Audio Spotlighting

PROJECT REPORT

Submitted in partial fulfillment for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

ELECTORNICS AND COMMUNICATION ENGINEERING

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NOVEMBER 2018

Bonafide certificate

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This is to certify that the Project Report entitled

Audio Spotlighting
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Acknowledgment

To the grace and generous of God Almighty, we attribute the successful completion of our Project. It is our duty to respectfully offer our sincere gratitude to all the people who have kindly offer their valuable support, guidance and support. We express our sincere gratitude to **Prof. Dr. Vinu Thomas, Principal, Govt. Model Engineering College** for opening up a plethora of possibilities and resources for our use.

Next we express our heartfelt thanks to **prof. Dr. Laila.D, Head of Department of Electronics Engineering, Govt. Model Engineering College** for her infallible support and timely advice and was pivotal in the completion of this Project. We thank our guide **Mr.Jayadas C.K,Associate Professor,Department of Electronics Engineering** for his advice and guidance. We extend sincere thanks to our Project coordinator and Guide, **Dr.Binesh T , Associate Professor, Department of Electronics Engineering** for allowing us to use the facilities available and for providing us with right guidance and advice at the crucial junctures and for showing us the right way.

We also extend our sincere gratitude to our classmates and other teachers who were ready with a positive comment all the time.

Abstract

Audio spot lighting is a very recent technology that creates focused beams of sound similar to light beams coming out of a flashlight. By "shining" sound to one location, specific listeners can be targeted with sound without others nearby hearing it. It uses a combination of non-linear acoustics and some fancy mathematics. But it is real and is fine to knock the socks of any conventional loud speaker. This acoustic device comprises a speaker that fires inaudible ultrasound pulses with very small wavelength which act in a manner very similar to that of a narrow column. The ultra sound beam acts as an airborne speaker and as the beam moves through the air gradual distortion takes place in a predictable way due to the property of nonlinearity of air. This gives rise to audible components that can be accurately predicted and precisely controlled. Joseph Pompei's Holosonic Research Labs invented the Audio Spotlight that is made of a sound processor, an amplifier and the transducer. The American Technology Corporation developed the Hyper Sonic Sound-based Directed Audio Sound System. Both use ultrasound based solutions to beam sound into a focused beam. Audio spotlight can be either directed at a particular listener or to a point where it is reflected. The targeted or directed audio technology is going to a huge commercial market in entertainment and consumer electronics and technology developers are scrambling to tap in to the market. Being the most recent and dramatic change in the way we perceive sound since the invention of coil loud speaker, audio spot light technology can do many miracles in various fields like Private messaging system, Home theatre audio system, Navy and military applications, museum displays, ventriloquist systems etc. Thus audio spotlighting helps us to control where sound comes from and where it goes!.

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Chapter 1

Introduction

The Audio Spotlight Hyper Sonic Sound Technology (developed by American Technology Corporation), uses ultrasonic energy to create extremely narrow beams of sound that behave like beams of light. Audio spotlighting exploits the property of non-linearity of air. When inaudible ultrasound pulses are fired into the air, it spontaneously converts the inaudible ultrasound into audible sound tones, hence proved that as with water, sound propagation in air is just as nonlinear, and can be calculated mathematically. A device known as a parametric array employs the non-linearity of the air to create audible by-products from inaudible ultrasound, resulting in an extremely directive, beam like wide-band acoustical source. This source can be projected about an area much like a spotlight, and creates an actual specialized sound distant from the transducer. The ultrasound column acts as an airborne speaker, and as the beam moves through the air, gradual distortion takes place in a predictable way. This gives rise to audible components that can be accurately predicted and precisely controlled.

1.1 Theory

What ordinary audible sound Conventional Loud Speakers lack? What we need? About a half-dozen commonly used speaker types are in general use today. They range from piezoelectric tweeters that recreate the high end of the audio spectrum, to various kinds of mid- range speakers and woofers that produce the lower frequencies. Even the most sophisticated hi-fi speakers have a difficult time in reproducing clean bass, and generally rely on a large woofer/enclosure combination to assist in the task. Whether they be dynamic, electrostatic, or some other transducer-based design, all loudspeakers today have one thing in common: they are direct radiating– that is, they are fundamentally a piston-like device designed to directly pump air molecules into motion to create the audible sound waves we hear. The audible portions of sound tend to spread out in all directions from the point of origin. They do not travel as narrow beams—which is why you dont need to be right in front of a radio to hear music. In fact, the beam angle of audible sound is very wide, just about 360 degrees. This effectively means the sound that you hear will be propagated through air equally in all directions. In order to focus sound into a narrow beam, you need to maintain a low beam angle that is dictated by wavelength. The smaller the wavelength, the less the beam angle, and hence, the more focused the sound. Unfortunately, most of the human-audible sound is a mixture of signals with varying wavelengths—between 2cms to 17 meters (the human hearing ranges from a frequency of 20 Hz to 20,000 Hz). Hence, except for very low wavelengths, just about the entire audible spectrum tends to spread out at 360 degrees. To create a narrow sound beam, the aperture size of the source also matters—a large loudspeaker will focus sound over a smaller area. If the source loudspeaker can be made several times bigger than the wavelength of the sound transmitted, then a finely focused beam can be created. The problem here is that this is not a very practical solution. To ensure that the shortest audible wavelengths are focused into a beam, a loudspeaker about 10 meters across is required, and to guarantee that all the audible wavelengths are focused, even bigger loudspeakers are needed. Here comes the acoustical device "AUDIO SPOTLIGHT" invented by Holosonics Labs founder Dr. F. Joseph Pompei (while a graduate student at MIT), who is the master brain behind the development of this technology.

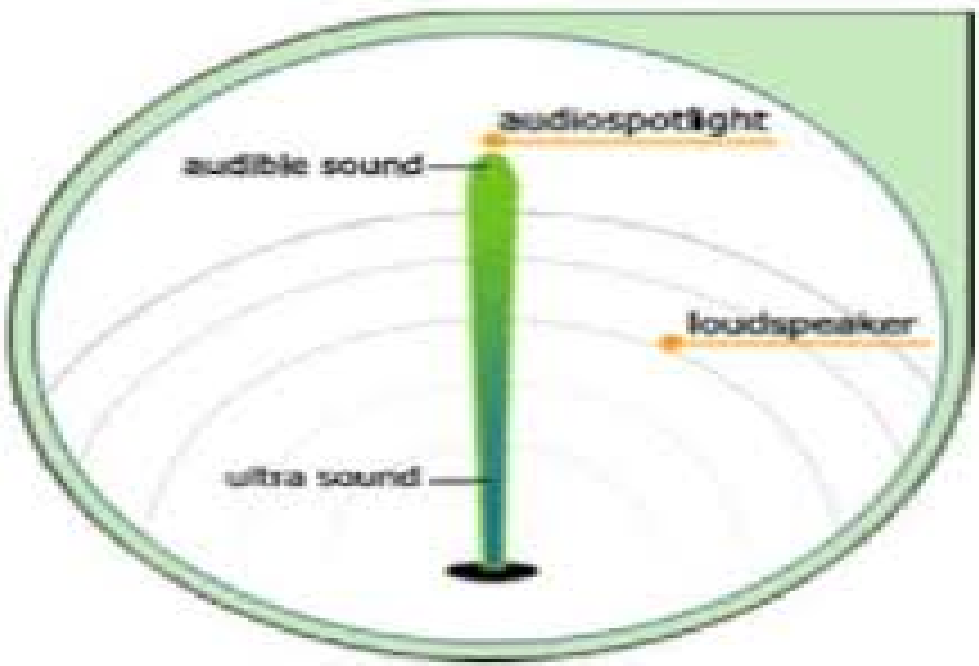

Figure 1.1: audio spotlight creates focused beams of sound

Audio spotlight looks like a disc-shaped loudspeaker, trailing a wire, with a small laser guide-beam mounted in the middle. When one points the flat side of the disc in your direction, you hear whatever sound he's chosen to play for you — perhaps jazz from a CD. But when he turns the disc away, the sound fades almost to nothing. It's markedly different from a conventional speaker, whose orientation makes much less difference.

1.2 Modes Of Listening

DIRECT AUDIO AND PROJECTED AUDIO

There are two ways to use Audio Spotlight. First, it can direct sound at a specific target, creating a contained area of listening space which is called “Direct Audio”. Second, it can bounce off of a second object, creating an audio image. This audio image gives the illusion of a loudspeaker, which the listener perceives as the source of sound, which is called “Projected Audio”. This is similar to the way light bounces off of objects. In either case, the sounds source is not the physical device you see, but the invisible ultrasound beam that generates it

Figure 1.2: Direct audio and Projected audio

Hyper Sonic Sound technology provides linear frequency response with virtually none of the forms of distortion associated with conventional speakers. Physical size no longer defines fidelity. The faithful reproduction of sound is freed from bulky enclosures. There are no, woofers, tweeters, crossovers, or bulky enclosures. Thus it helps to visualize the traditional loudspeaker as a light bulb, and HSS technology as a spotlight, that is you can direct the ultrasonic emitter toward a hard surface, a wall for instance, and the listener perceives the sound as coming from the spot on the wall. The listener does not perceive the sound as emanating from the face of the transducer, only from the reflection off the wall. Contouring the face of the HSS ultrasonic emitter can tightly control Dispersion of the audio wave front. For example, a very narrow wave front might be developed for use on the two sides of a computer screen while a home theater system might require a broader wave front to envelop multiple listeners.

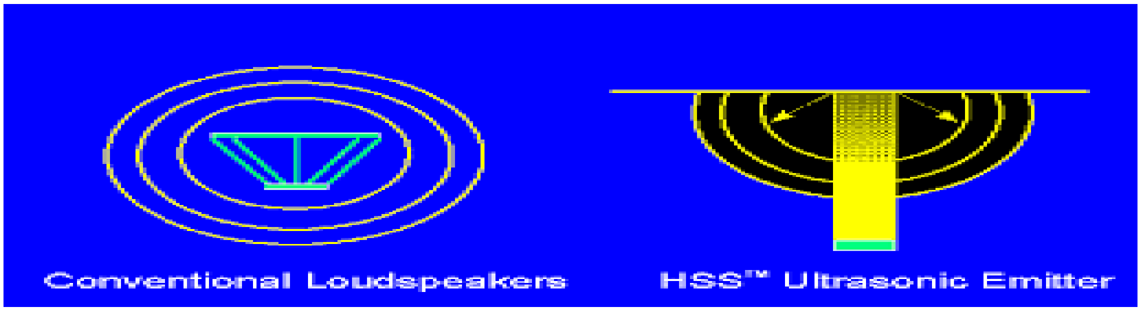

Figure 1.3: Conventional loudspeaker and Ultrasonic emitter.

1.3 Technology Overview

The Audio Spotlight Hyper Sonic Sound Technology (developed by American Technology Corporation), uses ultrasonic energy to create extremely narrow beams of sound that behave like beams of light. Ultrasonic sound is that sound that has very small wavelength—in the millimeter range and you cant hear ultrasound since it lies beyond the threshold of human hearing.

1.4 Component And Specification

Audio Spotlight consists of three major components: a thin, circular transducer array, a signal processor and an amplifier. The lightweight, nonmagnetic transducer is about .5 inches (1.27 centimeters) thick, and it typically has an active area 1 foot (30.48 cm) in diameter. It can project a three-degree wide beam of sound that is audible even at distances over 100 meters (328 feet). The signal processor and amplifier are integrated into a system about the size of a traditional audio amplifier, and they use about the same amount of power.

Chapter 2

Literature Survey

This technology was originally developed by the US Navy and Soviet Navy for underwater sonar in the mid 1960s. The researchers had not attempted to reproduce audio, also they nonetheless proved that such a device can be possible.

The technology was briefly investigated by Japanese researchers in the early 1980s, but these efforts were abandoned due to extremely poor sound quality (high distortion) and substantial system cost. These problems went unsolved until a paper published by Dr. F. Joseph Pompei of the Massachusetts Institute of Technology in 1998 fully described a working device that reduced audible distortion essentially to that of traditional speakers. The Audio Spotlight system uses non-linearly propagating ultrasound to create highly directional beams of sound in mid-air, which can be "shone" and "directed" much like light. Dr. Pompei was the first in the world to develop the mathematics and advanced engineering that allowed sound to be created literally from thin air with sound quality and reliability rivaling traditional loudspeakers. He presented his first paper and demonstration in 1998 to the Audio Engineering Society, and was met with a standing ovation from the world's top audio professionals[1].

The Audio Spotlight sound system, developed and manufactured by Holosonics, is currently used around the world for museums, tradeshows, retail displays, exhibitions, and special effects, and will soon be available for consumer applications. Companies such as Motorola, Time-Warner, DaimlerChrysler, Kraft Foods, Sega, and American Greetings have chosen the Audio Spotlight, and Audio Spotlight systems have been installed in venues such as Boston's Museum of Science, the Matisse Museum, Sega's Joypolis, Bibliotheque National de France, Boston Center for the Arts, the European PGA tour, and the Chicago Cultural Center[5].

Dirk Olszewski, Fransiskus Prasetyo, Klaus Linhard proposed an idea of steering audible sound beams generated by parametric arrays in air. So-called parametric arrays can be used in air to generate audible sound with high directivity, so that sound can be projected onto a target similar to a light beam emitted from a spotlight. The ultrasound wave is used as a carrier which is modulated by an audio signal, say music or speech. The nonlinearity of air acts as a demodulation device. The air itself then acts as a virtual loudspeaker since it demodulates the emitted sound waves.

To steer the sound beam into a desired direction, a phased array technique is used: ultrasound emitters are arranged in four sub arrays representing four different channels. The paper focus to create a hybrid system for steering an audible sound beam has been built. The paper shows clearly that steering of audio beams generated by parametric arrays can be done by applying phased array technique. Although emitters have been used that are not matching criterions for phased array purposes from the first sight, the hybrid approach still delivers an appropriate beam steering performance[4].

Chapter 3

Phase I Implementation

3.1 Li-Fi transmission of AUDIO

Device to device communication using LED Light is the next step of the information revolution. Li-Fi (Light Fidelity) is a fast and cheap optical version of Wi-Fi. This technology is based on Visible Light Communication (VLC). Li-Fi is a term of one used to describe visible light communication technology applied to high speed wireless communication. It acquired this name due to the similarity to Wi-Fi, only using light instead of radio. Wi-Fi is great for general wireless coverage within buildings and Li-Fi is ideal for high density wireless data coverage in confined area and for relieving radio interference issues, so the two technologies can be considered complimentary.

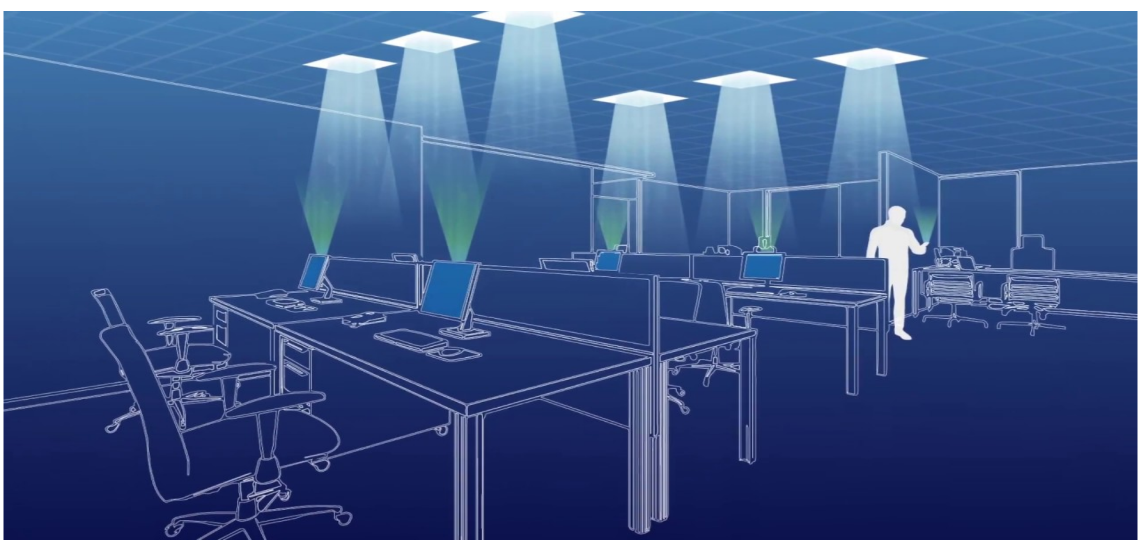

Figure 3.1: Schematic view of proposed Li Fi setup

Li-Fi Technology technology can transmit the data through high illumination LED devices that varied the intensity is very faster than the human eyes can follow. The LED bulb can cycle OFF and ON millions of times per second.

The visible light spectrum is 10,000 faster than the radio frequency spectrum. The data is encoded and send to the light transmitting devices which is driven the high illumination LED. It is feasible to encode the data which the LED bulbs on and off to give different kind of strings of 1s and 0s. The LED bulb intensity is changing very faster that which the human eyes cannot be notice.

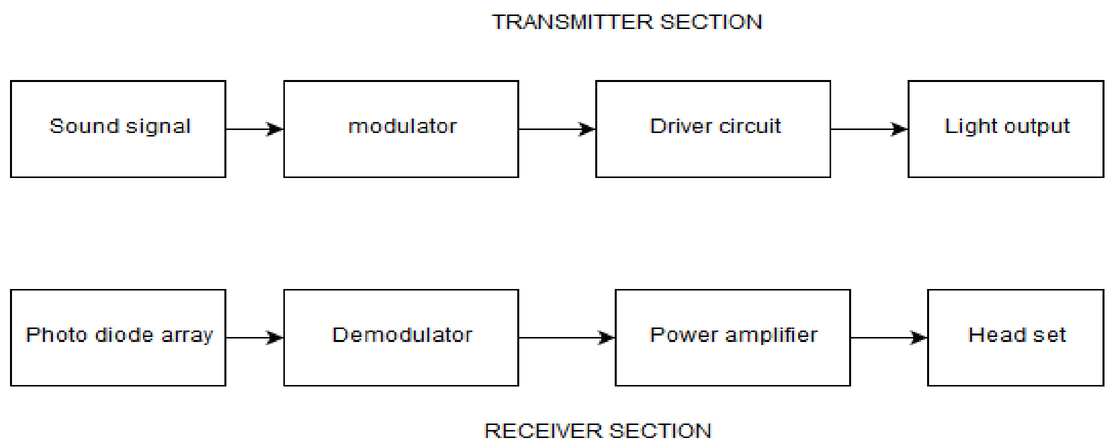

Figure 3.2: Block Diagram for Li-Fi setup

The above block diagram shows an approach to limit the sound in a particular area through li-fi method.It consist of two sections transmitter section and a receiver section.

In a transmitter section the sound signal from a mp3 player or from mic having a audible frequency range is act as an input to the modulator.Here modulator used is FM modulator IC.Then this modulated wave is passes through the driver circuit.Driver circuit is used here inorder to amplify the current needed for the output light so at the output the input sound signal is converted into its corresponding light output this is all about the transmitter section.

In the receiver section there is a photo diode array is mounted on the head set which receives the light that contain the sound.so the photo diode array convert this light in to the electrical signal. Then it passes through the demodulator circuit. Demodulator circuit converts the modulated signal into the audible signal then a power the headset in which hear the sound.

The major advantage of this technique is high noise free and major draw back is users wear the headset having large size because of the extra receiver circuit is added in the head set.

3.2 Component Description

Important components for the Phase I implementation of the Project (ie, Li Fi transmission of Audio) requires the following components:

- Monolithic Function Generator - XR-2206

  The XR-2206 is a monolithic function generator integrated circuit capable of producing high quality sine, square, triangle, ramp, and pulse waveforms of high-stability and accuracy. The output waveforms can be both amplitude and frequency modulated by an external voltage. Frequency of operation can be selected externally over a range of 0.01Hz to more than 1MHz.

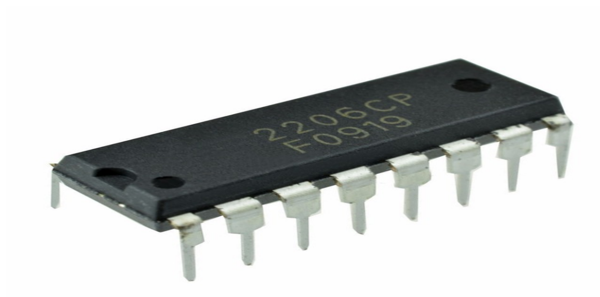

Figure 3.3: XR2206 IC

  The circuit is ideally suited for communications, instrumentation, and function generator applications requiring sinusoidal tone, AM, FM, or FSK generation. It has a typical drift specification of 20ppm/C. The oscillator frequency can be linearly swept over a 2000:1 frequency range with an external control voltage, while maintaining low distortion.

- IR2110

  500 V High and Low Side Driver IC with typical 2.5 A source and 2.5 A sink currents in 14 Lead PDIP package for IGBTs and MOSFETs. Also available in 16 Lead SOIC WB.

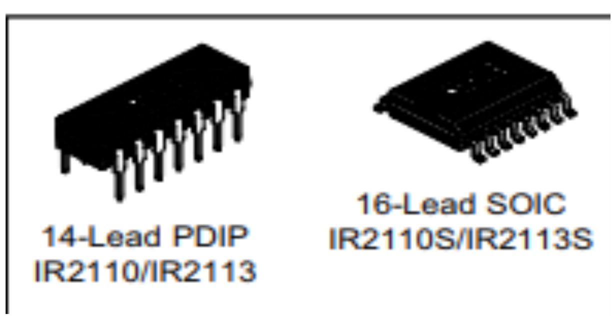

Figure 3.4: IR2110 IC

Summary of Features:

- Floating channel designed for bootstrap operation.
- Fully operational to +500 V.
- Fully operational to +600 V verstion available (IR2113).
- Gate drive supply range from 10 to 20 V.
- Logic and power ground + /- 5 V offset.
- CMOS Schmitt-triggered inputs with pull-down.

- IRF540

Third generation Power MOSFETs from Vishay provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness. The TO-220AB package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 W. The low thermal resistance and low package cost of the TO-220AB contribute to its wide acceptance throughout the industry

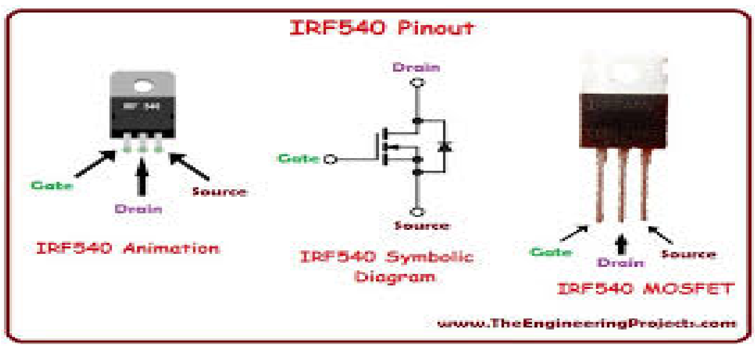

Figure 3.5: IRF540 IC

FEATURES

- Dynamic dV/dt Rating Avalanche Rated
- 175 C Operating Temperature Switching
- Ease of Paralleling
- Simple Drive Requirements
- Compliant to RoHS Directive 2002/95/EC

Chapter 4

Phase II Implementation

4.1 Working

As we know human audible frequency range is 20 Hz to 20 kHz. In this system originally the low frequency sound such as human voice or music is transformed into a high frequency ultrasonic sound which inaudible for human.

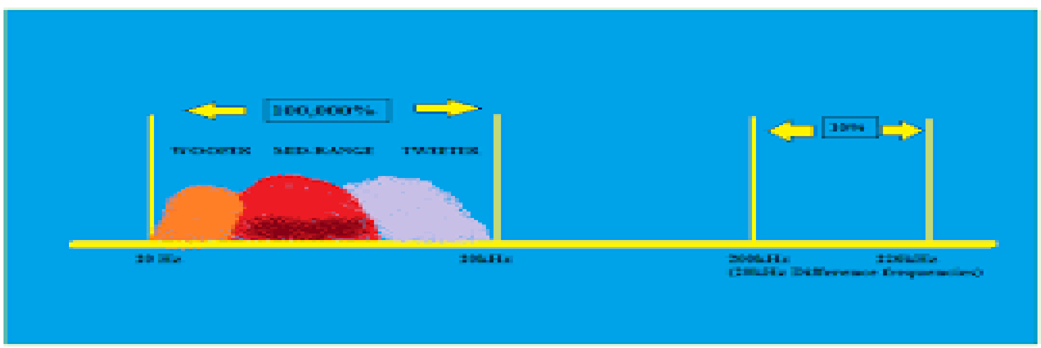

Figure 4.1: Showing the Difference in Modulating Audible Frequencies with Ultrasonic Carrier

In the beginning the human voice or music is applied to the audio spotlight emitter device. The low frequency data is modulated to a high frequency ultrasonic level. Since the wave length of the ultrasonic frequency is small of the order of mm and beam angle is also small hence the sound beam will be narrow with small dispersion. When inaudible ultrasound pulses are fired into the air, it spontaneously converts the inaudible ultrasound into the audible sound tones, hence proved that as like water, sound propagation in air is non-linear.

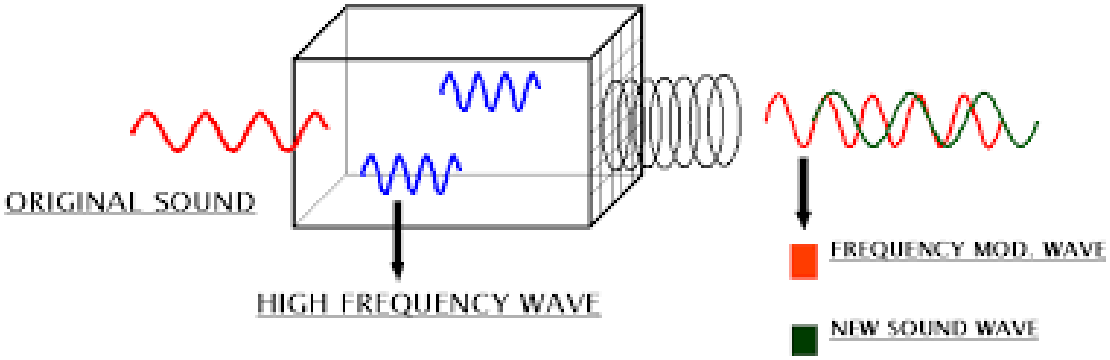

Figure 4.2: Audio spotlighting emitter

So due to its non-linear property the air slightly alters the sound wave, the alteration in the original sound wave gives rise to a new sound wave within the ultrasonic wave. The new sound signal generated within ultrasonic wave will be corresponding to the original information signal with human audible frequency range. Since we can't hear the ultrasonic sound wave we hear only new sound wave which is formed due to the non-linearity of air.

4.2 Block Diagram

1. Power supply.
2. Frequency oscillator.
3. Modulator.
4. Audio signal processor.
5. Microcontroller unit.
6. Ultrasonic amplifier.
7. Transducer.

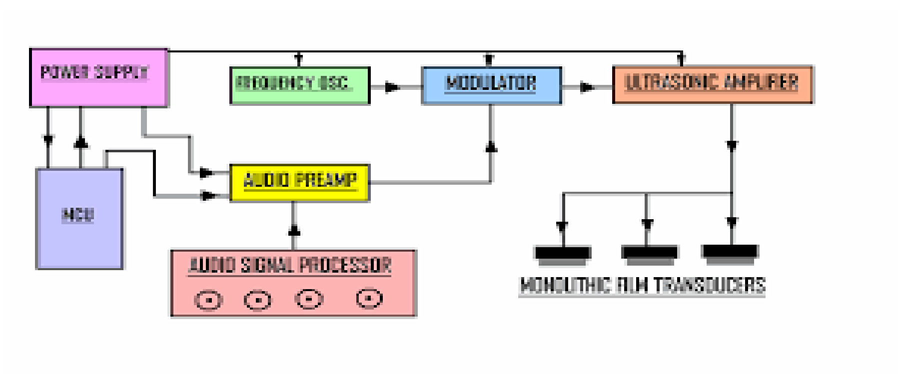

Figure 4.3: Block Diagram of Audio spotlighting system

- Power supply: Like all electronics the audio spotlight works off the DC supply. Ultrasonic amplifier requires 48v DC supply for its working and low voltage for micro controller and other units.

- Frequency oscillator: The frequency oscillator generates ultrasonic frequency of in the range of which is required for the modulation of information signal.
- Modulator: In order to convert the source signal material into ultrasonic signal a modulation scheme is required which is achieved through a modulator. In addition, error correction is needed to reduce distortion without loss of efficiency. By using a DSB modulator the modulation index can be reduced to decrease distortion
- Audio signal processor: The audio signal is sent to electronic signal processor circuit where equalization and distortion control are performed in order to produce a good quality sound signal.
- Microcontroller: A dedicated microcontroller circuit takes care of the functional management of the system. In the future version, it is expected that the whole process like functional management, signal processing, double side band modulation and even switch mode power supply would be effectively taken care of by a single embedded IC.
- Ultrasonic Amplifier: High-efficiency ultrasonic power amplifiers amplifies the frequency modulated wave in order to match the impedance of the integrated transducers. So that the output of the emitter will be more powerful and can cover more distance.
- Transducer: It is 1.27 cm thick and 17 cm in diameter. It is capable of producing audibility up to 200 meters with better clarity of sound. It has the ability of real time sound reproduction with zero lag. It can be wall, overhead or flush mounted. These transducers are arranged in form of an array called parametric array.

4.3 Non Linearity of Air

Audio spotlighting exploits the property of non-linearity of air. When inaudible ultrasound pulses are fired into the air, it spontaneously converts the inaudible ultrasound into audible sound tones, hence proved that as with water, sound propagation in air is just as non-linear, and can be calculated mathematically. A device known as a parametric array employs the nonlinearity of the air to create audible by-products from inaudible ultrasound, resulting in an extremely directive, beam-like wide-band acoustical source. This source can be projected about an area much like a spotlight, and creates an actual specialized sound distant from the transducer. The ultrasound column acts as an airborne speaker, and as the beam moves through the air, gradual distortion takes place in a predictable way. This gives rise to audible components that can be accurately predicted and precisely controlled.

However, the problem with firing off ultrasound pulses, and having them interfere to produce audible tones is that the audible components created are nowhere similar to the complex signals in speech and music. Human speech, as well as music, contains multiple varying frequency signals, which interfere to produce sound and distortion. To generate such sound out of pure ultrasound tones is not easy. This is when teams of researchers from Ricoh and other Japanese companies got together to come up with the idea of using pure ultrasound signals as a carrier wave, and superimposing audible speech and music signals on it to create a hybrid wave. If the range of human hearing is expressed as a percentage of shifts from the lowest audible frequency to the highest. No single loudspeaker element can operate efficiently or uniformly over this range of frequencies. In order to deal with this speaker manufacturers carve the audio spectrum into smaller sections. This requires multiple transducers and crossovers to create a 'higher fidelity' system with current technology.

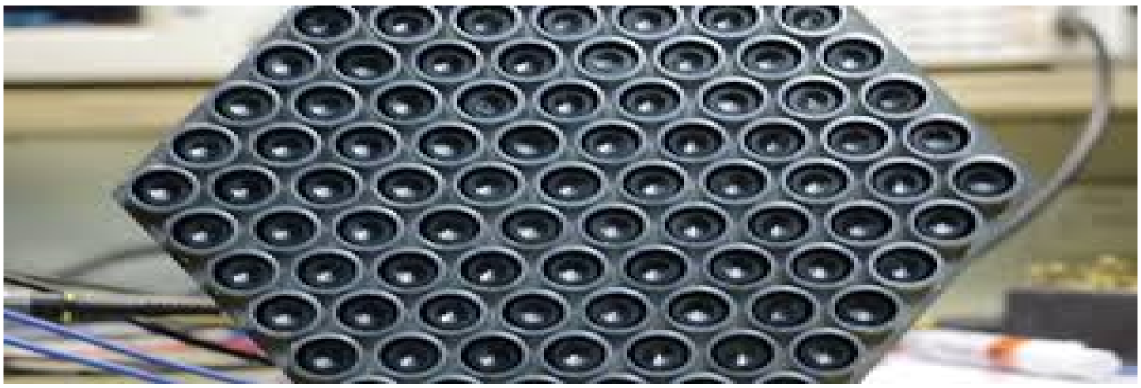

Figure 4.4: Parametric Array Loudspeaker

This is similar to the idea of amplitude modulation (AM), a technique used to broadcast commercial radio stations signals over a wide area. The speech and music signals are mixed with the pure ultrasound carrier wave, and the resultant hybrid wave is then broadcast. As this wave moves through the air, it creates complex distortions that give rise to two new frequency sets, one slightly higher and one slightly lower than the hybrid wave. Berktays equation holds strong here, and these two sidebands interfere with the hybrid wave and produce two signal components, as the equation says. One is identical to the original sound wave, and the other is a badly distorted component. This is where the problem lies—the volume of the original sound wave is proportional to that of the ultrasounds, while the volume of the signals distorted component is exponential. So, a slight increase in the volume drowns out the original sound wave as the distorted signal becomes predominant. It was at this point that all research on ultrasound as a carrier wave for an audio spotlight got bogged down in the 1980s.

4.4 Principle of a parametric loudspeaker

The fundamental theory of a parametric loudspeaker is based on the principal of the parametric array, which was discovered and explained by Westervelt in 1960, at a meeting of the Acoustical Society of America. In 1975, Bennett and Blackstock proved that a parametric speaker can work with air as the transfer medium by sending 18.6 kHz and 23.6 kHz collimated beams and observing the 5 kHz difference frequency wave.

The phenomenon of the parametric array was described by Westervelt as: "two plane waves of differing frequencies generate, when traveling in the same direction, two new waves, one of which has a frequency equal to the sum of the original two frequencies and the other equal to the difference frequency." Fig. 2 shows the creation of the sum and difference frequency waves, as well as higher harmonics of primary waves from the parametric array. It is noted that only the difference frequency is able to be perceived by the human ear. These generated frequency waves are attenuated in air and decay more rapidly for higher frequency components and at increasing distances from the speaker. The difference-frequency wave, which is lower in frequency and perceived by humans, is less abated by the air absorption. Therefore, after a short distance of propagation, only the audible waves in the sound beam remain sufficient amplitudes to be heard by humans.

There are two important distances to be considered in a parametric array, namely, Rayleigh distance and absorption length. Rayleigh distance is defined as the distance from the array at which there is a transition from a near-field region to a farfield region. Within Rayleigh distance, wavefronts are approximately planar. After Rayleigh distance, the wavefront becomes more spherical and attenuates more rapidly at a rate of –6dB per double distance. Absorption length is defined as the distance beyond which the nonlinear interaction no longer exists.

The absorption length is also called the effective array length, determining the extent of the distance traveled by the ultrasonic carrier before it ceases to generate any more audible sound sources. Effective array length is also explained as the range of end-fire virtual audible sources. Intermodulation process inside the primary beam excites air molecules to oscillate at the audio frequency, and the oscillation is regarded as a virtual source.

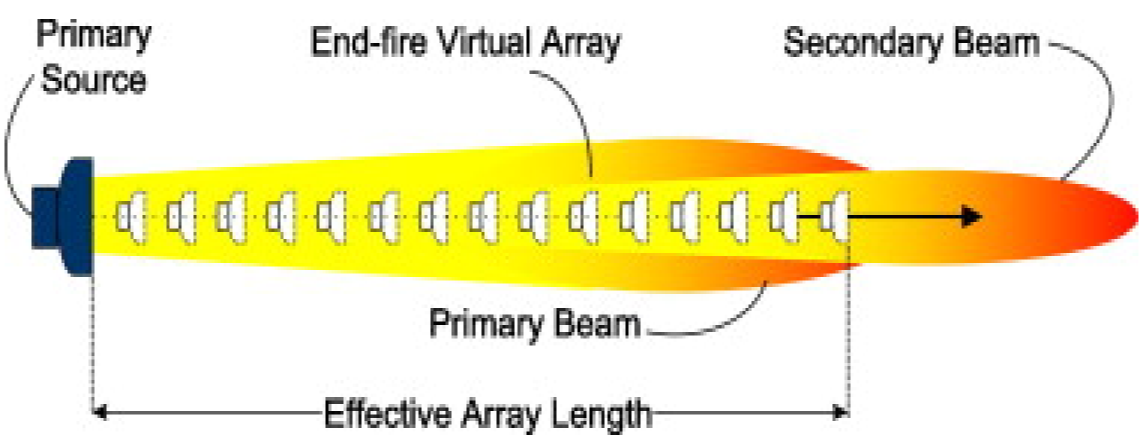

Figure 4.5: Geometric model of the parametric array.

Chapter 5

System Implementation Results

A frequency modulator for Transmitter section is designed.

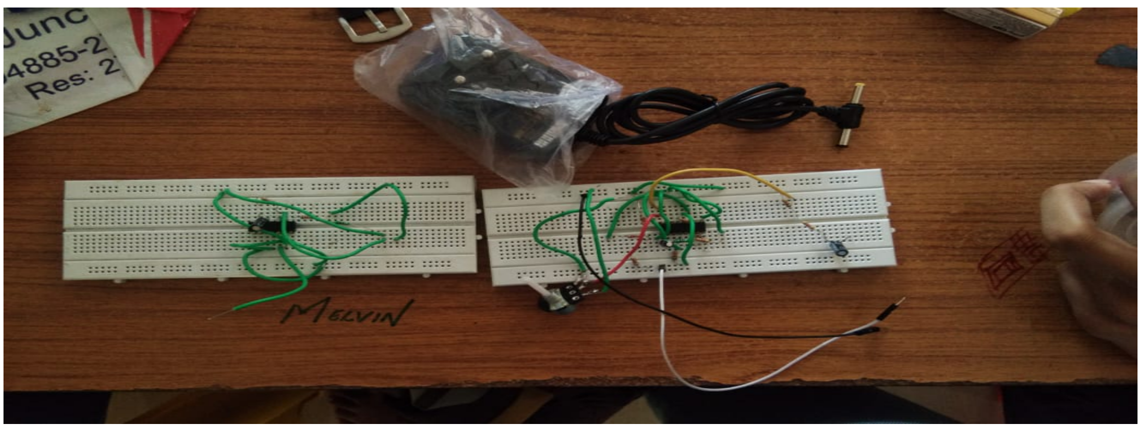

Figure 5.1: Breadboard implementation of FM Modulator and Driver Circuit

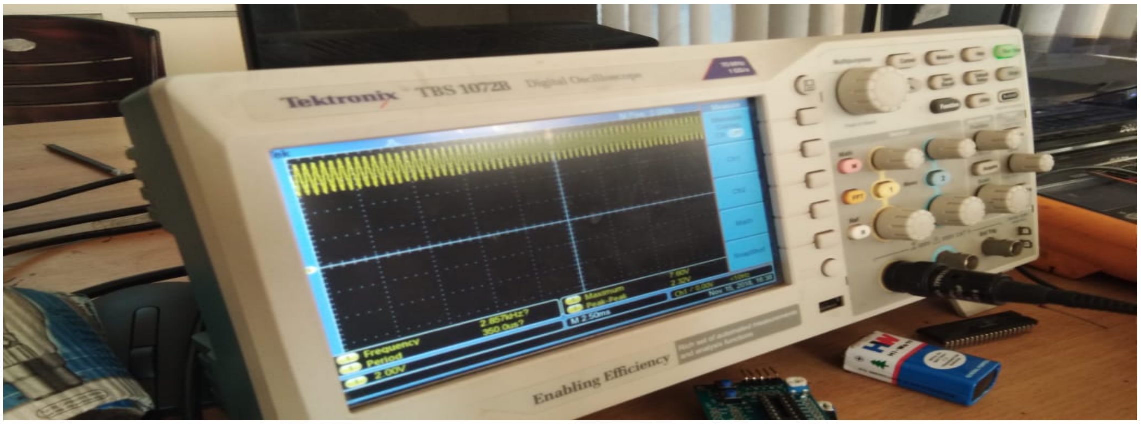

Figure 5.2: Checking the output of XR2206 IC

Chapter 6

Conclusion

Audio Spotlighting is going to change our view in sound transmission. The user can decide the direction of sound in which it should propagate. Since the sound in this system propagates in single direction, it is applicable in several fields. Audio Spotlighting will be an amazing experience for the users.

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