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The Resonant Tuning Factor: a new measure for quantifying the setup and tuning of cylindrical drums

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ABSTRACT

A single circular drumhead produces complex and in-harmonic vibration characteristics. However, with cylindrical drums, which have two drumheads coupled by a mass of air, it is possible to manipulate the harmonic relationships through changing the tension of the resonant drumhead. The modal ratio between the fundamental and the batter head overtone therefore provides a unique and quantified characteristic of the drum tuning setup, which has been termed as the Resonant Tuning Factor (RTF). It may be valuable, for example, for percussionists to manipulate the RTF value to a perfect musical fifth, or to simply enable a repeatable tuning setup. This research therefore considers a number of user interfaces for analysing the RTF and providing a new tool for quantitative drum tuning.

1 Introduction

Popular cylindrical drums are usually designed with a circular shell that supports two taut drumheads, which are held in position by circular rims that are connected to lugs on the drum shell by threaded tension rods. This arrangement defines a complex multi-degree-of-freedom system when considering the vibration properties (and hence the sound) of a cylindrical drum when hit. Tuning of cylindrical drums can therefore involve a number of procedures in order to ensure that, for example, the drum has the desired fundamental frequency, that drumheads are tensioned evenly around the drumhead, that the two drumheads are tuned relative to each other, as well as manipulating the attack and decay properties of the vibration. Prior research by Toulson et al. has discussed the procedures for drum tuning and the setting of the fundamental frequencies of drums in a drum set to a chosen musical scale [1]. Additional research by Richardson and Toulson has presented a quantitative method for achieving an even tension of the drumhead [2]. The research presented here specifically discusses the relative tuning of the two drumheads on a cylindrical drum (commonly referred to as the *batter* and *resonant* heads) and provides a new measure and analysis approach for quantifying the tuning relationship between them.

2 Vibration modes of membranophones

A single circular drumhead, scientifically referred to as a membranophone, produces complex and in-harmonic vibration characteristics when excited. The modes of vibration of an ideal membranophone are discussed and shown by Rossing, informing that modes are defined by two different types of vibration axes, as shown in Figure 1 [3].

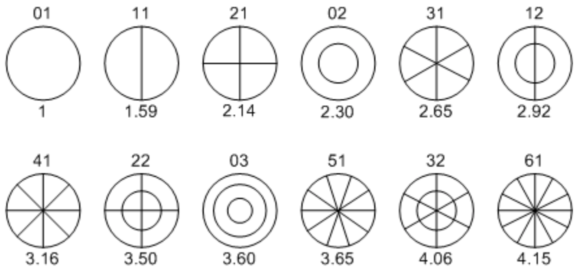

Figure 1. Vibration modes and in-harmonic factors of an ideal membranophone.

The vibration axes shown in Figure 1 are depicted by the positioning of nodes (positions of maximum displacement) and antinodes (positions of zero displacement) in the mode profile. The most apparent antinode is defined by the perimeter rim of the membranophone, such that the greatest vibration displacement is seen at the centre. This oscillation dictates the fundamental frequency of the system (denoted f_{01}) and is accompanied by in-harmonic overtone modes of the same form (f_{02}, f_{03}, f_{04} etc), see Figure 2.

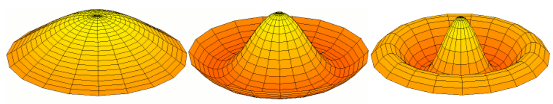

Figure 2. Modes f_{01}, f_{02} and f_{03} for an ideal membranophone.

The second type of vibration axis is evident along a diagonal antinode (denoted f_{11} for a single diagonal). Further vibration modes are therefore also exhibited with combinations of circular and diagonal antinodes. Modes with a single diagonal antinode therefore also define f_{21}, f_{31}, and so on, as shown in Figure 3. Equally, modes that form other combinations of vibration axes are also possible, denoted, for example, f_{21}, f_{25}, f_{44}, f_{63}.

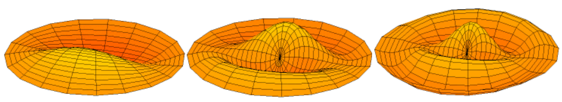

Figure 3. Modes f_{11}, f_{12} and f_{13} for an ideal membranophone.

The in-harmonic factors for the ideal membranophone modes are all calculated by considering Bessel functions, and are quoted also by Rossing. For example, the first overtone frequency f_{11} is calculated as being 1.59 times the fundamental f_{01}, whereas the f_{21} overtone is at 2.14 times the fundamental. In-harmonic factors for each node are also included in Figure 1 above. The fundamental frequency is a function of the membranophone diameter, thickness, density, elasticity and tension. Ideal membranophones assume that the tension of the drum is applied uniformly around the perimeter of the drumhead.

3 Coupled drumheads

Commonly used in popular music are cylindrical drums, which have two drumheads that are coupled by a suspended mass of air in-between, meaning that the two membranophones can have a significant acoustic effect on each other. As a result, the harmonic factors, or modal ratios, of a cylindrical drum do not adhere to those quoted for the ideal membranophone. Indeed, it is possible to manipulate the harmonic relationships through changing the relative tension of the two membranophones (as discussed by Richardson et al. [4]), which is common in the practice of drum tuning. By looking specifically at the relationship between f_{01} and f_{11}, it can be seen that, by tuning the two membranophones relative to each other, it is possible to manipulate the f_{11} modal ratio to values greater or less than that for the ideal membranophone (1.59).

Cylindrical drums are generally excited (hit) on one side only (the batter head) with a drumstick, beater, or similar object. The resonant membranophone (the drumhead that is not hit), therefore operates somewhat as an energy damper or reflector, and can be tuned to give the drum a more unique timbre or sound. It is valuable to note that, as the two drumheads are coupled by the mass of air within the drum, the fundamental frequency (f_{01}) is identical for both drumheads. The first overtone (f_{11}) for each drumhead will generally be different, although the f_{01} frequency of the batter head will be much more prominent and audible when the drum is played. To analyse these relationships for cylindrical drums, an iPhone software application called iDrumTune Pro has been developed, in order to capture acoustic percussion data (using the iPhone microphone) and to provide information and guidance that is valuable for assisting with drum tuning [5].

The frequency spectrum shown in Figure 4, verifies that the ideal membranophone modal ratio (1.59) can indeed be manipulated with cylindrical drums. In this example, the fundamental (f_{01} = 98.0 Hz) and first overtone peaks (f_{11} = 163.5 Hz) are visible and indicate a modal ratio value of 1.67. Additionally, the second overtone peak is also visible (f_{21} = 222.5 Hz), which exhibits a modal ratio of 2.27, rather than the value (given in Figure 1) that is 2.14 for an ideal single membranophone.

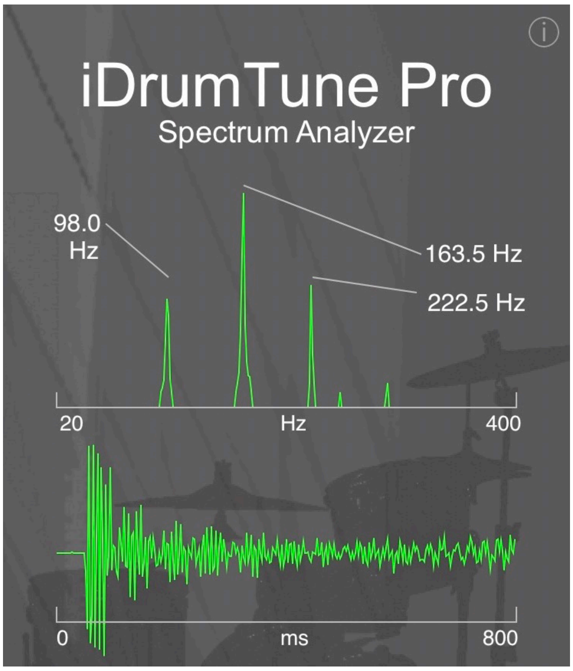

Figure 4. Example waveform and spectrum data of a cylindrical drum when hit on the batter drumhead.

Given that this manipulation of modal ratios is possible for cylindrical drums, it is therefore possible to tune the modal ratio of an overtone to be at a specific musical interval. For example, a modal ratio of 1.25 represents a perfect musical third; 1.34 represents a musical fourth; 1.50 gives a musical fifth; and 1.67 (as in Figure 4 above) denotes a musical sixth in the equal temperament scale [6].

4 The Resonant Tuning Factor

The modal ratio between the fundamental and the batter head overtone therefore provides a unique and quantified characteristic of the drum tuning setup, which has been termed as the Resonant Tuning Factor (RTF) in this research. It may be valuable, for example, for percussionists to manipulate the RTF value to represents a perfect musical fifth. Equally, percussionists may simply wish to use and record the RTF value arbitrarily to enable a repeatable tuning setup for their instrument.

In quantifying the f_{01} and f_{01} values for a given cylindrical drum - although it is possible to excite both modes in a single hit - it is also possible to excite each individually. For example, exciting and measuring the batter drumhead at the centre (the point of most displacement for the f_{01} mode) excites the fundamental most powerfully. Similarly, exciting and measuring the acoustic response at the edge of the drum most powerfully excites the f_{11} mode. It is therefore possible for percussionists to accurately capture and record the fundamental and overtone (and hence the RTF) data using the iDrumTune Pro application. To assist, a simple and dynamic user interface (shown in Figures 5 and 6) guides the user to take consecutive readings of the batter head at both positions, and then displays the calculated RTF value.

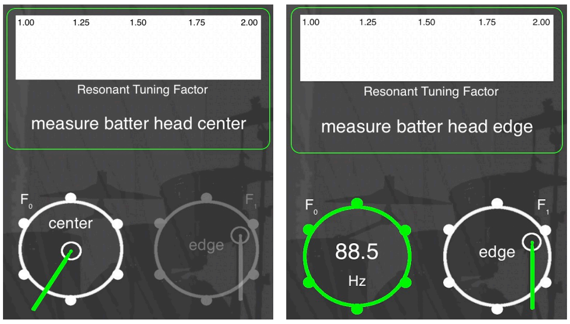

Figure 5. iDrumTune Pro first requests the user to measure f_{01} (center) followed by f_{11} (edge).

As presented by Richardson and Toulson [4], given the relationship between the batter and resonant drumheads and the air coupling in-between, it is possible to direct the user to either raise or lower the RTF value through tuning as follows:

- To increase RTF: tighten the batter drumhead and loosen the resonant drumhead.
- To decrease RTF: loosen the batter drumhead and tighten the resonant drumhead.

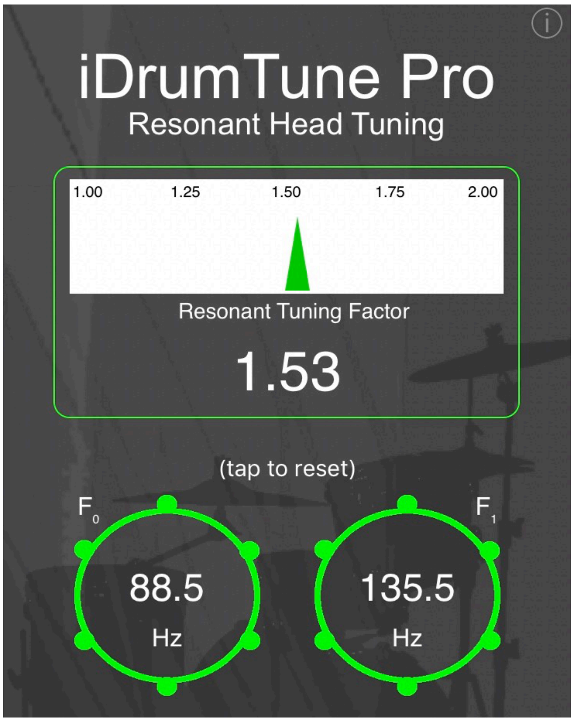

Figure 6. Once f_{01} and f_{11} are recorded, iDrumTune Pro displays the calculated RTF value.

5 Conclusions

It is shown that the modal ratios of cylindrical drums can be measured and manipulated, which can be of value for percussionists who require accurate and repeatable tuning, and for those tuning drums to specific musical intervals. To assist this, the Resonant Tuning Factor (RTF) has been termed to define the modal ratio of the f_{01} and f_{11} frequencies of the batter drumhead of a cylindrical drum.

A major objective of this research is to find new methods of communicating the science of drum tuning to musicians, percussionists and music producers in a way that is relevant to the creative practice of performance and studio recording. This objective has led to the development of the RTF terminology and a number of usable interfaces that allow drummers and percussionists to engage with more quantitative approaches to drum tuning.

Nowadays, studio tools and handheld mobile devices are capable of measuring and communicating such data, and the major practical challenge is in finding the best language, articulation and user experience for employing this scientific knowledge in a creative context.

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