A Study on the Performance of Bandpass Sampling Technique in Demodulating Fetal Doppler Ultrasound Signals

Mohd Afiq Wildan bin Halim
Universiti Teknologi MARA
40450 Shah Alam, Selangor
E-mail: m_afiq_wildan@hotmail.com

***Abstract*–Doppler Ultrasound technology has been widely used in medical field. One of the applications of this signal is to get the information about heart movements to check the sign of abnormalities. Demodulation technique has to be performed to extract information from the Doppler Ultrasound signal.**

There are few types of demodulation and one of them is bandpass sampling technique. A hardware set-up was arranged to send the data out from the PC. In order to create DUS signal that has the same characteristic as the real raw signal from patient, the signal from PC is mixed with Megahertz signal using a mixer. After the signal has downconverted using bandpass sampling technique, the signal is then analysed to confirm that the correct signal is obtained.

I. INTRODUCTION

In fetal heart monitoring, fetal heart rate is used to indicate the status of the fetus. The most common signal used nowadays is Doppler Ultrasound signal (DUS). Before the heart rate can be detected from the Doppler Ultrasound signals, the fetal heart motions have to be detected first. In practice, for detecting the valve motions, Doppler Ultrasound signals are recorded simultaneously with the fetal electrocardiogram.

Ultrasound is like ordinary sound except it has a frequency higher than human beings can hear. When sent into body from a transducer resting on skin, the sound is reflected off internal structures. The returning echoes are received by the transducer and processed by an electronic instrument to extract infromation embedded in the signals, for example cardiac movements, blood flow, heart rate and others.

The received Doppler Ultrasound signals are in Megahertz. To detect the valve motions, the Doppler Ultrasound signals have to be downconverted to baseband signals which in Kilohertz.

Currently, conventional approach to downconvert the signal is using analog downconvertion technique but the output signal will contain a lot of noise. Therefore, a few digital demodulation techniques have been implemented to downconvert the DUS signals. If the downconvertion process is done digitally, accurate result may be produced that will contain less of noise.

An investigation on the use of bandpass sampling technique have been carried out by Mansor [1] and Romli [2] to extract cardiac information using simulation. Further study on the use of this technique using hardware was attempted by Muhamad Kassim [3]. She has constructed a circuit comprised a mixer and an ADC to demodulate fetal DUS signals generated from a PC.

Due to the limitation of Data Acquisition (DAQ) card (attached to the PC), she has to use a mixer and a signal generator to produce a received DUS signal which is in MHz. She could only show that the mixer was working successfully but it could not produce the received signal. She did not manage to investigate the performance of bandpass sampling technique in fetal monitoring.

Therefore, this study investigates the performance of bandpass sampling technique in extracting signals from fetal heart using hardware.

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 below [3].

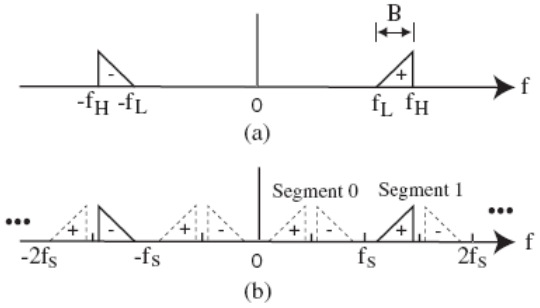

Figure 1: The spectra of (a) the original and (b) the sampled bandpass signals

In applying bandpass sampling to relocate signals to a baseband position, the signal-to-noise ratio is not preserved owing to the out-of-band noise being aliased. The degradation in signal-to-noise ratio is quantified in terms of the position of the bandpass signal [4].

The bandpass situation is depicted in Figure 2, where the sampling rate is expressed as f_S Hz and the bandpass signal is located between f_L Hz f_U Hz. The signal bandwidth B is less than $f_U - f_L$ and the positive frequency can be expressed as the interval (f_L, f_U).

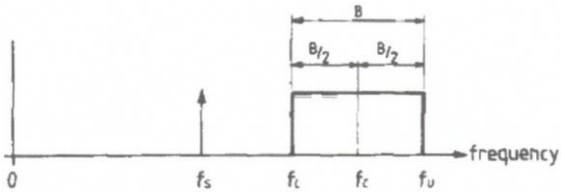

Figure 2: The bandpass situation as an analog signal spectrum. The sampling rate is expressed as fHz and the band is located at (f_L, f_u). Only the positive frequencies are shown.

III. METHODOLOGY

Bandpass sampling technique was used in this study to demodulate fetal Doppler Ultrasound signal. First of all, the fetal DUS from mother's abdomen is needed but since the heart monitor that can record the fetal DUS is not available in the faculty, the signal was replaced with the simulated fetal DUS created by Mansor [1].

In order to investigate the performance of bandpass sampling in demodulating fetal DUS signals, a hardware set-up proposed by Muhamad Kassim [3] was used in this study. The block diagram is shown in Figure 3 below.

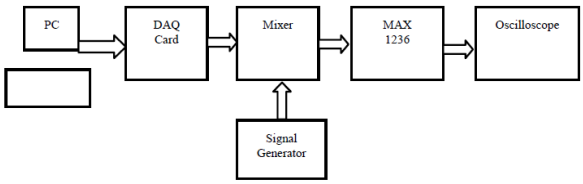

Figure 3: Block diagram of a Digital Demodulation Techniques

A PC is connected to PCI-1721 (DAQ Card) and PC was used to generate the fetal DUS signals.

The simulated signal stored in a PC was sent to external circuit using Visual Basic Programming. In order to create a MHz fetal DUS signal that has same characteristic as the real signal from patient, the signal from PC was mixed with Megahertz signal from a signal generator using a mixer.

This was done due to the limitation of DAQ Card in producing a MHz signal. The mixer designed by Muhamad Kassim [3] used in this work. An oscilloscope was placed at the output of DAQ Card and the mixer to examine the fetal DUS.

Then, the signals will be sent through MAX1236 board which performs the bandpass sampling technique.

Finally, the output signals from MAX1236 will be analysed using oscilloscope to investigate the performance of bandpass sampling technique in demodulating fetal DUS.

The flowchart representing the whole process of this project is shown in Figure 4 below.

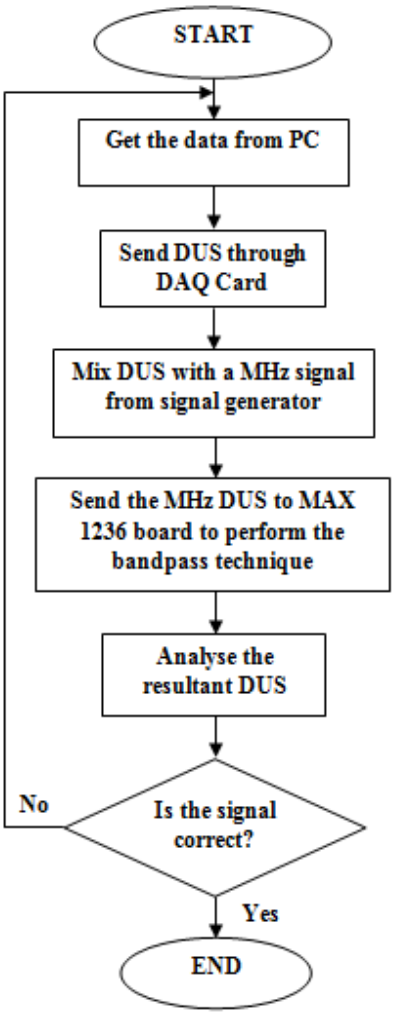

Figure 4: Flowchart representation of the whole process

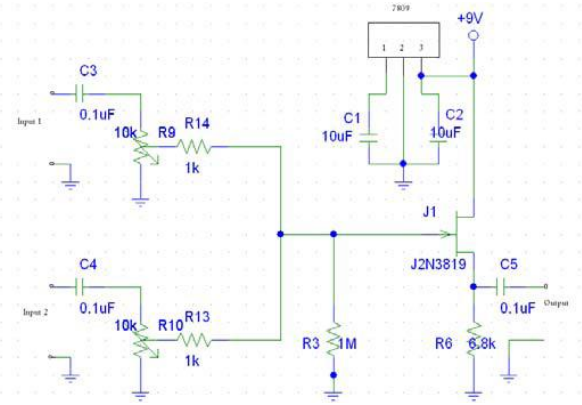

Figure 5: Mixer Circuit (Schematic Diagram)

IV: RESULT AND DICUSSIONS

A computer simulated fetal DUS that was sent to the mixer is shown in Figure 6. This signal has a frequency of 3kHz and is displayed on the computer screen using Visual Basic.

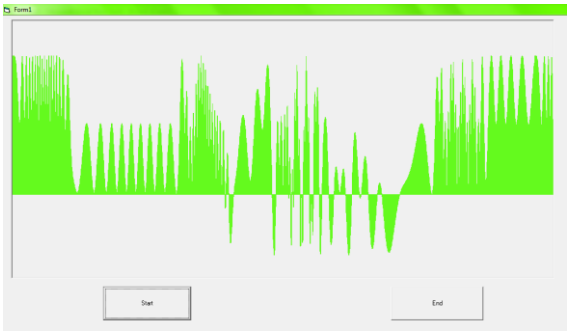

Figure 6: Simulated 3kHz continous received signal

Figure 7 shows the signal that is observed at channel 3 of the DAQ Card and displayed on the oscilloscope.

At first, the programming provided by Muhamad Kassim [3] cannot display the signal on the oscilloscope, so other program that is provided by the DAQ Card manufacturer was modified and used, hence the signal can be displayed.

An attempt on mixing the 3kHz with 2 MHz signal which is produced using signal generator had been done but due to some errors, the result still cannot be achieved. The troubleshooting still in progress to detect and solve the problem.

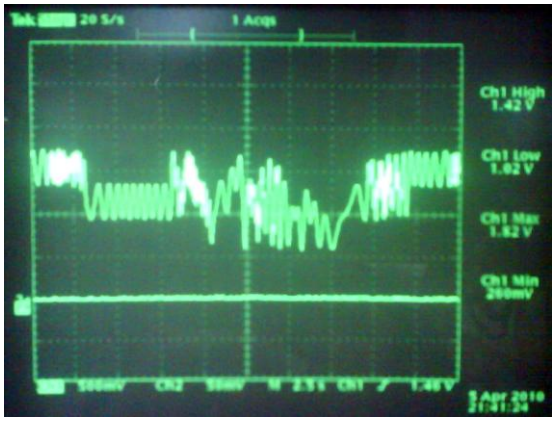

Figure 7: 3kHz signal displayed on the oscilloscope

V: CONCLUSION

An attempt to demodulate fetal Doppler Ultrasound signal using bandpass sampling technique has been described in this paper. At this stage, DAQ Card has been used and proved to be able to send out the 3kHz signal from the VB screen.

The mixing and bandpass sampling stages will be carried out to extract information from Doppler Ultrasound Signals.

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REFERENCES

[1] W. Mansor, "Fetal Systolic Timing Intervals Using Doppler Ultrasound," *Ph.D Thesis*, University of Nottingham, 2007.

[2] Mohd F. R. Romli, "Digital Demodulation and Extraction of Fetal Heart Valve Motions from Doppler Ultrasound Signals," *B.Eng (Hons) Thesis*, Universiti Teknologi MARA, Nov.2006.

[3] N. A. Muhamad Kassim, "Investigation on the Use of Bandpass Sampling Technique to Extract Information from Doppler Ultrasound Signals," *B. Eng (Hons) Thesis*, Nov. 2008.

[4] Rodney G. Vaughan, Neil L. Scott and D. Rod White, "The Theory of Bandpass Sampling," *IEEE Trans. On Signal Processing*, vol. 39, no. 9, Sept. 1991.