AUDIO-BASED DATA TRANSMISSION CIRCUIT

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INTRODUCTION

In the field of wireless data communication, the use of sound as a medium for information transmission has become increasingly attractive, especially in environments where the use of radio waves or traditional network connections is not feasible. This project focuses on researching and building a data transmission system via sound using the ESP32 platform in combination with frequency shift keying (FSK) modulation. The primary goal is to serve educational and research purposes. This paper presents the FSK modulation/demodulation process, key technical parameters, hardware and software configuration of the system, and evaluates the performance of the implemented solution in real-world conditions.

THEORETICAL BACKGROUND

MFSK: Digital data is divided into multiple nibbles. Each nibble is represented using a different frequency. (Requires sufficiently wide bandwidth). FFT: Converts signals from the time domain to the frequency domain to demodulate MFSK.
Reed-Solomon: A block error correction code commonly used to counter burst errors (consecutive bit errors). It operates on symbols instead of individual bits.
DSS (Direct Sequence Spread): The original low-bitrate data signal is multiplied with a high-speed binary sequence known as PN code (Pseudo Noise code) or chip sequence, spreading the spectrum to improve noise resistance

METHODOLOGY

The audio-based data transmission system utilizes FSK modulation with the ESP32 microcontroller platform and the GGWave library. The system is implemented through the following steps:

System Parameter Configuration:

- Sample rate: 6000 Hz (transmitter), 24000 Hz (receiver)
- Frame size: 128 samples (transmit), 512 samples (receive)
- Sample format: INT_16 (receiver), UNSIGNED_8-BIT INTEGER (transmitter)
- Data transmission protocol: MT_FASTEST
  - 1 byte $= 2$ nibbles $= 2$ tones
  - 3 frames/transmission
  - freqStart: 24Hz

Base Frequency Calculation

$$f_{\text{base}} = \text{freqStart} \times \frac{\text{sampleRate}}{\text{samplesPerFrame}} \tag{1}$$

- f_{base}: Base frequency (Hz)
- freqStart: Starting FFT bin index
- sampleRate: Audio sampling rate (Hz)
- samplesPerFrame: Number of samples per FFT frame

Tone Frequency Calculation

$$f_{\text{tone}} = (\text{freqStart} + \text{nibble}) \times \frac{\text{sampleRate}}{\text{samplesPerFrame}} \tag{2}$$

- f_{tone}: Specific frequency of each tone (Hz)
- nibble: 4-bit data value (from 0 to 15)

System Setup:

- ESP32 combined with GGWave library[1]
- Transmitter ESP32 connected to a mini speaker for audio output
- Receiver ESP32 connected to a microphone via I2S for audio input
- Enable TX, RX, and DSS (Direct Sequence Spread) modes to enhance noise resistance

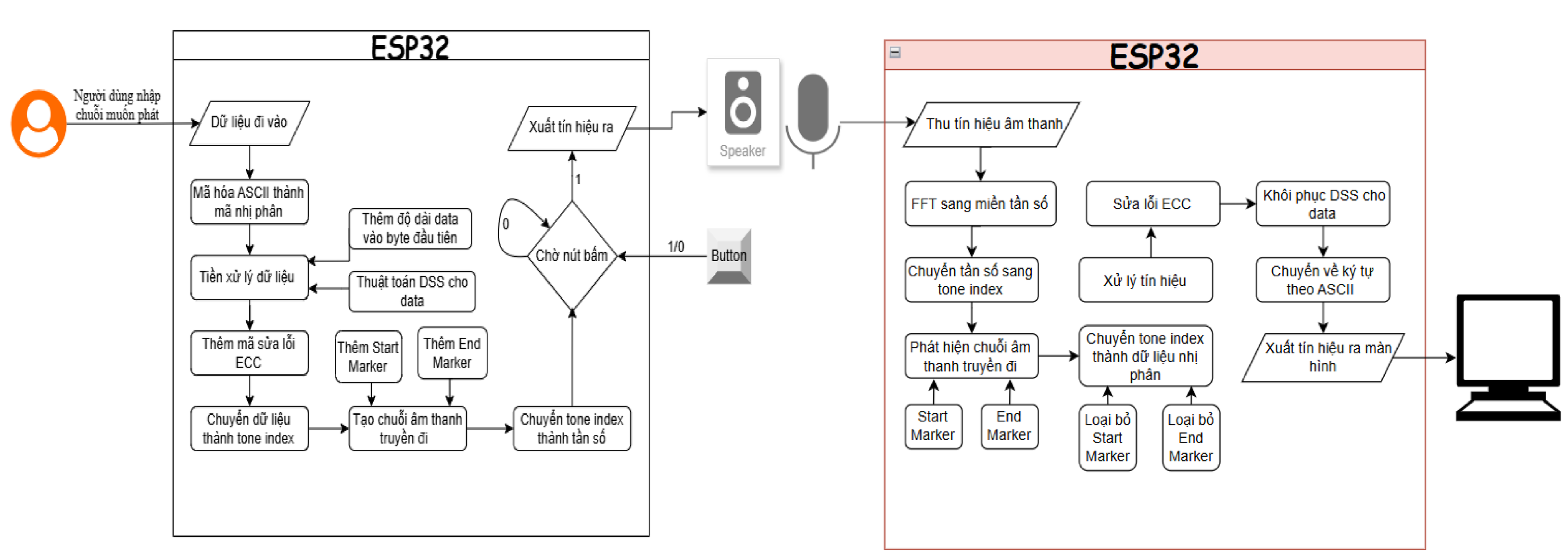

Figure 1: *Diagram illustrating the end-to-end transmission and reception flow using ESP32*

This implementation enables short-range reliable data communication over sound while maintaining signal processing accuracy even under moderate noise conditions.

IMPLEMENTATION RESULTS

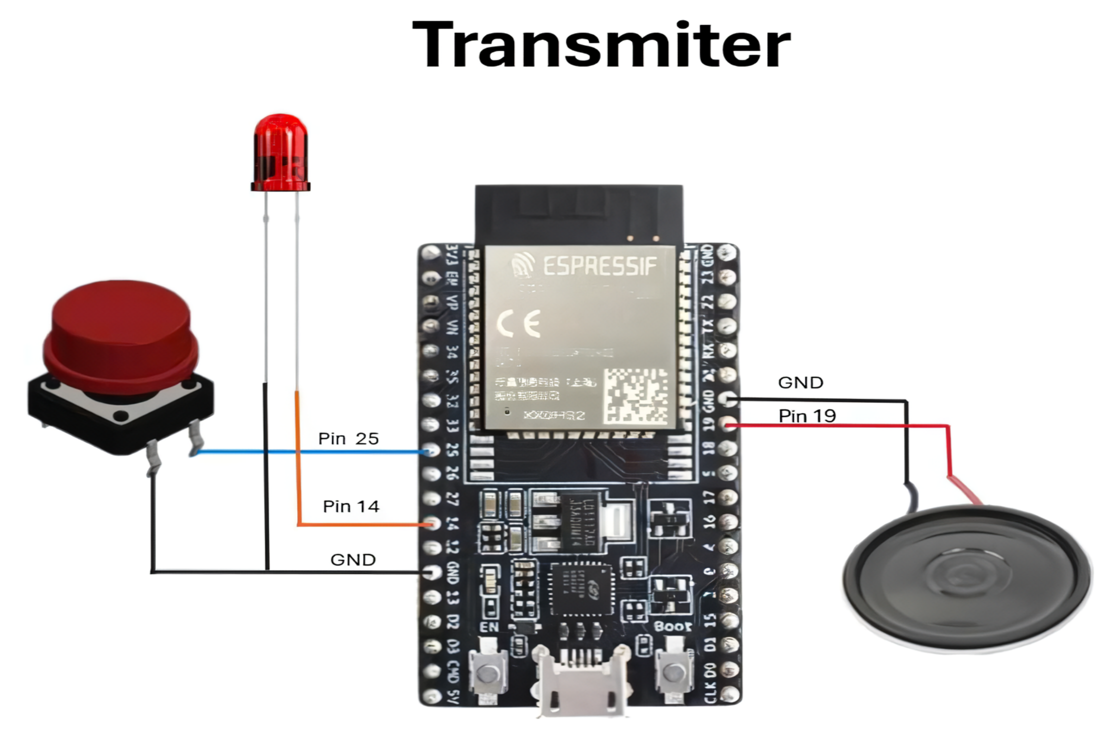

Figure 2: *Connection Diagram of the Receiver Circuit*

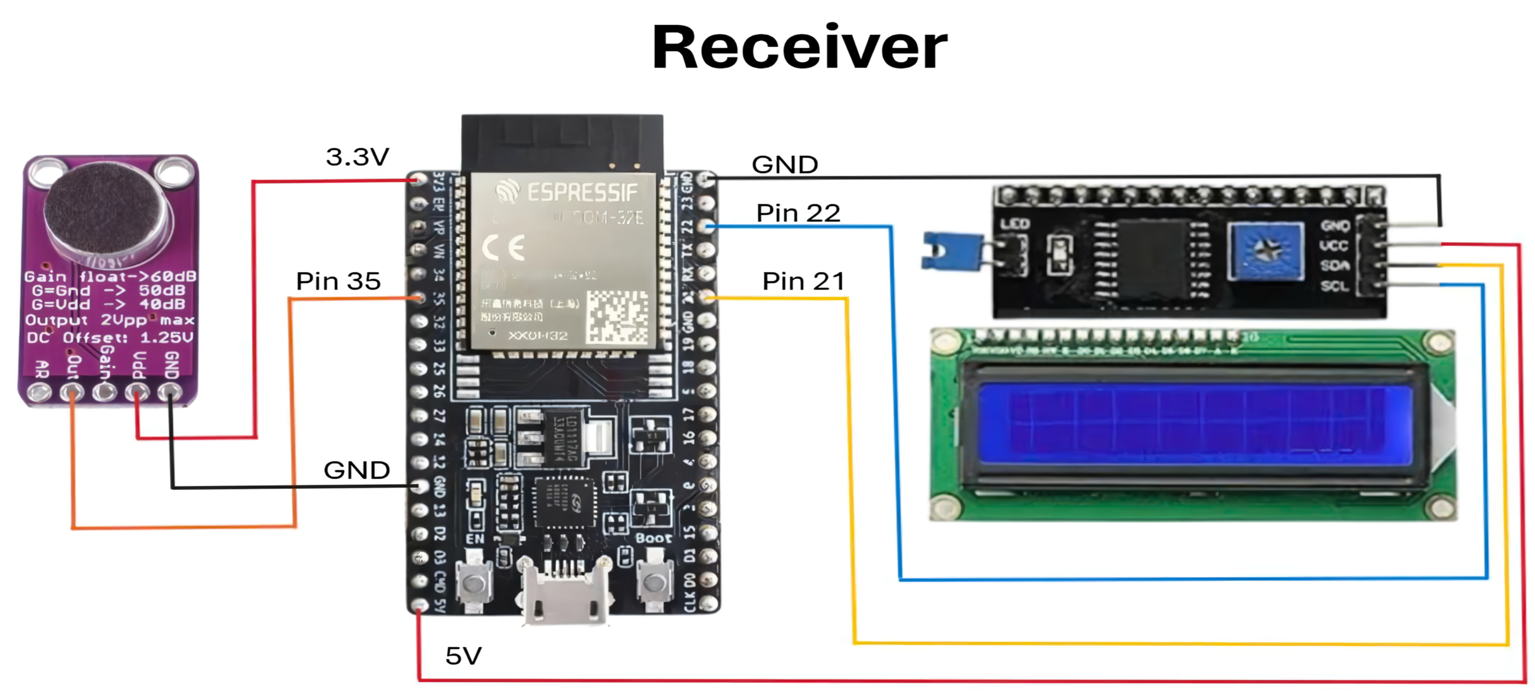

Figure 3: *Connection Diagram of the Transmiter Circuit*

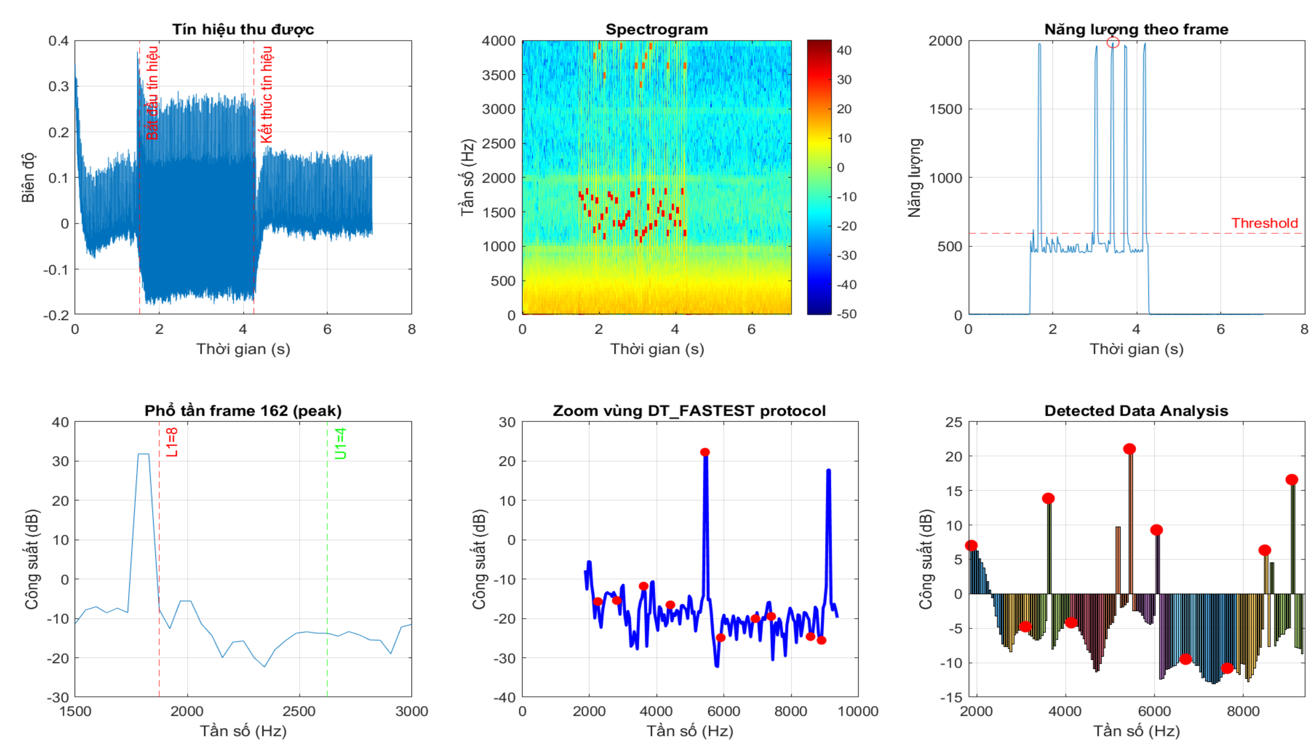

Figure 4: ***Results of signal analysis from data received by the receiver show accurate frequency detection and reconstruction of transmitted data, confirming successful demodulation.***

CONCLUSION

The sound-based data transmission system using FSK modulation and the ESP32 platform, integrated with the GGWave library, was successfully implemented and met the requirements for reliable and stable data communication in test environments. Techniques such as Reed-Solomon coding and Direct Sequence Spread (DSS) significantly enhanced the system's robustness against noise. However, limitations remain in terms of bandwidth and signal processing capability in highly noisy environments. Future improvements may include optimizing signal processing algorithms, applying advanced filtering techniques, or experimenting with different protocols and parameter sets to improve stability and transmission efficiency.

REFERENCES

[1] Georgi Gerganov. ggwave - data-over-sound communication library. `https://github.com/ggerganov/ggwave`.

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[3] Martyn Riley; Iain Richardson. Introduction to reed-solomon codes. `https://www.cs.cmu.edu/~guyb/realworld/reedsolomon/reed_solomon_codes.html`.