Principles and Techniques of Modern Radar Systems
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Lecture – 29
Tracking Radar (Contd.)

Key Concepts: Hybrid junction, components of monopulse receiver

Welcome to this NPTEL lecture on Techniques and Principles of Modern Radar Systems. We were discussing for last few lectures about mono pulse technique. Now, we have seen the mono pulse ratio d by s, it is a complex ratio because we are dealing with complex envelopes of the RF signal.

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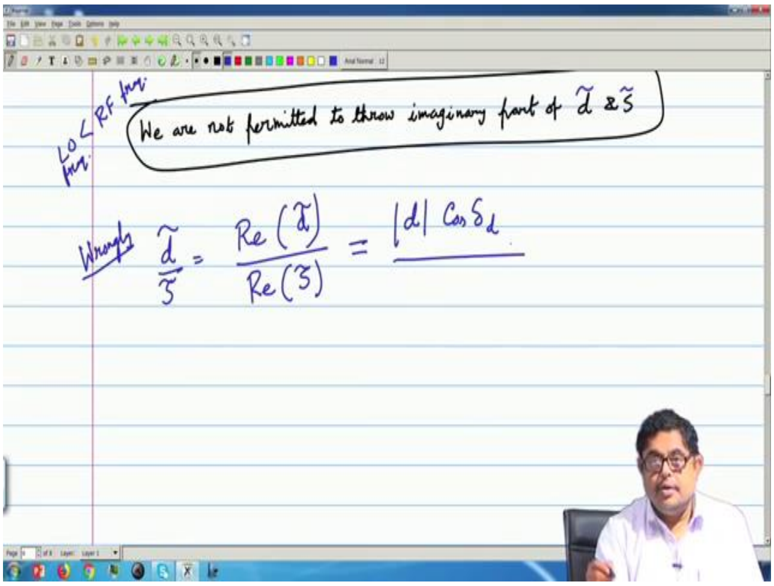

Now, I have mentioned that we are not permitted to throw imaginary part of d and s. Now, today we will see what happens if we throw that, that means; obviously, this means that we have a LO which is less than RF frequency. LO frequency is less than RF frequency. For the opposite case, we will write we are not permitted to throw real part of this ok. Now, what is let us say that d by s ratio, we are taking as wrongly, but d by s we are taking as real part of d and real part of s. Let us say that wrongly we do it. I am writing, so that later you do not think that I have told it. So, wrongly let us now what is real part of d that will be d cos delta d, I think you remember that we are talking about this phasor diagram, we have drawn a phase diagram.

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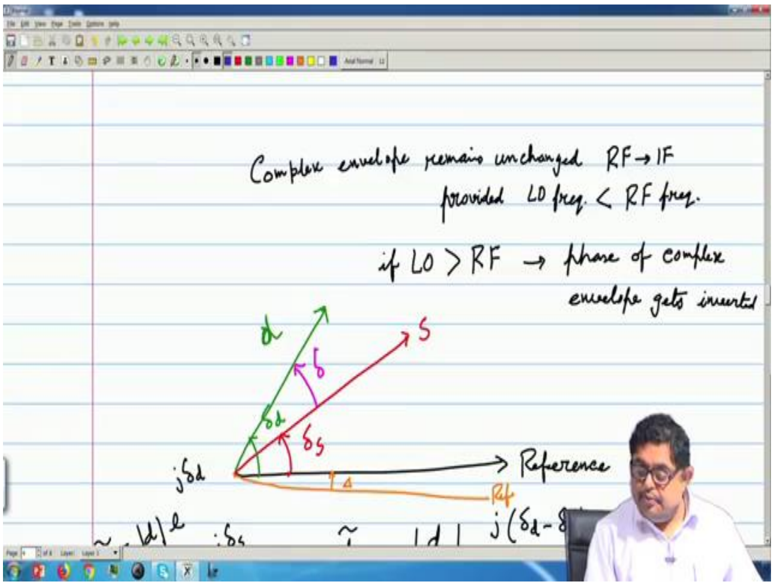

So, d is having an angle from the reference delta d, s is having from the reference angle delta s.

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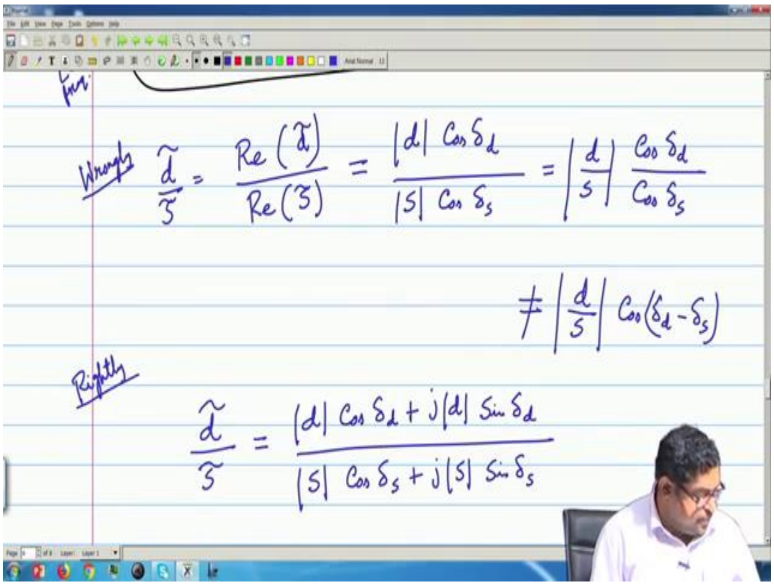

So, it will be s cos of delta s. So, this will be d by s cos of delta d by cos of delta s. So, you see this is not same as the actual thing, actual thing is d by s cos of delta d minus delta s.

$$\frac{\tilde{d}}{\tilde{s}} = \frac{Re(\tilde{d})}{Re(\tilde{s})} = \frac{|d| \cos\delta_d}{|s| \cos\delta_s} = \left|\frac{d}{s}\right| \frac{\cos\delta_d}{\cos\delta_s}$$

$$\neq \left|\frac{d}{s}\right| \cos(\delta_d - \delta_s)$$

These two are not same. So, this is wrong. And but if we rightly write that what then we should do? When we are taking this ratio, d by s we should take as full d cos delta d plus j d sine delta d that means we are not throwing away the imaginary part cos delta s plus j s sine delta s.

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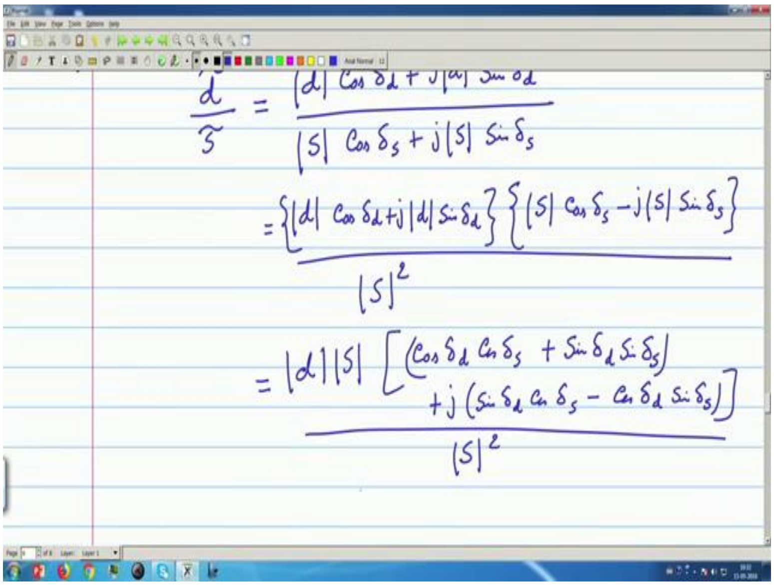

Then what we need to do we will have to this rationalize, so this thing we can do. So, d cos delta d plus j d sine delta d, this whole thing, we should multiply by s cos delta s minus j s sine delta s. And here, we will have the s square cos square delta s minus j square. So, I think I can write directly the s square that I think you will understand.

$$\frac{\tilde{d}}{\tilde{s}} = \frac{|d| \cos\delta_d + j|d| \sin\delta_d}{|s| \cos\delta_s + j|s| \sin\delta_s}$$

$$= \frac{\{|d| \cos\delta_d + j|d| \sin\delta_d\}\{|s| \cos\delta_s - j|s| \sin\delta_s\}}{|s|^2}$$

So, this is I can take if you multiply that every term will be d into s into you can write like this cos alpha d cos delta s plus sine delta d sine delta s plus j sine delta d cos delta s minus cos delta d sine delta s by s square.

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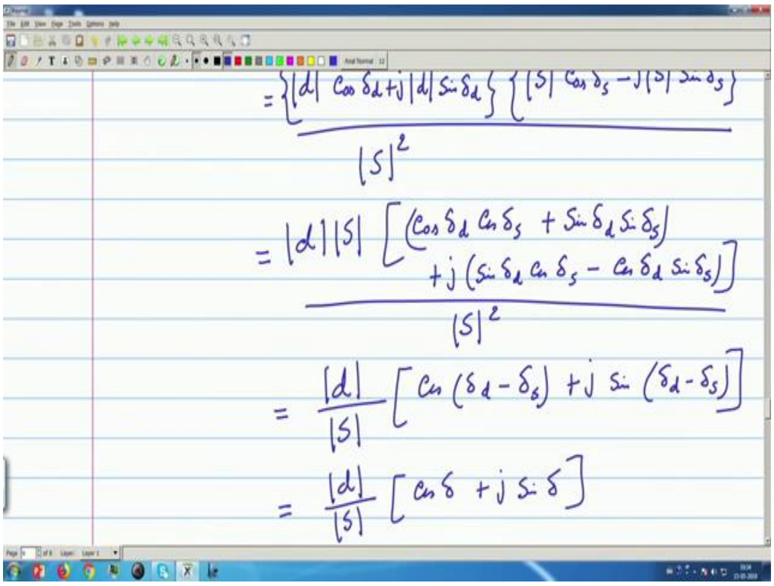
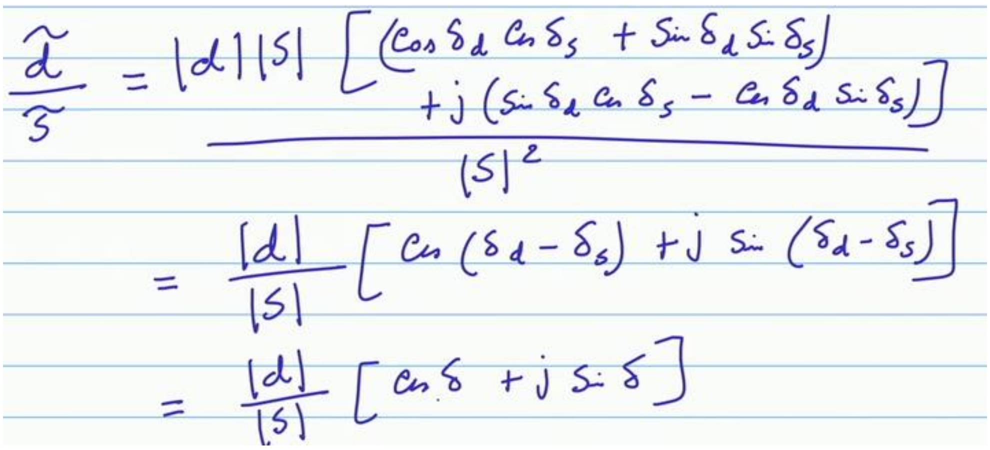


And that is d by s, then you are getting cos delta d minus delta s plus j sine delta d minus delta s. So, you have got it correctly that d by s cos delta plus j sine delta.



And if your LO is less than RF, you take d by s real part will be cos delta; if the opposite you take d by s sine delta. So, you see here we can throw away the imaginary part after we have done the calculation. So, this cos delta this is important, so that means, in the hardware also we should be able to extract this d by s cos delta.

Now, that is a interesting thing please wait for that before that we want to see some more things, then we will come there that what type of circuit etcetera can do that. So, anything let me see, I have left this discussion on complex envelope and this ratio. So, now we can say we are resuming that discussion on the mono pulse radar circuitry.

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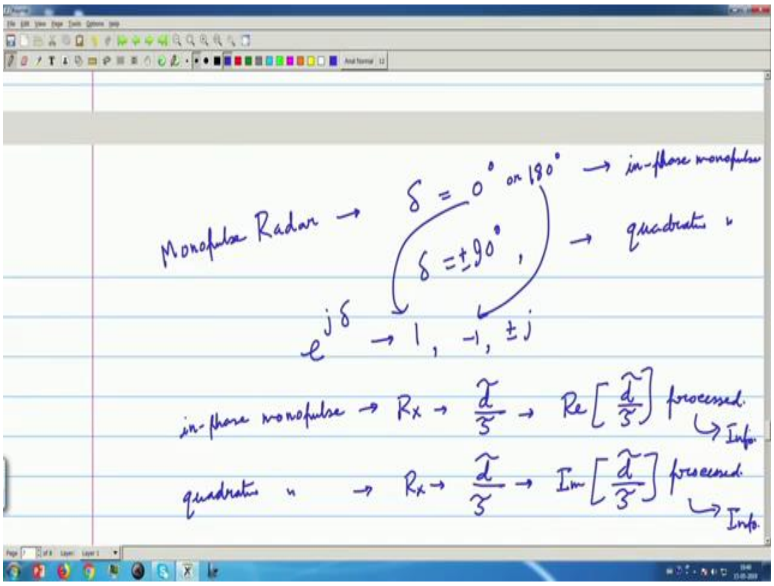

So, I can say that most radar signals, most this radar signals, they can be considered narrow band signals because their bandwidth seldom exceeds 10 percent of RF carrier frequency, 5 percent on each side. Usually much less 5 percent is very high, but I am saying that suppose now a days those modern digital various processing is done on the radar signal so 5 percent. So, still we can consider them narrow band. And then we have seen the that in the processor, they will be processed by the a thing. So, by the ratios so ratio we have seen.

So, for many mono pulse radar, mono pulse radar that delta that means, the difference of phase angle of d pattern and sum pattern that if it is chosen because it is in your hand that how will you choose the antenna patterns. So, delta if is chosen as 0 degree or 180 degree, then your e to the power or cos delta, you can say that cos delta will be either plus 1 or minus 1, that means, a real number ok. So, these radars are called, this mono pulse are called in phase mono pulse. And if you have delta is sorry 90 degree. If delta is 90 degree may be plus 90 or minus 90, then what will be your cos delta will be 0, but it will be j. So, the ratio that radar is called quadrature mono pulse.

Monopulse Radar $\rightarrow$ $\delta = 0^\circ$ or 180° $\rightarrow$ in-phase monopulse

$\delta = \pm 90^\circ$, $\rightarrow$ quadrature "

So, I can say that for all these three cases e to the power j delta that will be in one case, for this case 1; for this case minus 1, and for this case plus minus j. So, for in phase or quadrature mono pulse, it is a special case of mono pulse. You see that the ratio d by s ratio is either pure real or pure imaginary, so that is an advantage. So, because you will be able to find out that in presence of noise etcetera, the ratio may be obtained differently; but you will be able to find out that you are getting a problem. So, generally radars are designed either as an in phase or quadrature mono pulse.

Now, in phase mono pulse, you extract this d by s ratio. So, I will say that in phase in phase mono pulse, the receiver calculates the d by s ratio, then real part of d by s is processed. Whereas, in case of quadrature mono pulse, the receiver finds d by s ratio, and process the imaginary part, the real part is thrown away. So, this you should remember because you have these choices.

So, actually this in phase mono pulse, this real d by s this has the main thing as we have seen that it is magnitude d magnitude s and cos delta. And this is magnitude d magnitude s sine delta. So, in here this is the information signal. So, information here this is the information.

Now, we need to have a microwave circuitry that can extract this directly; that means, let us say that we are talking of in phase mono pulse.

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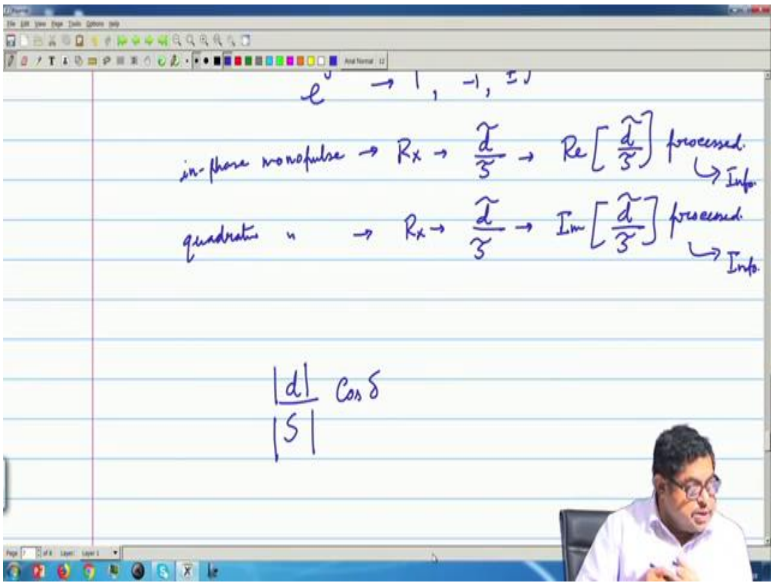

So, what is the circuit that can give me the magnitude d magnitude s cos delta, so that is an interesting thing as I am saying so, the thing that we will see.

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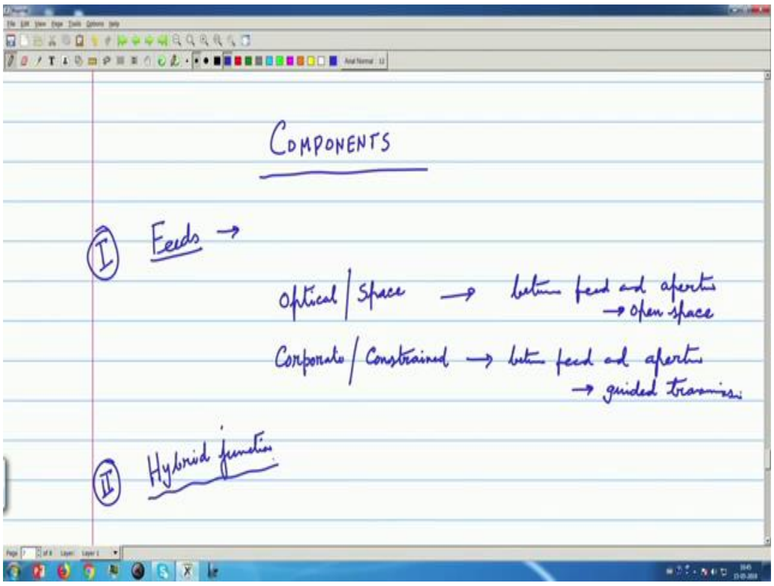

So, first we will discuss the various components used in mono pulse radar one by one components. Actually this initially I will refresh you, so that in microwave technology course in undergraduate, many of these things have been taught. So, that I will just refresh, and then we will see that what is that circuitry which gives us the mono pulse ratio directly. So, first you see that the horn feeds. So, I will not say much those are horn antenna is covered in antenna classes, but one thing I say that what is a feed. A feed is that part of an antenna that distributes power from the transmitter to the main aperture. Aperture may be a lens, a reflector, an array etcetera in a desired manner.

So, what is a feed? A feed is that part of an antenna that distributes power from the transmitter to the main aperture in a desired manner, and also collects the power captured by the aperture with some desired waiting for transfer to the receiver. This is the definition of the feed now. So, in our mono pulse, you can understand that horn is the feed, it is not the main antenna it is a feed the it is the main aperture is with the reflector. So, it is in a desired way, it is giving that power and also collecting the power that is why it is called feed. Now, two general classes of feed, one is called optical feed, another is called corporate feed.

Now, optical feed is also called space feed; corporate feed is also sometimes called constrained feed. So, what is optical feed? It is if you have a between the feed and the aperture, if there is a open space, that means, the feed is putting the power in the open space through radiation, and then aperture is receiving, then it is called I will say that between feed and aperture open space is there, then it is an optical feed. So, our this mono pulse is an optical feed, because we have horn as feed then there is free space and then there is a reflector. So, all reflector antennas there space feed. Similarly, in the reverse also when the power comes first, it comes on the reflector then the feed then the reflector radiates in that open space and feed collects that.

On the other hand, what is a corporate feed it distributes power from the transmitter to the aperture through some guided transmission line, may be waveguide, may be coaxial transmission line etcetera. So, here we can say that between feed and aperture, you have guided transmission. So, not radiation it is a guided transmission, so that means, we have in mono pulse I said optical feeds. So, we have four feeds etcetera. So, I do not think any other thing. That next components, so I will say this is one we discussed. Next, we can discuss something on hybrid junction. Now, hybrid junction is you have studied this in microwave technology in undergraduate.

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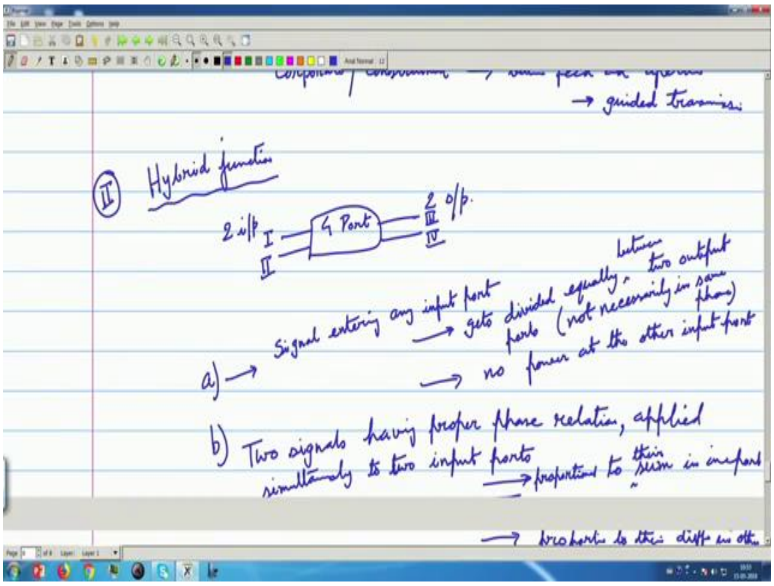

Now, actually any hybrid junction is a 4 port device also you can see actually we have some I think in one of my NPTEL lecture on basic building blocks of microwave engineering, you can find these in detail there, you can find you can refer to that lecture. But here for our present discussion we will say what is a hybrid junction, n it is a 4 port. Now, out of this there are two input ports. So, 2 input ports and 2 output ports, so that is a hybrid. And for hybrid with proper match terminations, we can have that. Here we will follow a terminology that these input ports we will call port 1 and port 2; the output ports are called 3 and 4.

And, but we will say that for the hybrid, there are two I will say characteristic, the first characteristic is that if signal is entering any input port, it gets divided equally in power between two output ports. So, the you see power gets divided equally into two output ports. The voltages need not be in the same phase, but power is equal, so that is the first property, also the power does not appear at the second port. If I give it at any port, suppose port 1 or port 2; if I give power at port 2, no power should come to port 1, this power should get equally divided here, voltage there can be any phase. We are not saying that same in phase voltage, but they should have equal power division.

And second property is that if two signals having proper phase relations are applied to the two input ports, then at one output port you will get sum at another you will get difference. So, now these two are the properties of the hybrid junction that we will use, because you see that this will be useful for us that it can divide power. The first property says that it is basically can divide power, and second property is saying that it can be used to generate sum or difference pattern is not it.

The first property as I said so I can write that signal entering any input port gets divided equally in two output ports, get divided equally between, let me write that will be more appropriate, between two output ports. And here I give a….. that not necessarily in same phase. We are not bothered about phase, but it should get equally divided this entering in one port, and also no power at the other input port. In technical terms we call that the second input port should be completely isolated from the first port. I am not using that. So, meaning is no power at the other input port.

And the second property of hybrid that we want is two signals having proper phase relation between them, phase relation applied simultaneously to two input ports will give me sum in one port or I will say that proportional to sum to their sum in one port, and proportional to their difference in other output port….. in one output port.

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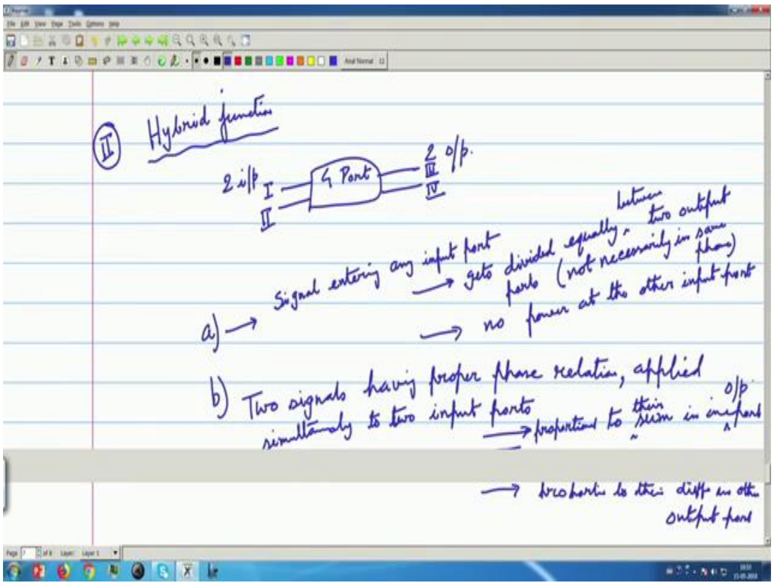

So, in the input if I give two signals simultaneously, obviously, there will be a proper phase between them; in one I will be able to get sum, and another I will be able to get difference. So, you see that if this is hybrid we you know there are examples of hybrid we will discuss. So, already you have seen that magic tee or the rat race or couplers hybrid couplers, so they can do this, so that will do our job of making sum and difference patterns possible. But still we have not got that circuit that we require not only sum and difference we require a circuit RF circuit microwave circuit which can give us d by s into cos delta that we have not seen yet that we will see actually that circuit will be making of sum of these elements together, and that is called mono pulse comparator. So, we will see that circuit actually what in the functional block diagram we referred as a microwave combining network will comprise all these things. So, I am trying to go to that microwave combing network that block diagram, yes.

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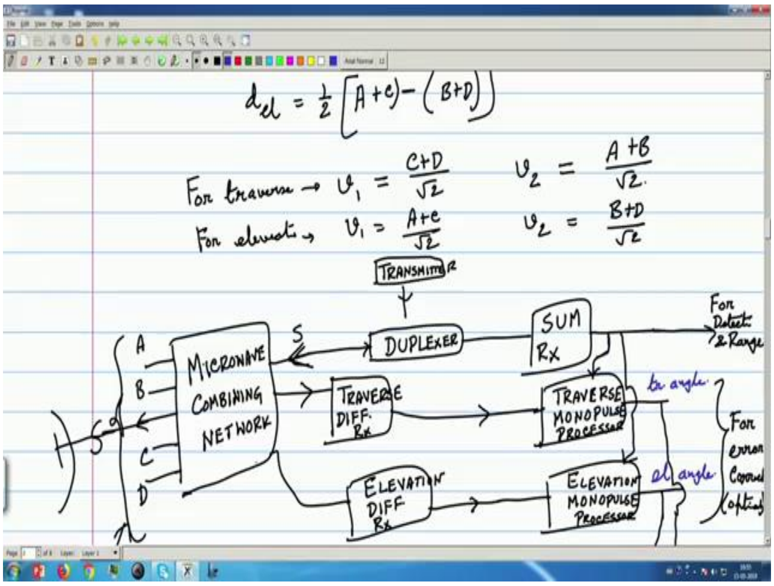

So, here you see that in the functional diagram this microwave combining network ultimately will be able to give us these ratios. So, we will or here we will get that thing. So, from where we can get ours a thing so that we will see. So, for that we will again continue our discussion on these hybrids. So, we will specialize what type of hybrid will be useful to us, because there are in phase or quadrature, so we will have to fix those angles, and then we will have to proper adjust them, so that you can do that that. We will do in the next class.

Thank you.