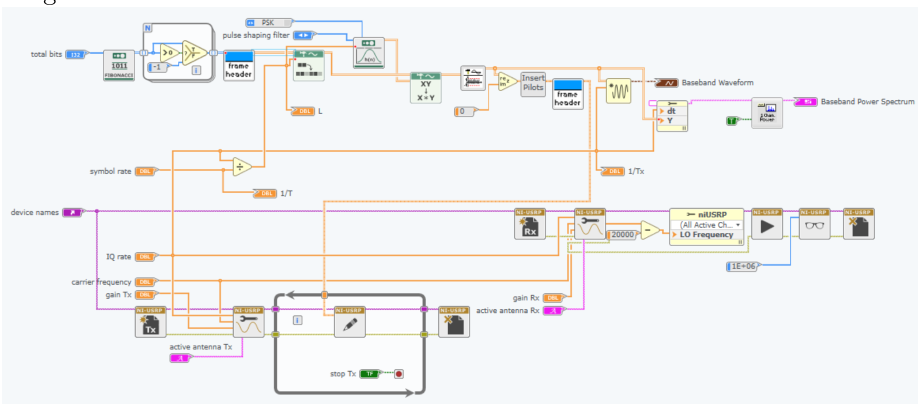
Lab 4 - Binary Phase Shift Keying (BPSK) Via USRP

Exercise 1 - BPSK Transmitter

Aim

In this exercise, we constructed a BPSK Transmitter

Diagram:



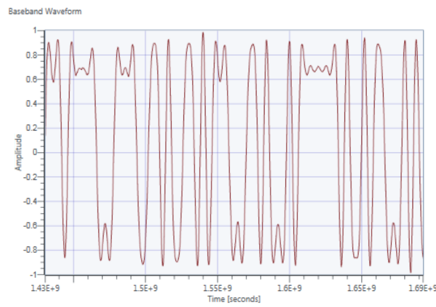
Observation

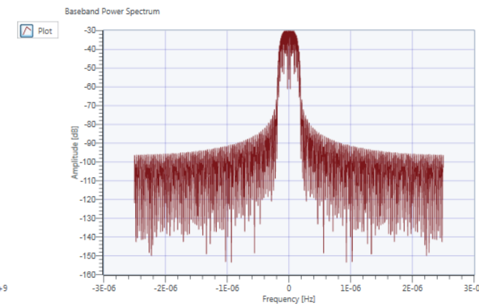
Values:

Carrier frequency	400 MHz
IQ Rate	200 kHz (Note: This sets the value of $1/T_x$)
Gain	0 dB
Active Antenna	TX1
Symbol rate	10,000 symbols/s
Message Length	1000 bits
Pulse shaping filter	Root Raised

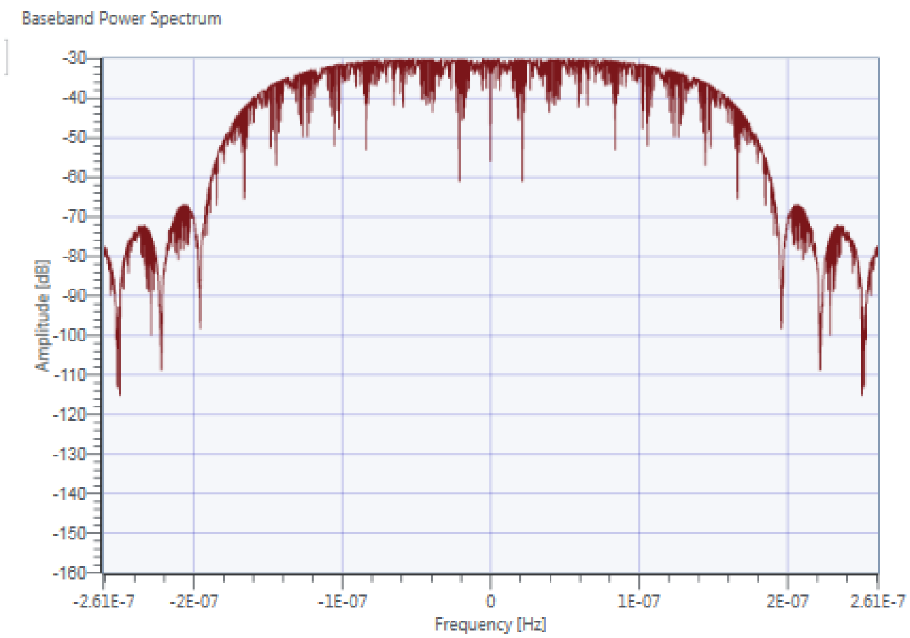
For a IQ Rate of 200k and a symbol rate of 10k the number of samples per symbol is 20.

Graphs for values above:



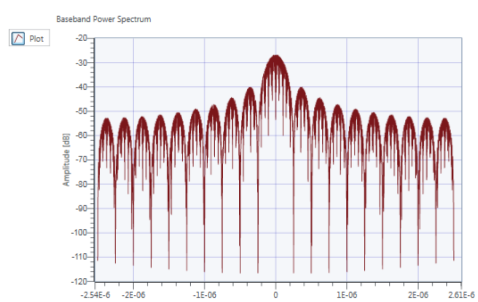


Main lobe:

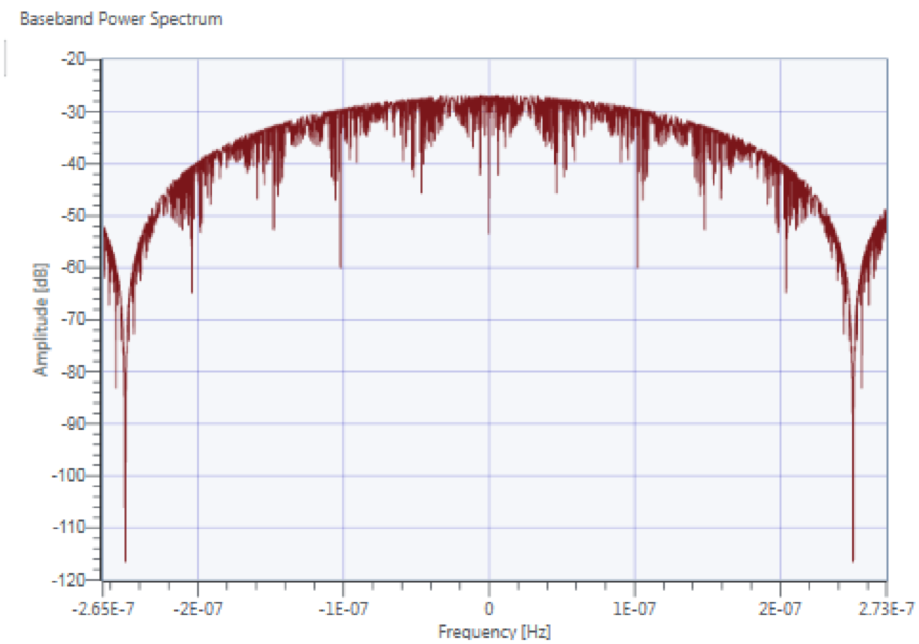


Main lobe bandwidth: 4e-07 Hz

No pulse shaping filter graphs:



No pulse shaping filter main lobe:



Main lobe bandwidth: 5.2e-07 Hz

- We observed that without a pulse shaping filter, the sideband lobes continued for a larger frequency range. This is because without a pulse shaping filter, higher frequency elements are required due to the rapid change in the message signal.
- Spectral rolloff is much faster using the pulse shaping filter.

Exercise 2 - BPSK Receiver

Aim

The steps needed to obtain the transmitted signals are:

1. Channel Estimation: This is required to remove phase ambiguity caused by the channel and the USRP oscillators. Because the Tx and Rx channels are both using free running oscillators, there will be some ambiguous phase offset that is highly dependent on the drift and skew of the oscillators themselves. The channel estimator attempts to correct this problem by reading the received pilots which you inserted in the Tx signal then performing the LSE channel estimation to find the channel transfer function. The channel transfer function is then inverted on the Rx signal to remove phase offset.

2. Matched Filtering: We will use a root-raised-cosine receiver filter. This filter's impulse response $g_{RX}[n]$ is matched to the pulse shape $g_{TX}[n]$ of the transmitted pulses. The matched filter gives optimum performance in the presence of additive white Gaussian noise.

3. Pulse Synchronization: The matched filter output is an analog baseband signal that must be sampled once per symbol time, i.e. once every *T* seconds. Because of filtering, propagation delays, and distortion caused by the communication channel, it is necessary to determine the optimum time to take these samples. A sub-VI called **PulseAlign** has been provided to align the baseband signal.

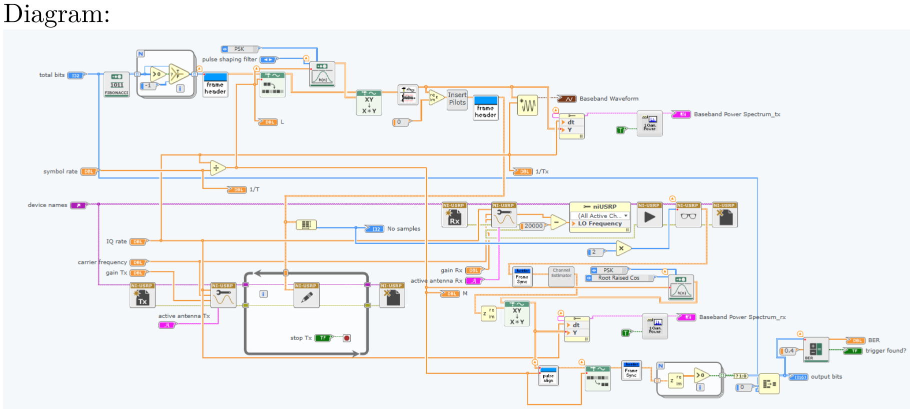
4. Sampling: The **Decimate** function will sample the aligned baseband waveform at index 0 and every *T* seconds thereafter.

5. Detection: Once the baseband waveform has been sampled, each sample must be examined to determine whether it represents a symbol of value 1 or a 0.

6. Symbol Mapping: The detected symbol values must be converted to bits. For binary PSK, this step is easily included in the detection step.

In this exercise, we constructed the BPSK Receiver

Diagram:



Observation

Tx Gain (dB)	Rx Gain (dB)	BER1	BER2	BER3	BER4	BER5	Average BER
0	0	0.499	0.508	0.002	0.002	0.003	0.203

Tx Gain (dB)	Rx Gain (dB)	BER1	BER2	BER3	BER4	BER5	Average BER
-35	-15	0.505	0.470	0.002	0.496	0.536	0.389
-37	-15	0.190	0.506	0.463	1	0.480	0.528
-40	-15	0.487	0.466	1	0.470	0.469	0.587

Exercise 3 - Error Correction Coding

Aim

Observation

- BER Module does not allow the program to compile.
- After doing all the steps, the program still did not work until the following steps were done:

1. Needed to turn the output from the final pulse align module to real from complex.
2. Needed to put a large constant into the number of samples port of the niUSRP Fetch Rx Data port so that it doesn't stop receiving data before the transmitter finishes transmitting.

Finally, when it was working, the BER was much lower:

Tx Gain (dB)	Rx Gain (dB)	BER1	BER2	BER3	BER4	BER5	Average BER
0	0	0	0	0	0	0	0
-35	-15	0.001	0	0.438	0.369	0	0.162
-37	-15	0.452	0.256	0.353	0.490	0.457	0.402
-40	-15	1	0.457	0.480	0.506	0.501	0.589

Exercise 4 - Differential Phase Shift Keying (DPSK)

What is DPSK?

In DPSK, the transmitted sends the difference between two adjacent bits and not the bits themselves. The table below shows how the difference is obtained for possible pairs of sumbols. Encoded sequence is obtained by bn=b(n-1)xan

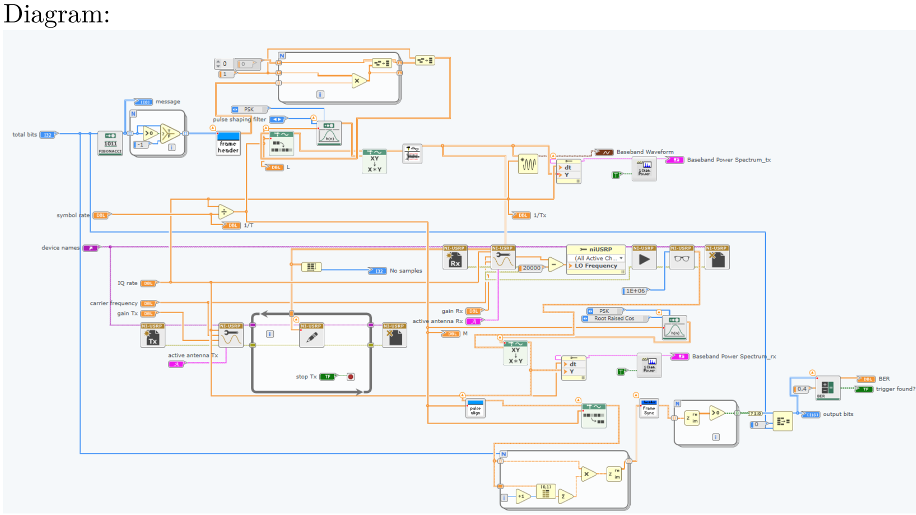
Information Symbols	{bn}	Decision
-	1 (reference bit)	1
1	1	-1
-1	-1	-1
-1	1	1

Information Symbols	{bn}	Decision
1	1	-1
-1	-1	-1
-1	1	1
1	1	1
1	1	-

Aim

In this exercise, we constructed a DPSK Encoder and Decoder and added it to the transmitter and receivers

Diagram:



Observation

Tx Gain (dB)	Rx Gain (dB)	BER1	BER2	BER3	BER4	BER5	Average BER
0	0	0	0	0	0.507	0.449	0.191
-35	-15	0.491	0	0	0.489	0	0.196
-37	-15	0.060	0.481	0.022	0.456	0.001	0.204
-40	-15	1	0.171	0.501	1	0.495	0.633

Comparison between DPSK and BPSK

With the data we collected, DPSK performed better until the Tx Gain was reduced to -40. In theory, DPSK is just sending the differences, so has protection from any phase flipping effect that may occur between the receiver and transmitter.

However, since DPSK only transmits differences, it is possible that errors get propogated forward which is why it performed worse at very low gain.