SFCW Signal Generation of Dual Frequency Channel Using LabVIEW Simulation

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***Abstract* — This paper describes the modelling process the dual channels stepped-frequency continuous wave (SFCW) signal generation using LabVIEW software. The developed signal generator is a flexible system where it can be used for any SFCW radar application with different frequency range as well as single or dual channels. The system is presented using two frequency range: 1MHz to 401MHz and 401MHz to 801MHz for channel one and two respectively. Both channels have 400MHz bandwidth and divided into 8 steps with 50MHz of frequency step size and generated concurrently. As the result, two waveforms are produced after generating the signals based on the mentioned parameters. The proposed dual-channel SFCW signal generator was then analysed and validated by deconstructing the generated signals from both channels to obtain frequency components that exist in each channel. The deconstructed SFCW waveform has been plotted which reflect the calculated frequencies components of 1MHz, 51MHz, 101MHz, 151MHz, 201MHz, 251MHz, 301MHz, 351MHz for channel one and 401MHz, 451MHz, 501MHz, 551MHz, 601MHz, 651MHz, 701MHz, 751MHz for channel two.**

***Keywords* — SFCW radar, LabVIEW system, Software Defined Radio, landslide detection system.**

I. Introduction

In remote sensing technique, an electromagnetics (EM) waves will be transmitted to the targets such as rocks or soils. When the EM wave hit the targets, it will be reflected due to the differences of conductivity and dielectric constant [1]. The velocity of the reflected waves is depending on the dielectric constant and the medium travelled by the wave. Therefore, the transmitted and received signals will have different velocity and it is useful in determine the characteristics of the targets such as distance of the target. On the other note, in landslide detection system or ground penetrating radar, it is crucial to choose appropriate frequency range because it will determine penetration depths of waves where for a deeper penetration requires a lower frequency range and vice versa [2].

The reliability of radar sensor system can be seen from its applications which is recently very close to our living environments. However, conventional fixed purpose radar system development still requires long development cycle and has several drawbacks such as hardly to be reconfigured as the hardware includes many sensors and systems. To overcome the limitations of conventional fixed purpose radar system, a flexible and adaptable radar system called Software-Defined Radar (SD Radar) was introduced where most of the hardware processing, like waveform generation and up/down conversion are performed by software. SD Radar has many advantages such as a multipurpose system, the ability to re-using the hardware, easy implementation of signal processing algorithms, faster development, and cost reduction.

Stepped-Frequency Continuous Wave (SFCW) is one of the Continuous-Waves that frequently applied ground penetrating radar (GPR) because according to [3] they have advantageous such as ability to transmit high average power which results in long range (deep penetration and the entire bandwidth (BW) can be very wide thus giving fine resolution.

From the research that had been carried out by [4]-[6], they have successfully developed SD Radar by using SFCW system. However, in their research, the SFCW signal was generated by a hardware platform such as direct digital synthesizer (DDS) board in [6]. The hardware platform requires extra care for the system where it add extra cost and extra size of the total system. Therefore, as a main part of SFCW SD Radar for landslide detection system, this paper will present a simulation of SFCW signal generator in order to get rid the hardware platform of the SD Radar design and to serve the aim of the research which is to develop a flexible SD Radar. The built system can be used for other applications that requires different frequency range where user can just change required parameters

SFCW signal contain of a group of N signals that are different in frequencies $(f_0, f_1, \dots, f_{N-1})$ and the frequencies are increased by a fixed frequency steps (Δf) as depicted in Fig. 1.

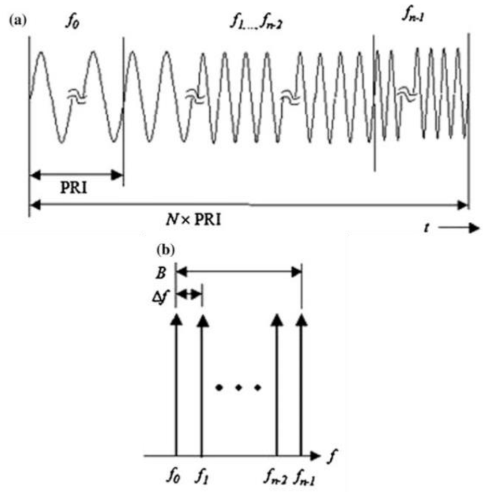

Fig. 1. SFCW signals and frequencies of SFCW radar in: (a) waveforms; (b) frequencies

II. SFCW Signal Generator Design

As a part of software defined radar system project to detect landslide for early warning system, this paper presents the simulation of SFCW signal generator. The intention of the mentioned project is to reduce the number of hardware involved in the system. This is because too much hardware involved will increase the complexity in troubleshooting, hard configuration, and increase the production cost per unit. In generating SFCW signal, direct digital synthesizer (DDS) and phase locked loop (PLL) are the common methods used in most studies because both methods are great in controlling frequency and phase of SFCW signal. However, their complexity of circuitry has limit them for troubleshooting works especially when they are embedded on the board. Therefore, in this paper, SFCW signal being generated by employing the LabVIEW software. The consideration of using LabVIEW software because it offers graphical programming which make programming and debugging much easier. The SFCW signal generated using LabVIEW 2018 software version in a HP Laptop with the following specifications installed:

1) Intel® Core ™ i7
2) 8GB RAM
3) NVIDIA GeForce MX250

This paper presents a simulation to generate dual frequency channels of SFCW signals in waveforms and frequencies according to Fig. 1. We propose dual frequency channel of SFCW signal generator because of the advantage of using multi-channel transmission. Usually, any application with wider bandwidth is suffering with the long transmission time and led to low sensing effectiveness. Thus, by splitting the spectrum into few channels, the transmission time can be reduced when all channels operate simultaneously.

This paper presents a dual channel of SFCW signals generator designed for large bandwidth application. So, it is impossible to see the generated SFCW waveform. However, we still can prove the generated signal is a SFCW signal by displaying the frequency components of the generated signals. On the other hand, the parameters value of the generated signal shall match with the expected parameters of SFCW signals to validate the generated SFCW signals. The parameters involved are listed in Table 1.

The designed SFCW signal generator acquire user to insert three parameters; start frequency, f_0, Stop frequency, f_{N-1} and number of steps, N. While other parameters will be calculated based on the value of f_0, f_{N-1}, and N inserted by user by using (1), (2), and (3).

$$BW = f_0 - f_{n-1} \tag{1}$$

$$\Delta f = \frac{BW}{N} \tag{2}$$

$$f_N = f_0 + N\Delta f \tag{3}$$

TABLE I
List of Parameters in SFCW Signals

Parameter	Symbol
Start Frequency	f_0
Stop Frequency	f_{N-1}
Total Bandwidth	BW
Number of Frequency Steps	N
Frequency Step Size	Δf
Frequency components	$f_N\ ; N = 0,1, \dots , N-1$

The system designed in this paper is tested for two frequency range. Channel one with frequency range of 1MHz to 401MHz while channel two with frequency range of 401MHz to 801MHz. Each channel has same number of steps, 8 steps, 400MHz bandwidth and 50MHz of frequency step size. According to (3) the generated SFCW signals must have 8 frequency components and separated with 50MHz between each other. Table I shows the parameters used to test the signal generator and expected value of frequency components in each channel.

TABLE II
Summary of Required And Calculated Parameters in SFCW Signals

Parameter	Symbol	Value	
		Channel 1	Channel 2
Frequency Range	-	1– 401 (MHz)	401 – 801 (MHz)
Total Bandwidth	BW	400MHz	
Number of Frequency Steps	N	8	
Frequency Step Size	Δf	50MHz	
Expected Value of Frequency Components	f_0	1MHz	4011MHz
	f_1	51MHz	451MHz
	f_2	101MHz	501MHz
	f_3	151MHz	551MHz
	f_4	201MHz	601MHz
	f_5	251MHz	651MHz
	f_6	301MHz	701MHz
	f_7	351MHz	751MHz

In LabVIEW software, the user interface is the front panel. From the front panel in Fig. 2, besides of having three inputs to the system, three outputs are being displayed as well where user can view the constructed SFCW waveform in the first graph, and the frequency components of the generated SFCW signals in the second and third graph for channel one two respectively.

The existing function from LabVIEW software make the programming easier. There are few functions that can be used to generate signal in LabVIEW. However, in this paper, SFCW signals are generated according to (3) by using 'Simulated Signal' express VI from LabVIEW software as shown in Fig. 3. The express VI is used because it has combined required parameters to generate the signals in one window which make the programming circuit simple and ease the debugging work

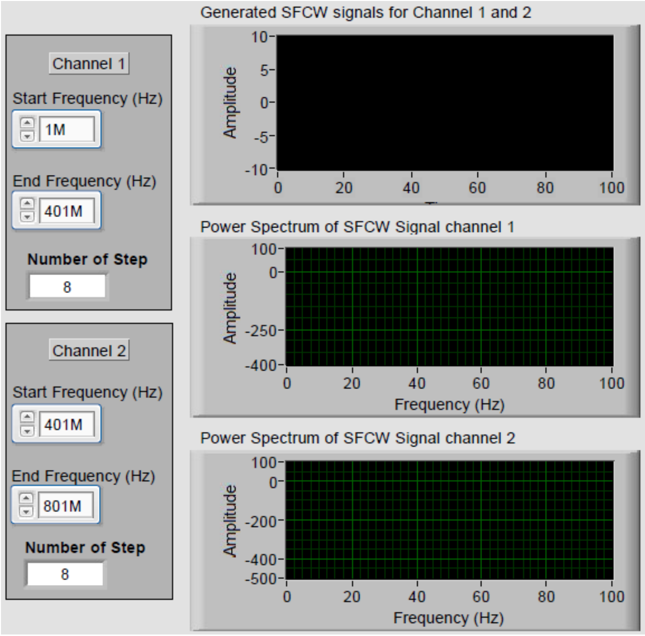

Fig. 2. Front Panel of LabVIEW

The SFCW signals are generated in while loop following mathematical formula in (3) where the condition is set to stop when the frequency component, f_N is greater than the stop frequency, f_{N-1}. By using this method, the signals are constructed for each frequency component and repeated with increasing frequency according to the frequency step size until it meets the condition. The SFCW signal for both channels are generated concurrently using different express VI and plotted on the same graph.

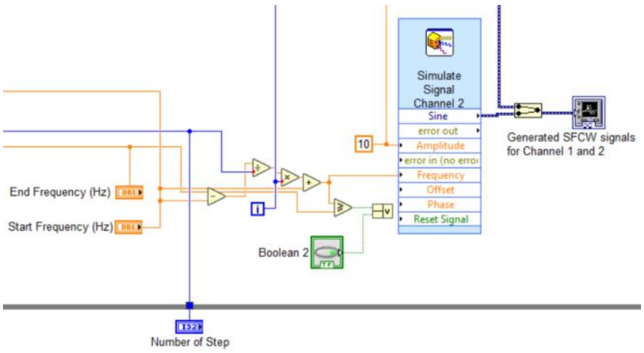

Fig. 3. Generating SFCW radar signal using LabVIEW software

As mentioned earlier, SFCW signals can be identified by deconstructing the waveform into frequency components. It could be done in LabVIEW software by using 'Spectral Measurement' express VI as shown in Fig. 4. The express VI allow us to measure the power spectrum of the signals and return the signal in the form of frequency components. In this paper, the returned power spectrum is being plotted on the front panel shown in Fig. 2.

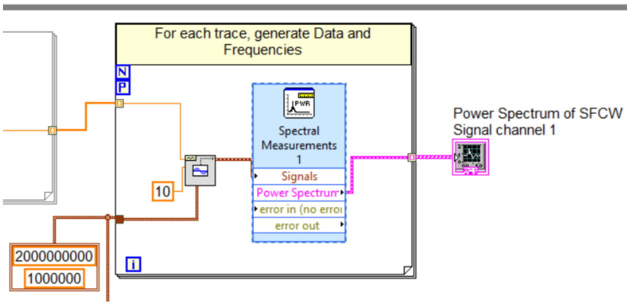

Fig. 4. Performing spectral measurement for the SFCW radar signal

III. Simulation Result

The SFCW signal generator has been tested for two different frequency bands by using two channels with same number of steps as summarized in Table II. There are two outcomes from the simulation. The first outcome is the generated SFCW signals from channel one and channel two which can be seen from Fig. 5. However, due to large bandwidth used, it is hard to identify the waveform produced.

To identify the signals generated, power spectrum of both channels has been measured to deconstruct the waveforms into frequency components and the frequency components of the generated signals must agree to the expected value of frequency components tabulated in Table II. From the spectral measurement process, the second outcome is expected from frequency components exist in the signals. From the simulation, all frequency components present in the generated signals has been plotted accordingly and presented by black, red, green, blue, yellow, pink, orange, and purple spikes as shown in Fig 6 and Fig. 7.

However, in the power spectrum plotted for channel one and channel two, it can be noticed that the noise floor exists for both channels. According to [7], the noise floor of the power spectrum is depending on the step size, Δf, of the spectrum which in turn controlled by the sampling rate and number of samples. In other word, the noise level at each frequency line reads as if it were measured through a Δf Hz filter centred at the frequency line. Nonetheless, the noise floor in this paper is not a concern as it does not bring any impact to the SFCW radar signals simulated.

Fig. 6 and Fig. 7 show there are 8 frequency components exist in the generated signals from both channels. Each of the frequency components are separated by 50MHz of frequency step size and exist in the frequency range in each channel. Table III summarise the value for all frequency components exist in both channels.

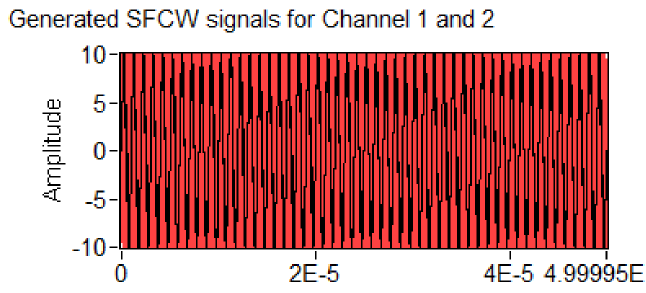

Fig. 5. Generated SFCW signal for channel one and channel two

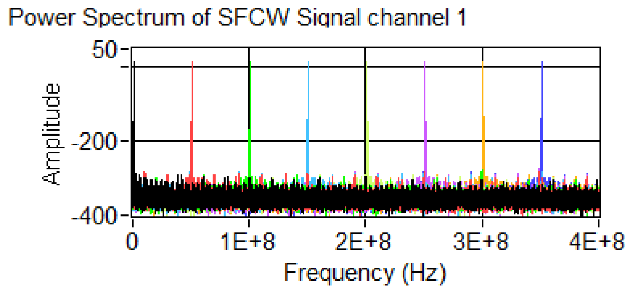

Fig. 6. Frequency components in channel one

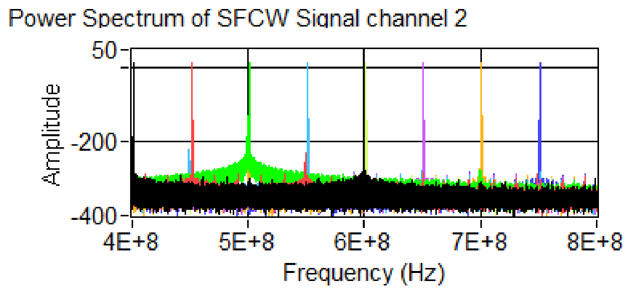

Fig. 7. Frequency component of channel two

TABLE III
MEASURED FREQUENCY COMPONENTS IN CHANNEL 1 AND CHANNEL 2

Signal Colour	**Frequency Component**	**Channel 1** (in MHz)	**Channel 2** (in MHz)
Black	f_0	1	401
Red	f_1	51	451
Green	f_2	101	501
Blue	f_3	151	551
Yellow	f_4	201	601
Pink	f_5	251	651
Orange	f_6	301	701
Purple	f_7	351	751

From the result of the simulation summarized in Table III, the measured frequency components are showing the same value as the expected frequency component as in Table II. For the first channel, the start frequency is 1MHz and stop frequency is 401MHz. The second channel has 401MHz start frequency and 801MHz. Meanwhile the bandwidth for both channels is 400MHz. Both channel of SFCW radar signals is divided into 8 steps ($f_0, f_1, f_2, f_3, f_4, f_5, f_6, f_7$) with 50MHz of frequency step size. Since the generated signals show the perfect agreement to the characteristics of SFCW signals following the parameters tabulated in Table II, it can be said the dual channel of SFCW signal generator presented in this paper is working well.

Therefore, it can be concluded that the system designed to generate SFCW radar signals to be transmitted is working well. The build signal generator offers flexibility in choosing the frequency band, number of channels and number of steps. Thus, this design could be used in other application which have different frequency bands as well as number of steps and required one or two channels for transmission. However, others should note that this design can only be used to generate SFCW signal.

IV. CONCLUSION AND FUTURE WORK

The aim to generate SFCW radar signal using dual frequency channels concurrently have been achieved by using the proposed design. For the first channel, the start frequency is 1MHz and stop frequency is 401MHz. The second channel has 401MHz start frequency and 801MHz. Meanwhile the bandwidth for both channels is 400MHz. Both channel of SFCW radar signals is divided into 8 steps with 8 frequency components ($f_0, f_1, f_2, f_3, f_4, f_5, f_6, f_7$) with 50MHz of frequency step size. The developed SFCW signal generator in this paper will be connected to USRP where few operations such as interpolation operation (DUC) and digital to analogue conversion (DAC) takes place before transmitting the SFCW radar signals through the antenna. The signal generator designed in this paper is developed for one run only. Looping with specific delay could be added for the signal generator to operate continuously in real time.

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