**SPECIFICATION:**
**Dual Low and High Frequency Surface Acoustic Wave Amplifiers For All Banjos and Similar Acoustic Stringed Musical Instruments**

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## 1. Background

When musical instruments are played their surfaces are covered in varying degrees with surface acoustic waves ("SAWS") which are tiny physical deformations on and just below the surfaces of the instrument. Since these waves are surface deformation waves and not air pressure waves they are inaudible. Experiments by the inventor have shown that once made audible the inaudible surface waves seemed to be accurate representations of the music being played. This apparent fact justified research into methods to modify surface acoustic waves to improve the sound of acoustic stringed instruments such as acoustic guitars and banjos. The advantages of this approach are many and some are outlined in the following paragraphs.

Because high quality banjos are popular but expensive, research was conducted over several years to determine if surface acoustic waves could be inexpensively captured, improved for sound volume and quality, and then sent back to the sound chamber where they would be converted into improved audible sound to mix with the normal audible sound of the instrument. The goal of this feedback approach was to greatly improve the volume and sound quality of the banjo at minimal expense. If successful this approach would make good quality banjo sound available to many more people, and an additional benefit would be to give the player more control over the sound of the instrument.

This recent attempt to improve both the volume and sound quality (See "Drawing") is the first noteworthy success of this multi-year effort, offering increased volume and very high quality, beautiful sound. The device: is simple; is easy to construct; should retail for less than $45; is easy to use; works with almost all banjos; and can be adjusted by the player to emphasize high or low notes. Because the instrument's sound volume and quality is noticeably improved the device should be especially popular for use in solo performances and in making recordings.

## 2. How It Works.

There is a principle in physics related to all forms of waves commonly referred to as "Constructive Interference" which states that waves of the same or similar frequencies which meet coming from different directions will add algebraically, e.g., generally amplify but possibly subtract or even cancel each other entirely. Conversely, waves of different or dissimilar frequencies which meet coming from different directions simply pass through each other, seemingly "ghost-like", without changing either wave. This principle of physics is the primary method of amplification used by this device. It is both easy and inexpensive to implement and enables control of the direction of surface acoustic waves with common materials such as surface wave conducting tape, paper cut into different shapes such as rectangles and common steel staples which can automatically pick up surface acoustic waves on their points on one side of a paper surface and cause them to crash "head-on" in the center of the staple's flat portion on the other side of the paper's surface. (See sketch at the bottom of page 2, Drawing.) A banjo is particularly well suited to exploit surface acoustic waves because the waves are both abundant and accessible when they circle the inside surface of the banjo's (usually wooden) rim. The rim is also ideally located for this purpose as it encloses the banjo's sound chamber. The surface acoustic waves are easily collected by physical contact between the banjo’s rim and surface acoustic wave conducting tape, paper, other sheet materials such as brass foil and the points side of staples.

From experiments it was learned that surface acoustic waves flowing over different materials pick up a “timbre characteristic” typically associated with the sound of the material over which the waves flow. For example, when surface acoustic waves are made to flow over brass and then are later made audible as pressure waves in air, the sound will have a “brassy” character. This “timbre characteristic” capability of surface acoustic waves is easily and inexpensively selected by having the surface acoustic waves flow over musical metals such as thin steel and brass and musical woods such as maple and walnut veneers.

Two methods which have been used successfully to convert surface acoustic waves into air pressure waves of audible sound are the use of cantilevers in various shapes and rectangular horn shapes. The rectangular horn shapes, which are more effective than simple cantilevers, have top and bottom rectangular panels of folded and creased brass foil or compressed paper with four staples placed in-line and closely spaced to connect two paper edges in firm contact. This firm contact creates a mirror image of the surface waves on both facing, diverging planes. As air is introduced where the planes diverge these opposing surface waves squeeze the air between the planes in an analogous manner to the surface waves on their surfaces to create an analogous air pressure wave of audible sound between the planes. This air pressure wave grows as it travels down the widening air space between the diverging planes. The two planes can also be thought of as cantilevers which are coupled by the air pressure wave between them. Experiments revealed that the line of four staples worked better than a fold of paper to create high quality low frequency sound, and that folded and creased brass foil worked better to create high quality high frequency sound. Both methods are used in the device.

The following paragraphs, which should be read while viewing the drawings, describe the theoretical paths taken from the inside and bottom surface of the banjo’s rim through both high and low frequency devices and ending with improved audible sound being emitted into the banjo’s sound chamber to mix with the sound already there.

Note from the left “Installation” sketch on the drawing that the surface wave conducting tape on both amplifiers is placed at a 45-degree angle to any circumference on the banjo’s rim. This placement enables the tape to act as a preamplifier to the surface acoustic waves picked up from the rim by the adhesive layer of the tape. This is because initial surface acoustic waves enter the adhesive layer on the tape, are reflected by the tape’s edges and immediately align themselves with the direction of the tape. This causes all subsequent surface waves entering the adhesive layer of the tape to intersect the initial surface waves at an angle, which causes amplification by the principle of constructive interference described earlier. This amplification is easily demonstrated by changing the direction of the tape away from 45-degrees.

The surface waves on the tape then travel down the tape and enter the front paper surface of both amplifiers beneath the tape to the staple points of the staple that is near the center of the front paper surface. Meanwhile, some or most of the points of the row of four closely spaced staples very near the top edge of the front surface are in direct physical contact with the banjo’s rim, which causes surface acoustic waves to enter those staples’ points directly and be amplified when they meet on those staple’s flats on the front surface of the paper. They are amplified again when they meet surface acoustic waves on the front surface of the paper which arrived from the other three staples. This very large number of amplified surface acoustic waves on the front surface of the paper meet multiple times, both on the paper and on the tape, and are eventually deposited on the staple points of the staple located beneath the tape end at the center of the front surface, which amplifies them on the staple flat on the rear surface of the front panel.

Meanwhile, the front surface of the rear panel, which has a single staple flat, is receiving surface acoustic waves from two side tape segments with adhesive layers in contact with the rim on either side of its staple flat, plus surface acoustic waves from its staple points which are in direct contact with the banjo rim.

The many surface acoustic waves on the back of the front surface and on the front of the back surface are mirrored into each other where the row of four staples along the top edge places the two surfaces in firm contact.  As the two paper surfaces begin to diverge the surface acoustic waves compress the air and form an air pressure wave that is analogous to the surface acoustic wave which grows in size and energy as the paper surfaces diverge.  The result is loud, high quality sound.

The above description of theoretical events is believed to occur in both the low and high frequency amplifiers which are similarly constructed except: the paper surfaces of the high frequency amplifier are smaller; a fold of creased brass foil has been added to the back of the front paper surface; and a row of three staples has been added with staple points on the front paper surface and with their staple flats on the inside front surface of the creased fold of brass foil.  This row of staples takes the many surface acoustic waves from the front paper surface to the inside surface of the creased brass fold.  Because the brass fold is hard creased both sides of the fold contain mirror images of surface acoustic waves which generate audible sound in the same manner as in the low frequency amplifier.  Because the brass foil is more responsive to high frequency displacements than the paper the fold of brass foil is able to create beautiful, loud, high frequency musical notes and high harmonics in low notes, and improved sound quality in all notes.

## 3.  Instructions. (See drawings.)

**Prepare the Amplifiers for Installation One at a Time.**  The player bends the top and bottom halves of the brass foil rectangle in the high frequency amplifier, and the paper halves of the low frequency amplifier, away from each other a small angle such as 10-20 degrees.  Audible sound is created in this diverging air space between these halves.  Next remove the red tape backing strips and install each amplifier, one at a time, while playing the banjo after each is installed to note the change in the banjo's sound after each is installed.  The player should hear high frequency audible sound when playing high notes created in the diverging air space between the brass halves, and rich low frequency audible sound that is created in the larger diverging air space between the paper halves. Good quality high frequency sound also improves sound quality of even the lowest notes because harmonics in the low notes are amplified.  This improvement in sound quality of all notes from the high frequency amplifier is easily demonstrated by removing the high frequency amplifier from the banjo and listening for reduced sound quality.

**Reposition Both Amplifiers To Find Their Best Location For Your Banjo.**

Note that the sketch shows both amplifiers a small distance apart located on the inside of the banjo's rim near the bottom of the banjo as it would be held by a right-handed player.  This location tends to keep the diverging air space angle small because of gravity.  If the amplifiers are located near the top of the banjo's rim (as the banjo is  held in the playing position) gravity will tend to enlarge this diverging air space which may or may not improve the sound of the banjo, depending on the banjo.  Try both top and bottom locations to find your preference.

The distance between the low and high frequency amplifiers will also change the sound of the banjo, so you will want to change this separation distance also to find your preference.

The distance between the output of each amplifier from the banjo head will also change the sound of the banjo since the audible outputs of each amplifier (air pressure waves) strike the inside of the banjo's head, providing audible sound feedback to the head creating desirable (or undesirable) sustain or “echo”.  Again, try different locations from the head to find your preference.

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