Department of Electrical & Electronics Engineering

Abdullah Gül University

EE3001 Lab 5

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Grade: / 100

OBJECTIVE

The objective of this lab exercise is to introduce suppressed carrier modulation and demonstrate its implementation through the design of a transmitter and receiver device using NI LabVIEW with the NI USRP 2900 platform. Specifically, the objective is to extend a "double-sideband suppressed-carrier" diagram that is capable about transmitting and receiving signals and data within specific design parameters. In addition, we have a phase synchronizer in the receiver to ensure proper demodulation and synchronization of the received character. Through this exercise, team members will benefit from hands on design information on the concepts of suppressed carrier modulation in NI LabVIEW. Moreover, phase synchronizer and its realistic application will be observed.

BACKGROUND

In communication systems, amplitude modulation, or AM, is a popular modulation method. However, the carrier signal contains most of the transmitted power, it is naturally inefficient. Techniques for suppressed-carrier modulation have been developed as a response to this inefficiency. Single-sideband (SSB) modulation and double-sideband suppressed-carrier (DSB-SC) modulation are two common methods.

The carrier signal is eliminated during DSB-SC modulation, leaving only the sidebands carrying the data from the message signal. The DSB-SC signal g(t) has the following mathematical expression:

$$g(t) = Am(t)\cos(2\pi f_c t)$$

Where:

- $m(t)$ represents the baseband "message" signal.
- A is a constant representing the amplitude of the transmitted signal.
- f_c is the carrier frequency.
- $\cos(2\pi f_c t)$ represents the carrier signal.

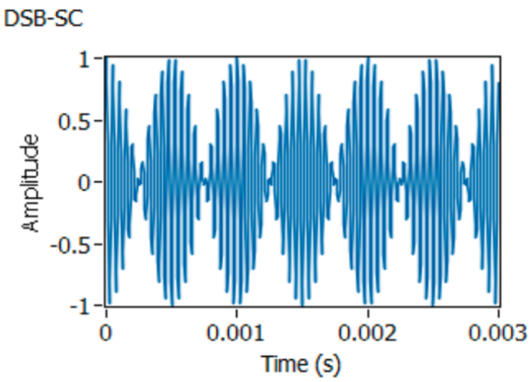


Figure-1 Double-Sideband Suppressed-Carrier Modulation

For the special case in which $m(t) = m_p \cos(2\pi f_m t)$, we can write

$$g(t) = Am_p \cos(2\pi f_m t)\cos(2\pi f_c t)$$

$$= \frac{Am_p}{2}\cos(2\pi(f_m - f_c)t) + \frac{Am_p}{2}\cos(2\pi(f_m + f_c)t)$$

The two terms in the equation above represent the lower and upper sidebands, respectively. When the DSB-SC signal reaches the receiver, it takes the form:

$$r(t) = D \,.\, m(t) \,.\cos(2\pi f_c t + \theta)$$

Where:

- D is a constant, usually much smaller than A.
- θ represents the phase difference between the carrier oscillators of the transmitter and receiver.

The phase error θ will change over time if the oscillators of the transmitter and receiver have a small frequency difference. The received signal may get distorted since of this phase mistake. Many strategies can be used to decrease this problem. Phase synchronization is one such method that seeks to ensure synchronization between the oscillators of the transmitter and receiver in order to reduce the phase error term $\cos(\theta)$.

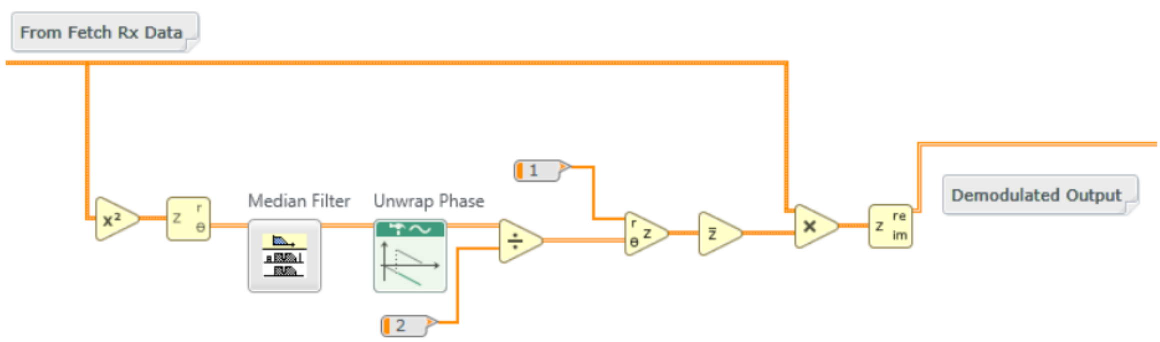


Figure-2 Phase Synchronization in LabVIEW Receiver Diagram

In this lab exercise, we use NI LabVIEW and the NI USRP 2900 platform to implement DSB-SC modulation. In order to decrease phase errors and enhance the fidelity of the received signal, we also use Phase Synchronization. Students who complete this experiment will have a better understanding of suppressed-carrier modulation methods as well as useful advice on how to deal with phase faults in communication networks.

RESULTS

- **PRELAB RESULTS**

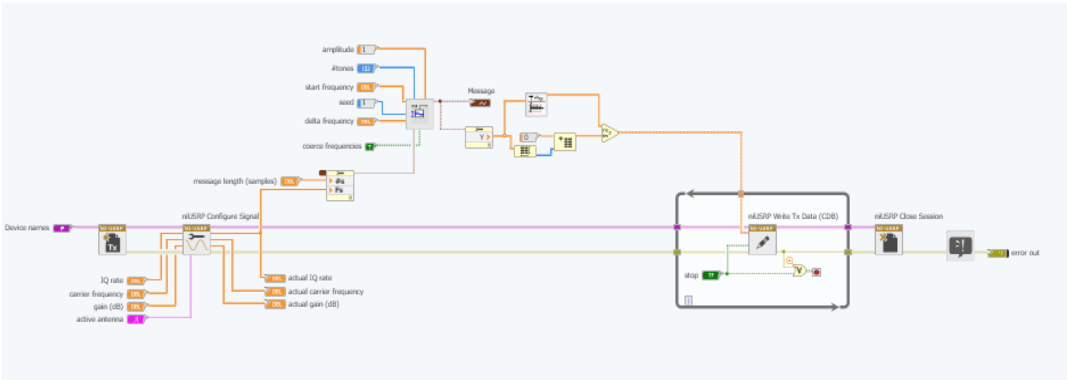


Figure-3 Transmitter Diagram

Figure-4 Transmitter Panel

The transmitter template in NI LabVIEW consists of a "message generator" module and four interface functions. The three tones which create the overall signal as this module generates at the frequencies of 1 kHz, 2 kHz, and 3 kHz, though these frequencies are adjustable. The message generator uses the summation of numerous sinusoids with constant amplitudes to generate signals. Additionally, the message generator has a "seed" mechanism built in to ensure that the beginning phase angles of sinusoids remain unchanged from program run to program run. This function encourages uniformity and helps debugging processes by allowing the same messages to be generated each time the transmitter starts. Let's examine each of the components of diagram and panel in more detail:

Diagram: The diagram is the main hub for signal processing in the transmitter template. It includes building pieces for interface integration, message writing, and tone generation, etc.

Panel: The interface of the panel gives users interactive controls to modify several parameters that influence the process of signal production. It is possible to adjust parameters like IQ rate, tone frequencies, and delta frequency to customize the signal to suit specific requirements.

- **Delta Frequency**: The value of this parameter indicates how much space there is between neighboring tone frequencies. It must meet the requirements of being an integer multiple of the sample frequency divided by the number of samples and guarantee appropriate frequency spacing.
- **IQ Rate:** The rate at which the signal generator interprets actual (I) data is indicated by the IQ rate. This parameter has a major impact on the signal generation process' accuracy and efficiency.

In conclusion, NI LabVIEW's transmitter template provides a solid framework for producing composite signals with modifiable properties. The integration of a message generator module including uniform phase angles and user-friendly interface controls improves signal generating efficiency and streamlines debugging procedures in communication system development.

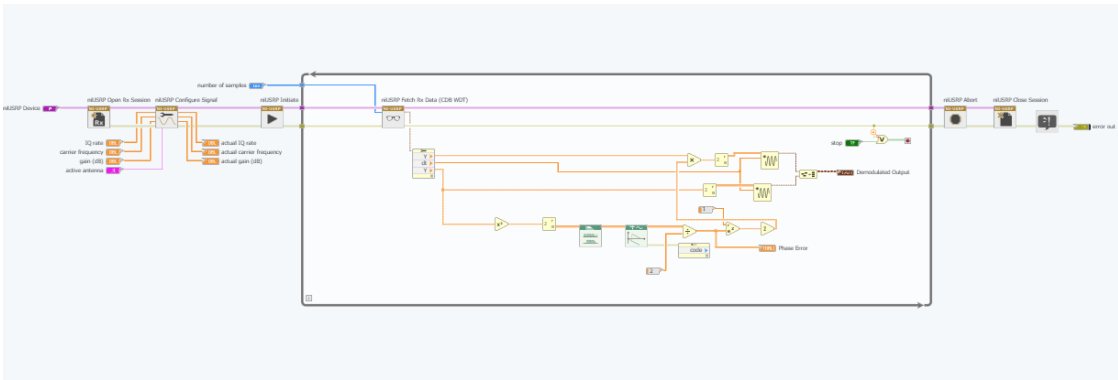


Figure-5 Receiver Diagram

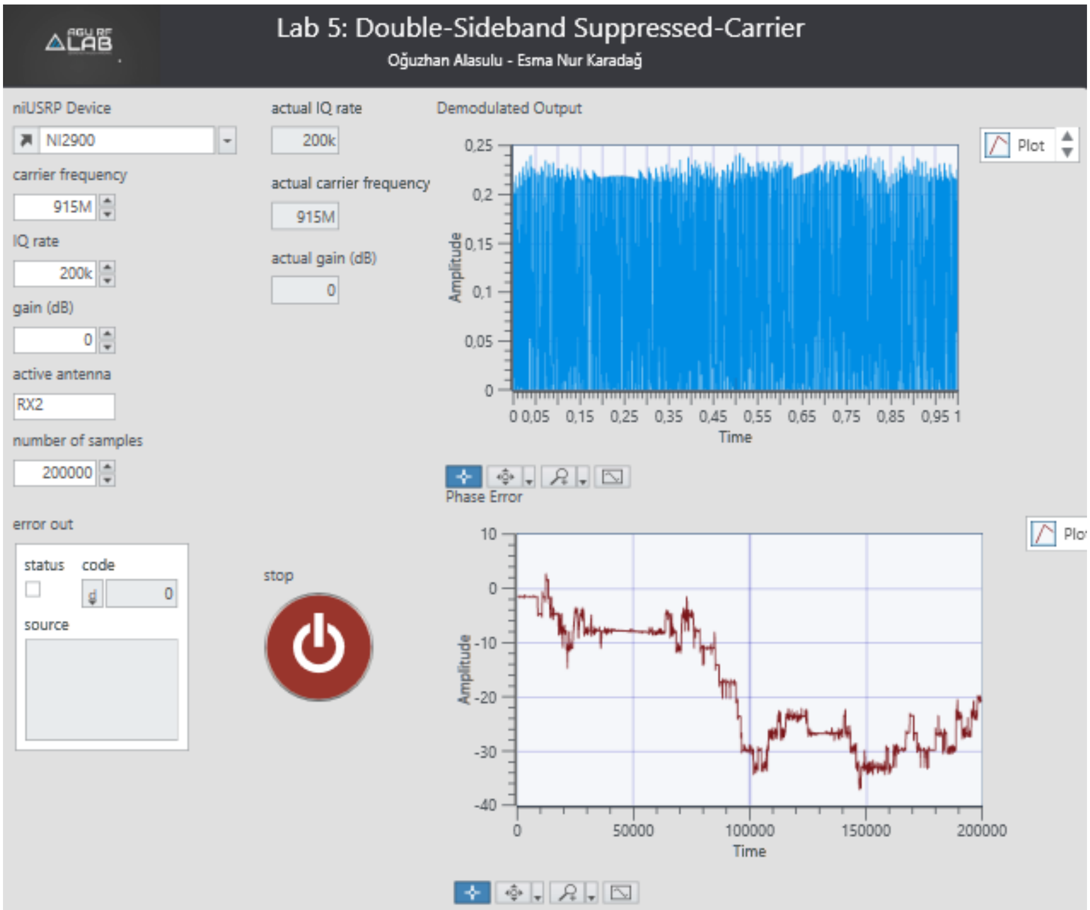
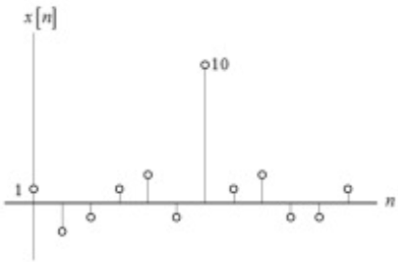


Figure-6 Receiver Panel

The receiver includes six interface functions. The receiver contains a waveform graph, providing a visual depiction of the demodulated output signal. One critical part related with the receiver is phase synchronization. Phase synchronization plays a crucial role in confirming the accurate demodulation of received signals, particularly in situations where small frequency differences exist between the transmitter and receiver oscillators. By implementing phase synchronization techniques within the receiver, we can mitigate potential phase errors introduced by frequency mismatches.

Prelab Questions:

- **Question 1:**



$$y[n] = median\{x[n-2], \dots, x[n+2]\}, \quad n = 0, \dots, 11$$

$$y[0] = median\{x[-2], x[-1], x[0], x[1], x[2]\} \rightarrow median\{0,0,1,-2,-1\} = 0$$

$$\dots$$

$$y[6] = 2$$

$$\dots$$

$$y[11] = median\{x[-13], x[-12], \dots, x[0], x[1], x[2] \dots x[13]\}$$

$$\rightarrow median\{0,0, \dots ,1,-2,-1, \dots 0\}$$

$$y[11] = 0$$

$$From\ this\ logic\ what\ we\ obtain\ for\ all\ n\ values\ are\ shown\ in\ below,$$

$$y[n] = [0,0,1,-1,1,1,2,1,1,1,0,0]\ for\ n = 0,1, \dots, 11$$

- **Question 2:**

$$r(t) = D\,.\,m(t)\,.\cos\,(2\pi f_c t + \theta)$$

$$Equation\ can\ be\ incorporated\ with\ the\ frequency\ offset\ by\ letting,$$

$$\theta = 2\pi\Delta f t$$

$$Then\ we\ have$$

$$r(t) = D\,.\,m(t)\,.\cos(2\pi(f_c + \Delta f)t + \theta)$$

$$In\ terms\ of\ complex\ baseband\ representation,$$

$$\bar{r}(t) = \frac{D}{2} m(t) e^{j\theta}$$

$$becomes,$$

$$\bar{r}(t) = \frac{D}{2} m(t) e^{j2\pi\Delta f t}$$

- LAB RESULTS

2- Transmitter Set Up

Figure-7 Transmitter Set Up

3- Receiver Set Up

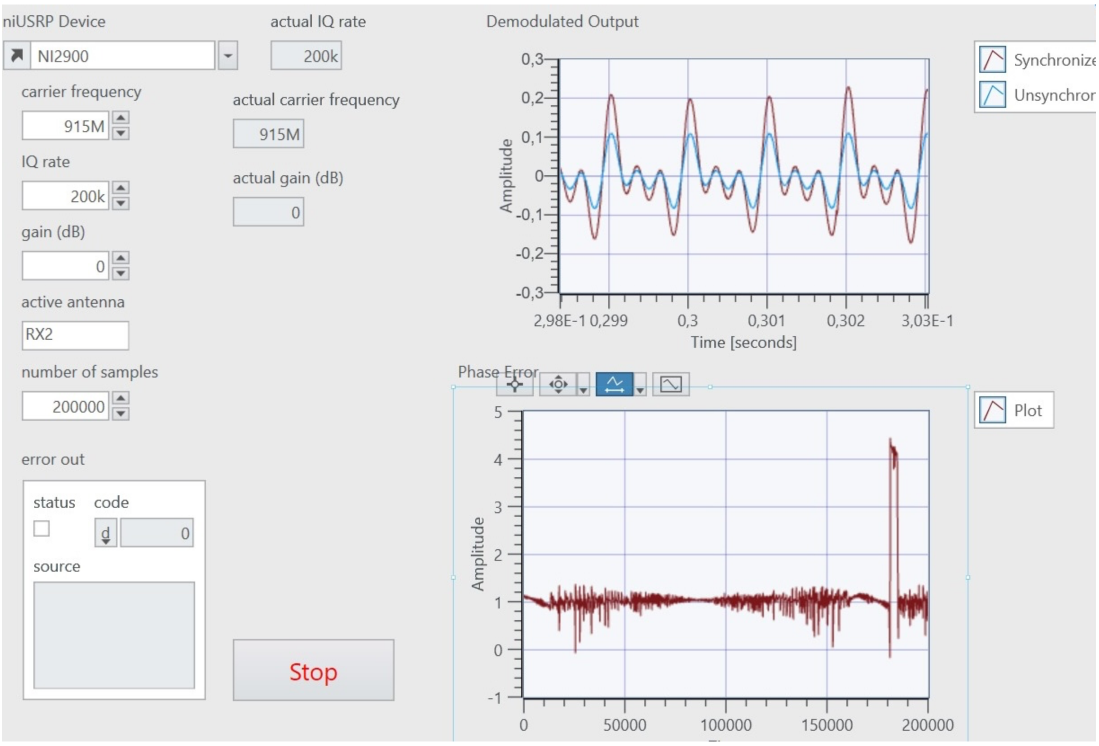


Figure-8 Receiver Set Up

4- Effect of Phase Synchronizer

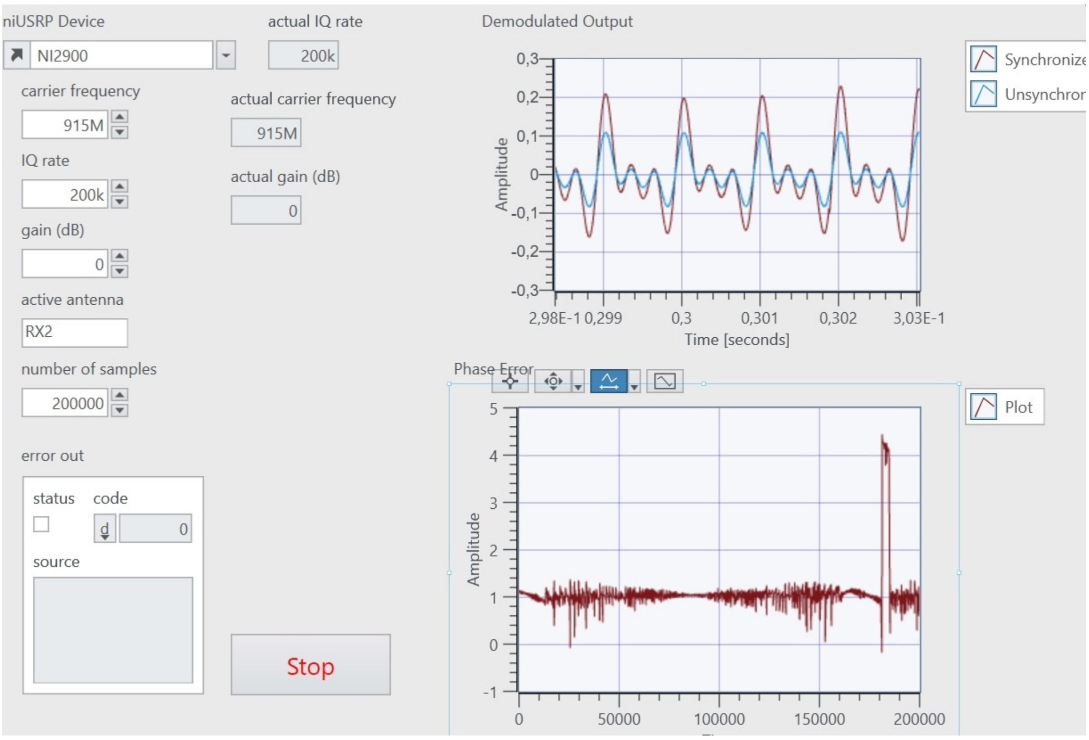


Figure-9 Receiver with Phase Synchronizer

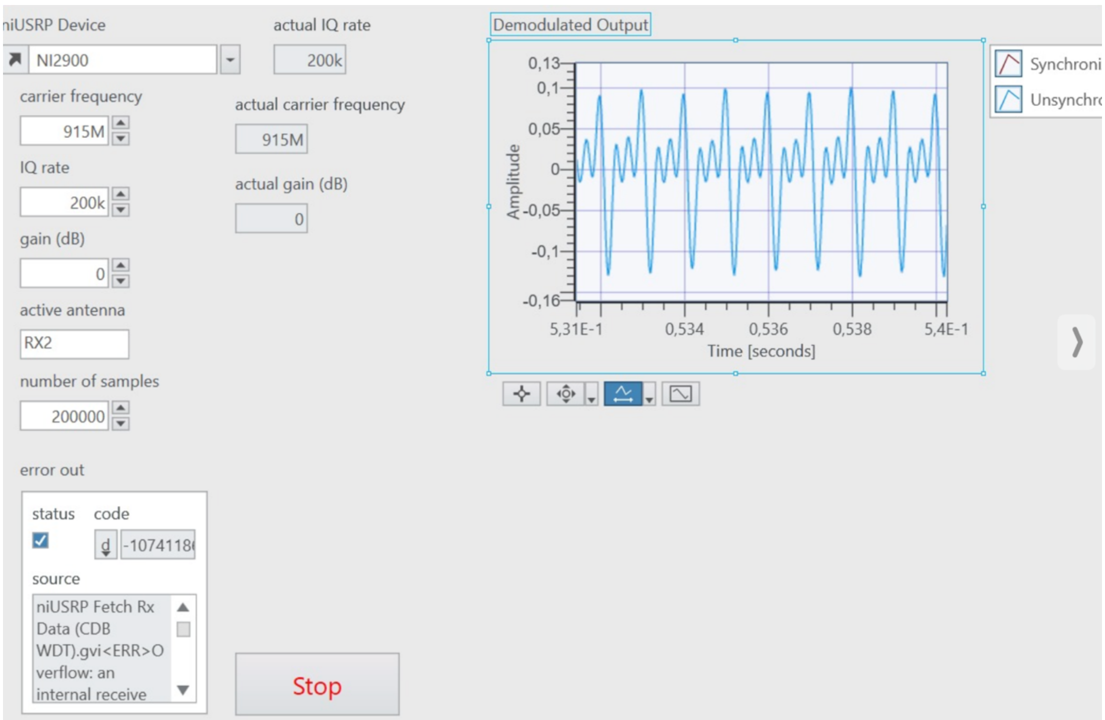


Figure-10 Receiver without Phase Synchronizer

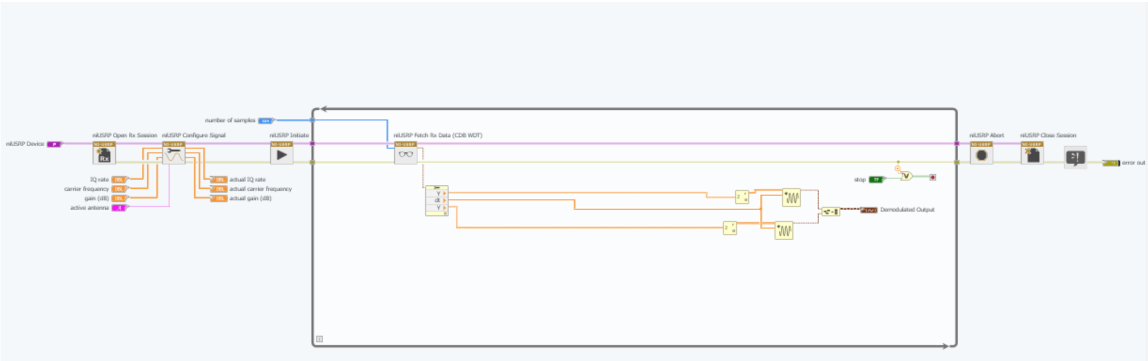


Figure-11 Receiver without Phase Synchronizer Diagram

Team members can obviously observe synchronized and non-synchronized graphs periodically at demodulated output with minimal phase errors with overlapping before we remove the phase synchronizer. However, the demodulated output appears slightly compressed and resembles the mirrored counterpart of the transmitter signal when the phase synchronizer is removed. That makes the impact of $\cos(\theta)$ clear to see.

5- Changing the Transmitter Frequency

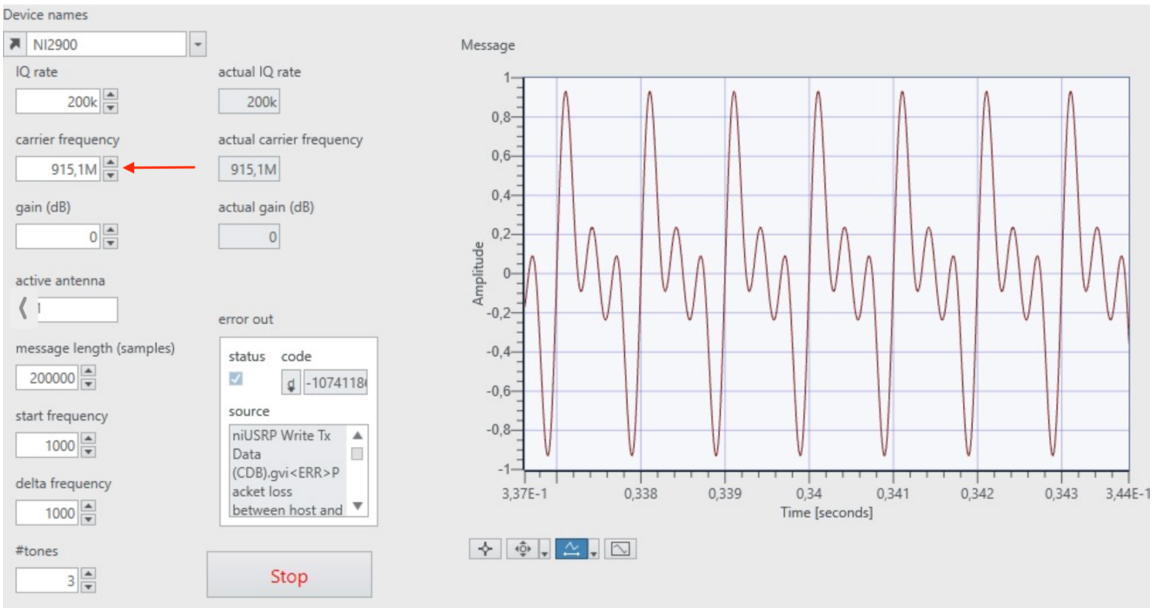


Figure-12 Transmitter with 915.1MHz Carrier Frequency

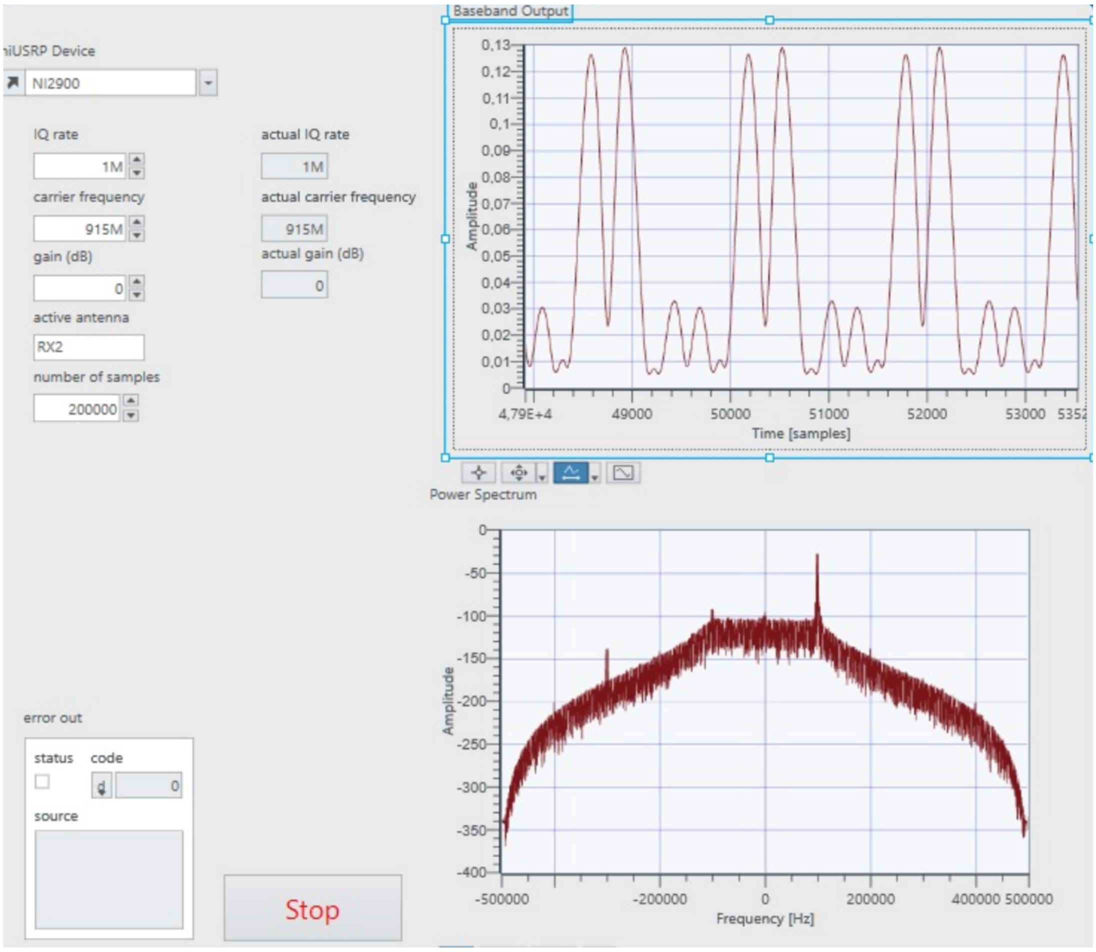


Figure-13 Lab 2 Receiver Panel of Transmitted 915.1MHz Carrier Frequency Signal

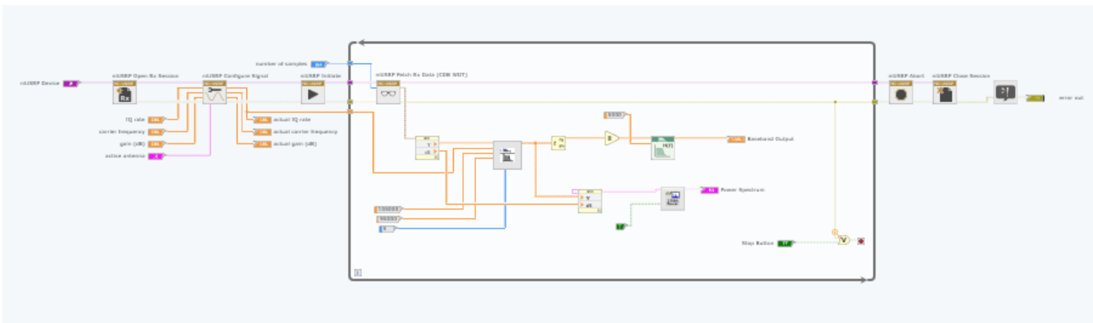


Figure-14 Lab 2 Receiver Diagram of Transmitted 915.1MHz Carrier Frequency Signal

In fact, it is clear from the findings that the envelope detector of AM receiver successfully demodulated the DSB-SC signal. In order to that, we use the This was seen in the power spectrum as well as the baseband output, indicating that the receiver could accurately demodulated the transmitted signal.

6- Frequency Offset Effect

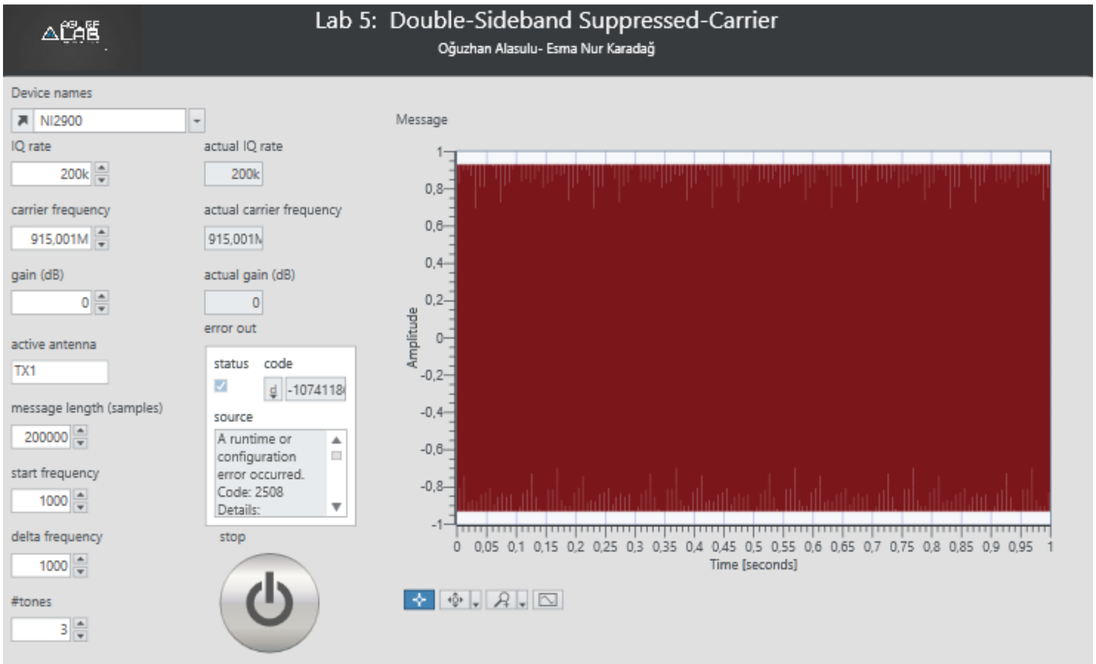


Figure-15 Transmitter with 1kHz Offset with Synchronizer Panel

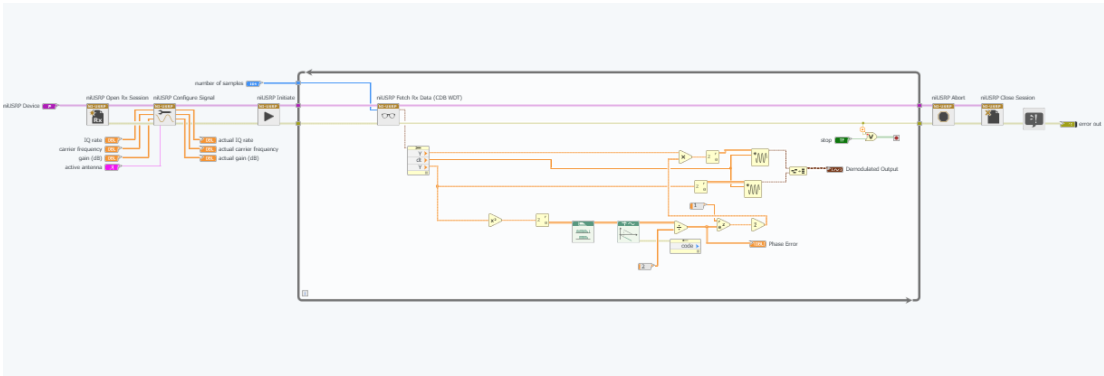


Figure-16 Transmitter with 1kHz Offset with Synchronizer Diagram

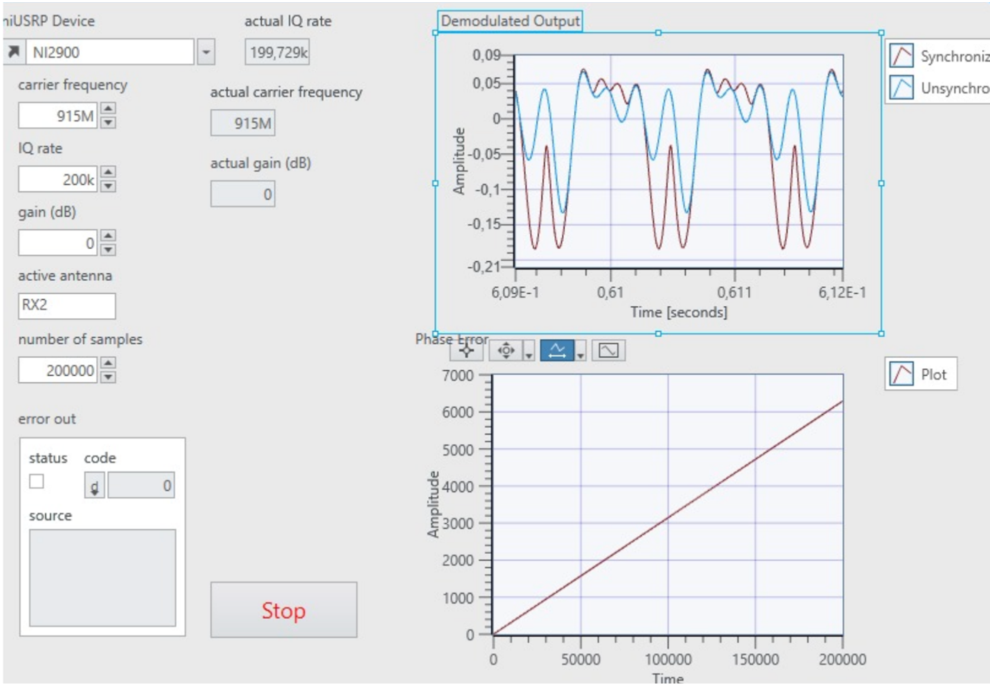


Figure-17 Receiver with 1kHz Offset with Synchronizer Diagram

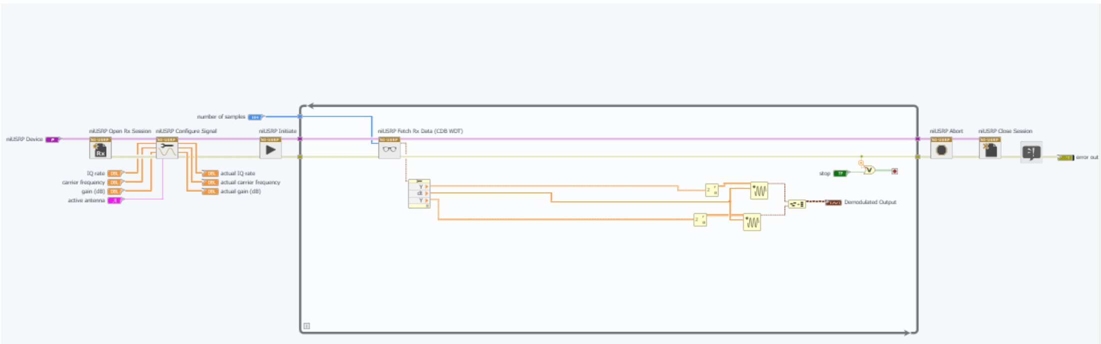


Figure-18 Receiver with 1kHz Offset without Synchronizer Diagram

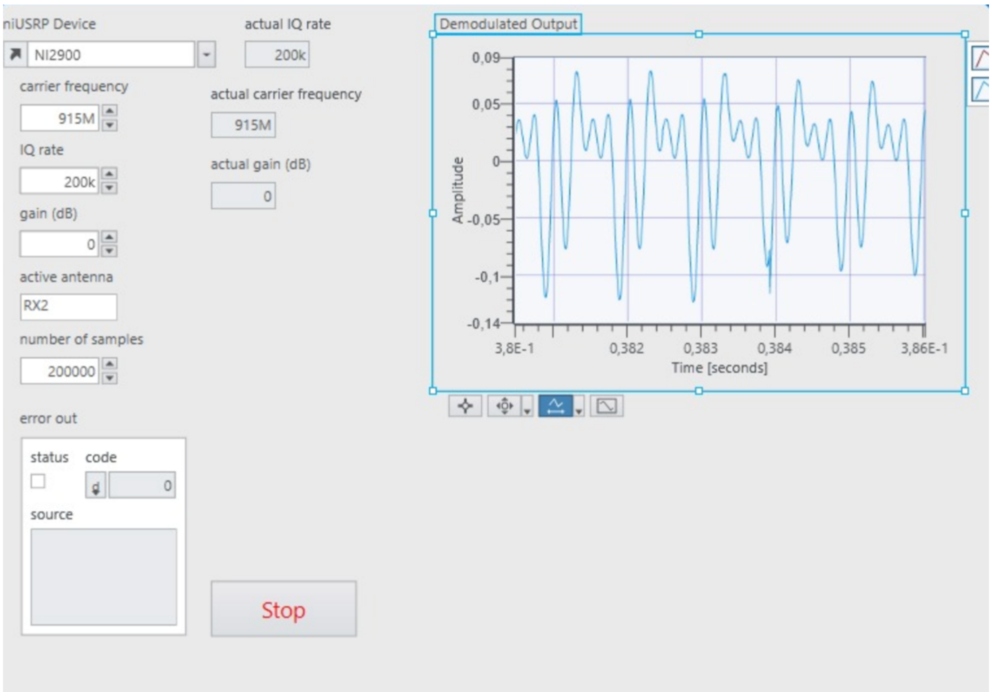


Figure-19 Receiver with 1kHz Offset without Synchronizer Panel

Undesirably, the team encountered challenges in applying modest frequency offsets of 10Hz and 100Hz due to their negligible impact on the carrier frequency. However, they successfully implemented a 1kHz frequency offset, as illustrated in Figure-15. Upon setting up the transmitter, the team proceeded to analyze the effects with and without the synchronizer, as depicted in previous figures in the “Frequency Offset Effect” chapter of “Lab Results” part of lab report.

As depicted in Figure-18, the synchronized diagram managed to handle the 1kHz offset, albeit not flawlessly. Conversely, removing the synchronizer resulted in distorted demodulated output waveforms.

CONCLUSIONS

Using NI LabVIEW and the NI USRP 2900 platform, the double-sideband suppressed-carrier amplitude modulation (DSB-SC AM) Lab 5 experiment has given us a thorough grasp of this modulation approach. Transmitter and receiver system design and execution have given us important new perspectives on the pragmatics of communication system development.

The task of changing the transmitter frequency was difficult at first, but we were able to complete this part of the experiment by using what we had learned in Lab 2 and modifying our strategy. Every assignment offered chances for development and learning, which eventually improved our understanding of how to use NI LabVIEW, USRP 2900, and telecommunications principles.

In addition, the investigation of team members into the phase synchronizer has been especially enlightening. Team members not only comprehend its importance in signal synchronization, team members additionally also have practical knowledge of using it in the LabVIEW environment. Team members continued to try to figure out how the phase synchronizer performed and how it affected things so that team members could learn more about the significance of phase synchronizer and DSB-SC AM on communication networks.

To sum it up, the Lab 5 project has been an excellent learning opportunity that has allowed team members to further develop their understanding of DSB-SC AM, NI LabVIEW, USRP 2900, and the real-world use of phase synchronization. It has given team members valuable skills and insights that will definitely help team members in future undertakings in the telecom industry and elsewhere.