Demo: Audio Streaming Via Body-Coupled Communication

Vladislavs Medvedevs, Juris Ormanis, Deniss Tiščenko, Atis Elsts
Institute Of Electronics and Computer Science (EDI), Riga, Latvia
vladislavs.medvedevs@edi.lv

Abstract

This demo presents an implementation of Body-Coupled Communication (BCC) technology, which enables the use of the human body as a communication medium by passing a low-voltage, low-frequency (less than 20 MHz) modulated electrical field through it. The BCC Demo setup is based on two software-defined radios and demonstrates real-time, standard-quality audio streaming over a communication link formed by the human body. This demo could serve as an example and inspiration to build BCC systems that have the potential to enable more secure and energy-efficient body-area sensor networks and data transfer applications.

1 Introduction

Body-Coupled Communication (BCC) is an emerging communication technology that holds the promise to enable more secure and more energy-efficient body-area sensor networks through using the human body as a signal transmission medium [3]. BCC has started to attract attention from the low-power wireless research community, including EWSN and ICC participants [1, 4]. However, experimental prototypes and setups remain scarce [2].

This demo presents a communication system that implements a frequency-shift keying (FSK) modulation-based protocol and achieves 48 kbps application-level datarate, with the goal to transmit a standard-quality audio stream over the human body. The system consists of the following parts:

1. Two Nvidia Jetson Nano single-board computers for signal processing and protocol-level logic.
2. Two software-defined radios (SDR) for signal generation and reception.
3. GNU Radio software modules to control the SDR.
4. Two pairs of SDR-connected gold-plated electrodes.

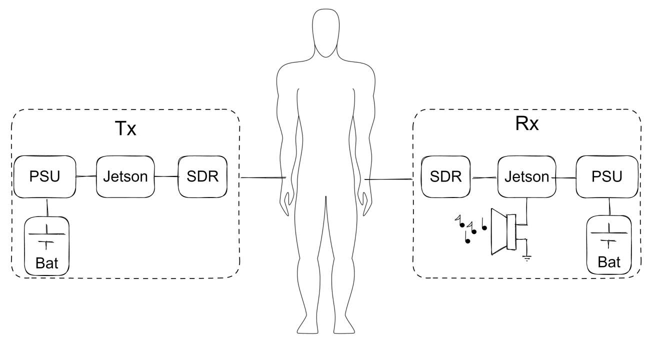

Figure 1: High-level overview of the BCC demonstrator.

5. A USB speaker for reproducing the audio on the Rx.
6. Last but not least, a human connects the transmitter and receiver by touching electrodes on both sides.

Unlike BLE or WiFi-based wireless communication demos which may have connectivity problems under the challenging conference conditions due to external electromagnetic interference, we expect our communication setup to remain robust, using an alternate communication channel and a lower frequency band (6 MHz center frequency).

2 System Architecture

To demonstrate the BCC technology, real-time audio file transmission through the human body is chosen as the primary method. The demonstrator is composed of a transmitter-side and receiver-side setup (Fig. 1). The experimental setup on each side consists of a single Jetson Nano single-board computer, HackRF One software-defined radio (SDR), and a power supply unit (PSU), as illustrated in the figure. The receiving device is additionally equipped with a dedicated speaker to reproduce the received sound. GNU Radio 3.10 is used for the software setup on both endpoints.

In order to ensure that the setup accurately mimics the connectivity between wearable devices located on the human body, it is essential to ensure that the electrical ground connection between both sides is eliminated. This is achieved through power supply isolation of both devices through galvanic separation. Additionally, this technique prevents undesirable electrical interference or disturbances from contaminating the transmitted signals, thereby preserving the integrity of the communication system.

Figure 2: Touch pad with electrodes attached to the SDR.

The connection between the devices and the human body is established using dry electrodes printed on PCB as shown in Fig. 2. The dry electrodes allow the demonstration of different types of coupling with a human body. Touching only the signal electrodes enables the capacitive coupling which uses “free space” signal propagation, and touching signal and ground electrodes shows up galvanic coupling which ensures “waveguided” signal propagation.

2.1 Modulation and transmission channel

For the physical implementation of the digital communication system was chosen frequency shift keying approach. We selected it due to its ability to provide stable and noise-resistant communication. The system’s performance was optimized by selecting a 6 MHz center frequency based on passband SNR characteristics Fig. 3. The Signal-to-Noise Ratio (SNR) was assessed using the following steps:

1. A frequency sweep was initiated with a fixed generator output amplitude to explore the entire frequency spectrum.
2. For each preselected frequency, the voltage drop at both the transmitter and receiver was measured by capturing a buffer, applying the Fast Fourier Transform (FFT), and extracting the amplitude corresponding to the generator’s frequency [2].
3. The generator was disengaged, and the input voltage drop at the Rx was measured for all preselected frequencies using the same method to determine the noise level

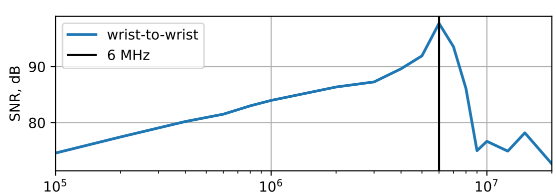

Figure 3: Passband SNR of human body

2.2 Transmitter Block Diagram

To transmit the audio file it is first read from the disk with a sampling rate of 48 kSps. The data is then encoded and modulated with a frequency deviation of 1.6MHz at a baseband, with 800 kHz harmonic used for the symbol “1”, and -800 kHz for the symbol “0”. The signal is then modulated with a GNU radio ”GFSK Mod” hierarchical block, which receives bytes, unpacks them, modulates, and applies a Gaussian filter to the output. However, our setup has the Gaussian filter disabled by applying the “BT” value equal to the “samples/symbol” value.

The resulting sample rate is 4.8M Sps. However, the closest sample rate that HackRF ONE supports is 5 MSps. Because of that, the output signal is resampled with the “Rational Resampler” block. The transmitter block diagram is shown in Fig. 4. Signal transmission power is set to 8 μW to ensure safe data transmission via the human body.

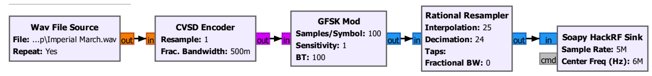

Figure 4: GNU Radio transmitter block diagram

2.3 Receiver Block Diagram

To receive and restore the incoming data, the detected signal is first filtered using a bandpass filter with a passband of 30 kHz. Subsequently, it is demodulated with the “GFSK demod” hierarchical block. The resulting demodulated bits are organized into bytes and further decoded into a sound format. To mitigate high-frequency noise, a lowpass filter is applied, effectively removing unwanted components. Finally, the processed signal was resampled by “Rational Resampler” and reproduced by an “Audio Sink”. The receiver block diagram is shown in Fig. 5.

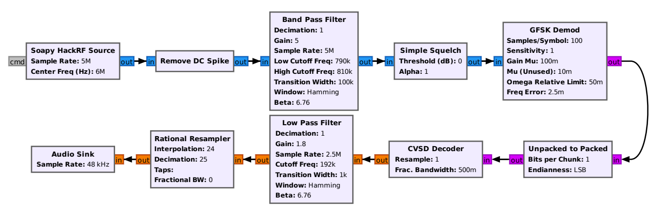

Figure 5: GNU Radio receiver block diagram

3 Acknowledgments

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4 References

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