Communication Engineering
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Lecture - 7
Analog Modulation of Carriers

So, last time if you recollect, we were talking about distortions, as a signal propagates through some channel, we were these are discussion in the connection in connection with base band transmission. That is, a signal transmits transmitted through a channel and we found that for distortion less transmission, the signal at best should be subjected to some attenuation and some propagation delay. If that is the case, the received signal is perfectly acceptable to us, as the replica of the transmitted signal and we are quite happy.

If however, the amplitude characteristics of the channel are not constant over the frequency band of the signal or the phase characteristics are not, linear function of frequency over the bandwidth of the signal, where signal will undergo either amplitude distortion or phase distortion. Both these kinds of distortions are known by the name of linear distortion, as against this kind of linear distortion, we can also have a kind of non-linear distortion, which will arise, if there is nonlinearity present anywhere in the communication system.

It could be at a transmitter, it could be in the channel, it could be in the amplifier, of course, the most common source of non-linearity is, the transmitter, power amplifier and receiver mixers, mixers at the receivers, which we will discuss later. So, now we shift from base band transmission to, let us say band pass transmission, where the message signal is not transmitted directly, but the information contained in the message is embedded on to a carrier.

And this carrier is what propagates through an appropriate channel and we have already discussed why there is a need for such a term. If you restrict yourself to, only base band transmission, there is only so much you can do, in as far as communication electrical communication is concerned. We cannot transmit many signals over the same pair of wires, for example, in telephone communication as you know, a separate pair of wires is required to carry out transmission from your home, to the exchange.

You can transmit only one signal, if you do not modulate your signal, if you do not frequency translates your signal. We require separate pair of wires for every set signal transmission, whereas if you over to do modulation, you could frequency translate various signals by different amounts and have non overlapping spectra and transmit all of them together, that is one of the advantages of modulation. Another advantage that we discussed was, if you want to propagate the signals through a medium like space free space or atmosphere, you need to generate radio waves we need to radiate radio waves.

Radiation of radio waves can be done efficiently, only if the size of antenna is comparable to the wavelength of the signal. For a 4 kilo hertz bandwidth voice signal, the wavelength will turn out to be a few order of something like 750, 000 meters, which is too large an antenna size to try to use in practice. So, there are all kinds of advantages, these are just two that I mentioned here again, of carrying out modulation or using modulation, as a means to translate the frequency spectrum of your signal before you actually transmit.

And that is the subject we will start with now, there is this analog modulation of carriers, so as we have seen earlier, there are several advantages of modulation, I will just repeat them for the sake of completeness.

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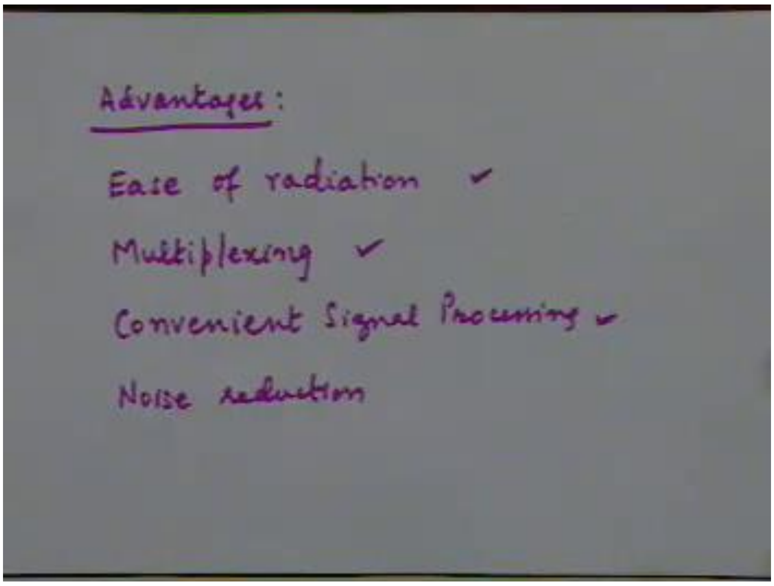

Advantages:

Ease of radiation ✓

Multiplexing ✓

Convenient Signal Processing ✓

Noise reduction

These are things, that we have discussed earlier, even today again, so I will just mention them, ease of radiation is one, multiplexing is another, convenient signal processing is another and noise reduction is one more reason, why we may want to do modulation. So, these are some of the reasons, why we would go for modulation, we have discussed this. Today again we discuss this today, this I will just briefly mention once again for your benefit.

It will be more convenient to carry out signal processing in a particular frequency band as against some other frequency, for a particular application. Suppose, you have a wide band signal being transmitted, then it is convenient to embed this on to a very high frequency carrier. And then, it turns out that we may have technology, you may have technology for carrying out signal processing at the receiver and the transmitter, around that frequency with the certain bandwidth, then attain the frequency.

So, therefore there is reason, to use the particular frequency, because technology to handle the frequency is available, be it high power frequencies or in they be in HF range or VHF range or optical frequencies, whatever they may be. So, depending on the kind of technologies that are available, you may like to use a particular frequency band, for a particular carrier frequency for your signal processing requirements. Similarly, certain frequency bands may be more noise free than certain all frequency bands.

As we have seen, the noise that is present in the channel, is a frequency dependent phenomena, it is not the same at all frequencies, also there are, the channel has different characteristics at different frequencies. For example, at certain frequencies, microwave radiation gets absorbed by the water vapor present in the channel, in the atmosphere. So you like to avoid such frequencies. So, depending on where you want to work, what you like to choose appropriate frequencies. So, noise reduction is another reason, why you may like to use one particular carrier frequency rather some other. The information bearing signal is typically a base band signal, in all this applications.

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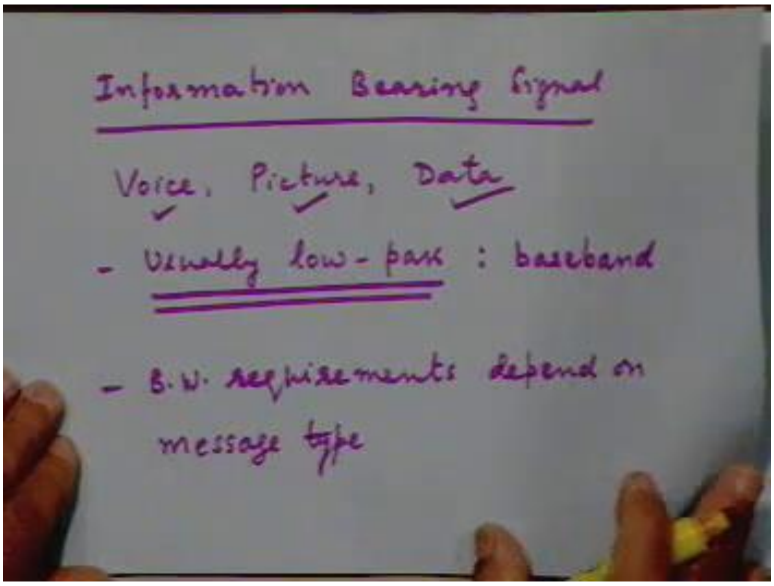

Information Bearing Signal

Voice, Picture, Data

- Usually low-pass : baseband
- B.W. requirements depend on message type

And we have mentioned this before, this could be typically voice, this could be picture, this could be data, we have three most commonly forms in which information is available to us and we need to transmit. So, they are usually low pass in nature, so these are usually low pass, low pass term, it is not used only to specify filters, which is the most natural even when you say low pass, it normally refers to something is pass, being pass to something.

And therefore, it has a convention of need of filter, but it has come to be accepted to use terms like low pass, even for signals, not necessarily only for systems. So, if you say a signal is low pass, assumptionally we are saying that it is spectrum center around 0. So, of course, there is another alternative name for it, we also call such signals as base band signals and as we just discussed, because of this varied nature, we require and this signals are not suitable for direct transmission.

It is preferable that they modulate this information is embedded on to a carrier and then transmitted, that we just discussed. But remember again, that the bandwidths of each of this kind of signals is different, this is a small bandwidth signal comparatively, this is a much larger bandwidth signal and this is a variable, depends on the rate at which you are transmitting them, it could be low bandwidth, it could be high bandwidth. For example, data communication that we carry out over telephone lines, do you data communication over telephone lines?

Student: ((Refer Time: 10:31))

That is not the only thing, you connect to your computers through a modem and to connect to other computers and the network that we are using there is a telephone network, which was not designed for telephone data communication. It was designed for voice communication, but yet we have found means of using the same small bandwidth, to transmit data at fairly good rates. For example, today you have models which go up to 56 kilo bits per second.

The bandwidth available is still the same, 4 kilo hertz, the bandwidth of 4 kilo hertz were able to transmit 56 kilo bits per second and that is possible, because of proper use of proper kinds of modulation in coding schemes, so that it is possible to use this bandwidth efficiently. So, the nature of the data will be depending, the bandwidth required by the data will depend on the rate at which you need to transmit it. If you have a high data rate application, you may require tons or megahertz of bandwidth.

You have a low data bit data rate requirement; you can mange with the few carrier hertz, like we do in telephone modems. So, bandwidth requirements depend on message type, so these are things which we are discussed before, but it is pertaining to review them once again, so that, things are seen in the proper context. Now, as we go along, we will discuss a number of different kinds of modulations, well most specifically there will be at least three different basic kinds of modulation that we will discuss.

Mainly, the amplitude modulation, the frequency modulation and phase modulation of carriers of which, the first kind, there is a large variations large variation of the first kind then there will be amplitude modulation, all of which are studied under the general title of linear modulations.

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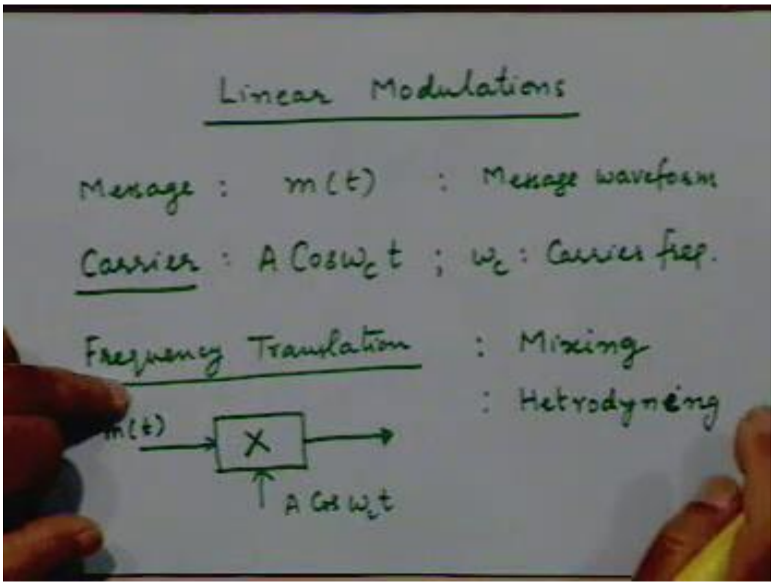

Linear Modulations

Message : $m(t)$: Message waveform

Carrier : $A \cos\omega_c t$; ω_c : Carrier freq.

Frequency Translation : Mixing

: Hetrodyning

So, we start our discussion, with what is typically meant by the name of linear modulation and now, we will develop a favor to study various kinds of linear modulations. To do that, let us introduce some very simple basic notation that we will use, typically in our discussion, we will denote the message by a waveform, denoted by m of t, so typically when I write m of t; it is a signal which represents the message waveform.

So, this is a message waveform, I assumes here we use the word message, because message has different connotations, so we will call it message waveform, some signal as a function of time, which contains the information of interest which you want to transmit. The carrier as we have seen earlier, we have discussed earlier is typically a suitably high frequency sinusoid. The exact frequency will depends on the application.

If it is a microwave link that you are working it, you are propagating your signal ON; you will choose a typical frequency in the VHF or higher band. If it is the ionospheric propagation that you want to deal with, you will use a frequency less than 13 megahertz, something like HF band. If you are carrying out broad cast in the using the ground wave propagation, you will use it in the medium wave frequency band. So, depending on what my application is, you will choose your carrier frequency differently.

But in each case, as far as this theory is concerned, we will denote our carrier by simply, cosine omega ct or some A sin omega ct, well omega c is the carrier frequency in radians per second. Now, as we have learnt from our discussion of review of signals and systems, there is a very basic technique for frequency translation and that is one of the main objectives of modulation.

We want to carry out a frequency translation of the message, which is a base band or low pass signal, to around some other frequency omega ct, to convert it to the band pass signal and the basic frequency translation theorem that we have learnt about. If we also known by the name of modulation theorem and now, you can appreciate the reason for that name is, what is the basic frequency translation technique that we know of?

Student: ((Refer Time: 15:54))

Just multiply these two signals in the time domain, so this operation therefore, is simply multiplication operation which takes the message signal, m of t and multiplies with the carrier A cosine omega ct, this is the most basic and fundamental operation in analog modulation and particularly linear modulation. So, this operation is variously known by the names of frequency translation, the other names depending on the context in which we are using this, this operation sometimes is also called mixing.

Because you are mixing two signals, of course, mixing is used in a slightly different context, but merely less the basic operation involved is the same, multiplication of two appropriate signals and another name is heterodyne. So, if you come across any of these name in some context, this is for the, basically we are referring to this operation, multiplication operation.

So, frequency translation could be carried out using a mixing operation or a heterodyning operation, which basically means multiplication, of the two signals. Actually mixing is slightly more than this case, that we will discuss that, as the time comes.

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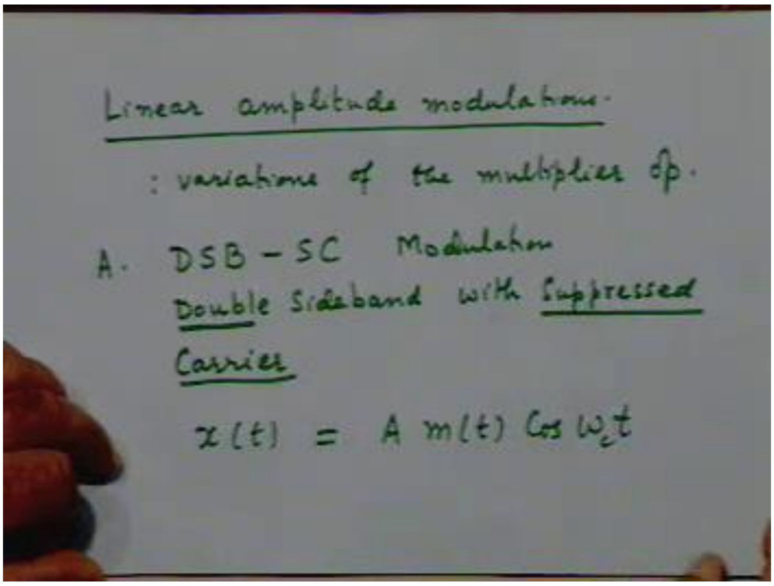

Linear amplitude modulations.

: variations of the multiplier o/p.

A. DSB - SC Modulation

Double Sideband with Suppressed Carrier

$x(t) = A\, m(t) \cos \omega_c t$

Now, this basic operation forms the basis of all linear modulations, what we call linear amplitude modulations. So, all this linear amplitude variations are, basically variations of the mixing the multiplication or the multiplier operation that we have discussed earlier, they are variations of this. Let us discuss these variations now, the simplest is just this process that we have discussed in terms of, our starting point could be, just this varied modulation that we have just discussed, mainly multiply mt with cosine omega ct.

We know that, this will lead to frequency translation, as we shown again it review, this kind of modulation, this is a kind of modulation is called, as we will see the name for that, reason for that, DSBSC modulation, standing for double side band with suppressed carrier. So, this is DSBSC modulation, so in modulation in which we generate two side bands, that is why it is double side band, we have to understand what the concept of side band is, in a few minutes we will do that and the carrier is suppressed.

We try to understand the meaning of each of these terms as it is coming up, the basic signal is the one that we just discussed. The modulated signal x of t is A mt cosine omega ct plus try to see, why this signal we call by this name, so when I refer to DSB SC modulation, we referring to this signal. The message mt multiplies the carrier A sin omega ct, before we go into the reason for, calling it by this name, let us once again review, what this signal look like, physically.

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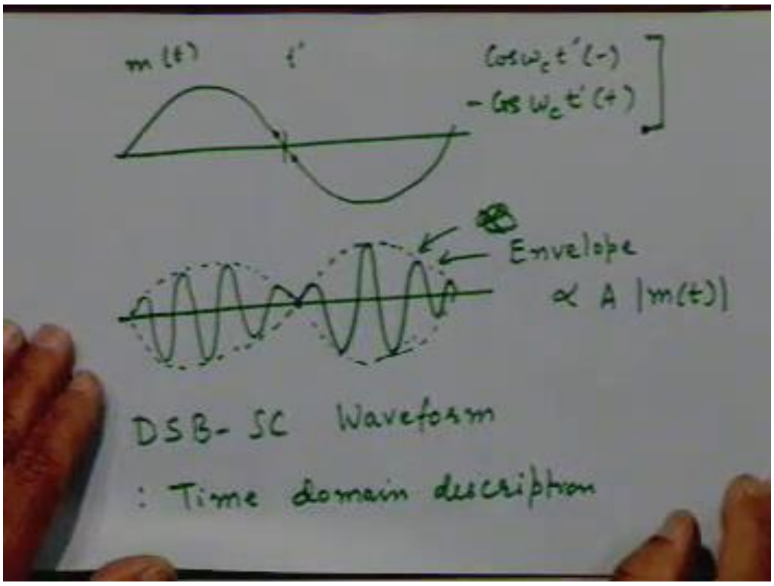

Let us say this is your, this for a sake of discussion, a typical message waveforms will not be sinusoids, typical message waveform will depend on, what signal we are actually interested in transmitting. For example, a voice signal, I do not know whether you had the occasion to look at the waveform of a voice signal on oscilloscope or on a computer generated computer. It does not look like a sinusoid at all; it looks very different from that.

But for sake of our simple discussion here, let us assume that our message signal is a sinusoid of low frequency, since it is to be a low pass signal, we will represent it by a low frequencies sine wave. So, let say this represents your mt and let us try to, now depict the modulated signal which is mt into cosine omega ct, we have discussed this earlier, so let us just quickly review this. The way to look carrier is, the following, cosine omega ct is a highly is a high frequency carrier.

That means the duration of one cycle of the cosine wave is much smaller than the duration of one cycle of the message signal, in this particular case, because this is a sine wave also. So, we could assume practically, that over one cycle of cosine wave of the carrier, the message signal mt practically remains constant, because that variation happens too fast for it to, vary significantly. So, if that remains constant, what do you see at the time is mt, you see a sine wave or a cosine wave of an amplitude A mt.

Because mt is merely constant over the whole cycle, so effectively the amplitude that, you will say the carrier basically a carrier, when an amplitude of A times mt, rather than A, that is what we will see. So, essentially therefore it is clear, that as this message changes, you will see carrier of different amplitudes, the carrier will have the largest amplitude here and a smallest amplitude here, the smallest amplitude here, zero amplitude at the zero presence and so and so here.

So, that is something that we have already discussed, so it will look something like that, these dotted line represents the, what we call them, envelope of the modulated waveform, if you already discussed, because this is the trace of the peaks of each cycle of the carrier. So, it will look like this; let us see what will happen to the carrier at this point, I just want to be a little more particular.

As we go from one half cycle of the message waveform to the next half cycle of the message waveform or as you cross the 0 in the message waveform, how does the carrier behave here. This see the carrier has been multiplied by some positive point at the just before the 0 crossing, a carrier is now going to be multiplied by…

Student: ((Refer Time: 24:06))

A magnitude point at the, just after the 0 crossing, so can you say something as to what will happen at the point at the 0 crossing?

Student: ((Refer Time: 24:16))

The phase of the carrier will suddenly go through a phase shift of 180 degrees, is it clear? So the carrier will not continuously smoothly keep on going like this. There will be a certain phase variation, by a about a 180 degrees, so you will start once again like this and so further of course, there are my picture is not perfect, the carrier cycle that have of uniform duration. But, they should be, because the carrier frequency remains at remains the same, throughout.

So, the important thing is, that the envelope is this, what is this equal to, the envelope in this case is proportional to, so suppose I call this e of t to denote, I will call this envelope, this dotted waveform which essentially gives me the amplitude waveform amplitude of the carrier waveform at different types and we had already seen that, this is also from this figure which is proportional to?

Student: ((Refer Time: 25:34))

We are forgetting something, modulus of mt, the envelope is this, the envelope is not this mt, this is mt, and envelope by definition is this. Envelope by definition is a trace of the peaks of the carrier, carrier waveform, so that is how we define the envelope obviously, as you can see, in this cycle the envelope is this, which is the modulus of this. Of course, the actual waveform is this.

Student: ((Refer Time: 26:12))

Very simple, the question is who wants to know once again, how there is a 180 degree phase shift in the carrier at the 0 crossing of the message waveform. At the 0 crossing of a message waveform, before the 0 crossing, the message has positive, so a positive number was multiplying cosine omega ct at that time. So, immediately after the message after this 0 crossing, a negative value is going to multiply mtor cosine omega ct and therefore, suppose you have some something cosine omega ct.

Suppose, this instant is called t prime, so you had some value cosine omega ct prime, minus let us say, this omega ct minus, just before this and after this what you have?

Student: ((Refer Time: 27:13))

Minus cosine omega ct prime plus, so you are going from t prime minus to t prime plus, the sin of the carrier changes and that is all we are saying and therefore, this is ((Refer Time: 27:32)).

Student: ((Refer Time: 27:33) If we assume that this frequency going to be or it will be the multiple of omega c t, what are the another output.

No, there is no such assumption required, this is something that will happen, I mean for the kind of the waveform I might have use that, but there is no such requirement, this will always happen, at a 0 crossing. There are not you say multiple of sub multiple of omega ct, this will always happen, because this property will always hold. So this is not a requirement, so when you will look at a DSB SC waveform. Let us say an oscilloscope.

I believe you will go through a communication lab some time, you must look at this feature carefully, that indeed at the points of 0 crossing, the carrier goes through a 180 degree phase shift. The carrier looks like, as if it is gone through a 180 degree phase shift, at the point of 0 crossings of the message waveform. So that is the typical, a picture of the DSB SC waveform in the time domain. So, this is the DSB SC waveform, so this is the time domain description of DSB SC.

We will soon see the frequency domain description, which is a reason for the name that we have here, so this is the time domain description. The important thing that we have learnt here really true, the envelope of DSB SC waveform may be proportional to A times the message waveform m modulus of message waveform m t and the second what we have learnt is, that at the points of 0 crossing of the message waveform, the carrier will go through a 180 degree phase shift.

So, these are the two basic characteristic of a DSB SC waveform, now let us look at the same waveform in the frequency domain, by looking at the spectrum of the DSB SC signal, which is fairly straight forward exercise.

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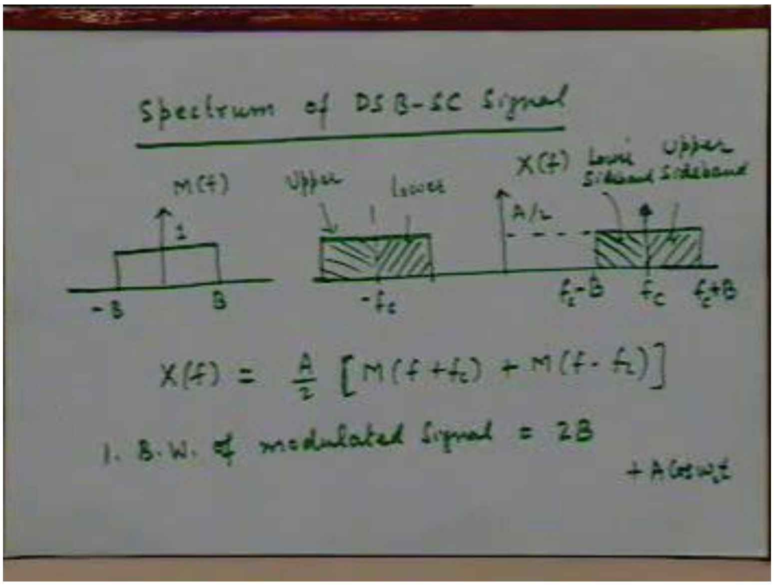

Spectrum of DSB-SC Signal

$$X(f) = \frac{A}{2}\left[M(f+f_c) + M(f-f_c)\right]$$

1. B.W. of modulated Signal = 2B

$+ A\cos\omega_c t$

To discuss this, let us assume, that your message has some spectrum and for the sake of this discussion, I will typically assume the spectrum to be real valued. So, that I do not have to carry out the two parts, one for the amplitude and the other for the phase, but it is implied that, if required one can do that, whatever we do for the amplitude plots is also valid for phase plots. For convenience, we will take the amplitude, the spectrum to be real itself.

So, that they get cluster of amplitude and phase separately, m of f directly complete completely describes the spectrum. So, let us say m of f is a low pass signal, again when I draw a spectrum like this, it is not to depict that the real signals will have such spectra. They may have any arbitrary shape; of course, it will be, if it is a real it will be even symmetric etcetera. Well, otherwise you can have any arbitrary shape, the important parameter here is the bandwidth of the base band signal, and we can assume it to be b.

It could be this shape, it could be any arbitrary shape, so what is the nature of x of f, as we know from basic modulation theorem, the spectrum of A mt cosine omega ct would be, A by 2 into tell me, m of f plus fc plus m of f minus fc. I do not want to review this, we have discussed it earlier and therefore, the spectrum will look like this, the modulated signal x t would have the spectrum which is centered around one component fc. So, if this is 1, this would be A by 2, peak value.

And the same thing will happen around minus fc and this point will be fc plus b, this point will be fc minus b and similarly on this side. Now, some where interesting, this is a very simple thing all of you know this, there is nothing new about this, but we will look at the spectrum and try to appreciate a few things from the spectrum. First thing that we notice is, let us compare the bandwidth of the original message signal, the base band signal and the bandwidth of the modulated signal.

Are they same, are they different, what could you say, are they same?

Student: ((Refer Time: 33:06))

Anyone confident answer?

Student: It will be twice the bandwidth of the message signal

It will be twice the bandwidth of the message signal, what is your bandwidth here?

Student: B

B, 2B if you include the negative frequency axis, but remember negative frequencies are not sometimes real, it is a mathematical concept, the real frequencies are basically the positive, I mean in this, you should not say positive or negatives. Really speaking we are talking of a spectrum, of let us say B hertz here, the negative frequency is an abstract concern, it is an abstraction, but in this case as you can see on positive frequency axis itself, we have an occupancy of 2 B hertz.

Because, this entire spectrum gets translated to around fc hence, width is 2 B fine, so the first thing that we note is; bandwidth of the modulated signal is 2 B. So, actually your modulated signal has a larger bandwidth than a message signal, is that a nice thing or a bad thing?

Student: Nice thing.

From the bandwidth conservation point of view, it is not very nice, now what is it mean, it means that perhaps we have transmitting more information than in it is necessary to transmit and we can see that happening. Can you see that how it is carrying more information than it is necessary to transmit?

Student: ((Refer Time: 34:42))

Look at this basic spectrum in M of f itself, as we know for any real signal, M of f will have some symmetry properties, what are the symmetry properties, it is amplitude spectrum is even, it is phase spectrum is odd. So, if I know the spectrum, on one side of the frequency axis I also know the spectrum at the other side of the frequency axis. What I am trying to do in this modulated signal, is transmit both the sides, the positive side as well as the negative frequency side.

So, that is why occupies a larger bandwidth, if I want to somehow transmit only this, I could as well derive the same information by keeping in mind, that actual spectrum is symmetric would be symmetric around fc, amplitude will be even symmetric and phase will be odd symmetric around fc, for a real modulated signal. So, if I somehow could use that, I could have conserve bandwidth by reducing it to B hertz only.

Because we will discuss that later, this is one of the modulation technique that is used, hence called single sideband modulation and that is why, this is called a double side band modulation. You refer to this portion of the spectrum, which lies above fc as the upper side band, so depict as if the modulated signal contains two sidebands, side refers to the carrier frequency, one above the side above the carrier frequency one below the carrier frequency and this portion is called the lower side band.

So, if we look at the corresponding negative plot, this will correspond to which portion upper or lower?

Student: ((Refer Time: 36:42))

Lower, because it has to be symmetric, so this will be lower and this would be upper.

Student: Excuse me sir?

Yes please

Student: When the LP signal, which is having take one right part of the signal ((Refer Time: 37:05))

The trouble is, for a real signal I cannot get rid of this, is it not, I cannot get rid of this, and the real signal implicitly has a negative frequency component it because it is just a mathematical notion. I cannot get rid of it, the only way I can get rid of it is, by converting it to a complex signal, is it not.

Student: So that effectively my right part is having the whole amount of information

True, true.

Student: So, when I am putting it in this part, I having a bandwidth of 2 B, but the bandwidth of 2 B is having only that information, which is originally present in the right part, so I am not getting any information additional information as such..

No, what we are saying is, presently we not getting any additional information, we are transmitting much more information, that is necessary to transmit, that is the point. If you do this, if I want to transmit, let us say only the upper side band, that equivalent to transmitting LF, because we transmit only the lower side band that is also equivalent transmitting the LF. So, as far as information content wise goes, I could not transmit only one of this side band somehow, by removing the other.

For example, I could have removed the lower side band and the spectrum would then look like this.

Student: But then it would not have the full information, it will.

It will have the full information because, I know there is a symmetry around fc and I could have exploited the symmetry somehow at the receiver.

Student: So that.

If I knew, a way of exploiting that symmetry I could do it.

Student: Since we have.

We will discuss this later, because that is not today's discussion, that we will discuss when we discuss single sideband modulation.

Student: Sir, once a minute.

Yes, please.

Student: Are the information which we have given symmetrical sir, when you call it real?

We know that the properties of a real signal, what are the properties of the real signal?

Student: ((Refer Time: 38:48))

The spectrum has to be symmetric around f, amplitude symmetric; it is even symmetric for amplitude spectrum and odd symmetric for phase spectrum.

Student: Sir, one thing.

That symmetry will now get translated to fc, is it not, when you do a frequency translation, these symmetry properties would translate around fc.

Student: Sir this thing only for real signal?

And minus fc, of course only for real signals, because in real life we transmit only real signals, complex signals will generate.

Student :((Refer Time: 39:21))

If we need to generate them, as a signal processing tool, we do not start with complex signals, actual waveforms that we will transmit, will be some voltage of function of time or some current as function of time, which are real signals, true. Can we proceed further then?

Student: ((Refer Time: 39:41))

So, the first we have learnt therefore, about this waveform is that it has an upper side band and lower side band, each of which carries the complete information about the message by itself. However, in this kind of signals, we transmit both the side bands and therefore, we call it double side band, it is a double side band message signal modulated signal. Now, the second part of the name, suppressed carrier, let us look at that, in this spectrum there is a carrier by itself, and show anywhere, other than the fact.

That the spectrum is shifted around the carrier, around the carrier frequency, shifted it to the around the carrier frequency, shifted around the carrier frequency there is no specific carrier component present as such, by that I mean, there is no impulsive component like this, add the carrier frequency. The carrier as a signal as a Sep, there is no component like this, a cosine omega ct B transmitted, which is a nice thing, that does not convey any information.

So, there is no impulse component at fc, if there is no impulse component at fc, because of that reason we call it suppressed carrier. That is, it does not have a carrier component located at fc; of course the signal spectrum if it is nonzero at 0, will imply that a non 0 values of the spectrum here, that is true. But, you know this is spectral density, it does not mean that there is a carrier component, for it for a carrier component to be present; you must have an impulse function there, is it not.

Because density, if you have some value of a density, it does not mean that the, suppose I ask you what is the spectrum, what is the energy present in the signal at any specific frequency, it is 0, because this is an energy density function, this is an amplitude density function. So, the actual amplitude will be proportional to the area under that curve, at that point, area of a single point, area occupied by the single point will be 0, unless there is an impulse present there.

So, since the since there is no impulse anywhere here and specifically it is not there at the carrier, we call it double side band with suppress carrier. So, the other properties that we have just therefore learned are.

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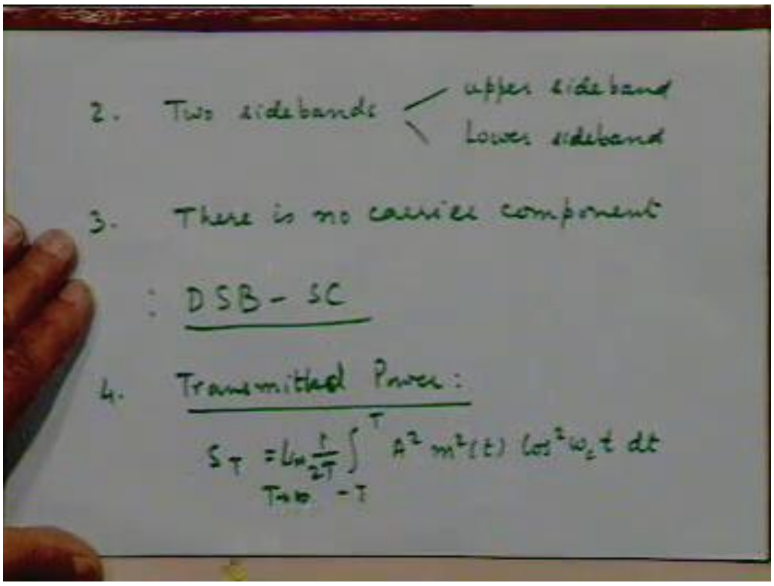

2. Two sidebands < upper sideband / Lower sideband

3. There is no carrier component

∴ DSB - SC

4. Transmitted Power:

$$S_T = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} A^2 m^2(t) \cos^2 \omega_c t \, dt$$

That the signal has waveform has two side bands, an upper side band and a lower side band and that there is no carrier component and hence the name double side band with suppress carrier. Now, let us look at the amount of power that is transmitted by this through this waveform, please quickly looking at some of the basic attributes of this, transmitted power. How will you calculate this, how do you calculate power?

Student: ((Refer Time: 43:31))

Sigma square time integral over

Student: ((Refer Time: 43:37))

Over some time interval and divided by the time interval, but in general, you message waveform may not be periodic. So, we cannot talk about a period at anything, but if it is not a periodic waveform, you can always do this, let us say minus t to plus t A square m square t cosine square omega ctdt. This will be the energy of the waveform in the interval from minus t to plus t, so divided by 1 by 2 t and what shall we do?

Student: ((Refer Time: 44:16))

Take the limit as T tends to infinity that will be the definition of our calculation of power of and for an arbitrary signal arbitrary waveform. So, if you want to do that, this would be equal to in our case.

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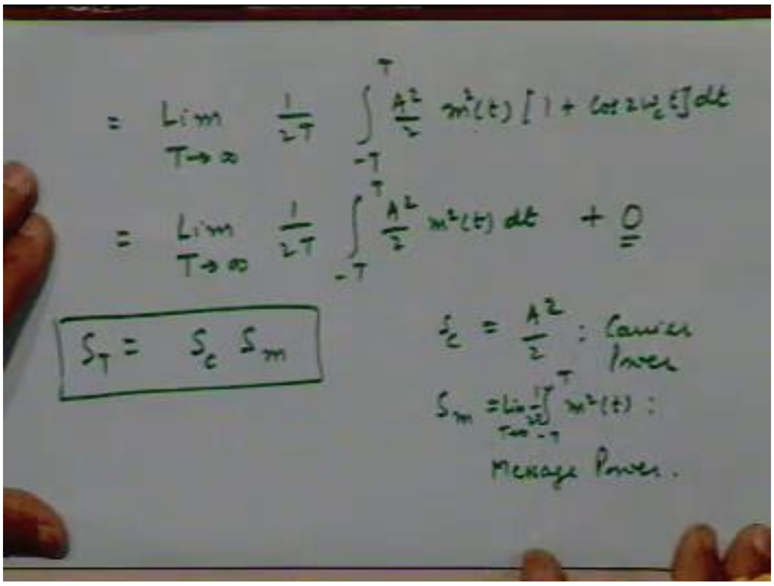

$$= \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} \frac{A^2}{2} m^2(t) \left[1 + \cos 2\omega_c t\right] dt$$

$$= \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} \frac{A^2}{2} m^2(t)\, dt + \underline{\underline{0}}$$

$$\boxed{S_T = S_c S_m}$$

$S_c = \frac{A^2}{2}$: Carrier Power

$S_m = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} m^2(t)$: Message Power.

Limit as T tends to infinity of 1 by 2 t, integral of let us split the cosine c, through the trigonometric identity to write cosine square omega ct in terms of the sum and difference component. So, in each case it will be, what is cosine square formula it should be, A square by 2mt into 1 plus cos 2 omega ct dt

Student: Sir m square t.

m square t yes, so which is consisting of two parts, from this is from minus t to plus t, that is the first part of the integral, what can you say about the second part?

Student: 0

0, what is the reason, what is the argument, the same argument which we discussed some time ago, because m square t is a slowly varying waveform, cosine 2 omega ct can be considered, we can you can consider as the integral, as integration cycle by cycle of the carrier, half cycle by half cycle. So, over one cycle, you can assume m square t is nearly constant and the positive half cycle will cancel with the negative half cycle. So, half cycle by half cycle, the value of second integral would be 0.

Because, cosine 2 omega ct is being multiplied by a very slowly varying function, compare to on it is rate of fluctuation. So, therefore, the second part is 0, the same argument if you have discussed earlier and therefore, what is now, if you take A square by 2 outside, what is left inside the integral, is nothing but the power in the message signal itself and what is A square by 2, is power of the carrier. Carrier in a cosine omega ct which, as it is power is A square by 2.

So, therefore, you can think of this as nothing but sc into s sub m, sosc sub c, is A square by 2, which is the carrier power and s sub m is the integral etcetera of the message etcetera, limit s t tends to infinity that is the message power. So, the transmitted power s sub t is the product of the carrier power and the message power, so I think with this we are more or less analyze the attributes of the modulated waveform completely. We have understood it is time domain nature, what it looks like.

We understood it is spectrum, we understood the fact that, if carrier has more information that has need to and therefore, occupies twice the bandwidth and we also looked at, the amount of power that is present in such a signal. So, that is more or less completes our study of the DSB SC waveform. The issue that is left to discuss is, all right we have transmitted this, and how do we get back?

Student: ((Refer Time: 48:11))

The message wave from mt from it, that is the only issue left, let us look at that one, I will just indicate that here, today and we will discuss it if required in detail next time. So, let us see, how at the receiver we can recover the base band signal back. Any suggestions, what do we need to do?

Student: Demodulate

Yes, how to demodulate, that is precise in that, when I say recover, then process of recovery is called demodulation, the question is what should we do to demodulate?

Student: ((Refer Time: 49:01))

You have to shift the transspectrum back to the base band, how do we do that?

Student: multiplying ((Refer Time: 49:10))

Once again, obviously some kind of a multiplication operation is required to be carried out, indeed that is the case.

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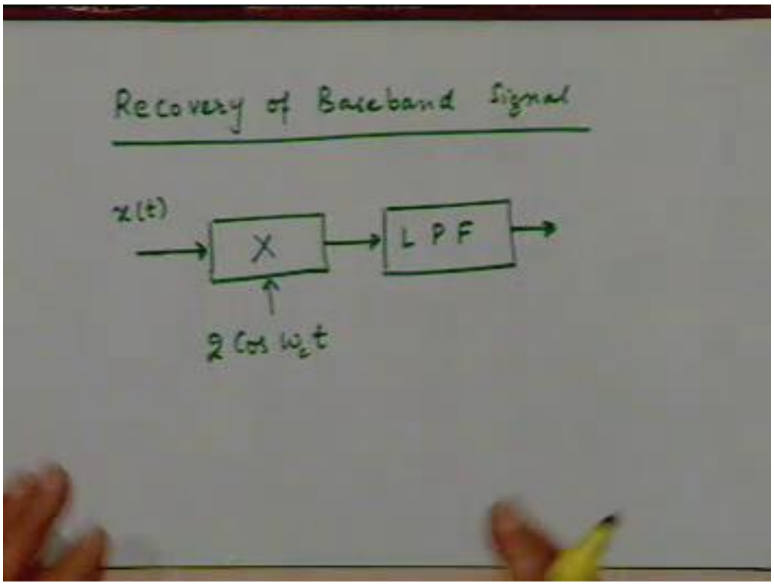

The first case would be, assume that at the receiver we have the replica of the carrier available to us, the carrier frequency is known to us and we can generate the replica of the carrier. For convenience, let me write 2 cosine omega ct that does not make any difference, it is a scaling factor and the received modulated waveform is multiplied with this carrier. Now, what will this do, what will be the spectrum that you will see here?

Student: ((Refer Time: 49:52))

As we saw in the case of modulation, the message waveform spectrum it is translated up by fc and also down by minus f c that is what happens. The same thing will happen to xt.

Student: ((Refer Time: 50:07))

So, the spectrum of xt, would after multiplication with 2 cosine omega ct, would translate to a component around 2 fc and also 0.

Student: ((Refer Time: 50:20))

So, what we need to do is, retain the component which is centered around 0 and remove the component somehow which is centered around 2 omega ct, which is very easy. So, the second that we must have in the demodulator is a low pass filter, to remove the double frequency component. So, we will look at this operation mathematically next time, it is more or less obvious and we have discussed further about the pros and cons of DSB SC modulation and demodulation.

Thank you very much.