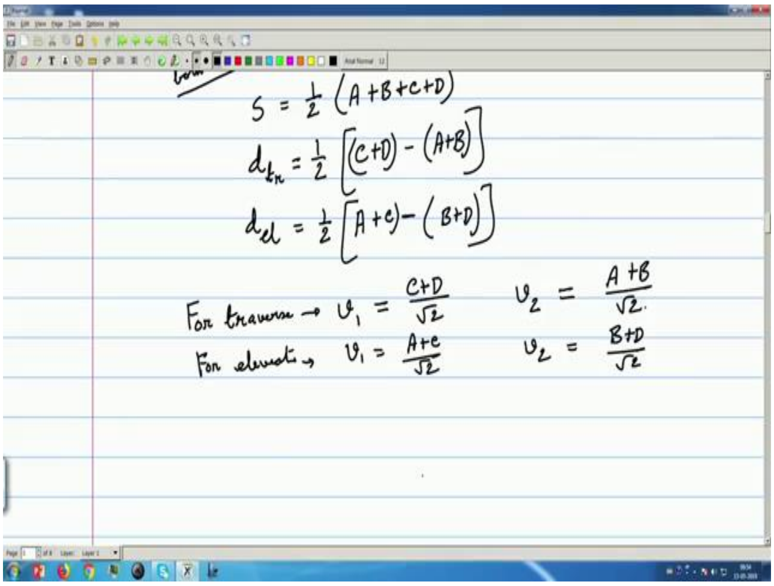
Principles And Techniques Of Modern Radar Systems
Prof. Amitabha Bhattacharya
Department of E & ECE
Indian Institute of Technology, Kharagpur

Lecture - 28
Tracking Radar (Contd.)

Key Concepts: Functional block diagram of monopulse receiver, complex envelope representation of monopulse and analysis

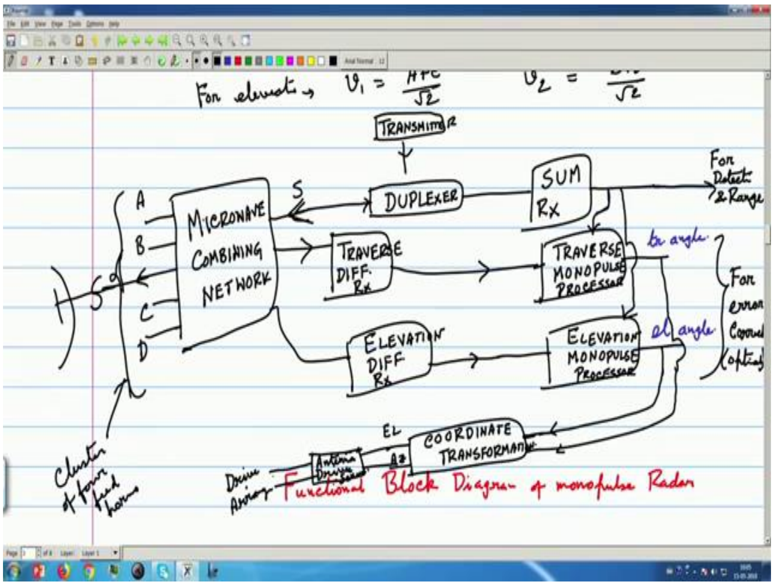
Welcome to this NPTEL lecture on Principles and Techniques of Modern Radar Systems. We were discussing Tracking Radar out of that in the last class we last 2 classes I think we have seen the monopulse technique. We are continuing that discussion, we have seen the angle detection for that a ratio monopulse ratio d by s complex ratio, that is useful that gives directly the angle a thing.

(Refer Slide Time: 00:57)



Now, we will see the implementation of that and so, we will first see the block diagram of the monopulse system. So, it is called functional block diagram; functional block diagram of monopulse radar.

(Refer Slide Time: 01:11)



So, we have a transmitter, now that transmitter gives a signal to the duplexer. So, the duplexer you see that, it should have gone to the antenna in normal pulse radars, but in case of monopulse, it actually passes through a microwave combining network. What is this we will later see, but what happens. Now, this duplexer that actually or this side it gets produced the actually this signal from this network, it goes to the 4 feed horns. So, we are calling them actually this side I can say, A B C and D these are the 4 feed horns.

So, it is from here. So, also to those 4 horns actually from them, these microwave a also produces a sum pattern and that sum pattern I should sorry. So, A B C D and let me call this one as sum pattern. So, that sum pattern goes to the antenna. So, you can think like this that, this sum pattern going, actually it is not a separate entity this A B C D, but this network makes a sum and that is produced. They are equally excited A B C D from the transmitter, via duplexer and that produces in the circuitry a sum we will see that microwave combining network will be able to produce a sum. So, that sum is transmitted.

Now, while receiving from the target the echo is received, that echo is A B C D. So, we can say that this A B C D they are the cluster of 4 feed horns. So, these horns will receive that signal, that we are calling A B C D that we are putting to this network. And here also then that S will come whatever has been received from that S, what has been transmitted that S is I am writing here also.

So, duplex are then, it will go to the receiver, this receiver we call it sum receiver. And also this microwave combining network A B C D has been input to them, it will give us also a circuitry called an another receiver, traverse difference receiver, also there will be an elevation difference receiver. So, three receivers we have, one is sum receiver only sum receiver is through the duplexer, because sum is transmitted these are received ones. So, traverse difference receiver, elevation difference receiver.

Now, this thing needs to be given to two processers; one is called traverse, monopulse, processer and it output will be the traverse angle. So, traverse angle similarly there will be also elevation monopulse processor. So, its output will be elevation angle.

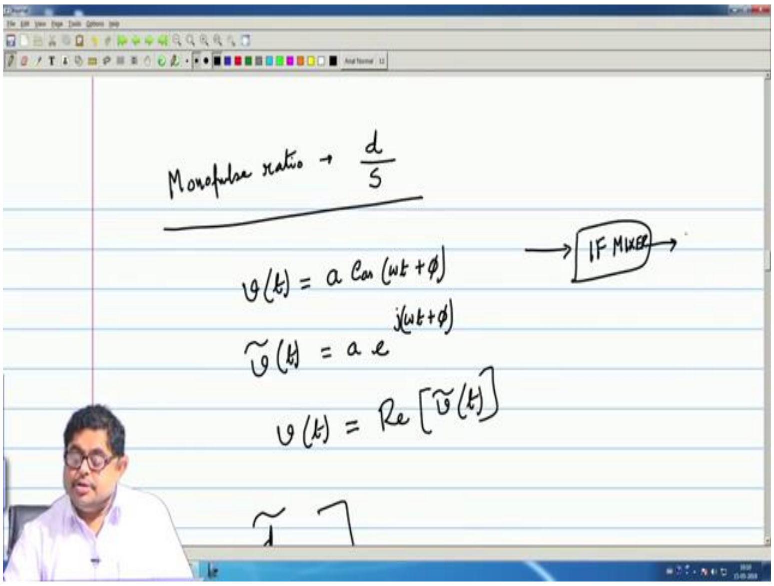
And also to have this processer this sum receiver output that also sum receiver output also to be fed here and sum receiver output also needs to be put at the input of this elevation monopulse processer, then only they will be able to process. And this sum receiver after this; that means, angular thing is detector, then it goes for detection and range etcetera those things are performed.

And what is done with this? Now, we have got this two angle a thing. So, this if required that you want to align the radar monopulse radar to the direction of the target, because that is the job of tracking. Then, it is given to for error correction, error correction, this is actually optional part. And also still you see we have got traverse and a thing, but actual thing is the elevation and azimuth. So, what is done this two things are taken and here is a block to which this is. So, what is this block? This is coordinate transformation. So, it gives you the elevation and azimuth and then there is another block to which this is given that, the antenna drive servos.

So, servo will control that mechanical drive ok. So, this is now given to the drive motors, servo motors, drive motors, drive arrangement you can write drive arrangement. So, this is a now main you see that, now we will be focusing on this microwave combining network that, how from the received squint beam voltages I can produce the traverse angle and elevation angle.

Actually, the heart of that will be that monopulse ratio d by s, we will find out the mathematics we will find out the circuitry everything, but before that I want to say a thing, which is very important many times we ok. So, we have written the monopulse ratio.

(Refer Slide Time: 12:03)



We have seen monopulse ratio is that d by s.

$$\text{Monopulse ratio} \rightarrow \frac{d}{s}$$

But actually it is a complex quantity phasor, why it is complex? I recall that, the concept of complex envelop. So, if we have r f voltage sinusoidal voltage because we have carrier a cos omega t plus phi. So, we in phasor notation we write it as v t where, v t is a e to the power j omega t plus phi.

$$v(t) = a \cos(\omega t + \phi)$$
$$\tilde{v}(t) = a e^{j(\omega t + \phi)}$$

So, we know that to get the real signal v t we need to take the real part of v t; that means, we know that, we can work conveniently with these, because if there are multiplications actually in modulation etcetera or in A C circuits you have this phasor concept. Now, if you have any operation, particularly multiplication, division type of operation, then phasors are handy, because multiplication division of e to the power something is convenient compare to cos and sin.

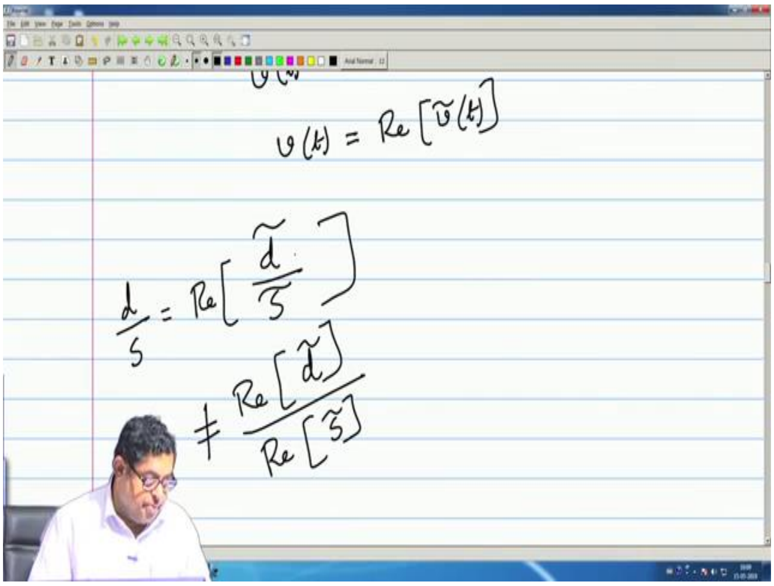
So, that is why we do that, but when we come back we again make that v t is nothing, but real part of v t that is fine.

$$v(t) = Re\left[\tilde{v}(t)\right]$$

So, we know that our real signal is for actually all signals are real. So, real signal is nothing, but the real part of the complex signal phasor signal.

Now, what happens, that if I have a ratio then, we need some caution that, we need one caution that is we have seen that the ratio, d by s I tell you these are r f voltages and the phase is important.

(Refer Slide Time: 14:41)



So, actually we will the radar also while analysing we will take that these are the phasor ratios. So, actual d by s is what actual d by s is real part of this phasor. Now, while doing that, actually I want to tell you probably you know it, but still many times that students make a mistake that. This is not real d by real s.

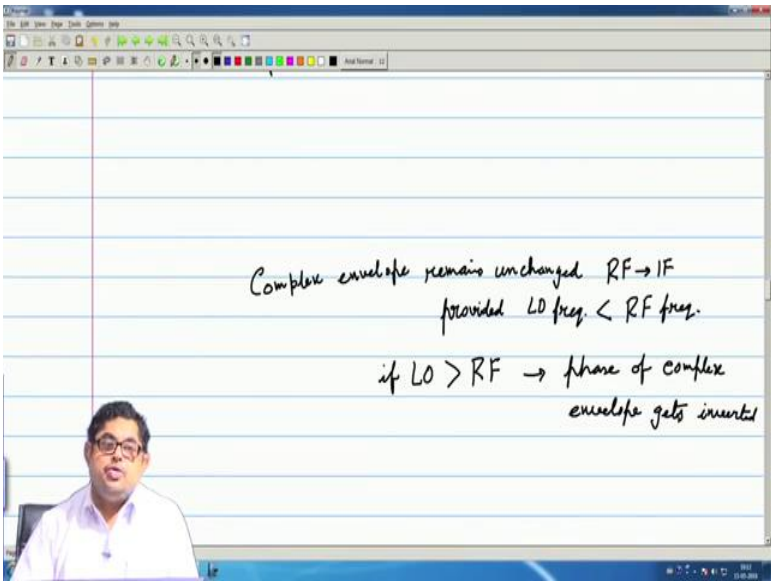
$$\frac{d}{s} = Re\left[\frac{\tilde{d}}{\tilde{s}}\right] \neq \frac{Re[\tilde{d}]}{Re[\tilde{s}]}$$

If you do that this will be wrong; that means, individually you cannot make that this means real d by real s, no it is you up till you make this ratio final calculation, you keep it as phasor, then only the whole thing that can you make real part. Now, here also there is a caution the you see that at r f level we are making this making this r f signal where a monopulse ratio.

Now, I am saying that this is a actually the voltages are r f voltages, but for analyse and their band pass signal. So, we represent them by complex envelop and makes this as a complex quantity, and actual thing is real part of these quantity provided, you see we are in the receiver, after I am getting the signal in the receiver there is a IF mixer. So, in the mixer the this phase information should be preserved.

So, this receiver of the monopulse receiver should preserve that, now there is a concept that it is.

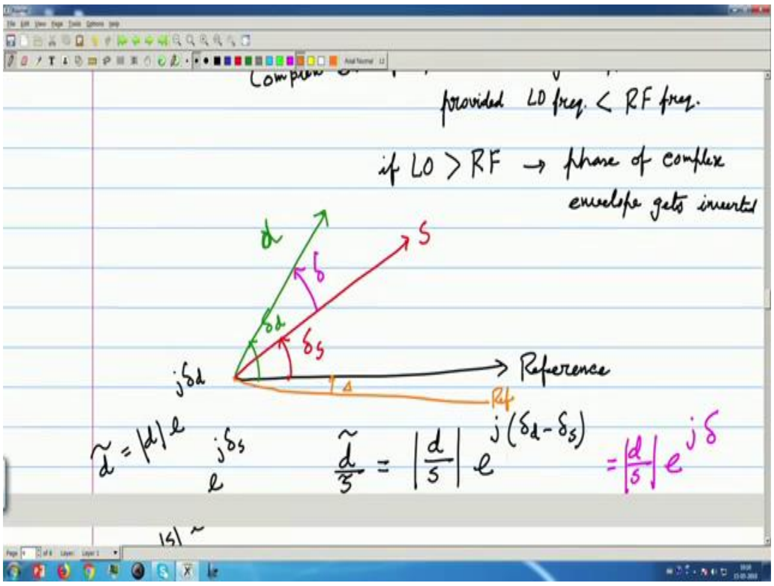
(Refer Slide Time: 17:05)



The complex envelop the complex envelop remains this can be proved remains unchanged when we make RF to IF conversion. But, there is a catch actually generally in communication this catch always is not mentioned that, this is true remains unchanged provided a LO frequency local oscillator frequency is below RF frequency. And if it is not if LO is because I can make LO also greater than RF also the then the phase of complex envelope gets inverted.

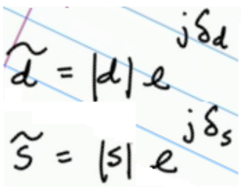
So, in that case when finally, taking you will have to take the imaginary part of the complex ratio to get the actual d by s ratio. So, remember this also there is another thing that, I will now take the help of a diagram actually in the receiver.

(Refer Slide Time: 19:03)



The reference phase let us say that oscillator reference phase is like this and the sum pattern in the phasor diagram sum pattern is let us say it is angle is delta s and I think green. So, let us say the difference pattern its angle is delta d; delta d delta.

So, when we will form the ratio d by s what is this phasor d by s? Now, separately what is actually phasor d, I can write this is the magnitude part the length of this arrow. And, e to the power j delta d, what is s? s e to s e to the power j delta s.

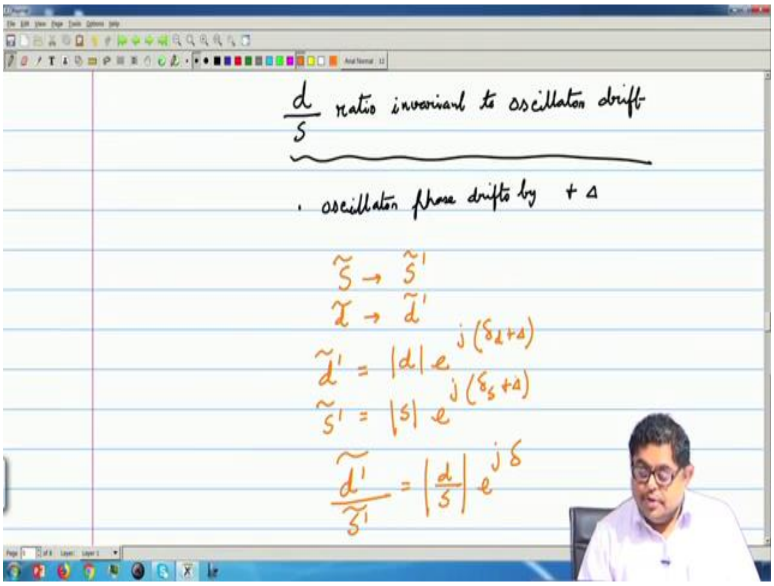


So, what will be d by s? It will be d by s e to the power j delta d minus delta s which what is it is, actually this let me call delta. So, this is d by s e to the power j delta.

$$\frac{\tilde{d}}{\tilde{s}} = \left|\frac{d}{s}\right| e^{j(\delta_d - \delta_s)} = \left|\frac{d}{s}\right| e^{j\delta}$$

So, actually this part contains all the information and now we will prove various things that this if this reference oscillator that drifts, you see if this reference oscillator drifts, what we get? So, I will see a concept that.

(Refer Slide Time: 22:07)



Because previously I have mentioned that d by s ratio is invariant to oscillator drift, that I will prove now. Let oscillator phase drifts by delta capital delta. So, I can draw the reference diagram again or in that diagram. So, now, I will have to take the this is now delta; that means, reference has drifted. So, we can now say that this is the reference and we will say all these with respect to reference all these quantities will change and they will be called that new delta. So, I will call that. So, now, our s has become s dashed and d has become d dashed.

So, what is d dashed or I can say s has become s dashed d has become d dashed.

$$\tilde{s} \rightarrow \tilde{s}'$$
$$\tilde{d} \rightarrow \tilde{d}'$$

What is d dash? It is as before the magnitude will not change, but this is e to the power j delta d plus delta this is s dashed. So, s e to the power j delta s plus delta.

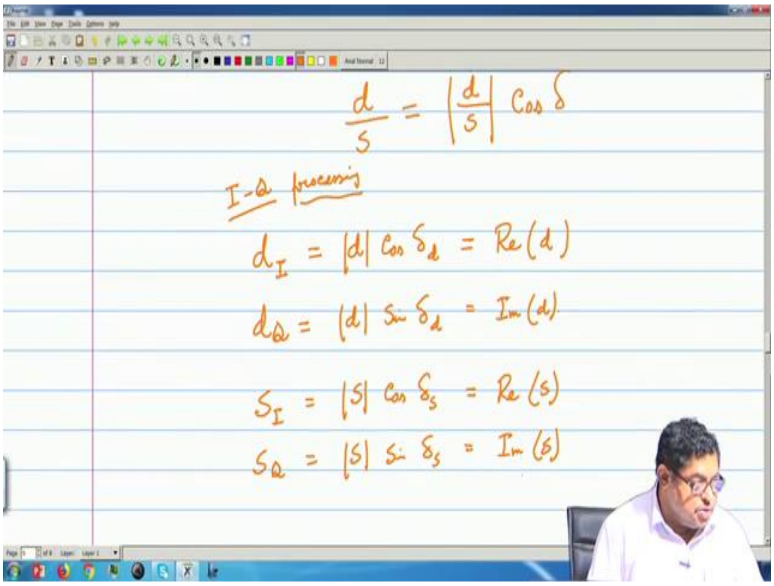
$$\tilde{d}' = |d| e^{j(\delta_d + \Delta)}$$
$$\tilde{s}' = |s| e^{j(\delta_s + \Delta)}$$

So, their values have changed, but you see what is happening to d dash by s dash. So, this is d by s e to the power j delta as before.

$$\frac{\tilde{d}'}{\tilde{s}'} = \left|\frac{d}{s}\right| e^{j\delta}$$

So, it proves that oscillator phase does not change. Also you see that actually what is the real d by s ratio?

(Refer Slide Time: 25:03)



Any time what is d by s, d by s is these then if we have the real part; that means, our LO is less than a cos of the angle delta.

$$\frac{d}{s} = \left|\frac{d}{s}\right| \cos\delta$$

Is not it this is the actual scenario now this cos delta will come if we treat everything as a complex envelop; that means, at the RF level. If we RF or IF level, but if we go throw away the phase, we would not be get that cos and that will change the value and that will make the measurement erroneous.

So, these you should remember now some radars they also what they do that, they have the receiver chain as I Q things. So, what they do that, I will come there that this thing that some radars in the receiver they are have that in phase and quadrature components. So, they are this ratio will change, but the concept will not change I will also mention that that suppose in the receiver.

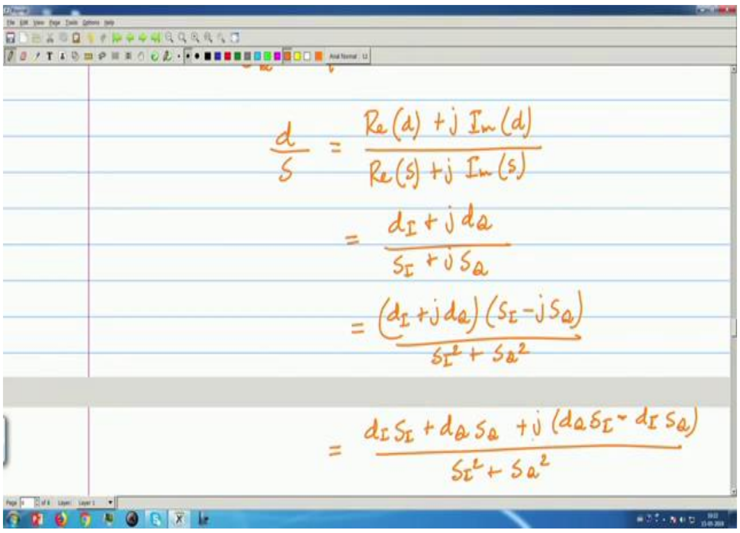
So, I will say that I Q processing. So, receiver is I Q base receiver actually most of the modern digital receivers are like this. So, this concept also should be seen, what is d I actual d I is d cos delta d and let us call it real part of d. Similarly, d Q it is d sin delta d that is imaginary part of d.

$$d_I = |d| \cos \delta_d = Re(d)$$
$$d_Q = |d| \sin \delta_d = Im(d)$$

Similarly, what is S I? S cos delta S is equal to real is all respect to our that diagram phasor diagram S Q is s sin delta s let me call it imaginary part of s.

$$S_I = |S| \cos \delta_s = Re(s)$$
$$S_Q = |S| \sin \delta_s = Im(s)$$

(Refer Slide Time: 27:55)



So, what is d by s ratio, d by s ratio I can write as real d plus j imaginary d divided by real s plus j imaginary s. So, that is I can write d I plus j d Q by S I plus j S Q. So, this d by s ratio now I can make it d I plus j d Q into S I minus j S Q and here S I square plus S Q square. So, this will be d I S I plus d Q S Q plus j d Q S I minus d I S Q divided by S I square plus S Q square.

$$\frac{d}{s} = \frac{Re(d) + j\,Im(d)}{Re(s) + j\,Im(s)}$$

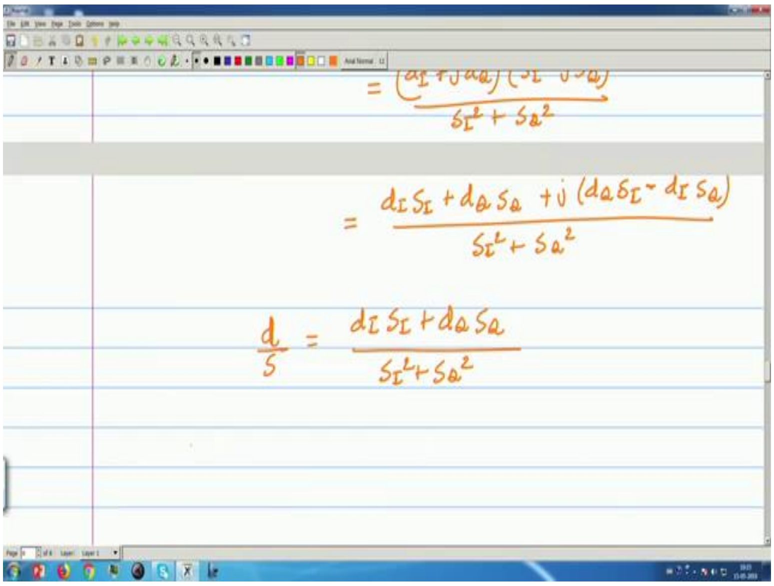
$$= \frac{d_I + j d_Q}{S_I + j S_Q}$$

$$= \frac{(d_I + j d_Q)(S_I - j S_Q)}{S_I^2 + S_Q^2}$$

$$= \frac{d_I S_I + d_Q S_Q + j(d_Q S_I - d_I S_Q)}{S_I^2 + S_Q^2}$$

So, if your LO frequency is less than RF frequency you will take the real part.

(Refer Slide Time: 29:49)



So, what is your d by s ratio d by s ratio will be d I S I plus d Q S Q by S I square plus S Q square. So, it is not simply the d I by S I or something.

$$\frac{d}{s} = \frac{d_I S_I + d_Q S_Q}{S_I^2 + S_Q^2}$$

So, this is your actual ratio. Now, actually you will show that, if you throw away that, then you are not; that means, we will prove actually in the next class we will start with this, that you cannot we are not permitted suppose we are having that LO is less than the RF frequency. So, we are interested in the real part, but we cannot throw away the imaginary part before we finish our processing.

So, that we will prove mathematically and then we will go to the I think this concept actually is known, but I am a thing that actually my d by s ratio since it is a complex ratio in real terms it is d by s cos delta. So, this cos part actually makes the measurement precious. If we throw away this cos part there will be errors. Similarly, all this has required to make the measurement of d by s ratio precious this should be kept in mind while having or designing a monopulse radar.

Thank you.