Basics of Noise and Its Measurements
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Lecture – 38
Measuring Impedance Using the Two Microphone Method

Hello, welcome to Basics of Noise and its Measurements. I am Nachiketa Tiwari, this is the seventh week of this course, and this week we will be discussing an assorted number of topics, and today and tomorrow, we will be discussing as to how to measure impedance using the different approach. Now, earlier when we had discussed the measurement methodology for impedance, we had discussed about traveling microscope method and the equipment was known as cons tube.

One limitation of that method was that you should have, you need to have a long hole in the impedance tube. So, that the microscope, not microscope; the microphone can travel easily. Along the length and that creates problem because once you have to have a slot, and then because of that noise leaks and it is no longer planar and it distorts the field, pressure field in that tube. So, to address these concerns people have figured out a different way to measure impedance and that is much more popular.

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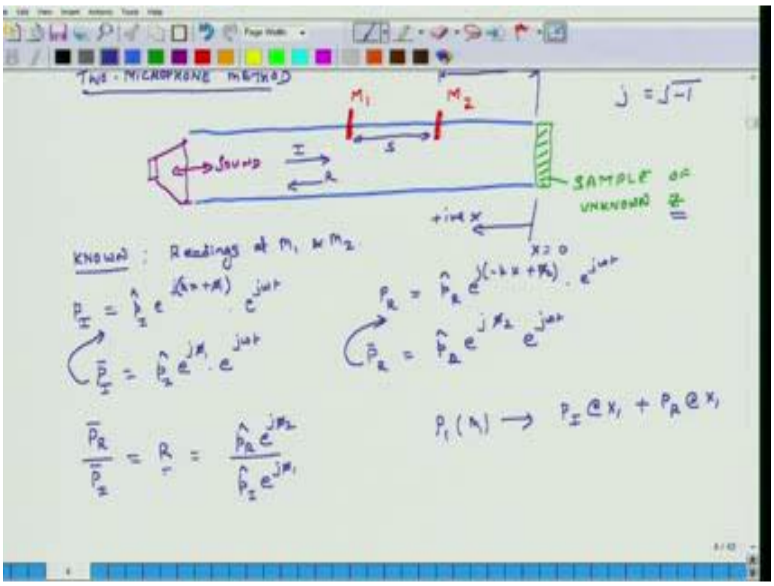

This is known as the two microphone method and a key differentiator of this approach user view the other approach is that, in this approach we do not have a moving microphone. So, both these microphones have fixed and using the signals measured at these 2 locations we are able to compute impedance.

So, that is why we are going to discuss today the two microphone method. So, first I will make a picture. So, you have a tube and at this end of the tube, I have the sample and I have to measure it is impedance of unknown z, it is specific acoustic impedance. At the other end, I have a loudspeaker. So, this is generating some sound and I placed 2 microphones. So, this is M1 and this is the second microphone M2.

One important thing to remember is that, in this case, this is my x is equal to 0 and conventionally; we have taken x as positive when, we move from origin to the right side, but here we will use this as positive x the spacing between these 2 microphones is s and the position of the second microphone with respect to x is equal to 0 is l. So, my aim is to find the value of z. What is known is the radio set microphone 1 and microphone 2. If you have, once I play the sound I can record the signals at M1 and M2 locations. So, readings at M1 and M2, this is known, and this unknown z is unknown. So, I have to figure out a relation in terms of the known parameter.

So, that I can calculate z, what else this is my incident direction which I refer as I and this is my reflected direction, which I refer as r because; a sound when I start it starts from this speaker travels along the length of the pipe hits this sample with unknown z and then it gets reflected. So, the reflected direction is r. Now, if we go back to our transmission line equations, then PI which is complex pressure in the incident direction at yeah is a PI hat e to the power of j. So, j is s square root of minus 1. j j is equal to square root of minus 1 times k x plus phi 1 times e j omega t.

Now, in the other original transmission line equations, the incident wave had a coefficient of negative j, e voice to the power of minus j k x, but here I am putting it positive because my x direction is changed, and x positive x is moving in the left direction. So, this is important to remember and my reflected wave. So, PI is a function of x as well as t and similarly PR is function of same thing.

So, this is again some number PR e to the power of minus j k x plus phi 1 times e 2 the power of j omega t. So, what I define is, PI bar is nothing but PI hat e to the power of j phi 1 times e to the power of j omega t and similarly; PR hat is equal to PR hat e j phi 2 e j omega t this is one. So, I am just defining this. So, PI bar is basically a function of time, also remember this, I am not explicitly put it in brackets, but it is the function of time and it also depends on phase phi 1 and this depends on phase phi 2.

So, this is, it should have been phi 2. So, if I unique these I plug this back into these relations and what I also that is that. So, PR bar over PI bar this is nothing, but my reflection coefficient because e j omega t cancels out. So, this is equal to PI hat e j phi 1 and actually, I would actually make a small modification here, I think I made an error. So, this should be minus k x plus phi 2 and then, I have 2 of course, multiplied by j. So, this negative sign from here it goes away. So, this is equal to PR hat e j phi 2 over PI hat e j phi 1 that is my reflection coefficient. So, if I use these two things then I can read out my expression for p. So, what I will do is, this is my reflection coefficient and then the value of pressure at M1 will be PI. If I calculate at x is equal to x 1 plus PR if I calculate the same thing at x is equal x 1 right p 1 which is at M1 location it will be basically PI at x 1 plus PR at x 2 x 1. So, I can calculate pressure at location 2 for my 2.

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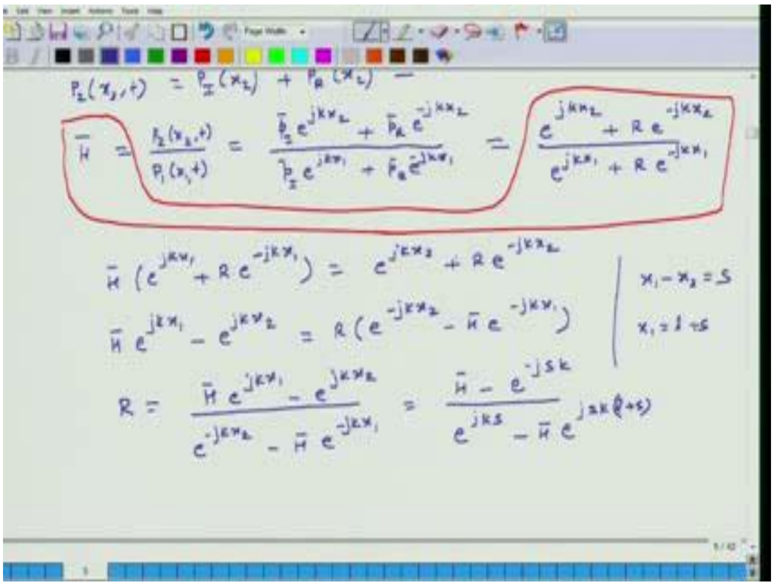

So, I will just write down these relations. So, p 1 which is been calculated at location x 1 and time t is equal to PI which depends on x 1 plus PR. If I calculate it as location x 1 and PI is dependent on x and time. So, we can do this. So, let p 2 which is being evaluated at location 2 is equal to PI at x 2 plus PR at x 2. Now, I define a function H and this is basically the transfer function. So, that I define it as p 2 x 2 t over p 1 x 1 t. So, what is that? It is a transfer function between 2 microphones, my reference microphone here is, the first microphone and with respect to that I am finding the pressure at second location.

So, this is equal to and if I use these relations and also in the place of PI and PR are have actually plug-in the original things. Then, what I get is PI e j k x 2 plus PR e j k x 2 divided by PI e j k x 1 plus PR e j k x 1 and no, there should be a negative here and there should be a negative here, right, it should be negative sign here. So, this I can now I know that PR is equal to r times PI, we have defined it here, this thing. So, actually I should have made both of these bars on them if I had been careful. So, I will actually put these, right. So, that there is no confusion. So, if that is the case and if I divide the whole thing by t I the numerator as well as denominator then, I get e j k x 2 plus r e minus j k x 2 divided by e j k x 1 plus r e minus j k x 1.

Now, what I do is I look at this equation and I think that, I have take in this equation H is what it is the transfer function, can I measure this transfer function the answer to that is, yes how can I measure it, I take the readings at microphone 1. I take the readings at microphone 2 and using this p 2 over p n I, can get the value of H bar right and on the left side on the right side I exponent to the power of j k k I know because, if I send in a particular frequency, I know it is wavelengths I can calculate its wave number I know the location x 2 I know the location x 1. So, I know x 2 and x one. So, I know on the left on the right side I know everything except r and on the left side I know H. So, I can calculate r left side I know H through experiment right side I know x 2 x 1 and a k. So, I can find r. So, the relation is e j k x 1 plus r e minus j k x 1 is equal to e j k x 2 plus r e minus j k x 2. So, I am going to collect things related to r on one side.

So, what I get is H bar e j k x 1 minus e j k x 2 minus is equal to r e minus j k x 2 minus H bar e minus j k x 1 right and from this, you can compute r and r is H bar e j k x 1 minus e j k x 2 divided by e minus j k x 2 minus H bar e minus j k x 1. So, the next thing is that I divide this numerator, by e to the power of j k x 1 and also the denominator by e j k x one. So, what do I get I get H bar and remember, x 1 minus x 2 is equal to s, if you look at this picture this is x 1 this is x 2. So, x 1 minus x 2 is s. So, my relation becomes, H minus e j to the power of k x 2 minus x 1. So, it is basically e minus j s k and in the denominator I get e again, I am dividing this new denominator also by e j k x 1. So, I get e j k s and then minus H bar and then I get e j times 2 k l plus s. So, what is l plus s? x 1 is equal to l plus s, which we had defined earlier, this is l x 2 is same as l. So, I get this relation. So, this is by final form.

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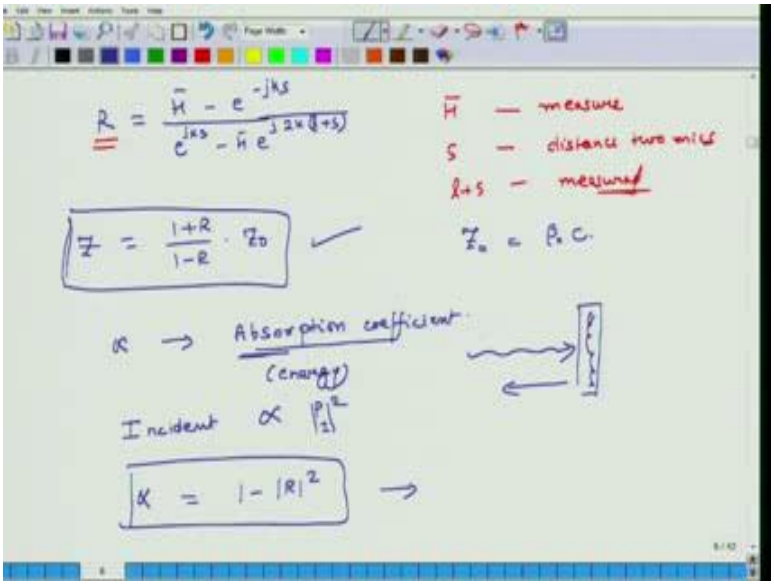

So, my final form is reflection co-efficient equals H bar minus e to the power of minus j k s divided by e to the power of j k s minus H bar e to the power of j times 2 k l plus s. So, in this relation H bar, we can measure s is the distance between 2 mics and l plus s and it also can be it is also a property of the tube. So, this is also it can be measured. So, we are able to measure both of these all these things I can calculate r and then, we know that z which is the specific acoustic impedance of the material is, what 1 plus r divided by 1 minus r times z naught where z naught equals rho naught c. So, I can calculate the value of z, once I know r.

So, I know how to calculate r. There is one more parameter I can calculate and that is alpha this is known as absorption co-efficient. So, what is absorption co-efficient sound is coming in some of it is getting reflected and some of it is, getting absorbed by the material. Now, whatever is be absorbed by the material. So, of it may be transmitted out also, but absorption total absorption energy will be what, whatever is been incident minus reflected energy incident energy minus reflected energy the difference between 2 will be the absorbed energy, these absorbed energy will be partly converted into heat in the system and partly it will be transmitted on the other side. So, this is related to energy it is not related to amplitude.

So, my incident energy is directly proportional to amplitude of the wave right; not, but it is square same thing about reflected energy it is. So, the incident energy is directly proportional to the incident pressure waves amplitudes square same thing is do for reflected energy. So, absorbed energy will be what and this is coefficient it is not the actual amount. So, this will be nothing, but 1 minus magnitude of r because, r is a complex quantity, so magnitude of r square that is your absorption coefficient. So, it is not square root of that because it is it helps us understand how much energy is being absorbed. So, using this I can calculate absorption coefficient for the material.

So, that we have learnt here is how to use this two microphone method to calculate the impedance of an unknown material, and in the next class we will continuous the discussion from the standpoint of some practical considerations, and how you go around designing impedance tube for these kind of measurements.

Thank you.