Department of

Electrical & Electronics Engineering

Abdullah Gül University

Prelab 3 Report – Frequency Division Multiplexing

EE3001 Telecommunication System Design Capsule

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Grade: / 100

OBJECTIVE

The objective of this prelab is to understand impact of phase error θ on the demodulated output signal in a frequency multiplexed amplitude modulation system. Frequency Division Multiplexing (FDM) is used to transmit multiple signals over different frequency bands. The goal is providing analytical proof to illustrate that the phase error does not affects either demodulated output signals. This study plays a role in gaining understanding for the robustness of the modulation scheme against phase variations and ensuring reliable signal recovery. In addition, in this prelab, the implementation of AMonSubcarrier sub-VI helps us to generate modulated signals and receiver design will filter and extract transmitted signal.

BACKGROUND

The basic idea of amplitude modulation (AM) lies on amplitude of a carrier signal is varied in proportion to a message signal. In this lab, multiple signal frequencies are multiplexed onto subcarriers and transmitted simultaneously. FDM enables the simultaneous transmission of two distinct information signals over the same communication channel by allocating them to separate frequency bands. Phase error is one of the concerns in AM, arising from imperfect synchronization between transmitter and receiver. The signal can be distorted by phase shifts. However, in envelop-based detection, phase error may not affect the output depending on the system setup. To validate this, analytical approach will be taken to show that phase error does not affect the extracted message. The pre-lab tasks involve creating a sub function to generate modulated signal, which is designed to facilitate this process by ensuring that each signal is appropriately modulated and transmitted without interference.

DESIGN AND TEST PROCEDURES

A key requirement for the main lab is the development of a sub-function responsible for generating a signal modulated by a sub-modulator (oscillator). This function will be integrated into the transmitter (TX) configuration to implement a frequency division multiplexing (FDM) technique.

First, here is the sub-function created in NI Communication Suite (Figure 1).

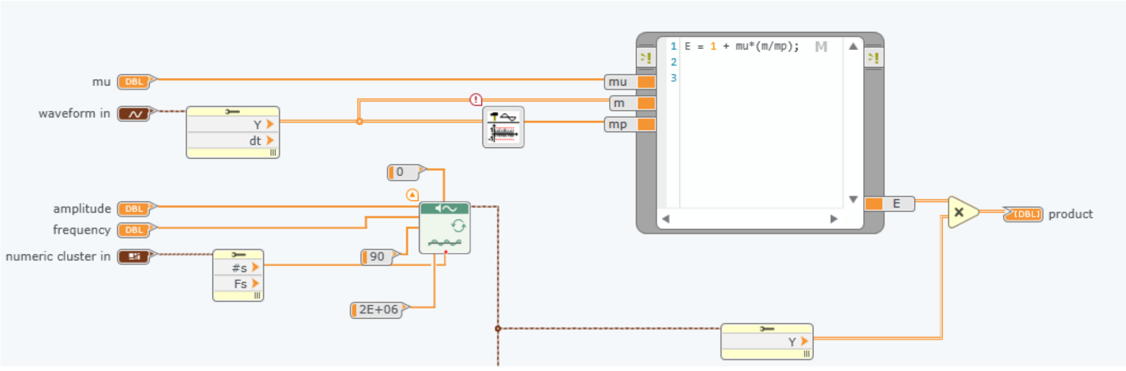

Figure 1 – Sub-function to handle signal generation for Frequency Division Multiplexing system

As prelab document refers to input and output document[1], function has 5 input (Figure 2) and 1 output.

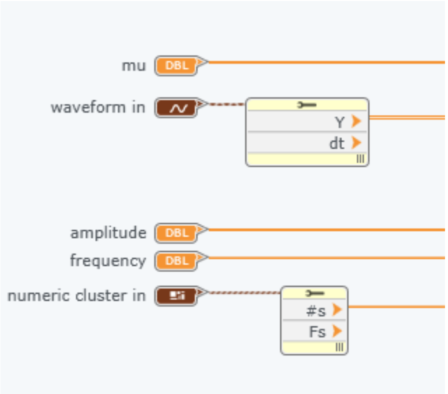

Figure 2 – Inputs of the function

numeric cluster in is used to get sampling information from Tx session. mu is modulation index. Next to modulate signal for FDM, a waveform generator and a Quick Scale 1D, which is a function to find peak value of the message signal, are needed (Figure 3).

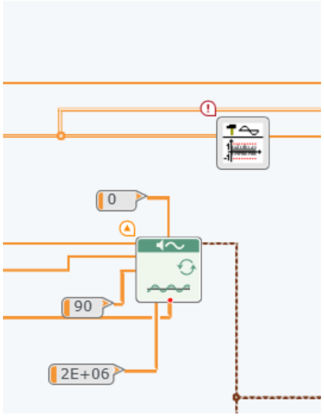

Figure 3 – A waveform generator with 90-degree phase shift (to produce cosine signal), 2 million sample input and 0 offset

Next, to apply modulation index and peak value of the signal, a Math Script is used to formulate, and a multiplication block is used to modulate (Figure 4).

[1] Introduction to Communication Systems, Lab Based Learning with NI USRP and LabVIEW Communications, page 32, table 1

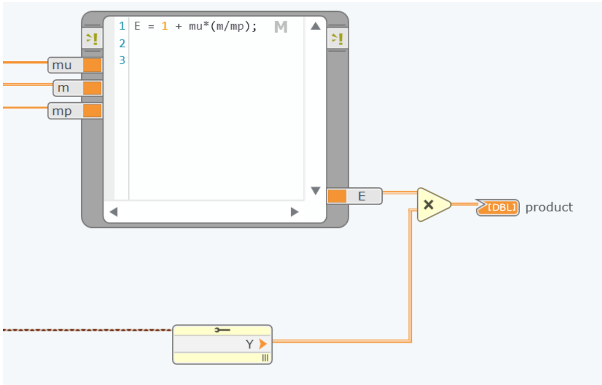

Figure 4 – Math Script is for performing a calculation on the signal and multiplication is for modulation with signal and waveform generated as cosine

At the end, a product as a output is obtained and the function block is created (Figure 5).

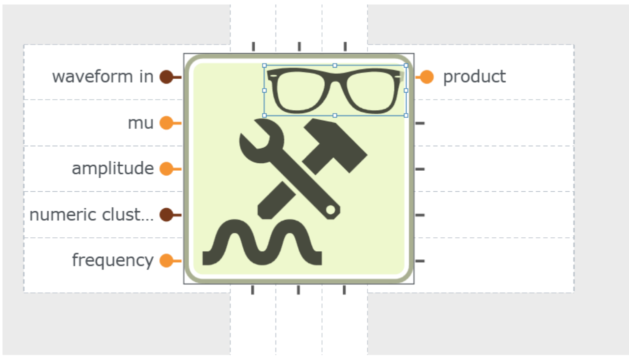

Figure 5 – Block of sub-function

In Tx session two Basic Multitone function is used to produce two different outputs. Then the signals are sent to the sub-function to modulate independently from each other. Next, the outputs of the functions are summed (Figure 6).

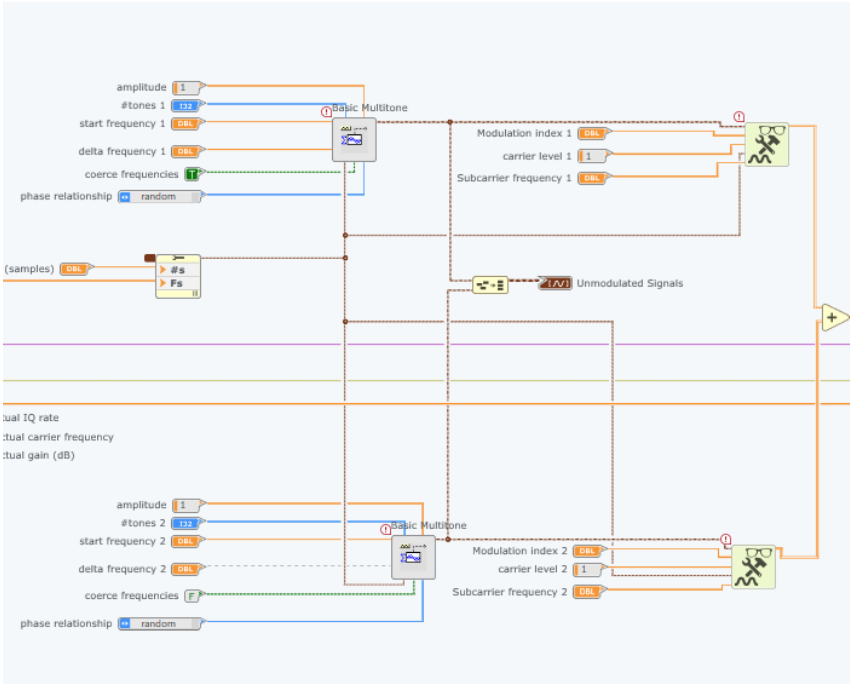

Figure 6 - Basic multitone functions and sub-functions to create and to modulate signals

Next to write the data on niUSRP Write Tx Session, a Build Waveform, a Re/Im to Complex and reciprocal is used to generate complex data. The main process in Figure 7 is simply creating a array with zeros as complex elements and the real part comes from the function outputs in Figure 6.

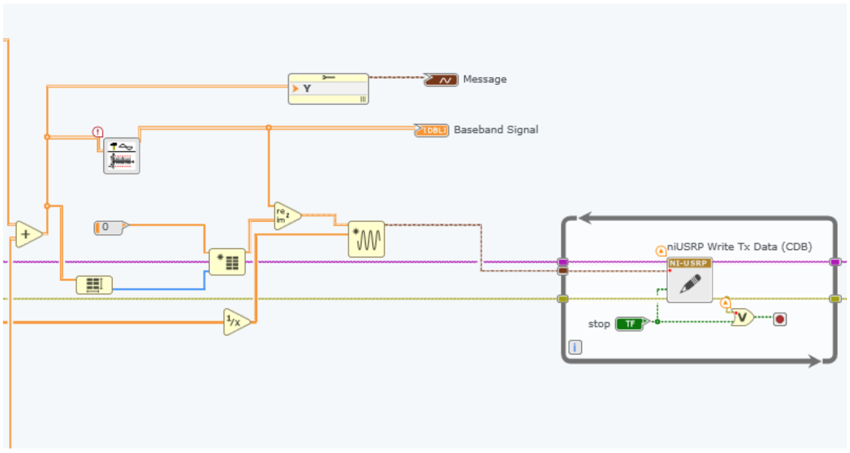

Figure 7 – Excluding of complex elements as making them 0

In the Rx session the demodulation process involves a separation process of the two individual messages from the received signal. This is accomplished using two bandpass filters, each designed with cutoff frequencies. The first bandpass filter has a low cutoff frequency of 495 kHz and a high cutoff frequency of 505 kHz. The second bandpass filter has a low cutoff frequency of 505 kHz and a high cutoff frequency of 515 kHz. Following the bandpass filtering part, an envelope detector is employed to retrieve the original information signals. The envelope detector consists of: An absolute value operation, which acts as a rectifier. A low-pass filter with a cutoff frequency of 5 kHz, ensuring that only the essential information is retained while eliminating high-frequency components. Additionally, a signal power measurement module is incorporated into the RX system, as illustrated in Figure 8, to analyze the received signal's power characteristics (Figure 8).

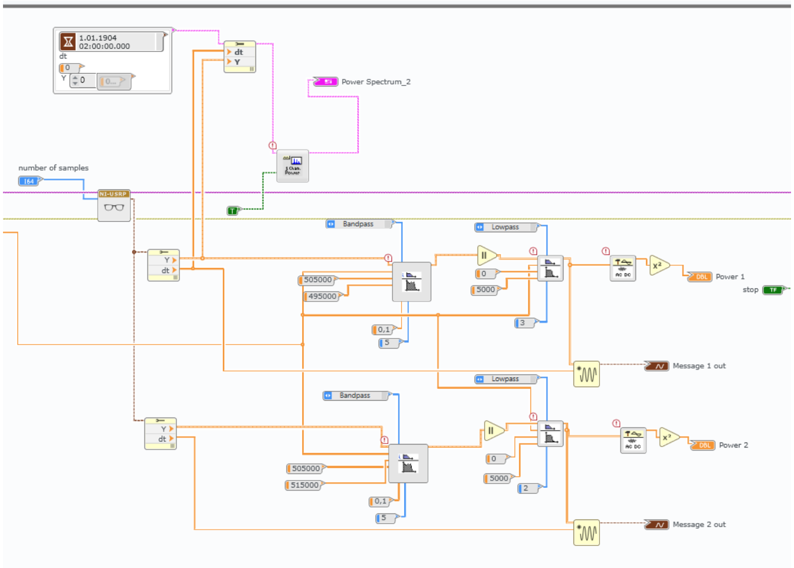

Figure 8 – Rx session function, bandpass and envelope detection

In the Prelab 3, there is a question that is wanted to be answered. Here is the question,

Question: Starting with Eq. (5), show analytically that the phase error θ does not affect either demodulated output signal. Note that in this lab project we do not take the real part of r(t) prior to bandpass filtering.

Answer: In the prelab document, Eq. 5 is as follows,

$$\tilde{r}(t) = D[g_1(t) + g_2(t)]e^{-j\theta}$$

The term $e^{-j\theta}$ comes from the phase difference between Tx and Rx oscillators. $e^{-j\theta}$ can be written as,

$$e^{-j\theta} = \cos\theta + j\sin\theta$$

And the $\tilde{r}(t)$ as

$$\tilde{r}(t) = D[g_1(t) + g_2(t)]\,[\cos\theta + j\sin\theta]$$

$$\tilde{r}(t) = D\cos\theta\,[g_1(t) + g_2(t)] + Dj\sin\theta\,[g_1(t) + g_2(t)]$$

Then signal is sent to bandpass filter to separate information

$$I_1(t) = D\cos\theta\,[g_1(t)] + Dj\sin\theta\,[g_1(t)]$$

$$I_2(t) = D\cos\theta\,[g_2(t)] + Dj\sin\theta\,[g_2(t)]$$

Next both signal $I_1(t)$ and $I_2(t)$ are sent to an envelope detector which takes at first its absolute value,

$$|I_1(t)| = g_1(t)|D\cos\theta \ + \ Dj\sin\theta|$$

$$|I_1(t)| = Dg_1(t)|\cos\theta \ + \ j\sin\theta|$$

And it is known that $|\cos\theta \ + \ j\sin\theta| = 1$, as a result,

$$|I_1(t)| = \ Dg_1(t)$$

This is same for $I_2(t)$. Finally, there is no effect of phase difference between Tx and Rx oscillator on the message.

CONCLUSIONS

As a conclusion, analyzing the impact of phase error on demodulated output signals in a frequency-division multiplexed amplitude modulation system was studied. Through theoretical derivations and system implementation, it was demonstrated that the phase error θ does not affect the extracted message signals. This property plays a crucial role in ensuring reliable communication even when phase synchronization is defective. AMonSubcarrier sub-VI provides to generate and process signal effectively.

REFERENCES

[1] Black, Bruce A., Introduction to Communication Systems, Lab Based Learning with NI USRP and LabVIEW Communications