SPECTROGRAM ANALYSIS OF COMPONENTS OF A CENTRAL JAVANESE GAMELAN

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SPECTROGRAM ANALYSIS OF COMPONENTS OF A CENTRAL JAVANESE GAMELAN

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Abstract

Some preliminary spectrographic measurements are reported on elements of the bonang and kenong instruments from a Central Javanese gamelan. Although the elements from the two instruments are of different sizes and shapes, they seem to exhibit few characteristic acoustical differences. The second mode, which is always less than an octave above the fundamental, appears to play an important role in the musical behavior of the devices.

1. Introduction

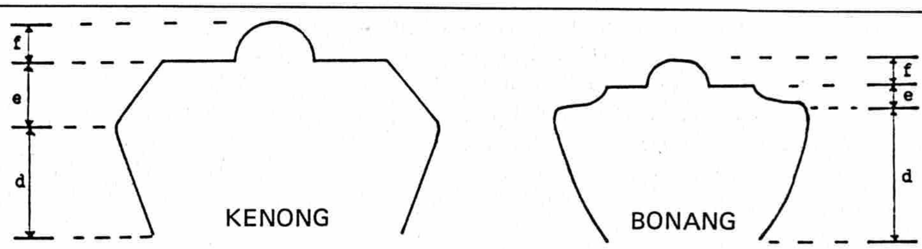
The term gamelan covers a wide variety of instrumental ensembles from Java and Bali. Each individual gamelan consists of a wide variety of instruments, chief amongst which is a group of metallophones, knobbed gongs, xylophones and membranophones. Gamelan can vary in size from a few instruments to over seventy. Two tuning systems are used in gamelans - the five-tone *slendro* and the seven tone *pelog*. These scales are hard to define precisely because any particular gamelan, while in tune with itself, has frequencies which are slightly different from all the others. Rossing and Shepherd [1] show typical tuning in relation to the number of cents in each interval, and to the Western scale of equal temperament.

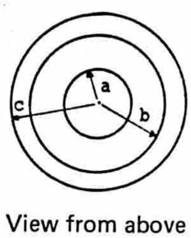
Relatively little appears to have been published on the acoustics of these elaborate ensembles and their components. Savage et al. [2] describe investigations on an old gamelan, concentrating in particular on the glides in frequency produced by the bar-form metallophones, and their relation to the form and mounting of the bars. More recently Kuo-Huang Han [3] has described the history and cultural uses of the gamelan and some of the musical characteristics of the gamelan angklung at Northern Illinois University [4].

It appears from the work of contemporary gamelan craftsmen [5] that the raising of a boss in the plate of a bonang gong tends to stiffen the plate, thus raising the frequency of the fundamental, and may be used as a means of tuning. However Rossing and Shepherd [1] found that in large gongs, the boss lowers the fundamental and first overtone partial and can bring them into an octave relationship. The larger gongs (e.g. the Chinese tamtam [6]) give an initial sound of very low frequency which is augmented after a few seconds by a louder sound of high frequency which then decays more rapidly than the initial low-frequency sound. Rossing and Fletcher [6] have measured the build up and decay of both acceleration and radiated sound in different frequency bands over the first two seconds of striking a tamtam. If the gong is not struck hard enough, the higher frequency does not appear to be generated. Experiments on gongs of simpler shape under radial stress (including the use of time-average holography) have suggested that the primary phenomenon involved is a non-linear coupling between the low and high frequency modes. This is supported by a theory that is semi-quantitative [7], due to the difficulty of describing the complex gong shapes analytically. For the tamtam not all the modes generated are axially symmetric, and the coupling between modes with high and low axial symmetry appears to depend on a ring of hammered bumps near the edge of the gong.

The present paper is devoted to some initial investigations of kettle-shaped components from two of the instruments (bonang and kenong) in a Central Javanese gamelan on loan to Cornell University from the Metropolitan Museum of Art in New York. Apart from their intrinsic musical interest, the components of these instruments have an intriguing shape as far as the theoretical determination of their natural modes is concerned (figure 1).

The work reported is a preliminary study of the possibility of using a spectrographic representation of the instruments in order to investigate the relationship between their shape and the sounds emitted. Some interesting questions emerge for future work.





Instrument/Pitch	Dimension (mm)					
	a	b	c	d	e	f
Bonang/upper pelog 3	32	68	100	76	22	29
Bonang/lower pelog 3	32	68	103	76	13	25
Kenong/pelog 3	51	116	178	146	70	44

Figure 1. Geometry of pots from the gamelan's bonang and kenong

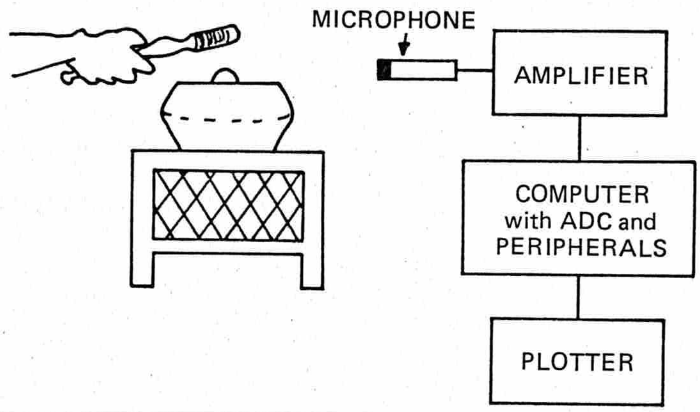


Figure 2. Experimental arrangement

2 Experimental system

The main purpose of the bonang in the ensemble is to play an elaboration of the melody, and that of the kenong to underline the structure of the piece by subdividing the musical period using appropriate pitches. In spite of these musical differences the instruments each consist of a set of upturned brass pots or 'kettles' with a knob on the top. The pots are suspended on leather straps and are struck on the knob with a wooden mallet wrapped with heavy string at its end.

Figure 1 shows the shape of the pots from the different instruments, the major difference being the greater size of kenong pots as can be seen from the representative dimensions which are also given in the figure. The measurements were limited to three frequencies (numbers 2, 3 and 5) in the pelog tuning. For the bonang, pots corresponding to both lower and upper octaves were chosen. This selection was made because although many of the frequencies of the two instruments are identical, the physical dimensions of the pots are very different (see Figure 1).

The experimental arrangement is as shown in Figure 2. The microphone (a Sony one inch condenser microphone) was mounted about 25cm from and slightly above the pot under investigation. The microphone was fed through a filter and preamplifier into the analogue-to-digital converter of a DEC minicomputer system. The limitation on the analysis was a data length of 12k words. Thus a 12kHz sampling rate permitted a 1 second time record for analysis, while an 8kHz sampling rate (that cut off some frequency components of interest above 4kHz, the Nyquist frequency) provided approximately 1.5 seconds of analysis.

The program, which is derived from that developed by Morris [8], stores and Fourier transforms 128 points of data at the chosen sampling rate, one set of 128 points overlapping the previous one by 40 points to provide a smooth transition between spectra as a function of time. The output is then displayed in a pseudo-three-dimensional form as spectral magnitude against frequency and time. The maximum frequency is the Nyquist frequency and the 135 spectra which are generated span the time available (determined by the sampling rate as described above). The sampling rates used for the different pots were 12kHz for the bonang upper pelog 2, 3 and 5 and lower pelog 2, and 10kHz for the remainder.

3. Results

The first investigation was the effect of hitting one of the pots with different degrees of force, being a light hit for soft playing, a medium hard hit for loud playing and an overly hard hit. The results are shown in Figures 3a, 3b and 3c respectively. The arbitrary linear vertical scale on the spectra obtained has been arbitrarily adjusted to optimise the display. The scale factors used are shown on each plot. It appears however that, apart from a difference of overall amplitude, the spectral content for the playing extremes (curves (a) and (b)) remains much the same. The effect of the overly hard hit is not only to raise the amplitude of the second mode by almost a factor ot two, to be almost equal to that of the fundamental, but also to increase very greatly the higher tonal content (and indeed may well have introduced frequencies beyond the limit of the analysis). The rate of decay of the higher tones seemed much the same in all the graphs. On the basis of these results it was decided to make all further measurements with the medium hard hit (corresponding to loud playing) since it appeared to produce similar harmonic content to the soft playing and provided a better signal level for analysis.

The results for the bonang upper octave, bonang lower octave and kenong are shown in Figures 4, 5 and 6 respectively. Different vertical scaling was used to try to clarify the display by making full use of the dynamic range of the ADC.

It can be seen from the plots that each individual pot has its own unique set of partials (overtones) which do not appear to correspond to any definite pattern for the different instruments. For the kenong (Figure 6) the partials are all relatively close to the fundamental frequency in comparison with the bonang (Figures 4 and 5). They have relatively high amplitudes when first struck but they decay quite rapidly. In comparison, the partials of the bonang (Figures 4 and 5) are more separated from the fundamental and are more distinct. However, their relative amplitudes are always smaller that those of the partials in the kenong. These conclusions can be confirmed audibly in that the fundamental of the bonang kettle tends to be audibly stronger than that of the kenong kettles, indicating less interference from and between the partials.

In all the spectrograms there is a very strong second peak. It is always lower in initial amplitude than the fundamental but always decays more slowly. In some cases (e.g. Figure 4a and 5c) the fundamental has died out less than a second after being hit, while the second peak appears to have decayed very little.

The second frequency peak appears always to be less than an octave away from the fundamental frequency. In some of the pots a beating in the second peak is clearly seen (e.g. Figures 4b, 5b, 5c and 6b) corresponding to the interval relationship of the second peak with the fundamental. The existence of this second peak can be easily verified audibly. On nearly every pot one can hear the fundamental die away while a pitch less than one octave higher continues to sound for quite a long period of time.

The parameters of the data collection facility available gave the primary limitation on the spectral resolution that could be achieved. The difficulty of visually extracting the frequencies of peak values from the perspective plots presented can be readily removed by suitable storage and display procedures although for the present work, circumstances did not permit this.

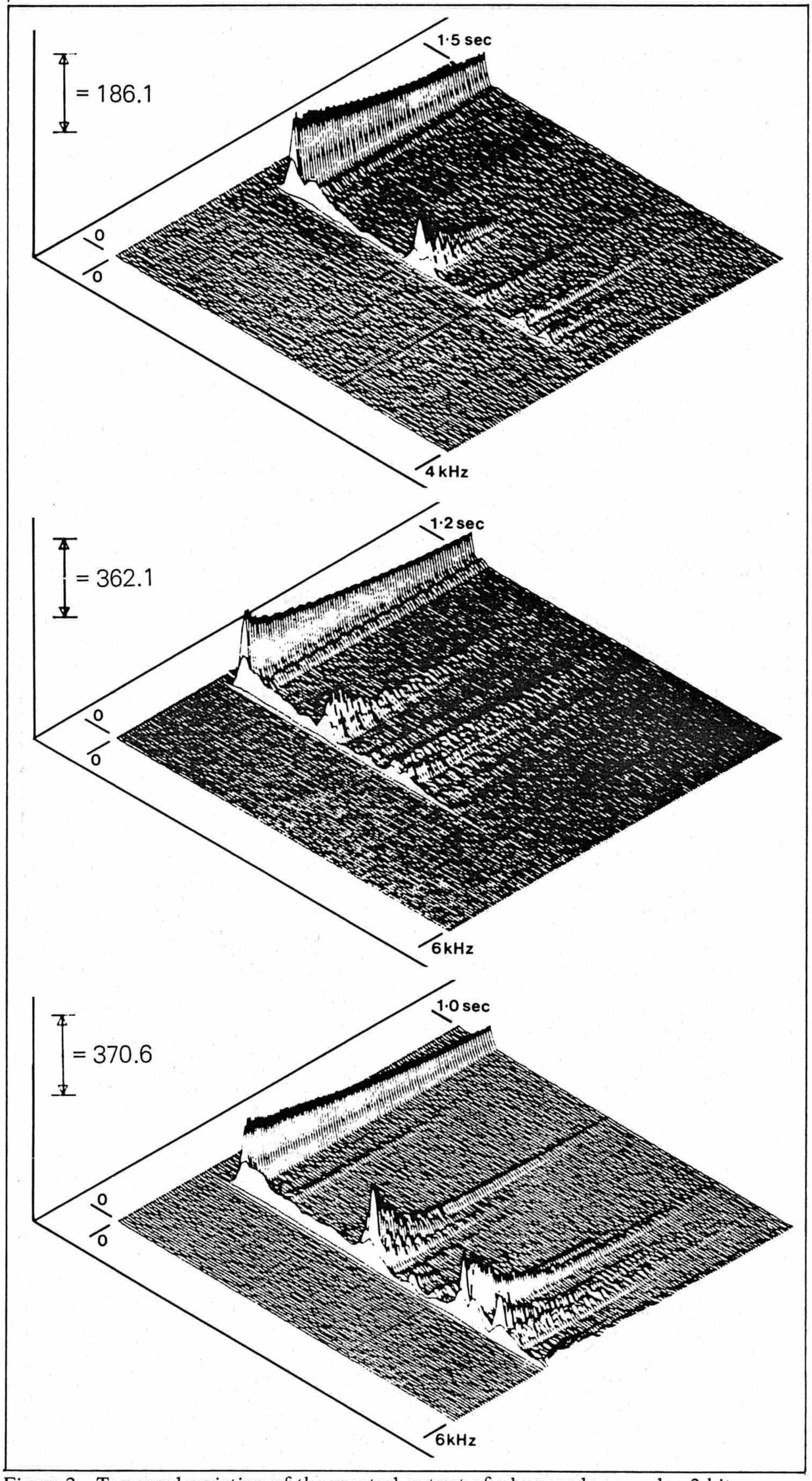


Figure 3. Temporal variation of the spectral output of a bonang lower pelog 2 hit: **a.** softly, **b.** with normal playing force, and **c.** overly hard.

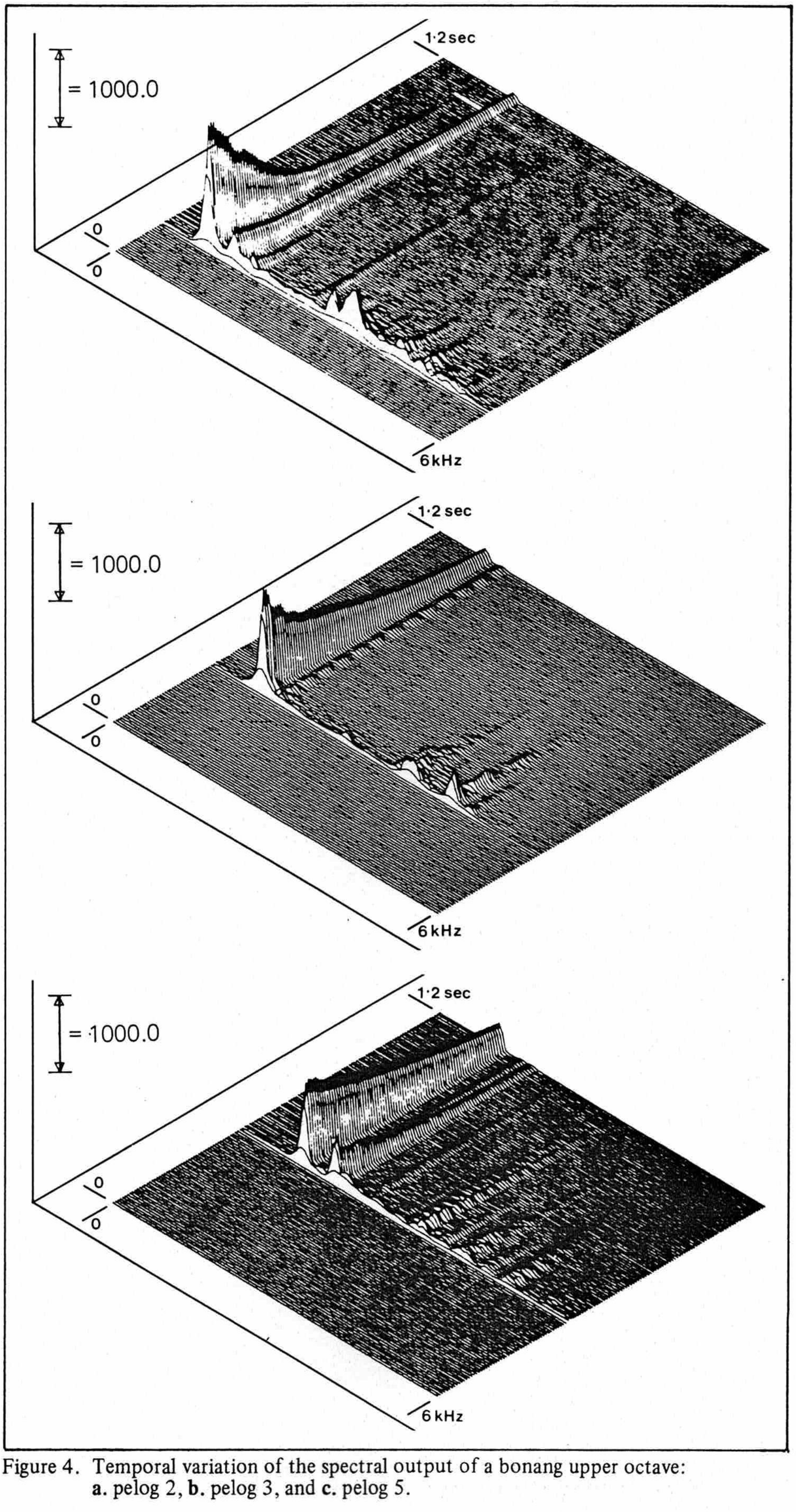


Figure 4. Temporal variation of the spectral output of a bonang upper octave:
a. pelog 2, **b.** pelog 3, and **c.** pelog 5.

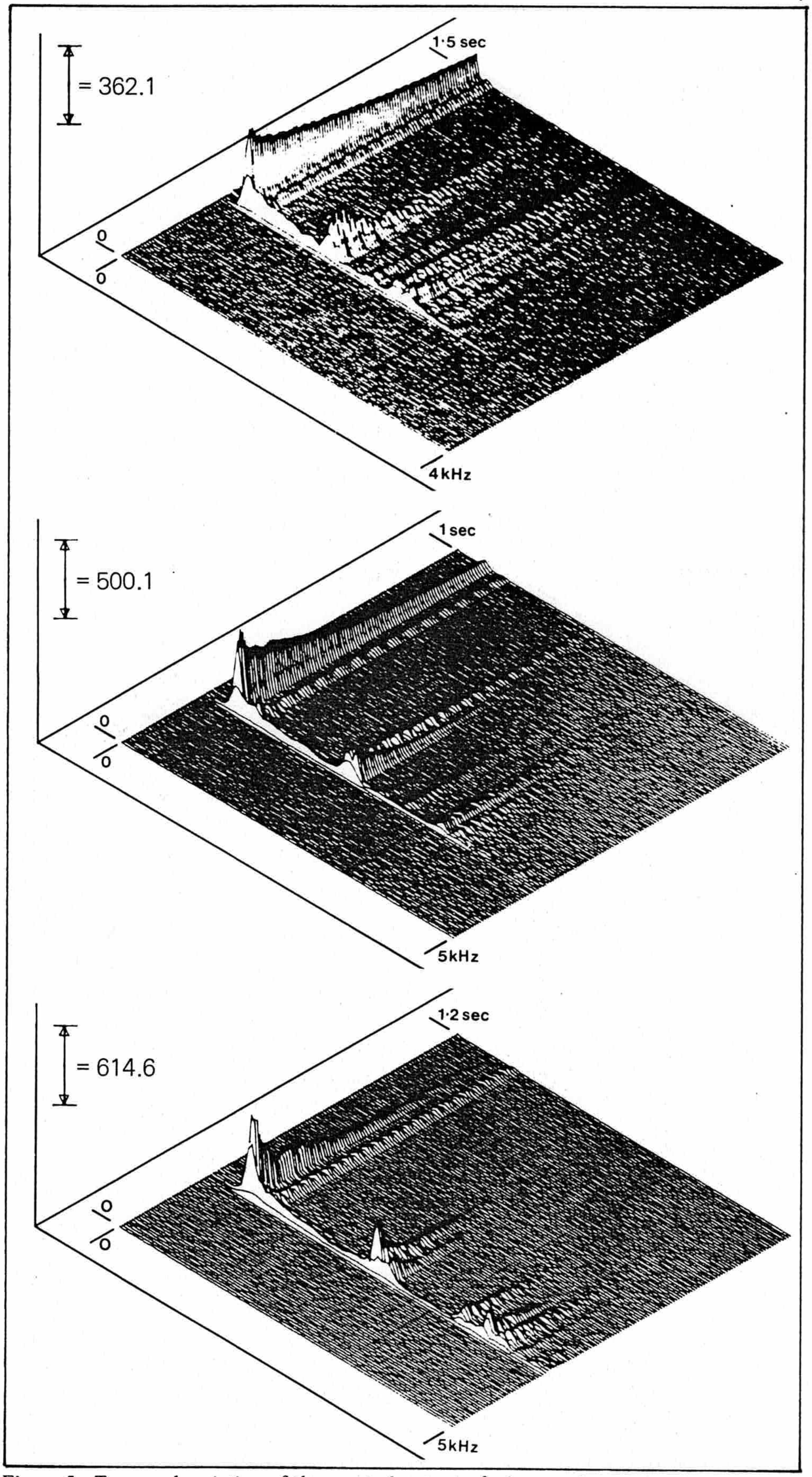


Figure 5. Temporal variation of the spectral output of a bonang lower octave:
a. pelog 2, **b.** pelog 3, and **c.** pelog 5.

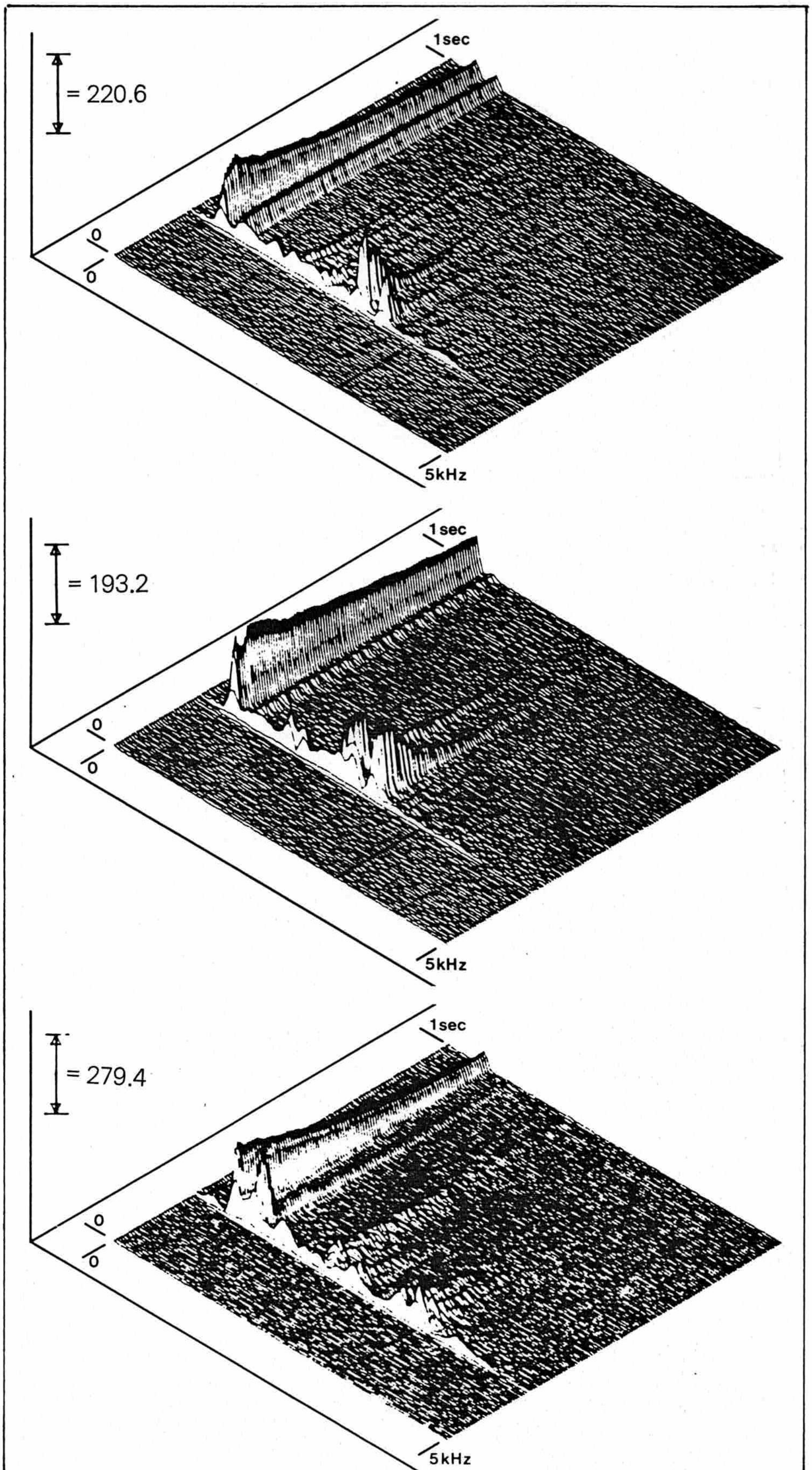


Figure 6. Temporal variation of the spectral output of a kenong:
a. pelog 2, **b.** pelog 3, and **c.** pelog 5.

4. Conclusion

The limited study reported here indicated the considerable value of a spectrographic analysis of gamelan components. The overtone patterns of the pots from two different instruments in the gamelan do not appear to be generally characteristic of the instruments. The only general consistencies observed are the greater relative amplitude of the higher harmonics for the kenong compared to the bonang, and the greater separation of the higher harmonics for the latter.

The characteristics of the first overtone (which always is less than an octave above the fundamental) are of interest in that for many of the pots the vibration associated with this overtone proves to be long-lived compared to the fundamental and in some cases exhibits beats. They appear audibly to correspond to important consonant musical intervals.

The major limitations on this preliminary study was the frequency resolution achievable with the arrangement used. It is clear however that there would be considerable value in a more extensive investigation (covering a wider range of pots) with a finer quantitative frequency analysis and of several seconds duration. The value of studies of this type is enhanced considerably if the results obtained are compared with independent aural assessments by skilled musicians.

Acknowledgement

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