ARM Processor based Implementation of Doppler Processing for Human Heart-beat Detection through a Wall

Nemani Sirisha, Paramita Barua, D. Anuradha
Electronics and Radar Development Establishment (LRDE)
C.V. Raman Nagar, Bangalore-560093, India
sirisha.nemani@lrde.drdo.in, anuradha.d@lrde.drdo.in

Abstract:
The growing security concerns worldwide have led to the development of wideband radar systems for detection of heart-beat and breathing rate of living objects especially human beings through walls. This paper discusses about the usage of Ultra Wide band SFCW based waveform, Doppler processing of the returns from beyond a wall using FFT for heart-beat and breathing detection of a stationary human and ARM processor based implementation of the same.Finally the presence of a human bieng is plotted as an image representing down range vs cross range on a 6"LCD Display.

Index Terms — Doppler, FFT, ARM, UWB SFCW waveform.

I. INTRODUCTION

Electromagnetic waves [1] have the ability to penetrate man-made building materials and to detect heart beat behind opaque structures. The frequency of human breathing can range anywhere from 0.1 to 0.5 Hz and that of heart-beat can range from 0.8 to 2.5 Hz. Hence an average value of 0.3 Hz for breathing rate and 1.5 Hz for heartbeat has been considered. The human being is assumed to be stationary. Hence, a signal with three frequencies can be expected from the human being: 0^{th} filter corresponding to the stationary part of the human body and two Doppler frequencies caused by breathing and heart beat. A total of 30dB (approx.) two way attenuation can be assumed in the reflected signal.

II. STEPPED FREQUENCY CONTINUOUS WAVE RADAR

Stepped frequency continuous wave (SFCW) Radars have gained momentum since the availability of fast frequency sweeping devices. The shift in position due to a minute Doppler (such as heart beat) changes the phase of the transmitted SFCW signal. Hence, the received voltage at the receiver is a function of phase. Basically, in SFCW transmission a series of single tone frequencies are transmitted in a given frequency range. Each step corresponds to a single frequency. The frequency step size (number of data points) determines the unambiguous range. The stepped-frequency scheme approximates a wideband signal using a finite number k of monochromatic signals with equally spaced frequencies f_k covering the desired bandwidth f_0 to f_{k-1}.

$$f_k = f_0 + k(\Delta f) \qquad [5]$$

$$\Delta f = f_{k-1} - \frac{f_0}{K-1}$$

$$where\ for\ k = 0,1,2,3..K-1$$

Where Δf represents frequency step size.

III. IMPLEMENTATION IN ARM PROCESSOR

The heart beat detection [2] using FFT is implemented using Cortex A9 based DM3730 ARM processor. The software codes are developed in C++ using Qt framework on Linux operating system. The time domain back projected image IQ data is transferred through external memory (EMIF) interface from FPGA to ARM processor. The acquired IQ data is converted to complex form (a + ib).The EMIF interface working at 200 MHz can transfer at 5 frames/sec .The ARM processor receives the data, performs Doppler processing. This includes Hamming windowing, FFT and filter drop, global thresholding and transfers the final output to display module. The debug statements and booting of Linux from SD card is seen in Hyper Terminal. The UART is configured for 115200 baud rate for ARM processor.

3.1. Hamming window

Windowing of a simple waveform like cos(ωt) causes its Fourier transform to develop non-zero values (spectral leakage) at frequencies other than ω. The leakage tends to be worst (highest) near ω and least at frequencies farthest from ω. The Hamming window is applied on the data. The window is optimized to minimize the maximum (nearest) side lobe. The main lobe to side lobe ratio after applying Hamming window is -43.8dB.

$$\mathrm{W(n)} = 0.54 - 0.46\cos(2 * \mathrm{pi} * \mathrm{n/N}),\ 0 < n < N \quad [3]$$

$$\text{Window length is } \mathrm{L = N + 1;}$$

3.2. Fast Fourier Transform

The FFT core accepts complex data samples and pipeline streaming I/O which pipelines several Radix-2 butterfly operations to offer continuous data processing. The input and output data format is in 32 bit floating point format. The ARM processor is working at 128MHz frequency. Here 64 point FFT is performed on each pixel collected for 64 series of images to detect the variation of intensity over the integration time. The total integration time is considered to be 6.4sec.

3.3. Filter Drop

Human heart and breathing [4] for a normal human being can be seen in the ranges of 0.2 to 0.5Hz and 0.8 to 2.5Hz respectively. These fall in the Doppler bins from 1 to 6.First few filters are dropped to have the visibility of detection of heart beat and breathing as the stationary wall reflections are strong and spread in first few filters. The inversion of the integration time gives Doppler resolution.

3.4. Global Thresholding

Thresholding is an image segmentation technique which partitions images into regions based on intensity values and/or properties of these values. Because of its simplicity of implementation and computational speeds, thresholding plays a central role in the applications of image segmentation. When the intensity distributions of objects and background pixels are sufficiently distinct, it is possible to use a single threshold applicable over the entire image.

Suppose we have an intensity histogram of an image, f(x, y), to extract the objects from the background, a threshold, T, is selected which separates these modes. Then any point(x, y) in the image at which f(x,y)>T is called an object point; otherwise, the point is called a background point.

$$g(x,y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x,y) \leq T \end{cases}$$

When T is a constant applicable over an entire image, the process is referred to as global thresholding.

3.5. Computational requirements

Doppler processing for the Through wall imaging Radar requires huge memory and computational requirement on ARM DSP core. Here ARM used is Sitara series AM 5728 with c66x DSP core. TI-SYSBIOS RTOS(Real time operating system) is running on the DSP core and ARM is running Linux operating system .IPC message Q and IPC shared memory is used for DSP-ARM communication for reading series of image data each of 400*100 pixels of 32 bit floating point. This data is stored in shared memory. Series of functions are used for memory allocation for storing window coefficients for Doppler FFT and twiddle factors computation.FFT is performed on each pixel and the filter bins corresponding to breathing and heart beat (6^{th} to 12^{th}) are taken for computation of Doppler. This requires sufficient memory for storage of data and for meeting timing requirements. To meet this multi threading POSIX threads are used. The proposed Doppler processing was able to produce the Doppler at every 7 sec on ARM 5728.

The final output is obtained as an image of intensity values of pixels 400*100 with the values of pixels being highest where a human is present. Depending upon the Doppler obtained for targets, they can be mapped accordingly by using color format where grey color indicates non-living stationary targets and red color indicates moving targets. Doppler overlay is presented on the back ground image which displays the static objects.

IV. DISPLAY

The final data is sent to Display as intensity values of pixels. The final output is plotted as an image on an LCD display. The display code is developed in C++ in Qt framework and fused as libraries along with the Doppler codes running on CCS (Code Composer Studio) software running on Linux platform and generates the executables needed to run on ARM processor.

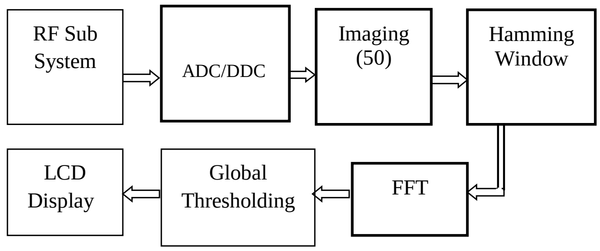

Fig.1: Data flow for Doppler Processing

V. EXPERIMENTAL SETUP AND RESULTS

Fig 1 shows the data flow for Doppler Processing which is achieved through an experimental setup. An RF sub-system consisting of a SFCW waveform generator that generates UWB Stepped Frequency Continuous Wave (SFCW) of a few GHz. bandwidth and a multi channel receiver, an FPGA based signal processor which acquires the IF data from the RF subsystem, digitizes the IF signal and performs DDC to down convert to a base band complex signal, performs back projection for imaging and an ARM processor based hardware which will carry out Doppler processing, Global Thresholding and sends the final output to the LCD display.

Fig 2(a) shows Single Target Situation where a human is at a position 3.0 m from the other side of the wall. The barrier is located at 0.0m range. The display for Doppler output and the result from the radar is given in Fig. 2(b)

Figure 2(a) shows single human where a human at a position of 3.0m from the other side of wall

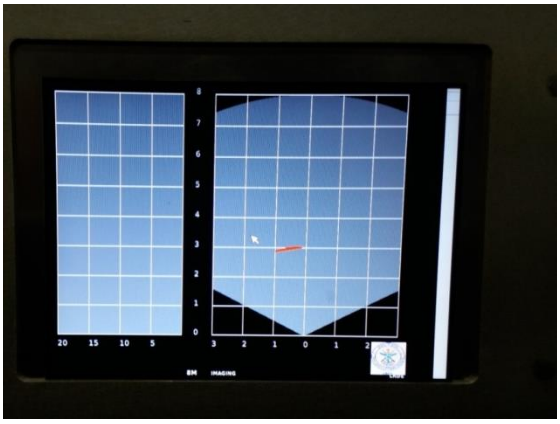

Figure 2(b) Doppler processing Display Result shown as an arc at 3m down range from radar on other side of wall on LCD display

IV. CONCLUSION

A software for Doppler processing and Display has been developed on ARM processor for Through Wall Imaging Radar application. The Doppler processing using SFCW signal can generate accurate detection of heart beat and breathing of stationary human being behind a wall. The display software is based on custom requirement for visualizing Doppler results clearly, by following a systematic approach which has been described in detail.

REFERENCES

[1]. Immoreev and Fedotov, "Ultra wideband radar systems: advantages and disadvantages," Ultra Wideband Systems and Technologies, pp. 201205, 2002.

[2]. Staderini, E.M.; "UWB radars in medicine" Aerospace and Electronic Systems Magazine, IEEE, Volume 17, Issue 1, Jan. 2002 Page(s)13 –18.

[3]. M. Aftanas, "Signal Processing Steps for Objects Imaging Through the Wall with UWB Radar," 9th Scientific Conference of Young Researchers, SCYR 2009. Faculty of Electrical Engineering and Informatics, Technical University of Kosice, pp.14-17, May 2009.

[4]. Through wall sensing of Human Breathing and Heart Beating by Monochromatic Radar by A.S.Bugaev, v.vchapursky, S.S Ivashov, V.V.Razevig, A.P.Sheyko, I.A.Vasilyev

[5]. "Compressive sensing for urban radar" edited by Moeness Amin,villanova university,Pennsylvania.

BIO DATA OF AUTHORS

Nemani Sirisha received B.Tech. degree in Instrumentation Technology from Andhra University in 2006. She is currently working as scientist in Electronics and Radar Development Establishment (LRDE). Her areas of work include embedded systems.

Paramita Barua received B.E. in Electronics and Telecommunication Engineering from Government Engineering college, Jabalpur MP in 2001. She is currently working as Scientist in Electronics and Radar Development Establishment (LRDE). Her areas of work include Radar Signal Processing.

D. Anuradha obtained her B.Tech. in Electronics and Communication Engineering from J.N.T.U Hyderabad in 1987. She has worked in DRDL in the IGMDP Programme upto 2005. She is presently the Project Director for LIC Radars in LRDE