Phonetics and Phonology: A broad overview
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Lecture 10
Acoustic analysis 3

Hello, welcome to the course on the Phonetics and Phonology: A broad overview. We are looking at acoustic phonetics and this is the third lesson on acoustic phonetics.

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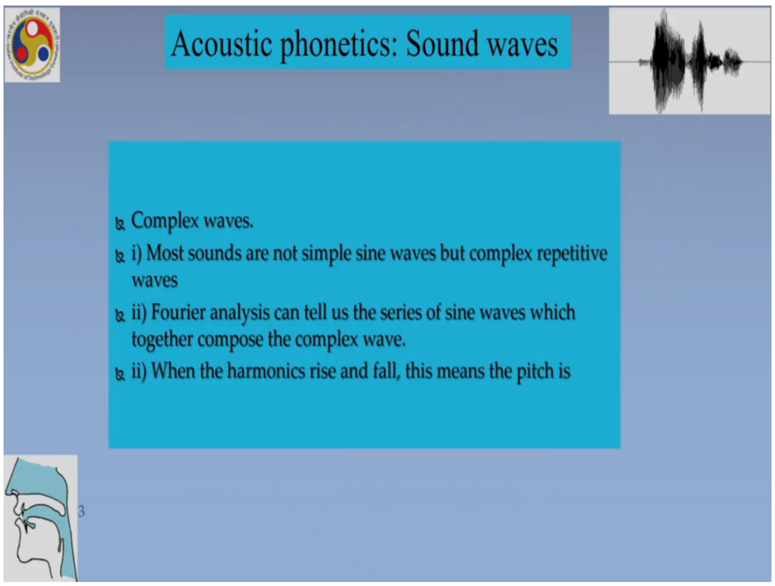

So, let us recap what we studied so far that sound waves are complex waves; and that most sounds are not simple sine waves, but complex repetitive waves. And Fourier analysis can tell us the series of sine waves which together compose the complex wave.

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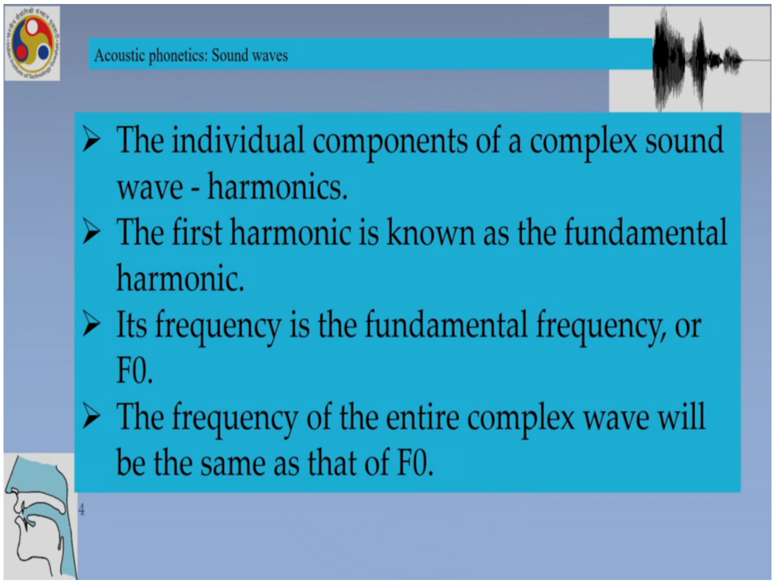

Now, the individual components of a complex sound, they are called harmonics. And we have already studied that; we are reviewing what we studied in the last class. The first harmonic is known as the fundamental harmonic; it is also called the fundamental frequency or f0. The frequency of the entire complex wave will be the same as that of the fundamental frequency.

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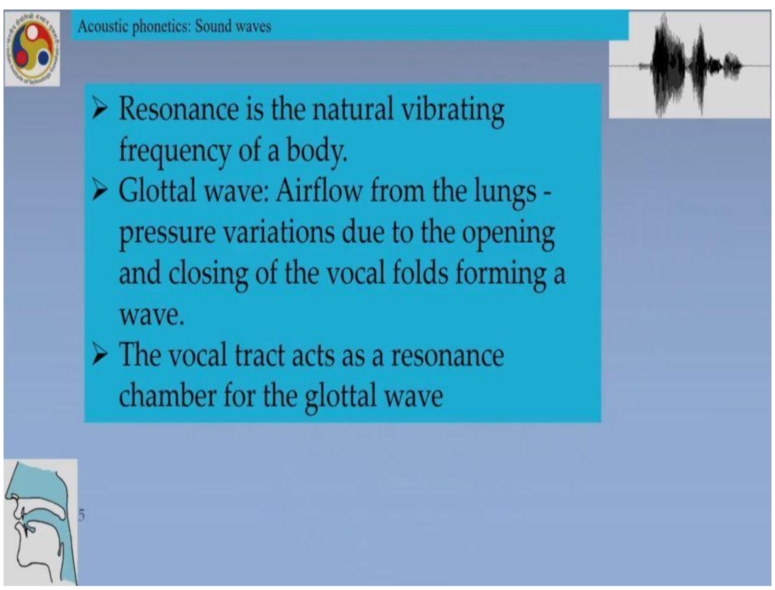

And we studied about resonance; resonance is a natural vibrating frequency of any object or body. And a glottal wave is the air flow from the lungs and which result in pressure variations, due to the opening and closing of the vocal folds forming a wave. The vocal tract acts as a resonance chamber for the glottal wave and gives it particular shape. So, we saw in the last class what happens to the glottal wave.

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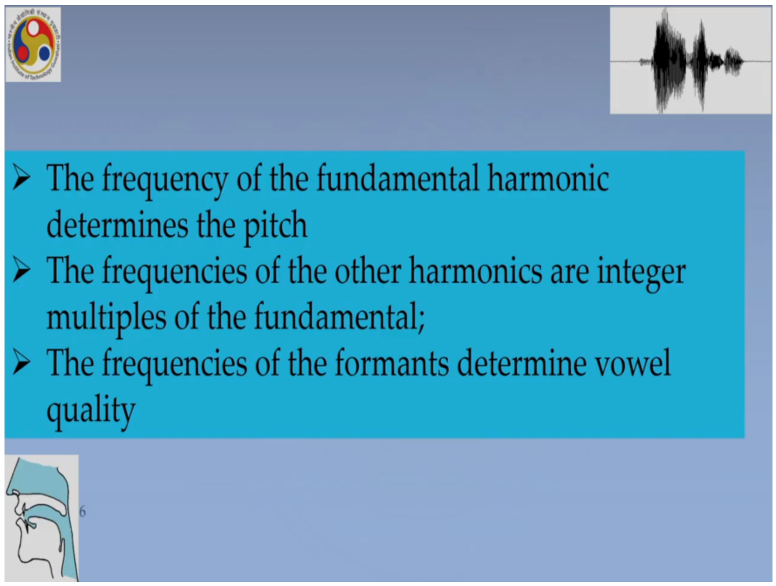

So, we are reviewing those things. The frequency of the fundamental harmonic determines the pitch; the pitch that we hear. The frequencies of the other harmonics are integer multiples of the fundamental; so these things are important to be remembered. And the frequencies of the formants determine vowel quality; so there is a difference between the formants and the fundamental frequency.

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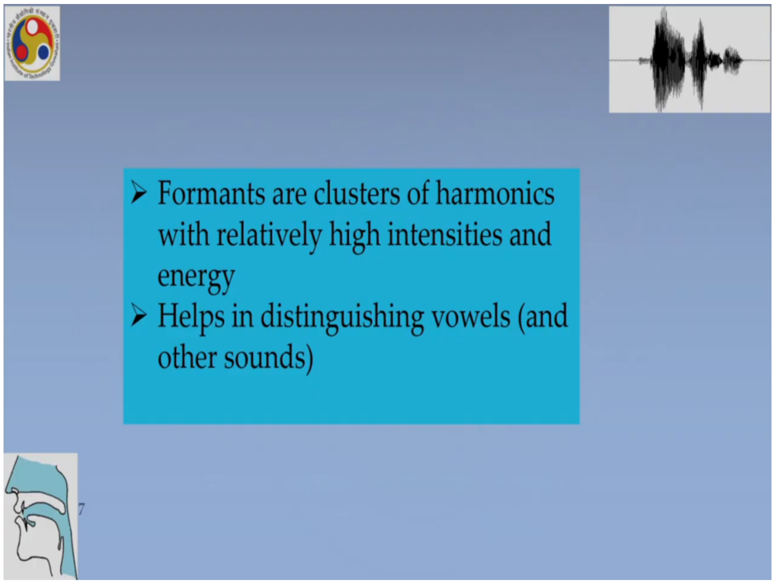

The formants are clusters of harmonics with relatively high energy intensity; they are seen as dark bands. They help in distinguishing vowels and also some other sounds, as we will see in the later half of this lecture.

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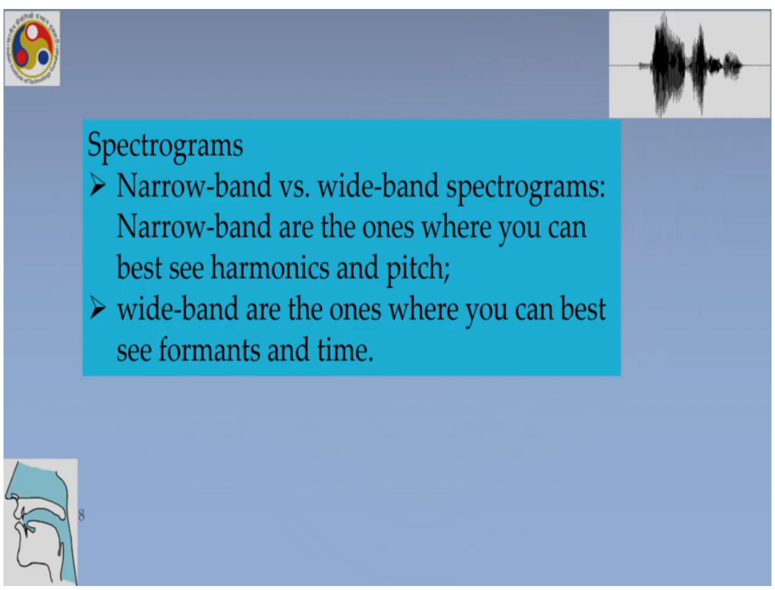

Then we saw what are spectrograms that there are there can be two types of spectrograms; narrow-band versus wide-band spectrograms. Narrow-band are the ones where you can see the harmonics and pitch; the component harmonics you can best seen in a narrow-band frequency.

However, wide-band are best for the performance, which that is why we use wide-band spectrograms to analyze vowels.

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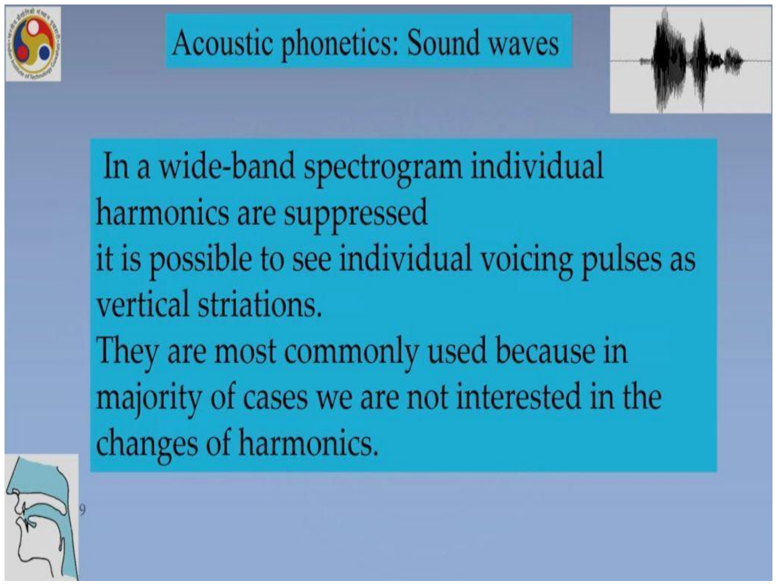

In a wide-band spectrogram individual harmonics are suppressed. It is possible to see, we will see wide-band spectrograms all along; it is possible to see individual voicing pulses as vertical striations. And they are most commonly used, because in majority of the cases the harmonics are not of importance to us; because if we want to study vowels. We want to study the formants, the harmonics with the most intensity the formants. So, those are the important parts that we want to study; we do not want to study all the harmonics.

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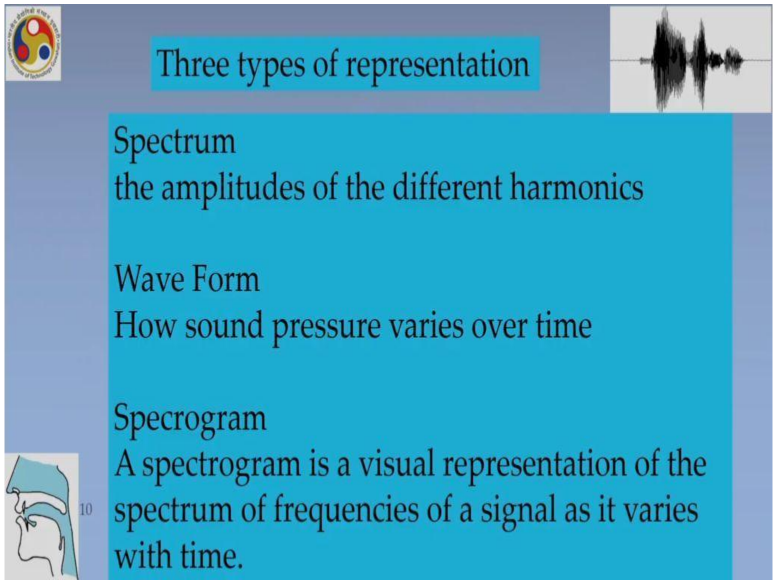

And we also talked about different types of representation; we have the spectrum, where you see the amplitude of the harmonics. You see a waveform, you see how the pressure varies over time; and in a spectrogram you see the change over time of the spectrum of frequencies, and also intensity and frequency. This information can be imposed on the spectrogram; as in various softwares you can see those as represented as different lines of different colors.

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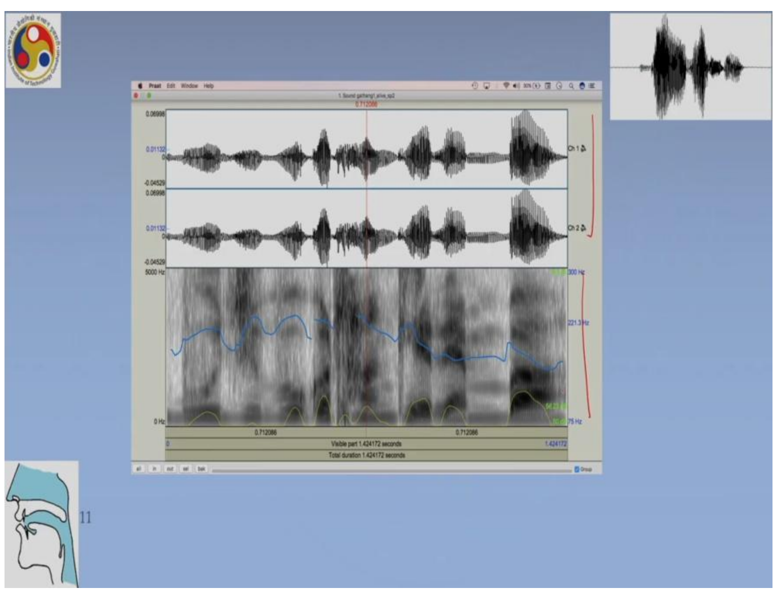

As you can see here, the first part of this diagram is that of a waveform. And this is a spectrogram, where you see the pitch is shown with the blue line; the intensity with a yellow line.

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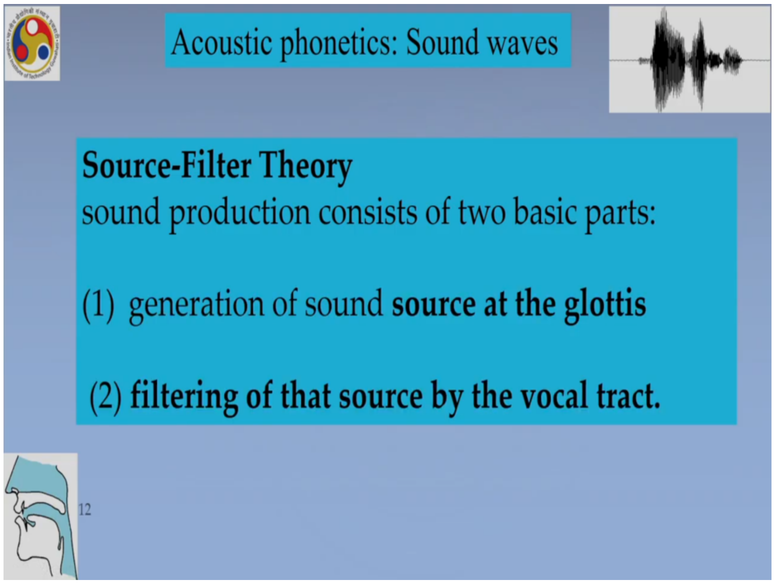

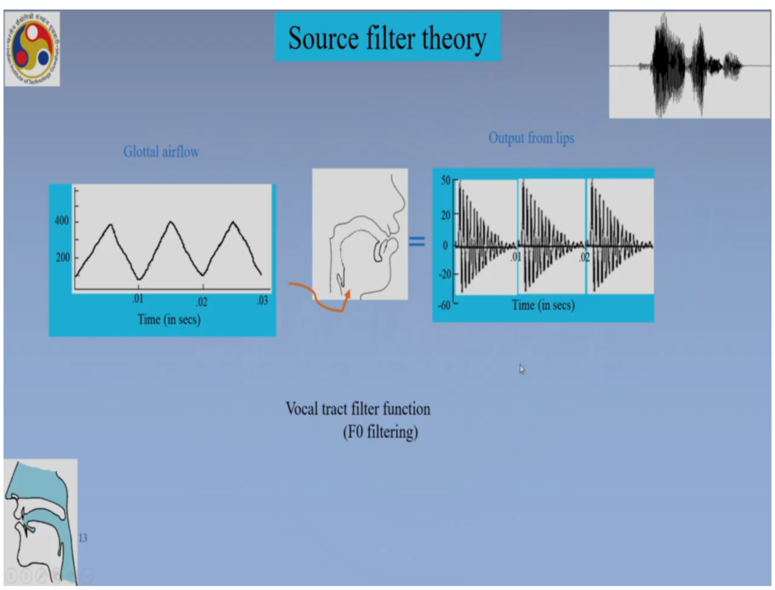

And we also studied about source-filter theory, how sound production consists of two basic parts: the generation and the filtering. And we saw how the glottal wave is filtered by the vocal tract and as a result we have the component frequencies, which are result of the filtering function of the vocal tract.

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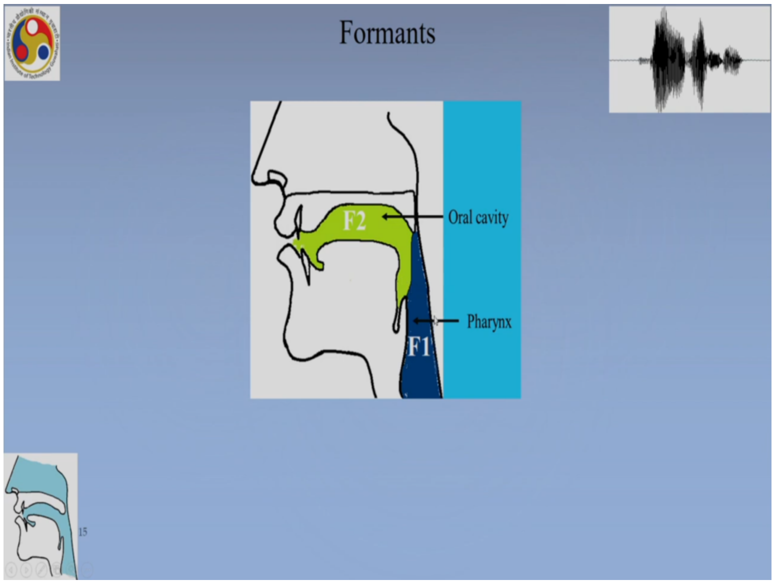

And these functions of the vocal tract the supraglottal space inside the vocal tract, which will give particular shape to the vowels. And especially formant 1, formant 2, first formants, second formant which are very important to the study of vowels.

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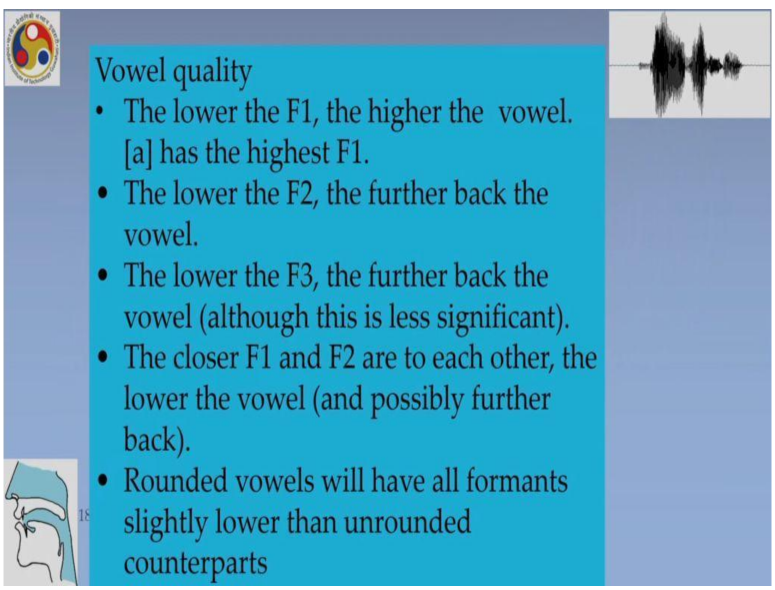

And finally this is what we studied that the lower F1, the higher the vowel; and has the highest F1. The lower the F2, the further back the vowel. So, if the vowel is very high, the F1 will be low; if the vowel is low, the F1 will be very high; and if the vowel is back, the F2 will be lower.

The lower the F3, the further back the vowel and although we knew; we do not use this consistently. And F1 and F2 closer to each other means that it is a low vowel, and also back vowel. Rounded vowels will have all formants slightly lower and then unrounded vowels. Now, we come to a manner of articulation.

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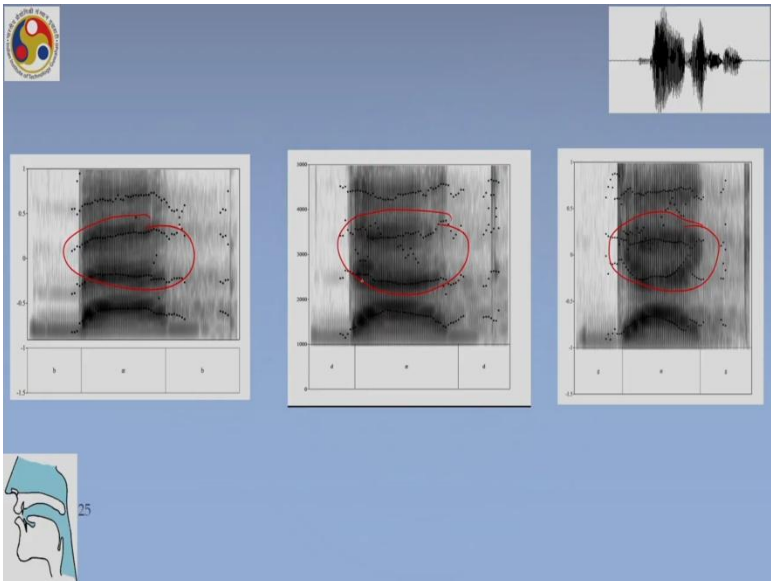

Let us see a few spectrograms before we talk about consonants. So, these are a few spectrograms which you see the formants marked there as black dots. And this is one which shows bab, this is one which shows dad, this is one which shows gag. And you see bab, dad and gag, put together you see that the formants of the same vowel are appearing differently in the vowel is the same. But, you can see that the shape of the formants are different. So, this is very significant for the study of consonants, so even though these formants belong to the vowels.

As we know now that this is the result of the vocal tract filtering function; that because of the resonance cavities, the individual the vowels will have particular formants. Now, we see something additional here that apart from the fact that the vowels will be given shaped by the vocal tract filtering. A particular consonant also changes the way the formants are appearing; they are not different formants. But, you can see the beginning and the end are different; now why is this so? So, this is this is the way we study spectrograms.

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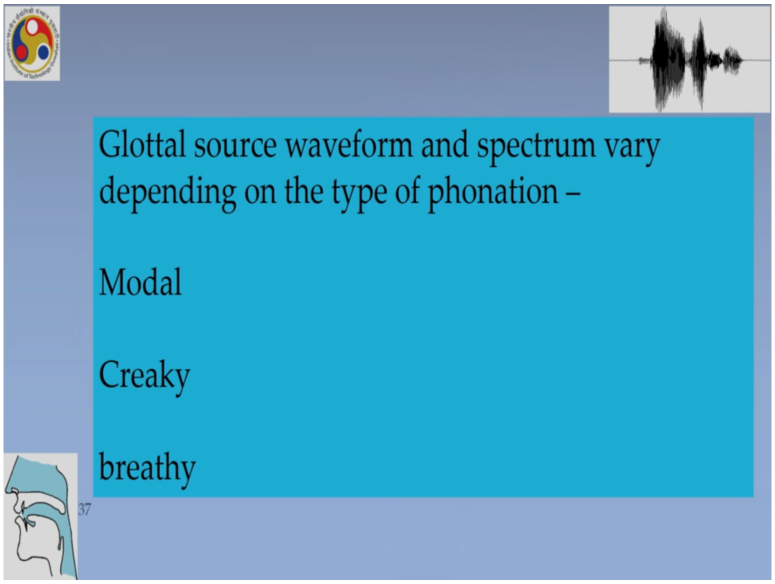

So, we have a lot of spectrograms to study, because we know a bit about the glottal source and filtering function. Let us now go thorough that a bit and go back to the vowel, the spectrograms that you saw and understand what is happening there. So, the glottal source waveform and spectrum vary depending on the type of phonation. We know that the glottal source can give a few characteristics to the sound; so it will depend on whether the sound is like a voice like aa; or it is creaky like uhh or if it is haa. So, all the three different sounds that you heard is not a function of the vocal tract filter; it is a function of the source.

However, as we know the sound, the filter gives a lot of other properties. The source gives a property of the periodicity like the difference between a voice and voice list, the periodicity. And there could be phonation differences like uh versus ah; so these are breathy versus creaky and versus modal that difference. Additionally, there could be other glottal effects and those are the properties of the source. And all everything else that you will see related to formants other properties given to the sound by the vocal tract filtering function.

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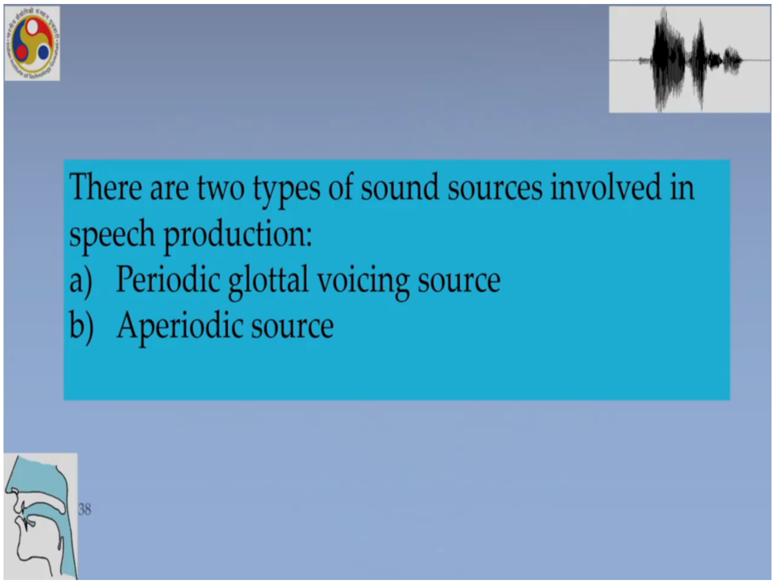

So, the sound source involved in speech production gives a periodic glottal voicing source, and also the aperiodic source can also be given by the source.

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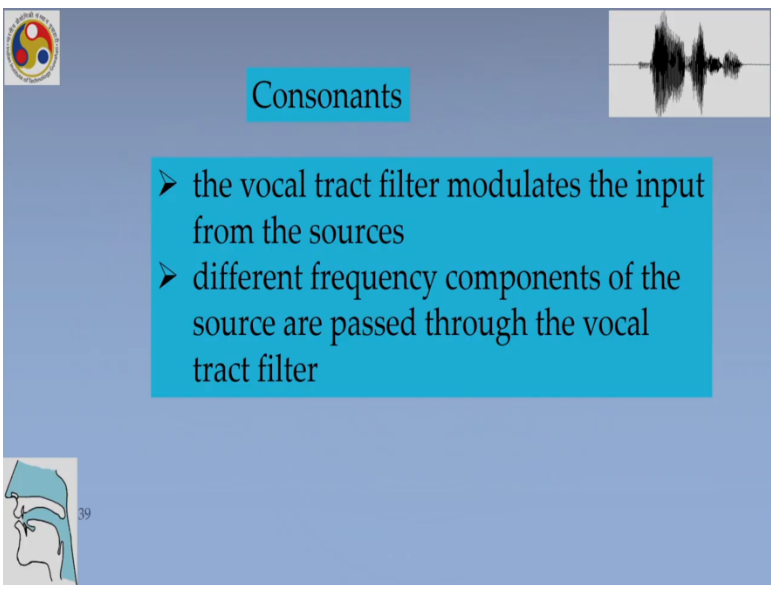

So, as we already know the vocal tract filter modulates the input from the sources and different frequency components of the source are passed through the vocal tract filter.

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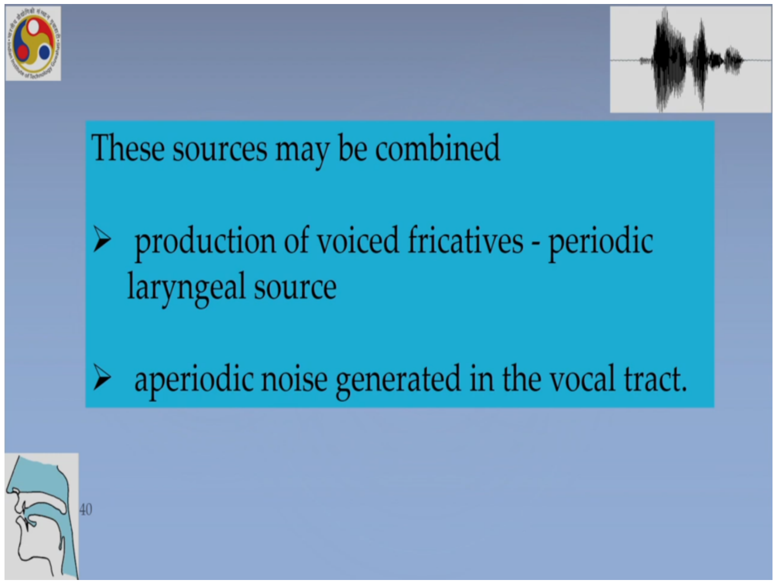

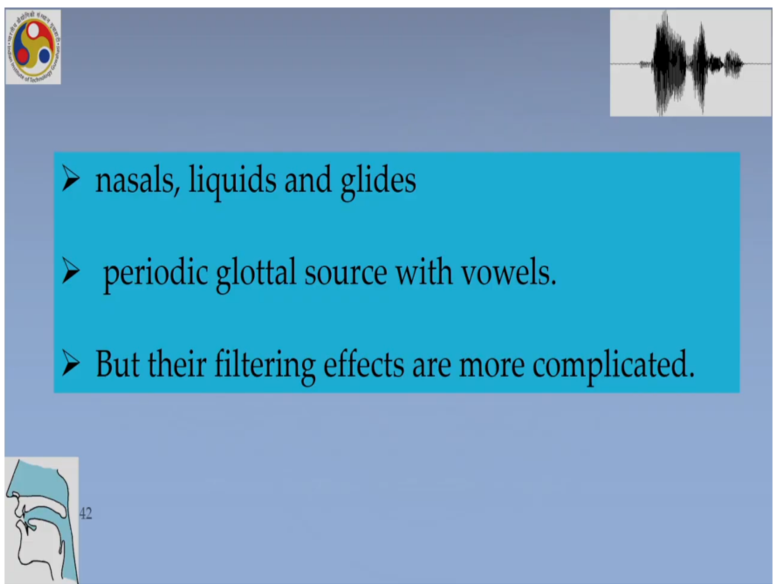

And importantly these sources maybe combined. So the production of voiced fricatives for instance, you have aperiodic laryngeal source; but, the aperiodicity is the result of the vocal tract. So, each sound may be a combination of the properties of the source and as well as the filter. So, for instance production of a voiced stop combines all the sources; and nasals, liquids, glides all of them include periodicity. So, the periodicity as we know comes from the glottal source; the filtering effects can be complicated in nasals, liquids and glides; we are again going to look at that.

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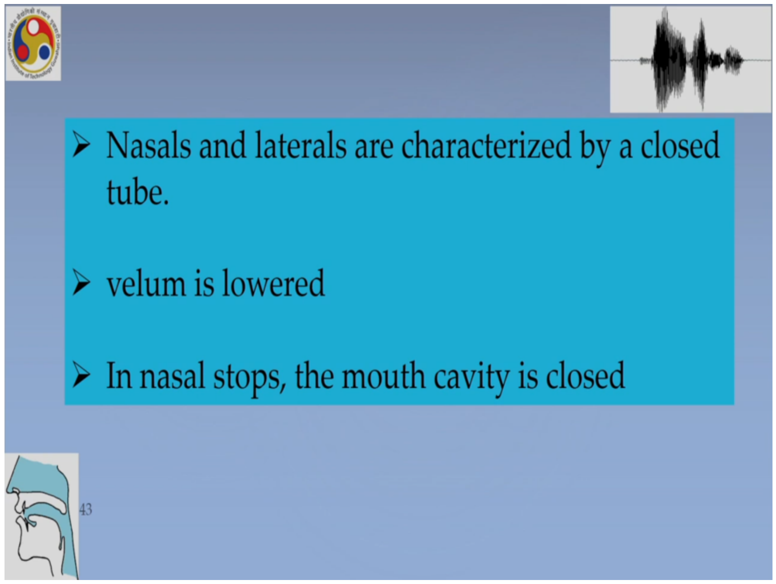

So, one important difference between nasal, laterals and vowels is that, while for vowels you have an open tube on one side. For nasals and laterals you have a closed tube; so for production of a nasal for instance, the mouth is entirely closed or releases through the nasal cavity. And all these properties of the filtering gives a particular property to the consonants. In nasal stops, the mouth cavity is closed; for laterals, we have the tongue tip closing at the region alveolar region if it is clear l. And you have released from both sides of the tongue.

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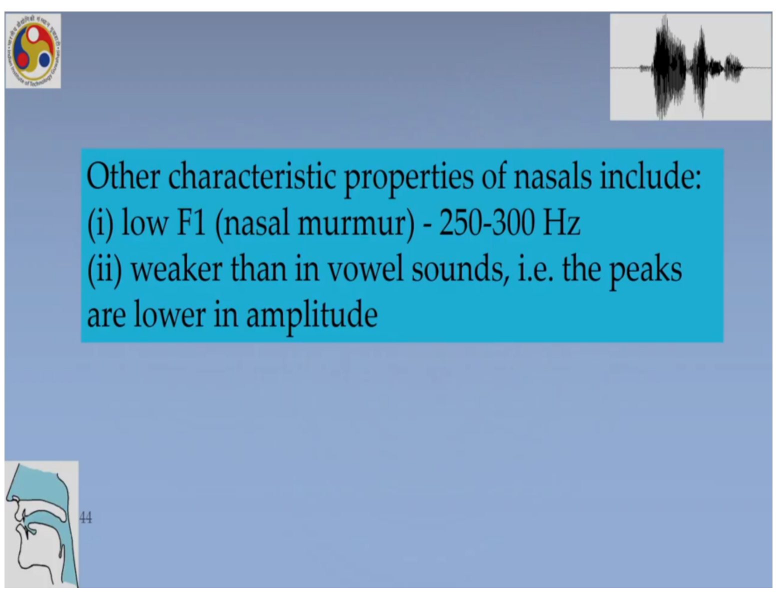

The vocal tract filtering gives very particular properties to the nasals, which you will see as low F1; and also very weak formants. Formants which are very low in amplitude; so which are not as dark as formants, as that we normally see. That happens because of the tissues inside the nasal cavity, which dampens the formants. And also with regard to stops the release burst maybe different, depending on the different consonants.

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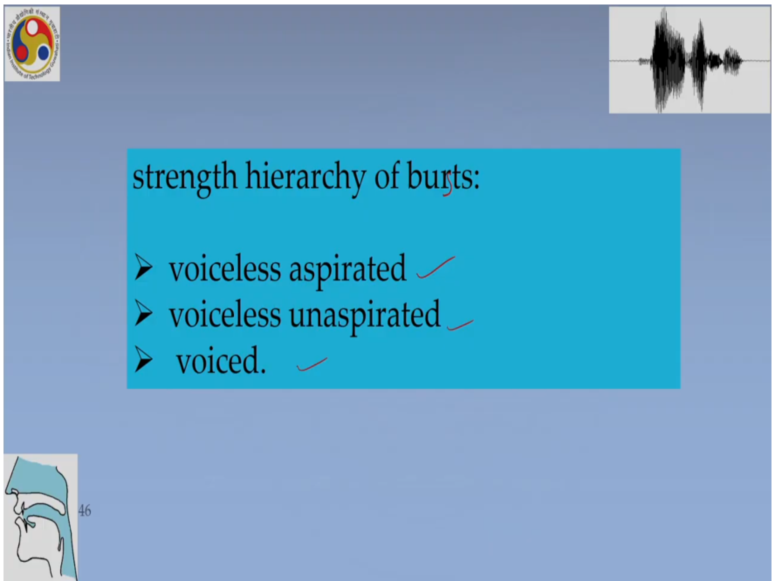

There could be a difference in the release burst. So, in voiceless aspirated the strength is the highest and then you have voiceless unaspirated, and you have the voiced. So, this is the strength hierarchy of release bursts in stop. So, another important property acoustic property of stops is the release burst. If we recall articulatory phonetics, we remember that this was a constriction that we saw in the production of the consonants. And this constriction reflects in the acoustic property as a release burst which we will see very soon.

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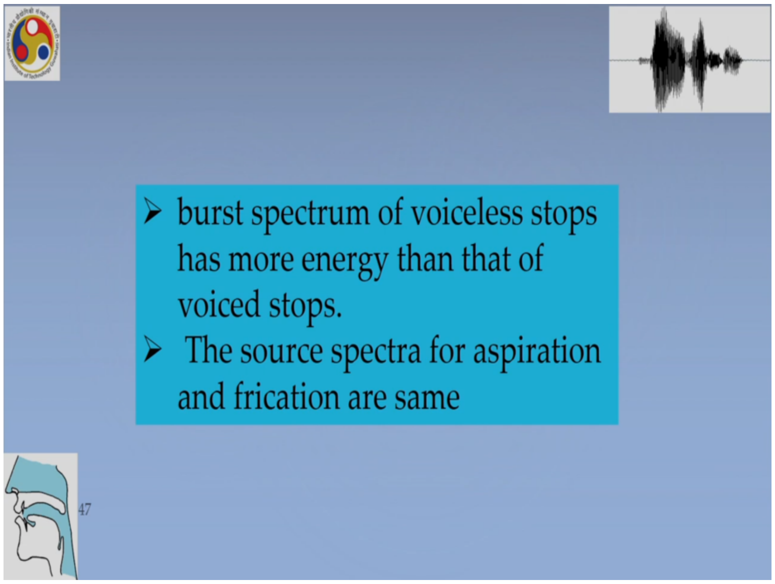

And also the burst spectrum of voiceless stops has more energy than that of voiced stops. And the source spectra for aspiration and frication are the same; so for both fricatives and aspiration, the source is the same. And we will see that how that extra puff of air shows up in fricatives and stuffs. Now, we saw a bit about the source and filtering effects in consonants; now, let us see the spectrograms themselves.

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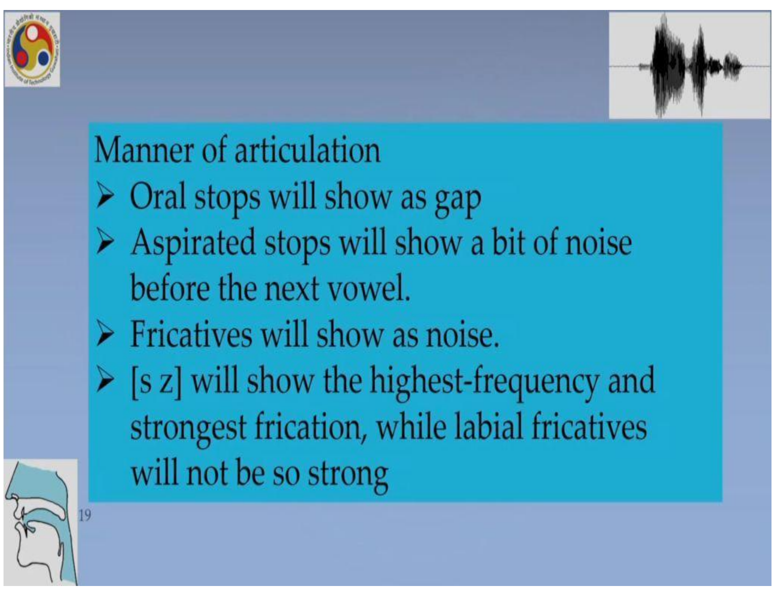

Now, couple of things that you will remember when we look at these spectrograms; it is important to remember that oral stops will show up as a gap. So, it is a stop, there will be period of silence. If the aspirated stops will show a bit of noise before the next vowel; fricatives will show noise. And also s z will show highest frequency and strongest frication noise, while labial fricatives will not be so strong; so, these are things that you have to remember. Oral stops period of silence, fricatives will show a period of noise; and also depending on the fricatives s z versus sh.

Where, you have the strongest noise, strongest frication; that will determine the difference between two fricatives. s z will be different from sha z and s.

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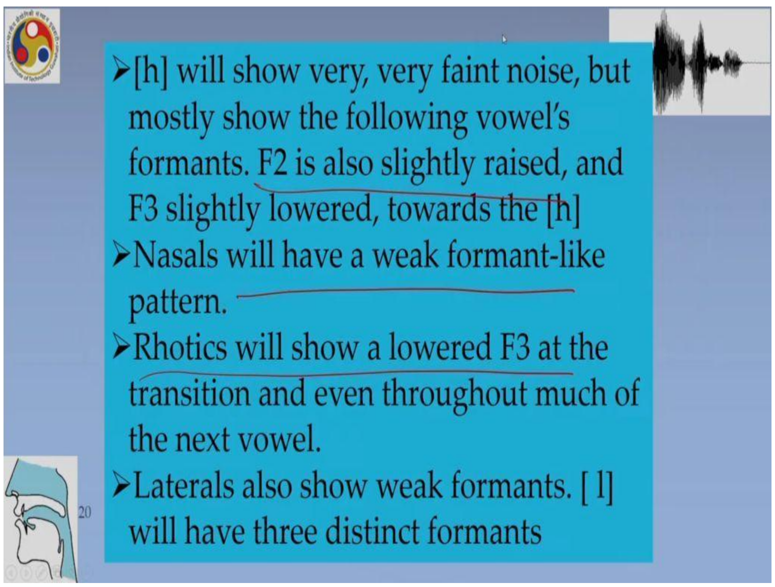

And then other consonants like h, for instance will show very faint noise; but mostly show the following vowels formants. F2 is raised and nasals have weak formants and then have a formant-like pattern will see nasals. Rhotics will show a lowered F3 and laterals and formants will have will also show weak formants. So, we will see how this happens rhotics with lowered F3, and h with the F2 raised. And nasals with their weak formant pattern and this was manner of articulation; stops fricatives, approximants and place of articulation.

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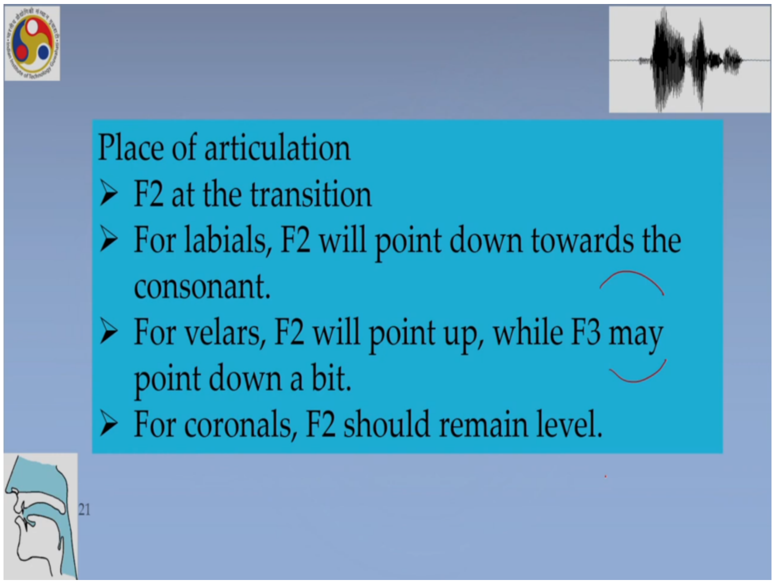

How do we know place of articulation? So, for labials F2 will be like this; for velars, F2 will be like this; for coronals, F2 maybe a level or something like that. So, this is how you will see the place of articulation.

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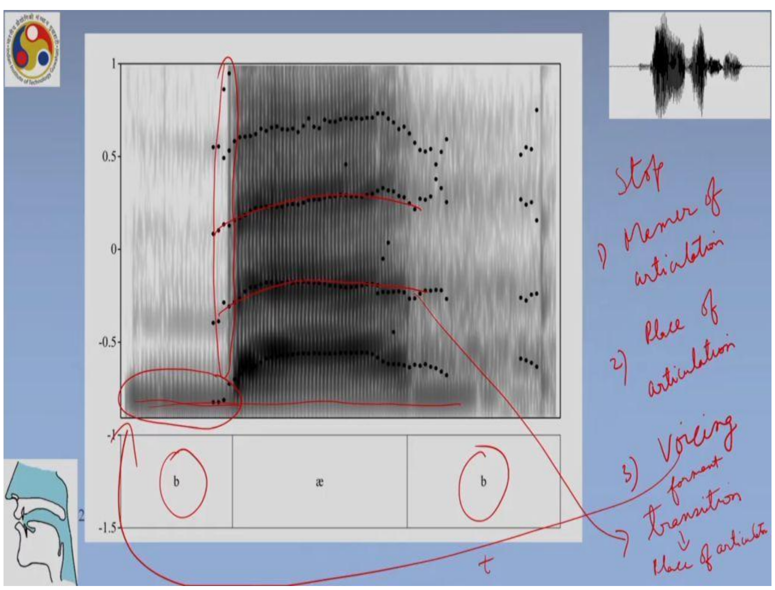

Now, we have gone through that background; let us look at actual spectrograms. So, this is a word that was produced by me bab; so look at the look at F2 and look at F3. So, recall two things manner of articulation, place of articulation; and also a third thing voicing. This is the way we had characterized the properties of sounds with regard to their articulation. Now, in acoustics how do we see these properties? What is the manner of articulation of a consonant like b; so it is a stop. Stop involved what do they involve complete closure and release; this is the burst spectrum that we are talking about, when it comes to stops.

The release is released as a burst here that you see; this burst as we just saw the bursts will be different depending on the different consonant type. So, for voiceless aspirate will have the strongest burst followed by voiceless stop followed by a voice stop. So, the release burst that you see here is not the strongest, when it comes to stops; but you still see a very distinct release burst. And after that what happens? What do you see in the spectrogram? This is called a voicing bar; you can see the periodicity. This part, where you see a dark band voicing band; it just shows us our voicing, this will be absent in a voiceless stop.

So, this will be a period of complete silence, but without this property there. And now we see the voicing, we see the release burst showing that it is a stop; third thing place of articulation. As we just talked about it, how do we see the place of articulation; this is called transition, formant transition which shows the place of articulation. The formant transition for a consonant like b, it starts low and goes down again; so, it is a it is a curve going down and both F2 and F3 are similar. Remember also that the consonant on both sides of this vowel are the same; so we have a mirroring effect here.

So, because the start of the consonant here is also b; we have a mirror image on this side. And remember that if the consonant suppose this was this consonant was a t here; this is not bab but bat. The transition here would not be exactly the same, because for different consonants we have different transitions. So, now we saw bab; now if we have to change these consonants; so if we change b to d, what did we change there? We change the place of articulation.

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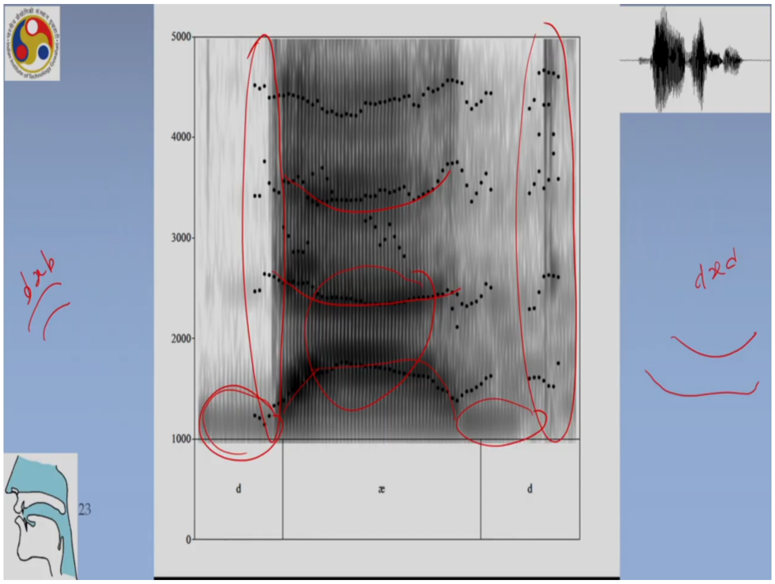

Everything else remains the same. So similarly, now we see see this here; here I included a bit of the release burst of of the following d as we. You can see the release here of the release burst spectrum of the d; and we also see that now how are these different. So, F2 now you can see is not like bab; it is level but it is going a bit up; F2 and F3 are like this in terms of that. Whereas, if you recall for bab, F2 and F3 were like this. So, now we can see that depending on the place of articulation, the F2 transition will change.

So, it is a very good giveaway of a different place of articulation. And this is how we most of the time can read a little bit from the spectrograms; the change the F2 transitions, the burst spectrums, the periodicity. So, again d is a voice consonant, so d and b the difference between d and b is in their place of articulation; b is labial, d is coronal. How does it show in the acoustics here? We can see that the transition is different with regard to F2. And again we see a period of a gap where nothing happens; and that is because this is a stop and then we see a final release.

So, again place of articulation is shown by the F2 transition; F2, F3 are different from bab. Manner of articulation, we see a stop release burst spectrum here; voicing is shown by this voicing bar. So, the three things here are crucial to understanding the consonants and vowels here. You might ask the question that what happens, so do the formants themselves change because of transition. So, it is it is only the beginning part which is changing though; the rest of the part is called the stable part, which is essentially the same in both the cases because the stable part does not change; it is only a transition which is different showing that they have different places of articulation.

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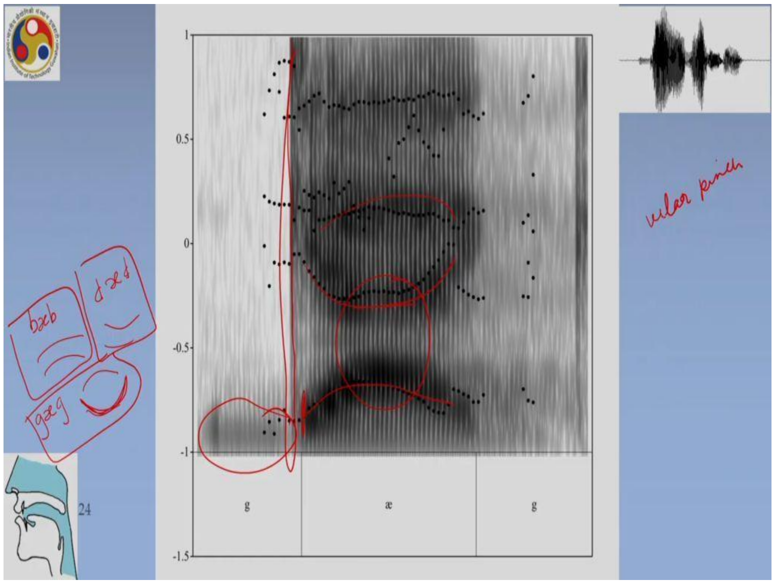

Again let us see a third one, so in English we have velar consonant g. What happens in the velar case? We see that something called the velar pinch. Velar pinch involves a very prominent unlike that of the; this is very prominent F2, starting with a very high in a very high position going down. So, and F3 might have this shape where it is it comes close to the F2 from the other direction. This type of a transition is called the velar pinch and very often for velar consonants, you will see this. This F2 starting very high and then going down and then F3 sort of stable, and not this a very sharp fall from starting very high.

So, this is about velars, so you can see again we have stable state though; even though we have a velar, we have a stable state for the formants here. And similarly again we see burst release spectrum before the start of the actual performance; we see a strong burst spectrum, and we have a voicing. You have periodicity here, which shows curve is a voiced consonant; and then we have this burst spectrum.

Again so if we are to recall what we saw till now with regard to F2, F3 for these three consonants. One bilabial, one coronal and one velar is that the F2-F3 transitions can be very different for it can be like this, it can be like this; it can be like this with a very sharp fall and rise for velar consonant.

So, this was we saw that this was for bab, this was for dad, this was for gag. So, we can see now that place of articulation can be seen to a great extent in formant transitions. So, even though the formants by themselves actually are representative of the vowels; but the way they transition from one position to another. Those give us a cue with regard to a lot of other things like place and manner of articulation.

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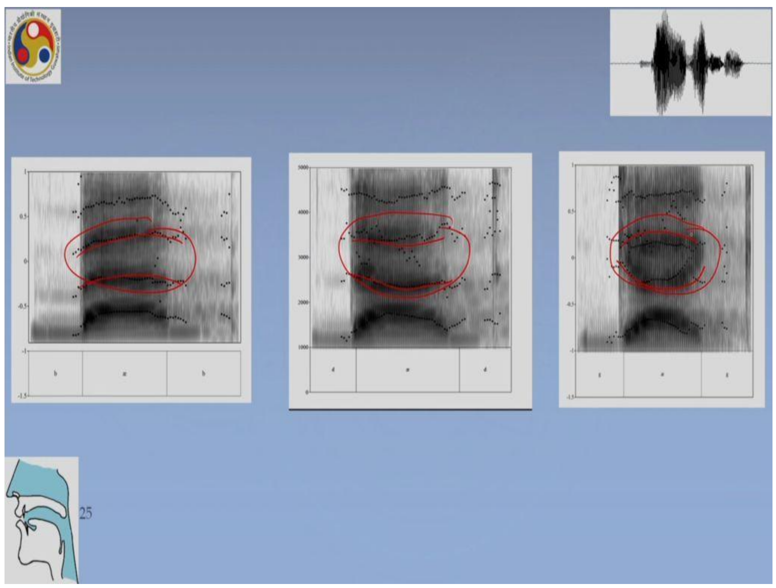

So, here is where we have compared the F1, F2, F3; F2, F3 of these three different.

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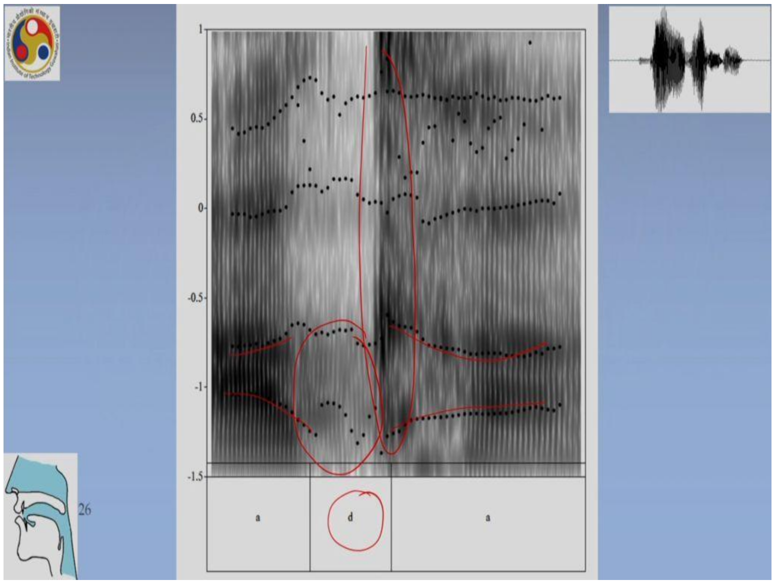

Again to show you how these things maybe different in different context, we if we take the consonant in the middle between two flanked by two vowels. Again we see that we have a burst spectrum followed by the vowel; and again we have these transitions. So, from moving away from the consonantal position and again for starting the consonantal position; we have period of gap here showing that this is a stop and then release burst spectrum.

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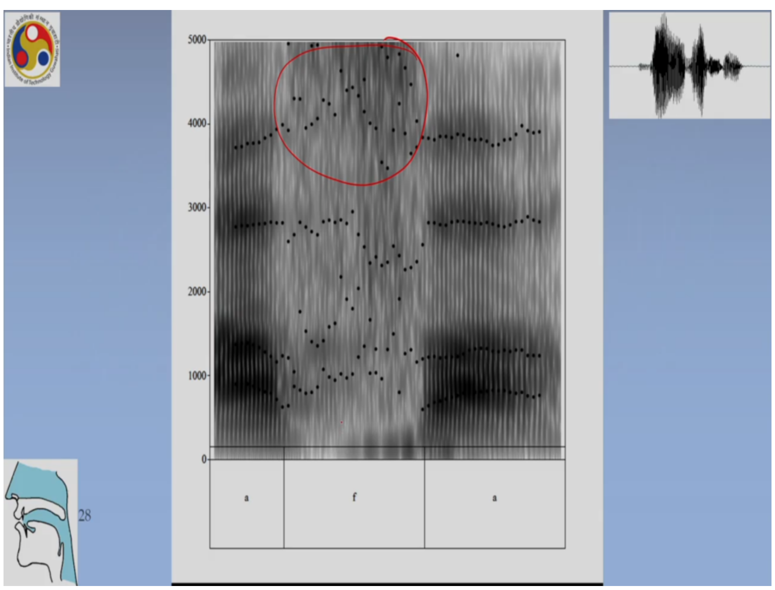

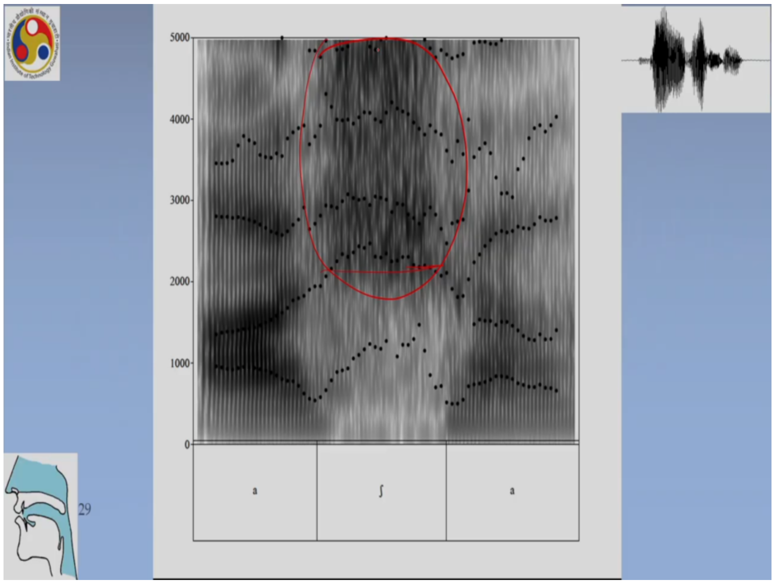

Similarly, for aba, again we have transitions, we have and then we have release burst spectrum which is not very strong. Now, let us look at fricatives and see how stops and fricatives can be different. As we said before fricatives are pre regions, where you see l affrication noise; so, we see a period of energy here.

And we do not see any release bursts as such, we just see places where you have some energy in the period of the noise; so, this is afa, this is asha. So, now we see that the noise starts much lower for fricative like sha; so it starts somewhere around 2000 although it goes up, but it starts quite low.

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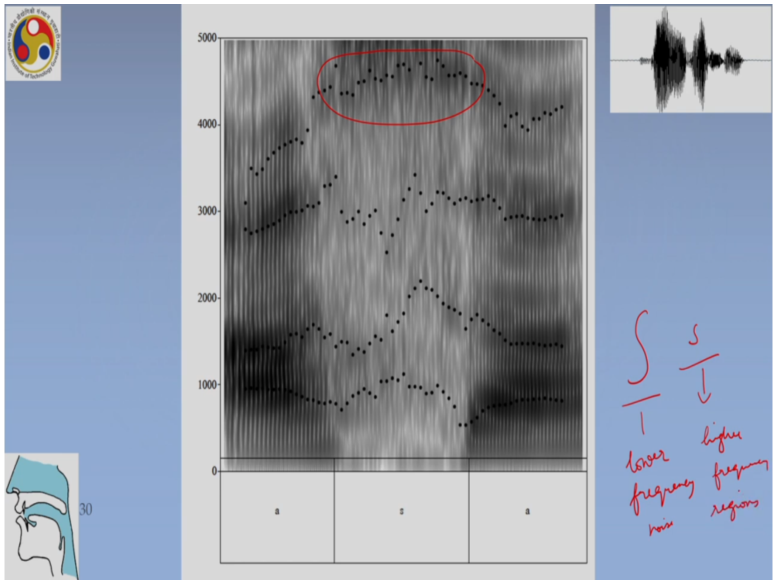

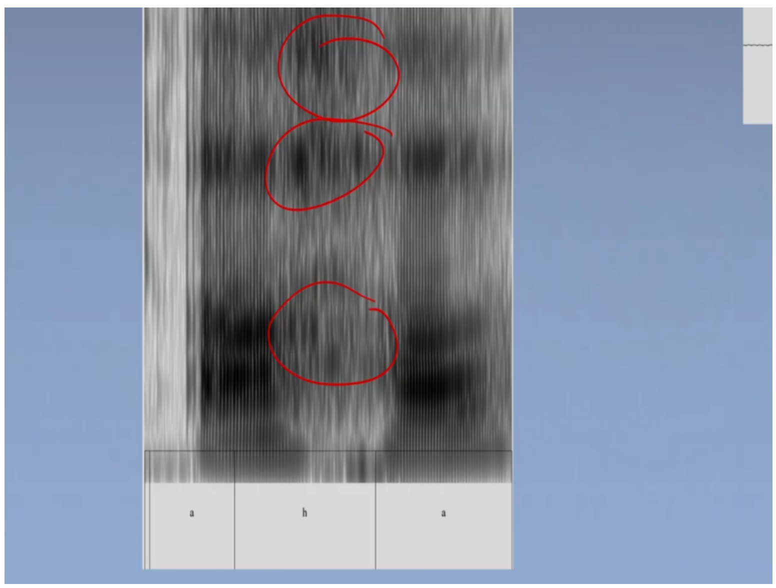

This is important because when you look at something like s versus sha differs in place of articulation. Two sibilants, one is sha, one is s; what do we see that in for sha, we have noise at much lower frequencies. So, lower frequency noise versus the s, where we see higher frequency at higher frequency regions.

Similarly, for s, again s is asa; here we have slightly higher then but more faint than s. So, as you can see if our fricatives the other important thing to note is that how strong are other frication regions. So, you can see that we have a lot of energy here, energy starts higher there; but we have very distributed sort of dispersed energy here for s.

And again now we move to ha aha. Now, important thing to remember about this fricative is that it will show frequency; it will sort of the frequencies of the vowels will sort of spread into them. So that is one characteristic of fricative like ha.

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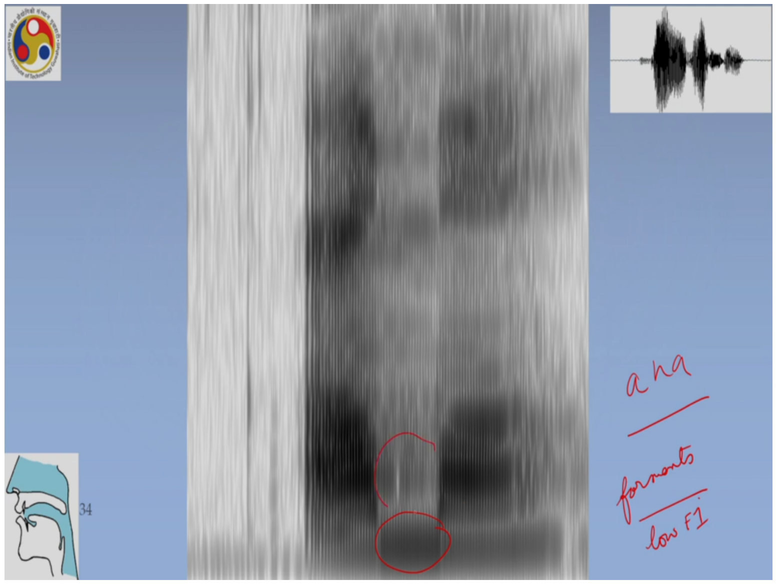

Now, we have few other fricatives, this is a nasal ana. Recall how we had talked about nasals having low F1; nasals will show properties like that of formants low F1. However, you can see that unlike the vowel, so you can see these dark regions formant regions in nasals; the formants will be very weak. So, that is how even though I have not transcribed this, you can easily see that this is nasal; because you can see a formant which is there. But, it is a very low F1, but again the formants are very dampened; so that is characteristic of nasals.

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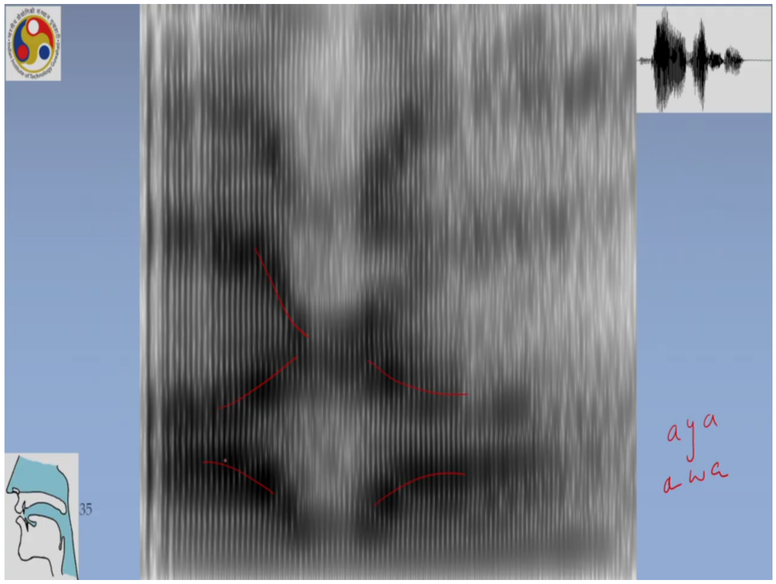

Now other consonants like semi vowels or aya, awa; so this is aya. One important property is that because of the glides, you will see these movements in the formants; especially F2, F3. So, F2 going high and F3 coming low; depends on whether it is aya, awa. This is aya, so the second one goes up and third one goes down. These are the properties of glides.