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DESIGNING A FRAMEWORK FOR VERSATILE LOCAL AUDIO SIGNAL DISTRIBUTI

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FACULTY OF COMPUTING

DESIGNING A FRAMEWORK FOR VERSATILE LOCAL AUDIO SIGNAL DISTRIBUTION(VLASD)

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ADVISIOR: TESFA TEGEGNE (PhD)

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Declaration

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can evoke penal action from the sources, which have not been properly cited or acknowledged.

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Date of submission: _____

Place: Bahir Dar, Ethiopia

This thesis has been submitted for examination with my approval as a university advisor.

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Approval of thesis for defense result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

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As members of the board of examiners, we examined this thesis entitled "Designing a Framework for Versatile Local Audio Signal Distribution (VLASD)" by Getie Balew Taye. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Masters of science in information Technology.

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Abstract

Despite advances in audio technologies, people are highly concerned with an effect of audio sound disturbance and privacy issues related to an audio access. Coming up with a new technical direction to eliminate audio signal disturbance at local environment is very vital. Among the tasks to be done, controlling audio disturbance, providing unlimited access and preserving privacy of users are the most common. Many researchers of the field developed different frameworks (Bluetooth, wired audio divider, headphone) for the above-mentioned tasks on different infrastructure context. However, most recent frameworks are very limited to the number of user access they provide. This thesis follows DSRM to design a framework of versatile local audio signal distribution to control sound signal disturbance and to preserve privacy.

To this end, the research conducts an assessment over existing system so as to define the exact problem and to identify user requirements. Based on the requirements, local audio signal distribution framework is designed. Design science research methodology is used to design and develop the prototype.

An attempt is made to simulate and demonstrate the designed framework to evaluate the effectiveness, efficiency, portability and spectral efficiency against the objectives defined and the requirements specified. As a result, the designed framework of local audio signal distribution is effective for avoiding unwanted sound hearing loss. It is evaluated against defined requirements, research questions and objectives and defined solution objectives. The designed framework is 90% effective, 100% efficient, 95% easy to learn, 95% easy to use, 90% portable and 95% spectral efficiency. On average, the framework has 95% overall performance.

Key terms: *Audio Disturbance, Framework, Unlimited Access, DSRM, Privacy of User, Transmitter, Receiver.*

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List of abbreviation and Symbols

AC-Alternate current

BJT- Bipolar junction transistor

DSRM- Design Science Research Methodology

DC-Direct Current

EMW-Electromagnetic wave

Hz- Hertz

IC-Integrated circuit

IEEE-Institute of Electrical and Electronic Engineers

IGBT- Insulated-gate bipolar transistor

ITU- International Telecommunication Union

MOSFET- Metal–oxide–semiconductor field-effect transistor

m/s-Meter per second

TV-Television

Wi-Fi-Wireless fidelity

WHO- World Health Organization

WLAN-Wireless Local Area Network

VLASD- Versatile local audio signal distribution

VHF- Very High Frequency

Chapter One: Introduction

1.1 Background

Computer generation is advanced and the need for smart environments and easy way of life is increasing. Technology of audio recording, transmission, storage and reproduction is rapidly advancing [1]. It supports practically unlimited generation and modification of sound and their properties. With a rapid change of audio technology, it is necessary to focus on integration of existing technology along with new direction of techniques. One of the new technical direction in sound related technology is an ability to control physical sound environments like rooms, meeting halls, class rooms (plasma and smart rooms with audio signals), and sound generation devices.

Audio frequency generator device are electronic devices that change electrical audio signals to audible sound for humans in the range of audio spectrum in the form of electromagnetic waves. Electromagnetic waves can transmit electrical signals from transmitter devices to receiver devices without material medium at a speed of light. Audio spectrum is the frequency range of electrical signal vibration in audio output devices that is 3Hz to 20KHz [2] . An audio frequency is a periodic vibration whose frequency is in the band of human's average hearing range.

Audio signals are transmitted through EMW by changing them into electrical system through transducers. Transducer is an electronic device that converts one energy to another energy [3]. When we transmit audio signal through EMW the carrier signals are used as an audio source. Carrier signals are electric charges that represents the transmitted sound. The transmitted signals from the transmitter will changed back into the previous sound by receiver. Transmitter comprises of different component which are audio sources from live or prerecorded sound, amplifier circuit, transmitter circuit and antenna. And receiver has amplifier circuit, antenna and speaker. Loudspeakers or headphones convert electrical audio signal back into the original sound [3].

The advancement of audio technology is based on electroacoustic and electronic inventions to transduce, transmit, store and playback audio signals [1]. Audio signal is a signal which carries sound that can be listen after it is amplified by amplifiers or can be uploaded to share the signals for other output devices by transmitter. Amplifier mixing small signal created by input devices like mic with external voltage for the desired output. Without amplifier small signal by itself has no power for the output device.

There are two audio signal distribution technologies; wired and wireless technologies. Wired technologies provide a one to one connection [4]. But, wired methods like eight portal jacks allows us to distribute signals from one source to eight receivers. In wired technology, the physical connection of wire is needed. However, access is very limited and within short ranges [4]. Wireless technologies provide multipoint and simultaneous connections [5]. The signal is transmitted in the form of electromagnetic waves through space and needs transmitter and receiver circuit. Transmitter transmits audio signal from the amplifier circuit which generates the target sound. The receiver receives a small signal from transmitter channel. For example, Bluetooth multipoint gives an ability to pair two different sources, but the main drawback is that it doesn't provide a simultaneous audio stream from both connected devices in reality, missing a simultaneous audio signal distribution capability [6].Therefore, the existing audio signal distribution systems restrict to access the number of users simultaneously. The group of users on the same circumstance cannot access audio data from a single source at the same time

According to WHO, the impact of sound disturbance is increasing in time at any place due to loud unwanted and excessive sound from electronic device that can have harmful effects on human health and environmental quality [7], [8]. The major effect of sound disturbance or unwanted sound is interference with communication, sleeplessness and reduced efficiency [8], [9].

In the era of advanced technology and smart environments, controlling audio signal generated from output devices, within local environments have a crucial benefit in preserving privacy of a user; one wants to hear while the other not. Regarding to this research the proposed system is connected with any single audio output device by Bluetooth or jack, and distributes audio signal to any nearby headphones wirelessly. Therefore, unlimited group of users within local environment can access audio from a single output device (such as TV, laptop, mobile).

The main aim of this research is to design a framework and develop a prototype for versatile local audio signal distribution so as to avoid audio signal disturbance by providing unlimited wireless and simultaneous access to the audio signal required.

1.2 Statement of the Problem

According to World Health Organization and International Telecommunication Union , reduce the risk of hearing loss posed by unsafe listening through personal audio devices and systems to allow the user to listen to various forms of media is important [3]. Due to the increment of loud unwanted sound generated from electronic audio output devices, audio disturbance becomes difficult from day to day at any place like offices, homes, villages, meeting halls, sporting events where many users want to access audio signals from a single output source like TV, Laptops, mobiles, tablets or iPads simultaneously [3], [10]. Sound disturbance by loudspeaker affects human health such as interference with communication, sleeplessness, reduced efficiency, deafness and mental breakdown [2], [8], [9]. Unlike text, audio and video may disturb other users who doesn't want to listen that sound.

Commercial audio/video player electronic devices have Bluetooth to connect the devices to another player. However, in reality Bluetooth doesn't allow accessing audio data more than two devices simultaneously [6], [11]. Wired audio dividers also have limitation to serve unlimited access, the maximum capacity being eight plugged headphones [12], [5]. Therefore, the previous designed audio output systems have some problems regarding to addressing the output audio. For example, when we use speaker from single audio source in university dormitory, home and offices some individuals and groups may be disturbed. Most common alternative way to overcome that problem is to use headphones/earphones. However, it has limitations, since no more than one headphones/earphone can be plugged into a single device. This problem happens especially at offices or homes where there is no any partition in the building and users share common classes.

In advanced research institutions and technology centers, researchers may need to watch videos/ listen audios for sharing information or to discuss about issues. However, when one group watches videos/ listens audios by loudspeaker, the other group will be disturbed [9]. Moreover, when we use loudspeakers in meeting halls, confidential information might be vulnerable to eavesdrop and affects the communication environment. To alleviate this, designing transmitter, unlimited portable receivers and integrated with safe listening devices is needed to transmit sound to the user.

Various researches have been done to distribute audio signal locally [13], [14], and to measure and notify unwanted sound or noise sound to a user [15], [16], [17]. However, almost all studies concentrate on only audio signal distribution and measuring the loudness of their environment continuously. Even worse is nearly all researches neglect audio disturbance avoidance. Moreover, all the previous research work doesn't provide unlimited access and doesn't consider disturbance controlling mechanism.

This research mainly uses electromagnetic wave to transmit audio signal from single audio source to unlimited listening devices(headphones/earphones) wirelessly in the radio frequency range. The framework is designed to distribute audio signal locally and simultaneously to unlimited number of users without disturbing others on the same circumstance. The outcome of this study is believed to keep the information recorded by information hackers and to perform the conferences or meetings without any extra audio disturbance in silent room.

The purpose of this study is to investigate the problem context and design a framework and develop a prototype for versatile local audio signal distribution based on the user requirements.

To this end, this study investigates and gives solution to the following basic research questions.

1. Is it possible to distribute audio signals from a single transmitter to unlimited wireless local receivers simultaneously for avoiding audio disturbance?
2. How to design a local, wireless, simultaneous and unlimited audio signal distribution framework to control audio disturbance?
3. How to simulate and demonstrate the designed framework?
4. How to evaluate the designed framework?

1.3 Objectives

1.1.1 General Objective

The general objective of this study is to design a local, wireless, simultaneous and unlimited audio signal distribution framework for avoiding audio disturbance when a group of user access single audio source.

1.1.2 Specific objective

In order to achieve the general objective, the following specific objectives are identified.

- Identifying local audio signal distribution requirements and technologies.
- Analyzing the current audio signal distributors.
- Designing local audio signal distribution framework.
- Designing transmitter and receiver circuit.
- Developing a prototype for the proposed framework.
- Evaluating the performance of the framework.

1.4 Scope of the Study

The main focus of this research is only on designing a local, wireless, simultaneous and unlimited audio signal distribution framework using electromagnetic wave. However, this research work does not include the internal details of storage media devices like personal computers, TVs, mobile phones and audio players which have digital audio outputs. Moreover, digital data distribution like text, image, video and regional or national audio signal transmission/distribution are out of the scope of the current research. This study focuses only on local audio signal distribution.

1.5 Significance of the Study

This research, upon completion, will be significant to the group of users in universities, colleges, offices, homes and researchers of the field. This automation framework will help group of users to keep any confidential audio information from recording in meeting halls, to preserve privacy of a user who doesn't want to hear any audio generated by audio output signal generator while providing others with an access effectively and efficiently, to enable unlimited connection to access audio signals generated by single output devices and to listen music without disturbing unwanted users.

Scientifically, the research will contribute to researches about wireless audio signal transmission or distribution especially focusing on wired audio signal transmission. It will have significant contribution in audio signal distribution by integrating audio output signal generator, audio output device, audio amplifiers, audio signal transmitter and audio signal receivers. It will add some knowledge in distributing any data using electromagnetic radiation wirelessly.

1.6 Organization of the Thesis

The rest of this thesis is organized as follows.

In Chapter Two, literature is reviewed on the concept of audio signal distribution and the approaches used for transmission are presented. Brief description audio signal transmission/distribution and ways of distribution are discussed. In addition, we have given a detailed description of communication system and electromagnetic radiation. Finally, a detailed analysis of different works related to audio signal distribution and safe listening device are presented. Only those works whose contributions are related to our work are discussed. In addition, the common gaps of the reviewed works and the way how we fill in the gaps are described exhaustively.

In Chapter Three, detailed description of the methodology is presented. Design science research framework procedural activities we have used in our research are discussed in detail. In addition, major components of the framework and the responsibility of each component are described.

Chapter Four, detailed description of the proposed framework is discussed. The simulation, demonstration and evaluation of the framework are described in detail.

Chapter Five, summarizes the thesis; presents the main contribution of the study; and future work.

Chapter Two: Literature Review

In this chapter, thorough review of literatures and analysis of related works are presented. Literatures on the concept of audio signal distribution and the approaches used for transmission are discussed. We begin with a brief introduction of communication system and audio signal distribution. Ways of audio signal transmission and electromagnetic radiation are discussed thoroughly. Finally, a detailed analysis of different works related to the distribution of audio signals are presented.

2.1 Overview of Communication System

Communication system is a system model describes a communication exchange between stations transmitter, and receiver. Signals or information pass from source to destination through channels, which represents a way that signal use it to move source toward destination [18]. Any communication system may comprise input devices like MIC to change sound to electrical sound, amplifier to amplify the small signal from mic to audio output devices(such as speaker/headphone/earphones) and output devices change electrical signal to audible sound [3]. However, when we listen sound from live transmission mechanism such as phone call, Bluetooth, TV and radio, receiver circuit is needed instead of Microphone (MIC). The receiver circuit consists antenna, amplifier, modulator and speaker to receive the transmitted signal. Data transmission and receiving including audio signal began after the discoveries of electromagnetic waves.

In 1861 Maxwell's, predicted that when there is a relative variation between electric and magnetic field, electromagnetic wave will be crated [19], [20]. The speed of electromagnetic waves is equal to the speed of light i.e. 300000000 meter per second [20], [21]. In 1888, German physicist Heinrich Hertz experimentally proved the prediction of Maxwell about electromagnetic waves [20], [22]. In 1876 the first successful telephone communication was started by Alexander Graham Bell through conductor wire [23]. Thomas Edison in 1877 discovered the first phonograph which used to record and play later sound again [24]. The phonograph records the sound by entering the recording sound into the cone shaped microphone's diaphragm and connected to a tiny metal needle. In 1897 the first wireless commercial radio communication was started by Marconi, in United Kingdom [25].

The communication system uses wired technology to transmit and receive signals until Marconi lunched the successful wireless signal transmission by using electromagnetic waves. Wired and

wireless communication are the result of magnetic and electric fields but, the transmission medium is different [20]. Wired communication uses conductor wire as a medium of transmission. Wireless technology has become an integral part of our daily activities, in addition to communication. It enables data sharing by radio frequency, without any conductor wires in the vacuum tube. Any information is transmitted up to hundreds of kilometers across the devices via well-defined channels [26].

The challenges of scientists in communication system is transmitting, receiving and storing audio signal. Audio processing is needed to transmit, receive and store audio files. Audio files are the code of sound in the form of electrical system which can be changed back to sound again when we want to playback.

Audio output devices consists of permanent magnet and insulated coil. The insulated coil is freely vibrating inside the magnet when an audio carrier signal is coming through it. Audio carrier signal is an electric current which swings or alternates based on the coded audio file recorded codes to create audible sound.

In 1876 Alexander Graham Bell invented the first loud speaker for his telephone part [27]. Edward W. Kellogg and Chester W. Rice in 1924 invent the widely used type of dynamic speaker [28]. Dynamic speaker is the well-known type of speaker which has permanent magnet to vibrate the winded insulated coil and the coil is connected to the cone-shaped diaphragm.

In 1960, the first subwoofer bass or sub bass speaker was introduced [29]. Subwoofer is low frequency and high-power speaker. However, subwoofer cannot be used alone, we have to add low frequency speaker in addition to it. The woofer creates smart sound especially it is good to listen instrumental beats in music.

In early communication system, the users have held the MIC and speaker by hands near to their mouth and ear. Therefore, it is difficult to perform other tasks since the user's hand is busy. To address the above-mentioned problem, the researchers designed or innovate headphones and earphones which have both MIC and speaker. Widely used instead of loudspeakers to avoid audio disturbance and to listen sensitive information privately. The size and internal orientation of magnet and coil is different. Headphones have wide and flat nature, which makes them safe since, the output audio doesn't penetrate the users ear drum.

After the discovery of semiconductor devices such as transistor, MOSFET, IGBT, BJT etc. digital amplifier circuit was started in 1947 [30]. This method makes the audio amplification, recording and mixing easily. Many users start to listen music when they are walk, sleep and also in working place without disturbing others.

2.2 Audio Signal Distribution

Audio signal distribution is a method of addressing sounds or audios in the form of electromagnetic waves. This method needs the processes of changing direct speech sound to electric signals and if there is a prerecorded audio files amplifying them. The amplified signals can be playback as sound directly or can be transmitted to another device through transmitter.

To change vocal sound from direct speech or songs from singers to electrical system, transducers are needed. Transducers are devices which used to change mechanical sound wave to electrical codes of audio signals, also known as microphone. In the early communication system, MICs was not designed in a better way as the current technology. In 1877 Emile Berliner, invented and introduced the first microphone in united states [31]. The working principles of microphones in early technology is different from the current digital technology. In the previous technology the microphones were work by analogue system. The sound entering into the cone-shaped MIC and it creates the vibration of diaphragm which is connected to the disk through the needle and tiny metal foil. These microphones were replaced by a modern type of MIC which is working by the principle of electromagnetic induction. The principle is, when mechanical sound waves heats the stretched foil connected to coil, the coil will have vibrated inside magnet. The relative motion between coil and magnet creates small electric signals coded as the sound which makes the foil to vibrate. Therefore, mic is used to input sound wave to electrical system to transmit, store and to play live. The signal which is created by mic is amplified by amplifier. An amplifier amplifies or mixes the small electrical signal with the large supply voltage. The working principle of the previous amplifier different from the current amplifier. In the previous technology, the amplifier was work by vacuum tube amplifier. However, the current technology for audio signal amplification uses chips like transistor, amplifier ICs such as; lm386, tda2822, tda2030 etc. The amplifier circuit amplifies signals from mic or antenna which is received from transmitter. Without amplification, small signals created by input devices is not large enough to listen by speaker or transmitted by the transmitter.

Music and speech in digital audio technology to be easily and reliably accessible to most users [32]. Digital audio technology has been closely linked in the early days with digital electronics, microprocessors, computers, storage media and related technologies [33]. In the home and office environments digital audio will soon be transmitted wirelessly inside networked devices. Bluetooth allows interactive compressed audio transmission wirelessly to distances up to 10m [34]. Audio peripherals such as power amplifiers, loudspeakers, microphones could be digitally implemented and connected via wireless means in the near future [33].

2.3 Methods of audio signal distribution

Audio signal distribution is the mechanism of distributing audio signals by amplifying them. Audio signal distribution needs signal amplification for addressing the target receiver. There are two methods of audio signal distribution to transmit audio signals from transmitter to receiver, which are wired and wireless [35].

Wired Transmission Methods

This method needs direct physical connection of conductor wires to transmit signals for the target receiver. In wired technology, the receiver and transmitter doesn't need antenna. In this transmission system, the signals are propagated by a material medium which is conductor wire in the form of electric current. The average speed of electric currents in conductor wire is equal with the speed of light [20], [21]. This method has strong signal and also the communication system doesn't block by seasonal change like heavy rain and strong cloud. However; it's difficult and expensive since, it needs many labor force and extremely large amount of conducting wires and also cannot direct continental across communication.

Wireless Transmissions Methods

In wireless transmissions system, the signals are propagated on vacuum without the need of any material medium [20]. This nature of electromagnetic waves makes them preferred communication method across every continent. In the era of wireless communication technology, the world becomes neighborhood. The communication takes place with our friend who live in another continent within a short period of time. Unlike wired audio signal distribution, audio signals are transmitted and received using transmitter circuit and antenna.

An antenna is a metal stick, coil, or dish which used to transmit and receive signals during wireless communication system. Antennas are used to radiate and receive EM waves (energy) and link this energy between the ether and a device such as a transmission line [21]. In transmitter, antenna is connected at the end of transmitter circuit and in receiver, antenna is connected before amplifier circuit. In 1880, the German scientist Heinrich Hertz invent the first antenna to prove the prediction of James Clerk Maxwell about electromagnetic waves [36]. Hertz uses flat metallic plates with a spark gap connected to the plates for both receiver and transmitter. Guglielmo Marconi, also use different types of antennas for wireless telephone [36]. The type of antenna is designed based on the transmitter and receiver devices. In wireless signal transmission, the audio signal may be distributed locally, nationally or internationally and the antenna used in each coverage area is different. Modulation or channel selection is needed in both wired and wireless audio signal distribution [21]. Without channel the receiver and transmitter frequency doesn't match. During antenna design, the designer considered the following things [21].

- Wavelength
- Band width
- Gain measurement
- Decibels
- Reflected power
- Impendence matching

Wave length

It is the distance between two successive crests or troughs or it is simply the ratio of velocity per frequency of the wave [20]. Its unit is meter. The wave length of electromagnetic wave depends on their frequency.

$$f=c/\lambda \quad (2.1)$$

$$\lambda=c/f \quad (2.2)$$

Where,

f is frequency in cycle per second.

c is the speed of light i.e. $3.00x10^8$ meter per second.

λ is lambda represents wavelength in meters.

As the frequency increase the wavelength will be decrease. High frequency electromagnetic waves are high energetic and low frequency electromagnetic waves are low energetic [37]. Therefore, the wavelength of the transmitted signal must be suitable for the receiver's antennae.

Band width

It is the maximum rate of data transfer across a given path or channel, or its the range of frequency at which the transmitter transmits the signal. For example, if the transmitter's transmitting signal in the frequency range from 10KHz to 10.2KHz, the bandwidth will be 200Hz.Therefore, the bandwidth must be considered during antenna design.

Gain measurement

Gain is the amplification ability of the amplifier which is measured by the ratio of input and output signal. Some amplifiers have high amplification ability to amplify very small signals and the other amplifier needs high gain of signals due to their poor amplification ability. Therefore, the gain of receivers has to be considered during antenna design.

Reflecting power

Reflecting power is the reflecting capacity of dish type antennas, when they reflect electromagnetic waves that strikes them. Electromagnetic waves are reflected by metals. By this property, dish antennas are used to pick up electromagnetic waves.

Impendence matching

Impendence is the internal resistance of the receiver's amplifier circuit for input signals from the antenna. When we receive signals from the antenna, the impedance of the amplifier and strength of the signals have to be considered, this is called impedance matching.

Properties of electromagnetic waves to characterize an antenna for transmitting and receiving electromagnetic wave are [20]:

Polarized: It's directional and can be used for some specified preferential direction of transmission and reception [20]. For example, satellite dish.

Reflection: Electromagnetic waves are reflected by objects [20]. It enables to develop antennas and to detect metallic objects like air crafts at a distance.

Interference: Interference mean the overcoming of two or more signals with same path or frequency. There are two in type which are constructive interference and destructive interference.

Refraction: Electromagnetic waves change their path if they get difficult to pass through objects [20]. This follows weak zone.

2.4Types of Antennas

Antenna types are different based on the transmitted and received signal characteristics. The characters of signal include, wavelength, frequency, signal strength, polarity and so on. Thus, properties of signal have great effect on the receiver antenna. The type of antennas is designed based on the signal characters. Common types of antennas that adopted today are:

Wired antennas

This type of antenna includes, Dipole antenna, Monopole antenna, Helix antenna and Loop antenna. It's preferable for medium frequency and high frequency.

Dipole antenna: Composed of two equal-length col-linear conductors, separated by a small feeding gap. This type of antenna can only surmount environmental challenges like mountains, valleys, buildings by increasing the signal's power level [21].

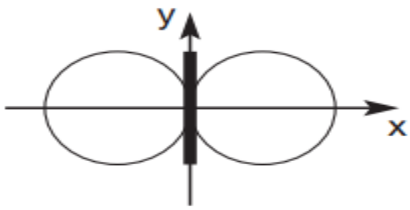


Figure 1 Radiation pattern of a simple dipole in xy plane

Monopole antenna: it's one half of dipole antenna and it has omnidirectional radiation pattern [21].

Helix antenna: it's a combination of the dipole and loop antennas [38]. It is used on the VHF and UHF bands for the FM radio and television broadcasting stations.

Loop antenna: it consists of an arbitrary-shaped wire loop fed by an input current [39]. There are two types of loop antennas: small loop antennas and large loop antennas [39].The shape of loop antenna can be circular, rectangular, triangular, square or hexagonal.

Reflector Antennas

Because of its structural simplicity and light weight, the reflector antenna is the most popular in spacecraft antenna systems [40]. A reflector antenna may consist of several reflectors and the surface may be parabolic, hyperbolic, ellipsoid or spheroidal. The parabolic one is the most common reflector antenna.

Lens Antennas

It refers to electromagnetic lens, which can converge or diverge electromagnetic signals by using electromagnet [41]. A lens antenna transmits and receives signals using the convergence and divergence properties of a lens.

Array antennas

Array antennas are a series of parallel arranged metal sticks, used for high gain signal receivers [42]. By changing their direction, the interference of data will be minimized. An antenna array is used to increase overall gain, provide diversity reception, cancel out interference and maneuver the array in a particular direction.

2.5 Local vs Regional vs national audio signal transmission system

Audio signals transformed into different waves to transmit, receive and to playback them again. Audio signals are analogue signals or alternative signals which are a representation of audio translated to audible sound by speaker. Speaker is a device used to change audio electrical signals to a vibration audible sound based on in the range of hearing frequency. Audio signal has three levels which are: MIC level, Line level and Speaker level. MIC level is very small signal in millivolt and it needs amplification. Line level signals are around 1volt and they are greater than MIC signals. These signals are audio signals in the circuit which can be divided for different ports such as, DVD, loud speaker. Speaker level signals are the final result the circuit process to speak out through speaker and the volts may be around 10 volts.

The input method of any data signal is different based on their working principle to transmit and receive signals. For example, the working principle of audio and video is different. Sound is a result of vibration of objects while image and video are the result reflection of light. When light is reflected by objects and the reflected light strikes back into photo voltaic cells, the image of the object will be changed in to electrical image and displayed by the displayer screens. Audio transducer use microphone to input mechanical sound in to electrical sound. Inside the microphone there is a freely suspended coil inside a permanent magnet. The freely suspended coil is directly connected to a thin paper like cloth membrane. When any sound strokes the thin membrane, the coil will be vibrated inside the magnet and induced small current called MIC level sound which encodes the mechanical sound in the form of electrical audio. Thus, electrical audio will be amplified by the amplifier and can be played by speaker, headphone, earphone and transmitted by the transmitter. We can also amplify it again for a better output. This audio known as Line level. The line level audio can be changed to a mechanical sound by a loud speaker, headphone or earpieces.

Audio signal may be transmitted locally, regional and nationally based on transmitting power and antenna.

Local audio signal transmission: is one way of transmitting audio data in local environment which is on the same circumstance like homes, offices and soon. It needs very short antenna and low power unless it may be accused by illegal users. It does not need any satellite; only short antenna is enough.

Regional audio signal transmission: is another way of transmitting audio data between different regions like city to city for example Bahir Dar to Gondar. It needs high power and tower antenna. The alternative current which applied to the antenna have to be powerful and long enough.

National audio signal transmission: it needs satellites for transmitting and receiving**.** Satellites are communication bridges used to connect transmitters and receivers at a distance even across a continental.

Generally, when the length of antenna is short, the wave can’t propagate long distance and the power of transmitter has to be large enough to travel the targeted distance.

2.6 Electromagnetic radiation

Radiation is the releasing or emission or transmission of energy without the need of material medium to propagate through space [43] . Naturally radioactive elements, cosmic radiant and electromagnetic energies are the source of radiant energy. There are different types of radiation, which are ionized, non-ionized and electromagnetic radiations [44].

Electromagnetic radiation is one form of radiation caused by the wave of electromagnetic waves propagating through vacuum space in the form of electromagnetic waves. For example, radio waves, microwaves, infrared, ultraviolet, X-rays, and gamma rays [43].

Electromagnetic wave is created by the relative variation between perpendicular electric field and magnetic field or a change between electric field and magnetic field [20]. Each wave has a range in electromagnetic spectrum based on their frequency. The discovery of these waves changes the world way of data transmission since, they can travel through space without a material medium. Electromagnetic waves can transmit audio signal, image, video in the form electric signals at a speed of light, which is 300000000 meter per second.

2.7 Methods of generating electromagnetic radiation

Any data exchanging systems like, phone calls, internet, radios, televisions do not work without electromagnetic radiation. Therefore, the first thing is knowing about how to create electromagnetic wave and how to create a variation between magnetic field and electric fields. This leads to how electricity is generated since generator and electromagnetic radiation has some similarity. Generators works based on the principle of electromagnetic induction which is “when there is a relative motion between a magnet and solenoid, electric current will be generated from the coil”, Michael faraday. Electric fields and magnetic fields have radiated and angular nature respectively.

To generate electromagnetic wave, electrical energy is needed [20] and to generate electricity by induction, magnetic field from permanent magnet or electromagnet is needed. Without electric current electromagnetic radiation is unbelievable. There are two types of electric current which are alternative current and direct current. An alternative current change its polarity throughout the time based on its frequency and needs rectification before use. For example, electric current from wall socket. Direct current has fixed polarity. For example, an electric current generated by solar cells

or batteries are direct current. Rectification is the process of converting alternating current to direct current.

In current carrying wire, both magnetic field and electric fields are existed. When the variation of electric field and magnetic field is perpendicular or if the current is alternative current, the current carrying wire emits electromagnetic radiation in the form of electromagnetic wave and when magnetic field and electric field are parallel or if the current is direct current, electromagnetic wave never created. Therefore, electromagnetic wave is generated by moving or oscillating charges [20]. Oscillating charges are created using oscillator circuit or switcher circuit.

Oscillation

Oscillation is a type of motion it may be swinging up and down or back and forth. It can be classified into two: mechanical and electromagnetic oscillation. Mechanical oscillation is an oscillation created by objects and matters. It needs direct contact with a material medium to propagate like sound, tide. Electromagnetic oscillation is an oscillation created by an electromagnetic energy like light, radio wave, x-ray and ultraviolet ray [20]. For example, when capacitor and an inductor connecting in series circuit and the inductance of the inductor and the capacitance of capacitor is equal, sinusoidal wave form is created.

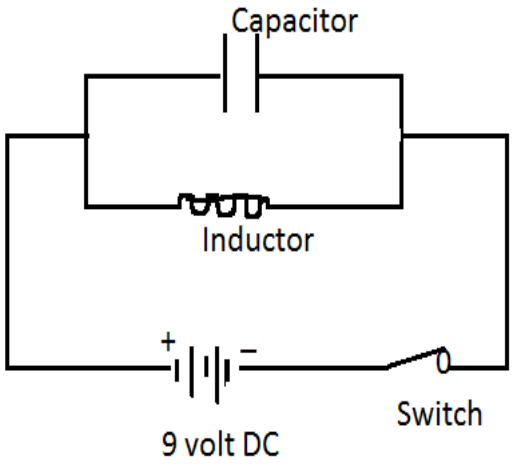


Figure 2 oscillation circuit

If the capacitance of the capacitor and the inductance of the inductor are equal and when the switch is on/off;

Let, xc…… reactance of the capacitor

xl…… inductance of the inductor

$$xl = xc \quad (2.3)$$

$$xl = \omega l \quad (2.4)$$

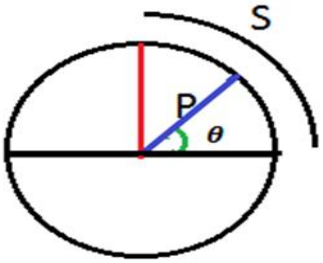
$$xc = 1/\omega c \quad (2.5)$$

$$\omega l = 1/\omega c \quad (2.6)$$

$$\omega^2 \, lc = 1$$

$$\omega = \frac{1}{\sqrt{lc}} \quad (2.7)$$

Let us consider the following figure below.



From the above diagram;

$$S - an\ arc\ of\ a\ circle$$

$$P - radius\ of\ circile$$

$$\theta\ - angular\ change$$

$$\theta = \frac{S}{P} \quad (2.8)$$

$$\omega = \frac{\theta f - \theta i}{t} \quad (2.9)$$

If $\theta = 360^0$ or 2π

$$\omega = 2\pi/t \quad (2.10)$$

$$\omega = 2\pi \frac{1}{t}$$

$$\frac{1}{t} = f$$

$$\omega = 2\pi f \qquad (2.11)$$

Substitute ω by equation $\mathbf{2.7}$

$$2\pi f = \frac{1}{\sqrt{lc}}$$

$$f = \frac{1}{2\pi\sqrt{lc}} \qquad (2.12)$$

Where, f- frequency

l- inductor

c- capacitor

Therefore, in the above circuit, the direct current battery is changed to an alternating Sinusoidal current. From equation 2.12, we can calculate change of polarity per second which is frequency.

Capacitor and inductor are temporary energy storage chips. The capacity of the capacitor to store charge is capacitance and the energy storage capacity of an inductor is inductance. When the capacitor is fully charged, the inductor will be discharge it and again the inductor will be charged and the capacitor is discharged. This charging and discharging cycle will continue until the energy is radiated to the environment in the form of heat and radiation even if the battery is removed. The discharged one is signed by negative (-) and the charged one is denoted by (+).

Switching

This technology was started after the discovery of transistor at Bell laboratory in 1947 by William Shockley [36]. Transistor is a semi-conductor device which has three terminals such as base, emitter and collector. It is used as voltage control, current control, as a switch and as amplifier. In 1959 Mohammed Atalla Egyptian-American engineer invents metal oxide semiconductor device which is called MOSFET [36]. MOSFET can contain more than 10000 transistors in a single integrated circuit or chip. This innovation leads to the digital technology. Semiconductor devices, Transistors and ICs are work by rapidly switching of current. The switcher on and off based on the designed frequency. Digital technology use switching techniques or methods in the form of 0 and 1 or on and off. Therefore, the main difference between oscillation and switching is modulation system.

2.8 Modulation

Modulation is the method of creating the relative variation or vibration between electric field and magnetic field to generate electromagnetic wave. Any electromagnetic wave needs modulation to transmit analog or digital data via certain frequencies [21]. There are different types of modulations some of are:

Amplitude modulation: in this modulation the amplitude of the carrier signal varies depending on the message signal and other variables such as phase and frequency remain constant [45]. The amplitude is varying throughout the time by changing the voltage. This modulation is simply demodulating the signal again by the receiver. Many Radio broadcasting were modulated by AM. The circuit also easy and the signals can travel in a long distance. It's used for video and picture transmission in television broadcasting and it is cheap to modulate relative to FM, but AM has narrow bandwidth. Amplitude modulation can be transmitted by long wave, mediumwave and shortwave bands. shortwave bands are used to transmit over a long distance across the continent.

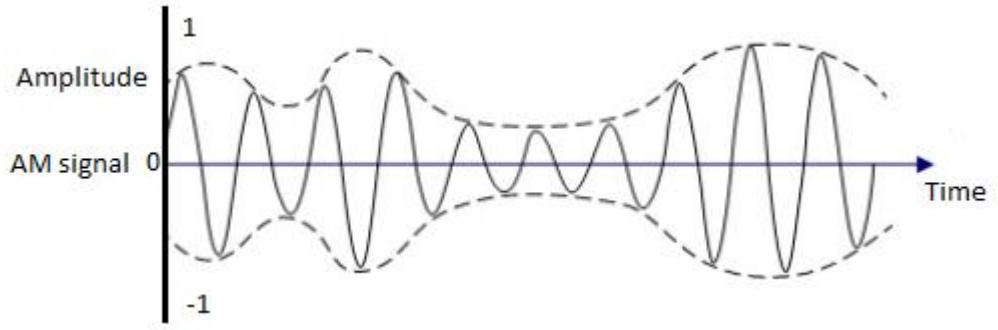


Figure 3 sinusoidal wave of amplitude modulation

$$V = A\ sin2\pi ft\ or\ A\ sin\omega t \tag{2.13}$$

Where, $A - is\ amplitude\ of\ the\ wave$

$\omega - is\ angular\ change\ per\ time$

$t - time$

$V - is\ supplied\ voltage$

$f - is\ frequency$ of the wave

Frequency modulation: in this modulation the frequency of the carrier signal varies depending on the message signal and other variables such as amplitude and phase remain constant [45]. Such method of modulation is commonly used in music and speech broadcasting, magnetic tape-

recording systems, two-way radio systems, and video transmission systems. Most of the time, frequency and amplitude modulation are applicable in sinusoidal wave. Frequency is a number of repetitions per second for any wave. In electromagnetic waves high frequency has high energetic and low frequency has low energetic. Frequency modulation has better signal quality than amplitude modulation. However, this are impacted by physical barrier.

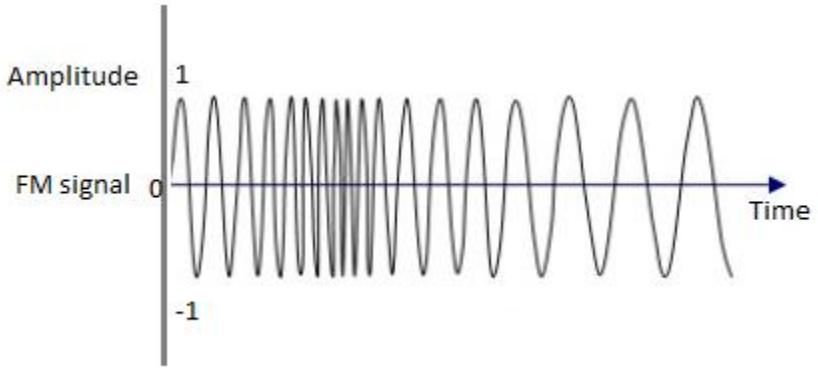


Figure 4 sinusoidal wave of frequency modulation

$$f = \frac{1}{2\pi\sqrt{lc}} \qquad (2.14)$$

Where, f- is the frequency of the wave

l- inductor

c- capacitor

Phase modulation: in this modulation, the phase of the carrier signal changes with respect to modulating signal. To change the phase of the carrier wave, the angle of the driving voltage will be changed. It is an analogue modulation system which combine both frequency and amplitude modulations. When we drive several analogue waves, which have the same amplitude and frequency, and if you want to separate them, we have to lag or forward their phase angle for filtering interference or noise. When the phase angle increase, the amplitude and frequency will decrease and when decrease, the amplitude will be steep and have several repetitions.

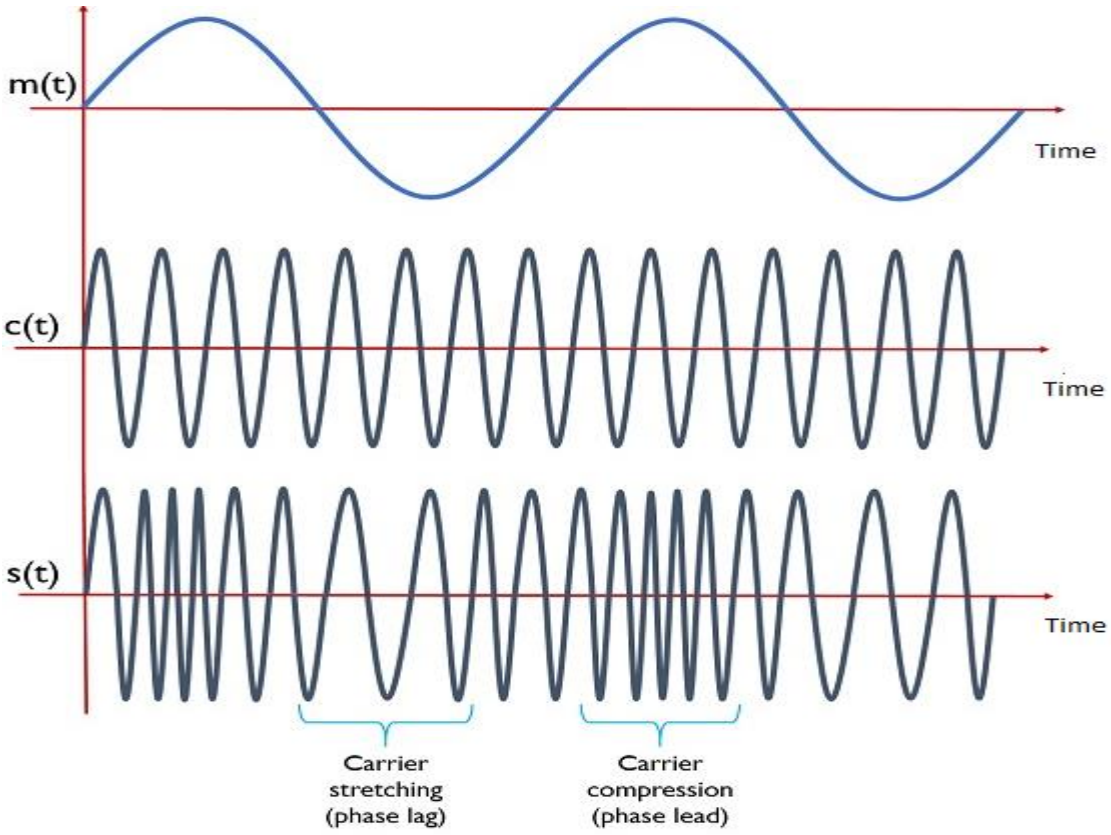


Figure 5 **wave form of phase modulation**

Pulse modulation: is a modulation type by switching electrical analogue data, change it to digital data. Used to transmitting, storing and receiving signals in the form of bit which is one and zero. Pulse is a beat of successive signals which are created by a continues electrical on/off switching devices such as MOSFETs, IGBTs and BJTs. The number one indicates that the switch is in ON state and zero indicates the switch is in the OFF state. Digital technology uses a series of BJTs to program the computer, to transmit, store, receive and to demodulate signals for several applications.

2.9 Related Works

In this section, a detailed analysis of different works related to local audio signal distribution are done. The idea behind the local audio distribution environment is to distribute and control audio sound locally so that individuals can listen their own audio contents without disturbing others.

According to [13], directional speaker has been proposed for limiting local audio environments to reduce audio disturbance. Most scientific researches on directional speaker technology focused on ultrasonic technologies. The piezoelectric transducers in the directional speaker produces two ultrasonic waves, both of which are at frequencies too high to hear. The transducers pump out the waves in a focused column, waves are modulated and travel as one wave. When the two waves hit something, they slow down and demodulate producing a new wave, this is the wave we hear. But when there is nothing standing in the beam waves keep on travelling without producing an audible sound wave. However, as even highly directional speakers radiate some sound outside the desired area, they are not suitable for all environments except for an idea of localized to a certain area, even the worse is it doesn't fully control disturbance. Moreover, they did not consider controlling disturbance from one source on local environment, where we can allow unlimited number of people to listen without disturbing others.

Noel Lee at [14], have designed audio and video signal distribution system and method. In this system the plurality of input signal distributing from one location in a building to another location in the building. They used a switcher to select input signal. This is used for home audio and entertainment system were one or more source components are located in one room along with loudspeakers for reproducing their output signals and components are connected via wire with loudspeaker. However, their work doesn't provide unlimited access and researchers doesn't consider disturbance controlling mechanism. Their gap can be filled by developing versatile local audio signal distribution using wireless communication mechanism.

According to [15], Hearing Health app has been proposed to facilitate the integration of safe hearing standards, to increase Noise induced hearing loss awareness and facilitate improvement of user's listening behaviors. The proposed app can be paired with hearing technology hardware, including personal sound amplification device, to track daily exposures to audio and environmental sounds, provide warnings based on WHO -ITU and US requirements, and engage users by providing guidance and information that can be incorporated into their occupational needs,

everyday lifestyle and recreational activities [15]. However, their work doesn't provide unlimited access when a group of users want to access single audio output devices. Moreover, researchers don't consider disturbance controlling mechanism when many users want to listen music or watch videos from single output source. Simply the proposed app installed on user mobile device and monitoring sound levels to estimate the user's sound exposure for notifying risks about unsafe noise exposure based on WHO-ITU standards.

Automatic and continuous measurements of environmental noise were done [16]. It considers putting noise measurements into the hands of the peoples by developing a smart phone application which allows the users to automatically and continuously measure the loudness of their environment and to enable users to continuously measure their noise exposure. The researcher adopts and applied a participatory sensing approach to measure the noise levels on the environment and generate general noise maps, were they allow sensing to be performed in regular intervals, and it provide two kinds of user participations namely active participation (where users actively participate using SoundOfTheCity application to work on noise measurement).The application allows to assess personal exposure to noise and public awareness participation comes with web portal which makes interactive noise and sound maps accessible to the general public. The general architecture of this research work is developed as client-server architecture, were client is running on smart phones operated by end users and server (the SoundOfTheCity) putted on other side used to control the overall performance and activity of the application. The designed server consist four modules with different purposes such as (Data input gate which is responsible for receiving all data reporting and access requests , Media streaming and encoding module used to stream captured sound to the requesting clients, Data visualization and interaction modules is responsible for aggregating available noise measurement data into meaningful visualization and allow interaction between user and provided maps and the last one is Data storage and management module responsible for storing and managing the data on the server). They designed Sound of The City application as a health monitoring application assessing not just as the personal exposure to noise pollution but also as the exposure of communities. The main motivation behind this research was the idea that the modern environment confronts people with noise emitters where noise exposure brings many health-related problems like total decline in health, quality life, hearing loss, annoyance, high psychological effects and so on. However, their work only focusses on an application-based measurement of noise (user's exposure to noise). They didn't work on how noise

disturbance can be reduced within the environment so that we can provide ways to reduce health related problems of device sound disturbance like (annoyance, psychological effects). Their gaps will be filled by designing local, wireless, simultaneous and unlimited audio signal distribution framework.

A wearable product M^+ which is used to smartly monitor blood pressure and heart rate of a person was proposed by [17], its framework also have an embedded anti-noise technology. They have proposed a new invention which focuses on providing immediate action on finding out the adverse effects of noise on blood pressure and heart rate besides of keeping track of noise pollution. The main aim of this novel research work lays on reducing physiological and psychological effect of noise pollution on humans. They have proposed prototype of M^+ wearable device that uses a miniaturized circuitry (which is an extension of the sate-of-the-art solution in sound pollution monitoring). Their proposed prototype incorporates many things like power supply for powering the microprocessor, pressure sensor used to monitor pressure of blood and capture immediate pressure changes, sound sensor used to recognize various frequencies reaching the device, ATmega328P AVR Microcontroller-IC (MC) is used to collect values from the sound sensor, then MC feeds values to sound emitter which is attached to wearable circuit, and in order for emitters to emits out-of-phase sound waves they have created and applied destructive interference, which is a concept wherein two sound waves of equal loudness and pitch cancel out each other. A Wi-Fi module is another component which they have used as part of their proposed circuit component for communication, this keeps user updated and they have also used a display for displaying the sound level. The proposed new invention was embedded with anti-noise technology which helps to control change in blood pressure/heart-rate caused by unevenness in the surrounding noise, which make their invention effective in reducing the extent of health hazard caused by unnecessary and excessive noise. However, there are more effective ways to help individuals keep themselves a way from excessive and unwanted sound noises than forcing them to use wearable device in order to manage noise pollution. Their gaps will be filled by designing local, wireless, simultaneous and unlimited audio signal distribution framework.

This are still not reliable and feasible as per the requirements of users. We design a framework for versatile audio signal distribution to avoid audio disturbance in local environment and provide unlimited simultaneous access.

Summary

Table 1 Summary of related works analysis

Research title	Authors	Proposed work	Limitation
Local Control of Audio Environment	Jussi Kuutti , Juhana Leiwo, Raimo E. Sepponen	Directional speaker has been proposed for limiting audio signal distribution with in local environment to reduce audio disturbance.	• radiate some sound outside the desired area. • they are not suitable for all local environments except for an idea of localized to a certain area. • it doesn't fully control disturbance. • Doesn't allow unlimited access within local environment.
Audio and video signal distribution	oel Lee, Calif	Designed audio and video signal distribution system and method for distributing input signal from one location in a building to another location in the building.	• Components are connected via wire with loudspeaker. • Doesn't provide unlimited access. • Doesn't consider disturbance controlling mechanism.
Development of Hearing Technology with Personalized Safe listening features	Shayan Gupta ,Xuan Xu , Hongfu Liu 2, Jacqueline Zhang, J o sh u a N B a s and Shawn K. Kelly,	Hearing Health app has been proposed to increase Noise induced hearing loss awareness and facilitate improvement of user's listening behaviors.	• doesn't provide unlimited access. • Doesn't consider disturbance controlling mechanism. • Applicable only in mobile devices.

SoundOfTheCity-Continuous Noise Monitoring for a Healthy City	Lukas Ruge, Bashar Altakrouri and Andreas Schrader	smart phone application has been proposed for measuring the loudness of their environment continuously	• doesn't provide unlimited access and doesn't consider disturbance controlling mechanism when a group of users want to access single audio output devices.
M+: A Novel IoT Device for Reducing the Physiological and Psychological Effects of Noise Pollution on Humans	Vijay A. Kanade	Designed a novel wearable system 'M+' to reduce the health effects of noise pollution on humans.	• doesn't provide unlimited access and doesn't consider disturbance controlling mechanism when a group of users want to access single audio output devices.

Chapter Three: Methodology

3.1 Overview

Research methodology is the specific procedures or techniques used to identify, select, process, and analyze information about a topic, used to undertake consistent and successful research. It is a framework to conduct researches so that the ultimate goal in addressing selected research issue(s) is achieved. The ultimate goal is to obtain better performance by using scientific methods of gathering and interpreting information. The basic research processes include problem discovery, problem definition, research method selection, sample design, data collection, data encoding, data processing and analysis, result interpretation and reporting. A research methodology is a system of principles, practices, and procedures applied to a specific branch of knowledge which helps researchers to produce and present high quality design science research which is accepted as valuable, rigorous, and publishable [46].

3.2 Research Design

This study will follow Design Science Research Methodology (DSRM), mainly focusing on investigating the problem context, analyze users need and designing an artifact (a framework) to automate audio signal distribution. It is an applied research that will later be supplemented with design project implementation. Design science research is the investigation and design of artifacts in the context [47]. It extends behavioral science capabilities by creating and innovating artifacts [48]. The goal of behavioral science is search of truth and theory formulation whereas the goal of design science research is suggesting improvement through artifact design. The former paradigm provides theories and truth and the later paradigm provides utilities [49]. Design science results in an artifact which represents a real world to solve problems and it is also a process of designing and evaluating artifacts. As a result, the aim of design science research is to develop technology-based solutions to relevant problems [49].

Design science research has uniquely identified research problem, goal, question and framework of design. The design problem [goal] is to design an artifact to improve the problem context and to answer knowledge questions (both empirical and analytical) about the artifact in context [50]. Design Science research methodology would include three elements: conceptual principles to define what is meant by design science research, practice rules, and a process for carrying out and presenting the research [49]. As a principle, design science research designs an artifact to solve

observed problems, contributes to research knowledgebase, evaluates the artifact and communicates it to audiences. Practically, design research should create an artifact which is "relevant to the solution of a theretofore unresolved business problem and its utility, quality and efficacy" and should be rigorously evaluated [49]. Together with the principles and practice rules in DSRM are design science research procedures, which make DSRM complete.

According to [49], the following are six design science research framework rigorous procedural activities we have used in our research: problem identification and motivation, design the objectives for a solution, design and development, demonstration, evaluation and communication.

3.2.1 Problem Identification and Motivation

This involves defining research problem and justifying the value of the solution. While problem definition is helpful to conceptualize the problem and develop an artifact contributing to the solution, solution's value justification plays two important roles. First, it helps the researcher and users to understand the solution and accept the results. Second, it helps others to understand researcher's reasoning associated with the problem.

Due to the increment of unwanted sound from audio output devices, audio disturbance becomes difficult from day to day at any place like Office, home, village, meeting halls when many users want to listen music or watch videos from single output source. Recently a lot of work has been done to overcome the stated problem. However, previously discovered audio output system has some problems regarding to addressing the output audio. When we use speaker some individuals and groups may be disturbed. Most common alternative way to overcome that problem is to use headphone/earphone. However, it has limitations, since no more than one headphone/earphone can be plugged into a single device, which are limited access. This problem happens especially at offices or homes where there is no any partition in the building and users share common rooms/classes. As a result, such kind of technological limitations might lead to a conflict between family members, colleagues, etc.

To clearly identify the underlying problem in the context, article review, targeted interview, and field survey have been used. From the articles reviewed, we filtered out the problem contexts defined, the solutions designed, technologies used and artifacts developed. From the interview, and field survey, we analyzed the existing systems and the problem context.

As per our targeted interview, environmental observation and literature review, the following are the main problems in local audio signal distribution.

Audio disturbance

Loud unwanted sound generated from electronic audio output devices (TV, laptop, radio, speaker, etc.) disturb other unwanted users at any place on the same circumstance like offices, homes, villages, meeting halls, sporting events when many users want to access audio signals from a single output source. This disturbance affects human health and environmental quality. Major effect of sound disturbance or unwanted sounds are interference with communication, sleeplessness, reduced efficiency and sometimes conflict becomes common in family members, offices etc.

Limited access

The existing audio signal distribution systems restrict to access the number of users simultaneously. For example, Bluetooth multipoint gives an ability to pair two different sources, but the main drawback is that it doesn't provide a simultaneous audio stream from both connected devices, missing a simultaneous audio signal distribution capability. The other wired audio splitter methods like eight portal jacks allows us to distribute signals from one source to eight receivers. The maximum capacity of wired dividers being eight plugged headphones. Therefore, the group of users on the same circumstance cannot access audio data from a single source at the same time.

Exposure to eavesdrop

When we use loudspeakers and mega bus in meeting halls and cinemas, confidential audio information might be recorded by hackers which means vulnerable to eavesdrop or sensitive information stolen by hackers.

3.2.2 Defining the Objectives of the Solution

Based on the problem definition and justification of the solution, objectives of an artifact will be defined, were it should meet the solution. These objectives describe how the new artifact will support the solution of the problem which has been identified or how much the desired solution is better than the existing work.

From the problem definition framework and solution value justification, we defined the following pillar qualitative objectives of the solution to be achieved after artifact design.

Avoiding audio disturbance: audio disturbance is the pillar problems, when a group of users want to access audio data from single audio output device on the same circumstance, the solution framework should enable VLASD transmitter which receives audio signal from external audio source and distribute audio signal to unlimited number of VLASD receiver with the respective headphone/earphone, and a group of user access audio by wearing headphones/earphones without disturbing unwanted users. Therefore, the group of users listen music or watch movies in silent room.

Enable unlimited accesses: the designed framework provides unlimited access. The new designed VLASD transmitter framework distributes audio signal to the nearby VLASD receiver using electromagnetic wave in the form of radiation. Therefore, any nearby VLASD receiver receives audio signal distributed by the new designed transmitter which means unlimited number of user's access audio data from single audio source. For example, a group of users can watch a movie from a single PC, TV, or mobile by unlimited headphone receivers.

Preserve audio information from recording: the designed framework preserves unwanted recording activities since, the designed VLASD receiver with the respective headphone can't give recordable mechanical sound wave for recorder devices. To record a sound, mechanical sound wave is needed to vibrate the recorder microphone. The designed framework does not provide recordable sound.

Provide simultaneous access: the artifact designed provides the method to transmits audio data to unlimited number of receivers at the same time. The number of users listen audio data simultaneously on the right place at the same time.

3.2.3 Design and Development

This is developing or designing solution of an artifact to the defined problem, it can be a framework. Research artifact is any designed object which research contribution [49] and problem solution is embedded with the design. To move from setting up the objective to design of an artifact knowledge of existing theories is required [51].

We used Bluetooth or jack to connect audio external source with the new designed versatile local audio signal distribution(VLASD) as overall audio transmitter, oscillator is used to transmit and receive electromagnetic data (audio signal) between VLASD transmitter and user carry-able

receiver which can be assembled by electronic chips such as; capacitor, resistor, inductor and diodes, LM 386 Amplifier IC is used to amplify or mix small signals with supplied voltage for VLASD transmitter and VLASD receiver, Barrier Antenna to transmit and receive audio signals, 10k resistor for current control, 100µf capacitor is used for Nosie filter, 100mh Inductor is used for voltage regulator(control), soft iron core inside the inductor is used to increase field lines, single phase step down transformer is used to stepdown 220v AC to 6v AC, Rectifier(diode) is used to rectify AC to DC, 6v rechargeable battery is used to supply voltage for VLASD transmitter. 3.7v -6v battery is used for VLASD receiver to supply voltage, external sources (mobile, TV, laptop etc.), VLASD transmitter, VLASD receiver, headphone and earphone are used for demonstration.

3.2.3.1 VLASD System Architecture

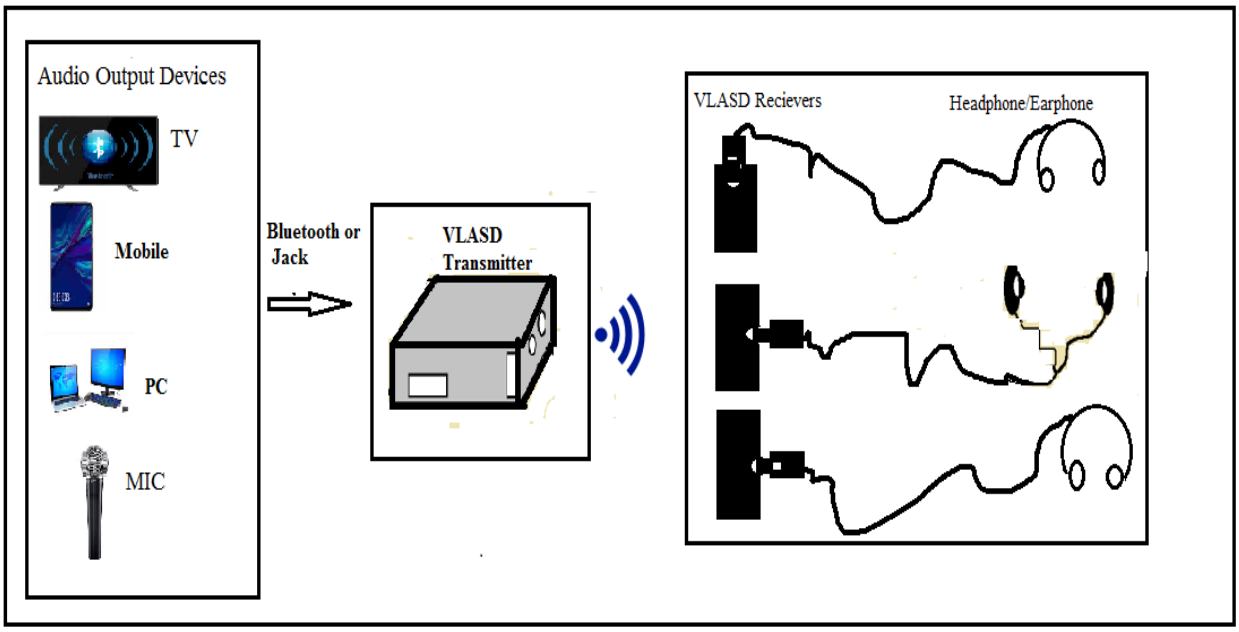


Figure 6:System Architecture

The above diagram shows the overall system architecture. The audio signal is transmitted from audio output device such as TV, Mobile, PC and MIC via Bluetooth or jack to VLASD transmitter. The VLASD transmitter receives audio signal comes from single audio output devices and distributed to VLASD receivers. The VLASD receiver receive the audio signal distributed by VLASD transmitter. VLASD Receiver is connected with safe listing output devices such as headphone/earphone.

3.2.3.2 Components of the framework

To solve the above-mentioned problems, we design versatile local audio signal distribution framework which distributes audio signals, providing unlimited access while avoiding audio disturbance. The framework has the following major components to transmit or receive any data through an electromagnetic wave.

Audio Source Component

The source of audio data in this framework is TV, Radio, Mobile, Laptop, Tablet, Microphone, etc. Bluetooth or jack plunge is used to transmit audio signal from the source of audio to the new designed VLASD transmitter.

Distributor or Transmitter Component

VLASD Transmitter is an audio signal distributor to transmit audio signal in the form of electromagnetic wave, which received from a single audio output source via Bluetooth or jack to unlimited VLASD receiver. Therefore, the transmitter transmits audio signal to several headphones/earphones simultaneously. It consists different subcomponents: -

Bluetooth Modulator and jack: These are input methods used to receives audio signal from external audio source. Most electronic devices support Bluetooth connection for local data sharing. However, some devices does not support Bluetooth connection. For these devices we can use jack to connect with VLASD transmitter.

Amplifier: An amplifier is used to mix small signals with the supplied voltage since, the received signal from external audio output device is very small. We use LM386 IC Amplifier, to amplify or mix small audio signals.

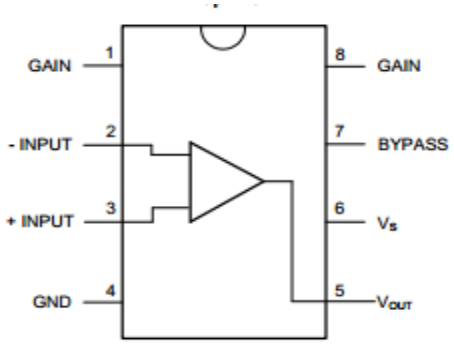


Figure 7 LM386 pin diagram

PIN 1 and 8 are the gain control PINs to increase the power of IC amplification by controlling the power. The gain of LM386 is set to 20 internally but can be increased up to 200 by using a capacitor between PINs 1 and 8. We used 10µf C1 capacitor to get the maximum gain, i.e. 200.

Pin 2 and 3 are the input PINs for sound signals. Pin 2 is the negative input terminal, connected to the ground, and Pin 3 is the positive input terminal for the amplification of the sound signal.

Pin 4 and 6 are the power supply Pins of IC, pin 6 is + Vcc and pin 4 is ground, and the circuit can be powered by voltage between 5-12v.

Pin 5: This is the output PIN to get the amplified sound signal.

Pin 7: This is the bypass terminal which can be grounded using a capacitor for stability.

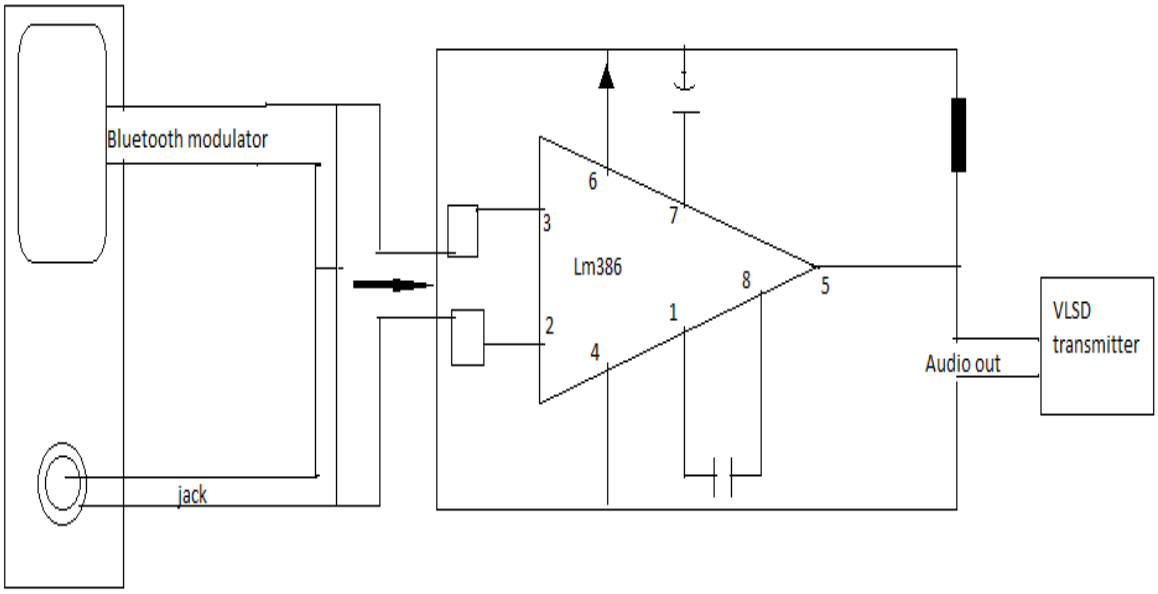


Figure 8 LM386 Audio Amplifier Circuit

Transmitter Antenna: VLASD transmitter uses potential barrier radiation antenna between the point of transmitter and receiver. Potential barrier antenna is an antenna which transmits audio signal by accumulating and amplifying in the form of voltage. This antenna decreases the current flow of signals to preserve them from wastage. When the current flow decrease, the signals voltage will increase and the frequency also increase, and creates the relative motion between the metal rod of antenna and electromagnetic field of the voltage.

According to Lenz's law, when there is a relative motion between metal rod and magnetic field, motional electromotive force will be induced from the metal surface. This force will be added to the primary signal voltage and increase the transmitted signal strength.

Oscillator: VLASD transmitter oscillator uses RLC oscillator in the range of 0-20KHz to distribute audio signal for VLASD receivers. There are different ways of creating electromagnetic oscillation such as; crystal oscillators, integrated circuits, LC and RLC circuits. Crystal oscillators are mechanical oscillators by using quartz crystal, iron crystal or any possible crystals to create mechanical vibration of electric signals based on the designed frequency. Integrated circuit creates

electromagnetic oscillation by switching. LC and RLC circuit create electromagnetic oscillation by charging and discharging of signals.

Stepdown Transformer: is used to transform high voltage to low voltage i.e. 220v AC to 6v AC.

Rectifier: is used to convert alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.

Rechargeable battery: is used to supply voltage for VLASD transmitter.

VLASD Transmitter Circuit Diagram

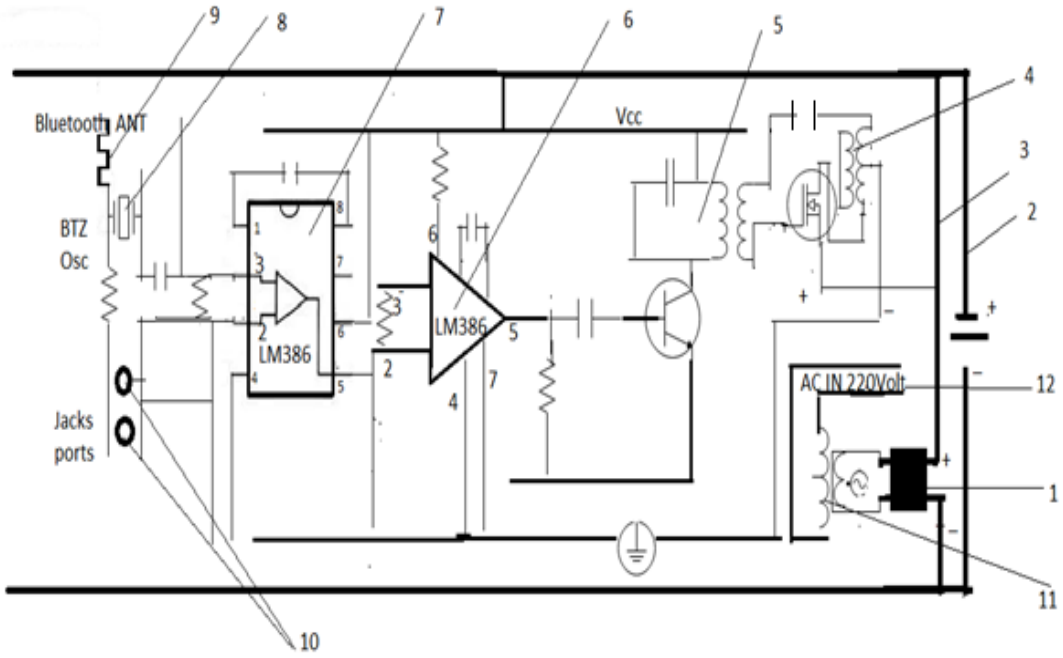


Figure 9 VLASD transmitter circuit

As illustrated in FIG. 9 the VLASD transmitter the number (1) MB6F Rectifier used for rectify AC to DC since Alternative current cannot use directly, (2)Battery, if there is no AC access, we can use batteries or direct current for voltage supply, (3)DC supplier is a rectified voltage by IC MB6F, (4) Barrier antenna is a VLASD signal transmitter that generates and pumps audio signal for several receivers, (5)Primary signal driver is a final amplification stage and the primary transmitting stage. We use class C amplifier transistor to balance the frequency and stability of signals. Class C transistors are efficient amplifiers due to their high switching property i.e.

$80° \; to \; 120°$. The resulted signals will be induced to the transmitter barrier antenna circuit in the form of voltage, (6) Secondary amplifier used for a better amplification and to decrease the load of primary amplifier, (7) Primary amplifier is the first amplifier which amplifies small signals, input from Bluetooth or jacks, (8) is a Bluetooth crystal oscillator used to receive signals transmitted by Bluetooth, (9) Bluetooth antenna which receives Bluetooth signals from external audio source, (10) is female jack ports used to connect external audio output devices by male jacks, (11) Stepdown transformer which is static electronic device used to stepdown alternative current from wall socket and (12) is AC supplier which is the source of power from generator or from wall socket.

Receiver Component

VLASD Receiver is used to receive audio signal, distributed by VLASD transmitter. They are different subcomponents:

Oscillator: VLASD receiver uses RLC oscillator in the range of VLASD transmitter (0-20KHz) to receive audio signal from VLSAD transmitter based on the modulation system. The modulation system used in this framework is variable modulation which is by varying amplitude and frequency of audio signals.

Amplifier: used to amplify or mix small signal which received from VLASD transmitter with supplied voltage. We use LM386 amplifier, to amplify small audio signals received from VLASD transmitter.

Receiver antenna: this antenna used to receive audio signal from transmitter antenna in the range of transmission band.

1.5v -9v battery: is used to supply voltage for VLASD receiver.

Jack: is used to connect VLASD receiver with headphone/earphone.

10k and 100k Resistor: is used to control the flow of current on a circuit

10µf and 100µf Capacitor: is used for filtering noise signal, oscillating and phase control.

VLASD Receiver Circuit Diagram

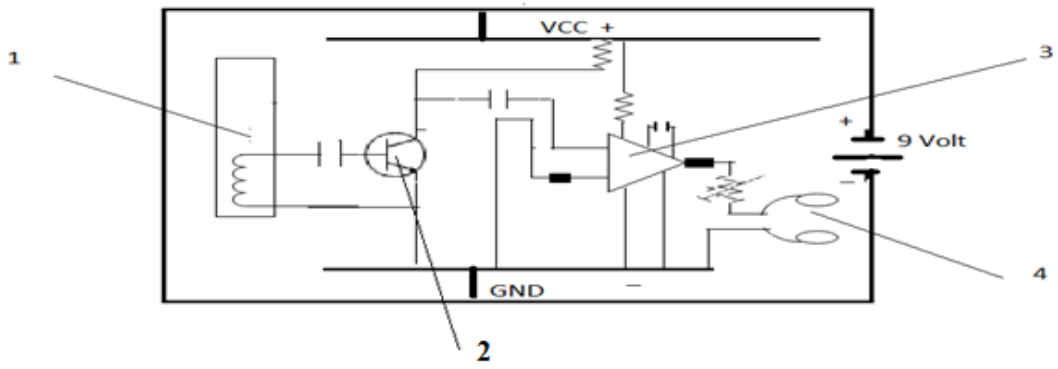


Figure 10 VLASD receiver circuit

As illustrated in FIG. 10, the VLASD receiver the number (1) is VLASD antenna which received the transmitted signal from VLASD transmitter, (2) is Class C transistor amplifier which are efficient transistor class to switch the signal and used for modulation, (3) is LM386 amplifier IC which is a well-known audio amplifier integrated circuit to amplify small signals and (4) is Headphone/Earphone which is a transducer, converts amplified audio signals to audible sound.

Headphone/earphone output component

Headphone/earphone is a wearable output component of the framework which is connected with VLASD receiver jack, used to deliver the sound signal to a human being. This wearable device helps us to avoid audio signal disturbance.

3.2.3.3 Modulation system of the Designed framework

The modulation system of the VLSD transmitter and receiver are variable modulation system. This means the frequency; amplitude and the phase of the transmitted signal is variable. They will shift when the signal is shifted, which has no any constant amplitude or frequency but it has band limitation i.e. 0-20KHz. This doesn't affect the receiver modulation system because the receiver can analyze any change of the transmitter signal pattern. When the distance between transmitter

and receiver increase, the signal strength will be decreased since, the potential difference is decreased.

The final modulation of the designed framework is the resultant of amplitude and frequency modulation. Therefore, the amplitude and frequency of the VLASD transmitter and receiver vary.

In amplitude modulation, the supplied voltage of the wave is expressed as in equation 2.13 is:

$$V = A\ sin2\pi ft\ or\ A\ sin\omega t$$

In frequency modulation, the frequency of the carrier signal is expressed as in equation 2.14 is:

$$f = \frac{1}{2\pi\sqrt{lc}}$$

Therefore, the final modulation of the designed framework mathematically expressed based on amplitude and frequency modulation as follows below:

$$Fm = V.f \tag{1.15}$$

Where, Fm-final modulated frequency

V- voltage

f – frequency

3.2.3.4 Mathematical equation of Transmitter and Receiver

To calculate the distance between VLASD transmitter and VLASD receiver, we use the formula shown below

$$\frac{\mathrm{Vp}}{\mathrm{Vs}} = \frac{1}{D}\left(\frac{\mathrm{Np}}{\mathrm{Ns}}\right) \tag{1.16}$$

Where, Vp −Primary voltage of VLASD transmitter antenna

Vs − Secondary voltage of VLASD receiver antenna

Np − primary turns of VLASD transmitter antenna

Ns − secondary turns of VLASD receiver antenna

D − distance between VLASD transmitter and receiver.

$$\frac{\mathrm{VP}}{\mathrm{VS}} \equiv \frac{\mathrm{Tx}}{\mathrm{Rx}} \tag{1.17}$$

where, Tx − Voltage in VLASD ransmitter

Rx − Voltage in VLASD Receiver

$$\frac{\mathrm{Tx}}{\mathrm{Rx}} = \frac{1}{D}\left(\frac{\mathrm{Np}}{\mathrm{Ns}}\right)$$

$$(NsTx)D = (Rx)(Np)$$

$$\mathrm{Tx} = \frac{(\mathrm{Rx})(\mathrm{Np})}{(\mathrm{Ns})\mathrm{D}} \tag{1.18}$$

Based on equation (1.18), we will maximize or minimize the range of audio signal transmission at a specific distance. The distance is the product of the ratio of voltage in the transmitter and receiver multiplied by the ratio of primary and secondary antenna turns.

For example, we can calculate distance at a given parameters such as; $\mathrm{Tx}, \mathrm{Rx}, \mathrm{Np}, \mathrm{Ns}$.

$$\mathrm{D} = \frac{(\mathrm{Rx})(\mathrm{Np})}{(\mathrm{NsTx})}$$

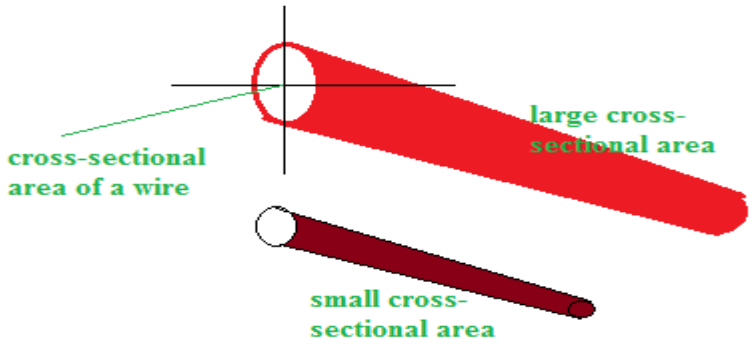
Generally, the number of transmitter and receiver antenna turns and transmitter power has a great effect for the result of signal transmission. For balancing the number of transmitter and receiver antenna turns, considered the following questions.

How many ratios of antenna turns is better?

The best ratio of turns of VLASD antenna is 1:1, since if the number of turns of transmitter and receiver is equal, strong signals is available at the target distance. Unless the number of turns of transmitter antenna have to be greater than turns of receiver antenna. When, $Np < Ns$, the transmitter signal will be low and the receiver will be out of range. In a general rule, if the number of turns increase, the signal strength will be increase. However, the turns of receiver antenna must be less than or equal to the transmitter antenna unless antenna turns consume the input signal due to the increment of internal resistance.

Which gauge of wire is best?

The antenna turns of VLASD is made from long insulated copper wire which is measured by American Wire Gauge (AWG) international standard. The smaller cross-sectional area is the thinner and high resistance while the larger cross-section area is thicker and low resistivity. Since, resistance increase, signal strength decrease. Therefore; larger cross-sectional area is preferable.



To choose the best wire gauge, considered the volume of the antenna and size of the wire we use. For example, when the volume of the antenna increase, the sensitivity will be increase. The size of the designed antenna is affected by the size of a wire. The equation is as follows:

$$\mathrm{D(V(Ns)Tx)} = \mathrm{V\big(Np(Rx)\big)} \tag{1.19}$$

Where, V – is volume of turns of antenna.

The volume of transmitter and receiver antenna may be different. The size and number of turns have to be proportional. For equal number of turns but different cross-sectional area of wires, results a variation of volume. The increment of volume can increase the effectiveness of the signal distribution of transmitter and receiver capacity.

How much is the effect of iron core inside the turns?

The iron core inside the turns can increase the signal strength based on the working principle of Lenz's law. Lenz's law states that, if there is a relative motion between a metal road and magnetic field, motional electromotive force will be generated. The iron core is static, but the signals are oscillated, this generates motional electromotive force.

Transmitter power

The power of transmitter is the source of $Tx\ or\ Vp$. When there is no any voltage in the transmitter circuit, no signals to transmit.

$$\mathrm{Pc} = \mathrm{IV} \tag{1.20}$$

Where, Pc – power before transmitted circuit

I – current or rate of charges per second

V – voltage generated by the amplifier circuit

$$\mathrm{Pxt} = \mathrm{Pc}\frac{\Delta\emptyset}{\Delta \mathrm{t}} \tag{1.21}$$

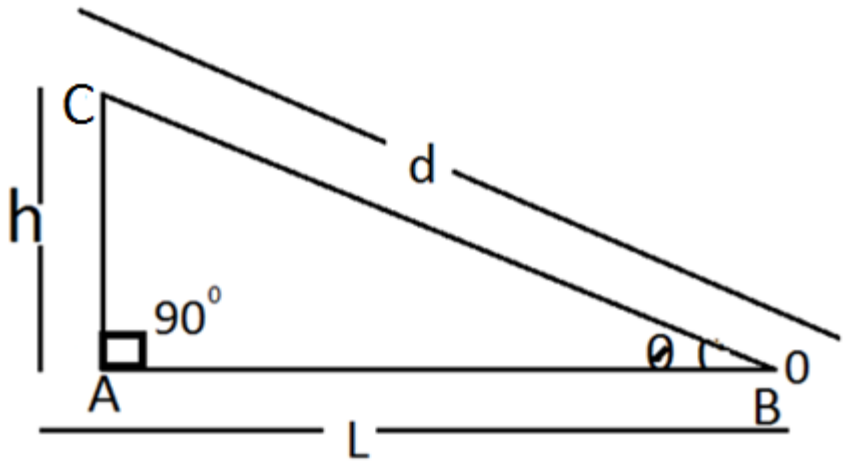
Where, Pxt – Total power of VLASD transmitter circuit

$\Delta\emptyset$ -change of flux

Δt-change in time

Flux is the area catted by an electromagnetic field when it is oscillated around the soft iron core antenna.

The transmission distance of VLASD framework is controlled based on potential difference between transmitter and receiver. The diagram below shows how potential difference affects the transmission distance.



When h is Increase L will be increase. Where; h- potential difference between point A and point C, L is the distance between point A and point B. The angle θ indicates the angle between L and d which is potential difference from point A to C. Therefore, when the potential difference increases the distance will be increase.

3.2.4 Demonstration

This activity involves demonstrating the effectiveness of the artifact. To demonstrate the framework, prototype is developed.

3.2.5 Evaluation

The framework is evaluated against the objectives that needs to meet the requirements. Evaluation is done based on the developed prototype.

3.3 Research Procedural Flow Chart Diagram

The research followed six procedural steps in sequential order. These are problem identification, solution-value justification, solution-objective definition, design and development, demonstration and evaluation.

During problem identification step, we gather reliable requirements, to clarify the existing problem and to know to what extent audio disturbance is affecting human's daily activity. This result in identifying the core problems and define the framework. Solution is defined from the Apriori and evaluated and detailed according to the problem definition during solution value justification step which is figure out depending on the framework. The Apriori of solution definition is the problem

definition framework and the researchers' logical and scientific reasoning. This step results in analyzed solution framework.

Depending on problem and solution framework the next solution-objective definition step describes the main objectives to be achieved so that the solutions stated in solution framework alleviate the problems stated in the problem framework. Overall, it provides us with a set of solution objectives that the solution achieves. The resulted solution is the framework to be designed at the next step.

At the design and development step, the architecture of the solution, the detailed component design and implementation are done. Versatile local audio signal distribution (VLASD) framework is designed architecturally. This step results in framework artifact design and implementation. This artifact is simulated in the lab, demonstrated to the user and evaluated according to the objectives set and the user requirements specified. These two steps result in simulation, demonstration and evaluation results compiled together with other intermediate results is the automation framework document of the research.

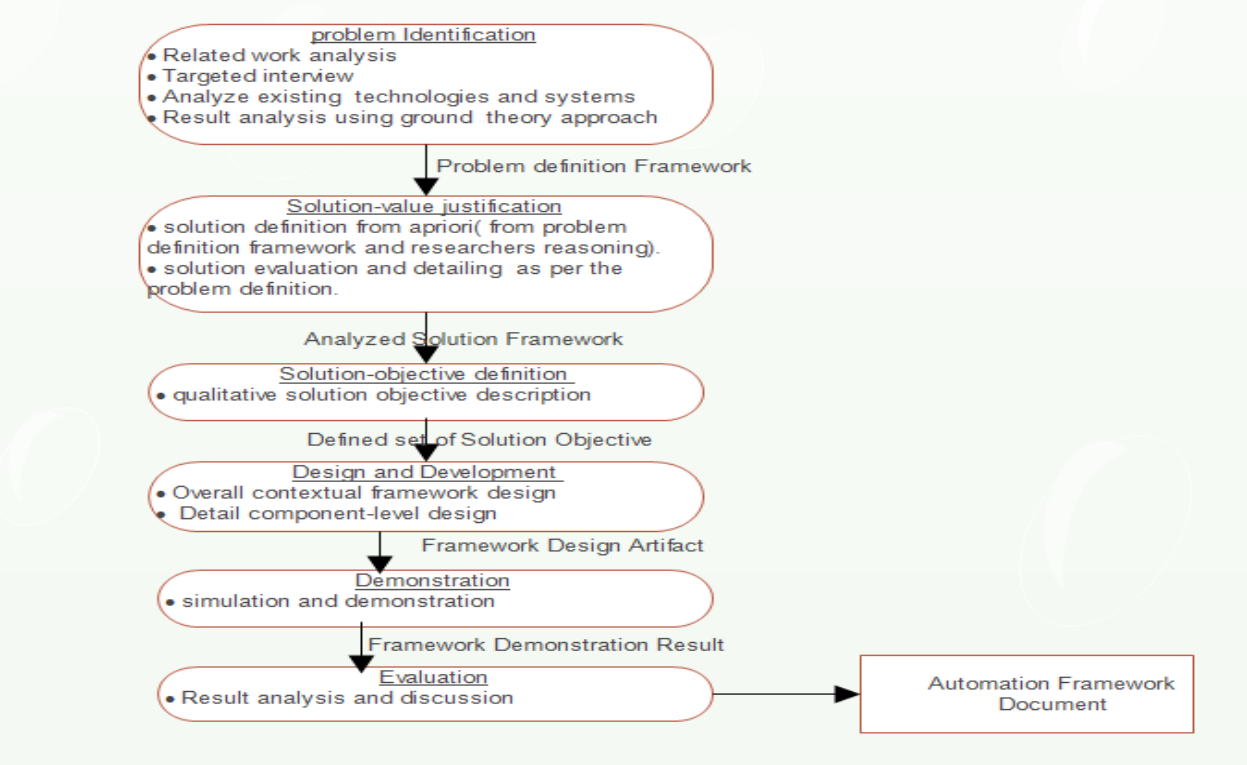


Figure 11 Research procedural flow

At the end of each positive decision of the decision points are the required outputs of research procedural steps. The final output is a research document containing the whole details of the framework; including the prototype/artifact and the detailed design.

To sum up, this chapter briefly described the problem definition framework and the solution objectives. Depending on the problem's definition mentioned and the solution objectives set, the solution framework (versatile local audio signal distribution framework) is designed. The following chapter details the design and development of this solution framework later evaluated according to the objectives and demonstrated to the users.

Chapter Four: Framework Design Development, Demonstration and Evaluation

4.1 Framework Design Development

This section describes how the solution is designed, what procedural flow is followed, and how it is developed. The procedural flow chart shows the sequence of tasks done throughout the research period and the corresponding intermediate results expected and actually achieved. The following are the details of the procedures followed and the framework designed and developed, at least as a prototype. The following figure illustrates the contextual framework of versatile local audio signal distribution.

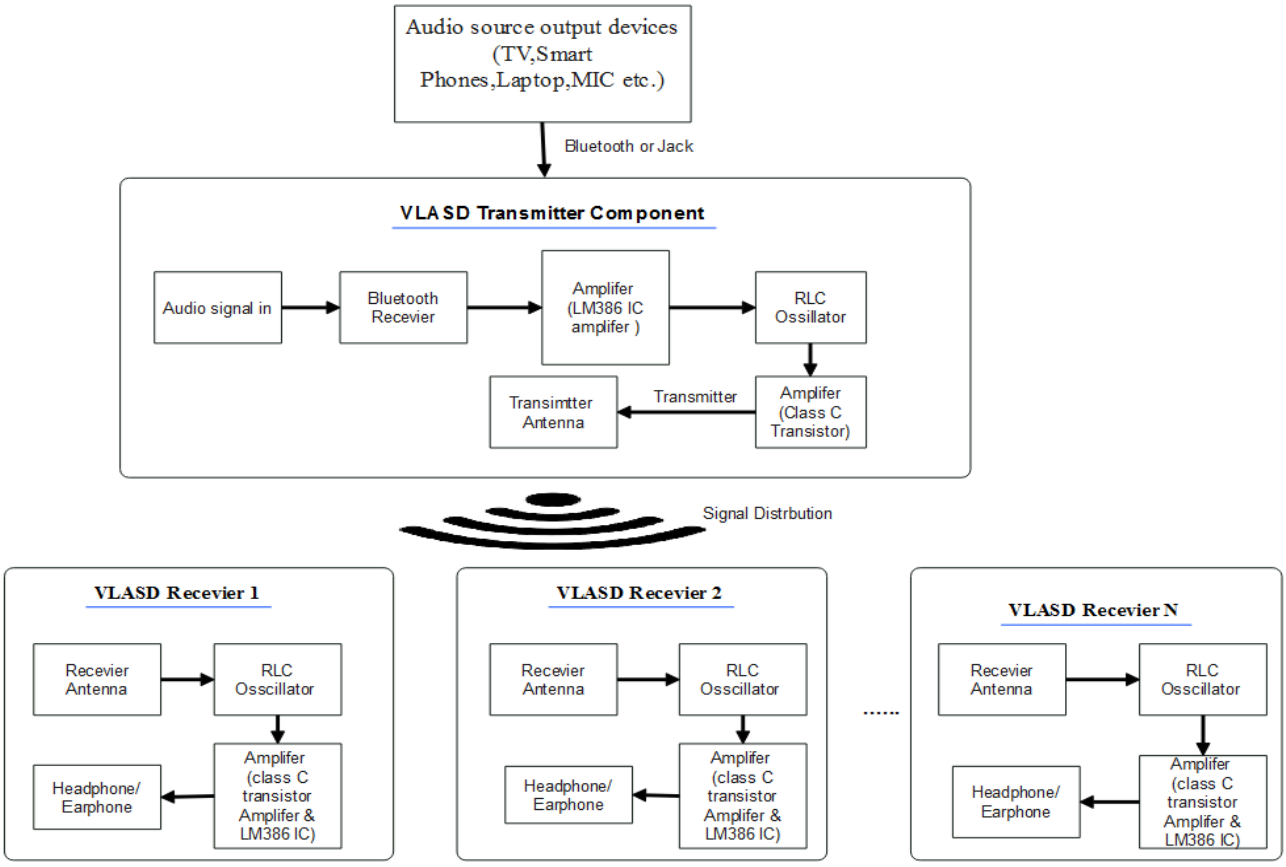


Figure 12 Architecture of versatile local audio signal distribution Framework

The above diagram shows the proposed conceptual automation framework. The signal is transmitted from external audio output device via Bluetooth or jack. VLASD transmitter receives audio signal comes from single audio output devices via Bluetooth receiver or jack plugged. The

received small signal is amplified by LM386 IC Amplifier and the amplified signal is reamplified. The amplified signal coming from LM386 IC amplifier is processed through RLC oscillator by class C transistor amplifier as a driver for better signal transmission technique. Class C amplifier and RLC oscillator formulate audio signals for transmitter. The signals from RLC oscillator will be transformed to the final RLC oscillator through electromagnetic induction.

After this the input signals from RLC oscillator through electromagnetic induction will be filtered and amplified by Class C amplifier transistor. The amplified signal will be transmitted to the transmitter antenna. Finally, the transmitter antenna generates and pumps the amplified audio signal for several receivers in the form of electromagnetic wave wirelessly. The VLASD receiver antennas receive the audio signal which is distributed by VLASD transmitter. The audio signal coming from receiver antenna is oscillated by RLC oscillator in order to receive and amplify audio signal and feed to LM386 IC amplifier. LM386 IC amplifier that reside within VLASD receiver amplifies the signal. Later on, unlimited VLASD Receiver is connected with safe listing output devices such as headphone/earphone to deliver the sound signal to a human being. Therefore, a group user can be able to access the audio signal coming from a single external audio sources without distributing other unwanted users.

4.2 Simulation Result

This step involves simulating the prototype and demonstrating to the user on how to use the artifact to solve the problems defined. The experimental simulation and demonstration of the framework is as follows.

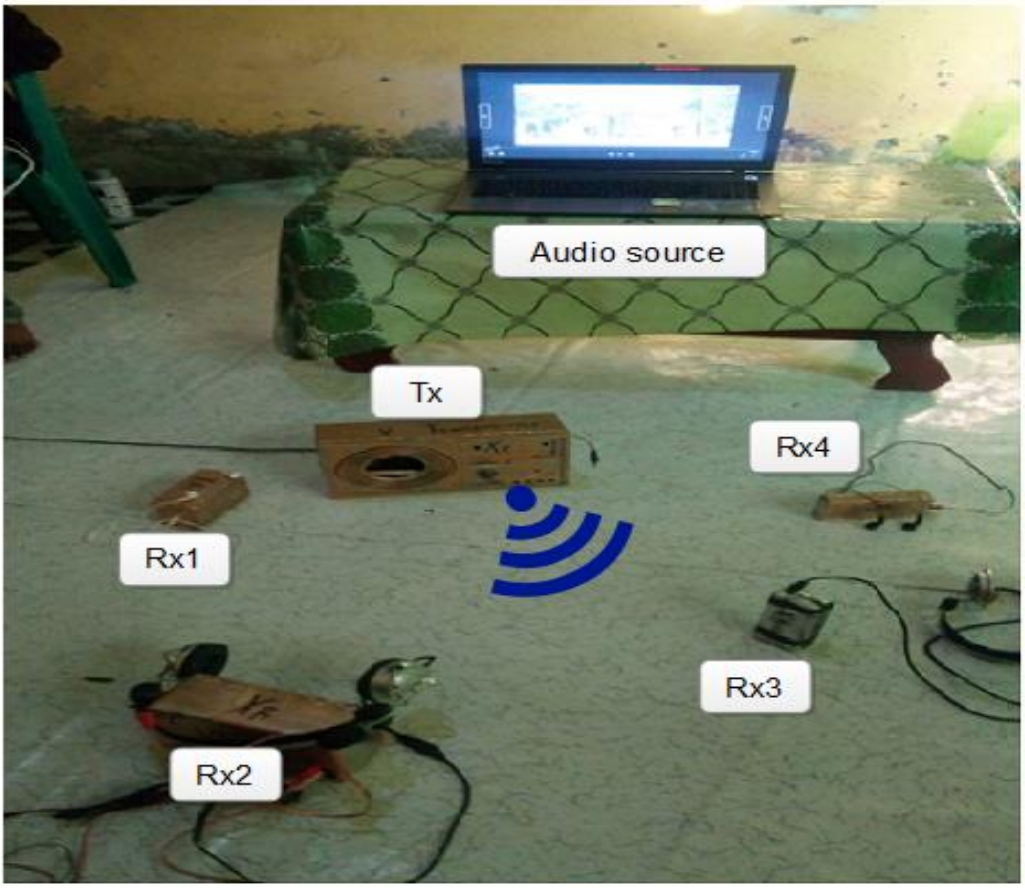


Figure 13 Prototype of VLASD framework

The above diagram shows the result of VLASD prototype. 6v power source and 9v power source are supplied to VLASD Transmitter (Tx) and four VLASD Receivers (Rx1, Rx2, Rx3 and Rx4) respectively. External audio output devices connected to the VLASD Transmitter via Bluetooth. Then VLASD Transmitter (Tx) distribute or transmit audio signal up to 2 meters for local VLASD receivers automatically. The VLASD receivers (Rx2 and Rx3) connected with headphones and VLASD receivers (Rx1 and Rx2) connected with earphones. Headphone/earphone is a wearable output device to privately listen audio without disturbing anyone in the vicinity. Therefore, the simulation result shows that four users can access audio signal by wearing headphone/earphone

simultaneously from a single laptop without disturbing the room members who doesn't want to listen an audio.

The four VLASD receivers' accesses equal distribution of audio signal from the VLASD transmitter. However, at equal distance from the VLASD transmitter, the receiving capacity of VLASD receivers is different since each receiver uses different amplification power antenna. Moreover, when the distance between VLASD transmitter and receiver increase, the signal strength is decreased due to the reduction of audio signal voltage/potential difference and the reverse is true.

We have tested the framework, weather the distributed audio is recorded by recorder device or not. The result shows that there is no any recordable audio in the room during watching movies when using the designed prototype since, there is no loud sound.

4.3 Demonstration Result

The demonstration result is demonstrated to the user using the developing prototype. The user connects single audio output devices such as laptop with VLASD Transmitter via Bluetooth or jack and each VLASD receiver with two headphone and earphone. Four users watch movies distributed by VLASD Transmitter up to 2 meters by wearing headphone on the head and earphone on the ear without disturbing others. The final result of the prototype demonstration is represented by the figure below.

Figure 14 audio signal distribution prototype

4.4 Framework Evaluation

The framework is evaluated against the five user acceptance measures (such as efficiency, effectiveness, portability, ease to learn and ease to use) and one system performance measures (such as spectral efficiency) taking sample feedback data from 20 users. Efficiency is an attribute that measures if the framework achieves the objectives in the right way with high quality or the ability to do audio signal distribution well, successfully, and without waste of time, effort and energy. On the other hand, effectiveness measures whether the framework performs the right tasks

to achieve the objectives. Portability is the measures whether the framework moves easily from place to place. Ease of use measures how quickly and easily users complete a task with in a system once they have learned how to use it. Ease of learning, however, measures how quickly and easily users can learn to use the system. Spectral efficiency is the measure of audio information rate that can be transmitted over a given bandwidth. All the feedbacks from the users are summarized with Table 2 below using a 5 scale Likert Scale, a psychometric scale used to measure individual's attitudes/agreements about some idea.

Table 2 Framework Evaluation Using Likert Scale

Questions	Strongly agree	Agree	Disagree	Strongly Disagree	Neutral	%of Majority vote
The framework performs a task successfully without wasting time (the framework efficient?)	20					100%
The framework distributes audio signal without disturbing unwanted users and preserving confidential audio information, provide simultaneous access correctly (Is the framework effective?)	18	2				90%
Is the framework easy to learn?	19		1			95%
Is the framework easy to use?	19		1			95%
Is the framework portable?	18	2				90%

Is the framework spectral efficiency?	19				1	95%
Average performance %	95%					95%

4.5 Result and discussion

As Table 2 above show, the designed framework is 90% effective, 100% efficient, 95% easy to learn, 95% easy to use, 90% portable and 95% spectral efficiency. On average, the framework has 95% overall performance. According to the samples, among 20 users 18 (90%) strongly agree that the framework is effective, 20 (100%) efficient, 19 (95%) easy to learn, 19(95%) easy to use, 18 (90%) easy to remember and 19(95%) spectral efficiency. Among the sampled users, one of them are illiterate and it was not easy for them to learn and adapt the framework. The ease of use evaluation entry of Table 2 clearly indicates this fact that 5% of the sampled users are disagree and are not sure about the issue of the framework. The framework distributes audio signal without disturbing unwanted users and preserving confidential audio information correctly evaluation entry of Table 2 clearly indicates this task that 10% of the sampled users are agree but not sure about confidential audio information is recorded by recorder devices. The spectral efficiency evaluation entry of Table 2 clearly indicates this task that 5% of the sampled users are neutral and are not clue about the audio information rate for a given bandwidth.

Generally, the framework designed is evaluated against the solution objectives: Avoiding audio disturbance, enabling unlimited access, keeping audio information from recording and providing simultaneous access. The framework avoids audio disturbance effectively when a group of users want to access music or watch videos from a single output device while the other not. In addition, the designed framework provides a simultaneous access of one single audio output devices at the same time on the same circumstance. Moreover, the framework preserves unwanted recording activities since, the designed VLSD receiver with the respective headphone can't give recordable mechanical sound wave for recorder devices and the framework enabling unlimited access since the number of receivers does not affect the transmitter. To the end, the designed framework is effective, efficient, portable, easy to use, easy to learn and spectral efficiency.

Chapter Five: Conclusion and Recommendation

5.1 Conclusion

In this research work we attempted to identify the major users need to access audio data on the same circumstance like homes, offices, dormitories and in meeting halls when a group of user lives together. As a result, the main problems identified are audio disturbance, limited access and exposure to eavesdrop. We tried to design a framework to address the above-mentioned tasks so that the problems are alleviated. Finally, we tried to simulate the framework and demonstrate the results to the selected sample of users so that we evaluated the efficiency, effectiveness, portability, ease of use, ease to learn and spectral efficiency. Accordingly, the framework has overall performance of 95% which is a promising result. The framework design answered the basic research questions raised by the researchers and met the objectives of the research set. Even though we tried our best to demonstrate and evaluate all the framework components.

5.2 Contribution

As a contribution to the scientific world or the knowledge, the proposed framework offered a systematic approach for avoiding audio disturbance and enabling unlimited access. Moreover, the designed framework provides a mechanism to access a group of users simultaneously from single audio device on the same circumstance locally. It uses both amplitude and frequency modulation system at a time simultaneously for modulating signals and designed the new barrier amplifier antenna.

5.3 Recommendation

Based on the findings of this study, the following recommendations are forwarded as future research directions.

- The designed framework does not consider the decibels of human hearing level at certain frequency. The researchers believe that an attempt in the future study should considered automatic measurement and controlling of the decibels of human hearing level at a certain frequency based on WHO-ITU Global standard.
- We recommended to integrate the new designed VLASD transmitter circuit with audio output devices such as; laptop, mobile, TV etc., and the VLASD receiver circuit with safe listing output devices such as headphone/earphone.

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