A Short-Range Radar to Detect Chest Movement of a Still Person

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***Abstract*—This project presents an FMCW radar system using off-the-shelf components controlled by a micro-computer. This device can be used as an experimental platform to test various ideas in vital signs detection research. The design expands on the MIT radar project to use as a non-contact solution to detect chest movements of a still person. As a backup system for comparison against the MIT device, an alternative independent radar system, Xethru, was used to study additional ways to detect vital signs.**

I. Introduction

This project is a short-range radar to detect chest movements of a still person in which a microcontroller is used to analyze the real-time data. The current design is a compact computer based low-cost low-power short-range frequency modulated continuous wave (FMCW) sensing system. The design architecture enables the detection of subtle displacement such as breathing and heart rate of a human being and displays the biometric information in real-time.

The device is based on high directivity PCB Yagi antenna, continuous ramp signal generation and synchronous modulation for linear sweeps, rapid transition analog filtration, and real-time digital signal processing. The raw analog data is acquired from a radar sub-system and delivered to a single board computer (SBC) for low latency audio-based analysis. The DSP implementation utilizes known discrete Fast Fourier Transformation (FFT) algorithms to facilitate plotting data on a per frame basis in real-time. The result is an efficient and compact portable device able to acquire and plot accurate biometric data in real-time.

The XeThru used in this project is a single chip radar subsystem that measures breathing patterns of a still person and connects to a computer for real time data analysis. It was used to show us an example of a similar product on the market.

II. Hardware

The radar sends sweeps with linearly increasing frequency at 1 kHz repetition determined by the chirp rate of the modulator to a data acquisition platform. For every sweep the heterodyne signal is received by a 10kHz low pass filter, sampled in 32-millisecond frames and Fourier transformed (512-point DFT) so that returns from the target at different distances can be separated. Then the phase of one of the DFT frequency bins (N/2-1) associated with the past distance to where the target is located is chosen. The same processing is done for all sweeps and plotted in real time.

A. RF Front-end

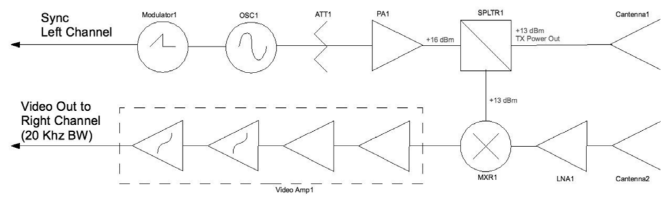

Figure 1 – RF Block Diagram [1]

The radar system begins with the modulator to drive the FMCW signal to produce a linear ramp to modulate the input to the oscillator. The oscillator is a Voltage Controlled Oscillator (VCO) where the input is proportional to the transmit frequency. Utilizing this VCO supports the FMCW system where the transmitting antenna will continuously propagate waves with varying frequencies and the receiving antenna will continuously receive waves. The output from the oscillator will then lead into the attenuator, which is used to lower the gain for the signal.

The power splitter works by using a single input to power two outputs. It is important to use a splitter with a high return loss and low insertion loss since the system is required to power two outputs. Low-noise amplification is applied to the microwave in two stages: once before transmission to compensate for line attenuation, and once after the reflected wave is received to compensate for attenuation caused by the transmission medium.

Directional patch antennas operating in the 2.4 GHz ISM bandwidth are used in this design for both the transmitting and receiving antennas. Upon receiving the reflected microwave, the signal is mixed with the transmit signal that was split before transmission. The mixer produces a center tapped intermediate frequency (IF) product signal from the ring modulator with a local oscillator (LO) frequency of approximately 2.6 GHz and marginally lower RF frequency, due to the Doppler effect, creates a conversion loss of approximately 5.44 dB.

III. Software

A. Signal Processing

The signal processing stage was approached using object-oriented programming to take advantage of vectorizable algorithms. Written in C# [2], a real-time DSP strategy was implemented that utilizes the forward Fast Fourier Transform (FFT) algorithm: $x_j = \sum_{k=0}^{n-1} z_k e^{\frac{2\pi ijk}{n}}$.

B. *Chest Movement Testing and Results*

When testing the software, audio signals are used to mimic the chest movement breathing signals that will be used in the final demonstration. Using a microphone, the software captures audio data in real time, performs the FFT, and plots it on an interactive graph (Figure 2). The heart normally beats 60 to 70 times per minute, while the breathing rate is about one-fifth of that. Using this information and the incoming signal, the heart rate can then be calculated by $\frac{60}{Duration\ of\ R\text{−}waves}$ and then plotted. Shown in (Figure 3), the results show an average heartbeat of about 82 BPM which was done via non-contact means. This was tested using the LattePanda MCU/Display which allows the user to obtain data while portable. A final graph was then made to track chest movements which has output data similar to that of the Xethru, which was the goal of this project (Figure 3).

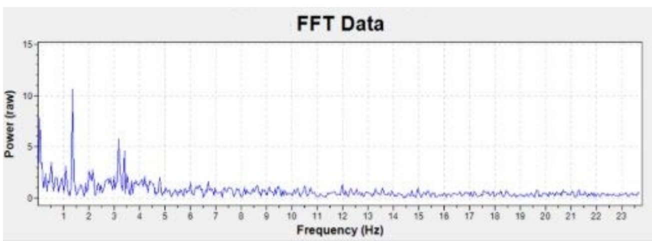

Figure 2 – Fast Fourier Transform Results

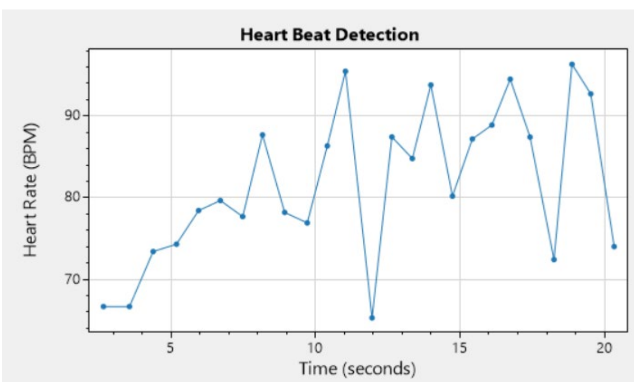

Figure 3 – Heart Rate Plot Results

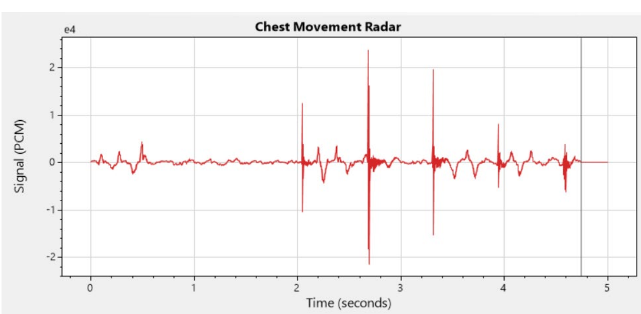

Figure 4 – Chest Movement Results/Xethru Comparison

IV. Xetrhu

The XeThru device can read vital signs data such as respiration rate and breathing pattern on people that are still. X4M200 is also able to sense human presence by detecting any motion such as a person walking and hand movements. This sensor can detect a presence up to 5 meters. In the low frequency band, X4M200 will operate within the 6.0 - 8.5 GHz band. In the high frequency band, X4M200 will operate within the 7.25 - 10.20 GHz band. The module is powered externally from either the USB port or an external power supply and the antennas are embedded onto the PCB. This XeThru device has data output similar to that of the goal for this project. The goal for this project is to have a device that processes respiration data in real time and to have a compact design.

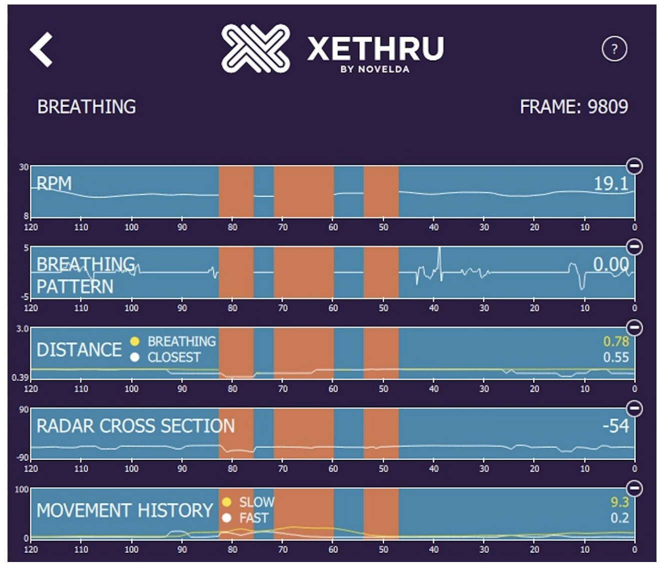

Figure 5 - Xethru Breathing Data

V. Conclusion

The solution to non-contact vital sign detection is a rapidly developing field of research. In this project we were able to achieve two low-cost, low-power alternatives for detecting chest movement and vital signs of a still person. These experimental radar platforms will help to pursue research on vital signs detection at NIU.

Acknowledgements

This project could not have been completed without the help of some very special people. NIU Senior Design Team 37 would like to thank Dr. Don Peterson who put great effort and dedication towards running the Senior Design projects, Dr. Veysel Demir for his invaluable technical insight and guidance, and Fahad Alqahtani, our teaching assistance, for his time and constructive feedback. Finally, Jeannie Peterson for her endless patience and making sure the team had all required materials.

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[1] Charvat, Gregory L. "MIT IAP 2011 Laptop Based Radar: Block Diagram, Schematics, Bill of Material, and Fabrication Instructions." MIT OpenCourseWare, Massachusetts Institute of Technology.

[2] ScottPlot free and open-source graphing library. Retrieved from https://swharden.com/scottplot