Investigation on the Use of Bandpass Sampling Technique to Extract Information from Doppler Ultrasound Signals

Nur Hanis binti Muhamad Kassim

Universiti Teknologi MARA

40450 Shah Alam, Selangor

E-mail: nurhanis14@gmail.com

Abstract— **This paper describes the study on performance of digital demodulation techniques of Doppler Ultrasound Signal in practice. The technique being focused is bandpass sampling. This project includes software and hardware part to show the technique of downconversion process. First, the simulated DUS signals were sent out from PC. Then, MAX-1236 board was used as it represents bandpass sampling technique in order to sample the fetal DUS. The output signals demonstrate the performance of bandpass sampling techniques that show the limitation using this type of downcorversion.**

***Keywords*—** Bandpass sampling, Doppler Ultrasound Signals, Downconversion

I. INTRODUCTION

With the advancement on biomedical instrument in recent years, several demodulation techniques have been implemented in medical field today. However, a few techniques those are useful, for demodulating Doppler Ultrasound Signals (DUS) from the fetal heart i.e. bandpass sampling have not been employed in the fetal monitor. The performances of these techniques have been examined by W.Mansor [2] using computer simulation but it has not been process using the real ADC circuit.

Doppler Ultrasound signals are the most common signals used to indicate the status of the fetus. Ultrasound is like an ordinary sound except it has a higher frequency than human being can hear. This signal is sent to body using transducer and the echoes will return back. The received Doppler Ultrasound Signals are in MHz [1]. It must be downcoverted before the doctor can examine the status of fetus. There are many downcorversion and demodulation techniques can be used; one of the techniques is bandpass sampling.

The study on bandpass sampling has been done in various disciplines including optics [4], radar [5], sonar [6], communications [7], biomedical signals [8], power measurement [9], and general instrumentation, such as sampling oscilloscopes. According to the studies, it was proved that bandpass sampling has advantages over downconversion techniques, since the analog stages can be eliminated, gaining in stability, reducing the phase distortion, eliminating the channel imbalances in the quadrature detection and reducing costs. The objective of this project is to investigate the performances of bandpass sampling technique via extracting information from fetal heart signals.

II. BANDPASS SAMPLING

Bandpass sampling is the technique of undersampling a modulated signal to achieve frequency translation via intentional aliasing. In the case of a bandpass signal, with low and high band limits f_L and f_H respectively, the condition for an acceptable sample rate is that shifts of the bands from f_L to f_H and from $-f_H$ to $-f_L$ must not overlap when shifted by all integer multiples of sampling rate f_s as shown is Figure 1.

Figure 2 shows the 4 stages of bandpass sampling process. Stage 1; The signal is processed by the low-noise amplifier (LNA) amplifying all frequencies within the bandwidth of this component. The amplified signal then passes through a narrow bandpass filter centered above the carrier frequency. Stage 2; this filter attenuates frequencies outside of the information band. Stage 3; sampling frequency is selected, which defines the resulting sampled bandwidth as well as the arrangement of the aliasing triangles depicted. Stage 4; the information band, as well as noise from each aliasing triangle within the analog input bandwidth of the ADC, is folded into the resulting sampled bandwidth. Thus, the information band is translated without any local oscillator mixing and image filtering.

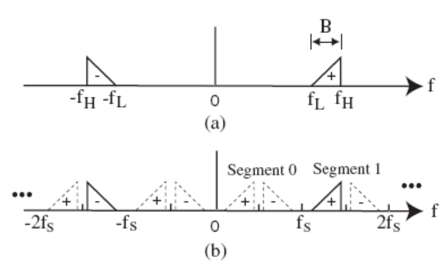
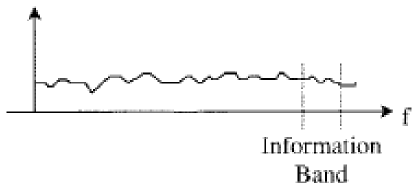


Figure 1: The spectra of (a) the original and (b) the sampled bandpass signals.

(a)



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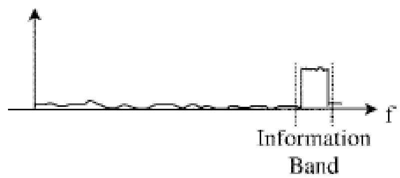

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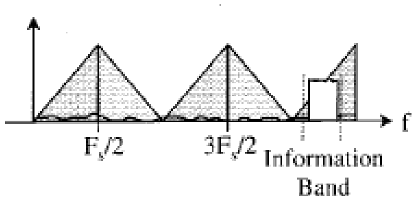

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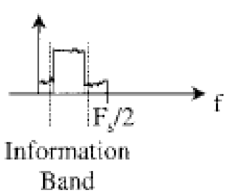


Figure 2: Frequency domain representation of bandpass sampling. (a) Stage 1 (b) Stage 2 (c) Stage 3 (c) Stage 4

III METHODOLOGY

In this project, simulated DUS signals were used to investigate the performance of bandpass sampling. Since a fetal heart monitor that can record the fetal DUS from mother's abdomen are not available in the faculty and this project is not funded (to allow the monitor to be borrowed). The frequencies of these signals are 3kHz and 6kHz (typical fetal heart signal frequency) were generated using computer simulation developed by W.Mansor [2].

In order to generate signal that is similar to that obtained from mother's abdomen in terms of shape, frequency and heart information, an experimental set up was developed as shown in Figure 3. A personal computer was connected to PCI-1721 (DAQ Card), mixer board and MAX1236 (ADC). PC was used to generate Doppler Ultrasound Signal. Since the simulated signal in the PC was digital signal, the DAQ Card was used to convert digital signal to analog form and then mixed with 2MHz signal which was produced by using signal generator. The design of mixer circuit is shown in Figure 5. Then, the signals were sent through MAX1236 board which performs the bandpass sampling technique. Finally, the output signals from MAX1236 was anlaysed using oscilloscope to investigate the performance of bandpass sampling techniques in demodulating fetal DUS.

The downconversion process is shown in Figure 4. At the first stage, an algorithm was developed to display and send the signal out from the PC using Visual Basic. After mixing with 2MHz signal, the signal was downconverted and demodulated using bandpass sampling technique. Then, the demodulated signal was analysed to examine the performance and the limitation of the bandpass sampling technique.

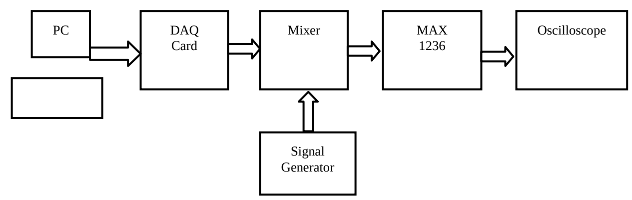


Figure 3: Block diagram of a Digital Demodulation Techniques

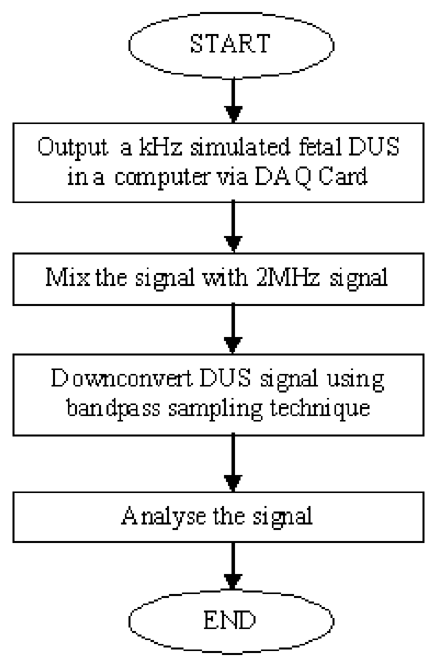


Figure 4 : Process of Downcorverting and Extracting Doppler Ultrasound Signal

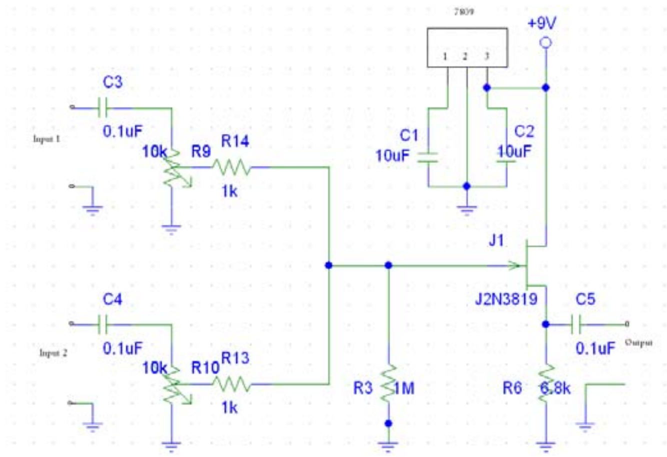


Figure 5 : Mixer Circuit (Schematic Diagram)

V. RESULT AND DISCUSSIONS

A pattern of computer simulated signal that will send to the mixer is shown in Figure 6(a). This signal has a frequency of 3kHz. The Visual Basic program was used to read data stored in .dat file and plot to display the signal. The program also has been used to create continuous signal as shown in Figure 6(b). At this stage, the signal still could not be sent out through the DAQ Card. The troubleshooting still in progress to detect the problem on the programming part.

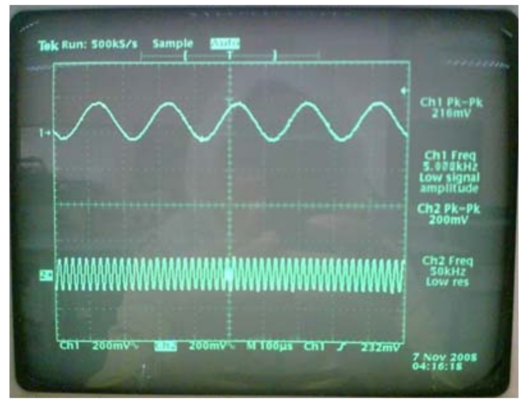
(a)

(b)

Figure 6: Simulated received signal (a) 3kHz (b) 3kHz-continuous

Figure 7 shows the result from the mixer circuit**.** In this experiment, two function generators were used as Input 1 and Input 2 to show the result from the mixer circuit. Refer to Figure 7(a), the input signal of the mixer was 5kHz and 50kHz. The output of the mixer circuit was about 53kHz is shown in Figure 7(b). Even though, the output frequency was not exactly the desired frequency which is suppose to be 55kHz, it is proved that the signal and frequency was added. The error probably due to noise and losses in the circuit. The improvement on performance of mixer circuit shall be done in future development.

(a)



(b)

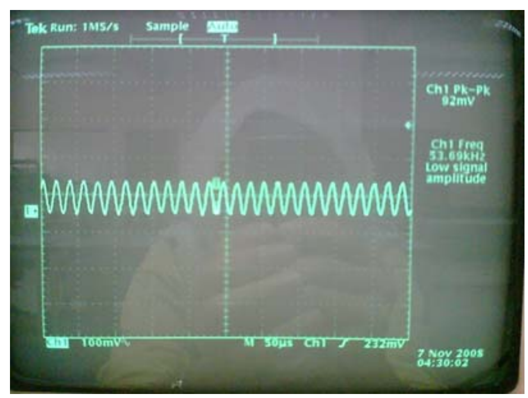


Figure 7: Output signal from the mixer (a) input signal (b) output signal

V. CONCLUSION

An attempt to demodulate fetal Doppler Ultrasound signal using bandpass sampling technique has been described in this paper. At this stage, the mixer has been successfully developed and proved to be able to mix two signals having different frequencies. For future development, further research in bandpass sampling and direct demodulation technique to extract information from Doppler Ultrasound Signals will implement.

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