Does Saxophone Mouthpiece Material Matter?

Introduction

There is a longstanding issue among saxophone players about how various materials used in mouthpiece manufacture effect the tonal qualities of a saxophone. Some people feel mouthpiece material has a direct impact on sound and some feel otherwise. Many people relate how school band conductors ask all players to use “hard rubber” pieces rather than metal to achieve desired sectional sounds. Some people think jazz requires a metal mouthpiece. The purpose of this article is to apply some physics measurement techniques to analyze whether mouthpiece material matters. The result is that there is no significant difference in a listener’s perception of saxophone sound when metal or hard plastic mouthpieces of similar dimensions are employed in playing long tones on a saxophone.

There are many qualities involved in producing a sound from a saxophone mouthpiece. Introductory descriptions of these elements are provided in commonly available books by Pinksterboer[1] or Teal[2]. A good introduction to the physics of sound has been written by Rossing, Moore, and Wheeler[3]. Mouthpiece interior chamber design, including baffles, can be quite important in sonic considerations. Interior dimensional changes as small as 0.05 mm can produce discernable differences. Exterior elements such as facing length, tip opening, and general dimensions of the beak affect sound as well. A large beak opens up the oral cavity of the player and thereby changes the saxophone-mouth cavity resonance lengths. For example, soprano sax players learn that opening the oral cavity brings the often-sharp higher end of pitches flatter, right into tune. A similar effect occurs for the larger saxes but is less pronounced since their mouthpieces generally are larger than soprano sax pieces and the sound wavelengths produced are longer.

Among all these variables in mouthpiece design is the selection of material. Mouthpieces commonly are made from various metals such as brasses or tin-based alloys and also from plastic mixes, some of which are referred to as “hard rubber”. There are tradeoffs in cost and ease of manufacture for the various materials. For reasons of strength, plastic pieces often have substantially larger external dimensions than metal pieces. Metal pieces usually are made smaller in external dimensions than hard rubber so that the weight of the mouthpiece is kept to acceptable levels. In any manufacturing process decisions about quality control of dimensional tolerances will affect consistency of the mouthpieces in playing when comparing a batch. The question arises as to how much the different materials used affects saxophone sound.

In asking how sound is affected, one must determine the place at which the sound is measured. Two obvious locations for determining saxophone sound are the player’s ears and a listener other than the player. As well, one could inquire about sound internal to the sax. For anyone’s ears, the surrounding room makes a difference in what is heard. For the player, proximity to the saxophone gives some specific sonic effects not heard by other listeners. First, because of the proximity, a player will hear the direct sound in greater proportion to sounds reflected in the room which also are heard by a listener other than the player. Significantly, the player also is connected physically to the saxophone. This means the player will hear some sound due to conduction through teeth, bones, and flesh to the ear. Everyone knows how different their own voice sounds when played back from a recording compared to what they hear when they speak. The differences between being a player and a listener other than the player clearly can be quite significant. Different mouthpiece materials can be expected to play a strong role in sound conduction to the player's ears due to their varying vibrational amplitudes and their ability to conduct sound to the player's jaw region.

However, it is not immediately clear that mouthpiece material should play a significant role in the sound heard by a listener other than the player. In fact, the contrary is suggested, that mouthpiece material largely is irrelevant and that only geometrical considerations in the mouthpiece matter. Technically, the Young's Modulus and mass densities of most mouthpiece materials taken in combination with their size suggests that the resonant frequencies of the mouthpiece are far above the usual pitches played. One may strike a loose mouthpiece with a spoon and hear the resulting pitch of the mouthpiece is well above normal playing ranges. In more detail, one may calculate the vibrational motion of the mouthpiece and estimate its excitation of sound waves in the air outside the piece to see that the mouthpiece does not radiate much sound heard by a listener. Does the mouthpiece material affect sound which is excited internally in the air column of the saxophone? In a similar manner, one may calculate mouthpiece vibrational feedback to the oscillating air column driven by the airflow past the reed and estimate that mouthpiece material does not affect internal sound production significantly. Yet, the bottom line is a measured end result of the sound which comes out of a sax. Estimates may overlook an important part of the science. Can a listener other than the player tell a difference between two mouthpieces which are identical except for material?

Experiment Design

A particular design of mouthpiece was obtained for testing. This mouthpiece design has been produced both in metal and plastic with similar physical dimensions internally and externally. Keeping in mind that metal mouthpieces may have relatively thin walls for which plastic may be viewed as too fragile, it is not surprising that there are few mouthpieces made in identical dimensions in both metal and plastic materials. Nonetheless, with some searching, it was found that Dukoff has produced a mouthpiece both in clear plastic and in what appears to be a tin-based alloy, which they stamped as "Super Power Chamber, Dukoff, Miami, Florida". This model was obtained in D7 specification for tenor saxophone for both pieces. A picture of the two pieces is shown in Figure 1. All internal and external dimensions of these two pieces appear the same, within the measurement error, except for the external throat dimension of the plastic piece where it contacts the sax cork being 0.8 mm thicker than the metal piece.

The Dukoff mouthpieces have a pronounced internal baffle. Dukoff pieces are known for their "edge" (or brightness) and "projection" capabilities and are favored for this property in some playing, such as rock and roll. In contrast to these two pieces, a Barone Hollywood 7* brass piece was tested alongside the Dukoffs. The Barone Hollywood has similar external dimensions to the Dukoffs but has a low baffle. By the experience of the author, the Barone Hollywood has less "projection" and less "edge" (it's darker) for a comparable dynamic level compared to the Dukoffs. It was expected that this difference should be discernable in the sonic spectra of the pieces.

The playing conditions were similar for all three pieces. The same Alexander Superial DC 2 ½ reed was used with Rovner ligature. The tenor saxophone used was a Selmer Paris Serie III, serial number 599260, with Selmer aftermarket red brass neck. The horn was played at mezzo forte in all cases. This was done for a variety of reasons. First, the signal-to-noise is good at this dynamic level. Next, it is known[4] that harmonics and overtones have relative strengths which vary with dynamic, so a constant volume was selected. Also, when taking a mouthpiece to forte and higher dynamics, the character of the reed oscillation changes such that the sonic spectrum is markedly different compared to mezzo forte and below[5]. At forte and above, the reed oscillates with a striking of the mouthpiece tip rail. Lower dynamic levels have a free oscillation of the reed end without beating on the mouthpiece tip rail.

The saxophone was set up in a physics laboratory at the University of California, Irvine for the sonic measurements. The sound pressure detected by a microphone placed 10 cm in front of the saxophone was analyzed for the spectral components of the sound. While a Hewlett Packard spectrum analyzer similar to that used by Benade and Lutgen[6] for testing a single tenor mouthpiece was available, it was found more convenient to record the microphone signal directly and use Fast Fourier Transform software to perform the spectral analysis. The DALCO EID-606 microphone and analysis software provided by Pasco Scientific were used in conjunction with an IBM ThinkPad computer for the data collection, analysis, and display.

The distinct sound of each musical instrument is the result of the varying levels of different frequencies excited which all join together to make a single note from the instrument. Though a particular note is played, many harmonics of the note and non-harmonic contributions determine the tonal quality. Differences in sound among different mouthpieces will manifest as different magnitudes of sound components at various frequencies. In essence, the frequency spectrum of a note is its fingerprint. If there is no difference between two frequency spectra, then the observer will say the played notes are the same.

Two notes were tested on all three mouthpieces played in 5 second long tones for each measurement. First, the 220.00 Hertz concert A3 tone was played. This is the note written for saxophones as B4 (on the treble clef staff) since the tenor sax is a transposing instrument in Bb. This was expected to have few contributions to the tone above the fundamental and second harmonic for a saxophone, as observed by Backus[7], since the tone holes are mostly open. The other note analyzed was the second-register written D5 on the staff, the concert C4 of 261.63 Hertz. Backus observed richer harmonic content when much of the sax body tube keys were closed.

Experimental Results

Figure 2 shows the spectrum of the metal Dukoff mouthpiece for playing concert A3, written B4. One sees the fundamental 220 Hz note as having the strongest amplitude and a contribution from the second harmonic at 440 Hz. In addition, there is some contribution to the sound in the range of 1500-4000 Hz, which can be seen above the noise level. The strengths of various components in the 1500-4000 Hz range varied during the long tone but are generally represented in amplitude by those shown in Figure 2. The overall shape of the spectrum is quite similar to the spectrum shown by Backus[7] for written C5 (right next to B4 on the saxophone). For quick comparison, the normal bottom pitch written Bb3 of a tenor saxophone is at 103.83 Hz and the upper written C6 just before going to the palm keys is 466.16 Hz.

The plastic Dukoff piece has a written B4 spectrum shown in Figure 3. Again, the signal in the range of 1500-4000 Hz had some variation over the long tone with amplitudes similar to those shown in the figure. One notices the essential similarity of Figures 2 and 3. A listener would not be able to tell the difference in the spectra of Figures 2 and 3.

In comparison, the Barone Hollywood written B4 spectrum was similar to Figures 2 and 3 in the 220 and 440 Hz components and all else below 1500 Hz. However, the spectrum above 1500 Hz showed no contributions above the noise level to the spectrum.

For the written middle D5 of the tenor sax, Figure 4 shows the metal Dukoff spectrum. Here we see the fundamental at 261.63 Hz and the harmonic at 523.25 Hz. The second harmonic is larger in amplitude than the fundamental, as observed by Benade[6]. We observe further harmonics, especially growing substantially from 1750 Hz to 3500 Hz and then decreasing. There is considerable sonic content in the range 2000-4000 Hz in addition to the expected fundamental and the second harmonic. Over the course of the long tone, there was some variation in how much the 784.89 and 1046.5 Hz harmonics were represented. As well, the 2000-4000 Hz spectrum varied in content over the long tone somewhat but overall showed the substantial peaking around 3136 Hz consistently.

Figure 5 shows the spectrum for the plastic Dukoff mouthpiece for written middle D5. As with the concert A3, one sees little difference compared to the metal piece. A listener in the laboratory was unable to identify whether the metal or plastic piece was being played for any of the tests.

In strong contrast to the metal or plastic Dukoff mouthpieces is the Barone Hollywood played at written middle D5, shown in Figure 6. Here one sees the fundamental and second harmonic clearly. However, there is almost no signal above the noise in the 1500-4000 Hz range. This marked difference probably explains the qualitative differences musicians attribute to the pieces.

Most people easily hear the spectral formant from 1500-4000 Hz, well above the normal range of the saxophone. This high-harmonics range of frequencies found in the Dukoffs causes a listener to perceive the sound as “bright” or “edgy” and probably contributes to the “projection” capability of the sound. In opposition, the Barone Hollywood is perceived as a “dark” mouthpiece often used for small ensemble jazz playing where projection and edge may not be desired.

Conclusions and Suggestions

In conclusion, the spectral content of Dukoff metal and plastic tenor saxophone mouthpieces made with mostly identical internal and external dimensions were indistinguishable by microphone measurement or to a listener’s ear when long tones were played. In contrast, a Barone mouthpiece with similar external dimensions but different internal baffle could be distinguished easily by measurement and by ear from the Dukoffs. There is a general tendency for plastic or hard rubber mouthpieces to have larger external dimensions compared to metal pieces (as opposed to the specific mouthpieces tested here). The plastic or hard rubber piece thus will open the player’s oral cavity more, on average, than a metal piece. It is suggested that this increased oral cavity volume reduces the “edge” or “brightness” in the sound heard by a listener. Thus, conductors seeking unison sectional tone quality actually are specifying a desire for particular mouthpiece dimensions rather than materials. A player may discern a heard difference in mouthpiece material since the sound conduction through the jaw may differ with varying mouthpiece material.

Acknowledgements:
The author would like to thank Mr. John Bretz for providing the Dukoff mouthpieces for the tests.

References:
1.) *The Rough Guide to Saxophone*, by Hugo Pinksterboer, Rough Guides Limited, London, distributed by Penguin Putnam, New York, 2000, pages 50-62.
2.) *The Art of Saxophone Playing*, by Larry Teal, Summy-Birchard Inc., distributed by Warner Bros, Miami, ISBN 0-87487-057-7, 1963, pages 17-20.
3.) *The Science of Sound*, T. Rossing, F.R. Moore, and P.A. Wheeler, Addison Wesley, San Francisco, ISBN 0-8053-8565-7, 2002.
4.) *Requirements and techniques for measuring the musical spectrum of the clarinet*, A.H. Benade and C.O. Larson, Journal of the Acoustical Society of America, vol. 78, pages 1475-1498, 1985.
5.) *Fundamentals of Musical Acoustics*, A.H. Benade, Oxford University Press, New York, 1976, page 443.
6.) *The Saxophone Spectrum*, A.H. Benade and S.J. Lutgen, Journal of the Acoustical Society of America, vol. 83, 1988, pages 1900-1907.
7.) *Input impedance curves for the reed woodwind instruments*, John Backus, Journal of the Acoustical Society of America, vol. 56, 1974, pages 1266-1279.

Captions:

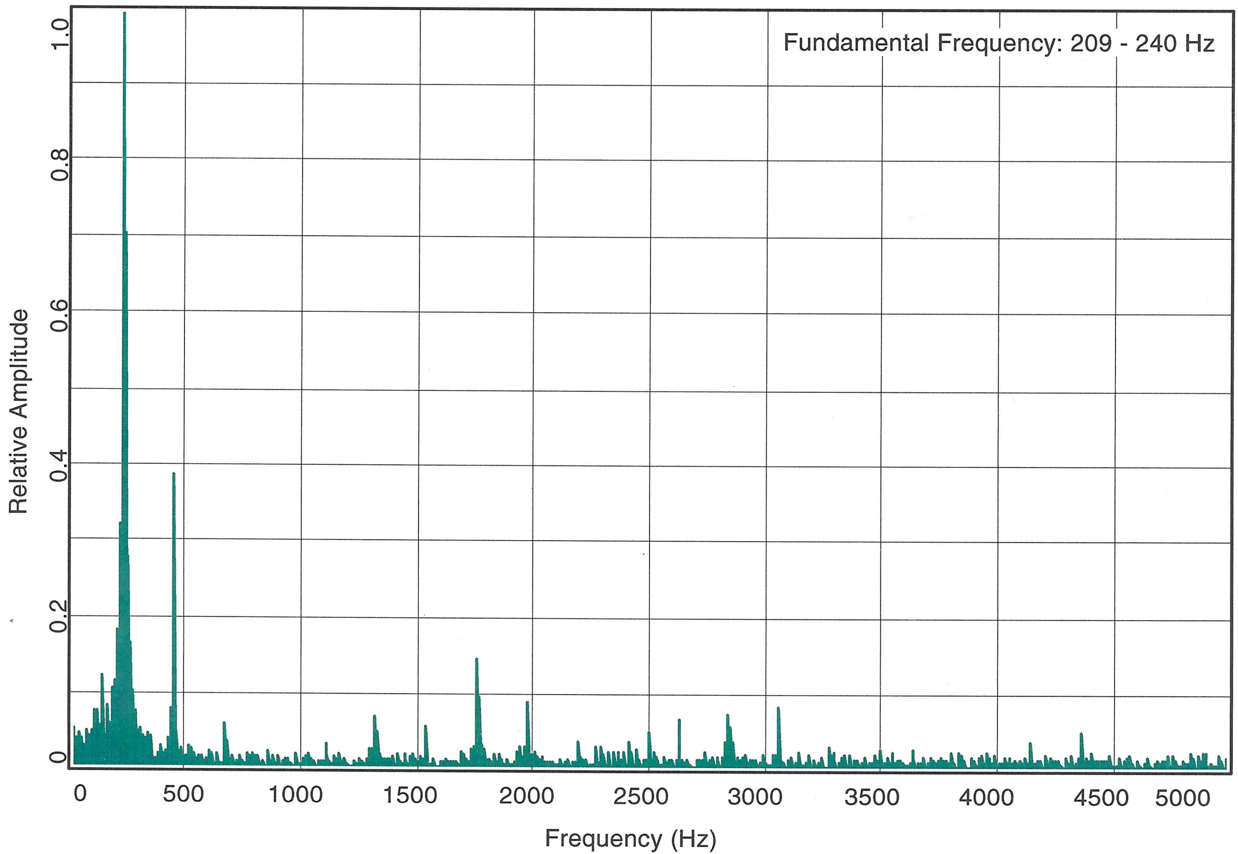
Figure 1: Photo of metal and clear plastic Dukoff “Super Power Chamber” tenor saxophone mouthpieces.
Figure 2: Frequency spectrum of metal Dukoff playing written B4.

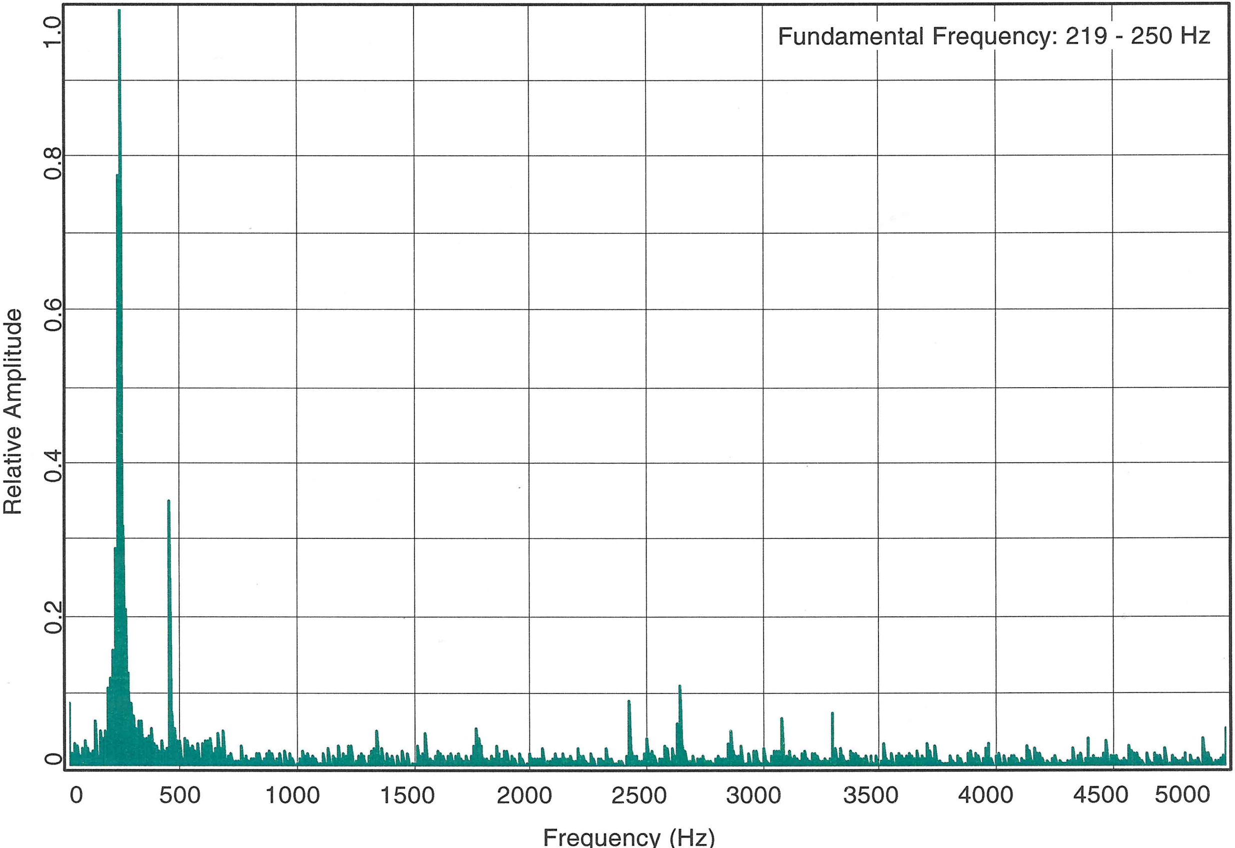
Figure 3: Frequency spectrum of plastic Dukoff playing written B4. Note similarity to Figure 2.
Figure 4: Frequency spectrum of metal Dukoff playing written D5. Note formant from 1500-4000 Hz.
Figure 5: Frequency spectrum of plastic Dukoff playing written D5. Note similarity to Figure 4.
Figure 6: Frequency spectrum of Barone playing written D5. Note differences with Figure 4, i.e. lack of high frequency formant thereby gives characteristic of "darker" tone.

About the author:

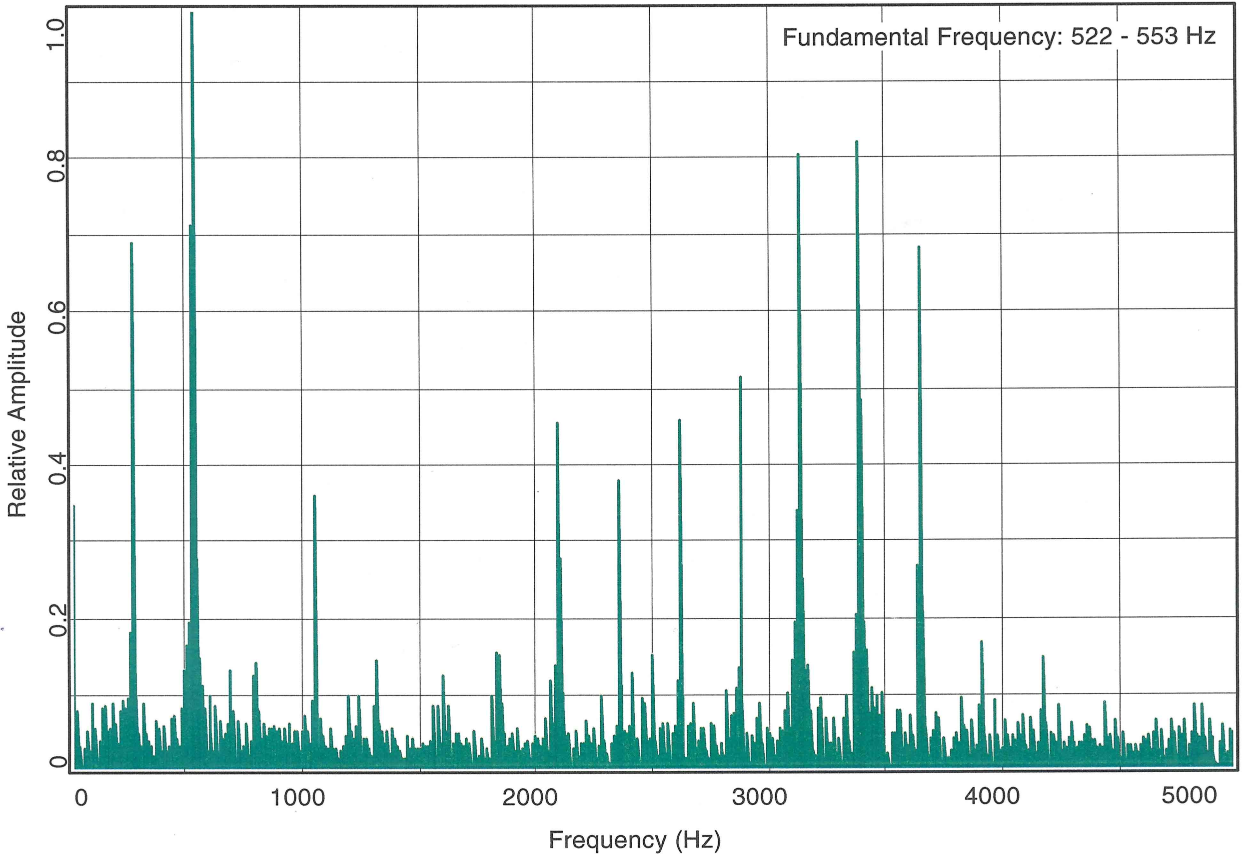
Dr. Roger McWilliams has been a Professor of Physics at the University of California, Irvine for 22 years since getting his Ph.D. at Princeton University. He runs an experimental physics laboratory in addition to teaching, which includes acoustical physics. At the obsessive hobby level, he runs a small jazz ensemble for bar gigs and bar mitzvahs and plays in jazz big bands. He plays Selmer Serie III tenor and Serie II soprano, both with Barone Hollywood mouthpieces with Alexander Superial DC reeds. As is obvious in the photo, he is influenced dominantly by Lester Young.

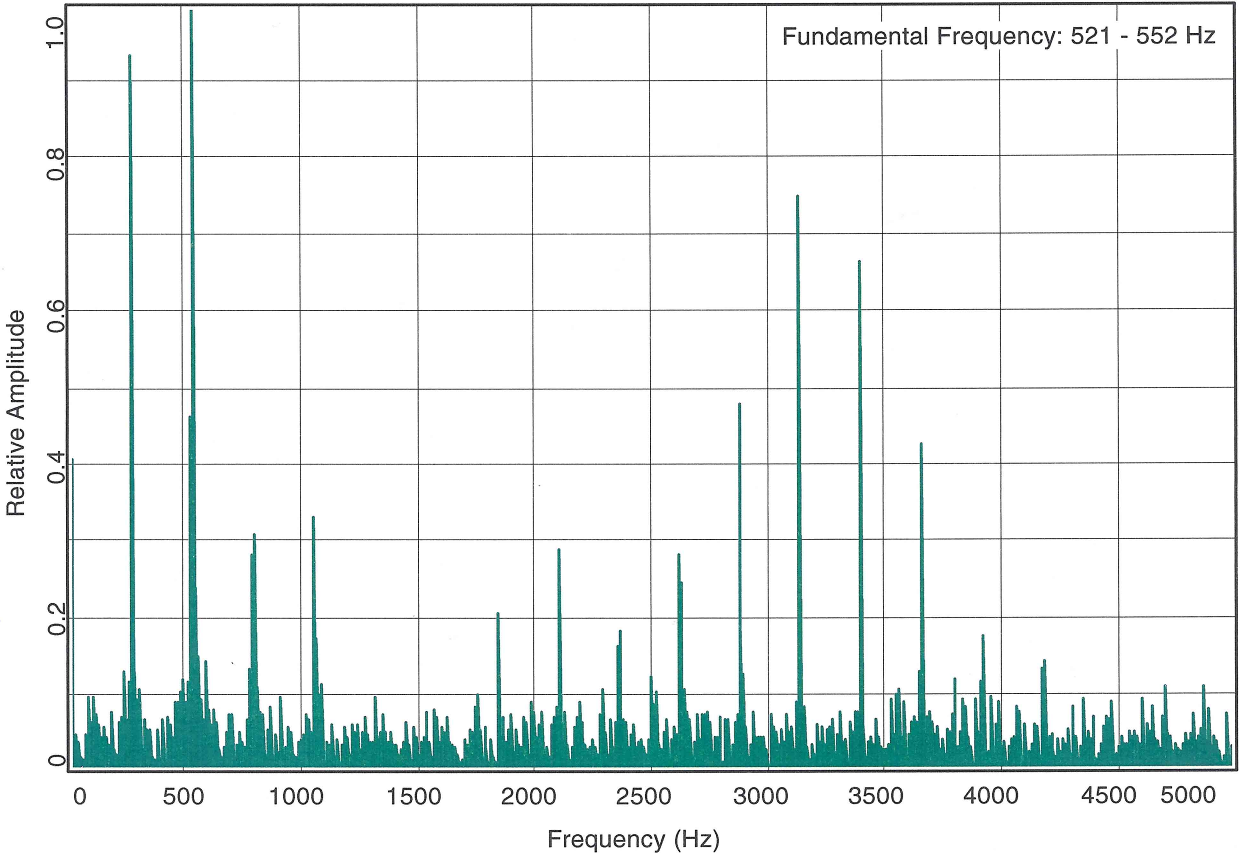

D7

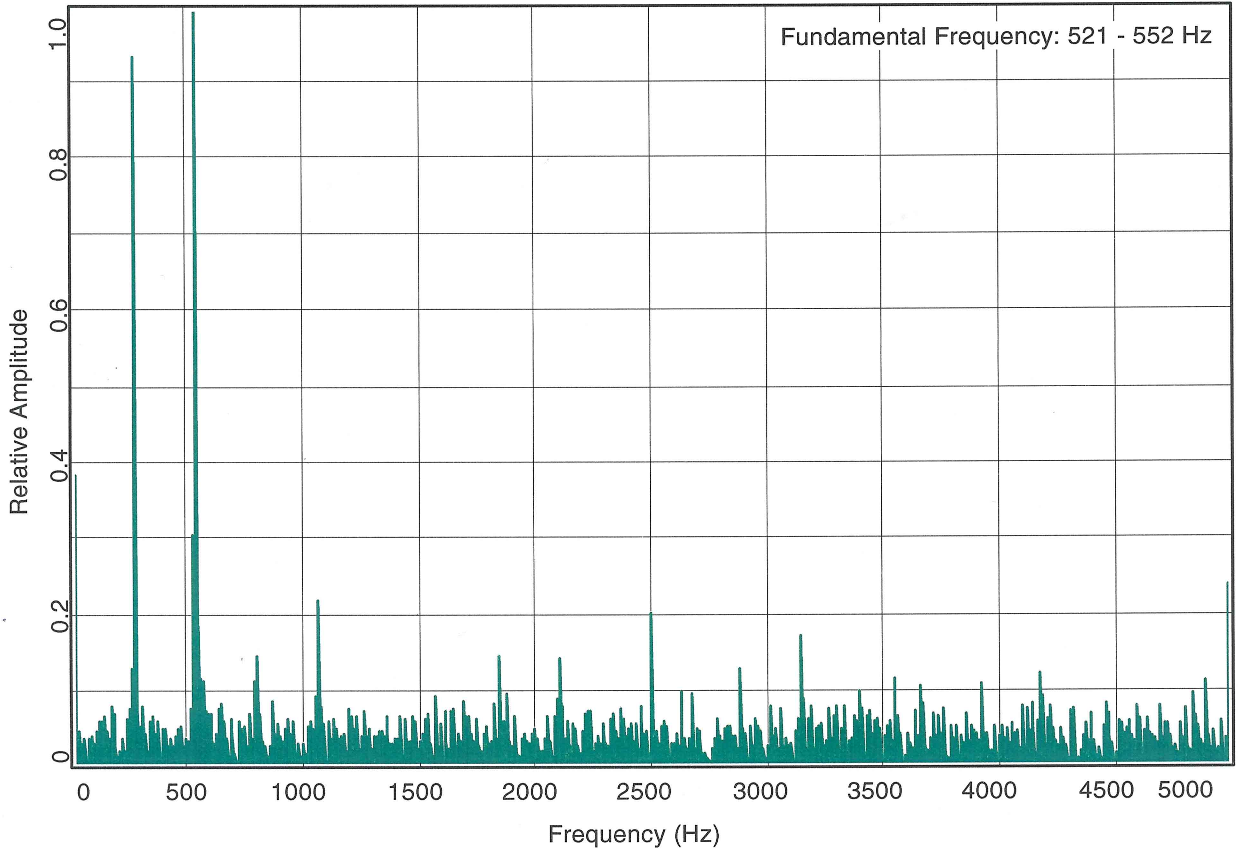

Fundamental Frequency: 209 - 240 Hz
Relative Amplitude
0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Frequency (Hz)



Fundamental Frequency: 219 - 250 Hz
Relative Amplitude
0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Frequency (Hz)


Fundamental Frequency: 522 - 553 Hz
Relative Amplitude
0
0.2
0.4
0.6
0.8
1.0
0
1000
2000
3000
4000
5000
Frequency (Hz)


Fundamental Frequency: 521 - 552 Hz
Relative Amplitude
0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Frequency (Hz)


Fundamental Frequency: 521 - 552 Hz
Relative Amplitude
0
0.2
0.4
0.6
0.8
1.0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Frequency (Hz)