Phone Audio FM Transmitter

ECE 445 Project Proposal

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1 INTRODUCTION

1.1 PROBLEM

In cars with older stereo systems, there are no easy ways to play music from your phone as the car lacks Bluetooth or other audio connections. There exist small FM transmitters that circumvent this problem by broadcasting the phone audio on some given FM wavelength. A significant safety flaw with these devices arises when the user enters an area in which a radio station is transmitting on the same frequency they are using. While operating the vehicle, the user must manually scan through the channels, identify an open frequency, and set the transmitter to that frequency, taking their attention off of driving.

1.2 SOLUTION

We will build upon these preexisting devices, adding the functionality of automatically switching the transmitter's frequency, creating a safer and more enjoyable experience. For this to work, several components are needed: a Bluetooth connection to send audio signals from the phone to the device, an FM receiver and processing unit to find the best wavelength to transmit on, and an FM transmitter to send the audio signals to be received by the car stereo.

1.3 HIGH LEVEL REQUIREMENTS

1. *Device will connect and receive audio data via Bluetooth.*
2. *Device will transmit audio via FM.*
3. *Device will scan FM stations and automatically select one with minimal interference.*

1.4 VISUAL AID

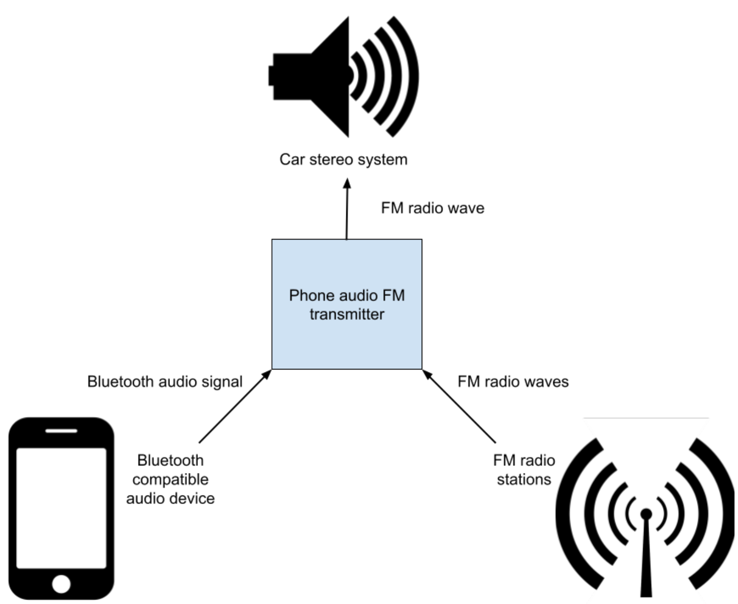

Figure 1: Phone Audio FM Transmitter Visual

2 Design

2.1 Block Diagram

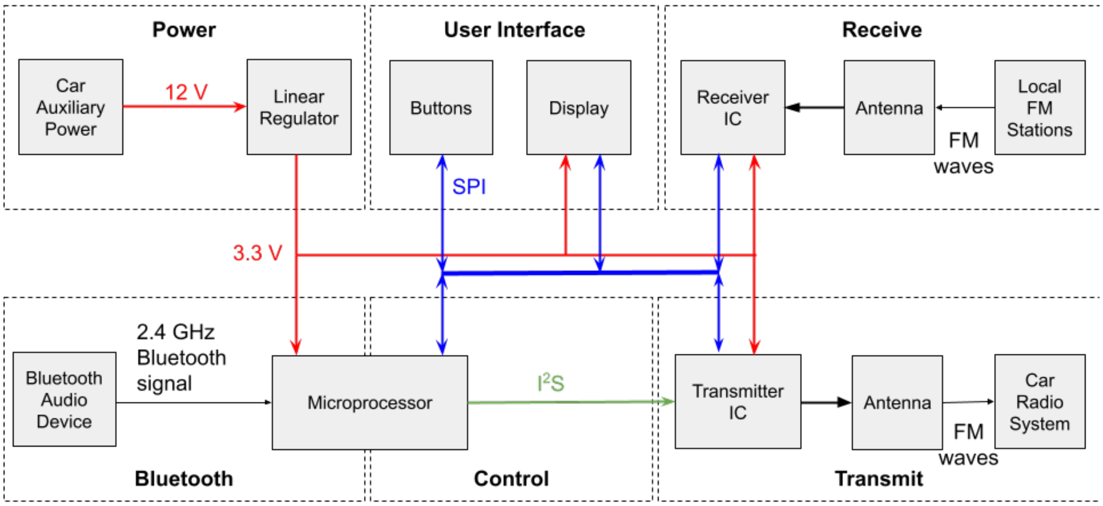

Figure 2: Block Diagram

2.2 Subsystems

2.2.1 Control

The control system will consist of a microcontroller and surrounding circuitry, capable of reading the power output of the FM receiver, and outputting a signal to adjust the receiving frequency, in order to scan the FM band. We will write and upload a program to determine the most suitable frequency. It will then output a signal to the FM transmitter to adjust the transmitting frequency to the band determined above. We are planning on using the ESP32-S3-WROOM-1 [1] microcontroller given its built-in Bluetooth module and low power usage.

Requirements:

- *The module must communicate with FM transmitter, FM receiver, and LCD display via SPI.*
- *The module must take inputs from user interface.*

2.2.2 Bluetooth

This system will interface with the user's audio device. It will connect wirelessly with the device using the Bluetooth protocol. The device will transmit audio data which the subsystem will parse and convert to PCM to be sent to the control subsystem. Because the microcontroller offers Bluetooth functionality, this subsystem will be entirely housed within it.

Requirements:

- *The module must implement the Bluetooth protocol to receive audio data from the user's audio device.*

2.2.3 FM Transmitter

This module will receive the audio signal digitally from the control unit (both on the PCB) and then transmit the audio via the FM radio frequency chosen by the control unit. This module will contain an integrated circuit that handles the digital to analog conversion, and FM modulation. The module will also contain the transmitting antenna and any matching networks between the transmitter and the antenna. We will use the Silicon Labs Si4711 [2] integrated FM transmitter and an embedded antenna.

Requirements:

- *The module must receive a digital audio signal from the control unit using I2S.*
- *The module must convert the audio to an FM radio signal and transmits at a specified frequency.*
- *The module must be able to adjust the transmitting frequency based on input from the control unit.*

2.2.4 FM Receiver

This module will be responsible for determining the RF power being transmitted at the frequencies specified by the control unit. The module will consist of an integrated circuit capable of measuring the power received and storing and communicating that information digitally to the control unit, and antenna, and any necessary matching networks and filters between the antenna and the receiver. The control unit will tell the receiver module to scan a specific frequency, it will then store the power content at that frequency. Then, the control module will read that data via a SPI interface. We will use the Silicon Labs Si4706 [3] integrated FM receiver.

Requirements:

- *The module must measure the power received at a specific FM frequency.*
- *The module must store the power received digitally.*
- *The control unit must be able to read the data about the power received from the receiver module.*
- *The module must be able to adjust the frequency received based on a signal from the control unit.*

2.2.5 Power

The device will be used in a car auxiliary port. Therefore, it will have an input voltage ranging from 12-15V. It will not require any active control so it will have no inputs other than the external power source and its output will connect to all power inputs of other subsystems.

Requirements:

- *The module must take the 12V input and output 600mA continuously at 3.3V ±0.3V*
- *The module must properly interface with automotive auxiliary power port*

2.2.6 User Interface

This system will provide the controls and feedback to the user. This includes a button to switch to a clear frequency and a display showing the broadcast frequency being used. More specifically, the display will be an LCD display to provide additional options for displaying text or other information for debugging or other uses. The system will receive the frequency to display from the control subsystem and send all inputs from the user back over the data bus. If we implement some of our stretch goals there may be additional buttons to play, pause, and skip songs or a switch to activate the automatic frequency changing between songs.

Requirements:

- *The module must display the frequency currently being broadcast on and provide an input to change said frequency.*

2.3 Tolerance Analysis

As discussed in the power section, our power system must output 600mA at 3.3V. 3.3V is within the ideal operating range of our chosen transmitter and receiver ICs as well as the MCU we have chosen.

However, this is not likely to be an issue. The potential failure points are downstream of the transmitter and upstream of the receiver. The following RF design points pose risk to the success of the project.

- *We must transmit sufficient power to be detected by a typical car FM radio receiver.*
- *The SNR of our transmission must be sufficient to achieve a clean audio signal at the output of the radio.*
- *There is likely a maximum measured signal strength from our receiver that will be required for transmission without interference.*

It is difficult to answer these questions at this point in the process because they depend so much on the design and measurements we will need to make in the lab. For instance, the power transmitted and signal strength we receive depend on the antennas we will use. Both of the ICs we have selected support embedded antennas. We will need to design the antennas, either PCB traces or wires embedded in our enclosure, and characterize the impedance and frequency response of the antennas

Our transmitter IC has an output signal to noise ratio of 58 dB, which should be more than sufficient. We will match our antennas to the transmitter and receiver to ensure maximum power transfer for optimal transmission. Because we are transmitting such a short range (from inside the car) we should not need a large amount of power. However, should the power available from the IC be insufficient, we may use a low power amplifier to boost the signal.

3 Ethics and Safety

In creating a device related to an activity as inherently risky as driving, it is imperative that throughout our design and production process we act ethically, using the IEEE [4] and ACM [5] Codes of Ethics as our guiding principles. First and foremost, we will meet the requirements of IEEE I.1 regarding safety and public welfare, which is also succinctly represented in ACM 1.2 to “Avoid harm” which they define as any negative consequence.

This device is meant to allow drivers to operate their vehicles more safely by automating the frequency selection process of the FM transmitter. This means if any aspect of our device causes the driver to be less safe or aware of their surroundings, we are not solving the problem we set out to. Therefore, we must ensure that we do not add any other steps or distractions than what the current systems on the market already have.

Additionally, the electromagnetic spectrum is subject to the regulations and oversight of the Federal Communications Commission here in the United States and we must meet the standard of ACM 2.3 to know and respect the rules relating to our work. We know that ignorance is no excuse to break rules and will ensure that we consult the FCC requirements and meet them.

3.1 FCC Regulations

Under the FCC rules, no license is required for this project given it is not sold commercially and that we follow the parameters for our transmitter specified by Part 15 [6]. These rules state we are allowed a maximum bandwidth of 200 kHz within the 88-108 MHz frequency range. Additionally, the maximum emitted power is 250 $\frac{mV}{m}$ at 3 meters away. To adhere to these specifications, our signal will be properly filtered to add minimal interference outside our operating bandwidth, and the output power will be monitored.

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