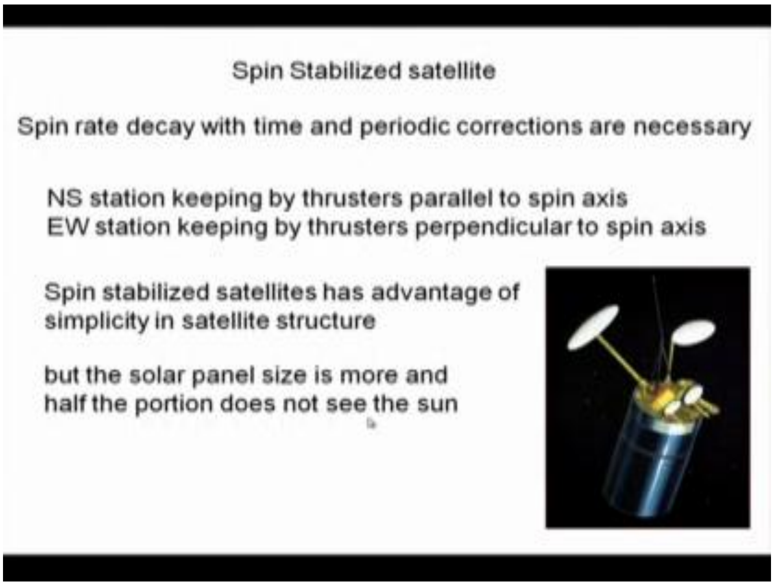
Then let us look at the orbit certain structure is also adjusted sometimes. Like jut now we have talked about the gyroscopic stiffness that can be generated. The satellite body itself could be a cylindrical body and it can be moved at a rate of 300 to 1000 rpm. If you move the body axis of the cylinder will be stiff, so this is we of keeping this stiff body. But then you see there is a problem that if there is antenna with parabolic antenna the focused antenna in one direction and if you rotate the satellite the antenna will not be moving will not be looking at the earth or service area, will be moving all around.

So therefore, this has to be adjusted. How it is adjusted when you put a slip ring along the body of the satellite. Body of the satellite contains the solar panels a cylindrical portion has the solar panels that are spun and the rest of the body de-spun by a lip ring. And that whole satellite structure is fitted to the slip ring.

This is the very simple arrangements and this is called spin stabilized satellite. Initial satellite if you remember in our first lectures that is we have shown you the initials of one which is a satellite of very small a weight and it was launched 1965 because earlier days this spin stabilizer satellite are very popular, even now there are some spin stabilize satellite are there.

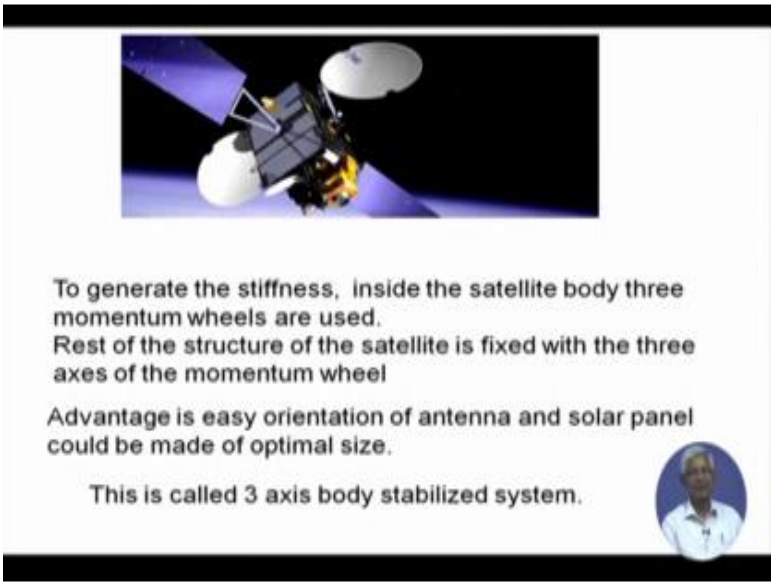
The disadvantage in this you can see that only half portion of the solar panel is seeing the sun. Another disadvantage is of course the satellite structure which contains the antenna has to be mounted on de-spun arrangement with the satellite. These two difficulties are to be recovered.

(Refer Slide Time: 06:52)



Now in this spin rate can be decayed with time and period corrections maybe necessary. The north South station keeping is done by the thrusters which are parallel to the spin axis that is you can see the toppling of that. And East West station keeping is done which is perpendicular to the spin axis. And then spin stabilize satellite have the advantage of simplicity, but has the problem of solar panel size is more and half of the portion of the solar panel is does not see the sun at a time.

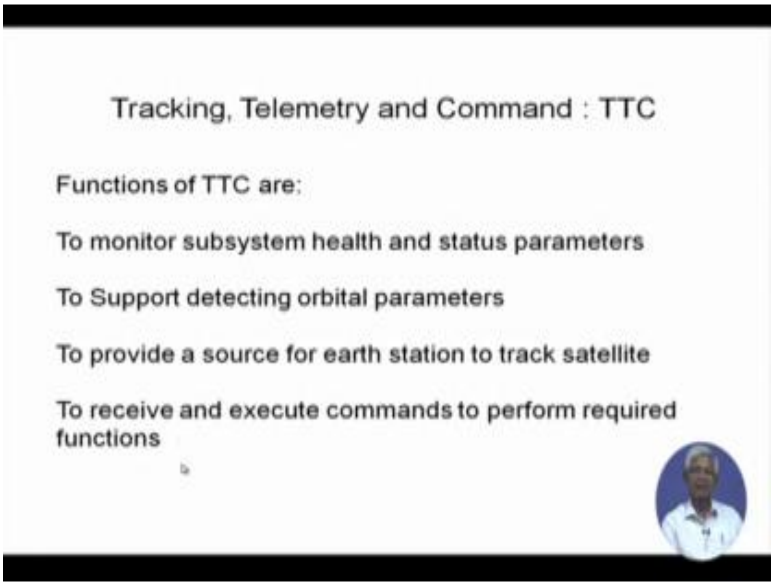
(Refer Slide Time: 07:32)



So, to generate this stiffness we can think of other techniques, is inside the satellite body three momentum wheels and three perpendicular axis can be used. And they will maintain the three axis stabilization. The rest of the structure of the satellite is fixed with the three axis of the momentum wheel using the slipping techniques itself.

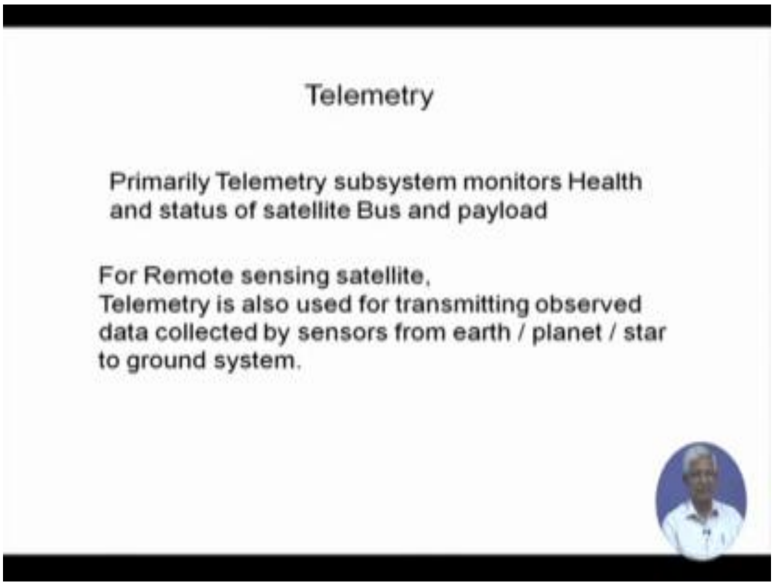
And advantage is easy orientation, satellite structure can be rectangular shape or any other shape and solar panel could be made of optimal size, always oriented toward the sun, antennas can be pointed to the service area. So, nowadays most of the satellites are this three axis body stabilized system that is the present form of satellite. So, this is the very brief description of what we have seen in attitude and orbit control system. So, let us now change over to the other subsistence which of more interest to us is a telemetry tracking and command in short TTC.

(Refer Slide Time: 08:38)



It is functions let us try to recollect that is to monitor the subsistence health and status parameter that is telemetry, to support detecting the orbital parameter the tracking. And to provide the source for the earth station to the track satellite obviously that is called tracking. And to receive and execute commands to perform the required function that is the command.

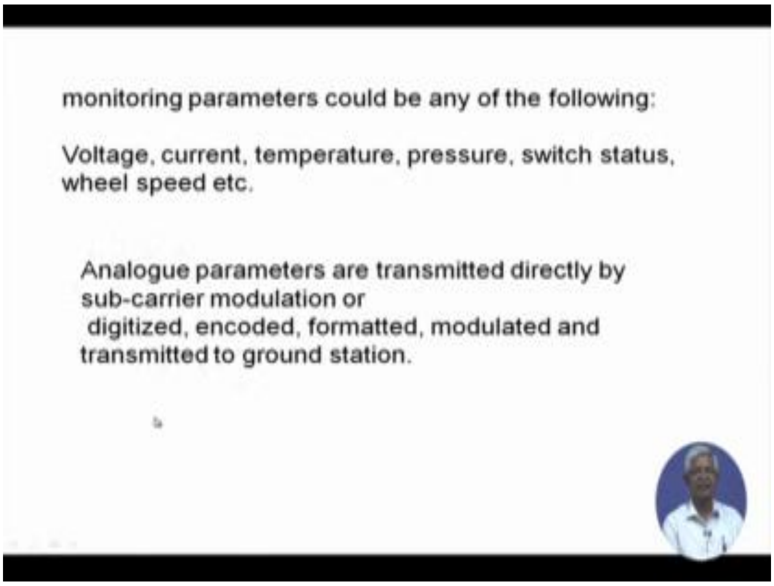
(Refer Slide Time: 09:02)



Now, let us see the telemetry. Primarily telemetry of the subsystem that monitors the health and status of the satellite bus as well as payload each of the subsystems has to been monitored how it is functioning. But in some cases for remote sensing satellites telemetry term is also used for transmitting observe data collected from the sensors which are looking towards the earth, planet, or the star to the ground system.

So, to the data collection is outside the satellite that is also called telemetry. But in this case our communication satellites will be (Refer Time: 09:42) our self to the health monitoring and status monitoring of the bus and payload that will call telemetry. Obviously, the data requirement the volume of data will be much smaller compare to the sensing data from other objects.

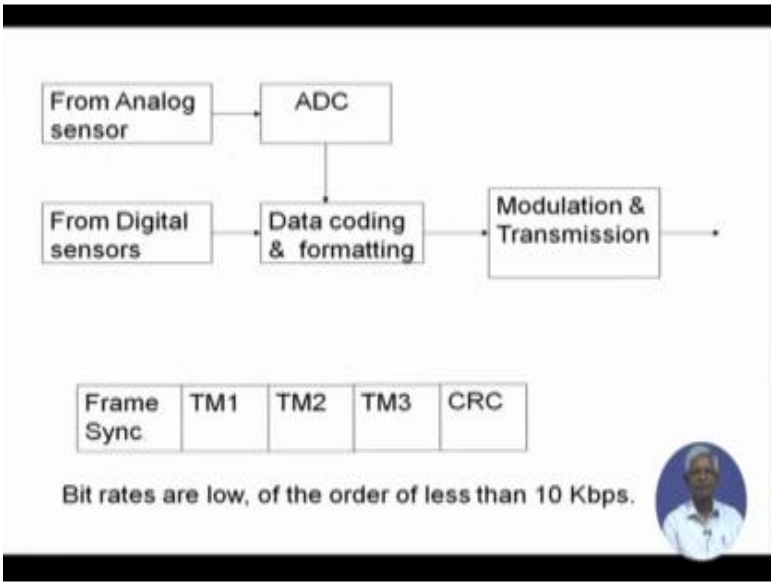
(Refer Slide Time: 09:57)



So monitoring parameter could be any of the following; like circuit voltage, current of the circuit, the temperature, the pressure, the status of a switch, the wheel speed or like that many other things.

The analogue parameters obviously are transmitted directly by sub carrier modulation or it is more popular nowadays is to digitized the analogue parameter, encoded, formatted, modulate, and transmit to ground station. Just like any other RF transmission.

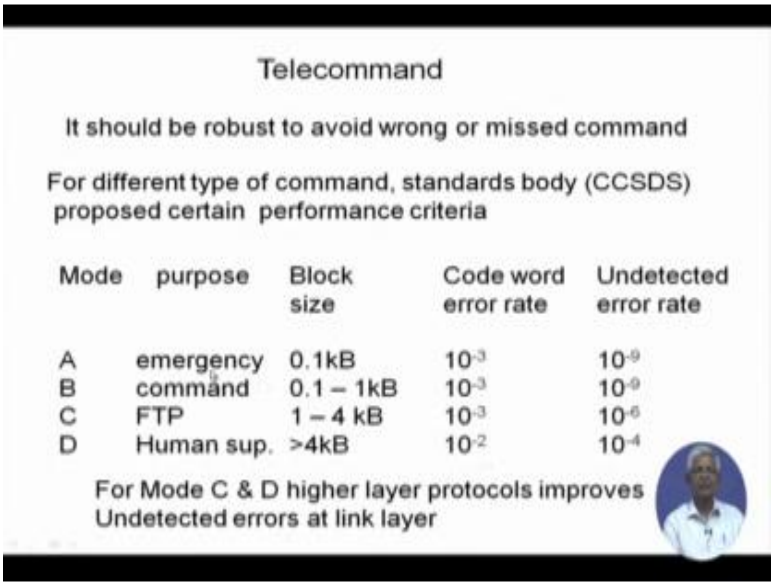
(Refer Slide Time: 10:28)



And a short block diagram of this concept is see analogue sensors are there you have a ADC converters and then the digital data comes from the digital sensors. All these data from analogue converted to digital as well as digital sensor data are coded formatted and modulation and transmission is done.

Now this coding and formatting is generally done in the form of blocks are frames. So, from the frames will be having a header which says is the beginning of the frame is called frame synchronization bits. And then you can have telemetry words like TM 1, TM 2, TM 3 and then there may be error correction code like error detection and correction code like CRC code etcetera. So, generally this is the form of a telemetry frame. Now, since the volume of data is very low the bit rates are also low. Obviously of the order of 1 kilo bit to 10 kilo bits per seconds this is what generally this telemetry is done.

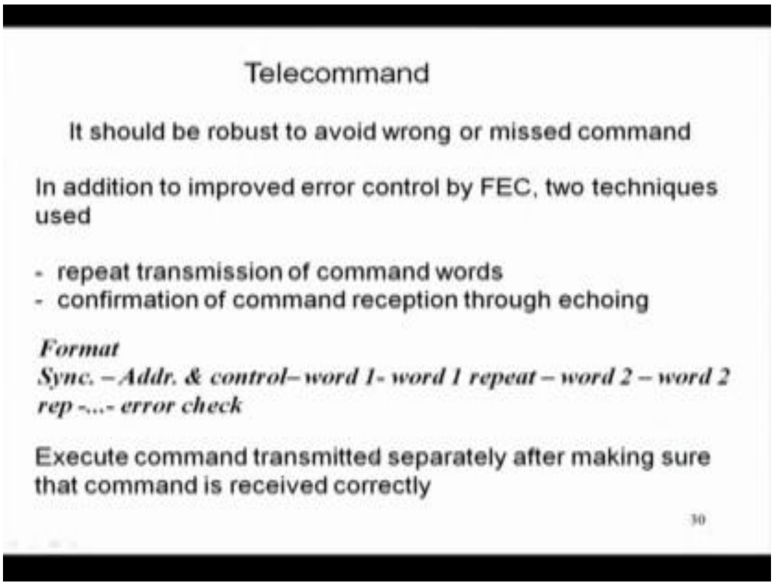
(Refer Slide Time: 11:35)



Now telecommand, in short it should be robust to avoid wrong or missed command you cannot give a wrong command to that. So therefore, different types of commands are define what should be the possibility of error that can be tolerated by a standard body (Refer Time: 11:53) standard body called consultative committee on space data system; CCSDS. And certain performance criteria they have proposed they have given certain modes like; emergence mode is A and where the block size of telecommand block size is about 100 pipes 0.1 kB, it is B for bites. And error on this code words is of the order of 10 to the power of minus 3 that is tolerated undetected can be 10 to the power of minus 9.

The B mode is command mode which is a slightly larger block size. The code error rates as well as the undetected code rate are same. Whereas in case of file transfer or human support system is more C and D which is the error rate is and the undetected error rate is much higher. That can be adjusted by higher layer of protocols that will improve the undetected the error rates. But in case of emergency and telecommand actual command mode A and mode B your error rate and undetected error rate is quite stringent.

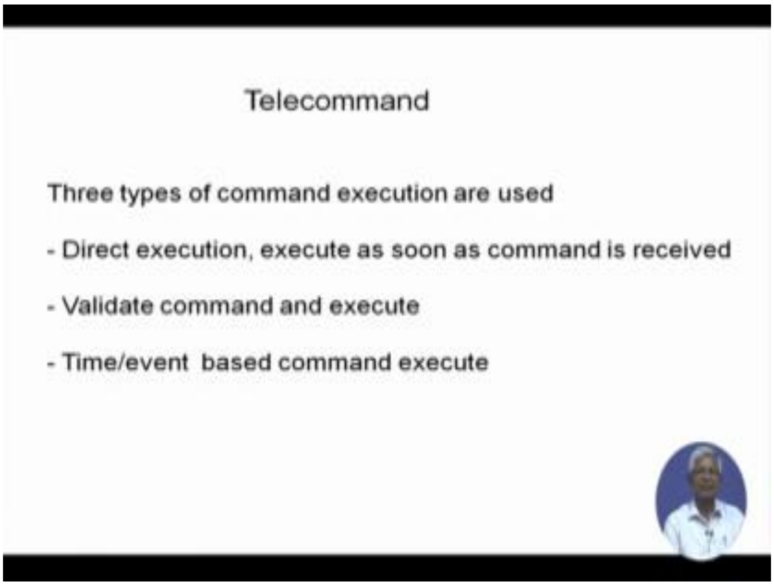
(Refer Slide Time: 13:04)



Now, telecommand should be robust to avoid the wrong or missed command so in addition to the error control which is for a error correction are any other air control that can be used. There are other standard techniques are which are used are repeat the command itself. And also an echo; that means portable command has gone the satellite will return it back to the ground station and ground station checks whether yes got back the what was sent is got back that one. You make sure that whole thing is correctly receive by the satellite.

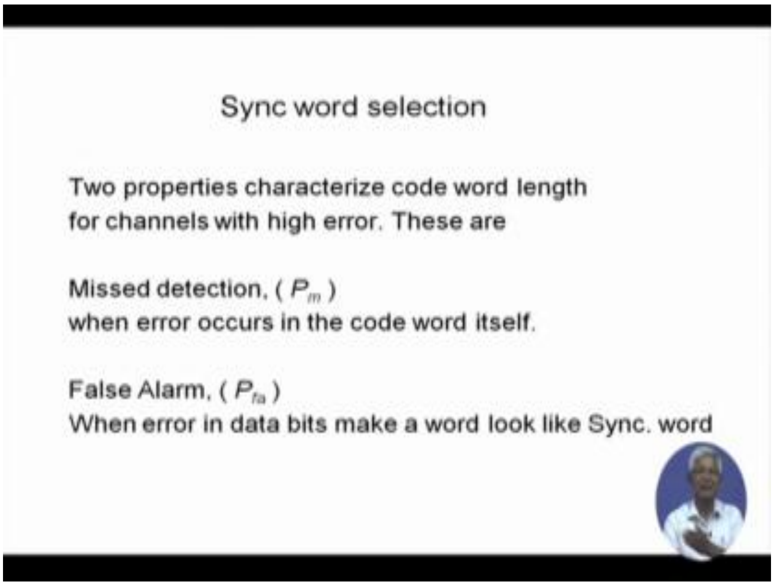
So, there is the frame format for the telecommand also starts with a syncs just like telemetry frame at the beginning sync word and then the address of the command and control then command word 1 command word 1 repeat command 2 command word 2 repeat etcetera and at the end of error check similar to telemetry format. But in all this processes you just see there in the frame beginning is to be identify properly then only you can identify all other bits including the error check bits. So, identifying the sync bit is a very important criteria for us. And then the command is gone to execute the command a separate command is transmitted after making sure that command which was sent is received correctly by the earlier method what I describe.

(Refer Slide Time: 14:42)



So three types of command executions are used; one is direct execution, as soon as command is gone and execute immediately. Second is validating the command and then execute. And third is you send the command and it will get executed after some time based on certain event if it is happening. So, these three types of execution are reduced.

(Refer Slide Time: 15:04)

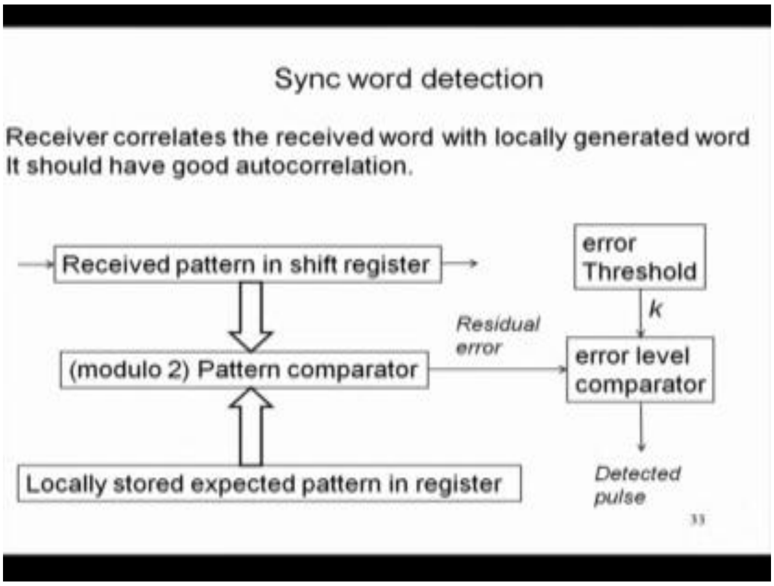


But let us try to concentrate little more on this synchronization word which is common to telemetry frames as well as telecommand frames. Now in this synchronization word two properties characterize the code word length for the channel with higher error. These are;

the missed detection probability P m, when errors occur in the code word itself that is detection is missed that is sync word has certain error. So, the sync word itself is missed so that is one problem. You can realize what is happening that is if the sync word is not detected the whole frame is loss. So, if there is error in the sync word itself you missed the sync word. So, what is that probability, it is based on what is the error probability that is happening on the sync word and the probability of missed detection can be calculated based on that. And in the actual command word or telemetry words if there is pattern which looks like sync word that will be false alarm. That will be starting point and you will slight try to detect that as a beginning of the frame then you will get into the wrong data detection.

So, there are two things missed detection and false alarm detection, when error in the data bits mixed a word look like a sync word. So, these two has sync carefully missed detection that is in the sync word itself there is error so you missed that detection itself. And there is in the data area there is a error which makes it look like sync. Generally sync word are selected such that it does not in the data area similar pattern does not appear that is another aspect, but let us let us look at these two things.

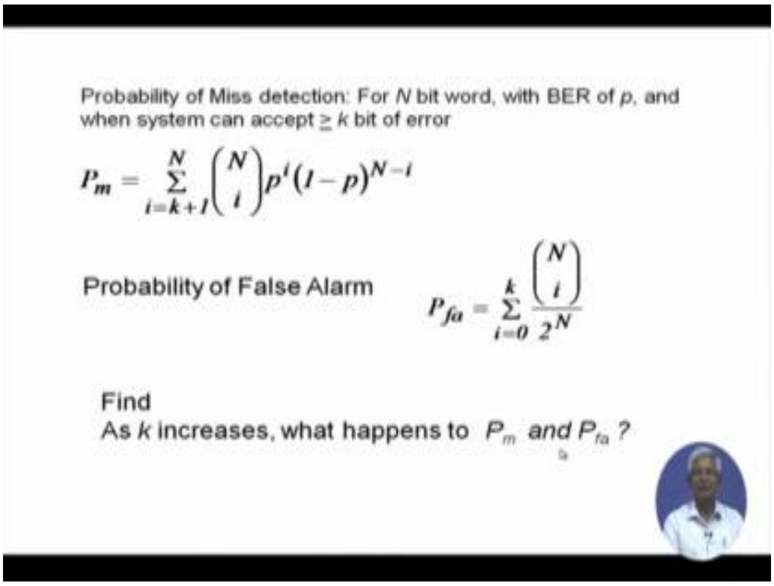
(Refer Slide Time: 17:06)



So, sync word how it is detected let us see first. Receiver correlates the received word with a locally generated because it is known at the satellite also it is known, what is the sync pattern. So locally generated word, it would give a good autocorrelation. Let us say there is a shift register in which the receiver pattern is received and it is getting shifted bit by bit. And there is a locally generated stored pattern which is the expected pattern which is stored in a register. Now these two are compared in modulo two comparisons; these two patterns are compared.

And if there is a mismatch there is a residual error and this error level sometimes we tolerate some error level. So, this error level is compare with a threshold error, I can tolerate one error I can tolerate two errors I can tolerate k errors. So, with this error threshold is compared and the detected pulse is generated. So k could be 0, in that case you are not tolerating any error.

(Refer Slide Time: 18:18)

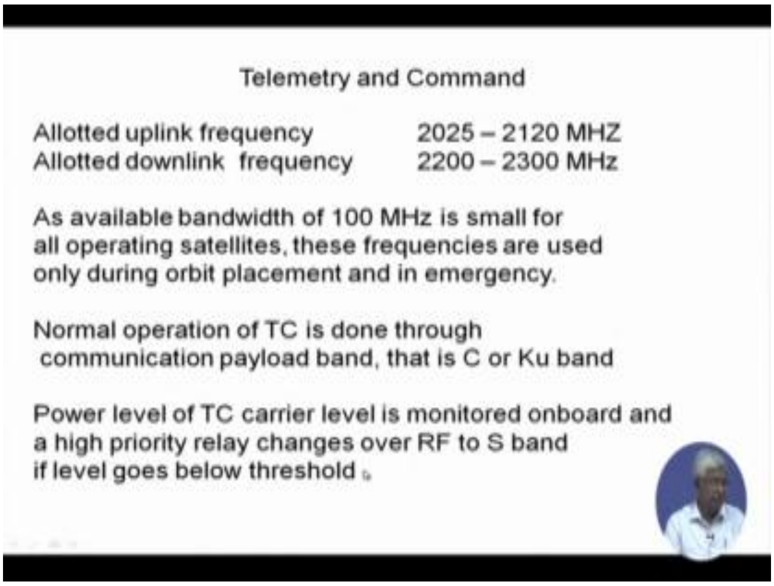


So, based on this let us it is frame equation or expression probability of missed detection that is for N bit word if shown the sync word is of N bit duration, so N bit word. And bit error rate of probability p; small p, and when the system can accept equal to or more than k bit of error can tolerate k b error k could be 0 1 2 3 it depends on the system.

Then the probability of missed detection or detection missed is expressed as some of i is equal to k plus 1 to N and then the (Refer Time: 19:02) of N i P to the power i 1 minus P to the power N minus i. This you must be known already to you these types of expressions. So, based on N and the probability that is the sync bit size and the probability of error BER and what you have decided about the k there is how many bits you can tolerate the probability of missed detection can be calculated. Similarly, for probability of false detection are falls alarm is also expressed as P of fa the sum of i is equal to 0 to k that is how many you can tolerate and then N i 2 to the power by 2 to the power N.

Now I give you a problem you solve it. As the k increases that is your tolerance of error increase what will happen to provide a miss detection and probability of false alarm with they will increase or they will decrease. I repeat, when the tolerance of errors k increases what will happen P m will increase or decrease. PFA; that is probability of false alarm will increase or decrease is problems left to you.

(Refer Slide Time: 20:26)

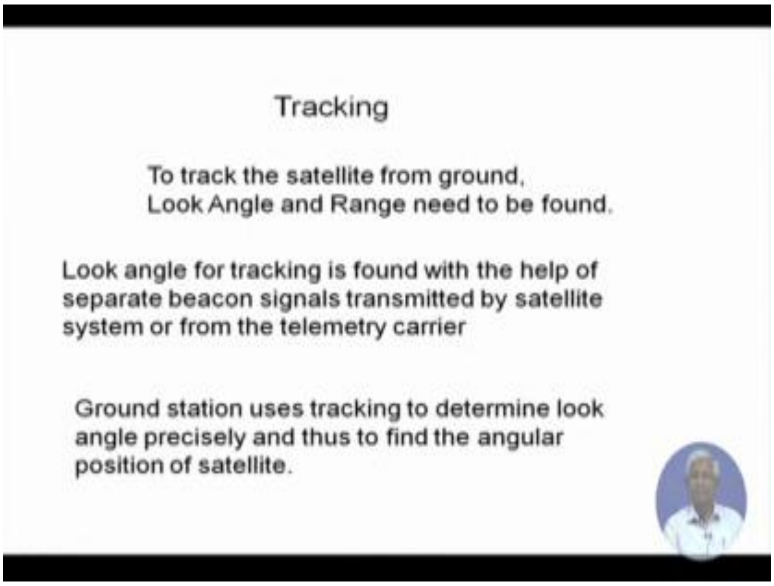


Let us go into some of the more destructed details that is the allotted frequency, appalling frequency which is for telecommand is in his band that is 2.025 gigahertz to 2.120 gigahertz; in terms of megahertz it is 2025 to 2120 megahertz, and downlink frequency which is telemetry is 2200 to 2300 megahertz. You can see it is only 100 megahertz band width available. And that is allotted worldwide. So, it is very small bandwidth for so many satellites which are operating.

So, these frequencies are only during the orbit placement and in case of emergency. Normally telemetry and telecommand is done though the communication channel which is generally in C band or Q band or ku band. So, telemetry and telecommand is done through communication payload band.

Now, in case of problem telemetry and telecommands are emergency type of things of times. So, in case of this power level of that telecommand or telemetry carriers in the communication band is reduced below certain threshold level that is if the power level of TC carrier level is monitored and if it is below certain threshold then the transmitter receiver would be switched on switched over to the emergency band which is listed about that is in s band. So this is generally done by the most of the receiver.

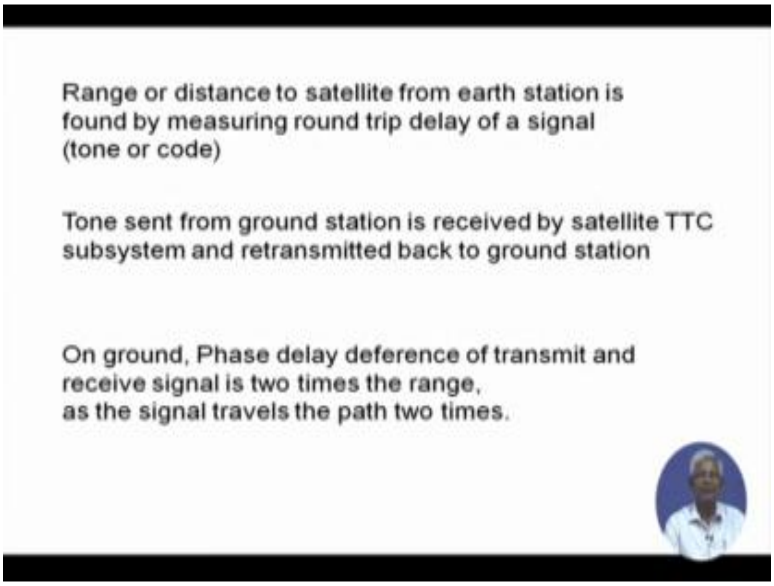
(Refer Slide Time: 21:54)



There is other part which is tracking; to track the satellite from the ground look angle and range need to be finding out. Look angle for tracking is found with the help of separate beacon signal transmitted by the satellite. We have seen orbit control from the ground we have transmitted the signals and at the satellite we are trying to look at that ground signal source. Similarly, satellite can transmit the signal and the antenna can be pointing to that signals and adjust and find out what is the azimuth and elevation angle of antenna. So, look angle can be found from the beacon signal from the satellite it is called beacon signal, and this general the telemetry carrier.

And ground station uses tracking to determine the look angle precisely and thus you can find out the angular position of satellite. What about the range, which is very critical to us that is it will give us a certain delay of sending some signals from ground to satellite or satellite to ground will see in our TDMA discussion that one effect of that, but we have to track it. So we have to find out the range, how do you do it.

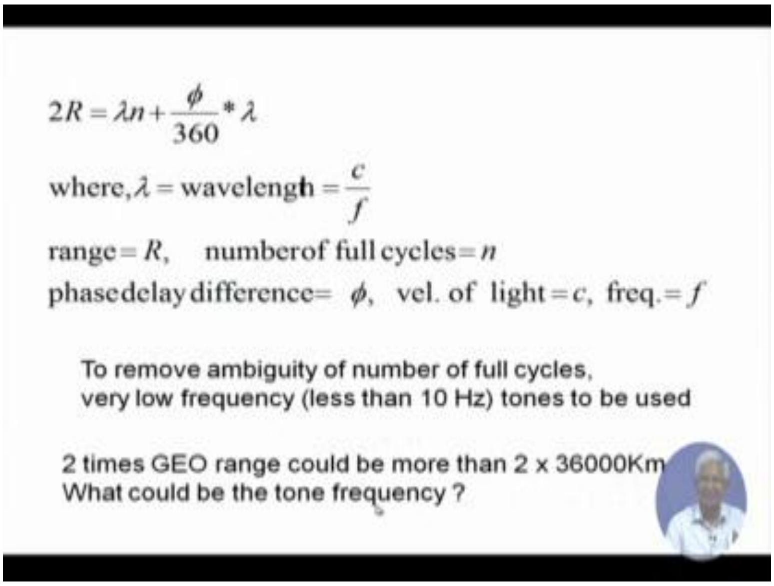
(Refer Slide Time: 22:55)



Range or distance to the satellite from the station is found by measuring round to delay of a signal that signal could be a tone that is single pure single frequency or a code.

A tone is send from the ground station is received by the satellite TTC subsystem and retransmitted back to the ground. So, whatever tone is sent it is sent back to the ground. You can measure the face delay that is delay of sending delay from the time of sending to the reception. And you can find out the delay and from the delay assuming at the signal is travelling at the velocity of light (Refer Time: 23:34) wave is travelling at the velocity of the light. So, it is you can find out the total path it has travelled divided by 2 because it is gone up and down so divided by 2 will give you the range is very simple.

(Refer Slide Time: 23:47)

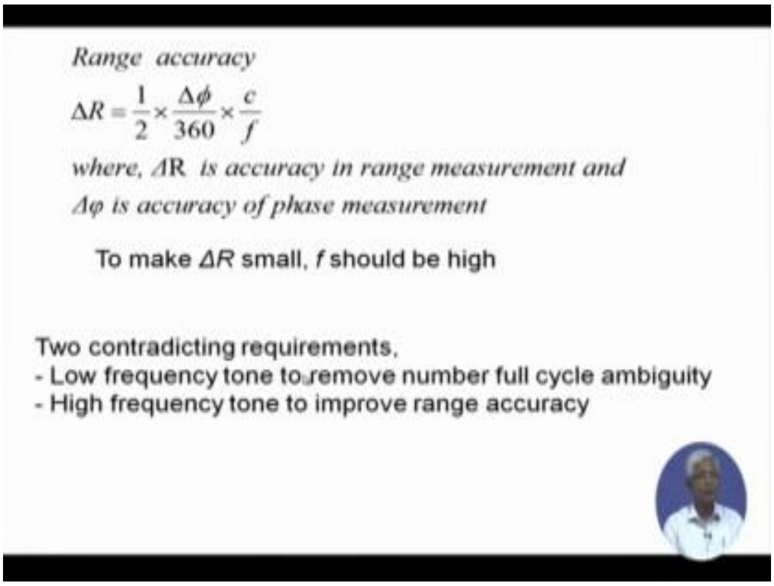


But then you are sending a tone let us see; 2 times if R is the range; so 2 times of R is many time that lambda has gone once it has reached satellite in (Refer Time: 24:02) come back. So, there will be many waves in times the lambda and a fraction of the lambda that is what you will be receiving. So, that phase difference will be in times lambda and a fraction of a lambda, it can be called as a 5 by 360 in that fraction lambda is a wavelength which is c by f, range is (Refer Time: 24:30), and number of full cycle is n, and the phase difference f is delay difference is phi velocity of light is c frequency is f.

You see in this equation, the unknown thing is this n you do not know how many cycles it is passed. The fraction you can measure, but unknown thing you cannot measure which is n that is ambiguity. To remove this ambiguity of number of full cycles just passed we can send a signal with such a low wavelength or such large wavelength, such low tone low frequency very low frequency so that in one wavelength itself will be more than the range two time range delay, which in case of we can calculate.

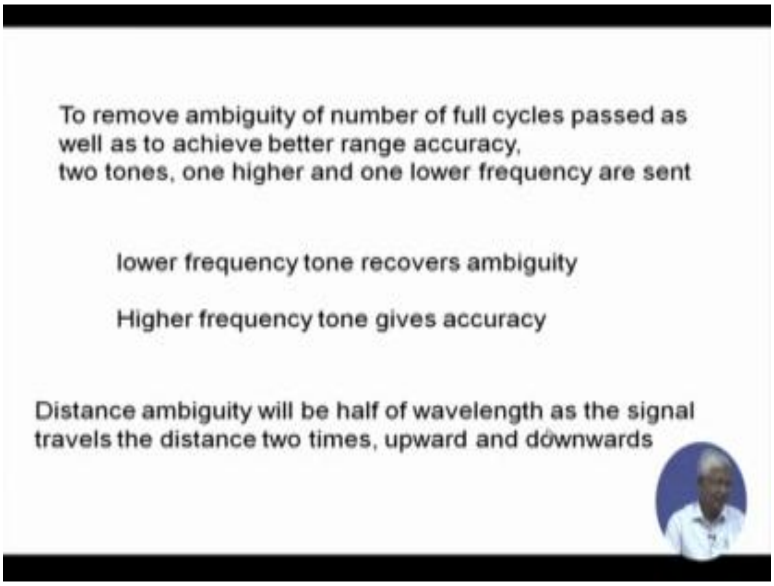
In case of two times of GEO range which is 36 of kilometre into 2 what could be the tone frequency it will be less than 10 hertz it will be the order of 4 hertz, so is the very small thing.

(Refer Slide Time: 25:27)



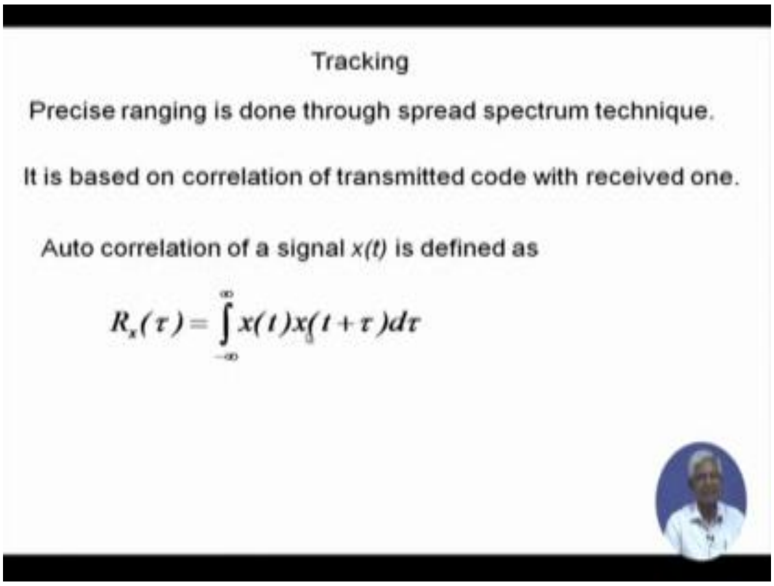
There is another issue with what accuracy you can measure that is let us call it delta R accuracy will be the phase accuracy which you are measuring based on your measuring instrument by 360 and into lambda that is c by f. So, delta R is the accuracy in the range measurement and delta phi is the accuracy in phase measurement to make the delta R small to make this equation delta R small the f has to go high. So, we have two contradicting requirement; one is low frequency tone that will remove the full cycle ambiguity and high frequency tone to improve the range accuracy.

(Refer Slide Time: 26:05)



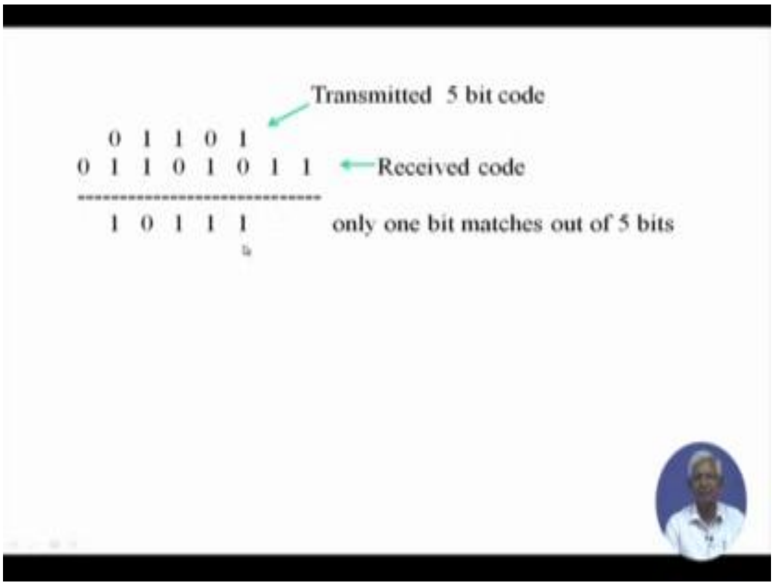
To remove the ambiguity the number of full cycle is passed as well as achieve better range accuracy two tones are used for tracking; that is one is higher and one is lower frequency. So, lower frequency tone recovers ambiguity higher frequency tone gives accuracy. The distance and ambiguity will be half of the wavelength as the signal travels the distance two times upward and downwards of course.

(Refer Slide Time: 26:31)



But then more précising can be done through a spread spectrum technique. It is based on a correlation of transmitted code with a received one. Auto correlation of a signal x t is defined as you know it is auto correlation function r x t tau is education of 0 to I mean minus infinity to plus infinity x t and x t plus tau theta.

(Refer Slide Time: 27:03)



Now, you know that what will do the today the time is not there much so will stop at this point and continue our discussion in the next class that will be continuing the tracking.

Thank you very much.