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The Quest for the Best Tin Can Telephone

Abstract

This project attempted to find which type of tin can telephone is best suited acoustically to the human voice through a brief experimentation of the frequency responses and resonances of tin can telephones. In this investigation, we used the same string on three different types of cans: one small, short can; one long can; and one wide, paper-sided can. Though these different types of cans introduces a myriad of different variables, we used these as an example of the various options one has for the making of tin can telephones. The samples we recorded from the “listening” side of the tin can telephone gave us a look into how the resonances of the cans affected the transfer of the sound of human vocals. Our results yielded interesting findings surrounding the calculation of a tin can telephone’s natural frequency as well as intriguing potentials for future research in this topic.

Introduction

Tin can telephones were originally created by Amos E. Dolbear in 1854, and the idea of this type of communication took off. A year later, according to Lewis Coe in his book *The telephone and its Several Inventors,* this type of telephone became commercially available complete with 200 feet of connecting wire. According to Coe, this device and its popularity inspired Alexander Graham Bell to research further and eventually invent a functioning telephone on the 10th of March 1876.

Tin cans function much like an ear drum or speaker driver. The sides and bottom of the can vibrate with the sounds coming into them, which are then transferred to the to the taut rope or string (in our case, yarn). The sound waves are then transferred to where the string is attached to the bottom of the second can, which causes this can's bottom and sides to vibrate and amplify the sound through resonance.

The can's natural resonance, we hypothesized, could be found using either the Rayleigh equation or the one-end-closed tube equation. Because we were driving sound directly into the can, we hypothesized that it would function much like a room as opposed to a close-tube. The lowest modes calculated using the Rayleigh equation were as follows: The long can was 1380 Hz, the small can was 2300 Hz, and the paper can was 1674.8 Hz. Using the equation for a tube with one end closed, the lowest modes calculated were as follows: The long can was 690 Hz, the small can was 1150 Hz, and the paper can was 917.6 Hz. Through our experiment, we were hoping to find which equation would predict how the can responded to sound.

The fundamental, natural frequency of the string we predicted would also affect how the tin can telephone would function. One issue we originally found in calculating this number was finding what number to use for . In the equation for finding the natural frequency of string, is density of the cross-sectional area with a unit of mass per unit length (kg/m). The label of our yarn informed us that the density of the entire ball of yarn was 70.9 grams. The length of our yarn was 109 m. for our yarn then would be 6.5 10^{-4}kg/m. With this calculation, we find that the lowest three (fundamental and first two overtones) natural frequencies of the string (which was held at 10 N of tension) to be 20.34 Hz, 40.68 Hz, and 61.02 Hz.

When creating the tin can telephones, we observed several things about each telephone. We found that each can delivered the person's voice at the other end a bit differently due to their own natural resonances. Our predictions were that the small can would be the most effective in re-creating frequencies that were present in the direct sound sample of a human voice because its resonance would probably be the highest and closest to the frequency range of the human voice. The cardboard can was questionable in our eyes because we thought it might not be capable of vibrating on the receiving (listening) side to recreate the original sound the way that a tin can might.

Procedures

The first thing that had to be completed for this experiment was the construction of the tin can telephones themselves. We chose three types of cans for our telephones; one tall tin soup can, one short tin tomato sauce can, and a wider short can that held cocoa powder and had cardboard sides. In order to keep the device controlled, we used a standard length of 10' (3.048 meters) for each strand of yarn. The same yarn was used for all three cans so that the independent variable was the type of can. A nail was used to punch a hole in the bottom of each can and the yarn was fed through and held by a knot. One additional hole was drilled into the rim of the open side in one of each type of can to connect to a spring scale, ensuring a constant tension during the recording process.

We performed our experimentation at the Quonset Hut in 34 Music Square East. In order to obtain our final data, it took three meetings and three attempts. The various issues that ensued were time constraints for studio use, complications with interfaces/monitoring and general trial/error as we discovered the best way to do things.

The setup for the experiment included two baffles to each side of the string that were placed as close as possible without touching the string and interrupting the sound waves' travel along it. These were used to help isolate the sound coming directly from the speaker and the sound that was playing back through the other side of the tin can telephone. A speaker was set up on one side of the baffles with an SM57 picking up the direct sound from 3 inches away (the tin can was also held 3 inches away from the speaker on this side). (Figure 1) A second SM57 microphone was placed on the other side of the baffles where the can was held close to it to simulate the way it would be held to a human ear. (Figure 2) The small spring scale was connected to the receiver side of the can and the string kept taught at a tension of 10N. This tension was chosen as a constant because at 12N the knots that were keeping the yarn connected to the cans could not handle the pressure and kept getting ripped out. 10N kept the yarn drawn tightly without causing too much pressure on the knots holding the entire device together.

We had three sample sounds that were to be played through the speaker and tin can telephone: pink noise, a sine wave at 4k and a clip of the human voice repeating the phrase, “All work and no play makes Jack a dull boy.” The microphones were connected to a Focusrite audio interface and Pro Tools was used to the record the experimental data. We first played the 4k tone through speaker and with each can, we recorded both microphones. This method was repeated using the other two samples (pink noise and voice). The wav files from these recordings would be used to yield results with frequency analyzing software such as Audacity and Pro Tools after. We also measured the SPL of the direct sound and the sound coming from the receiver side of the can with an SPL meter, but through our analysis, we realized that these values were inconclusive.

Results

After conducting the experiment, one of the final steps in finding results about frequency response of the tin cans was to process each recording through a frequency analyzer. We chose to use the Waves PAZ frequency analyzer plug- in for Pro Tools. Figures 3- 14 depict the results from the PAZ plug- in. From the frequency response graphs, we concluded that the human voice track was the most realistic representation of resonance not only because the results were audibly different, but because these graphs had noticeable spikes near our calculated resonance values. Figure 11 depicts the speaker microphone response, and figures 12-14 represent the frequency responses of the long, paper, and short cans respectively. Figures 12 shows a spike around 500 Hz, figure 13 shows a spike ranging from 500 Hz to 900 Hz, and Figure 14 shows a spike at 1000 Hz, which are both close to the calculated values of 690 Hz for the long can, 917 Hz for the paper can, and 1150 Hz for the small can.

Conclusion

In conclusion, through examining the frequency response graphs it was found that the small can has a frequency spike around 1000 Hz, the paper can has a spike ranging from 500 Hz to 900 Hz, and the long can has a frequency spike around 500 Hz. This could be contributed to the resonant frequency of the cans themselves at the controlled tension and SPL. Overall, there are a variety of factors that must be taken into account while doing this experiment. the length of the string, tension of the string, and the material of the cans and their bases were variables that needed to be controlled. Varying the tension could contribute to differences in resonant frequency, as well as the frequency of the sound being set through the telephone system, so we tried to control these variables by using a spring scale to measure the tension for every trial, and by sending various different types of audio tests through the telephones.

Further Investigation

For any sort of further investigations, we would probably try and control more variables for the can tests. Two of the cans were made completely of tin, but the paper can, was made of paper with an aluminum bottom that was thinner than the other two. The thickness of the base is also a contributing factor to resonant frequency, so it would be helpful to have been more consistent with materials in order to come to more valid conclusions about frequency response in the cans. Finally, we would have used a smaller diaphragm measuring microphone for our tests as opposed to an SM57. Although the 57 is a fairly linear microphone, it is not as accurate as a smaller diaphragm condenser would have been, or an omni microphone manufactured for room measurements. Another test that would have been helpful to us would have been to calculate the resonant frequency of the can and then drive the telephone system with that frequency in order to get maximum response. Overall, there are a few revisions that could be made to this experiment that could merit more accurate results, but for the sake of the frequency response graphs as well as just the audible results that we experienced, we found that material and can size affect the frequency response and overall transmission of audio through a tin can telephone.

Sources

Berg, Richard, and David Stork. *The Physics of Sound*. 3rd. San Francisco: Pearson, 2005. Print.

Coe, Lewis. *The Telephone and its Several Inventors*. Google Books; The Library of Congress, 1911. Web. 15 Nov 2013.

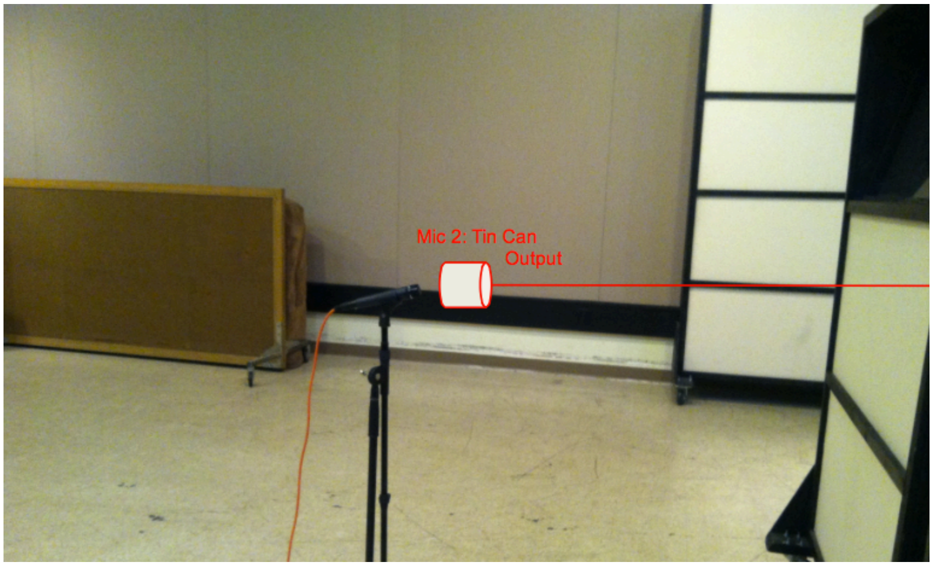
Everest, F. Alton, and Ken Pohlmann. *Master Handbook of Acoustics*. 5th. New York: McGraw Hill, 2009. Print.

"Q & A: Optimizing a tin can phone." *Department of Physics*. N.p., 08 Sep 2006. Web. 19 Nov 2013.

Appendix

Figure 1:

Figure 2:



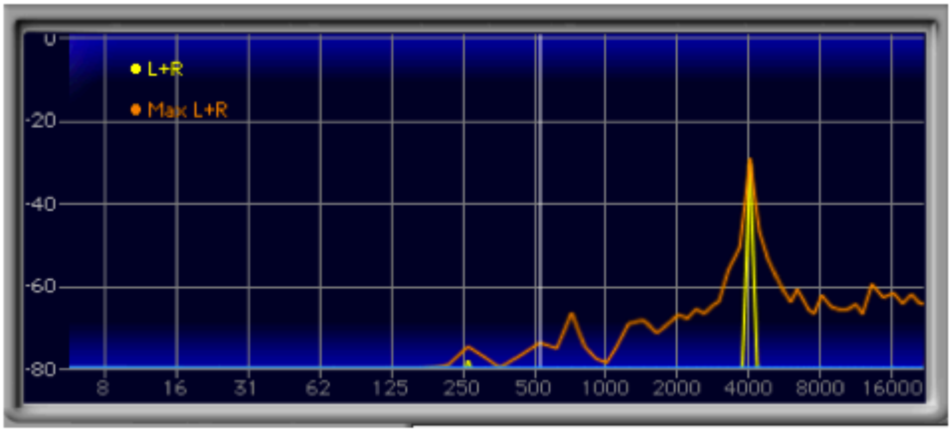

SPL v. Frequency for Speaker Mic, 4kHz Tone

Fig. 3 Frequency Response 3" from source speaker using a 4kHz tone.

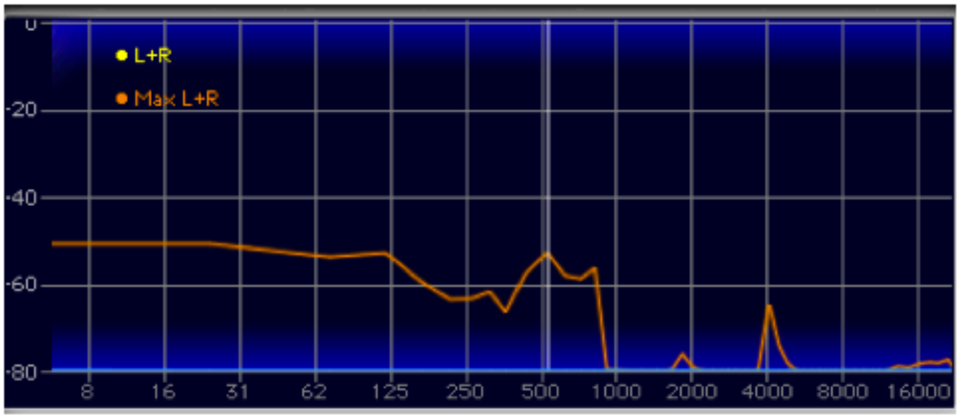

SPL v. Frequency of Long Can, 4kHz Tone

Fig. 4 Frequency response of the long can with the 4kHz tone from the can microphone.

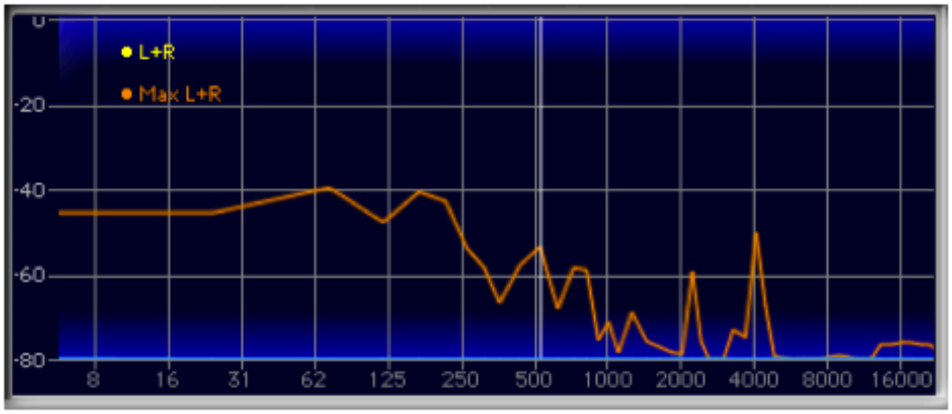

SPL v. Frequency of Paper Can, 4kHz Tone

Fig. 5 Frequency response of the paper can with the 4kHz tone from the can microphone.

SPL v. Frequency of Small Can, 4kHz Tone

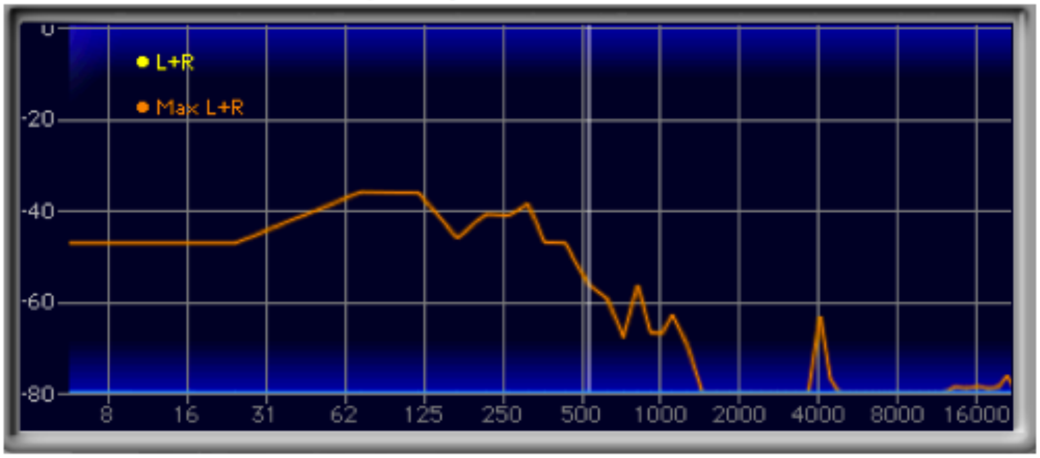


Fig. 6 Frequency response of the small can with the 4kHz tone from the can microphone.

SPL v. Frequency of Speaker Mic, Pink Noise

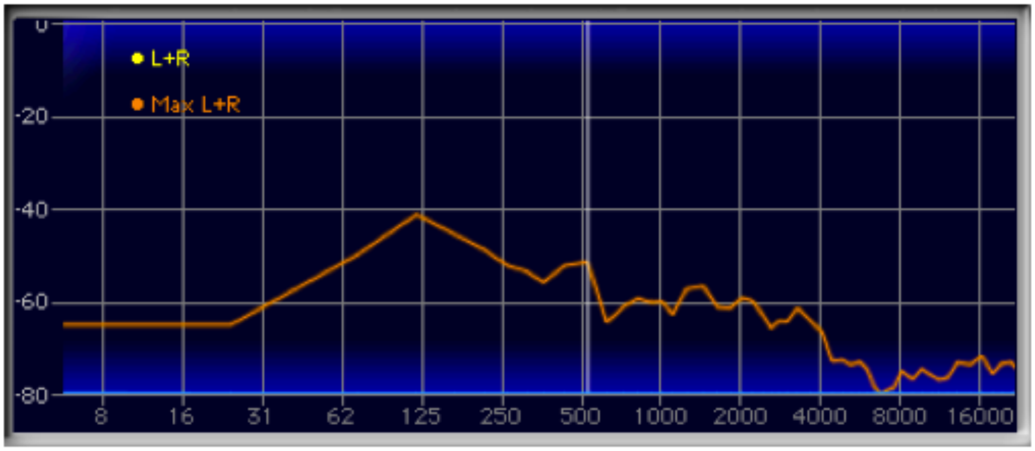


Fig. 7 Frequency response of the speaker mic 3" from source using pink noise.

SPL v. Frequency of Long Can, Pink Noise

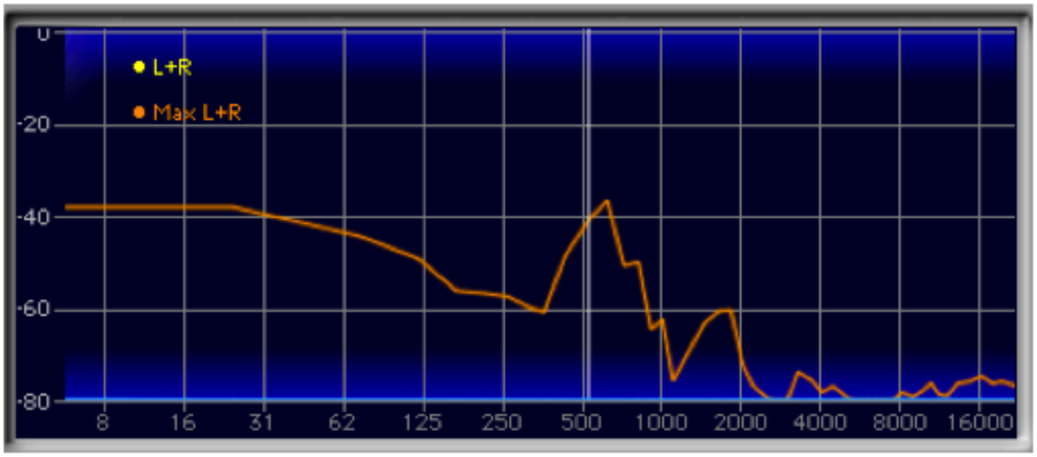


Fig. 8 Frequency response of the long can using pink noise from the can microphone.

SPL v. Frequency of Paper Can, Pink Noise

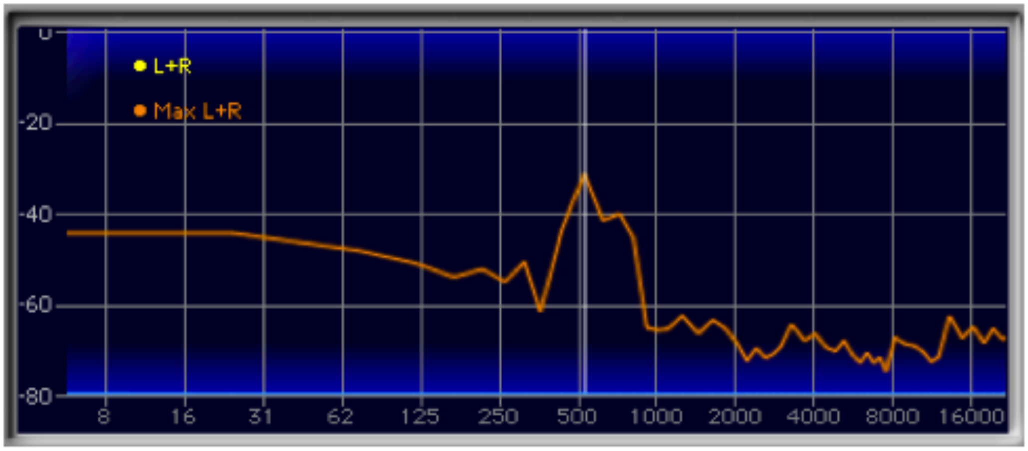


Fig. 9 Frequency response of the paper can using pink noise from the can microphone.

SPL v. Frequency of Small Can, Pink Noise

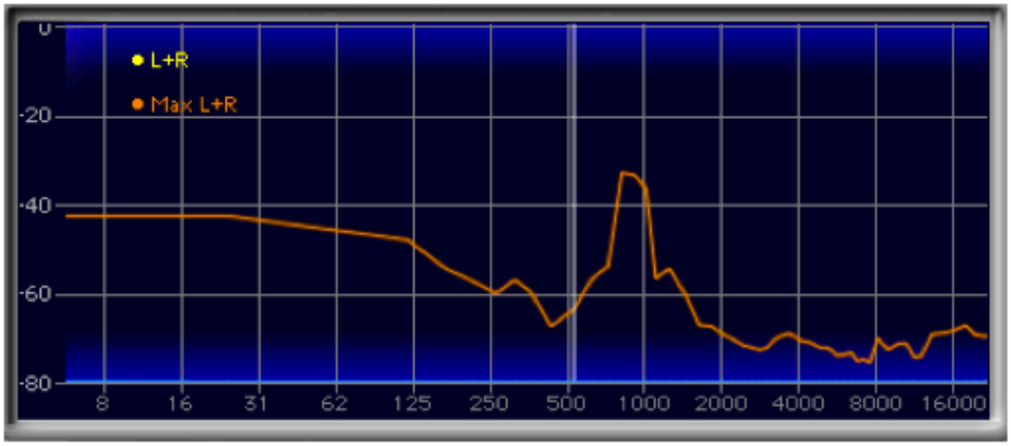


Fig. 10 Frequency response of the small can using pink noise from the can microphone.

SPL v. Frequency of Speaker Mic, Human Voice Sample

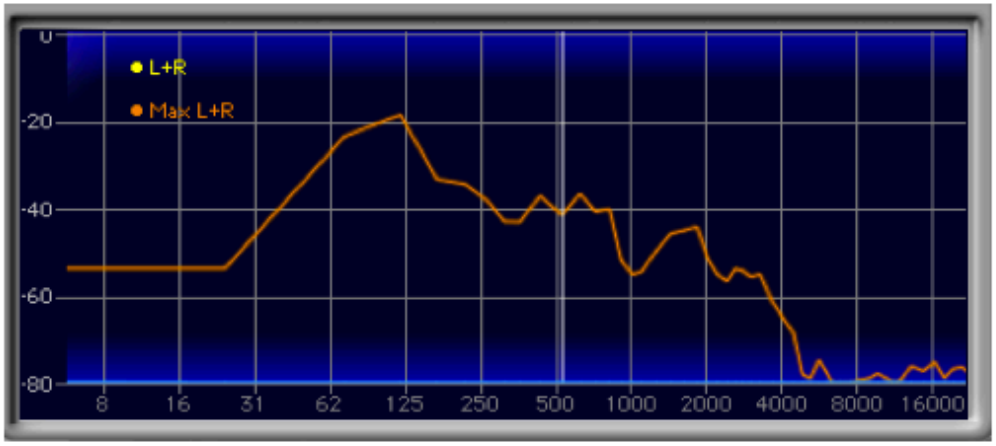


Fig. 11 Frequency response of the speaker mic 3" from source with the human voice.

SPL v. Frequency of Long Can, Human Voice Sample

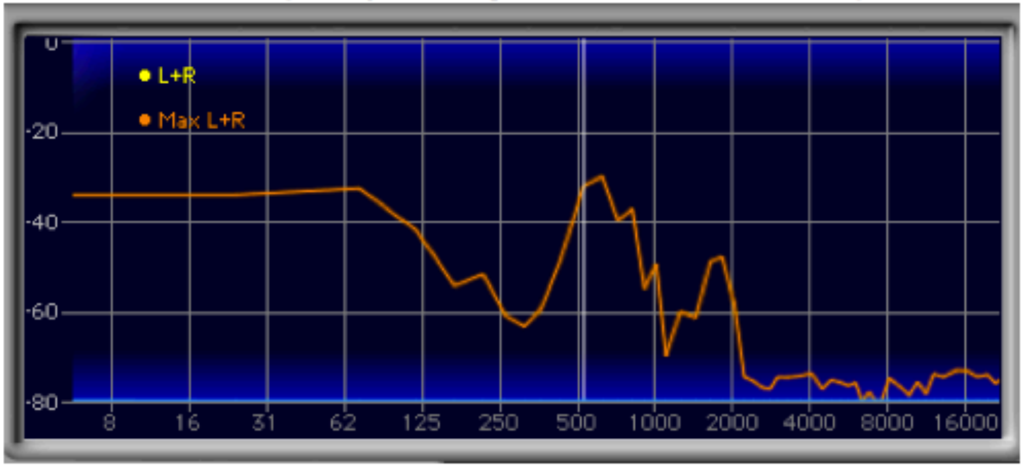


Fig. 12 Frequency response of the long can with the human voice from the can microphone.

SPL v. Frequency of Paper Can, Human Voice Sample

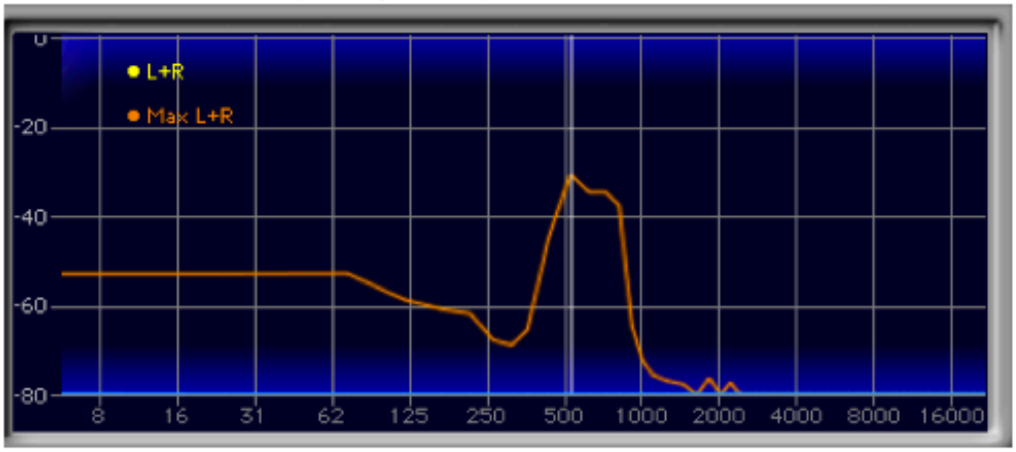


Fig. 13 Frequency response of the paper can with the human voice from the can microphone.

SPL v. Frequency of Small Can, Human Voice Sample

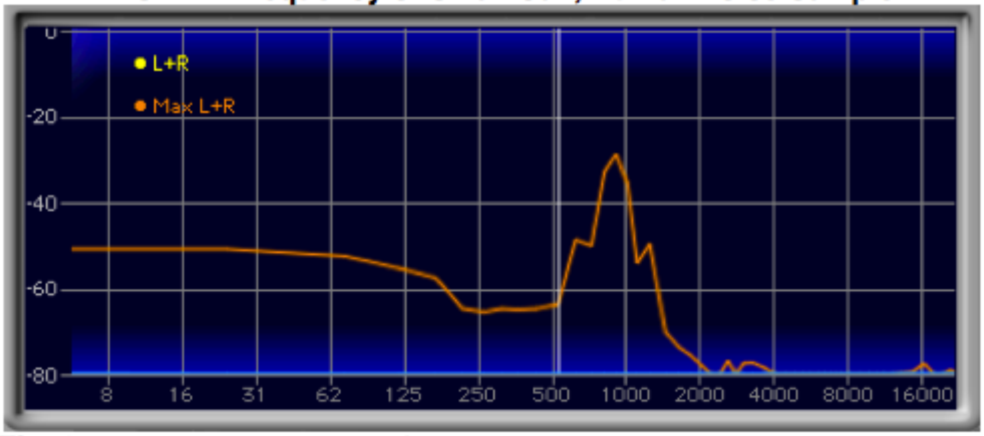


Fig. 14 Frequency response of the paper can with the human voice from the can microphone.