VOICE CANCELLATION

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Abstract

Developed societies experience an increased level of noise pollution which can be associated with industrial activities or higher human concentration. There are several noise categories, such as transport noise or social noise. A transportation system is a necessity and few places in urban development exist where transport noise cannot be heard. Social noise, however, is the greatest source of nuisance noise and complaints. Surveys from various geographical areas of the US estimate the adult population is/was bothered by neighborhood noise, more so than road traffic noise or aircraft noise. Engineers strive to improve the situation; however, people are people and they will make noise.

Solutions include the active control of sound. Making an anti-noise for every known noise volume, will cancel the two out. This is an old concept. "Fight noise with noise," was researched to solve noise pollution problems. Active Noise Control (ANC) is the reduction of unwanted system noise by introducing noise that is the inverse of (180° out of phase with) the unwanted noise. Active control systems are best suited for predictable, low frequency noise. Frequencies below 500 Hz have wavelengths longer than one meter and can be effectively canceled over large areas. Higher frequencies have shorter wavelengths so the noise may be either canceled or doubled. This university research project investigated this phenomena and optimized the system to work effectively to explore the noise cancellation effect.

This student noise cancellation project was a success. The equipment managed to mask the unwanted noise in an experimental box. Atmospheric silence is 57.5dB and the lowest noise cancellation level was 64.1dB during the experiment. The result can eliminate noise created by traffic, but requires improvement to mask human conversation (60dB).

Introduction

Noise control adopted passive systems, where the sound was reduced by insulation, padding, and over weighting of physical noise barriers. Sometimes these passive methods were obviously not effective and could not be applied to smaller systems such as single rooms, working cubicles, cars or a table in a restaurant and spectral shaping methods are necessary[1]. An active noise cancellation technology is presented in this research. The idea of "fight noise with noise“ can be adopted to solve problems of noise pollution. Active Noise Control (ANC) is the practice of reducing unwanted sound in a system by introducing additional sound that is the inverse of (180° out of phase with) the unwanted noise, Figure 1. Active control systems are best suited for predictable, low frequency noise. Frequencies below 500 Hz have wavelengths long enough (longer than one meter) to be effectively canceled over large areas. Higher frequencies have wavelengths so short that noise may be completely canceled at one ear but doubled at the other ear - the length of waveform period is similar to a distance between person's ears.

This paper includes a series of student experiments designed to achieve the best scenario in a noise cancellation area within an active control system. The achievement is graphically depicted in Figure 2.

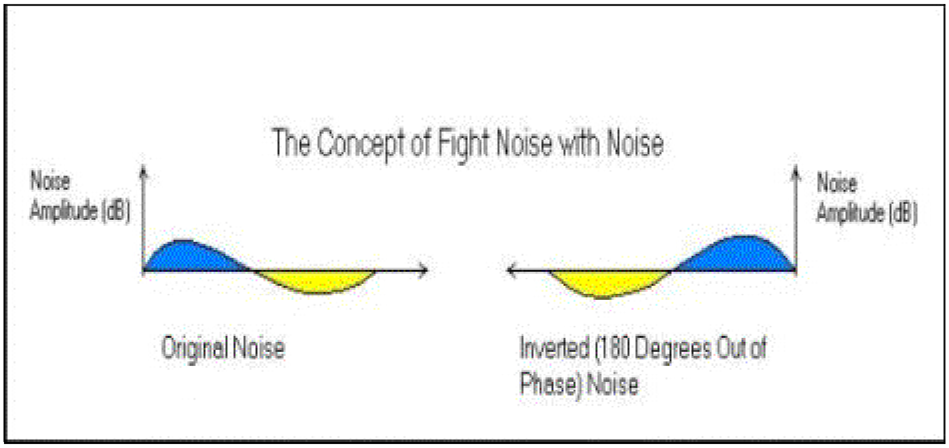

Figure 1: The Concept of Fight Noise with Noise

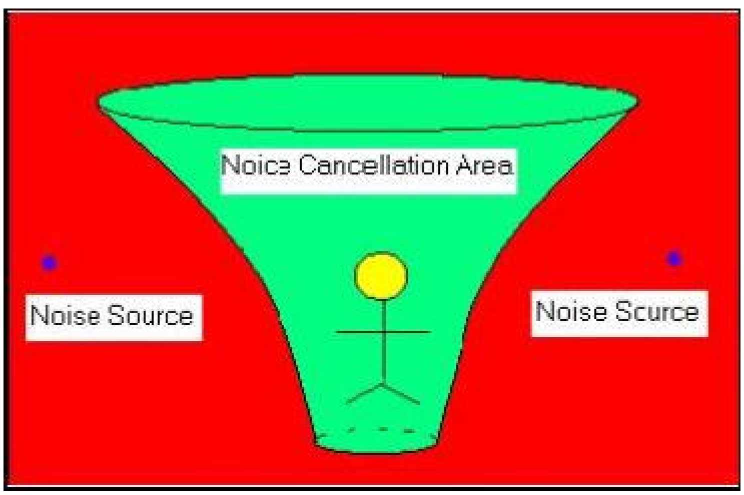

Figure 2: Ideal Noise Cancellation

Noise is the ordered motion of molecules in a medium through which the sound propagates - we call it a wave motion. The sound intensity and the distance from a source is an inverse square ratio. For example, if the distance from the source is doubled then the intensity decreases by a factor of four. The range of intensities which the human ear can detect is large. A logarithmic scale of multiples of 10 is used by researchers to measure the intensity in decibels. The threshold of hearing is assigned to a sound level of 0 decibels (0 dB); this sound level corresponds to an intensity of $1*10^{-12}\ [\frac{W}{m^2}]$. Table I includes examples of sound intensities.

Decibels	Intensity [W/m^2]	Dp/po	Example
0	10^{-12}	$2x10^{-10}$	Threshold of hearing
20	10^{-10}	$2x10^{-9}$	Whisper (at 1 m)
40	10^{-8}	$2x10^{-8}$	Mosquito buzzing
60	10^{-6}	$2x10^{-7}$	Normal conversation
80	10^{-4}	$2x10^{-6}$	Busy traffic
100	10^{-2}	$2x10^{-5}$	Subway
120	1	$2x10^{-4}$	Threshold of pain
140	100	$2x10^{-3}$	Jet on carrier deck

Table I: Sound Level Examples

Sound wave speed in air depends upon the air properties of pressure and temperature. Air pressure effects the mass density and air temperature effects the elastic property. Sound wave speed is approximated by $\nu = 331 + (0.6)T \ [\frac{m}{s}]$ at standard atmospheric conditions where T is air temperature, and ν is sound velocity.

Wave interference occurs when two waves meet while traveling along the same medium, Figure 3. The interference of sound waves causes the medium to assume a shape that results from the net effect of two individual waves. A constructive interference results when a compression of one wave meets with a compression of a second wave at the same location in the medium. The net effect at a particular location is an even greater pressure. A particular location along the medium repeatedly experiences the interference of a compression and rarefaction in destructive interference followed by the interference of rarefaction and compression. Then two sound waves cancel each other and no sound is heard. The absence of sound is the result of particles remaining at rest and behaving as no disturbance passing through the medium.

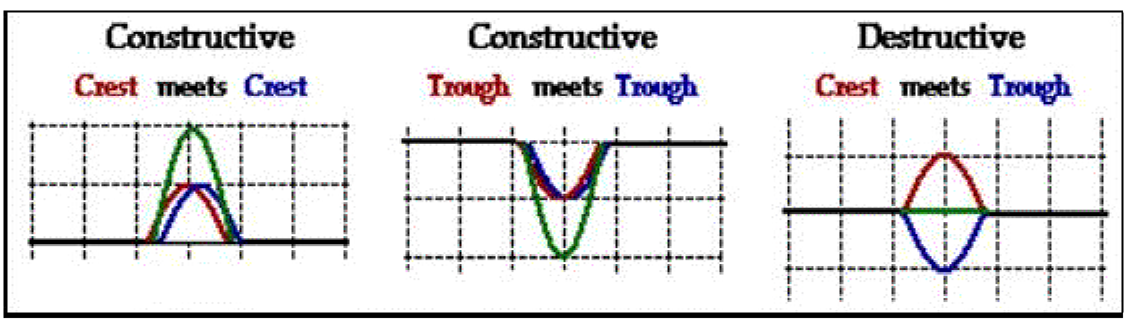

Figure 3: The Concept of Constructive and Destructive Interference

Experimental Setup

Two circuits were constructed; the noise inverter device and the pre-amplifier circuitry. The noise inverter device included two RLC passive devices with an operational amplifier, (u741). This operational amplifier was used to create an inverted or 180* phase out signal. A pre-amplifier circuit was built to amplify the signal since the microphone was not sensitive enough to pick up low amplitude or small signal noise. The noise inverter was capable of processing the input signal, Figure 4. The output of the LM384 was taken as input for the noise inverter device. The project's hardware was simulated using OrCad Pspice.

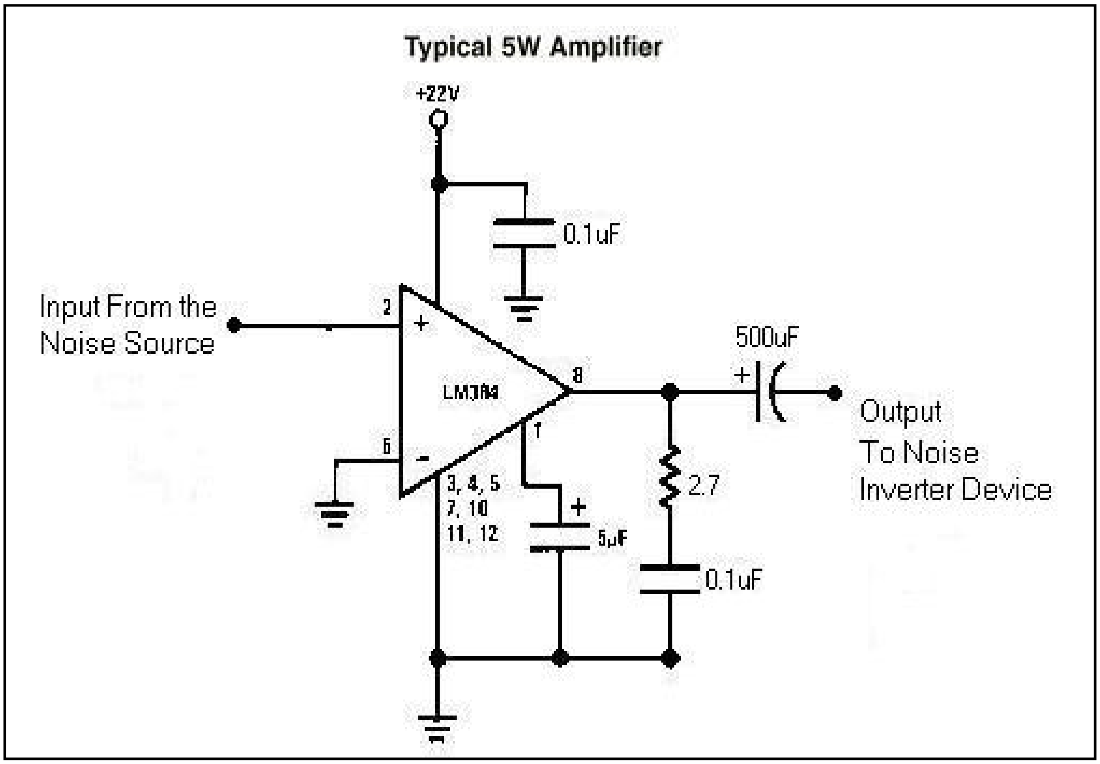

Figure 4: The noise inverter device circuit

The first experiment utilized the "2-Sided Cancellation Speaker." Figure 5 shows the 13"x13" x 10" volume used for this experiment. Two identical speakers were place at both ends of the box. The left speaker represented the noise source with 4kHz, 1V amplitude. The right speaker was connected to the voice cancellation device as an output. The microphone picked up the noise source signal and turned it into an electrical signal that was processed in the voice cancellation device and inverted into 180* out of phase and sent to the right speaker. Data were measured with a microphone and surface plots were created to identify the most significant area of noise cancellation. The second experiment, called the „4-Sided Cancellation Speaker, was designed to improve the effectiveness of voice cancellation in a larger space, Figure 6. A 20" x20" x 16" box was used with a speaker placed at each of the four vertical sides of the box, and the fifth speaker set on the box bottom. The bottom speaker represented the noise source with 4kHz, 1V amplitude. All other speakers were connected to the voice cancellation device as an output. The microphone picked up the noise source signal and turned it into an electrical signal. In the voice cancellation device, the signal was processed and inverted into 180* out of phase and sent to the right speaker. The experimental data were collected and graphically displayed in surface plots. The experiment was repeated with the noise source frequency changed to 6.5kHz and 10kHz. The data were collected and additional surface plots created for the analysis process.

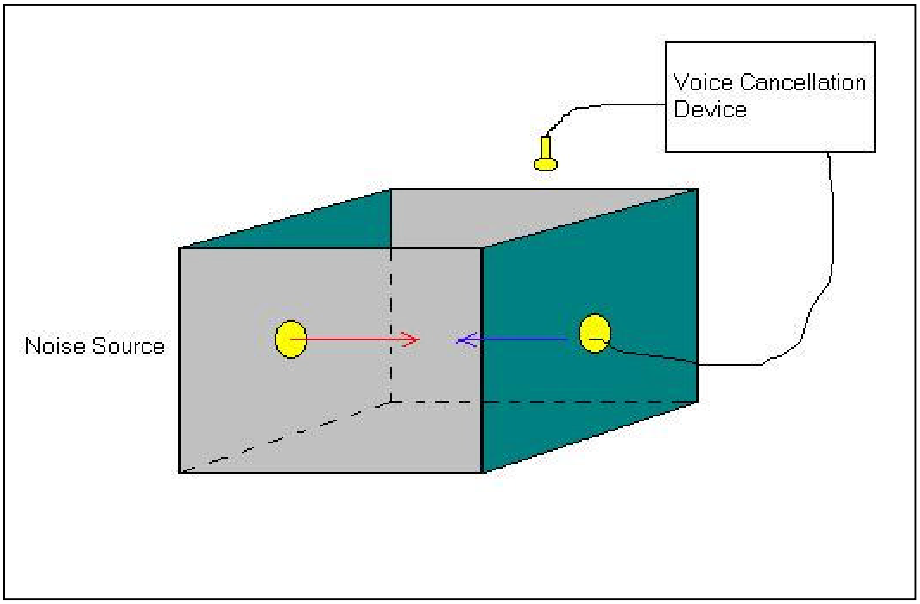

Figure 5: 2-Sided Cancellation Speaker Experimental Setup

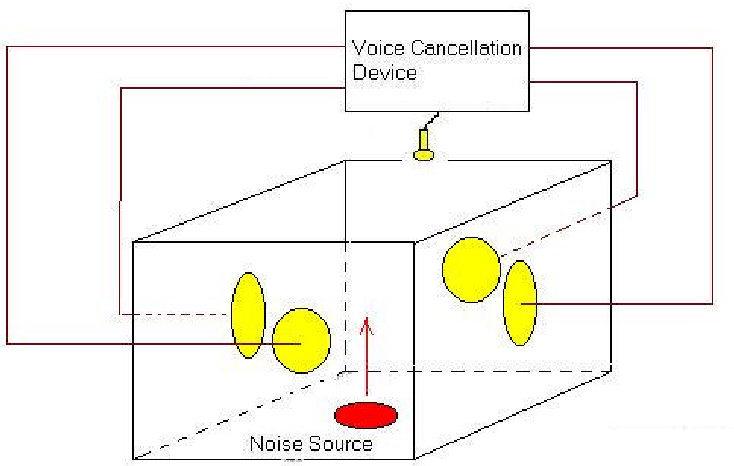

Figure 6: 4-Sided Cancellation Speaker Experimental Setup

Experimental Data and Analysis

The following data were measured for the 2-Sided Cancellation Speaker using a soundcard and a PC microphone. Several surface plots were created to analyze the effectiveness of the noise cancellation device, Figure 7., An atmospheric silence experiment was carried out at 57.5dB as a reference. A significant noise cancellation area was found in the middle of the chart which was due to a destructive interference effect by which the original noise signal was eliminated by a 180 degrees inverted noise coming out from the noise cancellation speaker.

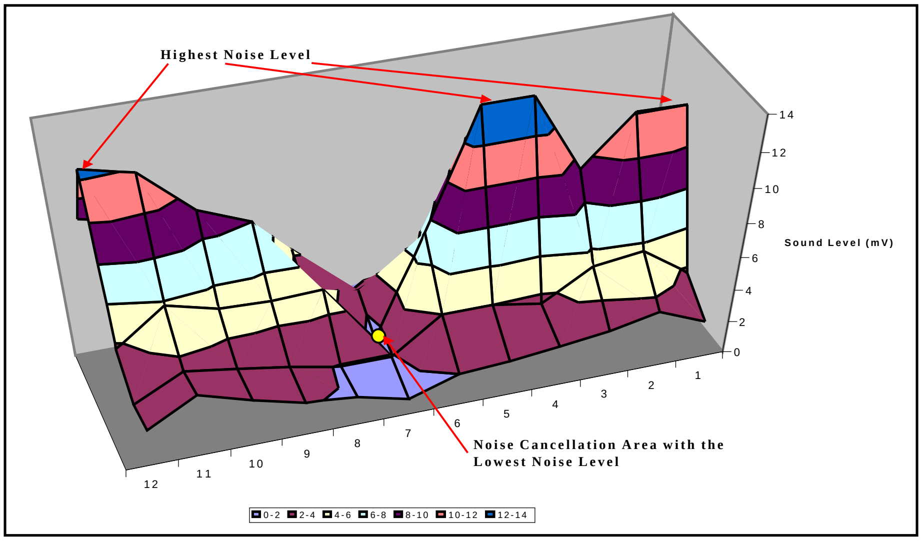

Figure 7: Contour Plot for 2-Sided Cancellation Speaker

The 4-Sided Cancellation Speaker experiment utilized a sound level meter, manufactured by Extech Instrument, Inc. The noise attenuation plots show the effectiveness of the noise cancellation device, Figure 8 and 9, where the 6.5 kHz noise source was used. Figure 10 shows the same set up using a 10 kHz noise source. It was possible to mask the unwanted noise to a minimum in the middle of the experimental area. The atmospheric silence (Table I) is 57.5dB and the lowest noise cancellation level was 64.1dB during the experiment. These experimental results are satisfactory enough to eliminate noise created by traffic, however, the equipment requires improvement to mask human conversation (60dB).

The noise attenuation project has many applications, i.e. in households where the production of noise is well known. The installing of a device to eliminate such noise is possible. The present data available indicate, for instance, that whenever a vacuum cleaner is switched-on, the system can successfully make the room noise free. However, the voice cancellation device eliminating human conversation needs further improvement.

The result will have a higher efficiency to reduce noise if the sensitivity of microphones is increased and the respond time of speakers is decreased. The long term goal is to design a smart room where proximity sensors will measure the distance of objects emitting a heat signature. This together with numerous microphones will be inputted into a super fast computer (future Pentium VI) which will recognize the source of unwanted noise (i.e., a little child in a pizza place). The computer will run an adaptive noise control algorithm, for example in[2]. Then it will cover the room with a sound waveform of opposite frequency. The same procedure could be used in household applications.

This project has been incorporated in the Special Electronic Problems course and in a graduate course - Embedded Microcontrollers where students will design the "smart quiet room."

Conclusion

While the theory of actively canceling noise has been recognized for almost 60 years, we are just beginning to realize its potential. The noise cancellation project managed to mask unwanted noise to a minimum. The atmospheric silence was 57.5dB and the lowest noise cancellation level was 64.1dB during the experiments. The experimental results were able to eliminate noise created by traffic, however, the process requires improvement to mask human conversation (60dB). A goal of this project will be to eliminate household steady noise, for example a vacuum cleaner. Speech cancellation must be improved. Although the theory is simple - fight noise with noise - the process of perfecting a voice cancellation device is still being developed. The long-term goal is to design a "smart quiet room."

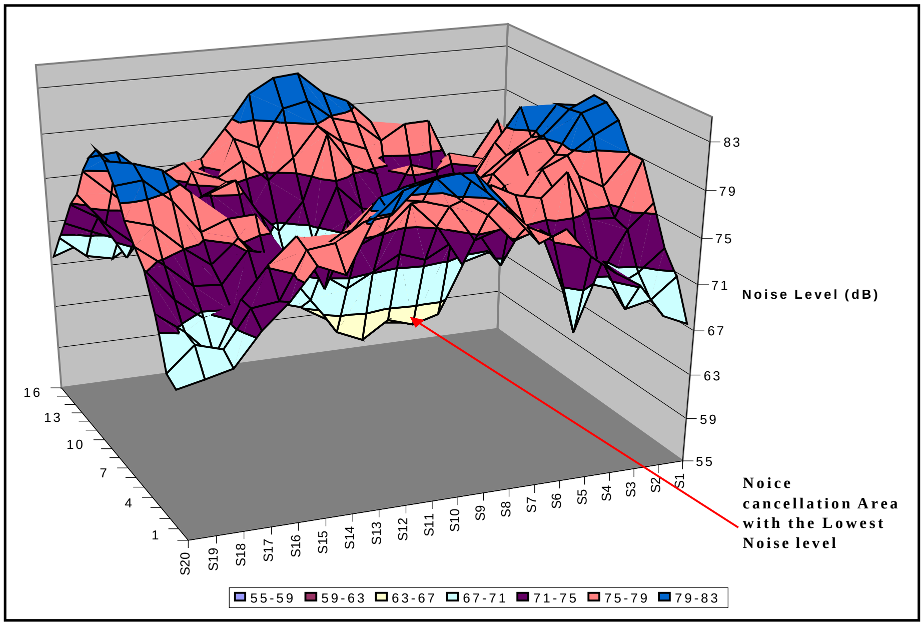

Figure 8: Surface Plot for 4-Sided Cancellation Speaker with frequency 6.5kHz

References

1. Orsak G.C.& all (2001). *Multimedia as Information Engineering*, Prentice Hall.
2. Chen S.J., Gibson J.S.(2001, March). "Feedforward Adaptive Noise Control with Multivariable Gradient Lattice Filters," *IEEE Transactions on Signal Processing*, 49: 3.

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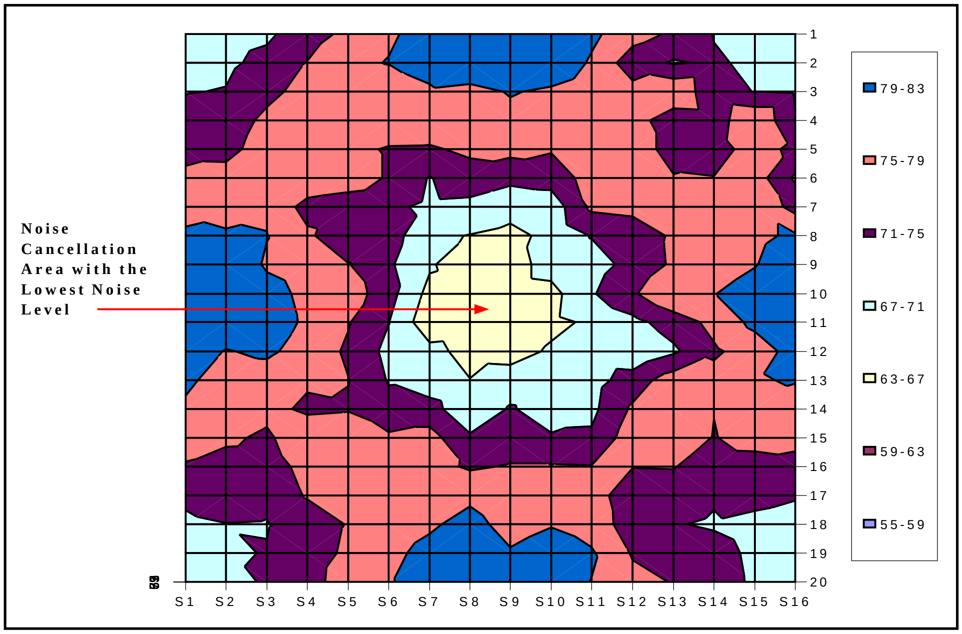

Figure 9: Top View of Surface Plot for 4-Sided Cancellation Speaker with frequency 6.5kHz

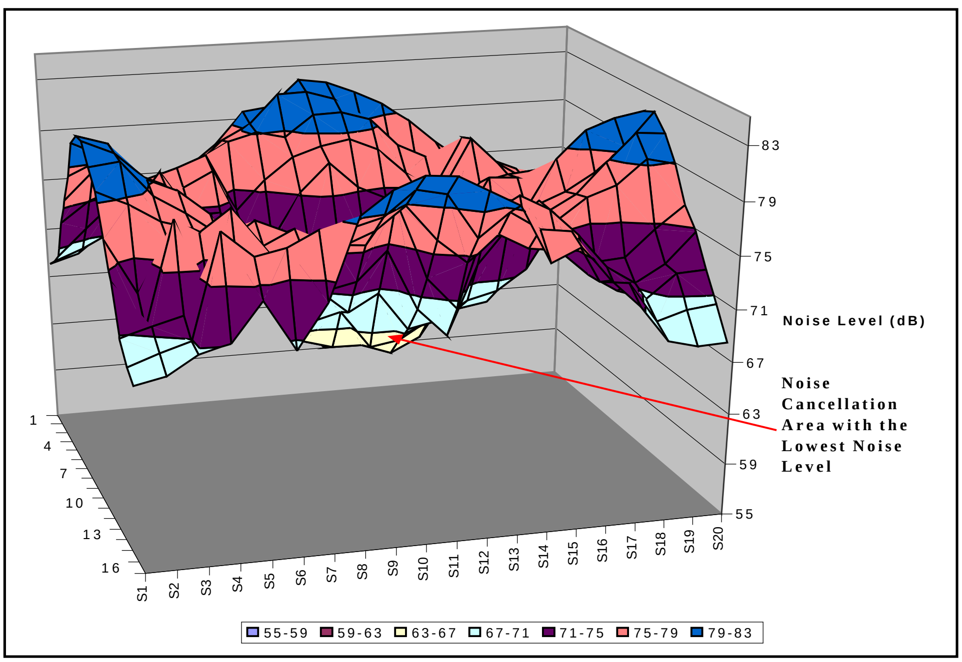

Figure 10: Surface Plot for 4-Sided Cancellation Speaker with frequency 10kHz