Basic Tools of Microwave Engineering
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Lecture – 14
Network Analyzer

In this lecture, we will see the instrument network analyzer.

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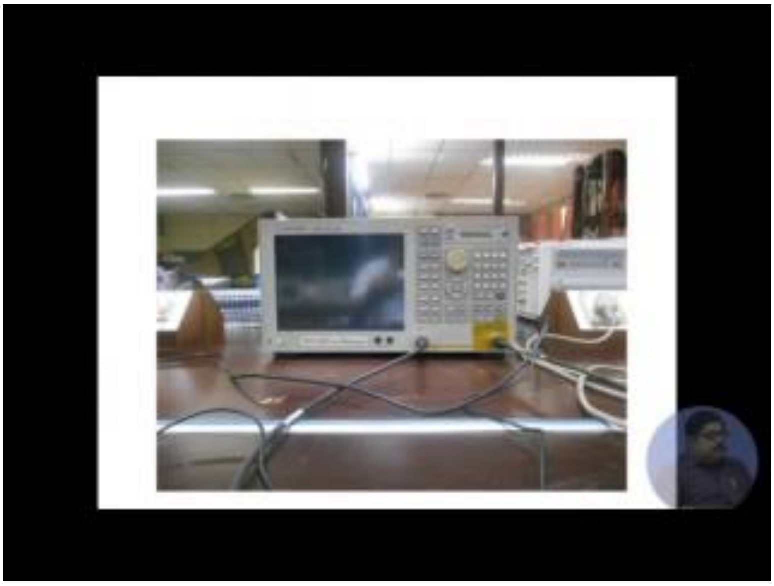

Already you are familiar with this picture in a previous lecture. We have shown this, I also describe some of the network this functions of the buttons.

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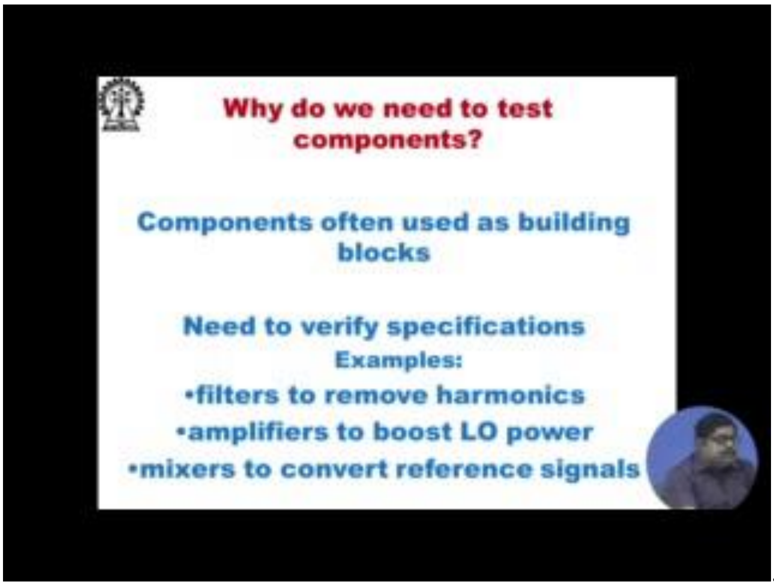

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Now, why do we need to test components at microwave components often used as building block microwave frequencies. Now, we need to verify specifications like filters, we need to see how much harmonics it is removing amplifiers whether the local amplifier power is local oscillator power is sufficient or not mixers whether it is properly rejecting various signals.

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Also suppose we are giving power to an antenna. Now, we need to ensure good impedance match whether whatever power we are supplying to the antenna whether antenna is radiating there.

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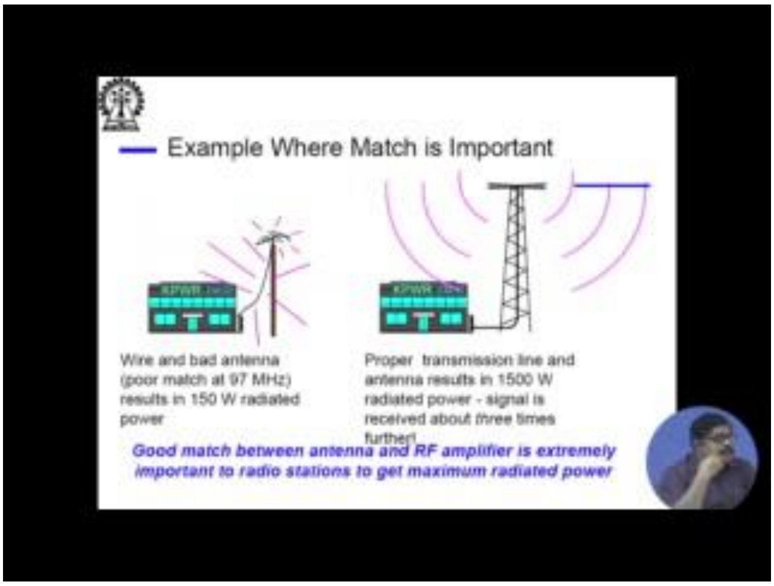

You see that, if we have a poor match, suppose the left side antenna is not properly matched and you see 150 watt radiated power gets wasted, whether in the right side you see the same thing when which was radiating 150 watt the same antenna is now with proper matching is radiating 1500 watt. So, the signal is received about three times further so that means, if previously it was 40 kilometer, now 120 kilometer you can go. So, good match between antenna and r f amplifier is extremely important to radio stations to get maximum radiated power.

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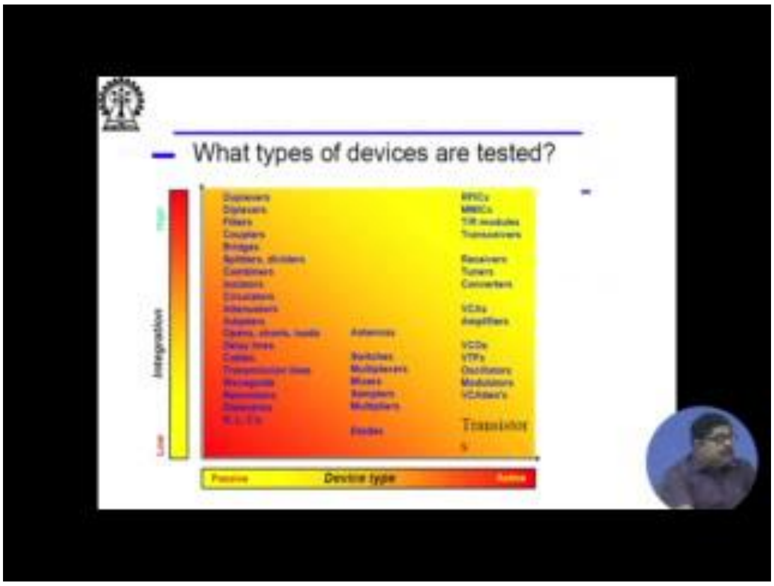

Now, what type of devices are tested, you see there is lot of a large list passive active various types of devices, various levels of integration you see transistors BCO's deceivers T r modules, T r modules are used in radars then those are also radar or high power devices satellites also use them at enervators adopters dilatoires many things are tested.

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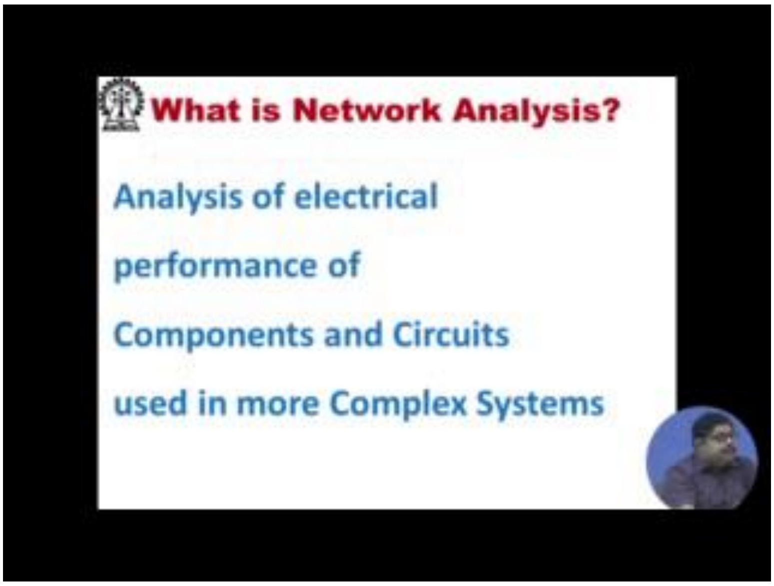

Now, what is network analysis of electrical performance of components and circuits used in more complex systems?

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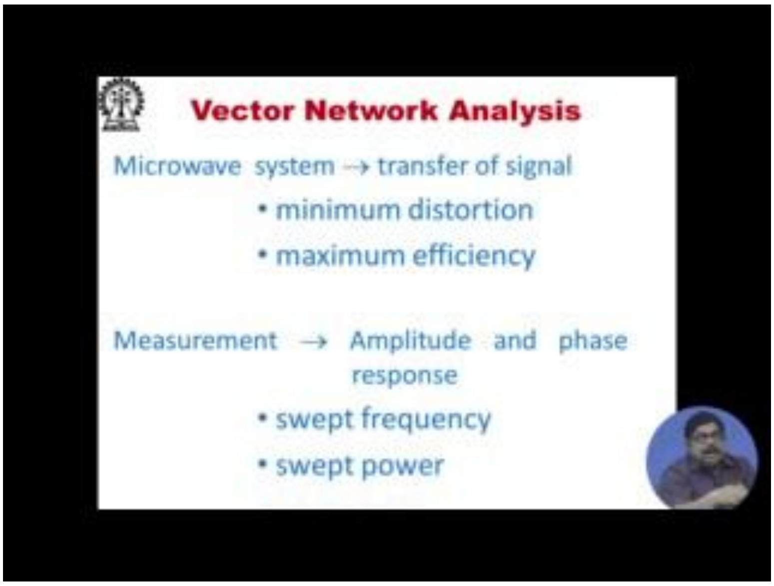

What is vector network analysis in microwave system? We want transfer of signal we want to do it with minimum distortion maximum efficiency. Now, for that whether minimum distortion and maximum efficiency will be attempted for that we want to measure and that measurement consist of both amplitude and phase response either we can sweep frequency that means, we can give amplitude and phase frequency response or we can sweep in power that means, amplitude and phase power response which is also called linearity characteristic because after sometime If I go on increasing the power the device becomes non-linear. So, that testing is also important because that will give me an idea whether I will be able to do the transmission without any distortion in the signal that means, quality of the signal should be kept.

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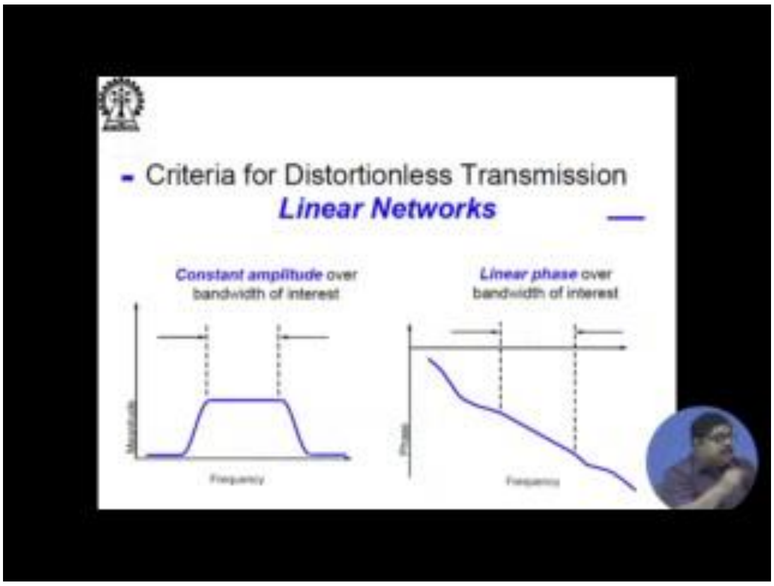

All of us know that for linear networks criteria for distortion less transmission is that what the band of interest my amplitude response should be flat, this left side graph flat response in the band of interest phase response should be linear in the band of interest, if this is there linear networks give distortion less transmission.

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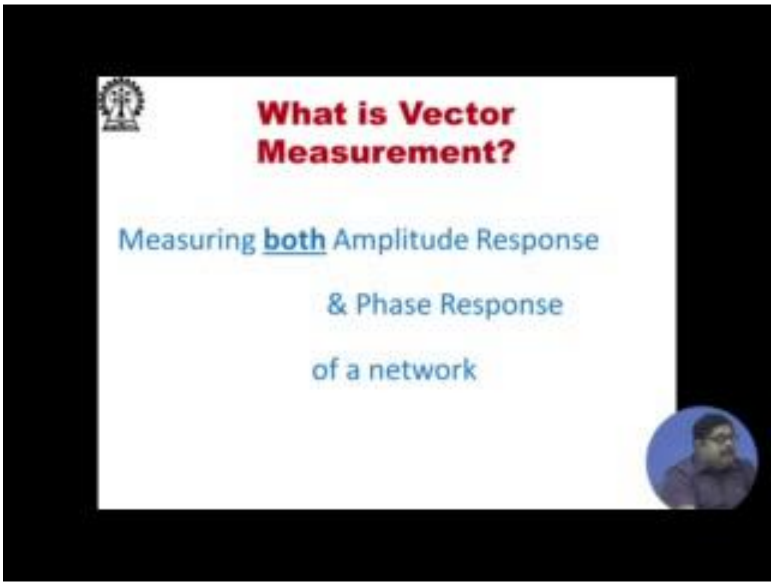

Now, what is vector measurement measuring both amplitude response and phase response of a network is called vector measurement. Network analyzers are available who does scalar, who are called scalar network analyzer they do not measure phase response they measure only amplitude response.

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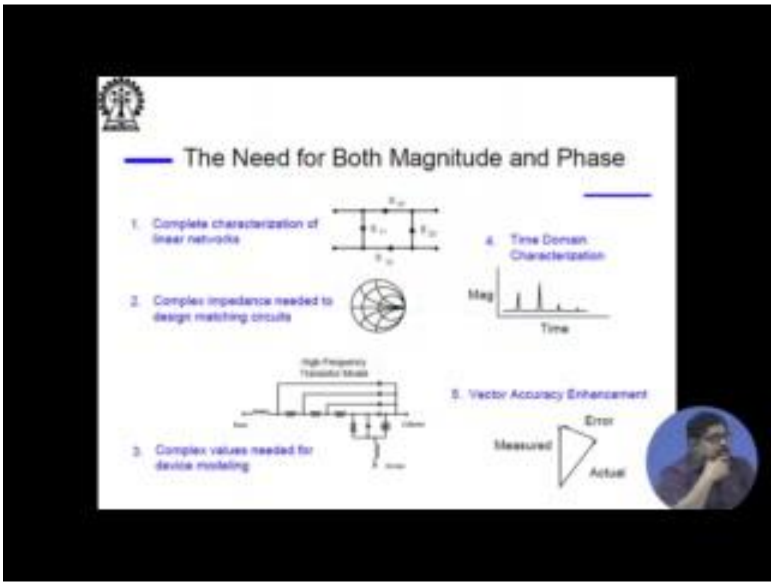

Now, you see that magnitude and phase both measurements are necessary like a's parameters they are basically complex quantities. So, you need to measure amplitude and phase both for them impedance we have seen that impedance is a complex quantity in a c circuits. So, we need to measure the impedance amplitude as well as phase, otherwise you would not get the idea of the reactive impedance. Then device modeling we know that you have r, l, c, etcetera. So, that requires complex values in time domain if I want to characterize anything, I need to carry out a Fourier transform or inverse Fourier transform. Now, Fourier transform and inverse Fourier transform also is a complex operation because the Fourier coefficients, if they are not done in complex wise complex number wise then there is problem, similarly vector accuracy enhancement that is also a vector operation.

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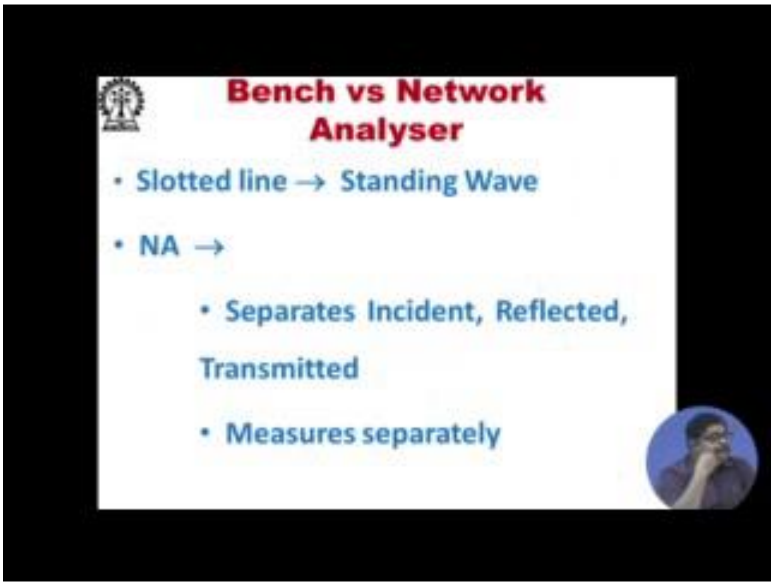

Now, network analyzer it is predator was microwave benches. We have seen microwave benches in the impedance measurement time, basically they work on standing wave network analyzers, do not work on standing wave phenomena they can separate incident reflected and transmitted wave.

So, the measures is incident reflected and transmission wave separately and that is the beauty of network analyzer slotted line did not have capability to separate the incident reflected transmitted waves that is why they had to rely on the standing wave phenomena from that VSWR, etcetera concept came, but network analyzer, once it can separate incident reflected and transmitted waves it does not need to carry out all those standing wave phenomena which are a bit complicated compare to the simple measurements done by network analyzer.

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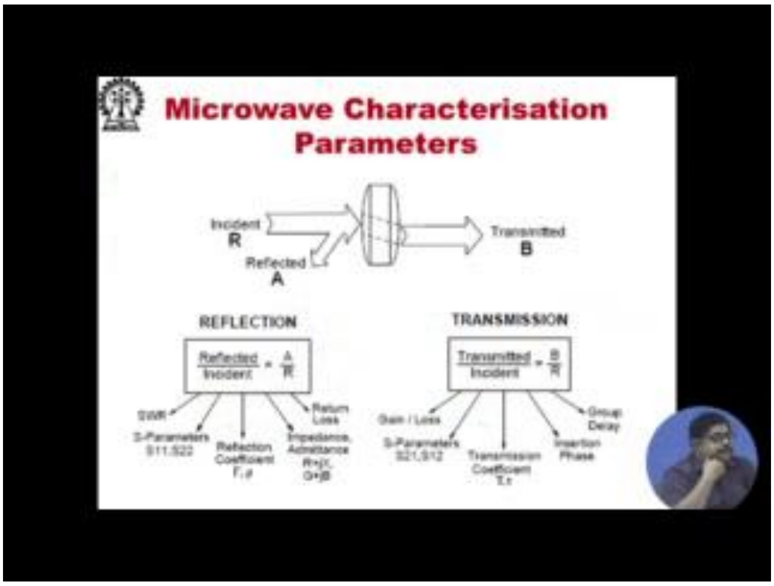

Now, these are thing that reflection phenomena. So, I have an incident wave some reflected thing comes, some power gets transmitted. So, reflection gets characterized by this reflected by incident a by r 1 of that is w r that time. We have seen that the reflection coefficient and VSWR there quite related s parameters is 1 s to 2 reflection coefficient gamma voltage reflection coefficient power reflection coefficient return loss impedance admittance similarly transmission is b by r that is given by gain or loss s parameters transmission coefficient t insertion phase group delay etcetera. So, these are various parameters used to characterize either reflection or transmission of waves at waves and microwave.

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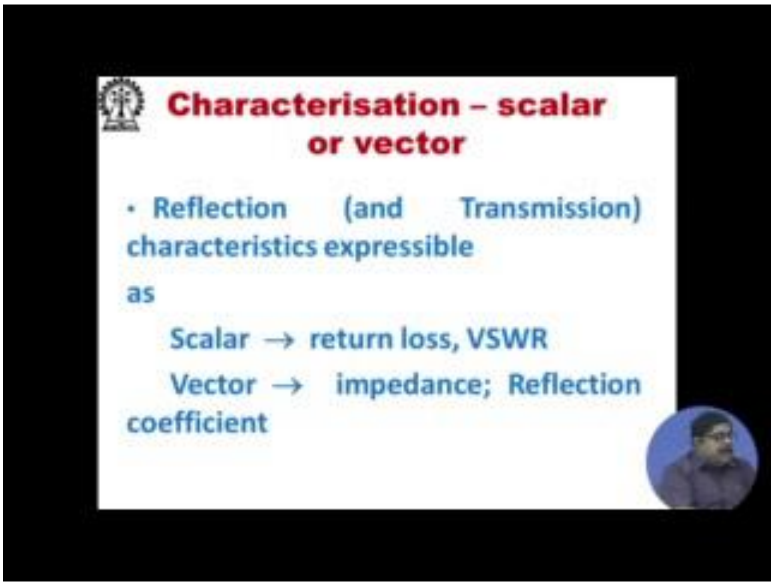

Scalar example of scalar characterization is return loss, it is a scalar quantity VSWR it is scalar quantity then example of vector characterization is impedance because impedance is a complex quantity, reflection coefficient it is a complex quantity it has both magnitude and phase.

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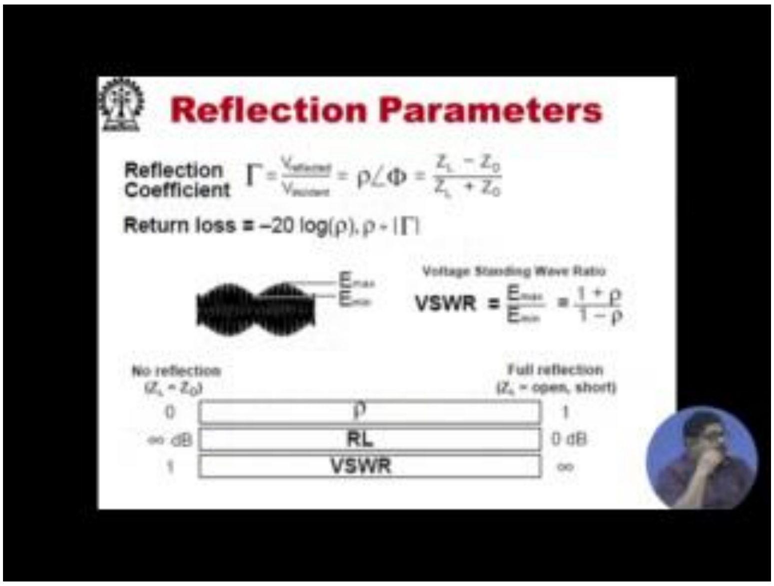

Return loss definition minus 20 log rho transmission coefficient.

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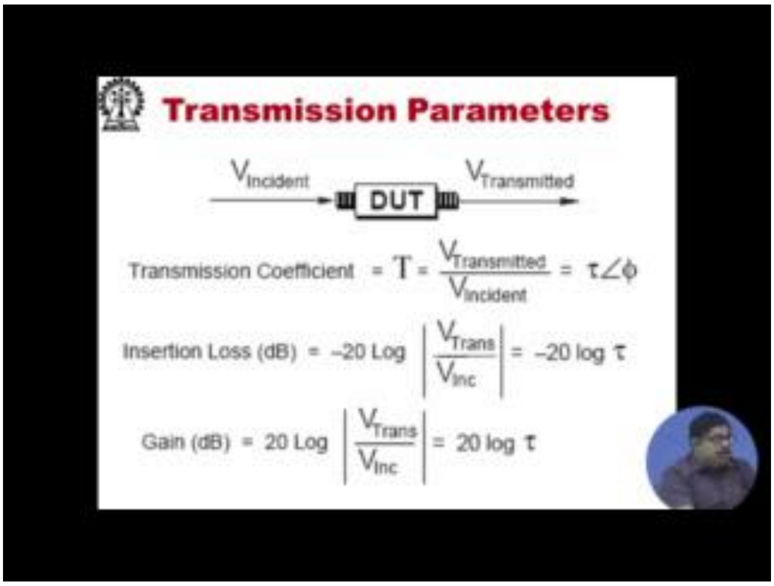

Insertion loss gain these are the characterization of transmission.

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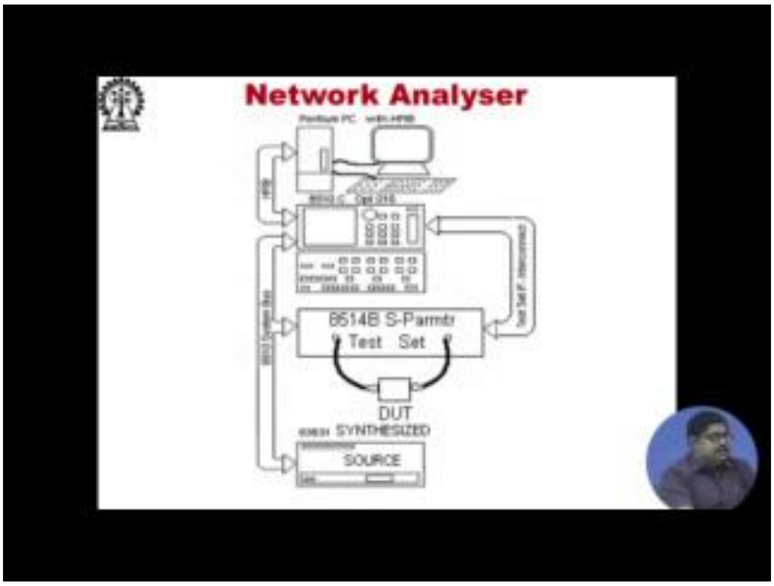

This is an architecture of 85 k network analyzer, a very popular network analyzer invented by Hewlett Packard company in early eighties very successful network analyzer 85 c, it had this was the box, this was the controller, this was a test is parameter is test set is DUT, it has a source then there were 20 MPC's with HPIB and bassets.

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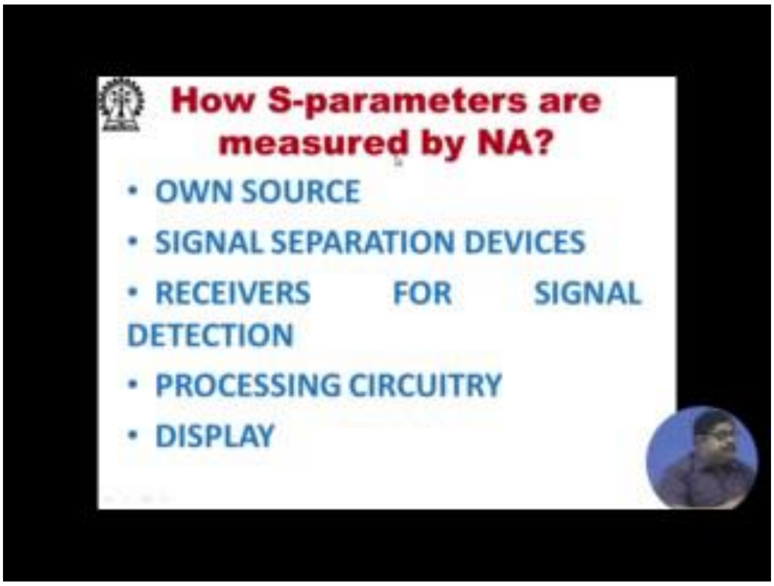

Now, basically how S parameters are measured by network analyzer, network analyzer has its own source, it gives a source. So, it gives the test signal itself and sees the response of the network from that it infers the characteristic of the networks in terms of S parameter. It also has signal separation devices I said that it has some directional couplers by which it can separate those signals, then it has receivers for signal detection a number of receivers and it has processing circuitry which has displayed.

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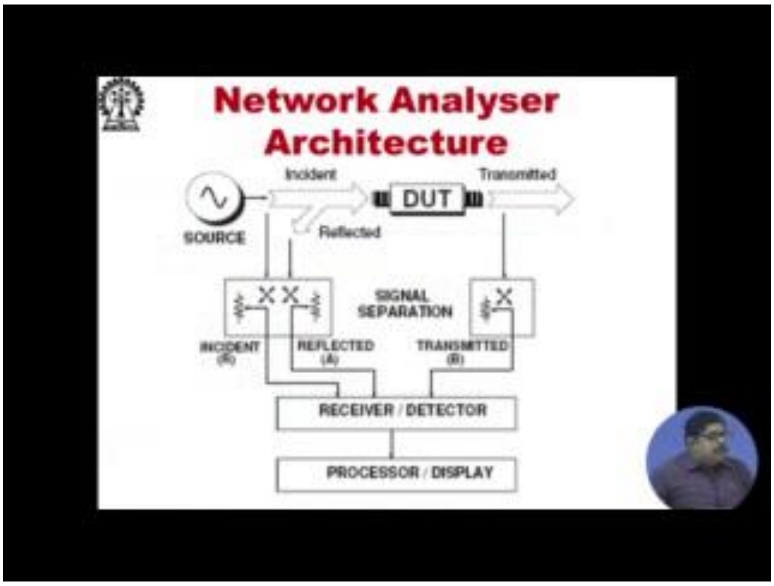

This is the network analyzer architecture it is having source is producing incident thing, then the thing is given DUT is the network that you are trying to test. So, it is giving reflected. Now, it can separate these incidents and reflected as you see here that. So, that goes to two parts incident and reflected and then also it samples the transmitted one. So, these 3 is given 2 various, 3 or 4 number of detectors and then.

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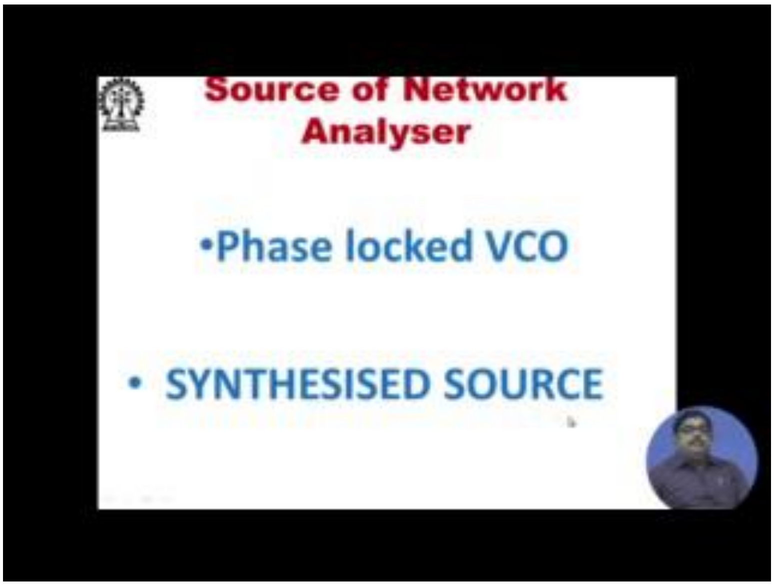

It processes and displays, now source of network analyzer it either a phase locked VCO; voltage control oscillator or a synthesized source synthesized source means the source at a particular frequency then from that various into 2 divide by 2 etcetera. So, that the source was having a particular range from that it synthesizes some other ranges. So, the source becomes a broadband source and gives lot of frequencies.

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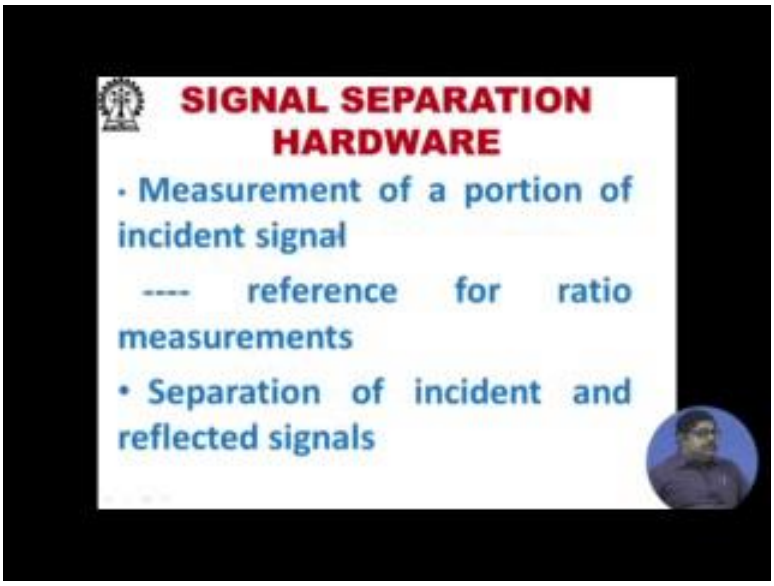

Signal separation hardware measurement of a portion of incident signal.

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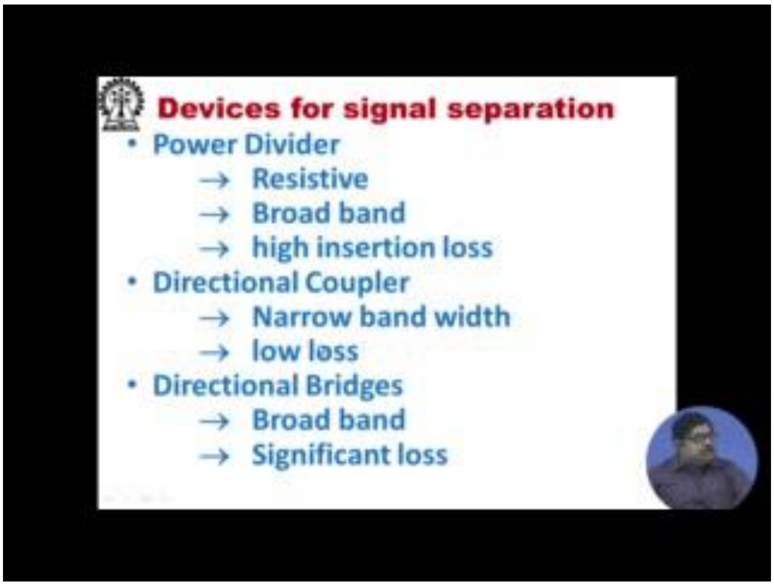

Then it takes a reference and it makes a ratio measurement. Now, if you make ratio of any measurement then your error becomes less devices for signal separation. I earlier said directional coupler along with that you can also have power dividers, but it has high insertion loss. Directional coupler is a very good it has narrow bandwidth low loss also directional bridges are used, but out of this directional coupler is one of the popular device for signal separation.

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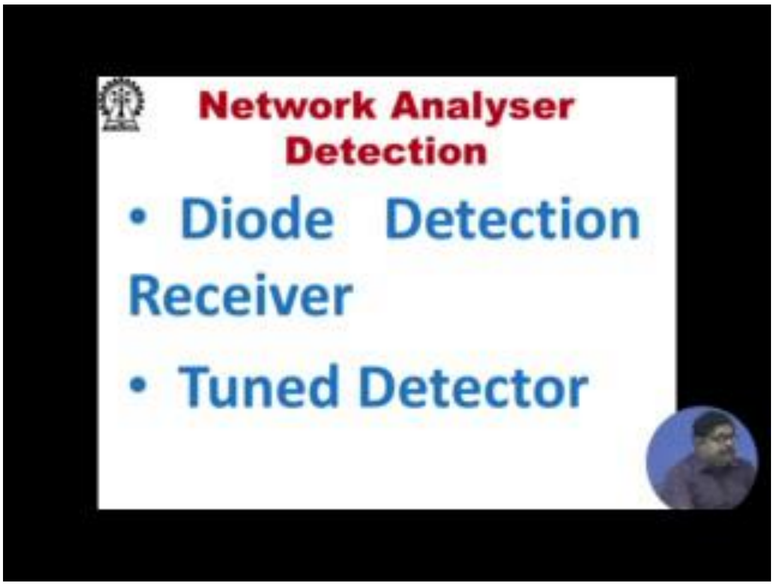

Then detection it uses diode detection receiver or tune detector.

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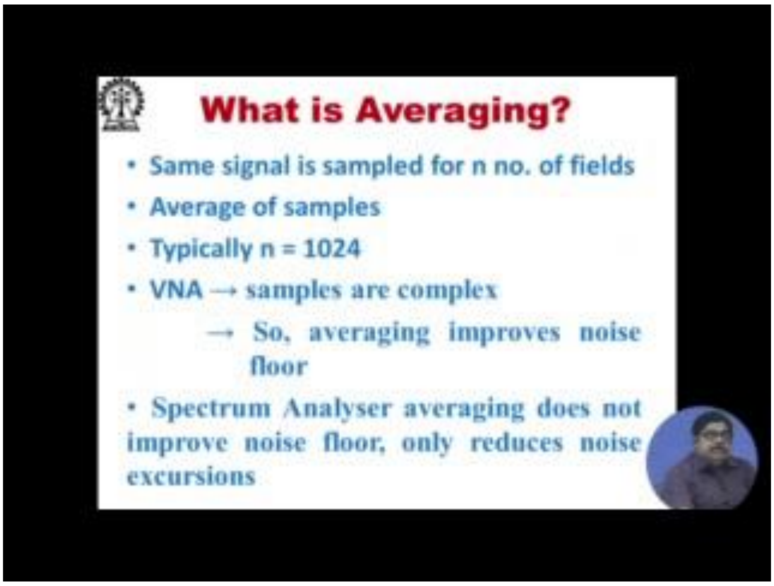

Now, averaging same signal is sampled for n number of times average of samples, typically n is equal to 1024 VNA samples are complex. So, averaging improves noise floor any random signal, if you go on adding it is addition will ultimately give you something like mean of the signal, now noise has mean 0. So, more number of measurements you average your SNR will improve. Now, you see the network analyzer magnitude error is typically less than 0.1 db phase error is less than 0.6 degree, it has various any measurement has some errors.

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No equipment is perfect, it has some systematic errors, some random errors, some drift errors, systematic errors means suppose I am saying that it should be defined, I want a perfect impedance match, but in reality I cannot always get impedance matched I say that at the port the terminal should be defined. In actual reality the may be port is extended a bit.

So, all these are systematic errors that means, errors in various assumptions we made and while implemented that assumptions we did not keep that is called systematic errors random errors we cannot say noise etcetera, they give random errors and drift errors after sometime the performance degrades. So, suppose if I am to work for longer hours my performance will degrade, similarly instruments if they work longer then their reliability degrades that is called drift errors.

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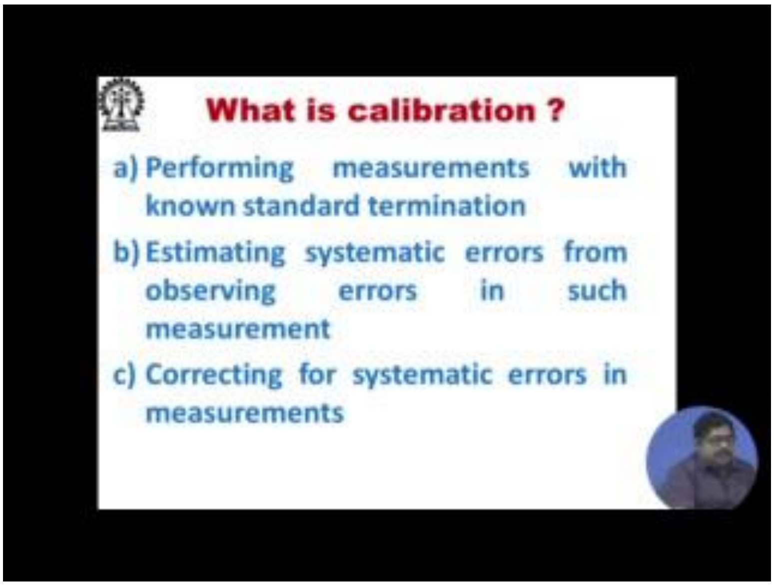

So, network analyzer does a calibration, what is calibration? Calibration has three parts, part to remove those systematic errors, for calibration we need to first perform measurements with known standard loads or termination, for example, you can take a shot and measure reflection coefficient, you know for a shot reflection coefficient should be minus 1, but if you do it you may not get minus 1, you may get 135 degree minus 1 means 120 degree, but you get. So, then you know that your actual shot is not implemented. So, whatever you are thinking as a shot, it is not a actual shot basically shot circuit means it should be a thick metal. So, that anything going there is fully reflected any wave falling on it fully reflected.

Now, if you have a thin metal plate that also will re plate may not be with full reflection. So, this is an example of a systematic error you have, there also the reflection coefficient should be plus one, but you can have an who is not giving plus one it may giving one thirty degree. So, that you can then, these performing measurements with known standard termination you can estimate systematic errors from observing errors in such measurement and then you can correct for those systematic errors in your measurement that means, now when you will take the actual measurement you will remember that these are the errors.

So, you can do error correction this whole process is called calibration network, analyzer does this calibration if you remember your oscilloscope there was also a calibration what let suppose oscilloscope is measure in something, how do you know that it is correct measurement. So, you give oscilloscope had 1 kilo hertz square wave signal. So, you put that button nowadays in the back side of oscilloscope, it is there earlier days it was at the front side. So, you press that button you get 1 kilo hertz square wave, but you measure you may see that 1 kilo hertz and I think 1 bolt pic to peak or something. So, you can then check you are not getting 1 bolt pic to peak. So, you add just your knobs.

So, that it becomes 1 volt pic to peak then you see that time period is 1 kilo hertz 1 millisecond will be the time period, but it may not be 1 millisecond. So, you correct that that is called calibration that with a known thing you do here the known thing is some standard termination then from that you estimate systematic errors and in actual measurement you correct for that this is called calibration.

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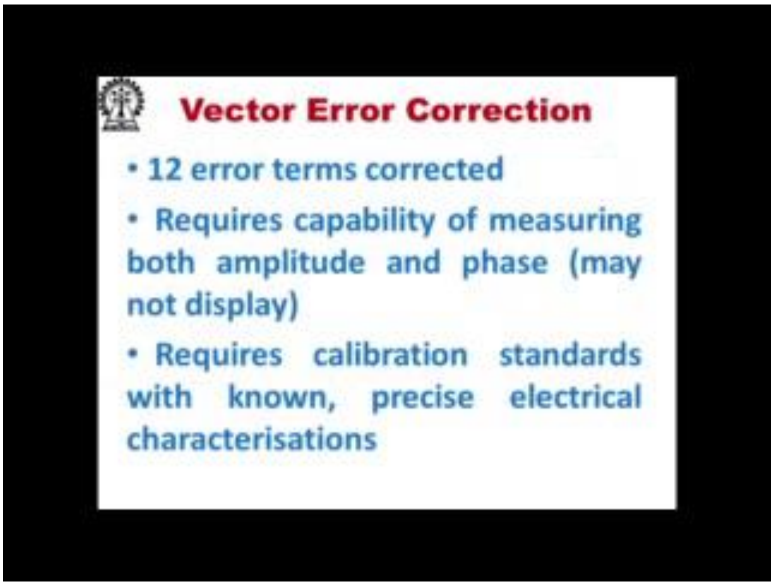

Now, vector error correction they are if you do this model 12 error terms are corrected, requires capability of measuring both amplitude and phase, requires calibration standards with known precise electrical characterization.

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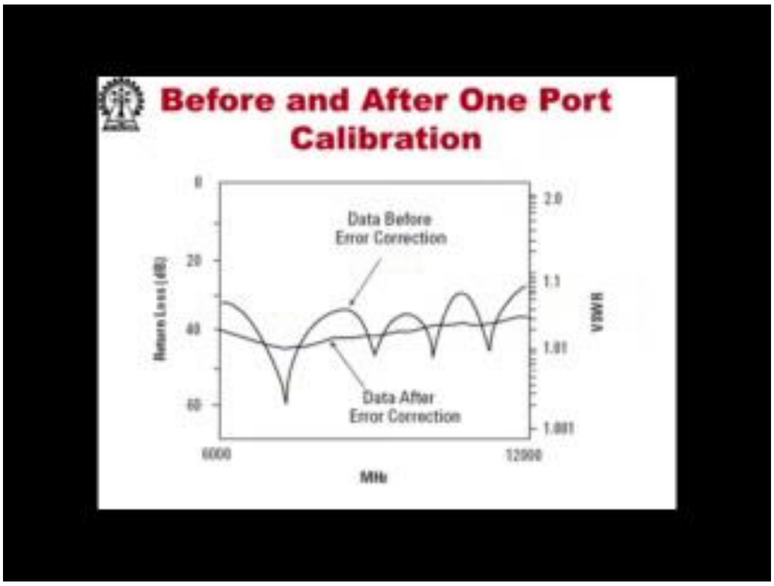

So, you see that data before correction is this curve v curve, but after correction error correction it may become something like these. So, these frequency response and these is an erroneous frequency response. So, you see that return loss with frequency ideally, it should be like this there should be minimum with frequency. There should be a frequency response, but a typical thing is you get like this with error correction the whole thing becomes this, that is the beauty of network analyzer that it can do calibration and by that it can eliminate various errors in measurement bench based measurement could not do that.

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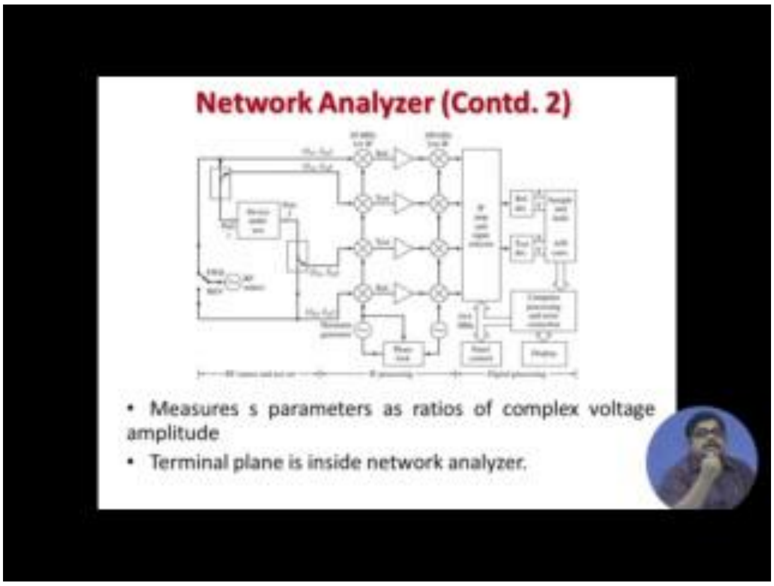

This is a detail view of this one thing it says that you see there are. So, many channels so that is why there are generally 4 receivers are there in the network analyzer, some designs instead of 4. It can have 3 then that is a bit less accurate, but in good network analyzer you have 4 receivers, but 4 receivers' means obviously, 4 microwave receivers are quite costly. So, network analyzer that is why it is a costly equipment measures s parameters as ratios of complex voltage amplitude that means, it has a reference with respect to that it calculates various ratios any time. You also remember these that suppose some quantity I directly measure and that same quantity, I take a ratio with respect to some standard thing.

Now, the ratio measurement always is a better measurement unfortunately the terminal plains of voltages etcetera they are inside network analyzer because you see when you are extending a port definitely network analyzer is sitting inside. So, his port definition is different what we are seeing is port is not always is port. So, that is why he commits some error that is get corrected in the error correction it was all about network analyzer is basics and what you can do basically with that you have two ports.

So, you connect your device between them and then you can measure your S parameters of the device for a two port network. For an n port network you need an either an input network analyzer you can 3-4 ports are also there and typically up to any microwave frequency nowadays even 550 mega hertz, 550 Giga hertz up to that you can measure various networks the thing even people are trying to build up 1 tita hertz network analyzer in packet company presently they are called technologies that company has in Japan. In Tokyo university they have made one such 1 tita hertz network analyzer.

So, you see that these technology can go up to 1 tita hertz, still these same network analyzer, the same principle they were and they find out the S parameters of those networks even up to not only in Giga hertz, 1000 Giga hertz that is 1 tita hertz. So, the second tool that S parameter that helps to characterize any microwave network and the network analyzer is the equipment by which you can measure that with this part is concluded. So, we have seen two tools; the first tool was the second tool in these series of lecture, we saw as S parameter and with this, we will see in the next lecture some problems based on these S parameters and that will conclude the lecture of this week.

Thank you.