Acoustics of Percussive Instruments

by

Dr. K. Varadarangan
Classification of Musical Instruments (Traditional)

- **Tata (String)** - Eg: Veena, Violin, Mandolin
- **Sushira (Wind)** - Eg: Flute, Nagaswaram
- **Avanaddha (Percussion)** - Eg: Mrudanga, Tabla
- **Ghana (Solid bodied)** - Eg: Ghata, Nattuvanga (Tala)
- **Jala (Water)** - Eg: Jalatarang

*Classification is based on the function of the instrument.*
Classification of Musical Instruments
(Scientific: Sachs-Hornbostel)

- **Chordophones** (String)- Eg: Veena, Violin, Mandolin
- **Aerophones** (Wind)- Eg: Flute, Nagaswaram, Clarinet, Harmonium
- **Membranophones** (Sound is produced by vibrating membranes)- Eg: Mrudanga, Tabla
- **Idiophones** (Solid bodied)- Eg: Ghata, Nattuvanga (Tala), Gongs, Bells, Cymbals
- **Electrophones** - Eg: Electronic Keyboard, Theremin

Classification is based on the *mechanism* of sound production.
Membranophones

Sound is produced by a vibrating membrane.

Eg: Percussion Instruments such as Drums, Conga, Djambe, Darbuka, Mrudanga, Tabla, Tavil, Phakwaj

**Kazoo is a non percussion Membranophone.**
The Kazoo is a wind instrument that adds a "buzzing" quality to a player's voice when the player vocalizes into it. It is a membranophone – a device that modifies the sound of a person's voice by way of a vibrating membrane.
Membranophonic Percussion Instruments
Operating Principle

A thin membrane stretched and held under uniform tension produces a pitched sound analogous to a stretched string.
Common Examples-Western Music

- Tom Tom
- Snare Drum
- Kick Drum
- Tympani (for concert music)
Percussion Instruments of Other Countries

- Conga
- Djambe
- Doumbek or Darbuka
- Bodhran
- Bongo
- Tambourine
Examples of Indian Percussion Instruments

- Mrudanga
- Tabla
- Phakwaj
- Khol
- Tavil
- Kanjira
- Chande
The Tom Drum

- Batter head
- Rim or Counter hoop
- Tension rods
- Mounting hardware
- Lugs
- Resonant head
The Tom Drum

- It is played using two sticks.
- There are two heads: the top one is the Batter head and the bottom is the Resonant head.
- The Batter head is the one that is beaten by the sticks (hence the name “batter”).
- The Resonant head may be tuned to the Batter head’s pitch or set to a higher or lower pitch to produce a “pitch bend”.

The Drum Head

- It is the most important component of a drum.
- The material of the drum head is a polyester film.
- The film is attached to a circular hoop made of aluminum.
The Drum Head

- Made of single or multiple ‘plies’ (sheets).
- May have a centre ‘dot’ to reduce harsh overtones.
- Ply thicknesses vary too.
- Thinner plies produce more overtones and higher sustain whereas thicker plies produce more *attack*, lower sustain, and reduced overtones.
The Shell

- This is the body of the drum on which the drum heads are mounted.
- The shell is made of multiple ply wood sheets glued together or of a single thick sheet of wood bent into a circle using steam and joined at the edges with glue.
- Made of Maple, Birch, Luan, or African Mahogany.
- The Shell has a resonant frequency of its own that depends on the construction and shell dimensions.
- Shells may also be made of metal, fiberglass, or acrylic plastic.
The Snare Drum

This is similar to the Tom Drum but the Resonant head is mounted with a snare to produce a rattling snare sound. The snare is a ribbon-like structure made of metal wires.
The Kick Drum

The Kick Drum is a large drum used for producing bass sounds. It is hit by a soft mallet attached to a pedal, which is operated by the foot.
A Typical Western Drum Set

Includes Cymbals, Hi-Hat, Snare Drum, Kick Drum, and Tom Drum.
The Tympani is a large bowl shaped drum, which has a great sustained tone of distinct pitch. The diameters vary from 20” to 32”.

- The pitch can be varied at any moment through a pedal mechanism.
- It produces harmonic overtones!! (More on this later.)
Some Percussion Instruments of the World
The Conga is the Cuban hand drum, about 2.5 ft. tall and more than a foot in diameter.

Each drum has a single head.

It is a tunable instrument. The tuning mechanism involves threaded hooks that are tensioned via lugs attached to the shell.

Used in *Latin Music, Salsa, Reggae, and Popular Music.*
The Djambe

- It is an African hand drum originating from Mali.
- It is about 2 ft. tall and slightly larger than 1 ft. in diameter.
- It is a rope tuned instrument, but key tuned ones are also available.
The Doumbek (Darbuka)

- It is a hand drum used in Middle East, North Africa, and Eastern Europe.
- It is about 1.5 ft. tall and about 10 inch in diameter.
- It is a key tuned instrument and the shell is generally made of fiberglass or metal.
- This goblet drum may be played by holding it under one arm or by placing it sideways on the lap with the head towards the player's knees in seating position. The other end is open.
The Bongo

- It is an Afro-Cuban hand drum.
- The Bongo is always used as a pair. The larger one is called *Hembra* (female) and the smaller one is called *Macho* (Male).
- It is a key tuned instrument producing relatively high pitched sounds compared to the Conga drums and should be held behind the knees with the larger drum on the right side.
The Bodhran

- The Bodhran is an Irish frame drum, somewhat similar to the Kanjira.
- The diameter ranges from 10" to 26". The sides are 3½" to 8" deep.
- The other side is open-ended for one hand to be placed against the inside of the drum head to control pitch and timbre.
The Tambourine

- It is a frame drum with jingles, with or without a head.
- The word *tambourine* finds its origins in the French *tambourin*, which is a long narrow drum.
- They are used in Greek and Italian folk music, Classical music, Persian music, Rock music, and Pop music.
The Physics of Percussive Instruments
Two Broad Categories of Percussive Instruments

1. Instruments that produce inharmonic overtones
2. Instruments that produce harmonic overtones
Overtones and Harmonics

- In general, musical sounds consist of a fundamental frequency and a number of distinct higher frequencies known as overtones.
- A harmonic is an overtone whose frequency is an integral multiple of the frequency of the fundamental.
An Example

Let us say an instrument produces the following frequencies:

100 Hz – Fundamental (also called the first harmonic)
120 Hz – First overtone
149 Hz – Second overtone
200 Hz – Third overtone (and also the second harmonic)
245 Hz – Fourth overtone
300 Hz – Fifth overtone (and also the third harmonic)
Overtones and Harmonics

If the overtones are all harmonic (as in a periodic signal) then,

Overtone number = Harmonic number - 1.

Thus,

first overtone = second harmonic,
second overtone = third harmonic,
third overtone = fourth harmonic,
and so on.
Instruments with Inharmonic Overtones

Most instruments produce inharmonic overtones!!
These include all the instruments described earlier, except the Tympani.
Instruments that Produce Harmonic Overtones

- The Tympani
- Loaded Indian drums such as the Mrudanga, Tabla, Phakwaj, and Khol

Thus, the Tympani is the only non-Indian drum that produces harmonic overtones.
How the Tympani Produces Harmonic Overtones

Two main factors contribute to the harmonicity of the Tympani:
1. The special bowl-shaped shell
2. Influence of air pressure inside the closed shell
How Indian Instruments like Mrudanga &Tabla Produce Harmonic Overtones

These instruments have their vibrating membrane loaded, which increases the surface density (mass/unit area) at the central area of the membrane.

The centrally-loaded black patch not only imparts great sustain to the tone, but also modifies the inharmonic overtones into a harmonic series. (More on this later.)
Modes of Vibration of Unloaded Circular Drums

A mode of vibration is indicated by a pair of indices \((m, n)\). The integer \(m\) represents variation along the angular direction while the integers \(m\) and \(n\) together determine the variation along the radial direction.
Nodal Lines and Nodal Circles

- A node represents a point where the vibration is zero.
- A nodal line represents a straight line over which the vibration is zero.
- Likewise, a nodal circle denotes a circle over which the vibration is zero.
In this mode, the entire drum head vibrates such that there are no nodal lines or circles. This mode is designated as the (0,1) mode. This is the mode with the lowest frequency $f$.

Animation courtesy of Dr. Dan Russell, Grad. Prog. Acoustics, Penn State.
First and Second Overtones

- **The first overtone mode:** In this mode, the drum head vibrates such that there is one nodal line due to variations in the angular direction. This mode is designated as the (1,1) mode. The frequency of this mode is 1.593 f.

- **The second overtone mode:** In this mode, the drum head vibrates such that there are two nodal lines due to variation in the angular direction. This mode is designated as the (2,1) mode. The frequency of this mode is 2.135 f.

Animation courtesy of Dr. Dan Russell, Grad. Prog. Acoustics, Penn State.
Third and Fourth Overtones

- **The third overtone mode:** This mode is designated as (0,2). There is no variation in the angular direction but there is a nodal circle formed due to variation in the radial direction. The frequency of this mode is 2.29 f.

- **The fourth overtone mode:** This mode is designated as (1,2). The drum head vibrates in such a way that there is one nodal line and one nodal circle. The frequency of this mode 2.917 f.
Fifth and Sixth Overtones

- **The fifth overtone mode:** This mode is designated as (2,2). The drum head vibrates in such a way that there are two nodal lines and one nodal circle. The frequency of this mode is 3.5 f.

- **The sixth overtone mode:** This mode is designated as (0,3). There is no variation in the angular direction but there are two nodal circles formed due to variations in the radial direction. The frequency of this mode is 3.598 f.
Overtones of Unloaded Drums

If we now look at the frequency ratios of the first six overtones with respect to the fundamental, we find that they are of values 1.593, 2.135, 2.295, 2.917, 3.5, and 3.598. Thus, none of these overtones are harmonics of the fundamental. Even the higher order modes exhibit a similar inharmonic behavior.
Overtones of Unloaded Drums

When such a drum head is sounded, although there is a perception of pitch due to the presence of the fundamental, the sound appears tinny and rather unmusical. Thus drummers who play these instruments often use muffling rings or patches to reduce the intensity of these inharmonic overtones.
Assumptions in the Theoretical Model

The theoretical models are ideal approximations to the real world drums. Some of these approximations are:

- The membrane is perfectly elastic with zero stiffness.
- The membrane is thin, uniform in density, and tension is uniform at all points.
- There is no damping of vibrations.
- Effects of enclosed air or other coupling effects (as in a double-headed drum) are neglected.
With these approximations made, the theoretical solution for the modes of vibration involve the Bessel functions and the frequency of the \((m, n)\) mode is given by:

\[
 f_{mn} = \frac{j_{mn}}{2\pi a} \sqrt{\frac{T}{\rho}}
\]

where \(a=\)radius of the membrane, \(T=\)tension (N/m), \(p=\)mass per unit area, and \(j_{mn}\) is the \(n\)th root of the Bessel function \(J_m\).

Eg: \(j_{01}=2.4, j_{02}=5.52, j_{11}=3.83, j_{12}=7.02, j_{21}=5.14, j_{22}=8.42\) etc.
Chladni Patterns

Vibrations of real drums differ significantly from the theoretical models due to the simplifying assumptions made in the model.

When sand particles are sprinkled over a vibrating drum head, they settle down along the nodal lines and circles giving a visual display of the vibrational modes. Such displays are called Chladni patterns.
Acoustical Properties of the Mrudanga

Right drum head
- Karane
- Outermost membrane with cutout (Rappe)
- Middle (main) vibrating membrane
- Shell
- Innermost membrane
- Outer membranes with large equal sized cutouts
- Left drum head
- Threaded hooks
- Nuts
- Lugs
- Indige
- Inner annular ring
- Eyelets
## Pitched Sounds of the Mrudanga

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name of the stroke*</th>
<th>Method of playing*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Meetu (Nam)</td>
<td>Striking the rim at the edge of the drumhead with the forefinger while holding the Karane at rest at its outer edge with the ring finger. This is generally known as the Rim Stroke.</td>
</tr>
<tr>
<td>2.</td>
<td>Chapu</td>
<td>Striking the Karane forcefully with the little finger. The playing position is such that the little finger is placed to extend from the outer edge of the Karane towards the centre.</td>
</tr>
<tr>
<td>3.</td>
<td>Arachapu</td>
<td>Played forcefully using the little finger supported by other fingers along the diameter of the Karane towards the far end. This stroke elicits the Tarasthayi Shadja quite strongly.</td>
</tr>
<tr>
<td>4.</td>
<td>Dhim (or Dhin)</td>
<td>Played using the forefinger extending a little inwards from the outer edge of the Karane while holding the ring finger pressed down at a point at the outer edge of the Karane about 60 degrees away.</td>
</tr>
<tr>
<td>5.</td>
<td>Dheem</td>
<td>Played by striking the Karane at the centre with the forefinger and recoiling immediately. This stoke elicits the Suddha Rishabha above the tonic.</td>
</tr>
</tbody>
</table>

* The names of these sounds and the exact playing technique may vary from school to school.
The Mrudanga Produces Near Harmonic Overtones

- Indian percussion instruments such as the Mrudanga and Tabla produce near harmonic overtones!!
- This is based on the principle that a symmetrically loaded circular membrane is capable of producing harmonic overtones.
- This remarkable property of the Mrudanga is a tribute to the greatness of Indian music!
- It was Sir C.V. Raman who first observed that these instruments produce harmonic overtones.
Harmonicity of the Overtones of the Mrudanga

However, several studies have shown that Raman’s observation needs a correction.

While the higher order overtones form a nearly harmonic series, the fundamental is actually out of tune which is in contrast with Raman’s observations.

The ratio of the actual fundamental is about 1.07 times the required fundamental frequency and this corresponds to the Suddha Rishabha Ri₁.

The Dheem stroke corresponds to the mode (0,1) where the whole membrane vibrates as a single entity and its frequency is higher than the required fundamental, as suggested by the harmonic overtones.
Modeling the Mrudanga

- Prof. B.S. Ramakrishna’s theoretical model of the Mrudanga as a *composite membrane* clearly proves the harmonicity of the overtones with the exception of the fundamental that is a bit high.

- Rossing’s experimental studies on the Mrudanga have demonstrated how the inharmonic overtones of the Mrudanga gradually move towards their harmonic slots as the Karane is built up layer by layer.
How do we hear the correct pitch in the Mrudanga if the fundamental mode (0,1) is out of tune?
Two Effects that Facilitate the Perception of the Correct Fundamental

1. The phenomenon of missing fundamental
2. Dynamic spectrum of the Mrudanga
The Phenomenon of Missing Fundamental

- A sound is said to have a missing fundamental, suppressed fundamental, or phantom fundamental when its overtones suggest a fundamental frequency but the sound lacks a component at the fundamental frequency itself.

- The brain perceives the pitch of a tone not only by its fundamental frequency, but also by the periodicity implied by the relationship between the higher harmonics, so we may perceive the same pitch even if the fundamental frequency is missing from a tone.
Suppressed Fundamental

- When pitched sounds (other than Dheem) are produced, the fundamental corresponding the (0,1) mode is suppressed substantially.
- What we hear as the tonic Sa is actually a non-existing component that is perceived by the brain due to the presence of harmonic overtones. It is purely a psychoacoustic effect.
- For example when the Meetu is played, the Karane is held at rest at its outer edge. This suppresses the fundamental mode (0,1) as it requires that this point needs to move up and down for this vibrational mode.
Spectral Dynamics

In many of the stokes, the out of tune fundamental is present during the initial phase but rapidly decreases in intensity in relation to the other spectral components with time.

So we hear, in effect, the missing fundamental due to the presence of the higher order harmonics.
The Idea of the Suppressed Fundamental

- Perceived fundamental
- Diminished out of tune fundamental
- Third harmonic
- Second harmonic
- Fourth harmonic

Frequency
Degenerate Modes in the Mrudanga

Two modes are said to be degenerate if they produce the same frequency. In the case of the Mrudanga, the following are degenerate among the first nine modes:

- Mode (0,1) corresponding to the lowest mode of vibration that produces a slightly out of tune fundamental at Ri₁, the Dheem sound.
- Mode (1,1) with one nodal diameter. This mode produces the second harmonic (Tarasthayi Sa) with a ratio of 2:1 to the perceived fundamental and is elicited strongly by the Arachapu stroke.
- Mode (0,2) with one nodal circle and mode (2,1) with two nodal diameters produce the third harmonic with respect to the perceived fundamental.
- Mode (1,2) with one nodal circle and one nodal diameter and mode (3,1) with three nodal diameters are all degenerate and they produce the forth harmonic.
- Mode (0,3) with two nodal circles, mode (2,2) with two nodal circles and one nodal diameter and mode (4,1) with four modal diameters. These modes produce the fifth harmonic.
Experimental Observations

A standard G-pitch Mrudanga is chosen for the experiment. This is a good quality concert Mrudanga made of Jack wood shell. The instrument was tuned to pitch G and the acoustic spectrum is observed on the computer using the Visual Analyzer 2011 software.
### Spectrum of Dheem

![Spectrum graph]

<table>
<thead>
<tr>
<th>Spectral component</th>
<th>Observed value (Hz.)</th>
<th>Ratio with reference to the second harmonic taken with the ratio 2:1</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental</td>
<td>214.7</td>
<td>1.07</td>
<td>Very prominent</td>
</tr>
<tr>
<td>Second peak</td>
<td>395</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Third peak</td>
<td>579.6</td>
<td>2.93</td>
<td>These may be degenerate peaks</td>
</tr>
<tr>
<td></td>
<td>590</td>
<td>2.99</td>
<td></td>
</tr>
<tr>
<td>Fourth peak</td>
<td>791</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Fifth peak</td>
<td>970.2</td>
<td>4.91</td>
<td>These may be degenerate peaks</td>
</tr>
<tr>
<td></td>
<td>990.0</td>
<td>5.01</td>
<td></td>
</tr>
</tbody>
</table>

General remark: The out of tune fundamental is very strong resulting in the *swara*, *Suddha Rishabha*. Other spectral components are at least 200 times smaller than the fundamental.
Spectrum of Meetu

<table>
<thead>
<tr>
<th>Spectral component</th>
<th>Observed value (Hz.)</th>
<th>Ratio with reference to the second harmonic taken with the ratio 2:1</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental</td>
<td>209.6</td>
<td>1.06</td>
<td>8 times smaller than the third harmonic</td>
</tr>
<tr>
<td>Second peak</td>
<td>395.2</td>
<td>2.0</td>
<td>Fairly strong</td>
</tr>
<tr>
<td>Third peak</td>
<td>585.8</td>
<td>2.96</td>
<td>Very strong</td>
</tr>
<tr>
<td>Fourth peak</td>
<td>779.0</td>
<td>3.94</td>
<td>Moderately strong</td>
</tr>
<tr>
<td>Fifth peak</td>
<td>980.3</td>
<td>4.96</td>
<td>Moderately strong</td>
</tr>
</tbody>
</table>

General remark: Third harmonic is very strong. The out of tune fundamental is somewhat over shadowed by the perceived fundamental, suggested by strong harmonic peaks.
Spectrum of Arachapu

<table>
<thead>
<tr>
<th>Spectral component</th>
<th>Observed value (Hz.)</th>
<th>Ratio with reference to the second harmonic taken with the ratio 2:1</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental</td>
<td>210.4</td>
<td>1.08</td>
<td>Strongest of all harmonics</td>
</tr>
<tr>
<td>Second peak</td>
<td>390.4</td>
<td>2.0</td>
<td>Strong</td>
</tr>
<tr>
<td>Third peak</td>
<td>590.1</td>
<td>3.02</td>
<td>Strong</td>
</tr>
<tr>
<td>Fourth peak</td>
<td>788.9</td>
<td>4.04</td>
<td>Moderately strong</td>
</tr>
<tr>
<td>Fifth peak</td>
<td>969.4</td>
<td>4.97</td>
<td>Moderately strong</td>
</tr>
<tr>
<td>Sixth peak</td>
<td>1186.9</td>
<td>6.08</td>
<td>Moderately strong</td>
</tr>
<tr>
<td>Seventh peak</td>
<td>1381.2</td>
<td>7.08</td>
<td>Moderately strong</td>
</tr>
</tbody>
</table>

General remark: Fundamental is the strongest. Second and third harmonics are also strong. A large number of strong near harmonic overtones are elicited. How then do we perceive the correct fundamental and a pronounced second harmonic (Tarasthayi Shadja)? The answer lies in the dynamic nature of the spectral components. (We will see this later.)
Spectrum of Dhim

<table>
<thead>
<tr>
<th>Spectral component</th>
<th>Observed value (Hz.)</th>
<th>Ratio with reference to the second harmonic taken with the ratio 2:1</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental</td>
<td>211.7</td>
<td>1.08</td>
<td>Strongest of all harmonics</td>
</tr>
<tr>
<td>Second peak</td>
<td>393.0</td>
<td>2.0</td>
<td>Strong</td>
</tr>
<tr>
<td>Third peak</td>
<td>581.8</td>
<td>2.96</td>
<td>Strong</td>
</tr>
<tr>
<td>Fourth peak</td>
<td>788.9</td>
<td>4.04</td>
<td>Moderate</td>
</tr>
<tr>
<td>Fifth peak</td>
<td>978.2</td>
<td>4.98</td>
<td>Weak</td>
</tr>
<tr>
<td>Sixth peak</td>
<td>1181.7</td>
<td>6.01</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

General remark: Fundamental is the strongest. Second and third harmonics are also strong. A large number of moderately strong near harmonic overtones are elicited. How do we perceive the correct fundamental here? Again, the answer lies in the dynamic nature of the spectral components. (We will see this later.)
### Spectrum of Chapu

![Spectrum of Chapu](image)

<table>
<thead>
<tr>
<th>Spectral component</th>
<th>Observed value (Hz.)</th>
<th>Ratio with reference to the second harmonic taken with the ratio 2:1</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental</td>
<td>209.6</td>
<td>1.06</td>
<td>Moderately strong</td>
</tr>
<tr>
<td>Second peak</td>
<td>394.6</td>
<td>2.0</td>
<td>Strongest</td>
</tr>
<tr>
<td>Third peak</td>
<td>582.5</td>
<td>2.95</td>
<td>Strong</td>
</tr>
<tr>
<td>Fourth peak</td>
<td>787.8</td>
<td>3.99</td>
<td>Strong</td>
</tr>
<tr>
<td>Fifth peak</td>
<td>987.2</td>
<td>4.00</td>
<td>Weak</td>
</tr>
<tr>
<td>Sixth peak</td>
<td>1192.4</td>
<td>6.04</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

General remark: Fundamental is somewhat subdued. Second harmonic is the strongest and third is also subdued. A large number of fairly strong near harmonic overtones are elicited. In general the even harmonics appear to be stronger as compared to the odd harmonics.
How is the Chapu Produced?

The Chapu is one of the most important sounds of the Mrudanga and gives it a very distinct “crackling” sound. How is this cracking sound produced?
The Chapu is a Result of a Make and Break Contact Process

The pieces of broom stick play a very important role in the production of this sound. When the main membrane and Rappe are appropriately tensioned and struck, and if the conditions are favorable, the two membranes start vibrating together. During a certain phase of the vibration, they come together and move apart in another phase. The broom stick pieces play the role of spacers and facilitate these vibrations. During the phase the two membranes move apart, they vibrate freely and produce maximum sound. During the phase they come close, they collide with each other, with the sticks acting like brakes to stop the sound. This reduces the sound intensity considerably. However, the vibrations do not stop completely because of the momentum of the membranes. In the next instant, they again move apart producing sounds of higher intensity. This concept is illustrated below:

Phase when the two membranes are moving apart. This produces strong un-hindered vibrations.

Phase when the two membranes are moving closer. As the two membranes approach each other, the sticks provide a braking action stopping the membranes from vibrating for a short while.
Waveform of Chapu

It can be clearly seen that after the Attack phase, the amplitude of vibration varies in a cyclical fashion while generally decreasing in an exponential pattern. This amplitude modulated sound gives us a perception of the distinct Chapu sound of the Mrudanga.
Overtones in the Tamboora Due to the *Jivala*

It must be mentioned here that the Chapu is a result of the “make and break” contact process of the vibrating membranes similar to what happens in a *Tamboora* due to the *Jivala* thread. Dr. B.C. Deva, in his book ‘Psychoacoustics of Music and Speech’ notes that in the Tamboora, the vibrating string hits the bridge and stops momentarily during such times. This gives rise to a number of overtones, many of them being harmonic. That is the reason for the rich tone of the Tamboora.
Dynamic Nature of Spectral Components

Spectrum of Dhim

Original spectrum  Spectrum taken after a small time delay
The Fundamental Decays Rapidly

It can be clearly seen that the out of tune fundamental has decreased 10 times at this point in time. This difference will get further accentuated with the passage of time until all components decrease to inaudible levels. A similar behavior is observed in the case of other pitched sounds as well. Thus we perceive the correct fundamental in each case except in case of Dheem where the fundamental is much stronger than the other components.
Conclusion

- Unloaded drums produce inharmonic overtones.
- Loaded drums such as the Mrudanga and Tabla produce harmonic overtones but the fundamental is slightly out of tune.
- The Tympani appears to be the only Western percussion instrument that produces harmonic overtones.
- The Mrudanga produces an “out of tune” fundamental that approximates the swara Suddha Rishabha. This is clearly heard in the Dheem stroke.
Conclusion

- The perceived fundamental is due to the psychoacoustic effect of the suppressed fundamental.
- In some strokes, the fundamental is excited strongly in the beginning but decays rapidly with time in relation to other frequency components and hence remains unnoticed.
- The Chapu is an amplitude modulated sound resulting from the make and break contact of the Rappe with the main vibrating membrane.
- This is analogous to the Jeevala effect as in a Tamboora.
THANK YOU