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SOFTWARE DEFINED RADIO FOR AUDIO SIGNAL PROCESSING IN PROJECT BASED LEARNING

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In communication and signal processing course there are some challenges in explaining the basic theory of signal and how to process the signal as well. Educational tool to demonstrate how the system works is important and more attractive to improve the understanding of student. Software Defined Radio (SDR) brings the concept of software-based processing. This paper implements the using of SDR as the innovative teaching method to demonstrate the fundamental concept in signal processing course. Students build the audio signal processing projects on SDR platform using GNU Radio.

Three interesting projects including the adjustment of sampling rate, DSB-AM modulation, and audio processing for gender identification are simulated using GNU Radio software. This Project Based Learning shows the positive result of the implementation of SDR in raising the student interest and motivation. Furthermore this study opens wide application of SDR based technique especially for education.

Key words: SDR, Signal Processing, Project Based Learning, GNU Radio

1 Introduction

Communication and signal processing course heavily based on mathematical models. The abstract and complex of the mathematical models in signal processing and modulation/demodulation can be difficult for students to understand. Practical laboratory typically deal with simple circuit and also often difficult to provide the opportunity for student to observe the actual signal [1]. An improved teaching method is necessary to gain the understanding of fundamental concept, and recently it can be done by utilizing the development of software technology.

Software Defined Radio (SDR) concept introduce the software-based processing for radio communication system. By using the software based processing the simulation of signal processing on software is performed to demonstrate how the processing works. The students are assigned to run the simulation on software in order to analyse how the signal processing is done. This learning approach helps the student to get more understanding about the real implementation of signal processing especially for communication system course. The use of SDR in education has been performed in 2009 by [1,2,3] in communication course and applied as the senior design project. From the point of education, the establishments of new platforms where students can model, simulate and test transmission systems from various aspects are important. Ref [3] gives an overview of a laboratory course incorporating the use of SDR especially for wireless communication system.

SDR platform composed by USRP hardware and GNU Radio is presented as a new approach for teaching telecommunications at schools of Electrical Engineering by [4], in year 2012. This paper brings potential result in giving the students the opportunity to focus their efforts on the learning of communications techniques and algorithms. Currently as the communication technology has highly developed, the communications engineering students need practical tools and knowledge to develop and test communications systems.

Then in 2014, Petrova at al stated that curriculum and the way to teach students or professionals have to face several challenges [5]. In this paper the integration of SDR into the university curriculum is discussed to help the community meet some of these challenges. SDR can be employed as an integrative construct that facilitates systems thinking and cross-domain learning via peers. In article [6], significant educational efforts are presented across six U.S. universities that have developed integrated curriculum in SDR, most including a significant laboratory component.

SDR concept can be implemented using various softwares. One of the commonly used software for SDR is GNU Radio. GNU Radio is an open-source solution for SDR specific applications, as a tool for development configurable digital radio [7]. GNU Radio applications are mostly written using the Python programming language, while the signal processing is implemented in C++ programming language using floating-point processor extensions. Then, the command process can be applied into actual radio systems and real-time based on field programmable gate array (FPGA) in the USRP.

2 Implementation of SDR

2.1 Sampling Rate for Audio Processing Project

In the first audio processing project, the students are assigned to run the audio sampling process on GNU Radio. Figure 1 show the GRC block diagram for audio sampling process in GNU radio. The block consists of a Wave File Source, QT GUI Time Sink, QT GUI Frequency Sink, and Audio Sink.

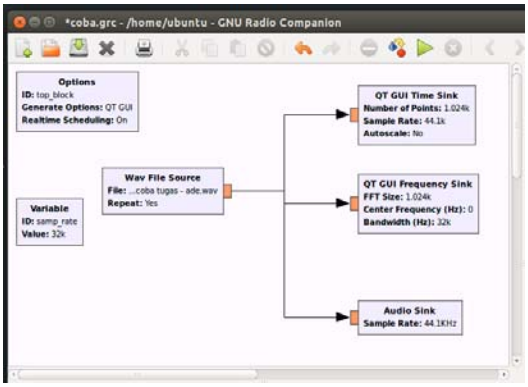

Figure 1. GRC block on GNU Radio for sampling rate adjustment for audio processing.

The parameter of sampling rate are changed in order to observe its effect to the output audio signal, and then to decide the best sampling frequency for a specific input audio. Audio signal used as the input signal is the voices of human in short time period. The characteristic of output signal are

evaluated on frequency domain (using GUI frequency Sink), and on time domain (using GUI time Sink) and also by testing the quality of real audio signal using speaker. The project tested six variations of sampling rate; 16 kHz, 22.05 kHz, 24 kHz, 32 kHz, 44.1 kHz, and 48 kHz. Figure 2 and figure 3 shows output signal with 16kH and 44.1 kHz sampling frequency.

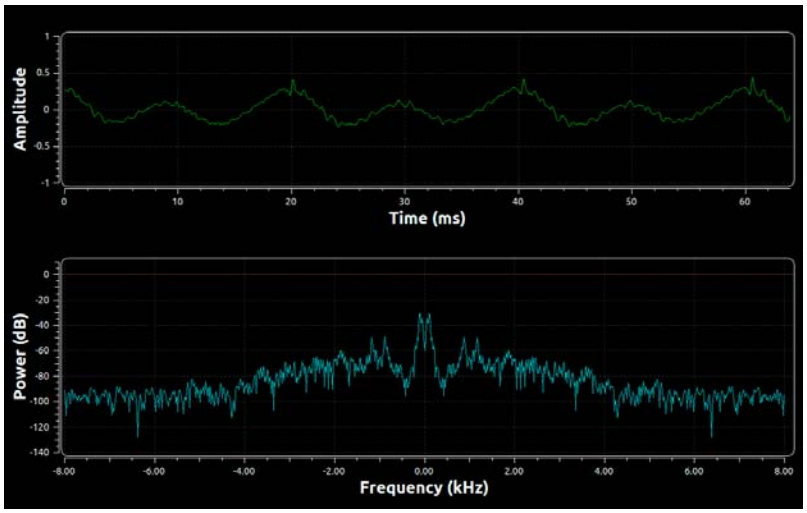

Figure 2 Output signal using sampling rate of 16 kHz, in Time Sink and Frequency Sink.

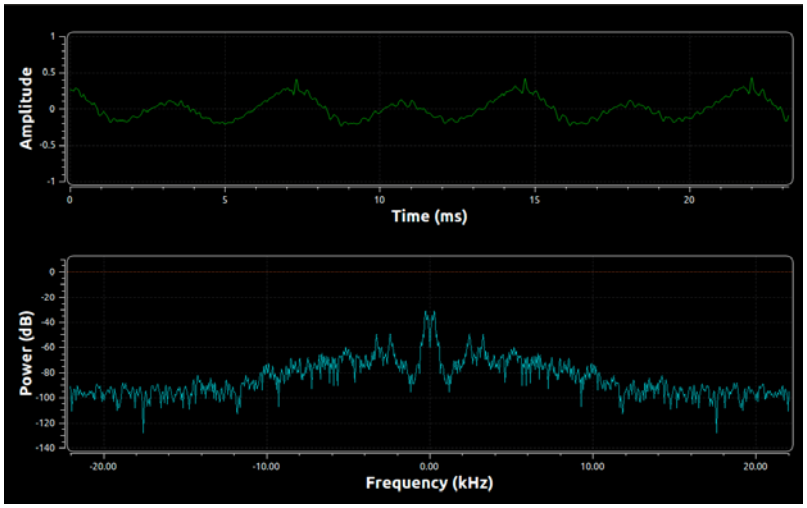

Figure 3 Output signal using sampling rate of 44.1 kHz, in Time Sink and Frequency Sink.

Based on experiments conducted using GNU Radio software, by using the greater frequency of sampling the output signal will resemble the original signal. The sound produced by using the higher sampling frequency is more approaching the original sound. For the specific input audio, the best appropriate sampling rate is 44.1 kHz.

2.2 DSB-AM Modulation Project

To study the radio communication system, the simulation of basic modulation technique; Double Side Band Amplitude Modulation (DSB-AM) is done on GNU Radio. The input audio signal is applied using Wav File Source block, and will be modulated on 3 kHz carrier signal generated using Signal Source block. The result of modulated signal is displayed on Time Sink and Frequency Sink, while the actual sound of output signal is sounded off using Audio Sink.

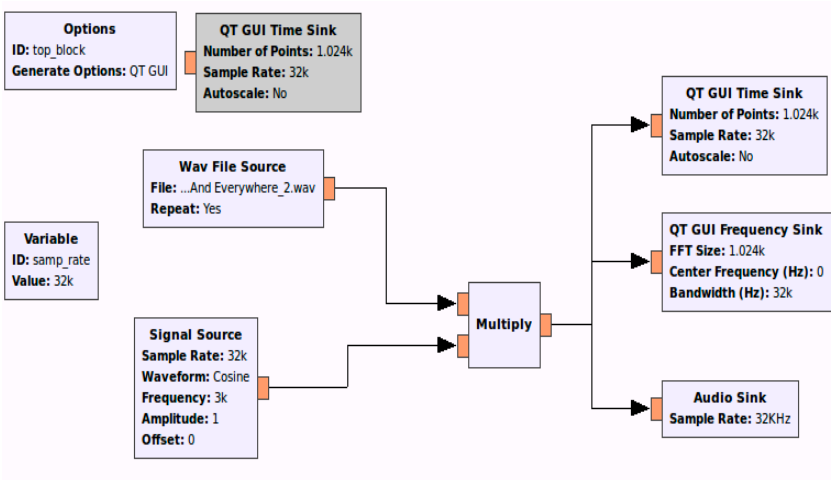

Figure 4 GRC block on GNU Radio for DVB-AM modulation technique.

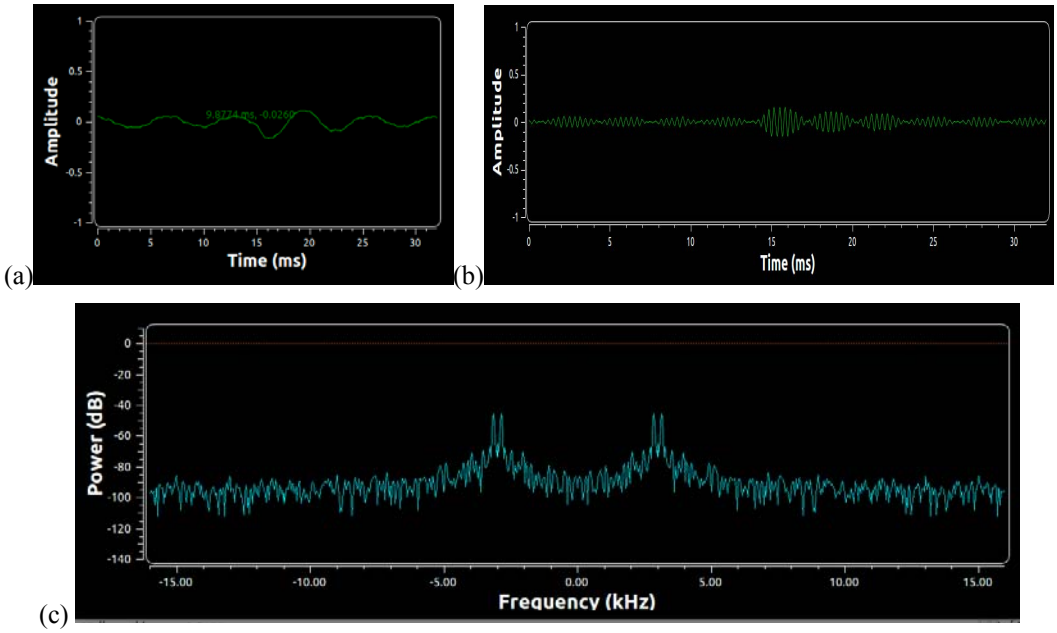

Figure 5 (a) Input audio (guitar instrument), (b) AM modulated signal, and (c) Frequency spectrum of modulated signal.

The simulation is run with various type of input signal in order to analyse how the modulation is done on audio signal. Input audio tested in this simulation involving the audio from guitar instrument and piano instrument. These two different signals are expected to have different frequency operation. The results of DSB AM modulated signal are presented in Figure 5 and Figure 6.

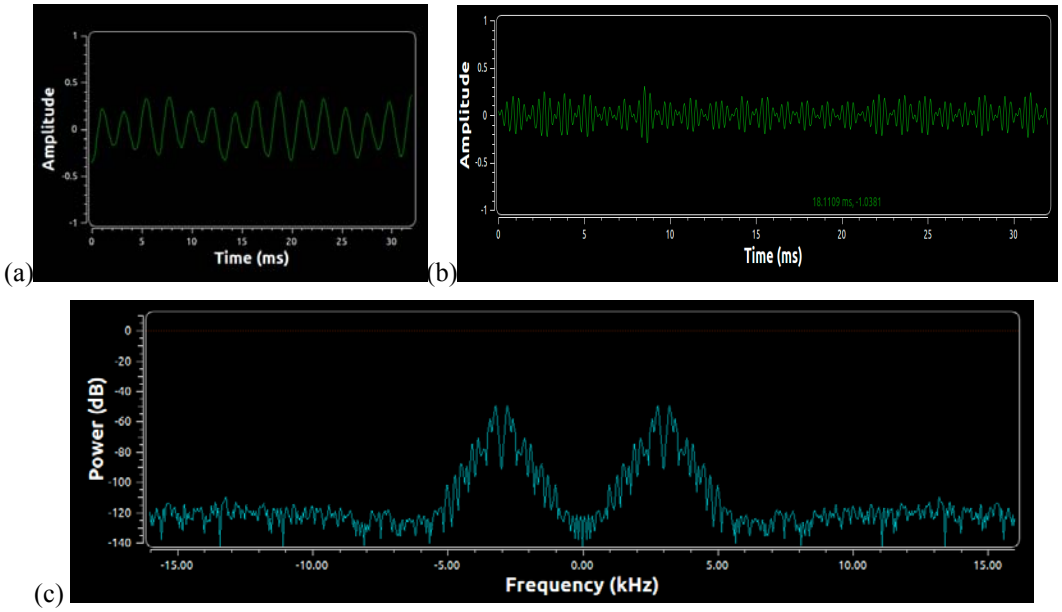

Figure 6 (a) Input audio (piano instrument), (b) AM modulated signal, and (c) Frequency spectrum of modulated signal.

The simulation result shows the audio signals which have been modulated using DSB AM modulation. The shape of modulated signal is presented in time domain and frequency domain. The spectrum shows there are two peak powers at lower side band and upper side band. The project shows that the audio from guitar instrument has lower frequency compared to the audio from piano instrument. The AM modulated signal also follows this characteristic. Then in spectrum frequency, the peak power is obtained in 2.9 kHz and 3.1 kHz for AM modulated guitar audio and in 2.6 kHz and 3.4 kHz for AM modulated piano audio. Another simulation is also done in this project to process the input audio with lyrics and without lyrics which produce the output that the audio with lyrics contained low and high frequency than the audio without lyrics.

2.3 Signal Processing for Gender Identification Project

The third project simulated is a special topic concerning about the implementation of audio signal processing. The selected topics is the using of audio signal processing for gender identification. Various type of male and female's voices are collected and tested in order to characterize the pattern of signal. The different characteristic of male and female's voices are analysed by observing its frequency spectrum. Figure 7 shows the GRC block diagram of audio identification on GNU Radio, then Figure 8 and Figure 9 shows the examples of male and female's audio respectively.

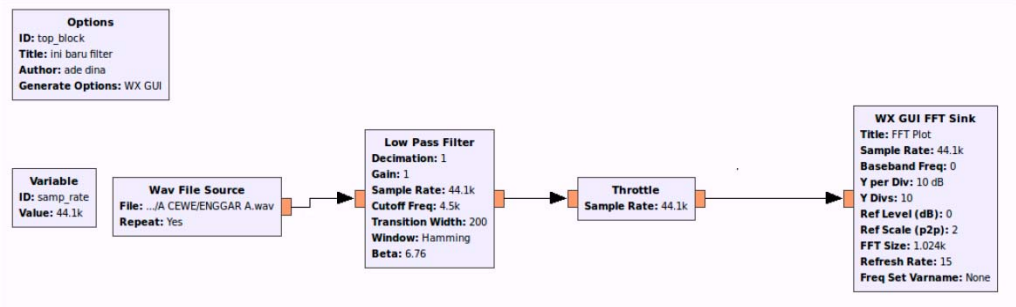

Figure 7 GRC block on GNU Radio for audio processing for gender identification.

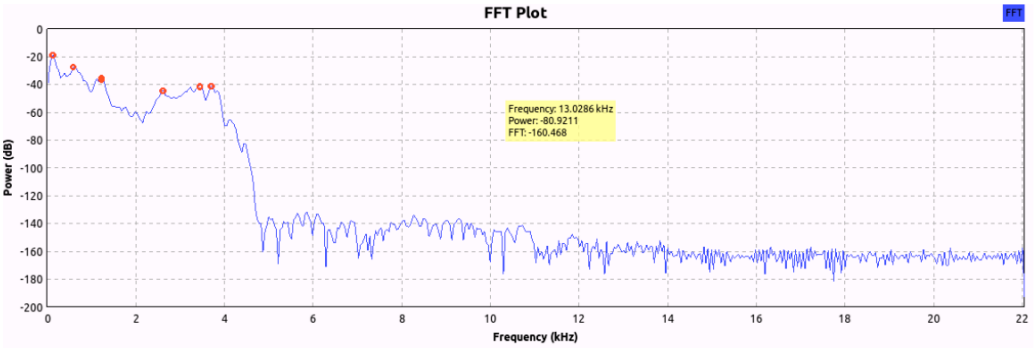

Figure 8 The example of frequency spectrum of male audio.

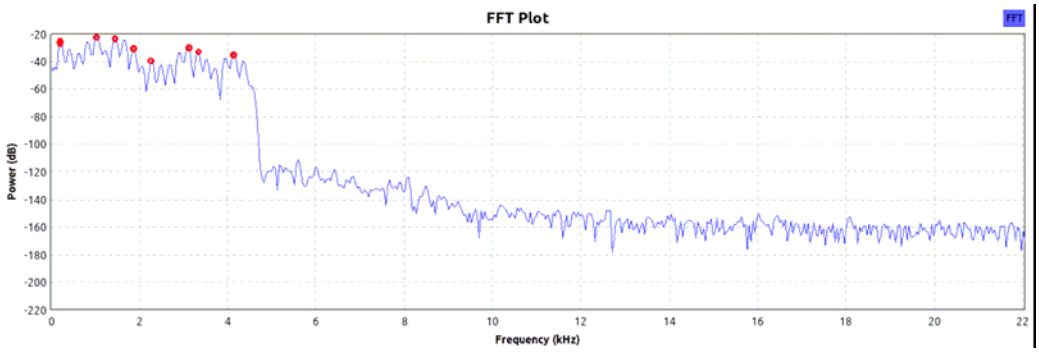

Figure 9 The example of frequency spectrum of female audio.

The characteristic of male and female's voices are analysed in frequency spectrum. The testing is done with collecting 14 sample voices, including 7 male voices and 7 female voices. One of the characteristic obtained from the simulation is that the female voice has more number of peak powers at low frequency than male voice. The average number of peak power of female's voice is

about 8.28 peak points (more ripple) while in male's voice there are about 5.71 peak points (less ripple).

3 Discussion

This paper presents the audio signal processing project using Software Defined Radio for the following discussion; Sampling Rate for Audio Processing Project, DSB-AM Modulated Signal and Frequency Spectrum Project, and Signal Processing for Gender Identification project. The projects are succeed to demonstrate the audio signal processing, both in time and frequency domain. The first project is explaining the effect of sampling rate to the audio signal generation, while the second project is successfully simulated the AM modulated signal with different type of input signal. The guitar audio produce the lower frequency than the audio generated from the piano instrument. The frequency spectrums of modulated signal are also showing its different frequency characteristic, in terms of AM bandwidth spectrum.

A special project in the last discussion is about the using of audio processing for gender identification. Male and female's voices are characterized by observing the frequency spectrum. One of the characteristic which obtained from the software based processing is that the female voice has more peak power at low frequency than male voice. The average number of peak power of female's voice is about 8.28 peak points, while in male's voice there are about 5.71 peak points.

The project based learning applied in DSP and communication course has showed a positive result in raising the interest and motivation of student to study the principal theory of signal processing and communication system. By observing the real signal processed by the software the student has better understanding of signal characteristic and have more enthusiastic in learning this course. This has been proven by observing that more number of students is continuing their study on further communication course.

4 Conclusion

A simulation based teaching method utilizing SDR platform is the more attractive way to demonstrate the fundamental concept of signal processing. Signal processing projects including the adjusting of sampling rate for audio processing, DSB-AM modulation project, and gender identification using signal processing are successfully simulated and presented using GNU Radio. Project result shows the implementation of SDR in raising the student interest and motivation. This study opens wide application of SDR especially for education since it is the simulation platform which is approaching the real implementation.

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References

[1] Sharlene Katz, James Flynn. Using Software Defined Radio (SDR) To Demonstrate Concepts in Communications and Signal Processing Courses. Proceedings of the 2009 ASEE Annual Conference. 2009.

[2] Sharlene Katz, James Flynn. Using Software Defined Radio in Multidiciplinary Senior Design Projects at California State University, Northridge. Proceedings of the SDR 2009 Technical Conference and Product Exposition. 2009.

[3] Gu¨ zelgö z, S, Tampa, Arslan, H. Modeling, simulation, testing, and measurements of wireless communication systems: A laboratory based approach. Wireless and Microwave Technology Conference WAMICON, 2009, 1-5.

[4] Reis, A.L.G., Selva, A.F.B., Lenzi, K.G., Barbin, S.E. Software defined radio on digital communications: A new teaching tool. Wireless and Microwave Technology Conference WAMICON. 2012, 1-8.

[5] Petrova, M. Achtzehn, A., Ma¨ hö nen, P. System-oriented communications engineering curriculum: teaching design concepts with SDR platforms. Communications Magazine IEEE, Volume 52 , Issue: 5. 2014. 202 – 209.

[6] Bilén, S.G. Wyglinski, A.M. Anderson, C.R. Cooklev, T. Software-Defined Radio: A New Paradigm for Integrated Curriculum Delivery. Communications Magazine IEEE , Volume 52, Issue: 5. 2014. 184 – 193.

[7] Luiz Garcia Reis, A., Barros, A.F., Gusso Lenzi, K., Pedroso Meloni, L.G. Introduction to the Software-defined Radio Approach. Latin America Transactions IEEE, Volume 10, Issue 1. 2012. 1156 – 1161.