

# Modal Testing of a Soprano pan using a 3D Laser Doppler Vibrometer

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## Abstract

Modal testing is a well established technique used to extract modal parameters such as natural frequencies, modal damping factors and vibration mode shapes from structures. Here, the technique is applied to a relatively new percussion instrument – the steelpan. The steelpan, also referred to as the Caribbean steel drum or pan, originated in Trinidad and Tobago during the Second World War. In this work modal testing is conducted on a soprano pan so as to obtain resonant frequencies and mode shapes as well as to provide a spatial illustration of modal tuning in the instrument. A soprano pan was excited with a periodic chirp signal from a loudspeaker and its response recorded by a 3-Dimensional scanning laser Doppler vibrometer. The results exhibited a nearly harmonic relationship among tuned modes in each outer note. There was also significant modal coupling between adjacent notes that have harmonically related frequencies.

## Introduction

The steelpan has become the subject of much research over the last three decades with modal testing being used to explore the vibrational behaviour of the instrument. However, modal testing on steel pans has mainly been limited to the use of time averaged holographic interferometry and there is a plethora of studies that have used this technique to study the instrument [1-13]. This technique offers good spatial resolution but modal parameters such as damping cannot be directly obtained from this technique. Modal analysis has also been used extensively to explore the dynamic behaviour of a variety of other musical instruments [14-19].

Other modal testing techniques use sinusoidal excitation (either mechanical or acoustic) or impact excitation. Both techniques usually incorporate an accelerometer which is attached to the structure in order to detect vibration response. In modal testing with impact excitation, the structure is tapped at a number of points on a grid with a hammer having a force transducer. The force and acceleration data is used to create a transfer function on which several algorithms may be used to extract mode shapes and other modal parameters [20;21].

The major problem with these techniques is that the addition of an accelerometer can reduce the values of the normal mode frequencies as well as add damping to the structure. A mode may also go undetected if the accelerometer is located at one of its nodal lines. Although, mode shapes may be accurately determined, the spatial resolution offered by these techniques is usually poor.

In this study a 3D scanning laser Doppler vibrometer was used in conjunction with a loudspeaker. This technique, like time averaged holographic interferometry, also offers good spatial resolution in addition to providing data from which modal damping can be deduced. The technique also allows the vibration behaviour to be observed without making contact with the steelpan.

## The steelpan – a brief history

The *steelpan* also known as the *Trinidad pan* or the *Caribbean steel drum* is a relatively new percussion instrument that was born from a process which was mainly influenced by the drumming traditions of West African slaves who were brought to Trinidad and Tobago to work on plantation estates. The early slaves played Congo drums which were eventually banned by the government out of fear that their usage would have incited an insurrection. However, love for music saw the emergence of another instrument which took the form of bamboo poles and was referred to as tamboo-bamboo, tamboo coming from the French word ‘tambour’ meaning drum. This was also banned as these bamboo poles easily became fighting sticks during clashes among rival bands. The people, having a profound passion, for music, began using garbage tins, dust-bins, car rims and car fenders as instruments for their music. However, this was short-lived as the expanding oil industry and the American Naval bases in Trinidad and Tobago provided a myriad of used oil drums which were used as a raw material for experimenting. The first steelpans took to the streets of Port-of-Spain in the Carnival celebrations a few years after the conclusion of World War II and since then the steelpan has evolved into a family of instruments which include soprano or tenor pans, double second pans, cello, guitar and bass pans with a musical range that spans 5 octaves. A brief description on the manufacture of the steelpan can be found in the paper on the Aubrapan which is also a part of this conference proceeding. A comprehensive history of the instrument can be found in Blake [22]. In this work a soprano pan (see figure 1) was used as it contains the largest number of notes and is likely to contain most of the vibration characteristics found on other types of pans.

## Experiment

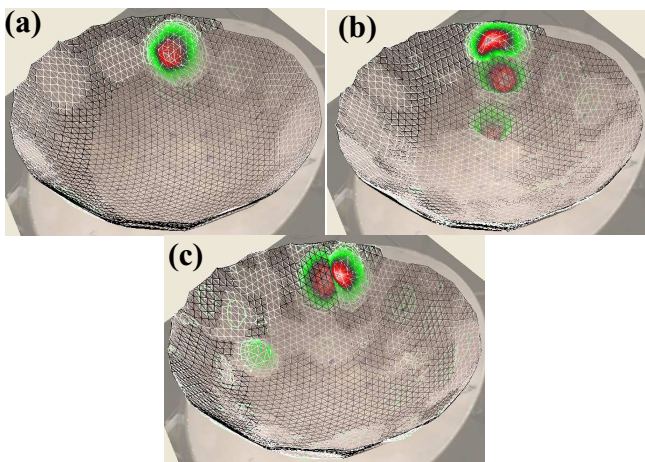
The soprano pan used in this investigation was manufactured and tuned by master pan-maker and panist, Aubrey Bryan. This steelpan adopts the Trinidad 4th’s and 5th’s note layout in which the notes are arranged into three rings: the outer ring, the middle ring and the inner ring. C4 is the lowest frequency note on the pan. The experimental set-up used in this work is shown in figure 3.



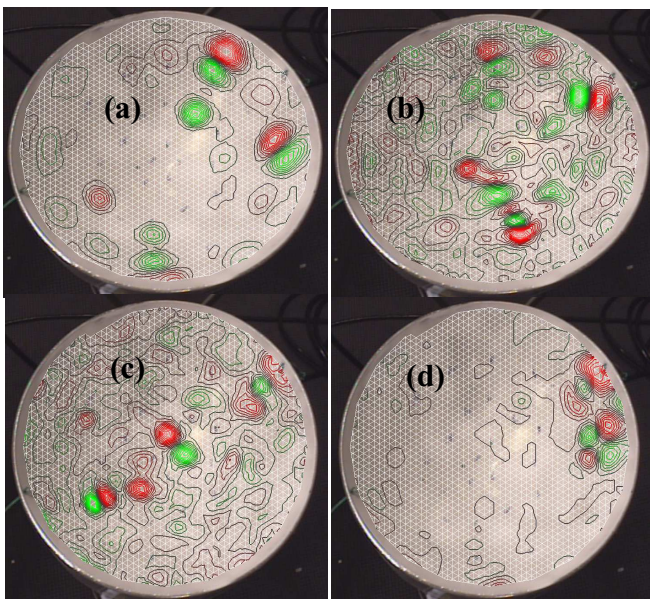


octave and approximately a major third above an octave. All other outer notes on the pan displayed the same mode shapes and frequency relationships. These first three modes are usually tuned into a harmonic relationship (see figure 6). In this case, the third mode does not fall into a harmonic series, but its ratio to the fundamental is nevertheless one which is pleasant to the human ear. Some tuners, are able to tune the third mode such that the ratio to the fundamental is 3:1.

Figure 4b also highlights another characteristic of the instrument. The fundamental mode (0,0) frequency of the C5<sup>#</sup> note is the same as the (0,1) mode for the C4<sup>#</sup> note. This is generally observed whenever modes have frequency values that are in close proximity. Figure 4c also illustrates this where the (1,0) mode of C4<sup>#</sup> and the (0,0) mode of E5<sup>b</sup> vibrate at 640Hz. The (0,0) mode of the E5<sup>b</sup> is also observed at 632Hz. Extensive modal coupling is also illustrated in figure 5.

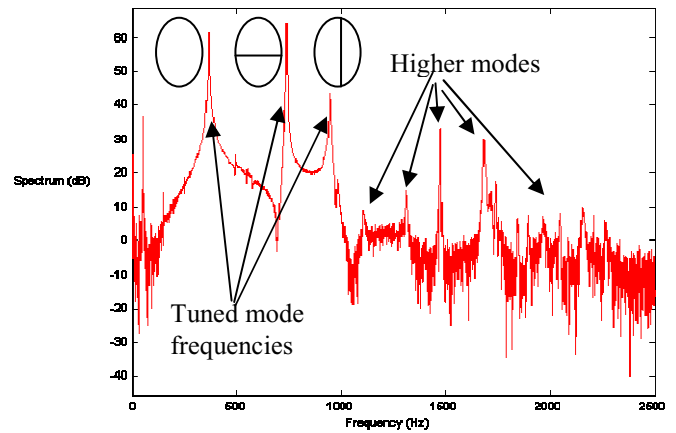


**Figure 4:** First three flexural modes of C4<sup>#</sup> note region: (a) 276Hz, (b) 550Hz and (c) 640Hz



**Figure 5:** Modal Coupling in soprano pan: This is attributed to the presence of partials of the same frequency in different note regions: (a) 681Hz, (b) 1067Hz, (c) 1252Hz and (d) 1359Hz

All of the modes observed in the frequency range of interest were flexural modes, indicating that the majority of sound produced from the instrument comes mainly from flexural motions of the note regions. However, some radiation of sound is expected to occur from the pan side since it is coupled to the pan dish.



**Figure 6:** Typical frequency response spectrum an outer note on the soprano pan. First three modes are usually tuned into a nearly harmonic relationship. Higher modes are not harmonic but contribute to the overall timbre of the steelpan. Obtained using 1-D scanning laser Doppler vibrometer and excitation using an impact hammer.

This study mainly observed mode shapes in the steelpan with the objective of understanding modal tuning but other useful information may be obtained by combining the measurements obtained in this study with other measurements, e.g. acoustic measurements. The information obtained from this investigation includes: normal mode frequencies, averaged mobilities (m/s/V) as well as flexural and in-plane motion. Damping properties can also be easily extracted. Additional information such as radiation efficiency and radiation damping can be obtained with acoustic measurements. The 3D measurements also produces a 3-dimensional mesh of the steelpan which may be used to perform finite element simulations (see figure 2).

## Conclusion

Modal testing of the soprano pan has provided a spatial illustration of mode tuning in the instrument. Pan-makers typically tune the first three modes of notes on the outer ring to have frequencies that form an approximate harmonic sequence. Only the fundamental mode is tuned in the middle and inner notes. There was also significant mode coupling among notes which contained partials of the same frequency. Although, modal testing of the steelpan is not new, modal testing with a 3D scanning laser Doppler vibrometer offers additional features which may be used in combination with acoustic measurements and finite element analysis to conduct a comprehensive investigation on the acoustics of the instrument.

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