Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
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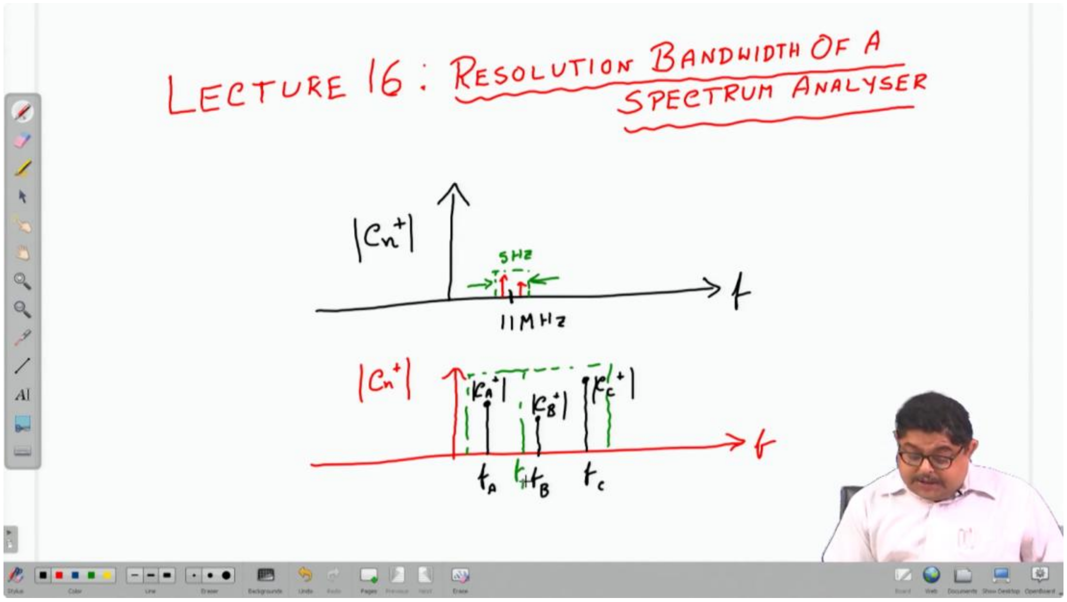
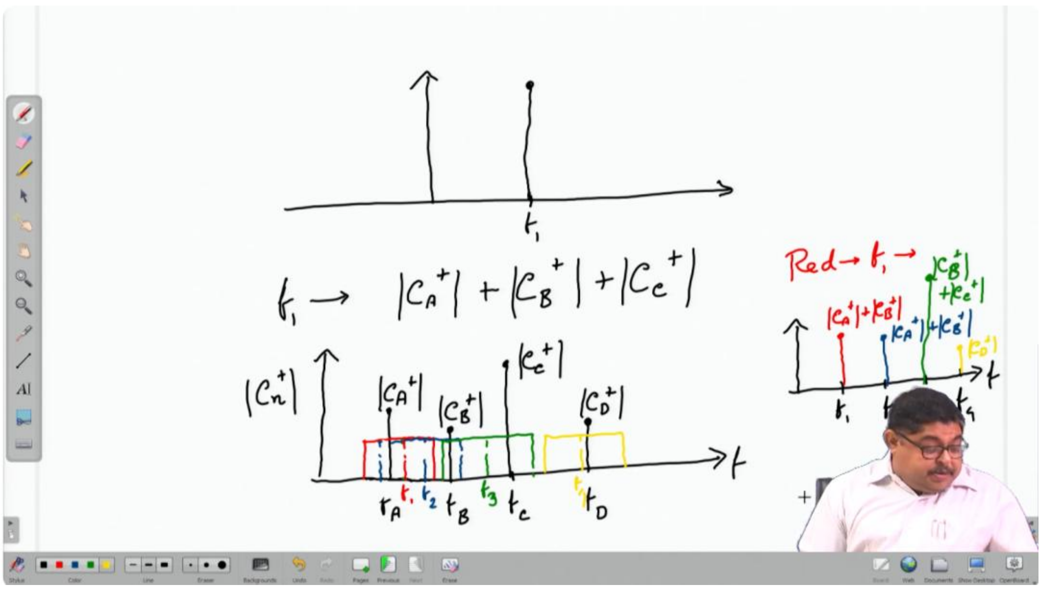
Week :04
Lecture 16: Resolution Bandwidth of a Spectrum Analyser

Welcome to the 16th lecture of the course on EMI, EMC and Signal Integrity Principles, and application. We were discussing the bandwidth what we should take for a spectrum analyzer. In the last class we have initiated the discussion, today we will see that in detail that. You see that let us assume that or actually it can be assumed that a spectrum analyzer is a band pass filter centered around a frequency which is given by your start, stop and steps of the frequency. Suppose you want to measure the spectrum from 10 megahertz to 1 gigahertz with a step size of suppose 1 megahertz. That means at 10 megahertz spectrum analyzer will see you some spectral amplitude value at 11 megahertz again it will show you some value at 12 megahertz it will show some value etcetera.

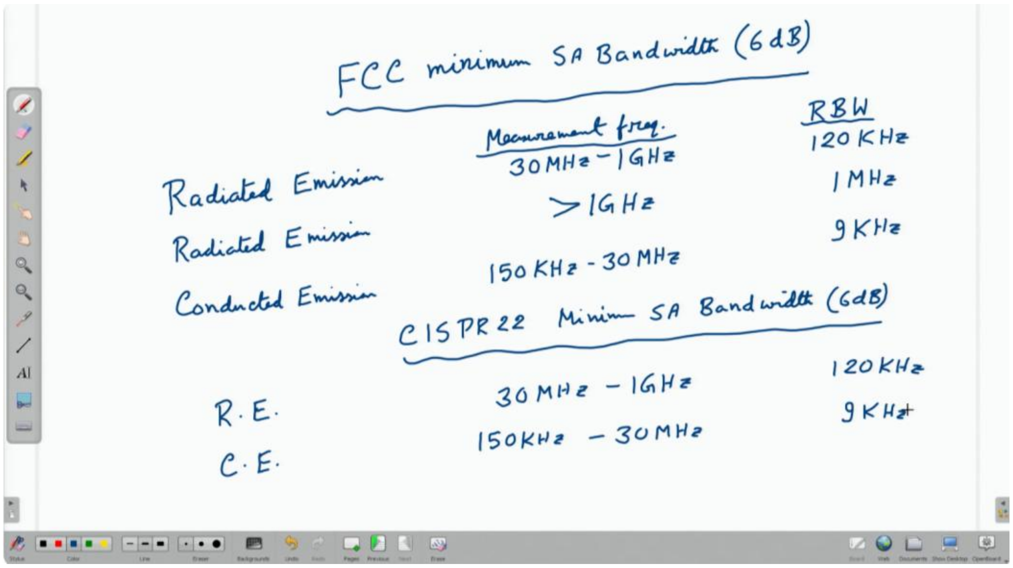
Now, the question is what it is saying about around 10 megahertz the actual signal may not have a component at suppose 11 megahertz it is showing some value 11 megahertz may not be a spectral frequency of or harmonic of the signal. So, what it is showing in 11 megahertz that is answered by this resolution bandwidth. So, what is does when it is suppose this is your f this it shows as cn plus. Now, at 11 megahertz what it is showing is actually I said that the spectrum analyzer can be thought of as a band pass signal. So, at 11 megahertz centered at 11 megahertz if you consider a bandwidth that let us say from let us say width of that bandwidth is 5 hertz. So, this bandwidth is your resolution bandwidth. So, anything it may not be there is a spectral component at 1 megahertz, but let us say that there is a spectral component here there is a spectral component here. So, at 11 megahertz 11 megahertz is the center and there is a 5 hertz band pass bandwidth resolution bandwidth. So, within that whatever spectral components are present it is showing some of them. So, the magnitude of the spectral components of the input signal that are present within the bandwidth of the SA at that point in time of the sweep is displaced. Now, spectrum analyzer uses a sweep signal the sweep frequency that means first it will go to 11 megahertz then it will go to 12 megahertz it will go to 13 megahertz and in everywhere it will put a 5 hertz band pass filter. So, let us consider an example that suppose this is my Cn plus. So, let us say that I have a spectral component here let me name it FA. I have a spectral component at FB let me call it show it this we have another spectral component at FC. And suppose my resolution bandwidth I have taken the center of that this resolution bandwidth let us say at F1. Now, this bandwidth is 6 dB bandwidth that means half of maximum. So, at against F1 what it will show. So, let us say that there are 3 spectral components of the signal shown by black color. So, at FA there is some component let me call that component as CA plus this one as CB plus and this one is CC plus. So, the center of this whole resolution bandwidth let us call that is F1.



So, actually spectrum analyzer when it will display it will display against F1 some value what is that value that value may be something like this. So, what is that that display will be CA. So, against F1 it is showing CA plus plus CB plus plus CC plus. So, the displayed level at the center frequency of the bandwidth will be the sum of the spectral levels that fall within the bandwidth of the filter at that time. Now, let us see another example that with whatever we understood let us take one more example that I have FA I have FB. So, this is CA plus this is CB plus this is CB plus this is CA plus this is FC CC plus and FD CD plus. Now, while sweeping what SA will show let me draw that. The red one in all the cases the resolution bandwidth let us say is same. So, in the first one you see that the red one I can say the red one at f1 it will show the spectral components of A signal and B signal sum.Then the next moment it will go to f2 the spectral A magnitude. So, let me draw it here. So, what I will get in the actual spectral analyzer A let us say f1 let us say f2 let us say f3 let us say f4. So, f1 is in red color. So, it will show me what is it? It is showing me c A plus plus c B plus only these two are encompassed here.Now, in the next one at f2, f2 is encompassing again the A and B. So, f2 will show you c A plus plus c B plus f3 it will show you c B plus plus c C plus. And fD or f4 that will show me only the c D plus it is encompassing only f4. So, from this you can see that it is you see here only it is advantage if I increase the resolution bandwidth then more and more signals are coming into pictures. So, spectral components are adding up. So, that may fail the regulatory limit. So, it is better to keep resolution bandwidth as low as possible. The flip side of it is it will increase your processing time that means spectrum analyzer will take more time to show because it is it will have to your if your resolution bandwidth is low, it will have to calculate this spectral components addition. So, it will take some more time, but that you leave it to the I think the instruments time etcetera that is not so that does not matter much, but you are getting less spectral components. So, that is advantageous because that will be able to pass the regulatory limits. But then what is ideal because I may take some resolution bandwidth someone else will take lesser resolution bandwidth and he will pass the test I may fail the test. So, that is why regulatory agencies have set a minimum bandwidth minimum resolution bandwidth to be used for every measurement of EMC. So, it would not be sensible to use resolution bandwidth larger than this minimum in the measurement levels would be higher.

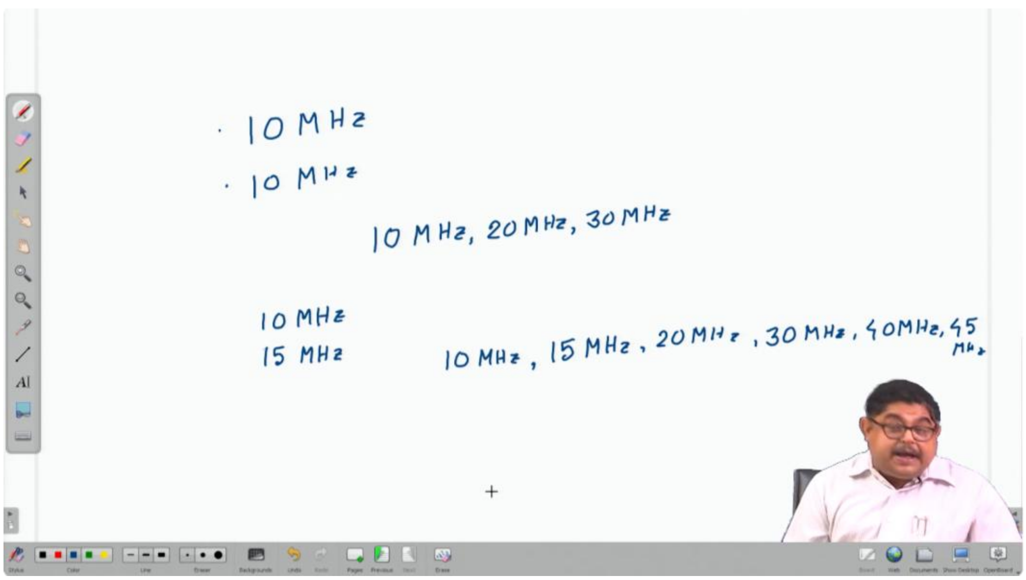


So, let us see those limits. So, FCC minimum SA bandwidth this is 6 dB bandwidth because whenever we say bandwidth you need to say so this is a spectral amplitude. So, it is 6 dB that means half of the maximum. Now for radiated emission, so for radiated emission my measurement bandwidth measurement frequency and then resolution bandwidth that should be taken. So, for radiated emission if my range is 30 megahertz to 1 gigahertz then FCC says that you take 120 kilohertz as the resolution bandwidth. That means every you should take band pass filters whenever you select it as 120 kilohertz that means 120 kilohertz is the resolution bandwidth taken. So, centered about that the spectral amplitude will be shown. Now if your radiated emission is greater than 1 gigahertz then you take resolution bandwidth to be 1 megahertz and for conducted emission that means if the emission comes goes by conducted path conducted emission their limits is measurement frequency may be 150 kilohertz to 30 megahertz then it should be 9 kilohertz. Whereas, SISPERS limit is CISPERS 22 minimum SA bandwidth 6 dB. Again I am writing in short for radiated emission they also have specified the same range that 30 megahertz to 1 gigahertz your resolution bandwidth should be 120 kilohertz. So, both the FCC and CISPERS same here for conducted emission you have 150 kilohertz to 30 megahertz that is also 9 kilohertz.

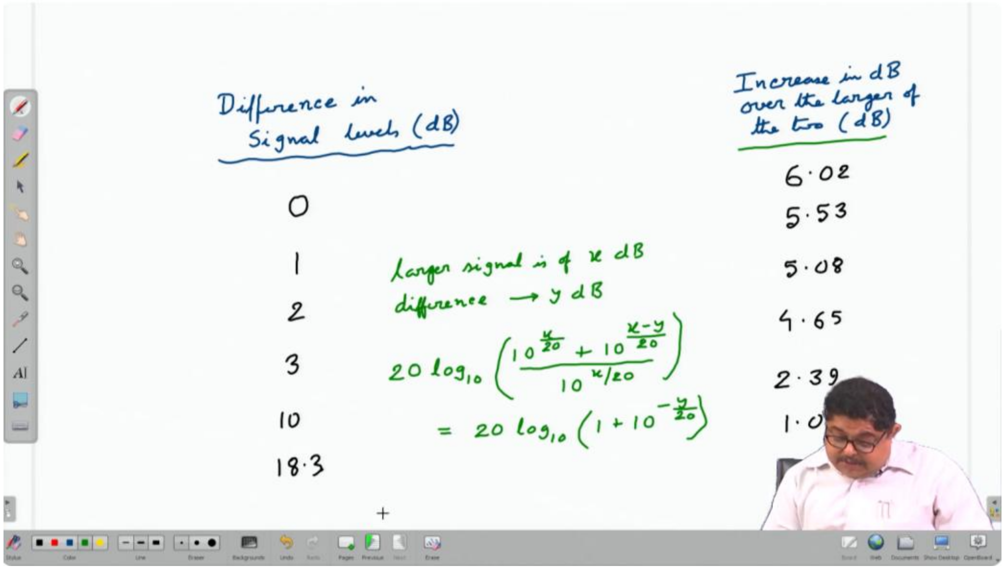


Now one of the fallout of this whole concept is that as spectrum analyzer adds up all spectral levels within its bandwidth and displays the sum as the level at the center frequency of the filter then you see if we have more than one signal more than one clock may be more than one data repetition rate etcetera. So, then we should see that suppose if I have a signal it will have various harmonics. So, two signals there two harmonics. So, none of these harmonics should come closer than the resolution bandwidth of the spectrum analyzer if they come then instead of one signal will be measuring two signals two harmonics. So, suppose I am giving an example suppose we have in the signal suppose one system has two subsystems and it has two clocks. So, one clock is at suppose initially let us say that both the clocks are 10 megahertz clock. So, each clock signal may radiate from different parts of the system. So, that total received signal at the spectrum analyzer detector is the sum of these emissions. Suppose this at where the where you are measuring there the total emission from these two are of equal strength equal amplitude equal phase etcetera. Then you see your measurement at 10 megahertz at 20 megahertz at 30 megahertz that means all the harmonics of the clock frequency there will get 6 dB higher values because both these signals are adding up. So, for one signal what you had you would have got from that it will be 6 dB higher.

So, that means double the value will get and that may fail your test. Instead suppose we choose one clock at 10 megahertz and other at let us take 15 megahertz 15 megahertz. So, now what will be my various harmonics of both the clock together in 10 megahertz I will get then 15 megahertz I will get then 20 megahertz I will get then 30 megahertz I will get then 40 megahertz I will get then 45 megahertz I will get etcetera. Now you see that at 10 megahertz what I am getting that is from one signal at 15 megahertz from one signal at 20 megahertz from one signal at 30 megahertz there is a problem that I am getting the third harmonic of the first clock and the second harmonic of the second clock. Then at 40 megahertz again from 10 megahertz clock at 45 megahertz from 15 megahertz clock only. So, except 30 megahertz I am getting at all like that I will get another one at 60 megahertz but before that I will get many things and for 30 megahertz also you see the third harmonic of the first clock and the second harmonic of second clock they are added. So, this is not as severe as the previous problem. So, if you understand resolution bandwidth well you can select your clock frequency or signal frequency between different subsystems at the systems level. Now here I want to show you one thing that even if the levels of two signal harmonics are unequal but their addition may becomes significant.



So, let us see that suppose between two different signals the difference in signal levels in dB let us calculate that difference in signal level and here I will plot or write I will write a table increase in dB over the larger of the two that is also I am writing in dB. So, if my difference in two signals is 0 dB that means they are same. So, what is the increase over the larger of the two that is 6.02 dB. Now difference is 1 dB. So, if two signals are difference by 1 dB what is the increase in dB over the larger of the two that will come as 5.53 dB. So, you see difference in 1 dB but increase over the larger of the two I am taking the more I think not over the minimum but over the maximum this is 5.53 dB over if the difference is 2 dB it is 5.08 if the difference is 3 dB it is 4.65. Like that I can go let us take some more typical values suppose I have 10 dB difference then also it is 10 dB is quite sufficiently the difference is small but it is 2.39 dB if it is 18.3 very very small difference but here there are 1 dB difference. How I am calculating this actually let us take that larger signal is of x dB and difference of the two signal is y dB. So, what is this side this side is you see 20 log of 10 10 to the power x by 20 plus 10 to the power x minus y by 20 divided by 10 to the power x by 20. So, that is 20 log 10 1 plus 10 to the power minus y by 20. You can check that I have got these values from this formula. So, the take away from this is that do not think that difference between the two signals is small. So, the if they add up the increase is insignificant no. Now, here the two we assume that two signals are in phase otherwise this addition will be lower. So, actually this table gives you the upper bound. So, it is not so it is upper bound. So, you are satisfied that you know that if the difference of two signals is this whatever it is giving the actual thing will be either this or less than that because actually they may not be adding in phase. Now, so it is important as a system checkup that whether two signals are adding up in the system how to do that. Now, a simple method to determine that is you go on reducing the resolution bandwidth. Now, obviously the regulatory limits have said something this is not for making those regulatory measurements, but just to check whether you have more than one signals or their harmonics are adding up. So, you go on reducing the resolution bandwidth of the spectrum analyzer. So, as the this example shows yes. So, if I reduce the resolution bandwidth ultimately it will happen that only one signal is coming into picture. So, suppose from 120 kilohertz the SA bandwidth is reduced to 30 gigahertz and etcetera etcetera and then if we go on doing that more and seeing that the spectral level is keeping same then we are certain that now I have only one signal. So, initially after reducing you may get that the level is falling, but after some time it will be only one signal and I told you that resolution bandwidth you can make very small 0.02 hertz even 0.002 hertz etcetera is possible with the commercially available and moderately cost spectrum analyzers. So, you can do this. Now, so that is all about our spectrum analyzer resolution bandwidth. So, for measurement EMC measurement you need to know this concept so that you can do choose these levels properly, the clock frequency properly, you understand what you are measuring etcetera etcetera. So, otherwise by default spectrum analyzer will take something, but as an engineer you should know every bit of this concept so that you can choose your measurement parameters properly. So, another thing that is remaining is what detector will use for spectrum analyzer measurements or this EMC measurements that we will take up in the next class. Thank you.



Difference in Signal levels (dB)
Increase in dB over the larger of the two (dB)
6·02
0
5·53
1
5·08
2
4·65
3
2·39
10
1·0
18·3
larger signal is of x dB
difference → y dB
$20 \log_{10} \left(\frac{10^{\frac{x}{20}} + 10^{\frac{x-y}{20}}}{10^{x/20}} \right)$
$= 20 \log_{10} \left(1 + 10^{-\frac{y}{20}} \right)$