Jacobs University Bremen

CO-522-B Intersession 2022

Communication Basics Lab

Lab Write-Up 1 : Transmitter Simulink Study

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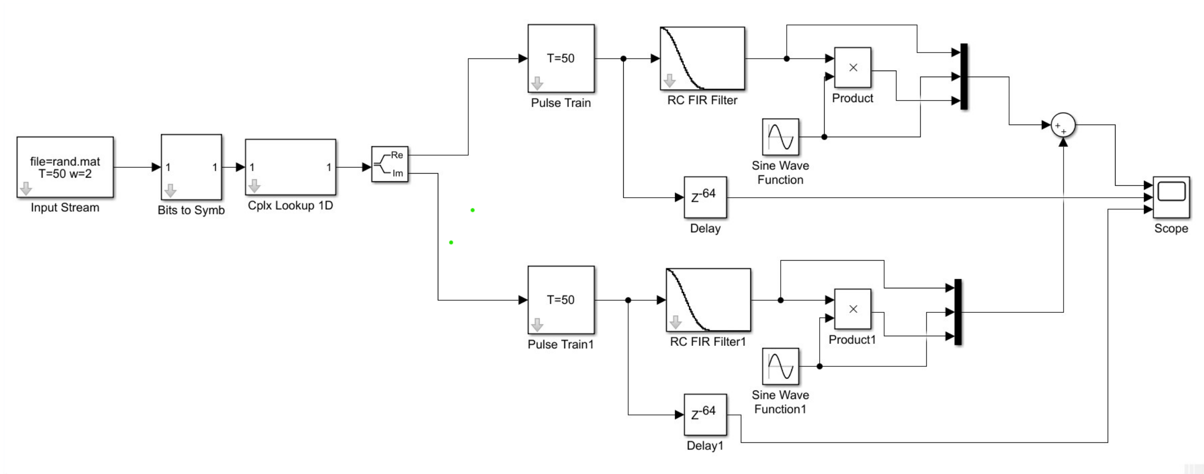
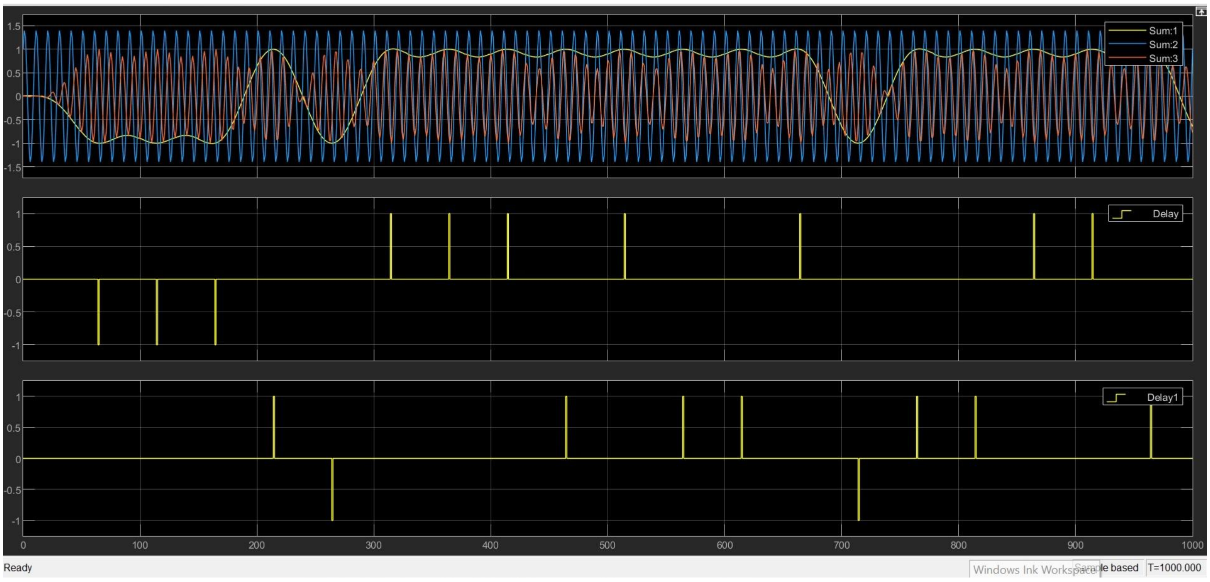
Explain in one or two paragraphs what you learned about communications systems that you didn't know before.

Although I had a rough idea of how a communication system worked before, it wasn't a complete one. Almost all the processes involved: i.e. Spectrally-Efficient Pulse Shaping, Decoding Pulses and Up Conversion were something new. Described henceforth is the actual process which was new to me. First, bits (or groups of multiple bits) are mapped to symbols which are represented as integers. Then, these integers are used to modulate a carrier wave (in this case, a sine wave at a high frequency) using a phase shift (hence the name BPSK - Binary Phase Shift Keying). This is done by changing the phase of the carrier wave according to the respective integer of the original message (since this is binary, each change from 1 to -1 or vice versa results in a phase shift of 180 degrees). This is only one method of modulation: i.e. even the amplitude of the carrier could be used to represent the original message. These properties of the carrier wave are represented by mapping the signal in a complex plane and representing them in terms of I/Q components. Each symbol is then mapped to a pulse 1 sample wide and superimposed with the other pulses. This modulated carrier is then received at a receiver and demodulated to get the original signal.

Show a picture of your final QPSK transmitter. Explain briefly what the different blocks are for. Explain how you checked that it was working correctly. A plot of the output showing important signals would be very helpful.



-Input Stream : Taken from the file ‘rand.mat’ which contains a single vector of 0s and 1s.
-Bits to symb: It converts the 1s and 0s (bits) from the Input Stream to symbols.
-Cplx Lookup 1D: In this block, the value from the previous block will be mapped into a new value according to the specified array in the parameters. In this case ‘[1 j -1 -j]’ is used to convert the value 00 to 1, 01 to j, 10 to -1 and 11 to -j.
-Complex to Real-Imag: Taking in the values converted in the lookup block, the signal is split to real and imaginary parts.
-Pulse Train: This is like a sampling operation. It obtains discrete values of the signal at a regular interval and is responsible for pulse shaping.
-Delay: The delay helps with comparing the original signal to the signal which has been filtered and combined by delaying the signal. In this case, two delay blocks on each branch are added to compensate for the 64-sample delay caused by the filter.
-RC FIR Filter: The filter eliminates interference and delays the signal by 64 samples. It cuts off unwanted frequencies with its properties to keep the bandwidth lower.
-Sine Wave Function: Responsible for the Up conversion of the signal (moving it to a higher frequency for transmission).
-Mux: Is used to get a single output from each branch of the transmitter.
-Scope: Both the imaginary and real parts are added and then fed into the scope for visualisation of the signal.



Since the real and imaginary parts of the pulse perfectly match the original signal as seen above, the transmitter was verified to be in proper working condition.

Explain why we do pulse-shaping in communication systems, rather than just sending rectangular pulses.

Rectangular pulses in the time domain result in spectra similar to sinc functions in the frequency domain which are usually quite wide and overlap with each other. Hence, since we would like to avoid this overlapping (which distorts the signal) and work on a limited bandwidth (which is usually much cheaper practically), a sinc-spectrum is undesirable, and hence rectangular pulses are inefficient and impractical. Therefore, it is more efficient to map each symbol to a pulse with a desired shape (and more limited spectrum in the frequency domain (lower bandwidth)) and transmit the superposition of these pulses in time.

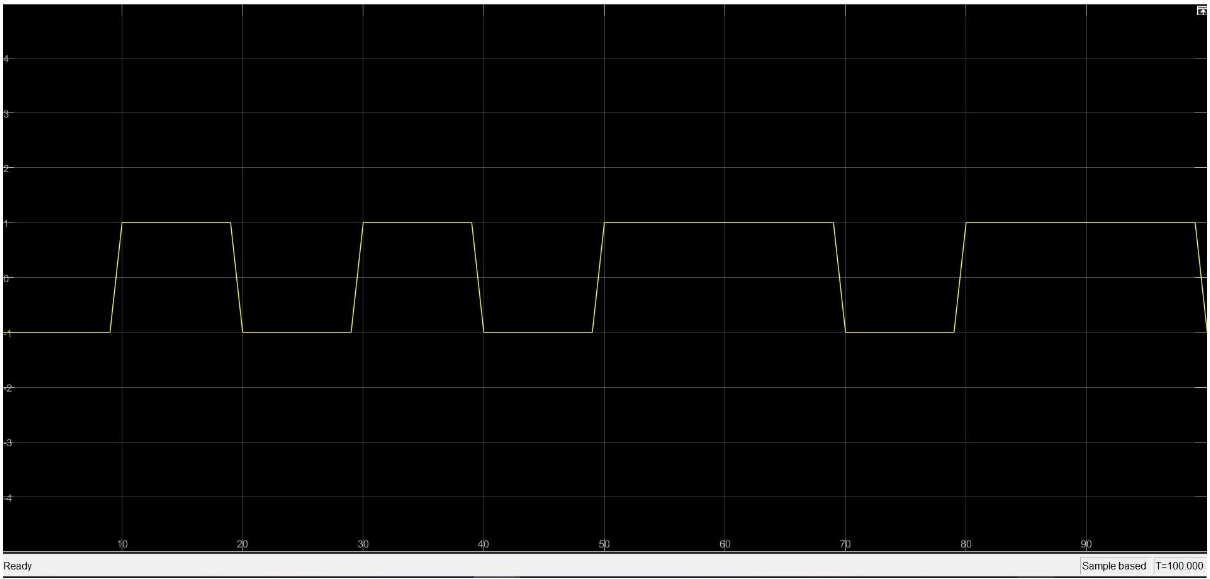
Tell why synchronization (e.g. sampling the received signal at the right place) is critical in a communications system that uses pulse shaping.

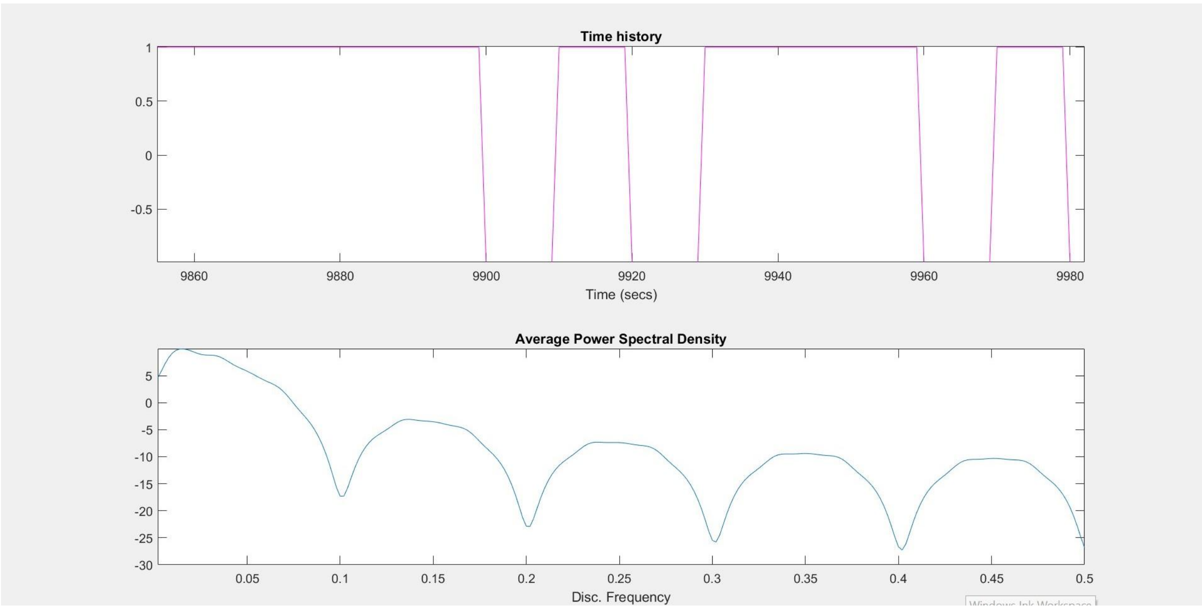
In most real world communication systems, the clocks of the transmitter and the receiver are not the same and the relative delay between transmission and reception is also not fully known. Hence, it is extremely important to correctly identify and locate the optimal sample points in the I/Q signals.This is where synchronization comes in to estimate and correct the sampling points and phase at the receiver in order to interpret the information stream correctly.

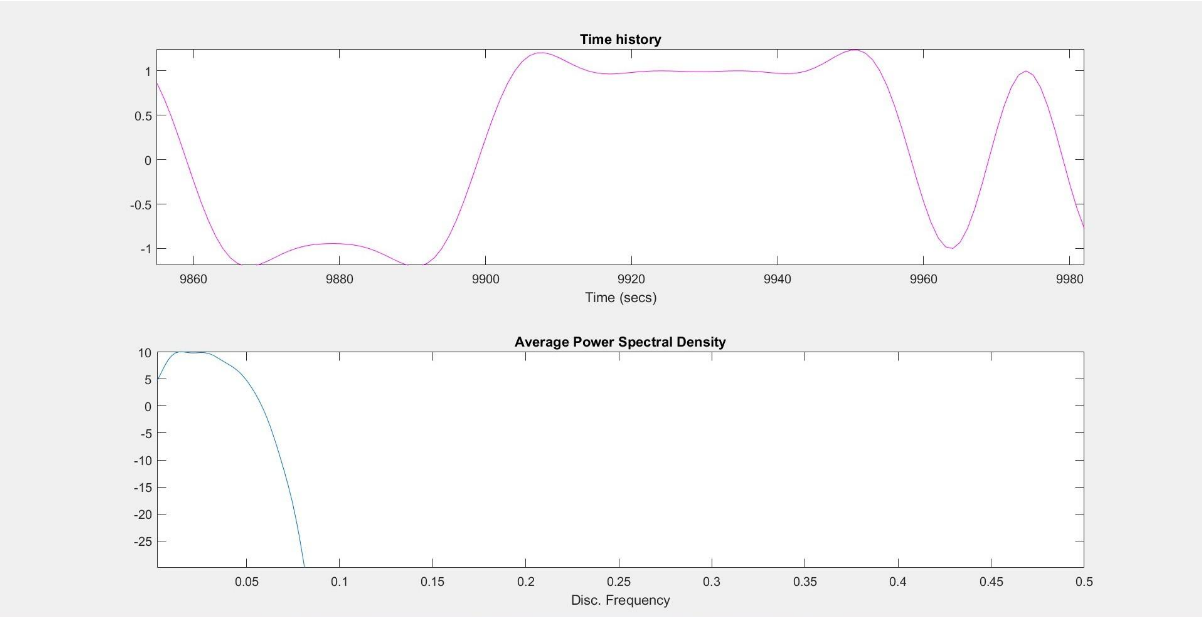
Describe any difficulties you experienced in getting your design to work and how you fixed these problems.

Initially, although the implementation was relatively easy, it was a struggle to understand what was actually going on in the system (the small details). However, this was also accomplished by taking a closer look at each block and understanding what the resulting output would be. The scope's visualisations were invaluable in this regard.

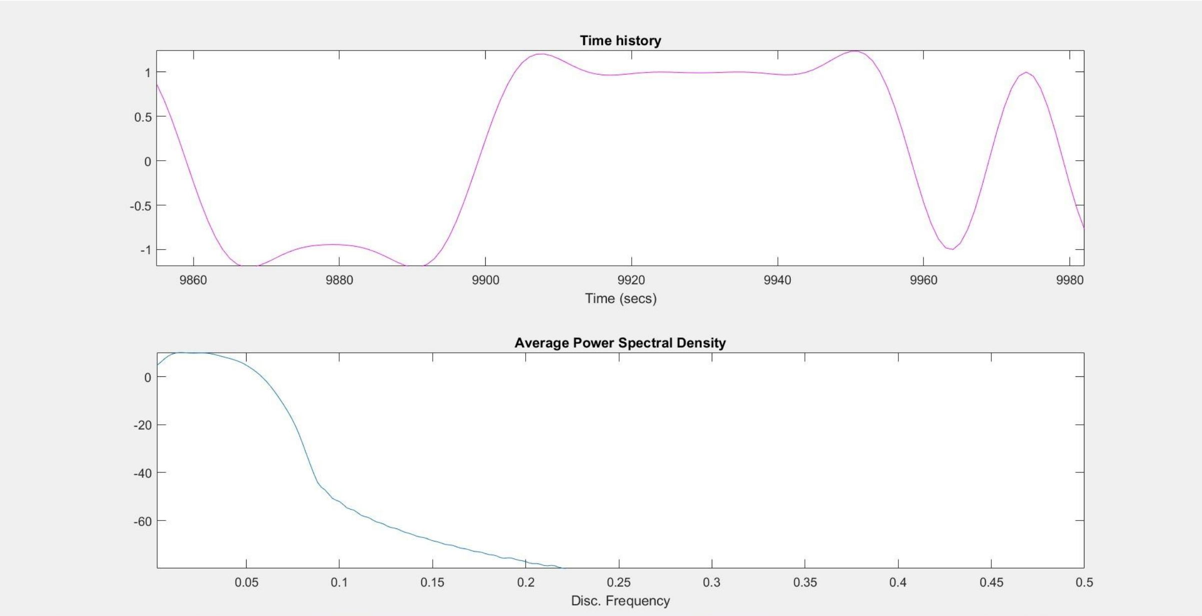
Appendix of Images from the Simulations conducted:



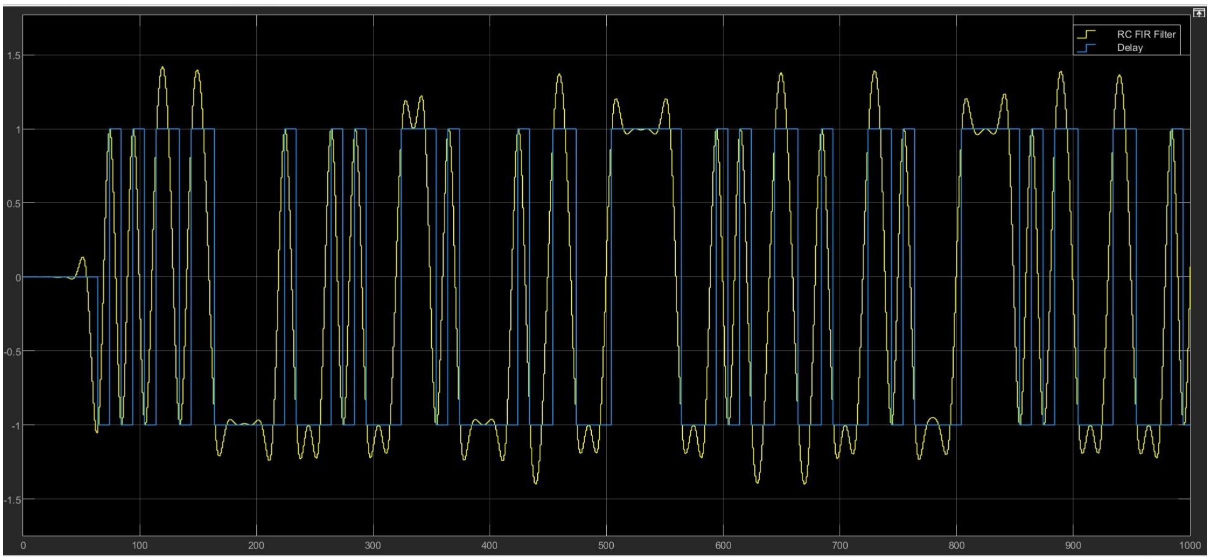


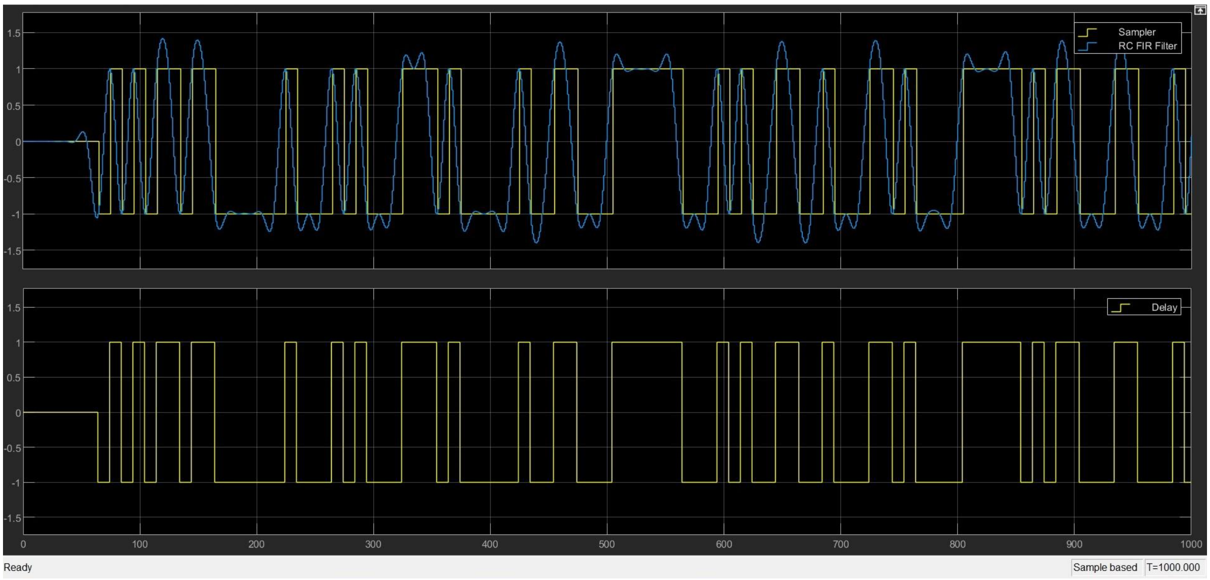


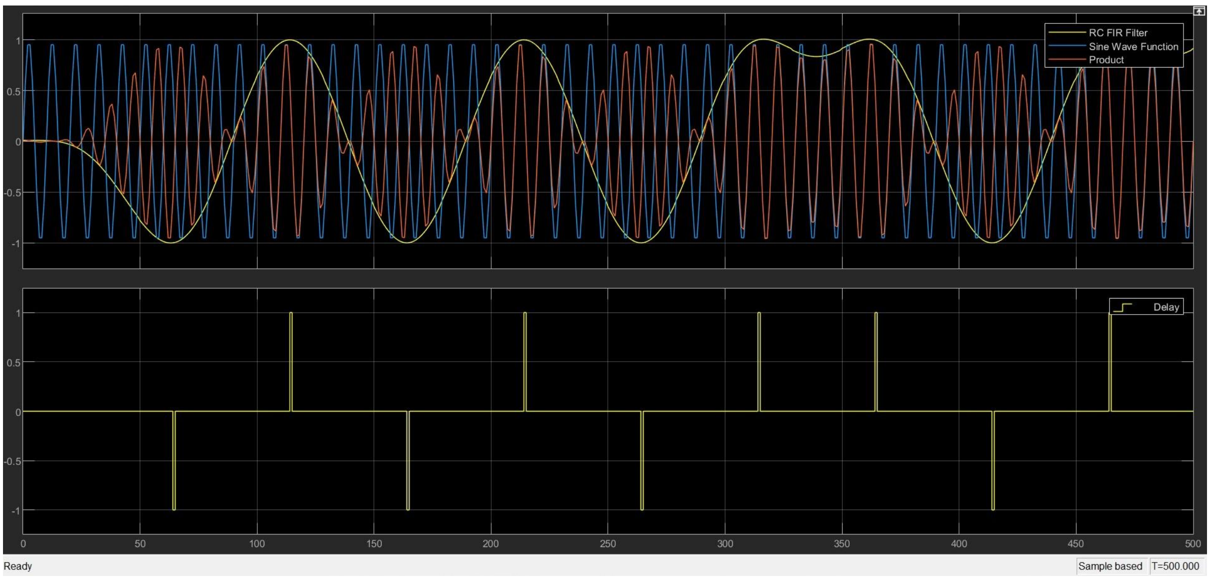
Time history
1
0.5
0
-0.5
-1
9860
9880
9900
9920
9940
9960
9980
Time (secs)
Average Power Spectral Density
10
5
0
-5
-10
-15
-20
-25
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Disc. Frequency

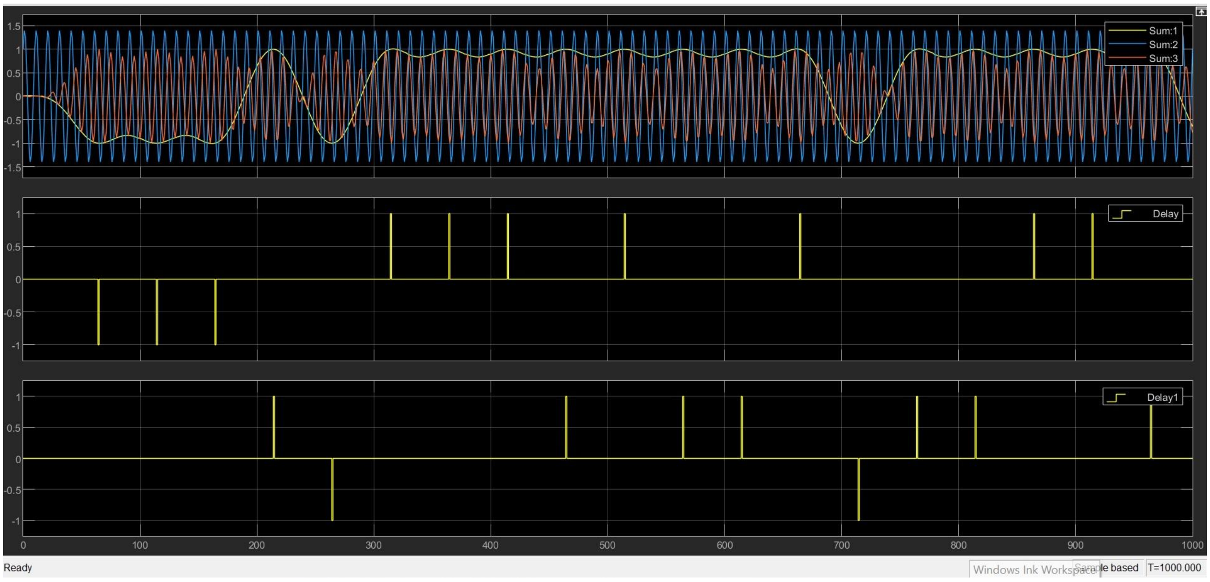


Time history
1
0.5
0
-0.5
-1
9860
9880
9900
9920
9940
9960
9980
Time (secs)
Average Power Spectral Density
0
-20
-40
-60
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Disc. Frequency


RC FIR Filter
Delay


Sampler
RC FIR Filter
Delay
Ready
Sample based
T=1000.000


RC FIR Filter
Sine Wave Function
Product
Delay
Ready
Sample based
T=500.000



Sum:1
Sum:2
Sum:3
Delay
Delay1
Ready
Windows Ink Workspace
Sample based
T=1000.000