IPRO 315 Final Report
Spring 2011

Audio Quality & Energy Efficiency for Mobile Devices and Intercoms

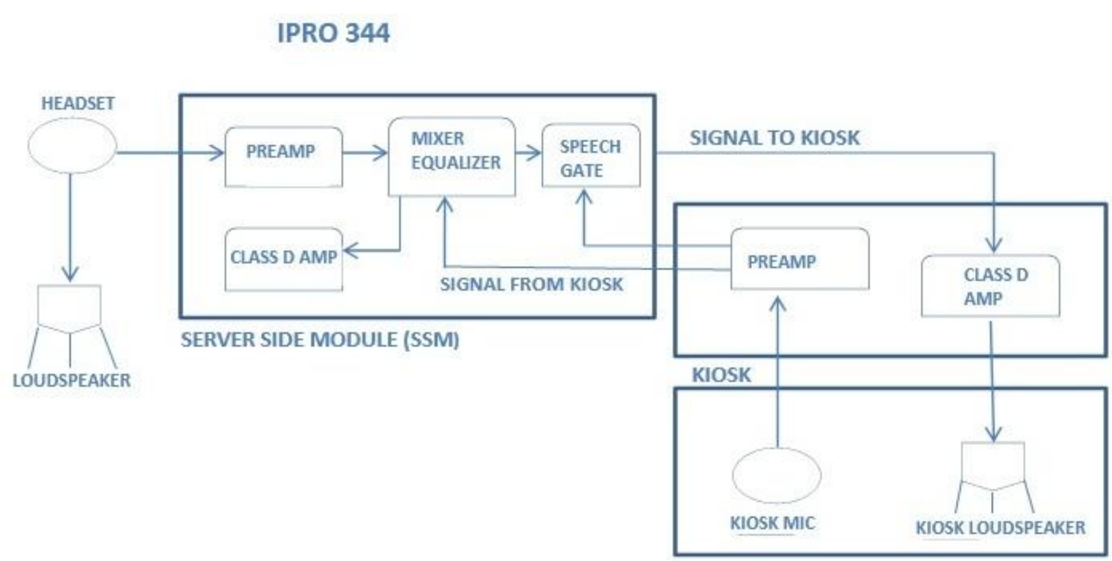
1.0 Executive Summary

1.1 Abstract

Building upon the previous semesters' work, IPRO 315 has been devoted to improving fast food drive-through order accuracy through modern technology. We divided into two teams with separate and specific goals: 1) the Wireless team implemented Shure transmitters and receivers into the server and client modules to make the connection between the restaurant and kiosk wireless, and ensured that the audio fidelity did not degrade from the wired connection, and 2) the Voiceless team designed and programmed an iPad application used to place orders within a short range of the same kiosk, ensuring a first-in-first-out queue compatible with the existing drive-through queue

1.2 Background

IPRO 315 is the sixth instantiation in a series of projects, formerly identified as IPRO 344, which were primarily concerned with audio quality and energy efficiency with the application of fast food restaurant drive-through intercoms. The previous semesters' research and design efforts culminated in a working model intercom system: a server side module inside the restaurant for the order-taker, for use with a headset, and a client side module within a kiosk containing a speaker and condenser microphone for the customer. Using class D amplifiers for energy efficiency the teams collected data on audio intelligibility to optimize the system and to reduce the likelihood of an order being taken incorrectly due to errors in speech transfer.



2.0 Purpose and Objectives
2.1 Problem statement

Customers lose time and the fast food industry loses both time and money because of incorrectly placed orders. Poor quality speech transmission is the primary cause of these mistakes and, our preceeding IPROs' having achieved satisfactory results in audio quality improvement, we recognized the need to improve the installation and maintenance process by implementing a wireless transmission system between the restaurant and the customer. We also needed to ensure no degradation in audio quality from the final product of the most recent semester.

Our second and more innovative task was to eliminate the potential for error caused by speech transmission altogether, utilizing the ubiquitous Wi-Fi technology of mobile devices to create an ordering application to be used in the proximity of the restaurant.

2.2 Sponsorship by Shure Inc.

The Audio electronics company Shure Incorporated has provided our IPRO with equipment for the Wireless team's portion of the project. They sent us two PGXD4 wireless receivers, two PGXD1 wireless bodypack transmitters, and 512 headset microphone.

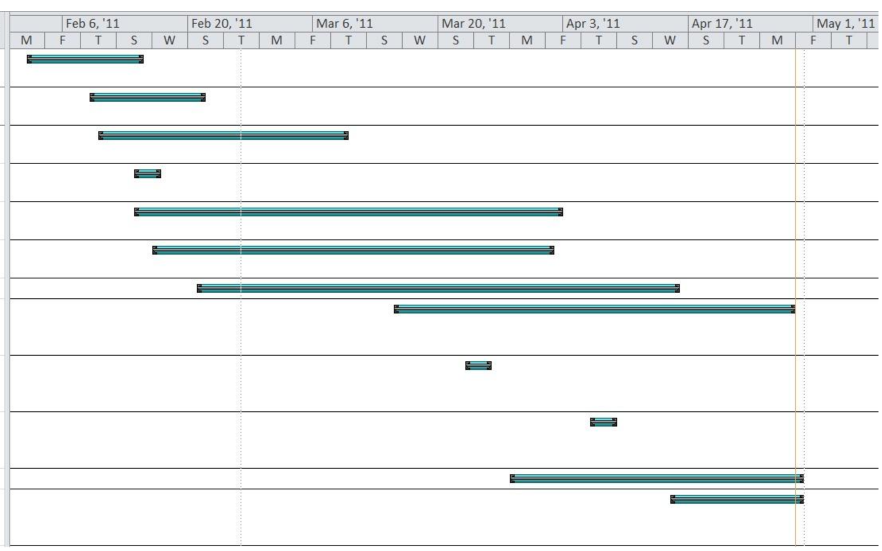
3.0 Organization and Approach
3.1 Team Structure

Having a team of only seven members and two major tasks to accomplish, we divided into a group of three for the Wireless team and four for the Voiceless team, capitalizing on the strengths of each member by major. Electrical and computer engineering majors comprised the Wireless team and two of the Voiceless team were computer science majors. We further divided duties amongst the group according to our sub team tasks each member was chosen based on their individual interests and aptitudes.

Carl Cochran (EE/CPE)	Shan Lu (MITO)	Tim Ranttila (EE/CPE)	Michael Olmos (CS)	Jaime Rodriguez (ArchE)	Joseph Taylor (PTC)	Tom Tsai (CS)
Documentation and Final Report	Purchasing	Team Leader	Meeting Minutes	Poster and Brochure	Poster and Brochure	Project Coordinator
Purchasing Video	Project coordinator Testing	Purchasing Electronics and testing	Web Page Programming	Inventory Video	Documentation and Final Report Video	Meeting Minutes Programming
WIRELESS IMPLEMENTATION	WIRELESS IMPLEMENTATION	WIRELESS IMPLEMENTATION	VOICELESS IMPLEMENTATION	VOICELESS IMPLEMENTATION	VOICELESS IMPLEMENTATION	VOICELESS IMPLEMENTATION

Scheduling of tasks was accomplished using Microsoft Project 2010.

Task Name	Start	Finish
Eval of network connectivity / topology options	Wed 2/2/11	Mon 2/14/11
Design approach for integrating wireless system	Wed 2/9/11	Mon 2/21/11
Choose and purchase hardware interfaces	Thu 2/10/11	Wed 3/9/11
Eval of of interface unification, iOS	Mon 2/14/11	Wed 2/16/11
iPad interface prototypes ready	Mon 2/14/11	Sat 4/2/11
All physical connections operational	Wed 2/16/11	Fri 4/1/11
Finalize user interface	Mon 2/21/11	Fri 4/15/11
Complete software/hardware interface evals	Tue 3/15/11	Thu 4/28/11
Determine necessary changes for next revision of interface	Wed 3/23/11	Fri 3/25/11
Evaluate headphone amplifiers for server-side module	Wed 4/6/11	Fri 4/8/11
Performance tuning	Mon 3/28/11	Fri 4/29/11
Compile list of recommendations for future work	Fri 4/15/11	Fri 4/29/11



3.2.1 Wireless

3.2.2 Methodology

The system created by the previous semesters was left open to install upgrades easily. The server-side module consisted of a case containing the following electronics:

1. A four-input mixer with individual gain and balance controls
2. An equalizer for three-band frequency control
3. A Client Priority Gate (CPG) to ensure communication etiquette
4. XLR and quarter-inch jacks for connecting a headset (unbalanced earphone plus microphone)
5. a class D amplifier for boosting the signal sent to the client-side module
6. A universal power supply for each other device

When we tested the electronics after about a year of storage since the last IPRO, some of the components were not working properly. We prioritized implementing the wireless system over making sure the nonessential modules operated: we removed the mixer, equalizer, and CPG entirely. The class D amplifier was used for the kiosk speaker (client-side), and with a wired connection it could have been placed in either the server- or client-side. Since our task was to convert to wireless, it was necessary to move the amplifier to the client-side module because the signal to be amplified came from the client-side receiver.

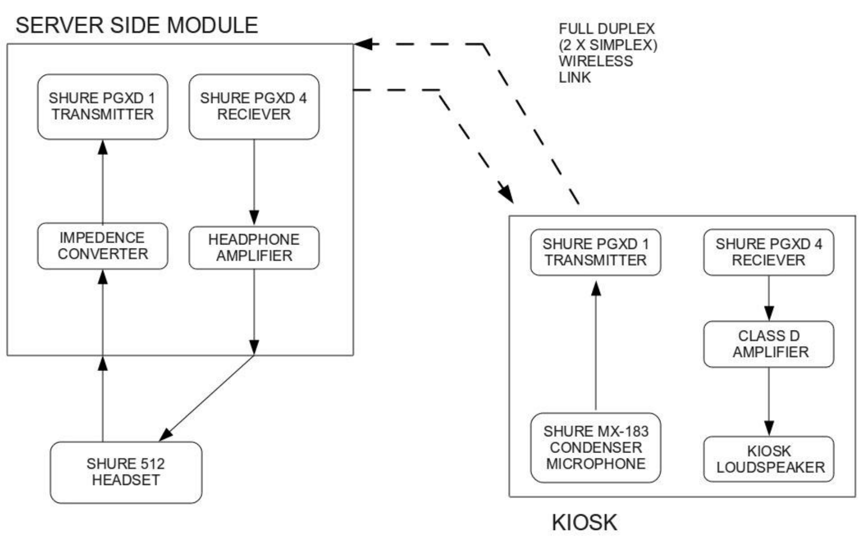


Figure 3.1 Wireless System Diagram

3.2.3 Challenges

Apart from the simplification by removal of some components, the primary challenge of the wireless project was to achieve the same level of audio clarity and speech intelligibility using the wireless system that had existed with the wired system. Their optimum microphone depth within the kiosk was discovered to be 7 centimeters and the distance from the source (customer's voice) to the microphone to be 1 foot.

3.2.4 Solutions

For the wireless system we decided on the Shure PGXD Series of wireless devices as they were designed to be used to in conjunction the Shure WL-185 condenser microphone which had been extensively tested by previous semesters of this IPRO. It was found that many parts of the previously built system failed to work correctly even with much debugging. We decided that these parts of the system were still experimental and they had not conclusively been seen to prove better audio quality, so we decided that we did not need them in our system. The previous system had relied on a Class D amplifier in the server side module to amplify the signal from the kiosk to loudspeaker level. We decided early on that if this were ever to be implemented in a production environment we would need to incorporate a headset. A headset would make it easier to hear an order being placed in a noisy restaurant setting. If we were only doing our testing on a loudspeaker, the data would be inconclusive since all sound degradation could theoretically come from the headset. We chose the Shure 512 Headset since it was equipped with only one headphone element and had a close range dynamic microphone with excellent noise rejection capabilities.

Since so many parts of the existing server-side module were not working we decided to build a completely new module that only incorporated the components being used by our system. The main parts of the new system were a headphone amplifier, two power supplies and an impedance converter.

When we tried to connect the Shure 512 headset's microphone to the Shure PGXD-1 wireless transmitter module, we found that the sound quality was distorted. After much research we found that the Shure PGXD-1 could be either used with a balanced condenser microphone or an unbalanced input. There was no capability for a balanced dynamic microphone so we determined that we needed an impedance converter. We had discussed in class how an operational amplifier could be used as a simple impedance converter and we had found an undocumented printed circuit board (PCB) that had been designed in a previous semester. We initially could not determine the function of this circuit since we observed from analysis that it had nearly unity gain, but after learning about how this converter could be implemented we soon realized that this was indeed an impedance converter and would work for our circuit.

3.3.1 Voiceless

The current system can be roughly divided into two parts: the applications and the database. The applications consist of the voiceless ordering application itself and a slightly modified version of the Amazon Web Services iOS browser sample. Database services are provided by Amazon Web Services's (AWS) Simple Database (SimpleDB) product.

The voiceless ordering application is an iOS-native application targeting Apple's iPad tablet platform. It uses the device’s Wi-Fi or 3G (untested due to lack of hardware) connectivity to transmit order information to AWS SimpleDB servers. The application's Bluetooth proximity detection functionality is provided by the iPad's Bluetooth receiver and a paired Apple Bluetooth Wireless Keyboard located within the ordering kiosk. The iOS browser sample application is used to view order information placed on the database by the voiceless ordering application.

3.3.2 Methodology

The purpose of the voiceless ordering application is to provide an alternative method for customers to place their orders at drivethrough food establishments. The application relies on Wi-Fi and Bluetooth, technologies that are nearly ubiquitous among smartphones and tablets, to provide data transmission and proximity detection, respectively and relies on Apple's iOS mobile device operating system to provide a positive user experience. The current system uses a slightly modified version of the Amazon Web Services iOS Browser demo to access submitted order information.

3.3.3 Project Objectives

1. Develop an ordering system targeting mobile devices
2. Create a simple, consistent user interface
3. Develop or leverage a low cost, scalable back-end system
4. Make special considerations for drive-through situations

3.3.4 Design Considerations

Four primary design decisions had to be made to address each of the four main objectives.

1. Choice of supported mobile operating systems

Initially, the IPRO team decided to support both Apple's iOS and Google's Android operating systems in order to support the broadest user base. However, due to lack of personnel and materiel assets related to Google's Android platform, the Voiceless Implementation sub-team leader decided to focus on Apple's iOS due to the availability of testing hardware provided free of charge by the Idea Shop and the lack of Android expertise among Voiceless team members. Additionally, the high cost and lack of availability of current generation Android tablet hardware played a significant role in influencing the design decision to focus on Apple's iOS.

The only available Android tablet running Google's Android 3.0, codename Honeycomb, OS during the time frame of the project was Motorola's Xoom tablet. While it debuted during the IPRO development period, the cheaper $600 Wi-Fi only model was not released until the final month of the IPRO development period. This presented two significant problems. First, even the Wi-Fi only model's price represented 40% of the IPRO team's budget. Its purchase had the potential to significantly undermine the viability of the Wireless portion of the IPRO had Shure not provided their equipment to us. Purchase of the 3G equipped model was simply not an option due to budget contraints as its $800 price tag represented well over half the IPRO team's $1500 budget. Second, the delayed access to testing hardware had the potential to put extreme time pressure on the application testing process. Having less than one month to perform device testing with the voiceless ordering application was deemed unacceptably short and the decision was made to drop support for the Android platform in the context of the Spring 2011 iteration of IPRO 315.

2. Choice of target device platform

The choice of the tablet form factor as the target design platform is related to both the availability of test devices as stated in (1) as well as the need to create a consistent interface. Due to the limited amount of personnel on the Voiceless Implementation, it was decided that producing both a smartphone oriented user interface and a tablet oriented user interface was not viable due to the disparate design requirements of each platform which would necessitate two separate user interfaces, one for smartphones and one for tablets. Secondly, the availability of iPads from the IPRO Office allowed the IPRO team to minimize strain on the team budget.

3. Choice of back-end provider

The choice of Amazon Web Services SimpleDB to provide data storage and database services was made with development flexibility and the economics of a production system in mind. A system that relied on other back ends such as MySQL would require set database schemata. Changes to the schemata during development would necessitate significant modifications to the entire system and negatively impact productivity. SimpleDBs "no schema" design would allow a large degree of flexibility during the development phase. Additionally, a production system utilizing MySQL or other popular database systems would require corporations or franchise owners to make significant, costly upgrades to their information technology infrastructure in order to support Internet-based ordering. The infrastructure would then have to be serviced and maintained by IT personnel, incurring additional costs on either the parent corporation or the franchise owner. By using Amazon Web Services, corporations and franchises would be able to leverage Amazon's extensive and reliable global IT infrastructure to provide service without incurring costs beyond the data and machine time usage charges. Indeed, in low usage situations, it is possible that businesses utilizing this system would not even go beyond what is provided for in Amazon Web Services free service tier.

4. Reliance on proximity detection

In order to account for the particular circumstances of a drivethrough ordering situation, an emphasis was placed on knowing the location of the order maker. In order to avoid the logistical nightmare of allowing customers to place their orders from any location, at any time, it was decided that the existing ordering kiosk would serve as a synchronization point for orders. As all orders would pass through the point one by one, it allowed for both a voiced and voiceless ordering scheme to seamlessly co-exist and for orders to be processed in their current manner as a First In, First Out queue.

To accomplish this, the team decided on using a Bluetooth device to act as a proximity sensor. Placed within the kiosk, the Bluetooth device would transmit a signal to be picked up by the customer's mobile device. Upon receipt of this signal, the device would allow the customer to submit an order. By significantly attenuating the Bluetooth signal by wrapping the device in aluminum foil, the team was able to reduce its effective range to approximately 12 feet. This allowed the system to restrict order submission, by either voiced or voiceless method, to one vehicle at a time as seen in Figure 3.2.

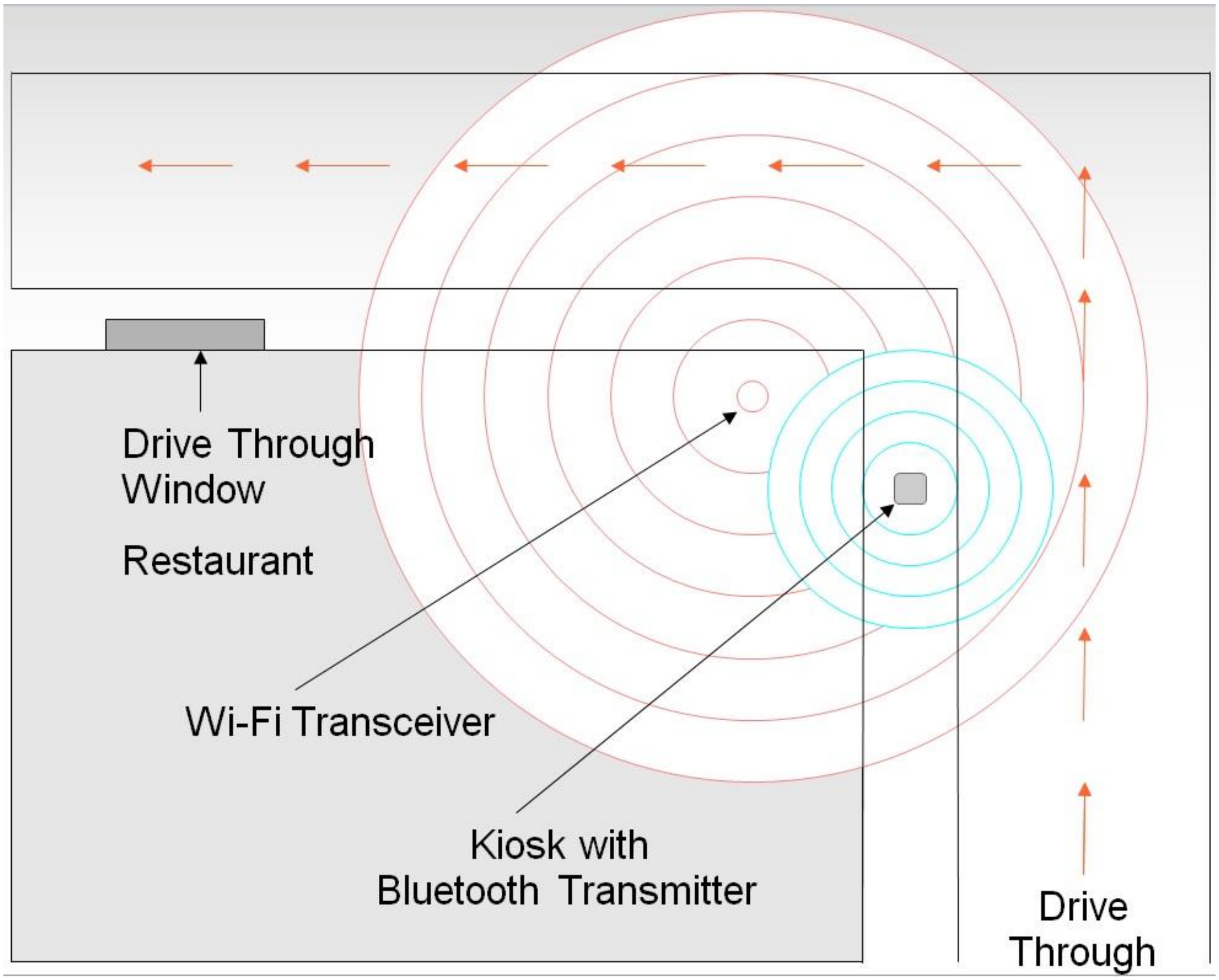


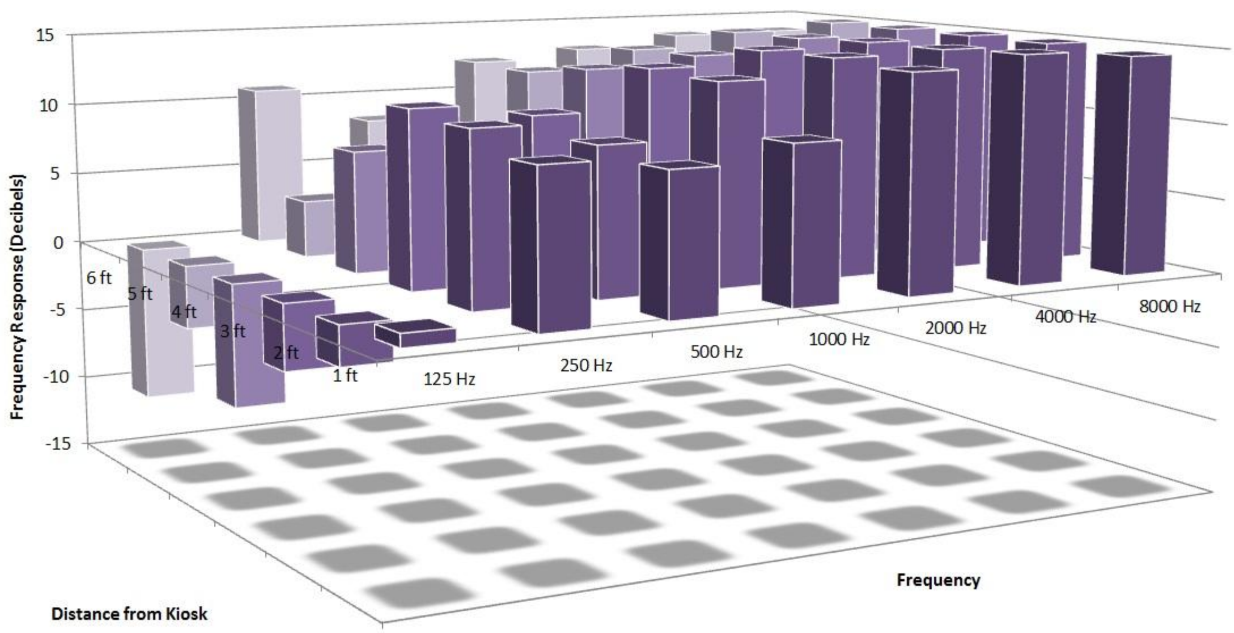
Figure 3.2 Voiceless Ordering System

4.0 Analysis and Findings

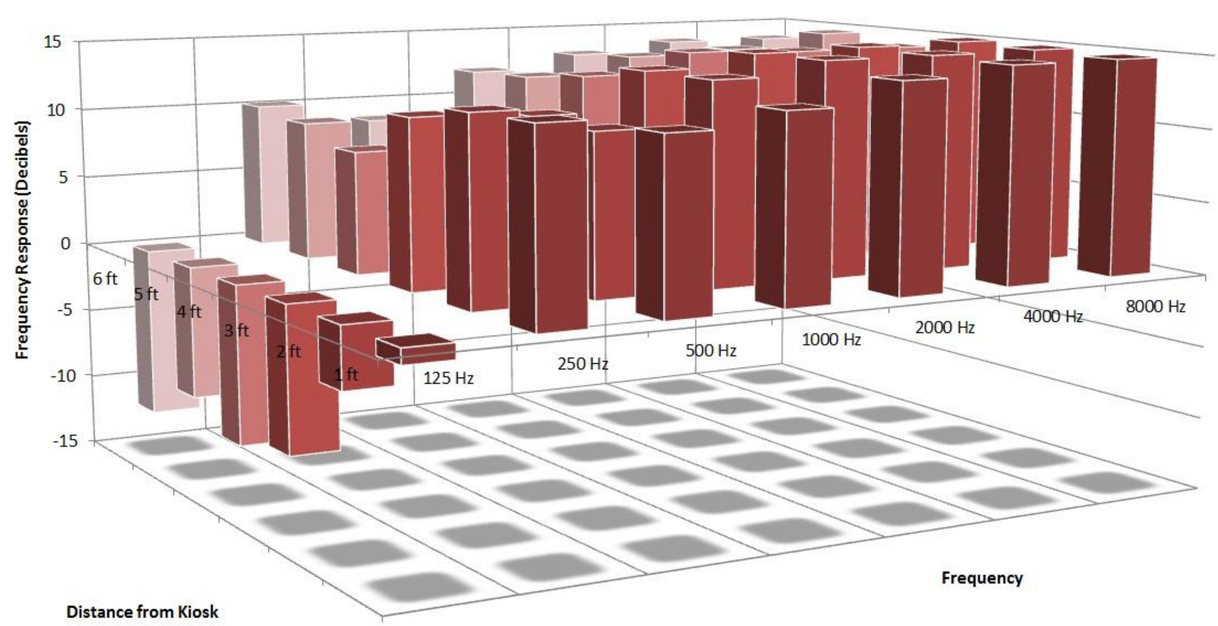
4.1 Wireless

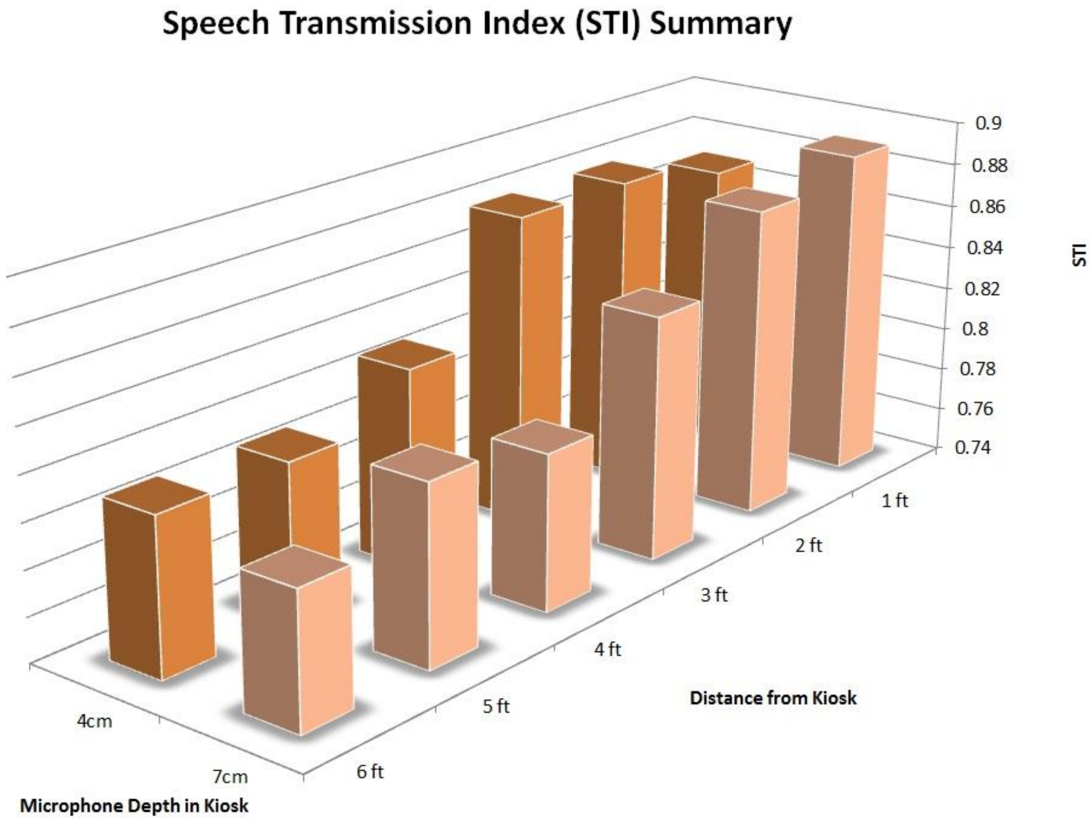
The test procedure that the previous semesters used involved analyzing the Speech Transmission Index (STI), a number between 0 and 1 representing the fidelity to the original speech, by using LexSTI software controlled by a MATLAB script. We reproduced a portion of their tests, excluding the ambient noise rejection testing since we did not possess the exact conditions of their ambient noise generation. We also did not re-test equipment and placements their test had already shown not to be optimum. Our tests involved placing a stimulus sound source in front of the kiosk and running the scripted software. The following charts summarize the test results:

Microphone Depth 4 cm



Microphone Depth 7 cm





5.0 Conclusions and Recommendations

5.1 Wireless

From our test results we were able to see that these new additions to this system did not degrade the signal as we were worried might happen. Future semester will be able to build easily off of our final results. Some recommendations for future semesters include creating a push to talk button, implementing dynamic range compression, and also to re-implement some of the systems that had been previously designed but were not incorporated into our final design.

5.2 Voiceless

It is our IPRO's belief that the voiceless system will never fully replace a voiced system and is only intended to become an alternative ordering process. This belief stems from a number of factors; peoples ability to have access to a mobile device or tablet PC, peoples ability to use a device, etc. We do however believe that by utilizing a voiceless application we can save a company in the fast food industry a substantial amount of money and improve efficiency through the use of automation. We have made a great deal of headway in regards to utilizing the existing drive through structure to implement a voiceless application but there are still a number of directions future IPRO teams can consider with regards to this application.

Custom Bluetooth transmitter hardware

The largest obstacle to creating a production system is the Bluetooth hardware. For Bluetooth devices to be detected by Apple products, they must be produced under Apple's Made for iPod program (MFi). Applying to this program would be necessary to produce such hardware and the process is non-trivial. An alternative development path would focus on implementing the system on Google's Android platform, which is far less restrictive in terms of Bluetooth connectivity and profile support.

Support for additional operating systems and platforms

Another clear development path is to return to one of the original project goals: developing an Android version of the application. This would require personnel with Android development experience, but the basic infrastructure, a data model and AWS support, already exists. Additionally, support for the smartphone form factor for either conclusion.

Point of Sale System Integration

Any production system would need to integrate the current system with an individual restaurant's Point-of-Sale system. The current method of having a server read from the database and manually input orders into the Point of Sale negates some of the time savings provided by using the system.

In-app payment

In-application payment would also have a significant effect on order completion rates. By allowing customers to securely store and send credit card payment information, an order's time from start to completion would be significantly reduced by minimizing the size of the transaction taking place at the drive through window and restricting it to transferring the order items to the customer.

6.0 Appendices

6.1 Purchases

Index	Qty	Description	/ea	Price	Vendor
1	1	PK2 phone plugs	3.99	3.99	Radio Shack
2	1	Detector plug	3.29	3.29	Radio Shack
3	1	DC Jack	2.99	2.99	Radio Shack
4	1	PK2 Open CIR Jack	2.99	2.99	Radio Shack
5	2	DC Jack 5.5/2.5	2.99	5.98	Radio Shack
6	2	PK2 UIN PLG BLACK	2.99	5.98	Radio Shack
7	1	50 UL Audio Cable	9.89	9.89	Radio Shack
8	1	Apple wireless keyboard	69	69	Amazon
9	1	Brother PT1290 label maker	25.5	25.5	Amazon
10	1	Power adapter for label maker	17.86	17.86	Amazon
11	1	3.3DC power supply	52.00	52.00	Amazon
12	1	Brother tape	12.27	12.27	Amazon
13	1	Tool box	32.41	32.41	Amazon
14	5	Conn Plug Phone 1/4”	5.18	25.9	DIGI-KEY
15	1	Switch Push Button	10.48	10.48	DIGI-KEY
16	1	Cover For the Box	11.52	11.52	DIGI-KEY
17	1	Alum Box	26.89	26.89	DIGI-KEY
18	2	Car Speaker	44.975	89.95	PolkAudio
		Total		408.89	

6.2 Headphone Amplifier Schematic

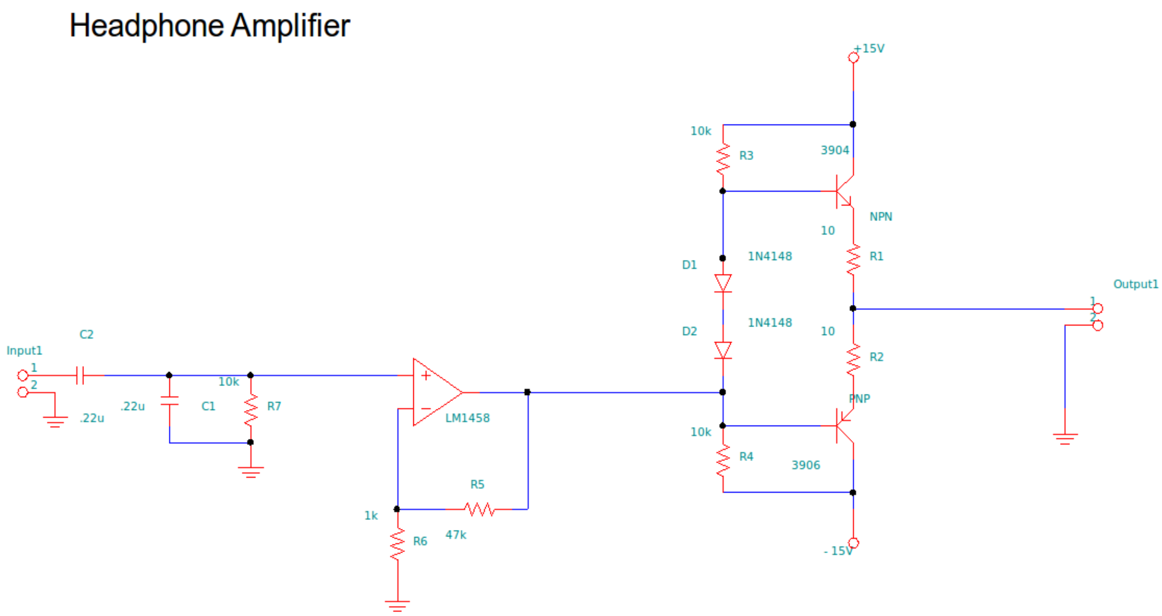


Figure 6.1 Headphone Amplifier