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Investigating the Possibility of Transmitting and Receiving Multiple Signals at Low Baseband Frequencies

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***Abstract*— Software defined radio technology is one area in the field of Radio communications technology that has advanced considerably over the past years. There are several challenges that are faced in ensuring that Radio communications. Traditionally, most signal processing algorithms have been done at Radio frequencies. However with the coming of Software defined radio, it become necessary to investigate the implementation of most hardware based signal processing algorithms using software. Software defined radio technology relies heavily of baseband processing. Baseband processing ensures that signals are processed at low frequencies as compared to the traditional radio frequencies. This paper considers a scenario where multiple signals combined and transformed to low baseband frequencies before being transmitted over a channel with a possibility of being extracted at the receiver as separate signals. The simulation is done using MatLab software and the results show that it is possible to have multiple transmission at baseband.**

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***Index Terms*— Low Frequency, Quadrature Baseband, Simulation, Modulation, Demodulation**

I. INTRODUCTION

Software radio refers to radio transceivers whose functionalities are largely defined and implemented by software, and therefore they can be reprogrammed to accommodate various physical layer formats and protocols without replacing the hardware. An ideal software radio should have two distinct features: software upgradability and hardware reconfigurability [1],[2],[3]. This paper looks at the possibility of sending multiple signals over a transmission channel at low Quadrature baseband frequencies. The signals used in the simulation analysis are Amplitude Modulated Double Side Band Suppressed Carrier (AM DSB SC) signals.

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II. THEORETICAL ANALYSIS

Three signals were generated and then modulated before being summed up and then converted to Quadrature baseband signal. The resulting signal is then sent over a transmission channel and then at the receiving end, the original signals are retrieved from the transmitted signal using Quadrature baseband demodulation. The block diagram below summarizes the procedure for the investigation that was carried out. In the diagram above, LO_1, LO_2 and LO_3 represent the different local oscillators that were used to modulate the input signals. The modulated signals are then summed up before being sent to the Quadrature baseband (QBB) converter as one signal. The resulting QBB signal is then sent over a transmission channel before being demodulated at the receiving end using QBB demodulation. The equations below illustrate the processing taking place. S_1 represents the first input signal, S_2 represents the second input signal and S_3 represents the third input signal.

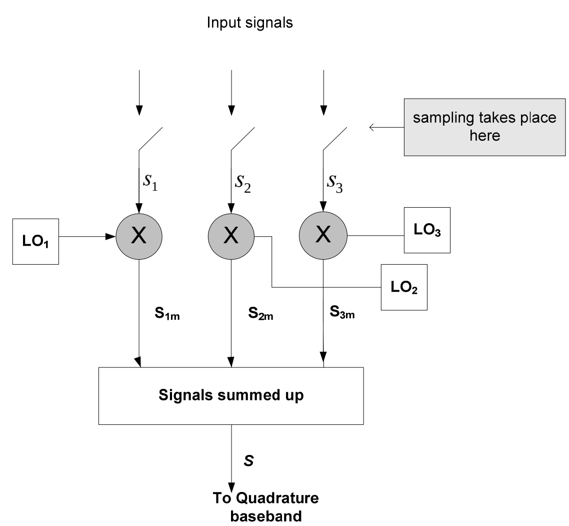

Figure 1: Signal input before baseband conversion

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Equation 1 below illustrates the signal inputs.

$$s_1 = \sin(\omega_{m1}t) \quad , s_2 = \sin(\omega_{m2}t) \text{ and}$$

$$s_3 = \sin(\omega_{m3}t) \qquad (1)$$

The carrier signals are represented by the signals below.

$$LO_1 = \cos(\omega_{c1}t) \ , \ LO_2 = \cos(\omega_{c2}t) \text{ and}$$

$$LO_3 = \cos(\omega_{c3}t) \qquad (2)$$

The modulated signals are represented by the signals shown below:

$$S_{1m} = s_1 * LO_1, S_{2m} = s_2 * LO_2, S_{3m} = s_3 * LO_3 \qquad (3)$$

The summed up signal is thus given by the equation below;

$$S = S_{1m} + S_{2m} + S_{3m} \qquad (4)$$

As mentioned earlier, it is required that the signal be converted to Quadrature baseband before being transmitted. This is the very task at hand in this investigation so as to verify whether the transmission process of the multiple signals is possible at QBB. A brief background of QBB is given below. **Quadrature baseband** is a term that refers to the generation of in-phase and Quadrature components of a signal at baseband. **Baseband** is an adjective that describes signals and systems whose range of frequencies is measured from 0 to a maximum bandwidth or highest signal frequency [5]. Usually, it is considered as a synonym to lowpass and an antonym to Passband. The simplest definition is that a signal's baseband bandwidth is its bandwidth before modulation and multiplexing, or after demultiplexing and demodulation. The figure on the next page illustrates the compares radio frequency and baseband.

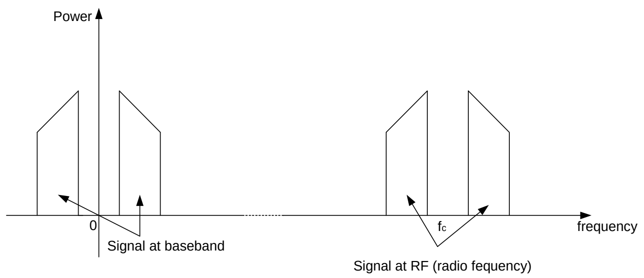

Figure 2: Comparison of the baseband version and RF version of an AM modulated signal. The RF signal sits at the carrier frequency f_c.

The conversion of an RF signal to Quadrature baseband is carried out by the following steps:

- The RF signal is multiplied with a complex carrier in what is referred to as down-mixing.
- The complex down-mixed signal is then lowpass filtered resulting in the Quadrature baseband version of the RF signal. The expressions given below illustrate these steps [4].

Let ω_c be the carrier frequency of the modulated RF signal, it follows that the complex carrier used in the down mixing process is a complex exponential with the same carrier frequency ω_c [4].

$$f(t)_{downmixed} = f(t).* e^{-j\omega_c t} \qquad (5)$$

The low pass filter then eliminates the high frequency component of the spectrum resulting in the complex baseband signal.

$$f(t)_{qbb} = | f(t)_{downmixed} |_{LPF} \qquad (6)$$

The real part of the lowpass filtered signal corresponds to the in-phase Quadrature component of the baseband signal. The figure below illustrates the process outlined above.

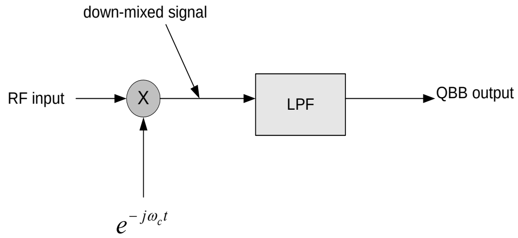

Figure 3: Conversion of an RF carrier to Quadrature baseband.

III. SIMULATION RESULTS

The simulation results are shown below. The input signals are shown in Figures 4, 5 and 6.

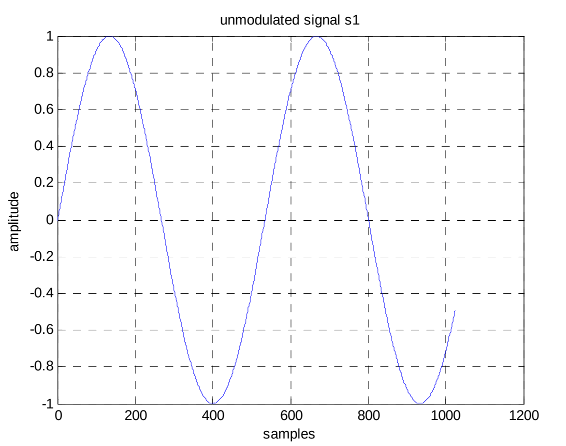

Figure 4: Input signal S_1

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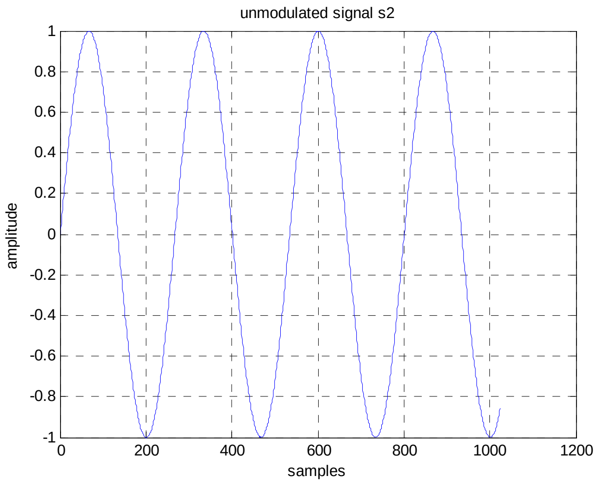

Figure 5: Input signal S_2

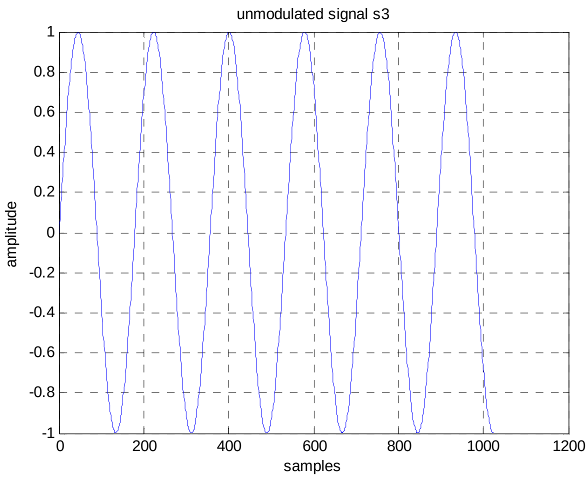

Figure 6: Input signal S_3

The signals were then modulated as shown in Figures 7, 8 and 9 below.

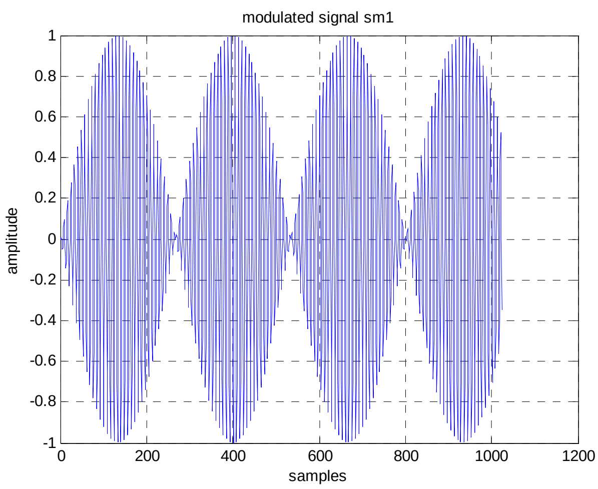

Figure 7: Modulated Input signal S_1

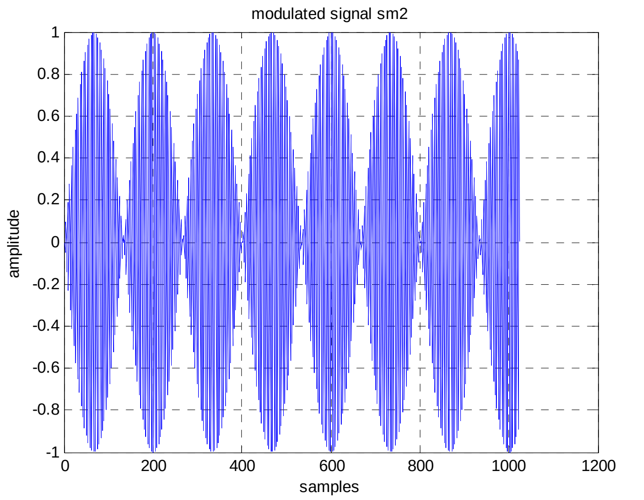

Figure 8: Modulated Input signal S_2

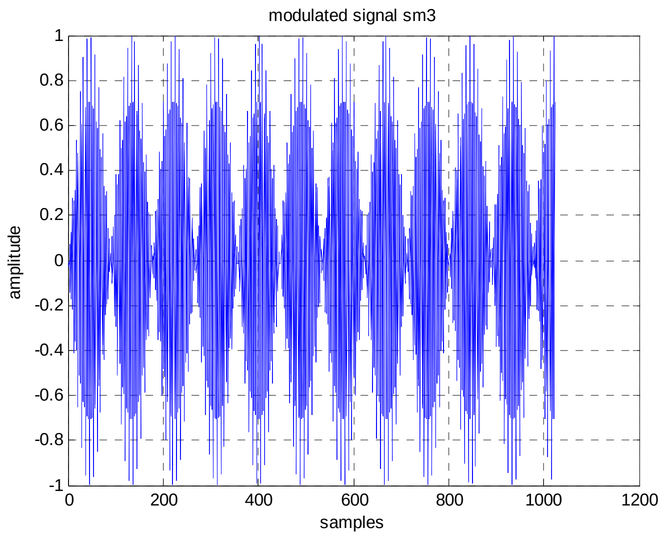

Figure 9: Modulated Input signal S_3

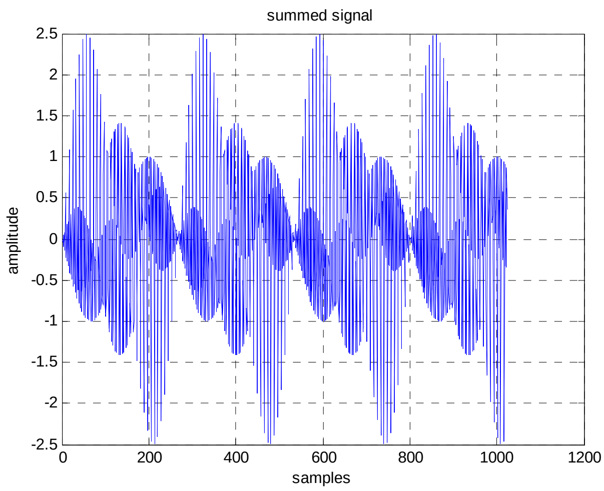

Figure 10: Summed Signal

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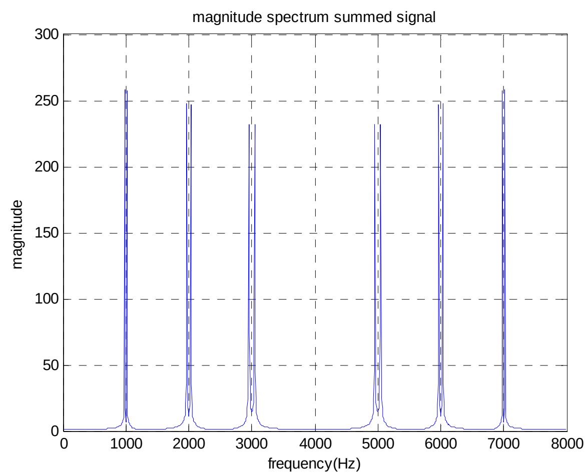

Figure 11: Magnitude spectrum of summed signal

Figure 10 above shows the summed up signal. This signal comprises S_1, S_2 and S_3 summed up. The magnitude spectrum in Figure 11 clearly shows the frequency components of the three signals and given the frequencies chosen for the experiment, it was possible to easily carry out the extraction of the individual signal outputs at the receiving end. Upon mixing down the summed signal to baseband, the following signal was obtained. Here it is seen that the signal is a complex signal having both a real and imaginary component.

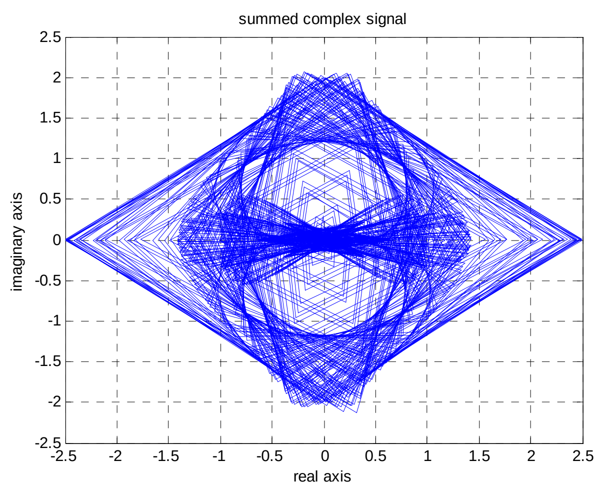

Figure 12: Received complex signal

The block diagram below summarizes the processing that took place upon receiving the transmitted signal. The block diagram shows that upon receiving the transmitted signal, the signals go through a filtering process where the individual signals were extracted and then passed through Quadrature baseband demodulation to retrieve the required individual signals S_1, S_2 and S_3.

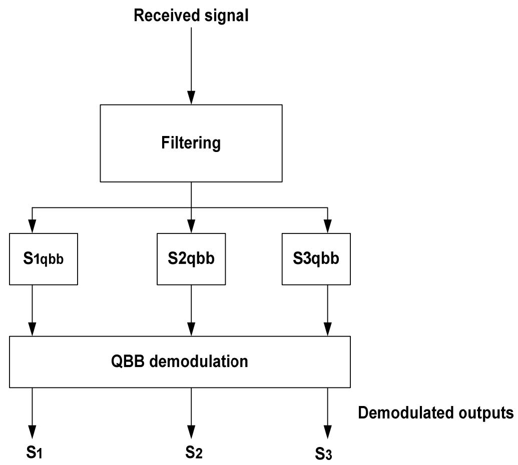

Figure 13: Received signal processing

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IV. CONCLUSION

The results obtained from the simulation show that it is possible to send multiple signals over a low frequency baseband channel and retrieve them at the receiving end. This study is a contribution to the various researches in baseband technologies that are necessary for the further advancement of Software defined radio technology which makes considerable usage of baseband processing. The original input signals were then extracted by carrying out filtering and then demodulating of the signals. It can also be noted that working at baseband provides for more sub-sampling given the face that the frequencies at baseband are lower.

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