Communication Engineering
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Lecture - 25
FM Receivers
Pre Emphasis, De Emphasis
And Stereo Broadcasting

We will continue our discussion on FM Receivers, today we will complete our discussion on Pre emphasis and De emphasis and spend some time on Stereo Broadcasting using frequency modulation.

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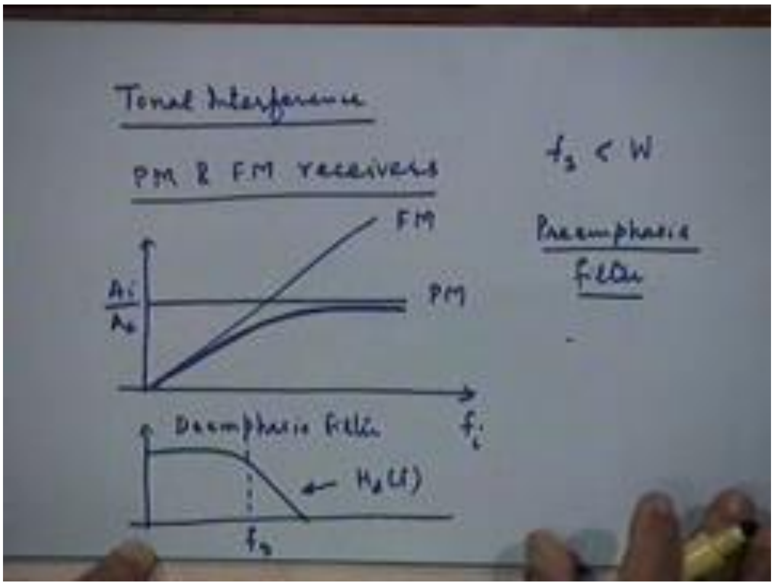

So if you may recollect, we have looked at the effect of interference, sinusoidal interference or tonal interference. On the performance of PM and FM receivers and what we have found was that if you look at the amplitude of the interference output as a function of the input interference frequency. For the case of phase modulation, this amplitude was constant equal to some value, some Ai by Ac or something.

For the case of this was the case for PM, for the case of frequency modulation this amplitude increase linearly with frequency. And we therefore, argued a case for putting at the receiver, a filter which would attenuate the interference frequencies of the interference amplitude of the higher frequency of the output. So, we said that we will use a low pass filter at the receiver which will attenuate the higher frequencies, the amp, so that the interference due to the higher frequencies in terms is reduced. And the overall response curve for the FM case, after introducing this filter at the output of the discriminator.

So, this is a low pass filter which we call the de emphasis filter, the overall response curve would be something like that. The cutoff frequency here is selected in such a manner that you get a response like that. This cutoff frequency which we called as f sub 3 is said should be typically less than W where W is the bandwidth of the message signal. However as somebody likely points it out since we are going to have at the output of the discriminator a filter like this, it will also distort the signal itself.

Because, this cutoff frequency is below the bandwidth of the signal, there will be some components of the signal which are higher than the frequency f sub 3 which will get attenuated as a result of this. So, to counter this effect we use so called pre emphasis filter at the transmitter, whose characteristics are opposite to those of the de emphasis filter. So suppose the de-emphasis filter has a transfer function let us call it H sub d f, so then the pre emphasis filter and the de emphasis filters must satisfy this condition.

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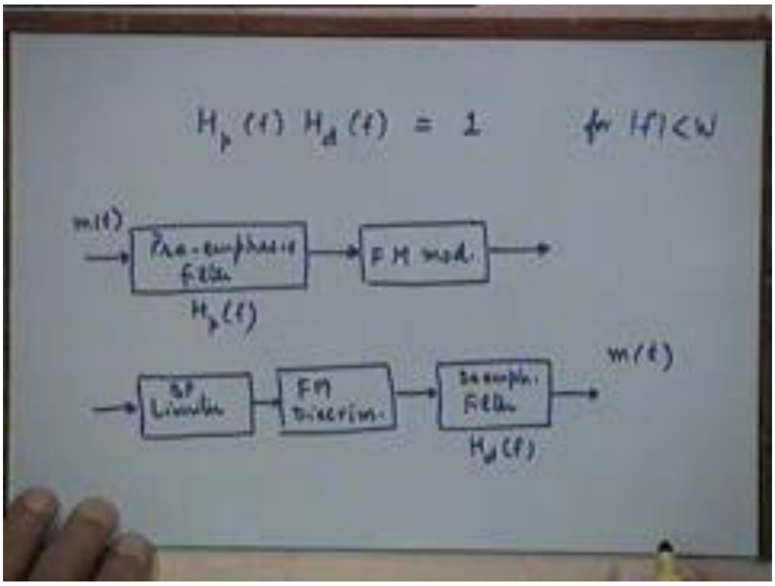

The pre emphasis filter transfer function H p f into the de emphasis transfer put the transfer function should be equal to 1. They should they should not cause any distortion, their product should be equal to a constant, well whatever it is question is, whatever the transfer function you have here. The transfer function H p f should be such that over the frequency band of interest that is from 0 to W the product should be a constant.

In particular that will be directly is affecting this particular region, because in this region it is anywhere constant more or less. So, for mod of f less than W, so basically what we are saying is your FM system, now look something like this, you have a message look at both the transmitter as well as the receiver. So, the message signal m t, instead of being sent to the frequency modulator directly is first pre distorted, it is pre distorted to taken at the fact that there is a de emphasis filter which otherwise will distort the signal.

So, it is pre distorted by using the pre emphasis filter and this has a transfer function, this filter has a transfer function its h H p f. The output of this filter is the one which is send to the FM modulator and this is what is transmitted, this is what is broadcasting. At the receiver you have your limited discriminator that is limiter band, pass limiter you have a FM discriminator. And finally, you have the de emphasis filter to the transfer function H sub d f and that will hopefully produce an undistorted message m t.

So, the job of the pre emphasis filter, the job of the de emphasis filter was to attenuate with high frequency interference that would come out with large amplitude at the discriminator output. The job of the pre emphasis filter is, because of that since the higher frequency components of the signal also get attenuated. The emphasis are amplified the higher frequencies of the signal, higher frequency components of the signal.

So, that is basically what we intent to do, when you do that there is slight side effect in as per as the modulator is concern. Because if we remember, the peak frequency deviation will depend on the amplitude, particularly in the case of FM amplitude of the higher frequency components more. So, the peak frequency deviation may slightly increase as the result of this, but that is hardly a major problem to worry about.

Since, signals to a typically otherwise if you take the example in audio signal or a voice signal. The higher frequency components are slightly lower in strength, so we has to therefore, guard against the fact that you are further attenuating them at the de emphasis by using the de emphasis filter. So, we must amplify them slightly at the transmitter itself, so that the effect of the de emphasis filter is taken care of, so we will have reason to come back to pre-emphasis and de-emphasis filters once again. And these methods of improving the performance of FM receivers, once again when we discuss effect of noise later on.

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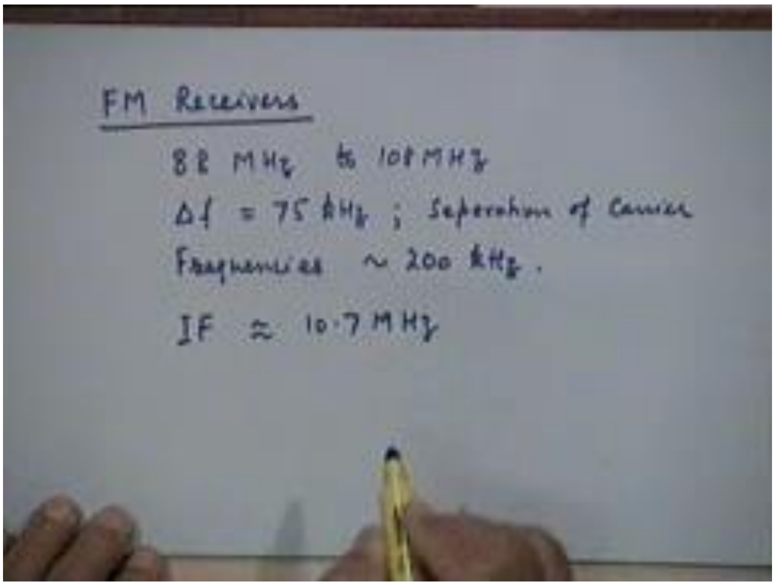

Let us, move on and let me talk little further on FM receivers, you all familiar with FM broadcasting these days radio for example. And you all know the example that the frequency band is do, you remember 88 megahertz to 108 megahertz. Typically, if we have multiple FM transmissions taking place in a region, because in our country in the city of Delhi I do not think we have too many FM broadcasting stations we only have two. But, if we have multiple broadcasting stations in the same neighborhood, we like to ensure that the transmission frequencies of each of the stations are well separated.

And how much should the separation be, let us make an estimate, we mentioned that the peak frequency deviation in typical FM commercial FM transmission is of the order of 75 kilo hertz. So, at the approximate bandwidth suppose they are transmitting music if bandwidth is about 15 kilo hertz, so the approximate bandwidth of the FM signal would be twice into 75 plus twice into 15, they will come to about 18 kilohertz.

So; that means, successive transmission station should be separated from each other by about 200 kilo hertz taking about 20 kilohertz is a carbon. So, typical separation between various transmitters separation of carrier frequencies will be of the order 200 kilohertz, this is as far as monophonic receivers are concern at the single channel receivers. Typically, the higher frequency at the receiver the intermediate frequency is of the order of 10.7 megahertz. In fact, this is the standard 10.7 megahertz is the intermediate frequency remember the concept of intermediate frequency in the super heterodyne receiver.

So, the concept of super heterodyne receiver is equally valid for FM receivers also, whatever we do for AM receivers is also carried over to FM receivers. All the advantages of the super heterodyne receiver would carry over to the FM receivers.

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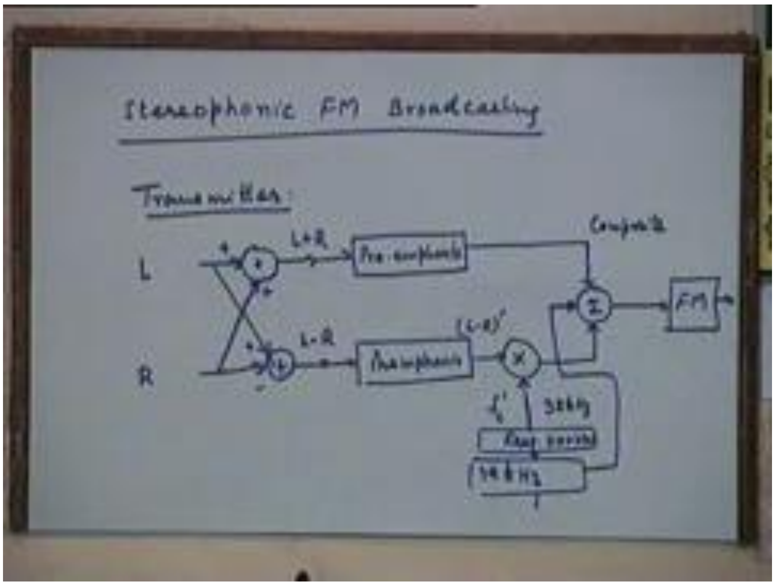

Lets next come to stereophonic FM broadcasting; in fact FM is most popular in carrying out this kind of broadcasting. Basically, it is used for transmission of high quality music and it is usually done to also capture enough the simple and monophonic effects in a music environment, but also a stereophonic effects. I hope you all appreciate, what the stereophonic effect means, basically it implies that you are trying to discriminate the music which we are listening on the basis of a spatial distribution of music regarding just the temporal waveform.

Of course, ultimately interested in the temporal waveform, but you must you also want to differentiate spatial we has to which instrument is playing in which related to each other in what spatial location. So, basically therefore, you need to have multiple receivers multiple sensors at the time of the cardinal music or at the time of picking up that music. They are in a single microphone you have distributed microphones in space and typically you can use as many as you like of course, and depending on the cost of the cause that you can bare.

But typically stereophonic systems, you pickup have at least two sinusoids which are clearly well separated from each other. To pick up the signals from let us say the left and of per performing states and then you have to send both the signals together and feed the signals to the appropriate speakers, so that you can keep the spatial discrimination possible that is basically the idea.

So, the since as far as, we are concern as far as the FM transmission is concern the implication is that instead of transmitting one signal we have to transmit two signals both the left signal as well as the right signal. So, the way we do it, I will just describe that, but before we describe, what we are going to do, we must also appreciate when you use stereophonic when of course, the this question is a little irrelevant today. Because today I think most FM radios would be stereophonic FM radios.

But, when these standards are formulated when they were formulating in the first instance they were FM station FM broadcasting or FM receivers which were not meant for a stereophonic broadcasting. Just FM broadcasting in the first institute was not fisting stereophonic broadcasting it was monophonic broadcasting transmission of the single signal which is the spectrum. So, these two systems must be compatible with each other, even if you are transmitting a stereophonic broadcast. A monophonic receiver should be able to pick up the signal in the way it should have heard otherwise.

So, stereophonic FM broadcasting is therefore, made compatible with a monophonic receiver. So, how that is done and how the stereophonic broadcasting is done is something we will discuss now, it is a very simple thing. We will soon see it is really a very simple system, but this system uses many of the concepts, what we discussed today, that is why I want to spend about 5 to 10 minutes for this.

Let us look at the transmitter first, as I said the spatial discrimination of the signals or spatial discrimination, let us say that signal as music like to pickup two signals which you call the left signal and the signal. And you do not transmit them as left and right, we have a matrix which combines this signals these are two other signals, one is called L plus R, the other is called L minus R.

So here, plus minus and here plus and the reason why we do that is, because for a monophonic receiver it is the L plus R which is relevant, you want to look at the total signal from the left half part of the state as well as the half part of the state. So, you want to look at both the signals together, so this is the signal which is of interest in monophonic receives both the signals in a stereophonic receiver from which of course, you can reconstruct L and R by again subtraction and addition. So, that is easy.

Now, we must send this through a pre emphasis filter both the signals, now that we have discussed the role of pre emphasis, we must we will do that. Remember another constrained that we have to have at the receiver is that we must be able to separate these signals at the receiver, because before we transmit we will have to somehow combine them. But, the combining process of these two signals, ultimately you have to transmit only one signal.

We are not actually need to transmit two FM signals, but we must transmit them sufficiently separated from each other in some sense that we are able to separate them at the receiver. We must have an L plus R and L minus R available. How can you do that, how should we transmit simultaneously L plus R and L minus R, when you transmit two signals from, so here we use one of the multiplexing techniques.

Typically we do, what is called frequency multiplexing here, because it is main multiplexing. We transmit L plus R in the base band and I mean you keep L plus R in the base band, but L minus R is shifted up in frequency. Before we do any FM this is done just to make sure there are we continue you have separate entities available is it clear. So, we have therefore, DSB SC modulator here, which has some carrier frequency f c prime the L I am call the signal L minus R prime signal this L minus R up to the pre emphasis call this call it L minus R prime and these two signals are carried together and transmitted.

So, since we are doing a DSB SC modulation here, because of the fact that we have the carrier coming here we just want to do a frequency multiplexing, we are shifting up this signal by an appropriate amount. But it also tells you the frequency that is used. Remember your base band signal has a bandwidth of about 15 kilohertz, because we are talking music kind of signals here.

So, the DSB SC signal are on f c prime would go up to f c prime minus 15 to f c prime plus 15. So, like to make sure that f c prime minus 15 is well above 15 kilohertz so that the two do not overlap and the standard frequency which is used for this purpose is 38 kilohertz. The carrier frequency we call it a pile, we call it a sub carrier, this is how the final transmission although as this is transmitted, but this is not transmitted as such so there is no frequency modulation. So, there is a sub carrier of frequency 38 kilohertz which is used to DSB SC modulate the and minus R signal.

Now, since we are using the DSB SC modulator, what kind of demodulator we will have to have at the receiver, for separating this out back, we have to have a synchronous receiver for this purpose. It is I must transmit this pilot carrier must transmit the signal by which I can extract the carrier properly. However, I do not do that I do not transmit the pilot carrier 38 kilohertz, because that is little more difficult to separate out as we will soon see, what we do is, we generate this 38 kilohertz at the transmitter by using a 19 kilohertz oscillator and a frequency doublers.

So, you generate 19 kilohertz in the frequency doubling and transmit this and this signal 19 kilohertz signal is also added on to the transmitted signal. So, the signal that you actually, the message that you actually transmit is the L plus R signal is the L minus R signal with the frequency shift of 38 kilohertz, DSB SC version of that and the sub carrier at half its frequency. These three signals form a composite signal, there is a composite signal is containing these three components and this becomes your basic message signal for the frequency modulator. So, you have an FM modulator finally, so the FM modulator works on this composite signal and transmits this.

((Student Refer Time: 23:17))

Of course, base band signal bandwidth means if you think of this as your base band signal, the spectrum of your base band signal will look something like this.

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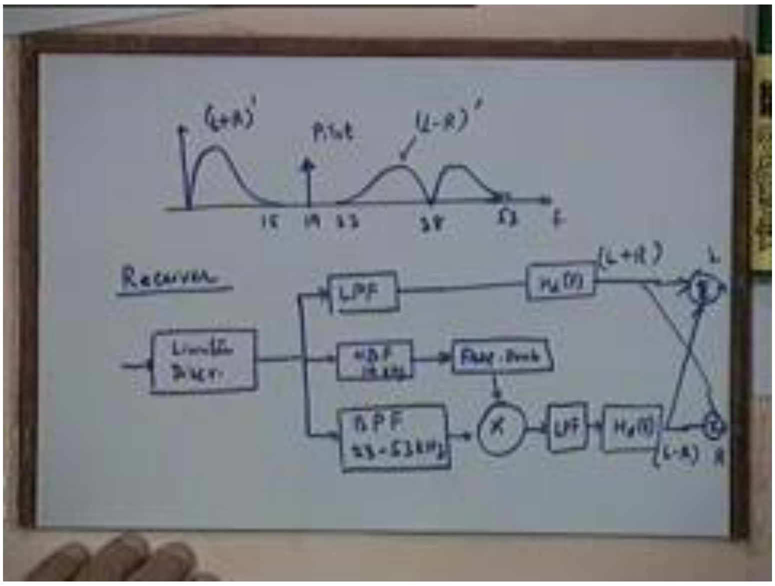

Let me, draw the spectrum, the composite signal have this kind of spectrum, let us say this is your L plus R signal goes up to I am only drawing one side of the frequency axis, they will be symmetry on the other side of the frequency axis. Then, the same signal L minus R is not the same, this is L plus R prime, L minus R prime will be DSB SC signal. So, the centre frequency here 38 kilohertz and the pilot carrier is somewhere here 19 kilohertz.

Student: ((Refer Time: 24:24))

So, that it is very easy to put out the pilot carrier and pass it through a phase locked loop to get a synchronous carrier. We had seen that the phase locked loop can be used to acquire a carrier input signal carrier. So, if I have a band pass filter with this extract this pilot carrier pass it through a phase locked loop, I will get a clean version of this 19 kilohertz signal which I can again double the frequency of and used for the demodulation of the L minus R prime signal, so this is L minus R prime would be a space modulation.

This becomes my composite signal which goes to the FM modulator. So, the base band signal which is going to the FM modulator as the band width of about 38 plus 15 about 53 kilohertz that 15 kilohertz in which we start it for 53 kilohertz.

((Student Refer Time: 25:25))

That is because the de emphasis filter will be used only in this channel at the receiver; we will not be using we will soon see plus the receiver that will become clear.

((Student Refer Time: 25:47))

Ask one question at a time first question was that why we use the pilot carrier of 19 kilohertz rather than 38 kilohertz that is your question I think this spectral diagram should make it clear. There is a clear separation here this is 38 minus 15 is, how much 23, so there is a very clean band 15 to 23 kilohertz which is my unused. So while I put a pilot carrier, where it is relatively easily filter this out, if I put it here filtering it out will become more complicated, because there is also the spectrum of signal present along with that.

So, it is much easier to filter it out at the receiver and call it off at the phase locked loop to acquire this pilot carrier, to have a local carrier which is synchronize which is in synchronize on this pilot carrier. It can certainly be done with 38 kilohertz also, but since we have designed this we designed it in such a manner that we get a clean region around 19 kilohertz, what was your question.

((Student Refer Time: 27:01))

Actually this will remember your bandwidth ultimately depends on delta f, so delta f will be given by this amplitude of this frequency components rather. Of course, BT the transmission bandwidth of the message signal also, the message signal bandwidth also contributes to the overall bandwidth, but it is a small friction. But, if your peak frequency deviation is 75 kilohertz, so it will become now something like 200 plus kilohertz, this is 100 plus, so it is almost become 250 kilohertz.

Typically in this consideration, in these broadcasting situations bandwidth is lot of primary concern bandwidth is not a bigger concern. Though slight time present bandwidth is wills that, this is not immediate concern, now let us look at the receiver and that will answer some of the questions regarding why the pre emphasis filter have been used. Here, we are having just before the FM modulator I think that was the question, so if you look at the receiver it will make.

So, what do we need to do at receiver, first of all we have a FM signal coming here, so here demodulate the FM signal? So, after you are demodulated this FM signal, you will get this composite signal with this spectrum and then we have to separate all the various components that are what we need to do. So, for demodulation we will use a limiter discriminator, here the combination of band pass limiter and FM discriminator that I have just called here discriminator here. Bands pass filter followed by FM discriminator this combination sometimes is briefly called limiter discriminator this combination.

So, when we are drawing the diagram in short instead of drawing, so many blocks, we just write the limiter discriminator, but we do not know, what kind of limiter, it is a band pass limiter, So, this produces your composite signal here, it will let us to separate them out, how can I get this part alone by putting a,

Student: ((Refer Time: 29:27))

Low pass filter, so I have a low pass filter in bandwidth is around 15 kilohertz, how can I get the pilot carrier for a band pass filter around 19 kilohertz center frequency at 19 frequency 19 kilohertz, so narrow band filter 19 kilohertz. And finally, this signal again will pass it through a band pass filter is a positive end of 23 to 53 center frequency are 38 kilohertz.

So, we have a third band pass, second band pass filter whose pass band is 23 to 53 kilohertz. For using these three filters you can separate all the three components, this we pass through a frequency doublers and this is the input to a synchronous demodulators. This is followed by a de emphasis filter and similarly as far this channel is concern I do not have to do anything else, I will get this L plus R back. So, I have simply write de emphasis filter here and now I got L plus R here and L minus R here and if I want to get L and R, I have to use once again add and subtract, so one will give you L and other will give you R.

For a monophonic receiver, you will have all this; we will have the FM discriminator followed by the low pass filter followed by the de emphasis filter.

((Student Refer Time: 31:47)) sure

You want to simplify the receiver design imagine trying a designer receiver which simultaneously tries to track two FM signals. It will be so much for difficult to design such a thing at the receiver and it is a tunable systems, you do not want to make your life very complicated, receiver designing the broadcasting environment you like to make your receiver design very simple that is the important.

((Student Refer Time: 32:21)

This filter, yes

((Student Refer Time: 32:29))

Every one of them, because this is part of your base band signal, it will see the there are some carries are all different for different signals. One transmitting station has composite signals of this kind, another transmitting signal also on the composite sig signals exactly of the same kind. But, the two composite signals are being transmitted using different FM carriers in totally different dispread; I mean there is absolutely no locking overlapping between the two transmissions is it not.

Because, the carrier frequency is in the FM modulator are totally different I hope you are appreciate this much. There is, it is like even AM broadcasting, we are transmitting voice and music they all occupy the same band. But, it meant multiplexing them in different frequencies by transmit by using different carrier frequencies, similarly here also we are using different carrier frequencies. So, in composite signals of every stereophonic FM system should be the same, there is no difference

((Student Refer Time: 33:31))

No, typically noise is when most common type of noise is we will see later, we will have more or less equal distributing of energy for all frequencies. We call it white noise

((Student Refer Time: 33:51))

No, noise is not proportional to the f i

Student: ((Refer Time: 33:56))

Besides there was if an interference signal as with of the frequency is f sub I the tuner frequency, then the response of the FM discriminator will be such that the higher frequencies will get more amplified. I think there is an interesting question here. Because the FM system is working on this and we have an FM discriminator, whether the de emphasis filter should be here and the pre emphasis filter should be just before the transmitter, it is what we have prepared I think that was the possibility. We cannot put the pre emphasis filter here and the de emphasis filter after the discriminator I think it will be wrong with that.

Student: ((Refer Time: 34:41))

Yes

Student: ((Refer Time: 34:43))

That is the easy thing that will be the requirement is that it is for using the compatibility requirement that you will be using in this diagram. Otherwise, ideally what you were saying is, I should put the pre emphasis filter here and the de emphasis filter here, for them it will not be compatible with the monophonic system.

Student: ((Refer Time: 35:16))

The point is as for the monophonic system is concerned, it will have only this chain.

Student: ((Refer Time: 35:26))

There is a difference; the monophonic limiter discriminator would have a low pass filter whose dimension is 15 kilohertz. This will be followed by a low pass filter corresponding to the massage bandwidth and if you what we are saying is have both, so that was you are saying.

Student: ((Refer Time: 36:07))

No

Student: ((Refer Time: 36:13))

What we are following system does not assume that there is a 15 kilohertz bandwidth it is only 15 kilohertz bandwidth. So, if your de emphasis filter is suppose de emphasis only these higher frequencies on this relation, there is incompatibility of some kind that you can see

Student: ((Refer Time: 36:31))

I mean in that case, there is change in design required in the monophonic system this is not possible when you are using compatible system. A compatible system must permit the proper operation of the existing system another redesigned system. Anyway with some of the points you have raised are very interesting and one need to look at those carefully if you are appreciate all those points.

In the rest of your today's time and in continuing in the next class, we will now take up another application another application is TV transmission. So, we will we are now looking at how these various modulations schemes which we have discussed are used in various kinds of communication systems. Particularly the most important once like the broadcasting applications for FM broadcasting or TV broadcasting.

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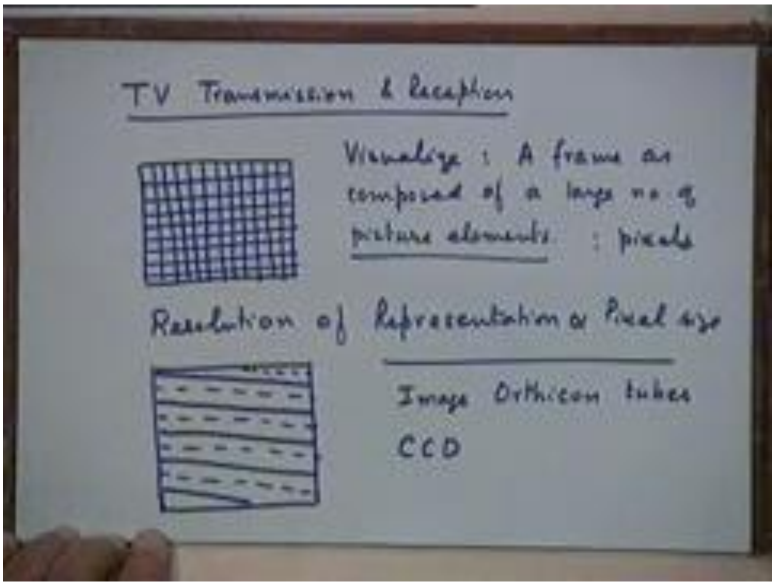

So, now let us spend sometime today on TV broadcasting, as we know as far as television is concerned it has to do with transmission of pictures. So, let us try to dwell up some basic understanding about the nature of these signals which we like to transmit and then see what else we need to do. So, for the purpose of discussion, the picture is like a let us say some frame that is given to us which contains information about the intensity levels or byteness levels of the various elements of the picture.

So, we can think of a picture as if it has large number of small little boxes, if you called pixels of which it is composed. For the purpose are just we having just thinking of how to visualize a picture from the point of view of a communication engineer, because we need to understand its features. So, let us assume as if this signal this frame of picture that you have is composed of a grid like that a fine grid.

In the sense that if I want to specify the picture electrically, so ultimately I have to have an electrical representation of this picture. An electrical representation of this picture will have to be based on some features of the picture. So, what we are saying is, we assume that the picture has a sequence of byteness levels distributed along this small little this fine grid.

So, you have some intensity level here some byteness level here, another one here, another one here and so on, so forth. So, if I can capture the sequence of byteness levels both along the horizontal as well as the vertical directions and represents this sequence of byteness levels in the form of electrical voltages or currents. And that will be an appropriate representation for the picture, you appreciate that.

So, that is one way of visualizing a picture, so you visualize as if a frame is composed of visualize, the frame as composed of large number of picture elements of this kind and these picture elements we called pixels. This number should be large, if we want to represent this picture by electrical signal in the sequence of byteness levels, the larger the number that we select for this representation the better your picture quality will be.

So, there is the resolution of this picture, that you represent resolution of your representation is the direct function of the pixels size depends on pixels size actually it is proportional to the inverse of the pixel size. The smaller your pixel size the better the resolution, so I will like the picture better, so if we have to reconstruct base band representation for the purpose of your eye we must have a very fine grid.

And ultimately, we must convert this picture elements this byteness levels or grey levels or whatever you like to call them by the suitable set of electrical signals. If you wanted to do a color transmission, we must not only capture the byteness level, but also must capture the RBG components of these levels, so that you can transmit multiple signals carrying all these information. So, let us have a moments discuss only the black and white situation.

Now, you can have when you are working on a computer it is nice to work like with the grid like this. But, in a conventional analog picking up a picture by using an analog camera, you do not exactly do things in this manner. How do you convert a picture into a single electrical signal you have to scan the picture and the scanning is usually done something like this.

You have this frame here, so you move from left to right and pickup the intensities or byteness levels of the various portions of the pictures along this line. As you can see, I do not move in a perfectly horizontal direction, we have typical analog system, I am while I am moving from left to right, I also slightly moving downwards. So, there get to the next line, by moving again to the left very quickly and keep on moving from left to right again fly back here keep on moving left to again, so that is the typical scanning process.

Typically, we also use that is called interlaced scanning that reduces the flicker effect significantly. So, that if the first frame starts like that, the next frame starts here and goes like this, we consider or you interlace the lines, we interlace successive planes, the lines are interlaced in this manner. And in the larger the number of lines that you use to pick up the byteness levels the better your resolution will be, so how many lines you use and how do you exact scanning process will depends on the various first let us say scanning process.

The scanning process will used in some kind of a TV camera, I am not going to go into discussion of various kinds of TV camera that you can have there is a variety of TV cameras that you can have. So, for example, in the good old days, we had the image orthicon tubes is TV cameras is used an optical system to pick up the byteness level and then this light was allowed to fall on a cathode and based on the amount of light falling. Certain number of electrons will get generated, which was then picked up by a circuit and convert into an electric signal that was a basic principle.

Today, you have more sophisticated charge coupled device on the cameras CCD cameras, again the description of this is outside the scope of this course, I will just mention these things for you. So, to any case, what are these cameras, what convert these scanned lines into the sequence of electrical signals, basically electrical signals as you are scanning you are generating a signal as a function of time is not it some voltage or current as a function of time continued in the next line.

So, basically this entire spatial information is transmitted over a period of time is not transmitted in simply, as you consider. I am not picking up the picture and transmitting the entire picture in space I am pick, so letting an electrical signal as a function of time. So, it will take a finite amount of time to scan this whole picture and that is the amount of time in which one frame will be transmitted.

And there will be a certain rate at which you have to transmit frames, so that your eye does not see as if the discs connected frames, but as a continuous movement as a continuous picture.

Student: ((Refer Time: 47:02))

No they do not depending on the size of the screen typically; it will depend on the resolution which we want

Student: ((Refer Time: 47:13)).

I have already answered that question, but le let me repeat that again. This is the process of scanning automatically possible, so what you are doing is, while we are moving to you have to transmit scan the whole picture.

Either you pickup pixel by pixel somehow the intensity level, but in a analog system it is convenient to draw the moving like this and like this you cannot exactly move like that. So, you move slightly to move to the little bit down while you are moving left and then we quickly move to the left and keep on moving this and then at the end of this you move back here.

So basically, you remember the scanning process will require some kind of a direction of an electro of an optical beam this is an optical beam to traverse the whole thing. For traversing its convenient like this, wherein in fact, that is the only way which we can think of, so that you can do both vertical scanning as well as horizontal scanning.

Student: ((Refer Time: 48:24))

This is I am showing it will go like this.

Student: ((Refer Time: 48:32))

This line.

Student: ((Refer Time: 48:35))

Here

Student: ((Refer Time: 48:39))

We assuming that this fly back time is very small in this time.

Student: ((Refer Time: 48:45))

It is let us look at that. These are these are question which are anyway coming to.

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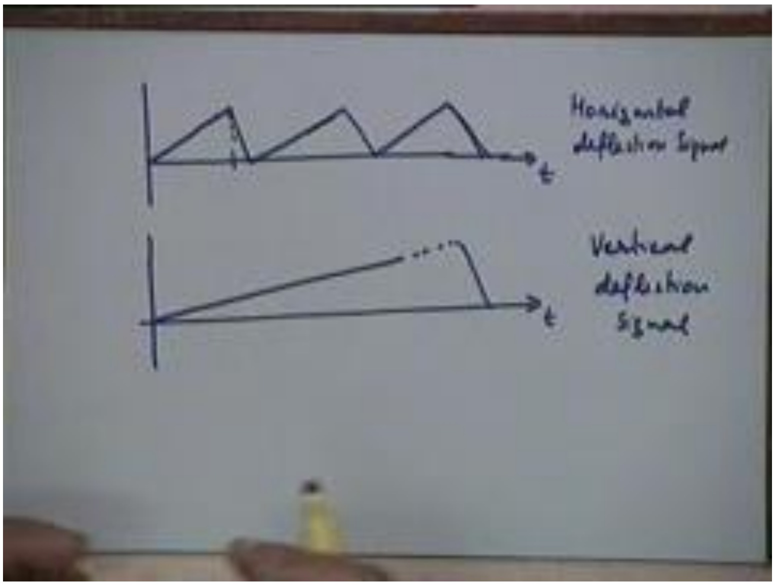

So, the scanning is actually done using the system which will make the light beam which is picking up the intensity levels for the camera system look at this portion of the picture in this manner. The camera system has to allow its optical system to pickup first this portion of the picture and this portion of the picture and so on and so forth, so it has to be controlled, it is controlled through an appropriate saw tooth waveform like this. So, on the optical beam moves like this from an optical beam moves to make the optical beam move like this the voltage controlling a move movement will move like this.

And then, to make it turn immediately to the left, you have a very short time in which you do for. I emphasis that time, but actually this time and which it just jumps to the left has to be very small and this will this process will keep on repeating. So, these are you can call horizontal deflection signals which is internal to the camera of course, this process is internal to the camera.

The camera having horizontal deflection system which allows this movements of the lines in this particular way and it has also vertical deflection system in vertical deflection system has to linear function of time, what are the vertical deflection system have to do, it has to gradually allow the motion to go downwards. So, vertical deflection has to gradually, so has the horizontal traversing is going on there is a vertical that the electro magnet system in that you have in oscilloscope something like that.

There is a horizontal deflection system and there is a vertical deflection system, so it will have to allow to deflect, it gradually downwards. So, that is happening at a much slower rate in a by the time the horizontal scanning is over we are only going down a little bit vertically. So, that is going to happen at a much slower rate than the horizontal deflection rate. So, you have a much slower saw tooth waveform going like that and then again at the end of a frame, it will move like that it will go to the top of the frame, so that is the vertical deflection signal. So, to remember these are all internal to the camera, so this is how the scanning process will actually occur.

Student: ((Refer Time: 51:54))

I am coming to that now that is a first is the scanning process. Now, the next question is when we are scanning like this, how do, we relate this scanning to this visualization that we have. Suppose, we have a certain number of lines how many lines you will use to scan a frame will depend on different standards.

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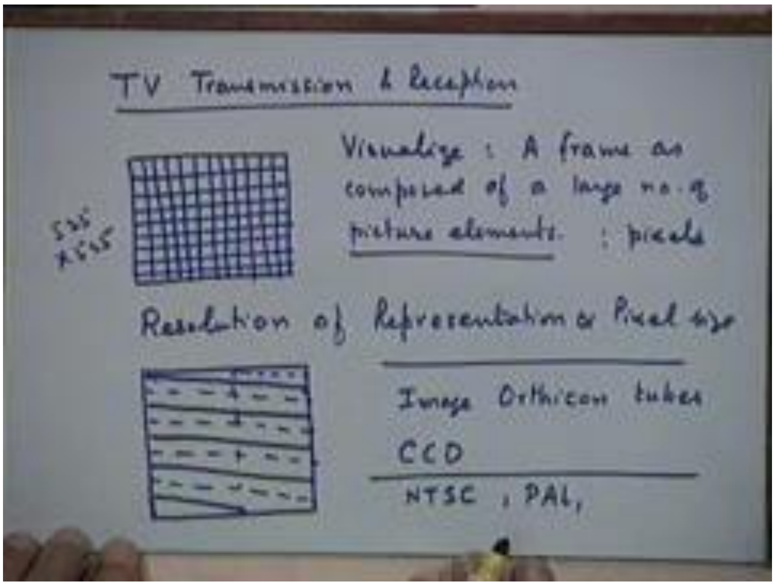

For example as you must have heard of there is a NTSC standard, there is a PAL standard, there are one or two more standards. So, each of the standards specifies there is a slightly different number of lines per frame, for example in the NTSC standard, you scan using 525 lines. So, the entire picture is represent in terms of a 525 lines what does it mean, it essentially means that you are dividing the entire vertical region into 525 portions.

So, which essentially means that one by 525th of the total frame vertical size is good enough from the eye point from the from the perception point of the view of the eye. Now, as long as far as the horizontal scanning is concerned, actually there is no quantization of that kind, we are picking all the elements along the horizontal line. But, from the point of view of trying to calculate exactly, how much is the resolution horizontally or how much the resolution vertically.

We assume that the vertical and the horizontal resolutions are the same, because our eye does not have spatial treatment leave that as the assumption here for discriminating vertically or horizontally. So basically, so when you say 525 lines it is kind of implies as a fewer representing your picture by a 525 into 25 grid and this is an implicit assumption or rather than this is an entire thing based on our scanning process, that it is implies that your this pixel gird has this kind of a composition. We will start from this point next time.

Thank you very much.