

Spectral analysis of Indian musical notes

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Music forms an important part of Indian culture. It is believed that Indian music originated from the *Samaveda*. It is now available in two forms, the Hindustani and the *Carnatic*. There is a lot of information concerning the technical aspects of musical renditions, but hardly any information on the sound aspect.

In this paper, attempts made to study the spectral aspects of Indian musical notes, particularly the *Carnatic* music has been discussed. Recordings were made of these seven notes of the classical music using three male and three female voices. The analysis of the waveforms using the appropriate software yielded the energy, frequency and time spectra, helping in identifying the formants of the signals which in turn define the signatures of the sound pattern.

Keywords: Musical Notes, Indian Music, *Carnatic* Music, Classical Music, Spectral Analysis.

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The characteristics of the sound spectrum of the *Omkaara Mantra* along with its constituent sounds of A, U and M have recently been reported¹. The *Omkaara* is one of the holiest sounds of the Vedic heritage and is an integral part of all Vedic rituals². It has now become widely known around the world and is regularly being used as a part of meditation process.

Another important contribution of Indian heritage is its classical music. During the last half-century, it has also become quite well known around the globe. A systematic study of the technicalities of the musical form from the point of view of musical renditions has been taken up. However, a study of the sound patterns themselves from the point of view of their spectral characteristics has not attracted the attention of the scientific community. This report, a preliminary attempt in this direction is expected to lead to detailed investigations.

Indian classical music has a hoary tradition. Its origins are shrouded in mystery. Traditionally, it is believed to have originated from the *Samaveda*. Vedas are four in number – the *Rigveda*, the *Yajurveda*, the *Samaveda* and the *Atharvaveda*. Of these, the *Rigveda* is the oldest consisting of hymns addressed to various godheads, composed by

sages, called Rishis about whom very little is known historically. These hymns form the *Mantra or Samhita* portion of the Rigveda.

The *Samaveda Samhita* consists essentially of the same hymns as the *Rigveda Samhita* but makes use of elaborate and ornate singing techniques based upon a scale of seven notes. The other *Vedic Samhitas* generally make use of three or five notes but the *Samaveda Samhita* makes use of the full scale of seven notes which later got reorganized into the standard notes of the classical tradition, viz. sa (*shadja*), ri (*rshabha*), ga (*gandhara*), ma (*madhyama*), pa (*panchama*) dha (*dhaivata*) and ni (*nishada*)³⁻⁴.

With the passage of time, Indian classical music got split into two branches – the *Hindustani* and the *Carnatic*. This appears to have occurred around seven hundred years ago⁵. Even though the two systems appear today to be almost independent of each other both of them owe their origin to the seven notes or *Saptaswara* of the *Samaveda*.

There are a large number of text books available on both systems. There are also scholarly tomes written by musicologists about the technical intricacies involved. But, there has been no systematic investigation into the nature of the basic notes themselves and their sound patterns as is available for western classical music. Since the time of Lord Rayleigh, there has been a lot of investigation into the sound patterns of the English alphabets and the western classical musical notes⁶. Corresponding studies on Indian musical notes have not been undertaken systematically. An attempt has been made using more or less the same techniques as adopted earlier¹ to study on the spectral characteristics of these seven musical notes.

Methodology

The experimental procedure consists of the following steps: (1) recording of the musical notes with the use of a sensitive microphone (2) digitizing the analog wave forms with the help of a computer using a sampling rate of 44100 per second (3) analyzing the digitized data to get information about the energy – frequency and frequency – time spectra and (4) identifying the predominant frequencies and formants. The procedure for recording was essentially the same as described earlier¹. Here also, experts from outside institutions vetted the quality of the signals.

The recording was done for a total of ten male and female voices for both ascending and descending scales. Two inclusion criteria were used – the steadiness of the voice and the perfection of the notes. Based on these criteria, four voices were eliminated. The rest of the six voices, three male and three female were then used for analysis only for the ascending scale since the variation of these voices for the ascending and the descending scales was hardly noticeable.

The ascending musical scale was that used in *Carnatic* music based on Raga *Mayamalavagowla*. The number of musical notes available for study was 42, half for the male voices and the other half for the female.

Observations

The wave forms for the seven musical notes for the six voices formed the raw data, which can be processed to yield the following information:

- (a) Short time window patterns of the waveforms usually of 100 millis displaying the periodic nature of the signals.
- (b) Energy – frequency spectra for all notes and voices displaying the energy distribution among the various harmonics and sub harmonics.
- (c) Frequency – time spectra for all cases complementing the energy – frequency spectra.
- (d) Predominant frequencies and their sub harmonics for all cases.

The total number of figures arising out of the analysis, works out to 111, with 6 wave forms, 21 short time window patterns, 42 energy – frequency spectra and 42 frequency – time spectra. All conclusions drawn have been based on the analysis of all these figures. Only a few representative ones are given here.

The wave forms for a male voice are given in fig. 1 and those for a female voice in fig. 2. The 100 millisecc window amplification of the signal for “sa” is shown in fig. 3 for a male and a female voice. The energy – frequency for the first four notes for a male voice are given in fig. 4 - 7 and the same for a female voice for the last three notes – in fig. 8 -10.

The most important figures from the point of view of the analysis are the frequency – time spectra. The spectra corresponding to the fig. 4-10 are shown in fig. 11 and 12. As mentioned earlier, these are only samples of the total information available.

Discussion

The raw data for the analysis are the waveforms as recorded directly with the help of the appropriate Sound Forge software. Several trials were conducted before selecting the reliable waveforms for further analysis.

Musical notes are expected to be highly periodic as compared to noise. The analysis of noise requires stochastic methods which follow their own methodology. On the other hand, analysis of periodical signals is a much simpler affair. Therefore, it was felt necessary that the current waveforms should be checked for periodicity. Short time windows of the waveforms were selected and amplified. It was seen that in all cases

the amplified signal displayed periodicity (Fig.3). Hence, it was felt that stochastic analysis was called for.

The energy – frequency spectra indicate the distribution of the energy of the wave form among the various frequencies of the periodic signal. The lowest frequency is the fundamental frequency and the higher ones are the sub harmonics. These frequencies are also called “formants”. It is seen from all the spectra that the energy expressed in terms of decibels decreases with increasing frequencies. Since the spectra (Fig. 4 - 10) use the logarithmic scale, it is easy to estimate the frequency at which the energy falls to 1% of its value at the fundamental frequency. This helps us in identifying the effective formants.

The identification of the sound is based upon the number of formants. The first formant is a characteristic of the voicebox of the reciter. The higher formants constituting the sub harmonics represent the characteristics of

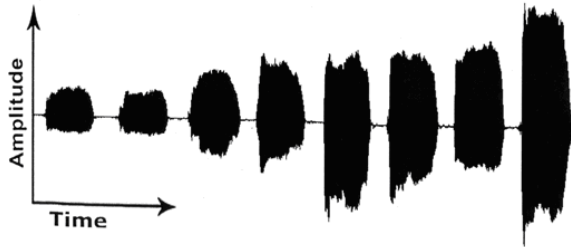


Fig 1. Wave form of the seven notes - Male voice



Fig 2. Wave form of the seven notes - Female voice

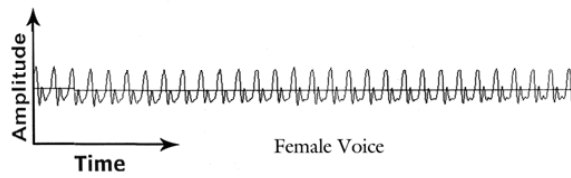
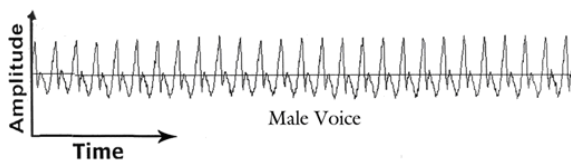


Fig 3. 100 millisecond windows for Sa

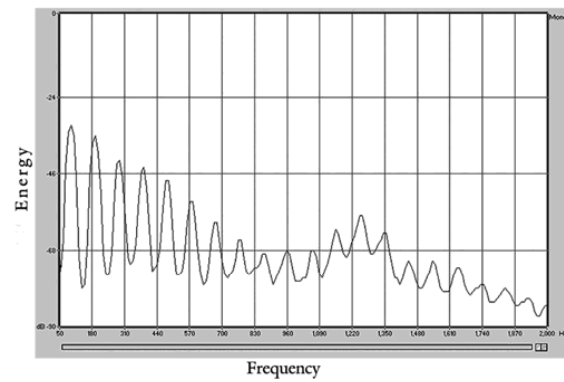


Fig 4. Energy Spectrum - Male voice Sa

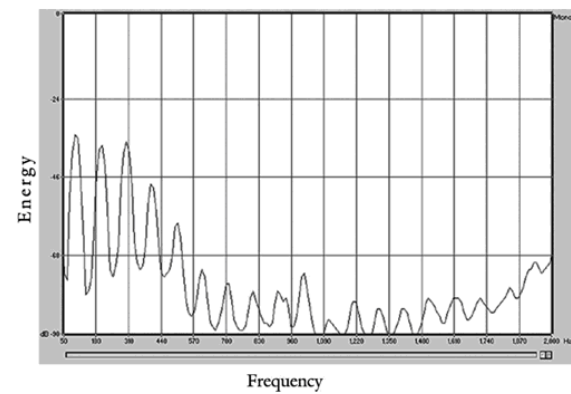


Fig 5. Energy Spectrum - Male voice Ri

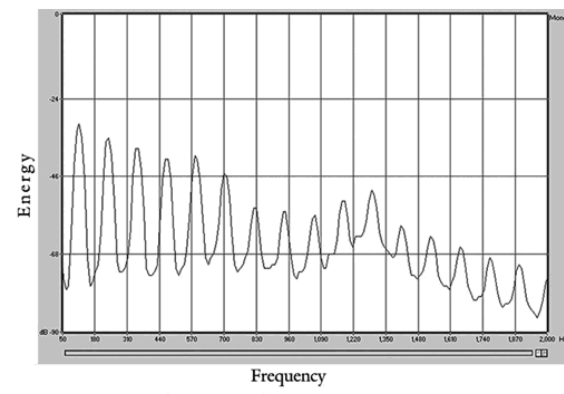


Fig 6. Energy Spectrum - Male voice Ga

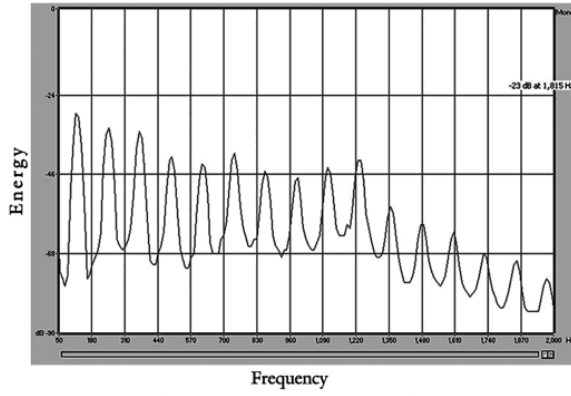


Fig 7. Energy Spectrum - Male voice Ma

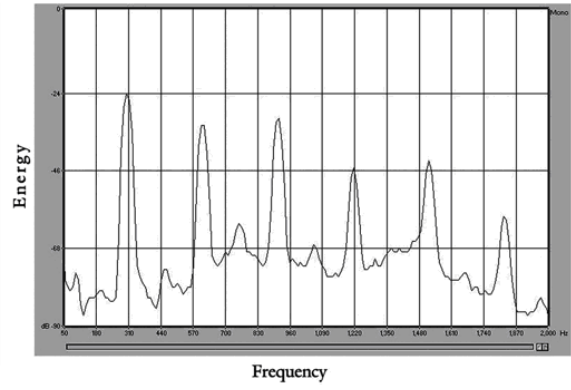


Fig 8. Energy Spectrum - Female voice Pa

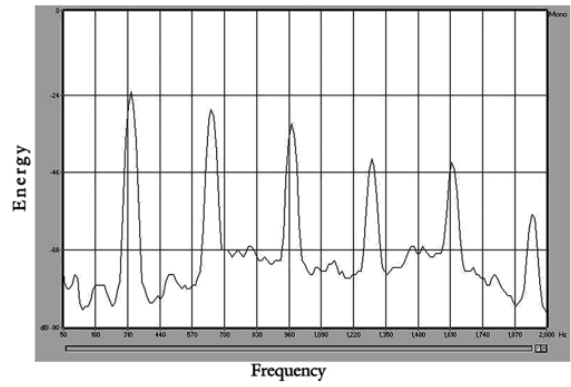


Fig 9. Energy Spectrum - Female voice Dha

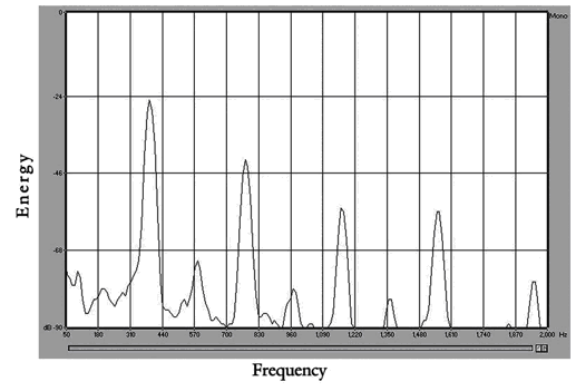


Fig 10. Energy Spectrum - Female voice Ni

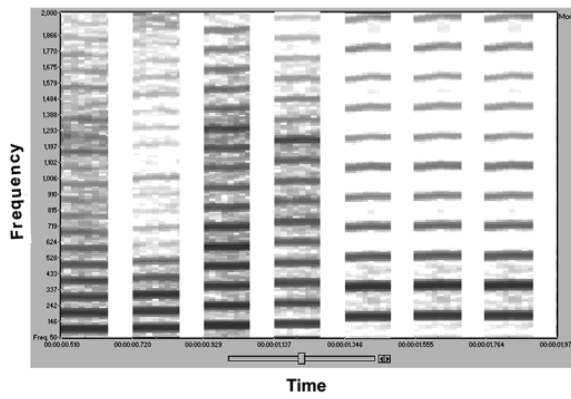


Fig 11. Spectrograms of the Seven Notes - Male Voice

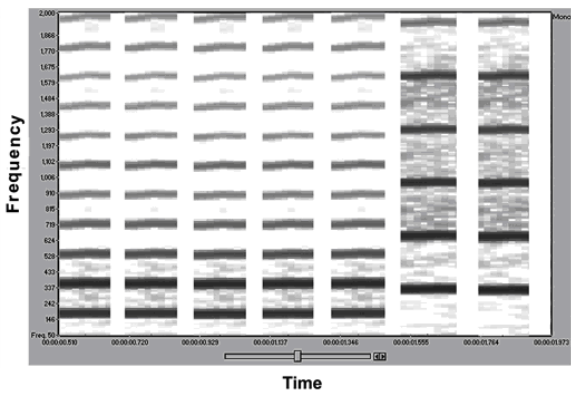


Fig 12. Spectrograms of the Seven Notes - Female Voice

first formant depends on whether the voice is that of a male or a female. Male voices usually have a lower pitch than female voices and hence a lower fundamental frequency. Usually, the ratio of the two pitches is 1:2.

The information contained in the fig. 4 -10 is presented in a complementary form in the figs. 11 and 12. These show the frequency – time spectra with the energy level as a parameter. These are called *spectrograms* and form in a sense the “signature” of the sound. They do not add anything to the conclusions but present a three dimensional display of the information and contain in themselves the entire information which can be extracted from the wave forms.

The number of formants depends upon the resonance produced in the voice box. Male singers are capable of producing higher resonance than female singers. This is a well recognized fact which has also been demonstrated by earlier workers¹. This is indicated by the larger number of formants for the male voices as compared to the female ones. For instance, in the present case the number of formants for all the male voices were 5(*sa*), 3(*ri*), 6(*ga*), 5(*ma*), 5(*pa*), 6(*dha*) and 2(*ni*). The corresponding values for the female voices were 3, 2, 3,3,3,5 and 1. It should be noted in this context that Indian music is predominantly nasal especially for female voices, unlike western music which is sung with the throat. This is the reason for the lower number of formants for the female voices as compared to the male voices. This, of course, requires a deeper study.

Conclusion

The information provided above helps in characterizing the sound pattern. It is a simple matter for an experienced person to be able to identify from this the musical note being produced and whether the voice is that of a male or female. However, if a specific voice needs to be identified more detailed investigations are needed which form part of the science of Speech Recognition.

The analysis in this paper has been confined itself to the individual notes of the musical scale. However, one specific feature of Indian music, which is not to be found in western music, is the use of *Gamaka* or the smooth transition from one note to another.

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References

1. Jina Devi Heisnam, Swamy N V C & Nagendra H R, *Spectral analysis of the Vedic Mantra Omkara*, *Indian J Traditional Knowledge*, 3(2) (2004) 154.
2. Jina Devi Heisnam, *Concept of Mantras and their corresponding qualities*, M.Sc. Degree Dissertation in Hindu Studies, Submitted to the Hindu University of America, Florida, January, 2003.
3. Prajnanananda Swami, *Music, its form, function and value*, (Munshiram Manoharlal, New Delhi), 1979.
4. Chandrasekaran J, *Indian Music – its origin and growth, Part I*, M.Sc. Degree Dissertation, Submitted to Swami Vivekananda Yoga Anusandhana Samsthana, Bangalore, January 2004.
5. Narasimhan Sakuntala, *All you wanted to know about Indian Music*, (Veenapati Center for Arts, Bangalore), 1999.
6. O'Shaughnessy Douglas, *Speech Communication – Human and Machine*, 2nd Ed. Indian Reprint, (University Press, Hyderabad), 2001.