Spring 2016

The Singing Blade: The History, Acoustics, and Techniques of the Musical Saw

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Recommended Citation

Stuckenbruck, Erin Else, "The Singing Blade: The History, Acoustics, and Techniques of the Musical Saw" (2016). *Senior Projects Spring 2016*. 383.
https://digitalcommons.bard.edu/senproj_s2016/383

The Singing Blade:
The History, Acoustics, and Techniques of the Musical Saw

Senior Project submitted to
The Division of Arts
of Bard College

by

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Annandale-on-Hudson, New York
May 2016

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INTRODUCTION

What is a musical saw? Even though the saw is a common household object, it is rare to find someone who would be able to answer this question. The musical saw is in fact, exactly what one might think: a handsaw that is used to make music. This might seem a bit strange to some. "How does it work? What does it sound like?" are common questions asked once introduced to the concept of a musical saw. These questions are harder to answer. The saw produces a unique singing tone that is difficult to describe. It has a beautiful pure and clean timbre but with an eerie quality to it. Descriptions such as a "soprano's lyric trill[1]," a haunting wail, a siren, or even singing from heaven have been used[2]. So what is a musical saw?

In order to find this out, there are few websites for saw players[3] and only one instructional book, *Scratch My Back*. The purpose of this paper is to combine and expand on these sources. The first section gives the reader a brief history on musical saw: its origin, important manufacturers that helped it progress, and its current status. The second section is an analysis of the saw's physical characteristics and acoustic properties, in order to gain a better understanding on how the saw is able to sing. The third section explores the various techniques by which the musical saw can be played.

Except for the presence of teeth, there is no physical difference between a handsaw and a musical saw. In fact, any handsaw can be used as a Musical Saw—it just depends on if the person picking up the saw views it as a musical instrument. Every maker of a handsaw fits into the category of a musical saw manufacturer so just like handsaws, musical saws can be very short or long, made from thick metal or thin,

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[1] Janet Graebner and James Leonard, "Scratch my Back: A Pictorial History of the Musical Saw and How to Play It," (n.p.: Kleidescope Press, 1989), 4.

[2] Natalia Paruz, "What is the Musical Saw or Singing Saw?" Saw Lady, Ameriklectic Music 2000-2008, accessed October 4, 2015, http://www.sawlady.com/whatis.htm.

[3] List of some websites: www.sawlady.com, www.playthesaw.co.uk/wp, www.musicalsaw.com, www.musicalsaws.com, http://www.musical-saw.com.

contain various metals, have different handles, and various attachments besides handles that hold the saw in place.

When buying a musical saw the main qualities one examines are the saw's length and the elasticity of the metal, it's clear progression of pitches (including microtones), its range, its overtones, and length of sustain. If the metal is too stiff it would require more force by the player to create a pitch. So the more flexible the saw the easier it will be to access more pitches; however the quality of tone may suffer from a blade that is too thin. It is also important that the grain of the metal be parallel to the non-cutting edge. The width and length of the saw affect the range and the quality of the tone; the width at the bottom compared to the top affects its range. For example, a 23" saw with 6" base and a 2" tip will produce a two-octave range, whereas if the top width was 1.25" the range will increase. Although, when the range is increased on a good saw the quality may suffer and some notes may not ring as well.

While most any saw can be made into a musical one, there are manufacturers who make saws specifically for music. These saws generally do not have teeth and are referred to by some players as musical blades[4]. It is actually illegal to play the musical saw on the streets of New York City if it has teeth[5]. So, any handsaw can be used as a musical one, but not every musical saw can be used as a handsaw. Here is a list of some of these manufacturers from around the world:

Alexis' "La Lame Sonore", France
Thomas Flinn & Company, England
Parkstone, England

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[4] Morgan Cowing, "General & Technical Information On Playing The Musical Saw," October 24, 2006, Accessed October 12, 2015, http://www.sawplayers.org/Saw_Instructions.pdf.

[5] Natalia Paruz, e-mail message to author, November 12, 2015. Says she received a $150 ticket in 2005 for playing the musical saw in the Times Square subway due to the saw having teeth.

Mussehl & Westphal, United States

Charlie Blacklock, United States

Wentworth, United States

Ralph Stövesandt, Germany

Feldmann, Germanny

Feldman-Dieter Schmid Werkzeuge GmbH, Germany

Bahco Sandvik-Stradivarious model, Sweden

Sandvik, Sweden

Seagull, China

Golden Musical Saw, China

And more…

Most of these companies make saws in different sizes and the prices can range from $50-$400. For example, Charlie Blacklock’s saws are available in four sizes: the “Tenor” saw can either have a 26” or 28” blade, the “Baritone” saw has a 30” blade, and the “Mini-Bass” has a 36” blade. These saws range from $70-$85.

Although the musical saw is an uncommon instrument, the existence of these companies and the growth in its players proves that it is not a dying instrument. It is hard not to be intrigued by the musical saw and its unique sound. Most instruments are manufactured for the sole purpose of creating a musical instrument. The musical saw is a special type of instrument whose beautiful, singing tone is produced from a household object.

Below are a variety of saws, their dimensions, and their range.[6]

Figure 1: Variety of Saws owned by author

Saw Company	Length (in.)	Base Width (in.)	Tip Width (in.)	Range[7]
1. Blacklock	37	8	1.5	D_3-D_7 (146Hz-2300Hz)
2. Blue Steel	34.5	7.5	1	D_4-G_7 (293Hz-3100Hz)
3. Sandvik-Stradivarius	30	7	2	G_4-C_7 (390Hz-2090Hz)
4. Gold Platted	26	5.5	2	A_4-A_6 (400Hz-1700Hz)
6. Ace Hardware[8]	25.5	5.5	1.5	B_4-B_6 (490Hz-1900Hz)
8. Bond	20	5	1.8	D_5-A_6 (580Hz-1700Hz)

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[6] All photographs were arranged by the author and taken by Judd Holland unless stated otherwise.

[7] Frequencies are approximated.

[8] Saws **5** and **7** are omitted due to their dimensions and range being very similar to **6**. Saw **5** is a True Value saw and saw **7** is a Disston saw.

HISTORY OF THE MUSICAL SAW

The exact origin of the musical saw is unknown. The Neolithic man understood the idea of abrasion to cut things. This idea found its way in hand tools made from various materials and eventually metals in the Bronze Age due to the necessity for weapons. There are some conjectures that the invention of church bells came when different pitches were heard from hitting a bronze helmet with a head in it as opposed to an empty helmet[9]. The notion that a metal object, especially a thin metal blade, can create a pitch is not too far from the idea of hitting a bronze helmet. In order for a blade to transform into a saw, further development and tempering of the steel needed to be done.

In the 18th century saws were considered the most complex hand tools to manufacture. A perfect balance between hardness, stiffness, flexibility, and smoothness had to be maintained in order for a saw to safely function[10]. During this time, a saw, if not only by accident, must have been struck or a blade may have been dropped, producing a “twang” like sound. This could have naturally led to further exploration.

One of the first records of a musical saw, dating about two hundred years ago, was found in obituaries of priests, stating that the musical saw was played during Sunday services[11]. Due to the advancement of steel foundries and the mass production of handsaws during the 19th century, the saw became part of liturgical music and the folk fabric of music in areas where handsaws were manufactured, such as the

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[9] Joel Shurkin, “Exploring the Evolution of Musical Instuments,” Inside Science, October 18, 2012, accessed November 2, 2015, https://www.insidescience.org/content/exploring-evolution-musical-instruments/819.

[10] “Saws,” Colonial Williamsburg, accessed November 2, 2015, http://www.history.org/almanack/life/tools/tlsaw.cfm.

[11] Natalia Paruz, “How to Play the Musical Saw: The Musical Saw in Church & Vaudeville,” Expert Village Video, March 11, 2008, https://www.youtube.com/watch?v=IGPk0SYEU6w.

Appalachian mountain range[12]. Therefore, more saw players were found in these areas and the saw was used for the music of that region. The folk song and hymns sung in churches became the easiest tunes to learn and the plethora of songs available in print made this a quick study. Thus, the saw became a part of local music traditions played in homes[13].

Most sources claim that the saw originated around the Ozark Mountains or the Appalachian mountain range in America and did not expand past the United States for some time. But evidence—such as the 78rpm recording of the musical saw from the turn of the 20th century from China—shows that saw playing made inroads in certain areas of the world with foundries, such as England, Germany, and Sweden[14].

One wonders how the saw could travel that far. Protestant and Catholic missionaries probably took the saw to China, Japan, Korea, India, parts of Africa, and the Caribbean in the 19th century. The saw was useful without an organ to carry the tunes of the hymns used in service, as well as a most useful tool for construction. Since that time, the saw continues to be played in these countries.

Back in America, around 1919, Clarence Mussehl, the first professional musical saw manufacturer, began experimenting with thinner steel and changes in width, creating a saw capable of producing approximately 16-20 notes. He was the first to develop thinner more malleable steel capable of better resonance and vibrato. In 1921, he began selling them commercially for the express purpose of playing music[15], although the elimination of teeth did not yet occur[16].

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[12] "A Brief History of the Musical Saw," *Home of the Musical Saw,* Mussehl & Westphal, accessed October 20, 2015, https://www.musicalsaws.com/.

[13] Graebner and Leonard, "Scratch my Back," 38.

[14] Robert Froehner, "The Saw," The Musical Saw and Theremin Page, April 4, 2015, accessed October 15, 2015. Http://www.theremin-saw.com/saw.htm.

[15] "A Brief History of the Musical Saw."

[16] Clarence Mussehl, "Clarence Mussehl Talks About His 1920s Musical-Saw Records," The Mainspring Records Collectors' Blog, July 25, 2013, accessed November 3, 2015,

Vaudeville music was immensely popular during this time. The Weaver Brothers were one of the many vaudeville groups who included the musical saw in their acts[17]. The saw also found support from clowns who performed on the saw in circuses all over the western hemisphere. These clowns kept the saw tradition alive in places where there was no vaudeville[18]. Musical saws were becoming a common household instrument in certain regions. So much so that in America, Mussehl sold about 25,000 saws per year during the 1920s and 1930s[19].

After this peak, many factors caused sales to plummet. The flex-a-tone was also invented and patented around the 1920s[20]. Its sound is very close to a struck saw and as it became more difficult to find a good saw player many orchestras and composers replaced the musical saw with other instruments. The flex-a-tone was a popular choice in the mid 20th century. For example, the second movement of the Piano Concerto by Aram Khachatorian originally had a saw part, which was changed to flex-a-tone[21].

Other factors for the musical saws decline was the growing popularity of the “talking machine,” record players, which caused a diminishing in home entertainment and a downturn usage of the musical saw. The invention of the Theremin, with similar timbre, began to overshadow the saw. The Depression and steel shortage of World War II caused many saw manufacturers to shut down[22].

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https://78records.wordpress.com/2013/07/25/clarence-mussehl-talks-about-his-1920s-musical-saw-records/.

[17] Graebner and Leonard, “Scratch My Back,” 16.

[18] Natalia Paruz, “The Musical Saw in Clown Acts,” Saw Lady, 2000, accessed October 6, 2015, http://www.sawlady.com/Clowns.htm.

[19] Graebner and Leonard, “Scratch My Back,” 55.

[20] Christopher Ariza, “History of the Flexatone,” Flexatone HFP, 1996, accessed November 2, 2015, http:///www.flexatone.org/article/flexatoneHistory.

[21] Natalia Paruz, “Flexatone,” Saw Lady, (Ameriklectik Music 2000-2008), accessed November 16, 2015, http://www.sawlady.com/flexatone.htm.

[22] Froehner, “The Saw.”

A revival occurred during the mid-1950s, the same time as Folk music was making a come back. Skiffle, a music genre played with elementary instruments such as the washboard, box fiddle, musical saw and more, became immensely popularafter World War II[23]. The musical saw began to be sold again and has since regained popularity. Today, there are hundreds of saw players around the world and saw festivals keep growing each year.

IN MOST RECENT YEARS:

The Theremin overtook the saw due to its wider range. There were also more serious classical musicians who took up the instrument as opposed to the folk traditions of the saw. Clara Rockmore was a great proponent of the Theremin. At an international festival of Theremin players in Asheville, North Carolina, in 2005, just before the death of the Theremin maker Robert Moog, a musical saw player was invited onto the stage on the final evening. Before that event the slow movement of the D-minor concerto for two violins by J. S. Bach was performed with the Theremin and musical saw accompanied by musical glasses, showing the integration of the saw with its more recent competitor.

In 2007, the New York Times, in cleaning their archival room for a move from 43rd Street, Manhattan, decided to make a list of the most bizarre recordings in its holdings. It voted a musical saw album, *Sawing to New Heights with Steve and Dale,* to be in this list of five recordings[24]. Perhaps this is a statement to the saw attaining a new status.

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[23] “Skiffle,” World Public Library, accessed November 12, 2015. http://www.worldlibrary.org/articles/skiffle.

[24] Daniel Wakin, “Sonorities of a Tenor Tuba and a Symphonic Saw,” The New York Times, June 23, 2007, accessed October 19, 2015, http://www.nytimes.com/2007/06/24/arts/music/24waki.html?_r=0

SAW FESTIVALS:

Saw festivals have been spreading around the world. The saw festival of Santa Cruz, now celebrating its 38th year, has been followed by the NYC Musical Saw Festival, organized by Natalia Paruz, which was noted by the Guinness World Record 2009 as having the most saw players in one location performing together—53. The most recent festival, the 11th gathering in 2015, actually had 60 saw players. There have been other festivals around the world such as Poland, Vienna, and Japan.

MUSIC FOR THE SAW:

Composing for the saw is a wonderful exploration of new sounds. The saw is notated an octave below its actual pitch, and generally in the G clef. Most songs that are within the range of the saw are adaptable to being played on the saw—from opera arias to plainchants. It is commonly said, if one can sing it then one can play it on the saw[25]. Because of this, the saw has encompassed a mass of playable literature not necessarily composed for the saw. As mentioned earlier, its popularity in the early part of the 20th century comes from the folk traditions of singing songs. Although, more recently, there has been repertoire written specifically for the saw. In fact, instead of the flex-a-tone replacing the saw, there have been instances where the saw has replaced the flex-a-tone. These pieces have become adventuresome and at times have driven the saw to amazing limits of pitch and timbres. Included below is a list of some compositions that shows the diversity of interests.[26]

Compositions for the Saw:

Divinations by Mirrors (1998), Michael Levine

Concerto No. 1 for Piano and Orchestra (1936), Aram Khachaturian

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[25] Cowing, "General & Technical Information On Playing The Musical Saw."

[26] Since any piece on the flex-a-tone can also be played on the saw, a list of flex-a-tone compositions has been included.

"Plainte" (1949), Henri Sauget

"Ancient Voices of Children" (1970), George Crumb

"The Old Homestead," *Hawks and Doves* (1974), Neil Young

Harlequin for Solo Bass Trombone and Piano (2000), Larry Lipkis[27]

Tracks from *More a Legend Than a Band* (1994), The Flatlanders

Harrisdale Concerto (2015), Alan Hirsh

"Scheherzade," Spike Jones

"2x4" (1992), John Link

"Pale Moon" (1920), Logan Knight[28]

Arrangements by Shiori Chazono for jazz saw and ensemble

Piece for Viola da Gamba, Sackbut and saw, David Loeb

Compositions for Flex-a-tone:

De Natura Sonoris No. 1 (1966), Krystof Penderecki

Fugue for Percussion (1941), Lou Harrison

"Eating Greens" (1994), Steven Makey

Carolin Mathilde: "Cross Lane Fair," "Stone Litany," Runes from a House of the Dead," "Symphony No. 9" (1991), Peter Maxwell Davies

Variations for Ochectsra, Op. 31 (1926-1928), Arnold Schoenberg

Nocturnal (1961), Edgar Varèse

Metropolis Symphony for Orchestra (1988-93), Michael Daugherty

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[27] Features the saw in the cadenza

[28] Song arrangement

PHYSICAL PROPERTIES OF THE SAW

This portion of the paper will examine the physical properties of the musical saw with particular focus on the bending mechanism that allows the saw to produce a definite pitch. The basic idea is that by Newton's second law of motion, it is a force that sets things in motion, including vibration. This force can be provided by an external tension, in the case of a string, or an internal stress, in the case of a metal plate. In more complex systems, such as the saw, due to the bending stress on the blade, there are spatial imbalances in the forces that contribute to making a sound on the saw. Through the study of certain physical proportions related to excited frequencies in more basic objects, a string and a metal plate, projections can be made about the workings of the musical saw.

STANDING WAVES:

It all starts from a sound wave: a disturbance in a medium caused by vibration. The resonance associated with the modes of these vibrations in the medium form wave patterns known as standing waves. These waves are formed by the constructive combination of reflection and interference with the incident wave[29]. In other words, reinforcing oscillations that vibrate at a set frequency. There are two types of standing waves, longitudinal and transverse. For a transverse wave, the oscillations are perpendicular to the direction of the traveling wave. While for a longitudinal wave, the oscillations are parallel to the direction of the travelling wave.[30] The latter wave can be excited on a string and throughout a solid.

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[29] "Standing Waves," HyperPhysics, August, 2000, accessed November 16, 2015, http://hyperphysics.phy-astr.gsu.edu/hbase/waves/standw.html.

[30] "Transverse Waves (Transverse and Longitudinal Waves)," HyperPhysics, August, 2000, accessed November 16, 2015, http://hyperphysics.phy-astr.gsu.edu/hbase/sound/tralon.html.

TRANSVERSE STANDING WAVES:

When exciting a transverse wave in a system, the driving frequency applied will match its natural frequency, known as resonance[31]. On a string, only standing waves in the form of sine and cosine waves occur when vibrations are sent through. But for a metal plate, hyperbolic sine and cosine waves can also be excited. This means there are waves that in space look like hyperbolic sine and cosine functions but in time appear as regular sine and cosine waves, sounding like definite tones. For a two-dimensional system, such as a metal plate, these wavelengths are relatively simple to derive. But for the musical saw, since one is bending the metal and therefore bending the waves, determining definite tones becomes much more complex: one would have to figure out when each curve hits another curve and solve it numerically.

The geometry of a system and the velocity of waves in a medium both contribute to the frequency of a wave. It is important to understand the relationship of the two when talking about complex systems, such as the saw. An overview of these relationships within simpler systems will help simplify the explanation of how the saw is able to sing, in hope that the reader will at least gain an intuitive understanding.

On a surface such as the saw, sound waves form two-dimensional patterns. In order to understand waves in two dimensions it is easier to first consider one-dimensional waves. A wave on a flexible string under tension, with fixed ends, is the simplest case of a one-dimensional transverse wave.

ON A STRING:

For an ideal string, its length, density, and tension applied determines what standing wave patterns occur. The length in which the pattern occurs is directly

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[31] Glenn Elert, "Standing Waves," The Physics Hypertectbook, 1998, accessed November 16, 2015, http://physics.info/waves-standing/.

related to the wave's wavelength. A full wavelength, denoted by λ, has one crest and one trough (Fig. 3)[32]. The fundamental of a string is the first standing wave that can be formed. This is when the string has only two nodes, one at each end, and one antinode (fig. 2). If a string has a length of L, the fundamental would have a length of $\frac{1}{2}\lambda$, resulting in $\lambda=2L$. The next possible standing wave, the second overtone, has 3 nodes and 2 antinodes. This would be two times the fundamental such that $L=\frac{2}{2}\lambda = \lambda$. For subsequent standing waves, an additional node appears, shortening the wavelength and increasing the frequency. This results in the frequencies of the harmonics to always be integer multiples of the fundamental frequency.[33]

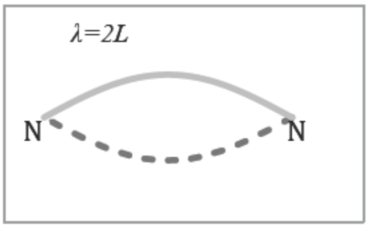

Figure 2: Fundamental Frequency

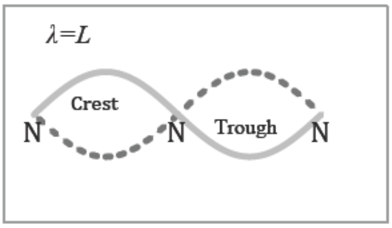

Figure 3: Second Harmonic (full wavelength).

The tension applied to a string and its density, mass per unit length, determines the wave velocity. Thus, the wave velovity is given by $v=\sqrt{\frac{T}{m/L}}$ (Eq. 1), where T is the tension, m is the mass, and L is the length of the string. This determines the relationship between the wave velocity, wavelength and frequency, resulting in the $f=\frac{v}{\lambda}$, where f is the frequency. Applying this wave relationship to the fundamental, one gets $f=\frac{v}{\lambda}=\frac{\sqrt{\frac{T}{m/L}}}{2L}$ (Eq. 2).[34]

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[32] "Standing Waves on a String," October 19, 1999, accessed November 18, 2015, http://hep.physics.indiana.edu/~rickv/Standing_Waves_on_String.html.

[33] Elert, "Standing Waves."

[34] "Vibrating String," HyperPhysics, August, 2000, accessed November 17, 2015, http://hyperphysics.phy-astr.gsu.edu/hbase/waves/string.html

In more complicated systems, multiple standing waves can form with different velocities resulting in complex patterns, but the relationship between the geometry of the system and the velocity of the waves still holds.

ON A RECTANGULAR PLATE:

The same reasoning used to understand the frequencies that can occur on a string can be applied to two-dimensional systems such as the musical saw. First, consider a rectangular plate. By moving to two dimensions, it is easiest to think of the surface of the instrument lying along the *xy*-coordinate plane. When exciting standing waves on a plate, nodes form in a variety of ways, depending on how the plane is bounded. For a rectangular plate a mode is described by (*m,n*), where *m* and *n* are the number of nodal lines in the *x* and *y* directions. In order to understand the complexity of the frequencies related to these two-dimensional waves a brief overview of the wave equation in two dimensions for a rectangular plate with free ends will be discussed. Since there is more than one standing wave traveling across a plate's surface the possible wavelengths, λ_x and λ_y, are:

$$\lambda_x = \frac{2L_x}{m} \text{ and } \lambda_y = \frac{2L_y}{n} \text{ (Eq. 3.1 and 3.2),}$$

where L_x *and* L_y are the dimensions of the plate.[35]

These wavelength are related to the wavevector, κ_x and κy, which describes how many oscillations per unit of space a wave completes, by $\kappa = \frac{2\pi}{\lambda}$. Since in a two-dimensional system direction needs to be taken into consideration, the wavevector is used to determine the frequency since it is direction dependent and describes the spatial angular frequency of the wave. The formula for a wavevector is:

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[35] Alasdair Campbell, *Vibrations of a Metal Plate*, February 7, 2006, accessed November 12, 2015.

$$\kappa_x = \frac{2\pi}{\lambda_x} = \frac{2\pi}{\frac{2L_x}{m}} = \frac{m\pi}{L_x} \text{ and } \kappa_y = \frac{2\pi}{\lambda_y} = \frac{2\pi}{\frac{2L_y}{n}} = \frac{n\pi}{L_y} \text{ (Eq. 4.1 and 4.2).}^{36}$$

This means the wavevector, or wave number, for each mode is:

$$\kappa_{m,n} = \sqrt{k_x^2 + k_y^2} = \pi\sqrt{(\frac{m}{L_x})^2 + (\frac{n}{L_y})^2} \text{ (Eq. 5).}$$

The phase velocity is dependent on the speed of sound in the plate, which is given by:

$$c_L = \sqrt{\frac{1}{\rho}\frac{E}{(1-\mu^2)}} \text{ (Eq. 6),}$$

where E is young's modulus, which defines the relationship between stress and strain, μ is Poisson's number, which measures the ratio of strain within the material, and ρ is the density of the material[37] [38]. Therefore, one can see that the wave velocity in a two-dimensional system also relies on the tension within or applied to the object (Eq. 1).

With a certain phase velocity, v, and wave vector, the frequency, $f_{m,n}$, of the modes can be calculated by the formula:

$$f_{m,n} = v(\frac{\kappa_{m,n}}{2\pi}) = \frac{v}{2}\sqrt{(\frac{m}{L_x})^2 + (\frac{n}{L_y})^2} \text{ (Eq. 7).}^{39}$$

From this equation one can see that, like on a string (Eq. 2), the frequency depends on the velocity, which relies on the tension applied to the material and its density, and the material's dimensions. These equations will give different results depending on if the edges of the plate are clamped or kept free but the relationships in the equations stay the same[40].

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[36] William C. Elmore and Mark A. Heald, "Physics of Waves,"(New York: Dover Publications, Inc., 1969), 54.

[37] "Elastic Properties of Solids," (NDT Resource Center, 2001), Accessed November 18, 2015, https://www.nde-ed.org/EducationResources/CommunityCollege/Ultrasonics/Physics/elasticsolids.htm

[38] Wolfgang Kropp, "Vibrations of Structures," Accessed November 18, 2015, http://www.ljudlandskap.acoustics.nu/downloads/ljudbok/specialister/kapitel_3/rubrik10/wave_in_structures.pdf

[39] Campbell, "Vibrations of a Metal Plate."

[40] There are 27 ways a plane could be bounded, each resulting in a different set of vibrational modes.

ON A SAW:

The saw can be thought of as a rectangular plate clamped in the y-direction and free edges in the x-direction. A pitch is made on the saw by bending the blade in an “S-Curve” (fig. 9) and hitting the surface or bowing the edge of the saw at the “sweet spot” (fig. 11).[41] The bending of the blade creates bounds, like fixed ends of a string, and when a pitch is excited the blade surface vibrates, radiating the pitch. The player then can change pitch by altering the curvature of the S-shape.

When tension is applied to a string, a restoring force is exerted. This is dependent on the materials elasticity. When a material is distorted it exerts a restoring force, which is the force needed to restore the material back to its original configuration, commonly proportional to the amount of stretch. The stiffer an object is, the greater its restoring force. A big difference between a string and a metal strip is that, in a metal strip, the restoring force is not the external tension but the internal strength of the metal.

By sending vibrations through the saw, slight bending motions are created, allowing the object to vibrate. With uniform objects, one can find the elasticity of the object and therefore can determine how vibrations pass through the object. But with the saw, when bent in an S-shape, the curvature varies throughout the blade. This means the blade does not have a uniform tension, as with the rectangular plate, but rather multiple stress points that create varying tensions throughout the blade. Therefore, when the blade vibrates, not all the frequencies transmit at the same speed. The phase velocity will increase in regions under more stress, more curvature, and decrease in regions with less curvature (Eq. 6). Relating the desired frequency to κ (Eq.

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[41] How to make the S-curve and find the sweet spot is described in the How to Play the Saw section on pages 20-25.

5), if a certain frequency is excited, a wave below the sweet spot would move in the direction of increasing curvature until it matches the desired frequency[42].

If a wave is traveling from the sweet spot to an inflection point, it is traveling from a lower to a higher area of stress. At the inflection point, the change in curvature creates a situation that in order to move to the next part of the medium, there would have to be an angle greater than possible[43]. In other words, any wave that moves toward higher curvature related to the desired frequency would cause the wave number to become imaginary, causing the wave to reflect back towards the sweet spot. This creates a region between the two inflection points where the vibrations are essentially trapped, analogous to fixed ends of a string. This means the vibrations never reach either end of the saw, which preserves the sound from damping[44]. Different pitches are then achieved by changing the applied tension, which shifts this trapped region to wider and narrower portions of the saw.

HELMHOLTZ MOTION:

When the edge of the saw is bowed, it acts in a similar way as when a string is bowed. The bow hairs pull the edge of the saw in the same direction at roughly the same velocity. But at a certain point, the blade will want to slip back to its equilibrium state. When the blade slips, it oscillates at a speed reliant on both the elasticity of the metal and stress in the saw, resulting in a different velocity as the bow[45]. Therefore, the saw adjusts the bow's interaction with the blade to match its own frequency, creating a positive feedback, which exponentially grows until the steady tone is

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[42] Note that the dimensions of a curve either exponentially increases or decreases, resulting in κ to do the same.

[43] Due to Snell's Law and total internal refraction.

[44] Neville H. Fletcher and Thomas Rossing, "The Physics of Musical Instruments," (Springer Science & Business Media, 2013), 666-667.

[45] This stick-slip motion is named the Helmholtz motion after Hermann von Holmholtz.

achieved. This means a saw player must be sensitive to what the pressure information the hand is getting through the bow. One must internalize this sensation in order to make adjustments to the bow speed to keep the sound going.

HARMONICS:

As described above, the harmonics on a string will always be integer multiples of the fundamental. If a string were plucked, all the overtones would be excited, mostly reinforcing the fundamental. If the overtones are inharmonic, meaning they do not reinforce the fundamental, distinctly different tones are heard. Given how the saw sets up its standing waves, simple overtones are not expected. If a saw were struck, the fundamental is heard along with a mixture of harmonic and inharmonic overtones, producing a "twang" sound.

The modes excited by bowing the edge of the blade at the sweet spot are those of the second symmetrical group classification (*2, n*), two nodelines parallel to the long sides of the blade (Fig. 4)[46]. By observing the Chalndi figures that form on the saw, one sees that when bowing within the sweet spot nodes in the y-direction form under the sweet spot and just like the string, the higher *m* and *n* are the higher the frequency will be[47]. In a video, by Oliver Doucet, showing different Chlandi Figures on the saw, one sees that when bowing below the sweet spot overtones can be excited creating modes where *m* equals 3, 4 or even 5.[48]

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[46] Photograph by Arnold Tubis. "The Physics of Musical Instruments," 666.
[47] Fletcher and Rossing, *The Physics of Musical Instruments*, 665.
[48] Oliver Doucet, "Chlandi Figures on Musical Saw!" Youtube video, posted by "MusicalSawMen," August 5, 2015, https://www.youtube.com/watch?v=6SN_qTbftNA.

Fig. 4: Two modes of vibration Chlandi Patterns on a saw.

It is surprising that the most common overtones found on the saw are within the harmonic series of the fundamental[49]. Once the fundamental has been set up, bowing below the sweet spot produces these harmonics. For example, when playing a C_5 the fifth partial can be found by bowing 11cm below the sweet spot[50]. On the same saw, when playing an $A_{5,}$ the fifth partial is found 8cm below the sweet spot and when playing a $D_{6,}$ the fifth partial is found 6cm below the sweet spot[51]. This shows that there is some correlation between the tensions within the saw and bowing the edge of the blade that allows this reinforcing relationship between the fundamental and these overtones[52].

Where to excite these overtones differs depending on what saw is being used, the stress applied to the blade (and all that goes along with the stress, mentioned above), as well as the pressure and speed of the bow. Perhaps, by bowing the edge, it stimulates the trapped region at a certain frequency, giving a reference for exciting

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[49] Note that overtones cannot be excited above the sweet spot due to Snell's law.

[50] The distance one needs to bow below the sweet depends on the tension being applied to the saw.

[51] This example was done on a blue steel saw 29.5 in. long, 7 in. wide at the base, and 1 in. wide at the top. Due to the increase of pitch (C_5-A_5-D_6), the S-curve tightens, cutting off the vibrations sooner resulting in the harmonics to appear closer to the sweet spot.

[52] This relationship depends on the saw being used and the stress applied to the blade.

overtones that are simply related to that frequency. This is due to the stick-slip mechanism of the bow, which is likely to pick up the harmonic by relating it to the stick-slip motion achieved by the fundamental.

HOW TO PLAY THE SAW

HOLDING THE SAW:

There are many ways to hold the saw. The most common is to be seated with the handle of the saw between the thighs or feet (fig. 6 and fig. 7). Another technique involves standing and putting the saw between the feet or knees (fig. 7 and fig. 8). The saw could also be clamped and placed on the floor.

Figure 5: Sitting and holding the saw between the thighs.

Figure 6: Sitting and holding the saw between the feet.

Figure 7: Standing and holding the saw in between the feet.

Figure 8: Standing and holding the saw between the knees.

BENDING THE SAW:

The saw is bent by holding the tip with the dominant hand and bending it down to the side, forming a slight arch (about 45°) to the left or right (fig 8). A "tip handle" is sometimes used to do this.

Figure 8: Forming the first arch.

Most tip handles are cylindrical pieces of wood with either a screw at one end or a slit near the bottom of the handle. No modification of the saw is needed to use the slit handle. Note: the length of the slit in your handle should be no more than a centimeter deep. If the slit is too deep it could shorten the range of the saw.

ACHIEVING THE S-CURVE:

If using a handle, with the saw starting in an arch, twisting one's wrist towards the body of the saw is enough force to create the S-curve (fig. 9). It is important to do this with the least amount of effort, merely using the weight of one's arm to assist in the leverage.

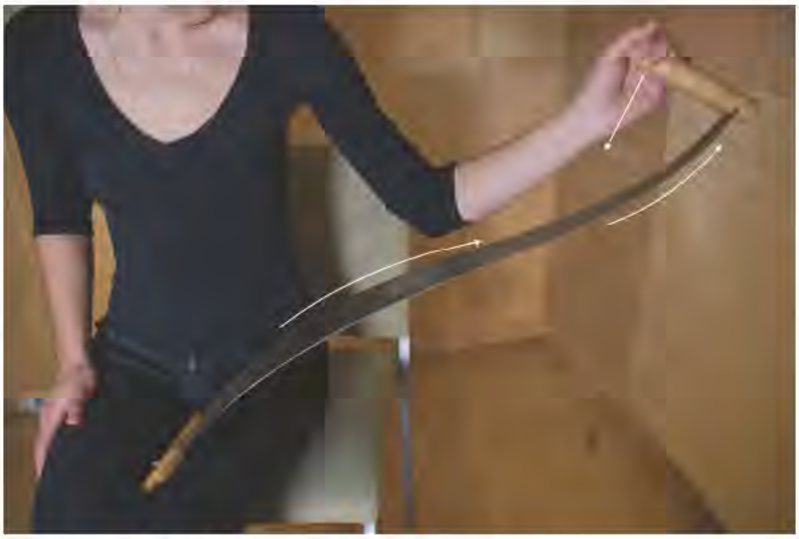

Figure 9: Bending the saw into an S-curve.

When using one's hand instead of a handle the saw is bent by pushing on the top of the blade with the thumb while pulling the tip towards the base of the saw with the other fingers (fig. 10).

Figure 10: Bending the saw with the hand

HOLDING, BENDING, AND ACHIEVING:

Seated:

When sitting while playing the saw, it is important to sit at the front of the chair so that one's knees are free to hold the instrument.

The knees should be slightly apart so that the blade can be inserted in between them. If the saw has teeth the teeth should be facing towards the player[53]. A little trick to keeping the saw secure is to get the base handle right under the thighbone (fig. 5). This way the base handle is more secure for bending the saw, allowing the legs to loosen a bit. Then bend the saw in an arch and achieve the S-curve (fig. 8 and fig. 9).

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[53] Note that one could play on the teeth by pressing the hairs of the bow past the sharp points into the wedges of the teeth.

Standing:

When playing the saw in a standing position, the heel of one foot should be pressed against the arch of the other. This allows for one knee to be behind the other[54]. The handle of the saw is then placed between the knees. The back knee is pushed into the hole of the handle, which is secured by the back of the other knee. This should be enough support to hold the saw with just the knees. Then bend the saw in an arch and achieve the S-curve.

FINDING THE SWEET SPOT:

Once an S-Curve is achieved one must now find the "sweet spot". This is easiest to find by using a mallet. The sweet spot is located exactly between the high and low curve. This can be done by finding the apex (peak) of the high curve and the bottom of the low curve (trough) and then striking the mallet on top of the blade, with a quick rebound to prevent deadening the sound, precisely at the halfway point (fig. 11). By doing this one should hear a ringing note. If the sweet spot is hit directly the note should sustain for at least 5 seconds. With practice, the sweet spot is quickly discovered.

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[54] Cowing, "General & Technical Information on Playing the Musical Saw."

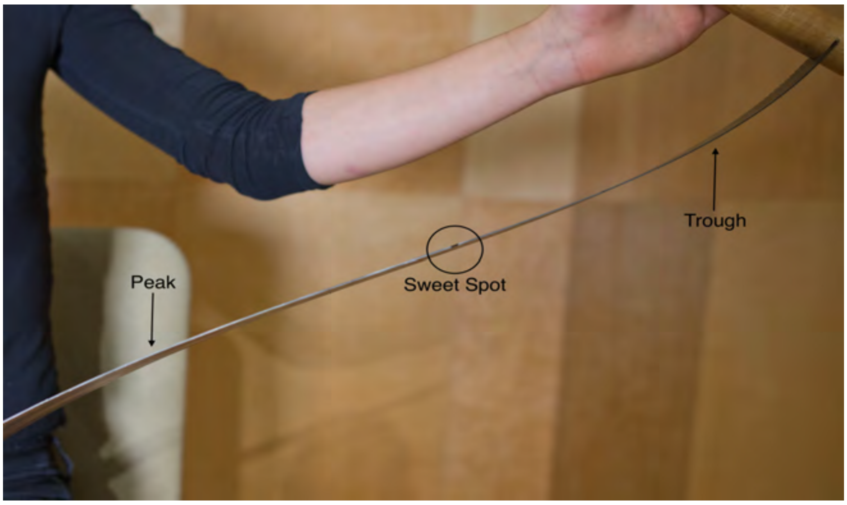

Figure 11: Finding the "sweet spot".

CHANGING PITCH:

Once a mallet or a bow achieves a sustained note, the goal is to produce this same ring throughout the range of the saw. The more tension within the blade the higher the pitch will be. Increase in tension can be made either by a larger beginning arch, by bending the blade further, or a tighter S-curve, by twisting the wrist further.

The best way to get familiar with changing pitches smoothly is by playing with a greater array of pitches, at increasingly greater distances, from the first successful ring. It is useful to first manage the distance of a half step. One can then go on to greater intervals through the complete range of the saw. It is essential in the beginning not to jump to the next interval but rather slide to it. This will sound like a slow glissando. Eventually, after feeling the distance of an interval and the change in tension, one can increase the speed of the shift.

The ability for the saw to sound after changing the pitch is dependent on the ring before the shift. A note can be found by slightly snapping the wrist when making the

S-curve. This will cause the body of the saw to vibrate a bit and one can then bend to the desired pitch. It is difficult to completely avoid a glissando when changing pitches, since the vibrations in the saw are still alive from the first note. The only way to jump from note to note with no glissando is by killing the vibrations in the saw before proceeding to the next note. But a fast shift will result in a shorter glissando and when mastered one can barely hear the slide in pitch. This is more difficult to achieve going down than up, due to the slower vibrations in the lower register.

It is very easy to make a shift and have the desired note not sound. This is another reason why the vibrations have to be kept during the shift. It is also useful to articulate the new note not only by the bow or mallet, but also through the shift itself. With the hand holding the tip one can articulate a note with a tiny flick in the wrist.

TECHNIQUES

OPEN SAW:

If one removes the handle of the saw and hangs the blade, the saw can be used like a gong by hitting it with a mallet. One can also hold both ends of the saw and snap the blade. This creates a quick-pitched “thwap” sound.

USING A MALLET:

Beyond finding the sweet spot, the mallet is used in performing to create various articulations. The difficulty in using a mallet is that the saw blade has a tendency to react and waver its pitch when the mallet strikes too strongly or in the lower register. (Some may wish to use this pitch variation for a particular effect.) Any striking device could be used, but the typical types are:

1. Padded mallet

   A padded mallet, which could be padded with cloth, string, rubber, or any soft covering, will create a softer color in its articulation.

2. Wooden

   A wooden mallet, including bamboo, or bamboo rod, induces a sharper attack in the desired articulation. It is important to note that one might hear more of the sound of the wood hitting the blade than the actual pitch created.

3. Plastic

   A plastic mallet has a softer articulation than the wooden mallet but the sound of the plastic is also heard when hitting the saw.

4. Metal

   If the metal is harder than the steel used for the saw it articulates more sharply but with less resonance than wood. Some saw players use metal bars, screwdrivers, and soft drumbeaters as a metal “mallet”, working the saw like a cowbell.

COMBINING MALLETS:

Two mallets could also be used to create quick repetitive articulations; one mallet hitting the top of the blade while the other hitting below. The two mallets can also hit one side at the same time, creating a more forceful ring. This is usually used for percussive purposes.

USING A BOW:

A bow is the most common instrument used to play the saw. The bow is held with the hairs facing towards the blade and the tip pointing down, near the frog end, with the thumb in between the space of the hair and bow and the rest of the fingers over the back of the bow (fig. 12). To make a pitch one must place the bow at the sweet spot (fig. 11) and drag it along the edge of the blade. One finds the sweet spot the same way as with a mallet except along the edge. It is normal to hear the sound of the bow sliding across the edge; some techniques on how to diminish the bow noise will be explained later on.

Figure 12: Two ways (out of many) to hold the bow.

The stick-slip mechanism determines how fast one must move the bow and how much pressure one needs to apply in order to excite a pitch (see page 20, Helmholtz motion). For the best quality of sound, the least amount of speed and pressure is recommended. But, as with most bowed instruments, the more pressure one applies and the faster one bows, the louder the sound becomes. Once a note is achieved, one can remove the bow from the blade and let it ring. If one wishes to sustain the note, more light strokes on the sweet spot will keep the vibrations alive.

The size of the bow, in terms of length, is only important for being able to sustain a note for a shorter or longer amount of time. Often a saw player will unnoticeably rearticulate the bow in the same direction, thereby subtly increasing the length of the bow. Various sizes and types of bows are found across the globe. Some are in the style of an erhu bow, a bow used by a western string instrument, with varying amount of hair. The hair might be flat or rounded. It is important that the bow is well-rosined and taught, in order to glide across the edge with enough pressure to create a sound. The more hair a bow has the more edge surface it can cover which results in a louder ring.

The tension of the hair changes the contact on the metal. The greater the tension the more pressure is needed to press the bow onto the blade. The less tension in the hair the less pressure is needed to keep the bow on the blade.

The speed of the bow has a great effect on the tone and style of playing. Some saw players like to play with a slow bow and others with a faster stroke. Some like to keep the bow on the saw blade almost continuously and others prefer the hair to touch the saw as little as possible. The more the hair is on the blade, the more there is a chance of a raspy sound, as mentioned above. This may be a preferred way for playing a Gospel song. A more classical approach would be to keep the hair off the saw, only to touch the blade for continuing the ring. If one restrikes the saw blade with the bow with greater speed, one is apt to hear less bow noise as well.

In order to get the best ring on the saw one should angle the bow so that the bow is perpendicular to the corners of the edge. This is done by angling the bow, less than 90°, towards the top of the blade when stroking up and towards the bottom of the blade when stroking down (fig. 13). By putting the bow flat on the blade edge not only can you hear the bow more but it can dull the ring and change the sweet spot by pulling on the saw.

Figure 13: Down stroke and Upstroke angle.

PLECTRUM:

A plectrum can be used to pluck the edge of the saw. When the edge is plucked, depending on the tension of the saw, different combinations of the partials is heard. A common one is the major third and the octave. This technique is also used more for percussive purposes than melodic.

VIBRATO:

Just as with any other instrument vibrato can be used to add expression to the instrument. A good vibrato needs to be even and flexible to the musical style. The vibrato color of a saw is most common, however quite a few saw players have attained a great lyrical beauty without vibrato or with only a little coloration. There are several ways to creating vibrato.

Vibrating the right or left foot is one way to obtain the vibrato if one is sitting with the saw between the knees. The foot that has the blade tucked under its thigh is the preferable foot to vibrate since vibrating the other leg, underneath the blade, may cause the blade to slip. In order to make one’s foot vibrate the heel must be lifted and as a reflex response the foot, along with it the whole leg, will begin to shake. With practice a player will be able to control this response and with it vary the speed of the vibrato.

Another way to play with vibrato is by shaking the hand that is holding the handle or the tip of the blade.

OPTIMAL EDGE:

Oliver Doucet, a Canadian saw player, sanded the edge of the saw to create a rounded edge. He found that by rounding the edge the bow it could glide with the curve and cover more surface area creating a fuller sound and a smooth release instead of going against an edge where the bow had limited control in the release[55]. This also helps decrease the rasping sound of the bow. This sound is hard to avoid when exciting a pitch but in order to keep a pitch ringing the bow has to re-enter the vibrating blade without stopping its ring. With a rounded edge the bow goes with the curve creating less disturbance to the vibrations as dragging a flat surface on an edge. Most classical styled players strive to avoid this sound.

SAME PITCH:

The same pitch can be made with different degrees of tension. Once a pitch is achieved, it will ring better if the saw has less tension running through it. However, it is possible to achieve the same note on different parts of the saw by changing the tension. While playing a note on the saw, if one either bends the saw more or tightens the S-curve slightly, the same note can be found, but with a new location for its sweet

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[55] Oliver Doucet, “The Musical Saw Tutorial: Optimal Edge,” Youtube video, posted by “MusicalSawMen,” June 9, 2013, https://www.youtube.com/watch?v=4BdxSKLeKYs.

spot. In the effort to create harmonics, as discussed below, this change in slight tension to obtain the same note is crucial.

HARMONICS:

The saw cannot be described in terms of the harmonic series, but there are some methods to finding certain partials more easily. Since the physical characteristics of the saw serve as a variable to these methods each saw will require a slightly different approach.

First, a clear fundamental pitch needs to be achieved so that the saw has a steady vibration. Then by bowing below the sweet spot different overtones can be achieved depending on the placement and pressure of the bow.[56] By increasing the tension in the blade while keeping the same pitch, by the method above, one can access more overtones. For example, referencing page 19, the fifth partial can be found depending on the placement of the bow and the tension running through the blade. By increasing this tension but keeping the same pitch, the second partial was found 10cm below C_5's sweet spot, 8cm below A_5's sweet spot, and 7cm as well as 3cm below D_6's sweet spot.

The overtones commonly found are the second partial, the fourth partial, the fifth partial, and the minor third, between the fifth and sixth partial. Other overtones such as the seventh partial, the ninth partial, and the perfect fourth, between the fourth and third partial, are obtainable as well. Interestingly, the saws that did not emit a full and beautiful sounding fundamental tone from the sweet spot were better at producing the overtones.

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[56] See page 18 for more detail on Harmonics.

COMBINATION TONES:

It is also possible to produce at the same time the fundamental and the partial, which creates the double-stop effect. This has to do with the bow pressure and placement. When two saws play at once, the ear produces a very audible combination tone, the summation of the two frequencies, or differential tone, the difference of the two frequencies. These tones, merely from two saws, are so loud that sometimes it is hard to even hear the actual pitches coming from the saws. The figure below shows the different pitches that result in the combination of two frequencies.[57]
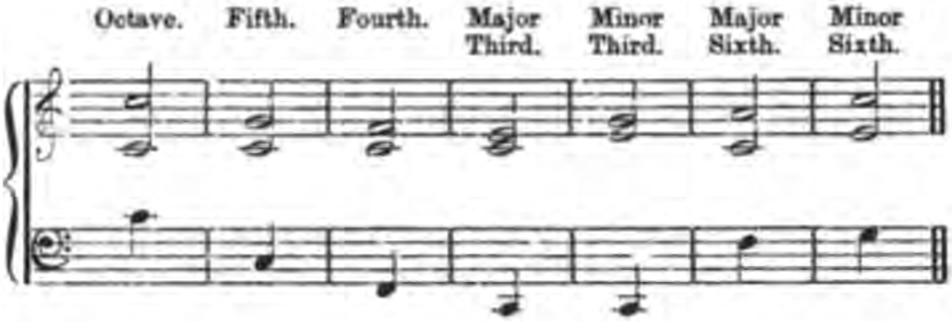
Figure 14: The treble clef shows the intervals made by, in this case, two saws and the base clef shows the resulting pitch.

From all these techniques, one can see that the range of possible sounds available on the saw is immense. It is able to produce a beautiful pure tone, like the flute or voice, as well as loud inharmonic tones, like the cymbal. This is what allows the saw to be used in various genres of music such as classical, jazz, folk, rock, and more.

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[57] Robert T. Beyer, *Sound of Our Times: Two Hundred Years of Acoustics,* (Springer Science & Business Media, 1999), 20.

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