Fundamentals of Acoustics

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Lecture - 41
Directivity

Hello, welcome to Fundamentals of Acoustics; today is the fifth day of the current week and what we planned to discuss today is the notion of directivity.

So, we know that if you have a spherical source sound propagates equally in all the directions, so that kind of a source is omnidirectional. But then if you have 2 sources which are interfering with each other and suppose these 2 sources are very close to each other and both these sources even though may not necessarily be out of phase, but if we are away from the these 2 sources the sound pressure level changes with respect to theta. So, the combination of these 2 simple poles or simple sources may not be necessarily a spherical in nature. But then there could be a third situation where a specific source; for instance you have an engine block and it may be generating more sound in one particular direction and less sound in some other direction.

So, sound sources have to be characterized not only in terms of the total amount of sound which they produce, but also in terms of how does sound pressure level change as I vary the angular orientation. So, this characterization of a sound source in terms of its directional characteristics is known as directivity.

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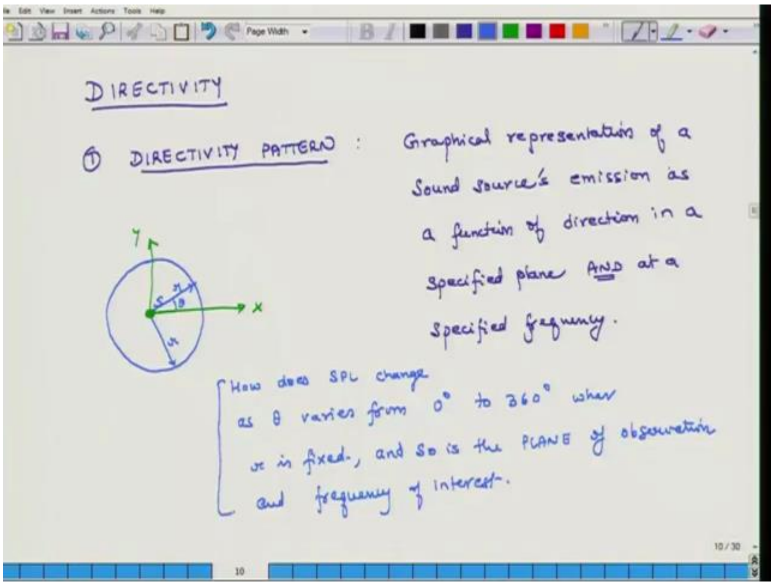

So, now there are several waves to quantify directivity, so our goal for today is to talk about directivity. So, there are 3 or 4 waves in which directivity of a sound source can be quantified. So the first one is directivity pattern; so what is the directivity pattern. So, first we will define it and then we will actually show you what it is, so it is a graphical representation. So, graphical representation of a sound source or actually sound sources emissions as a function of direction in a specified plane and at a specified frequency, so now we will explain what it means.

So, let us consider a sound source, let us consider that it is small for starters. So, it may not necessarily be a point, but a non zero size and first let us define the directions. So x, y and the plane through the board is the z plane. So, suppose I am interested in trying to understand that in the z plane which means that the plane normal is the z axis, in the z plane how is sound pattern changing. So, what I want to know is, so let us draw a z plane a circle in a z plane, so this is actually a bad circle because it does not place the source at the center, so this is somewhat better. So, I want to show our source is located at the center of this plane and this is r right. So, this is another position r and this is theta. So, what the directivity pattern tells us is that it gives us an idea that how does sound or if I am measuring sound in sound pressure level in decibels. So, how does SPL change as theta varies from 0 degrees to 360 degrees when r is fixed, so I cannot change r for a specific r, how does SPL change when theta varies from 0 degree to 360 degrees; so that is. And when r is fixed and so is the plane of observation and frequency of interest; so that is what the directivity pattern gives.

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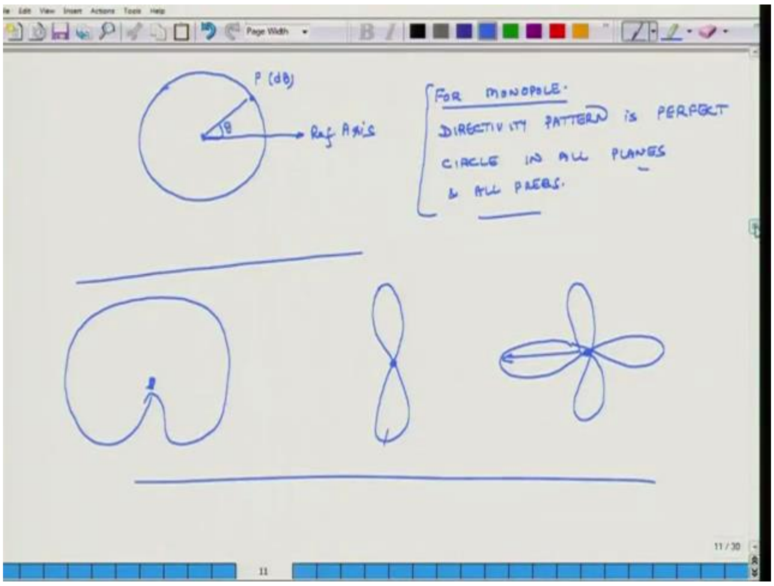

So, if we have a perfectly symmetric source, if it is a truly point source then how will the directivity pattern look like. It will just look like a perfect circle and what does the circle represents, the distance. So, this is my reference axis this point tells us what is the value of pressure in decibels in dB as theta changes. So, for monopole directivity pattern so directivity pattern is perfect circle, it is perfect circle and it is in all planes and all frequencies. So, that is what we have for monopole, but you can have 2 sound sources or you can have a source so, but they could be other situations where you may have a directivity pattern something like this or it could be something like this.

What does this kind of a directivity pattern tell us? That sound is being transmitted more in at theta equals pi over 2 and negative pi over 2, but at 0 n pi radians transmission of sound is very less. You can have several lobs for such directivity patterns, so source is always located at the center. So, all these are different directivity patterns and here the distance from the center represents the amplitude in decibels and the angular coordinate represents the angle at which you are measuring.

But please understand that these directivity patterns are specific to frequency, there could be a sound source which produces almost circular directivity pattern for very low frequencies, but as you increase the frequency it may be very complicated directivity pattern. So, it is important to understand that directivity patterns can change with respect to frequencies and also with respect to the plane of observation. So that is the first way to quantify directivity.

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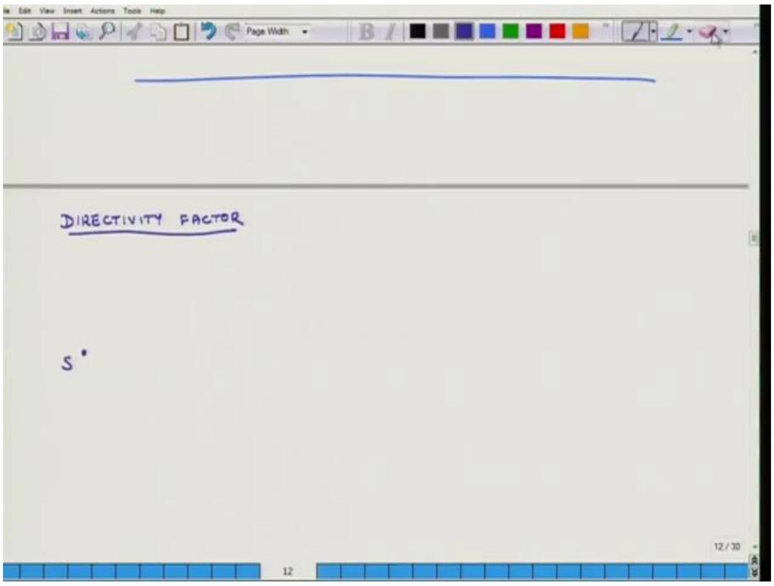

The next parameter which is used is called directivity factor. So this is the cycling measure for directivity. So, what does this mean? Suppose we have a sound source, so actually before talking about directivity factor we will talk about beam width because directivity factor is dependent on this understanding of beam width.

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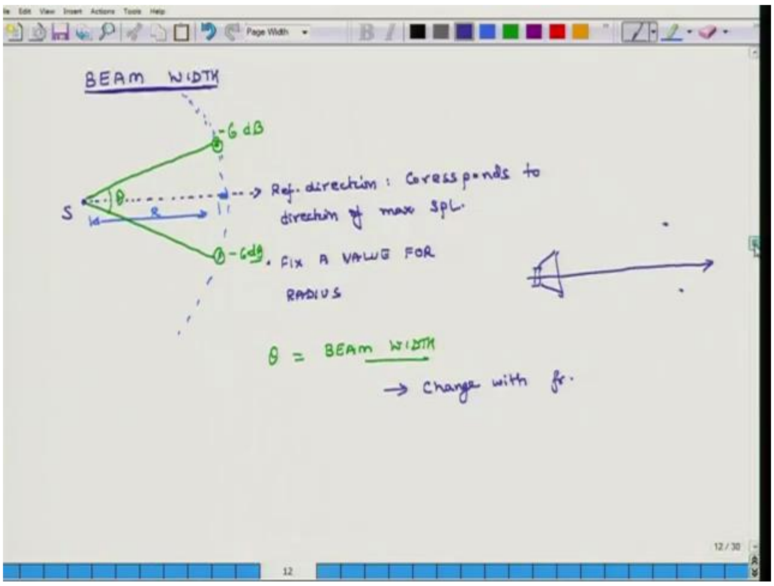

So, the second parameter which we will discuss is called Beam Width. So, suppose we have a sound source and let us say this sound source is emitting sound in this direction at maximum possible level. So, this direction corresponds to; so this is our reference direction and this corresponds to direction of maximum SPL. So, consider a loud speaker suppose, so this is sound source may be in this direction the sound pressure level is maximum, but maybe it is not that much in this direction. So, that is our reference direction.

Now this again going back to the example of loud speaker, sound is going in a particular direction, so it is going in shape of a kind of a beam. So, we want to define how wide that beam is. Now theoretically beam will be in all the direction, sound will be emitted in all the 360 degrees, but we still want to define how is strong this directionality is of the speaker or the sound source. So, what we do is we take some radius, so what we do is we first thing is we fix a radius, value for radius. So, let us say we fix this value, so we will say that the radius is going to be this; so this is my r.

And then I will take a microphone and scan the sound pressure level along this r which has a radius r and the center is s. So, sound pressure level is going to be maximum on at in the reference direction, but may be at this location. So, suppose here it is some decibels hundred decibels, but here it goes down by let us say minus 3 dB or minus 6 dB and here also it goes down by minus 6 dB then what I do is; I create a geometry. So, the location where the sound pressure level falls by minus 6 dB falls by 6 decibels, that location is identified and this angle is measured and this angle is known as beam width.

So what is beam width, a beam width it corresponds to the angle over which the sound pressure level for a fixed radius can drop or it drops by as much as 6 decibels and in this case we use a particular reference direction and the reference direction is chosen such that it corresponds to the direction where we perceive, where we measure maximum sound pressure level, so that is beam width.

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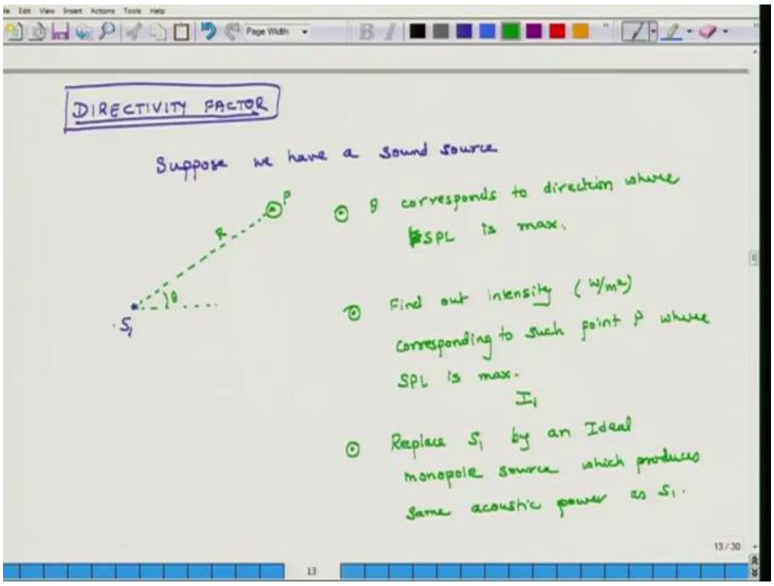

The third parameter for measuring directivity is called directivity factor, but before we talk about directivity factor I would like to retreat, this beam width is also it can change with frequency; it is important. All these parameters directivity pattern beam width directivity factor all these things they depend on frequency. So directivity factor, so what does beam width tells; it tells us how much sound is being directed in a particular direction it gives you that idea. Now the directivity factor helps us compare how much directional a particular sound sources; compared to a perfectly symmetrically radiating sound source.

So, suppose we have a sound source S, sound source S 1 and we are interesting in finding out its directivity factor. So, let us consider this point P, so the first thing to find directivity factor is to find some angle theta, what is this theta. So, at some point P for a given radius r; theta corresponds to direction where P or SPL is maximum. So, in some cases theta could be 0, so what do you do; you take a microphone and add it distance r you scan and you locate a angle theta where direction where some pressure level is maximum. So, that is one thing you record and so the first thing is that you identify theta, second thing is you find out intensity. So, what is it intensity; it is watts per square meter corresponding to such point P, so it is to such for where SPL is maximum.

So, let us say that this intensity is i 1. Then the third step we what we do is that we replace S 1 by an ideal monopole. So, what is an ideal monopole which emits sound with equal intensity in all directions? So, you replace sound this source S 1 by an ideal monopole source which produces same acoustic power as S 1, so you cannot just replace it with any monopole. Suppose the overall acoustic power which was being emitted by S 1 was n watts, you have to identify an acoustic source which is emitting and what is of power, but it has to be a monopole or it has to be a spherical symmetric and for such a symmetric monopole you measure intensity at point P because you have already indentified that point P.

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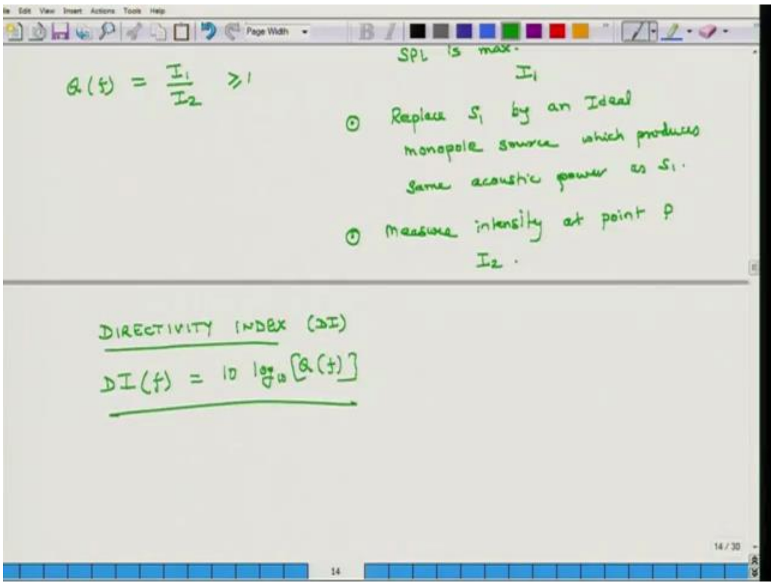

So, you will measure this intensity at point P and let this be i 2 then directivity factor and this is again specific to a frequency because you do this experiment for different frequencies. So, directivity free of factor for this particular source at frequency f is equal to i 1 over i 2 and this will be always greater or equal to 1, it can never go down because point P is the direction in which maximum sound pressure level is sensed, so it will always be there.

Then the third thing is directivity index, so lot of times it is referred as DI and DI which is again a function of frequency it is equal to 10, log of 10 q f. So, these are four different parameters for directivity of a sound source, directivity pattern which is a graphical representation, beam width which tells us how strong a beam is in particular direction, directivity factor which is comes out as a number and directivity index.

So, with that we conclude our discussion for today, and tomorrow will be the last day for this week and what we will discuss tomorrow will be complex power flow for spherically symmetric sound sources. So, with that have a great day and we will meet once again tomorrow. Bye.