# π/4 DQPSK Transmitter and receiver

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## Abstract

The objective of this project is to provide students a hand on experience of the HPADS software. The goal is to build a DQPi/4PSK transmitter and receiver.

The reference design of the transmitter was given for student to practice the schematics capture and the simulation techniques. Then the students are required to design and build the simulation model for the receiver.

The transmitter and receiver were built and the eye diagrams, constellation diagram diagram were recorded.

Three types of channel were tried and the bit error rates were recorded and plotted.

## The System

This is the system diagram of the overall testing system. The small block on the left is the transmitter. There are two signal paths. The upper path simulates a normal RF communication path. The lower path connects the original baseband data to the BER calculator for system evaluation.

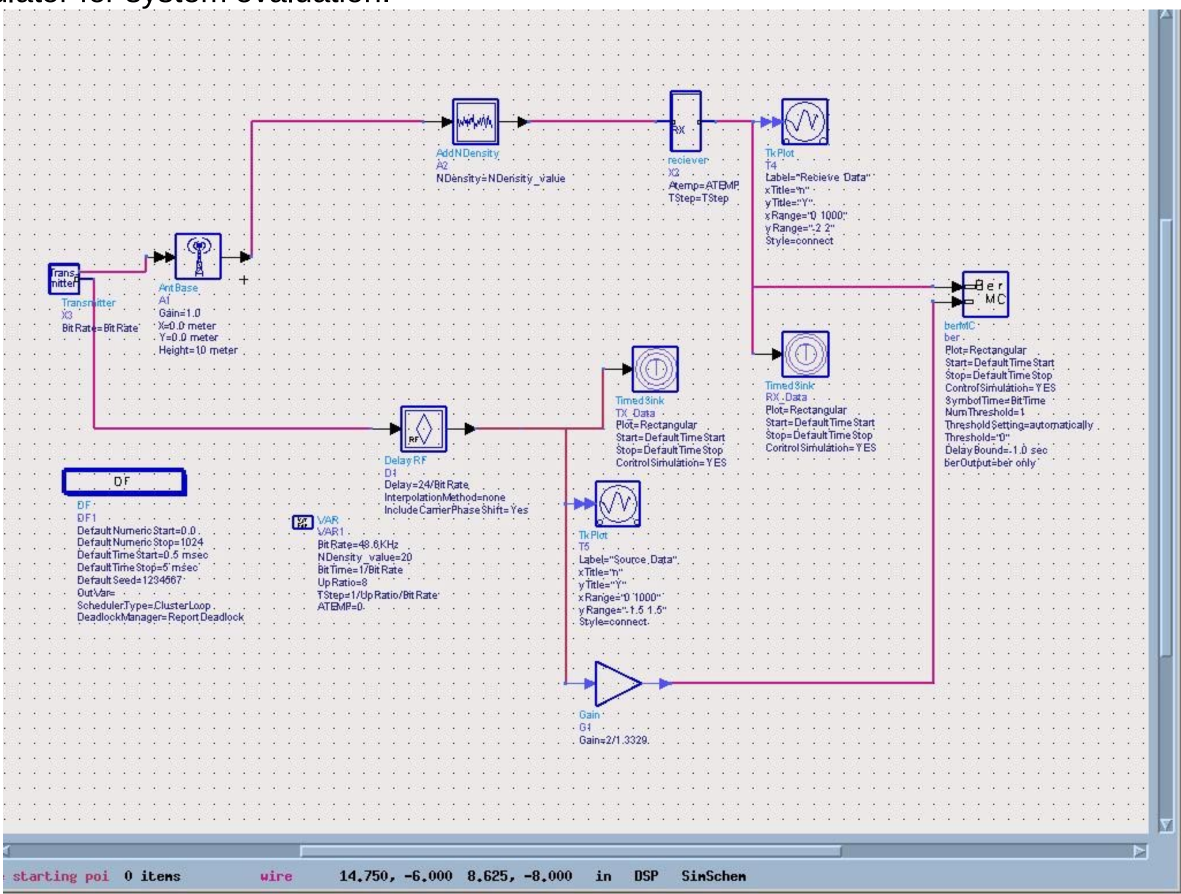



*Illustration 1 The Overall System*

The Upper Path:

The block with an antenna icon and that with a noisy waveform function as the channel. Three different channels were simulated and would be described in the Result section. The rectangular block is the receiver which converts RF signals into base band data.

The Lower Path:

The output of the transmitter on the lower path is the direct output from the data_source unit. The data content is exactly the data before all modulation and RF channeling. It acts as the reference data for bit error rate calculation. The data first pass through a delay block to compensate the delays for all the modulation, conversion and RF channel on the upper path. Then the signal is amplified to a signal level close the received data. At the end, the data from both paths are compared at the BER block. Hence the system performance is qualified.

## The Transmitter

The transmitter is consist of a data source, an IF module and a RF up converter. It is a typical transmitter for data communication.

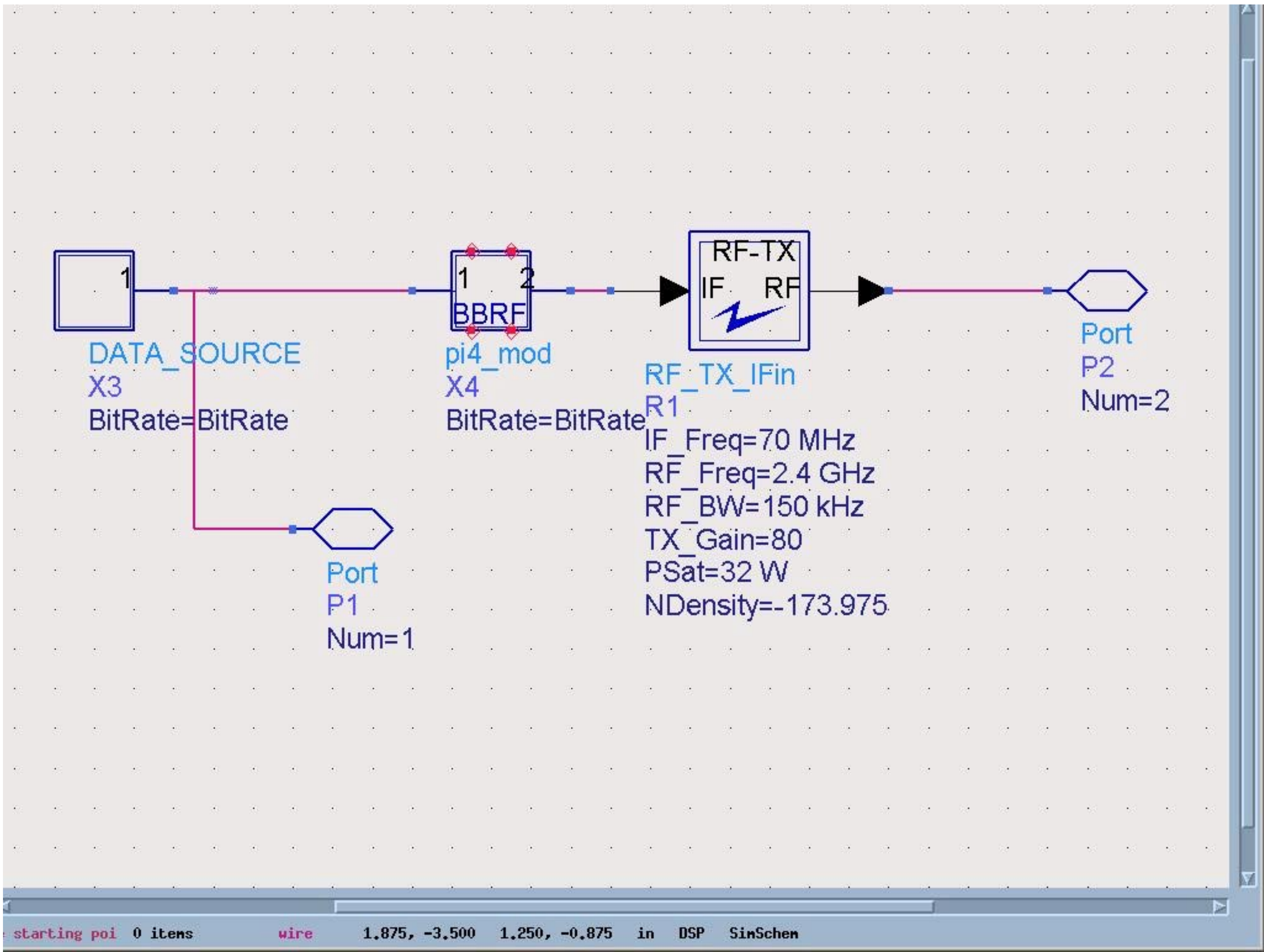



*Illustration 2 Transmitter System Block Diagram*

The data source:

The data source module consists four building blocks: The random bit generator, the LogicToNRZ, the FloatToTimed and the UpSampleRF. The random bit generator generate bit stream of one and zero according to the distribution defined. Given long enough time, all possible bit pattern would be tried. The LogicToNRZ is a block to convert logic signal of "0" and "1" into floating point number of "-1" to "1". It is a normal practice to convert logic signal to NRZ signal to avoid biasing subsequence circuit with a DC residuals.

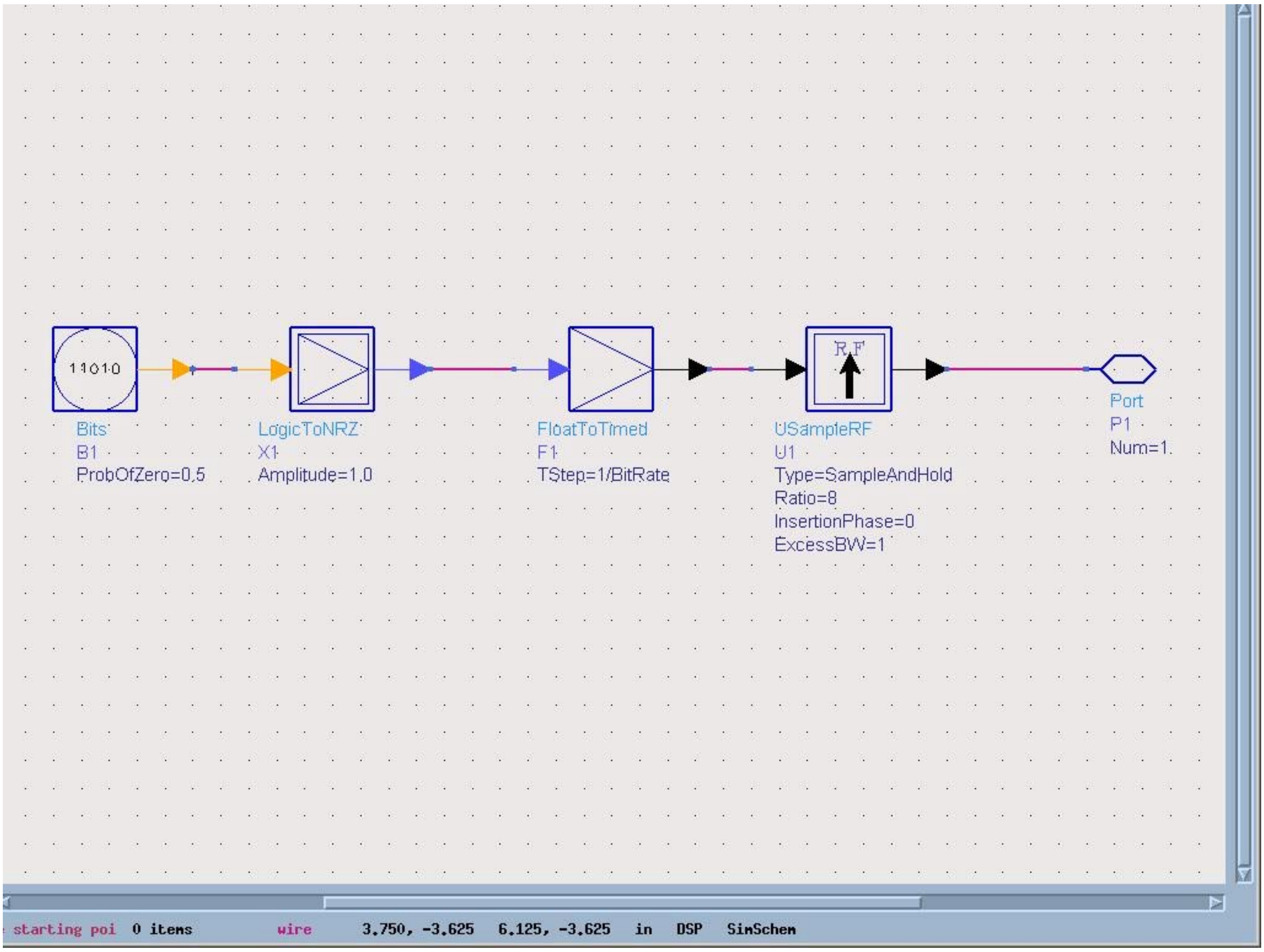



*Illustration 3 The Transmitter System*

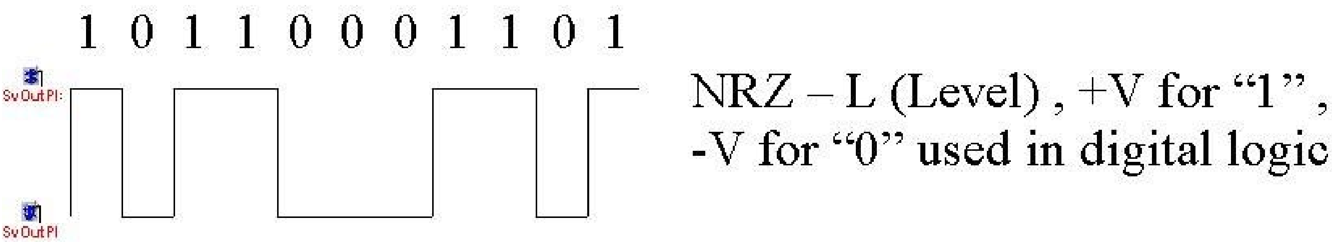



*Illustration 4 Data format of NRZ*

Then the floatToTimed block converse the floating point number into a time based signal for simulation purpose. The UpSampleRF element over sample the bit stream for simulation purpose.

The IF Module:

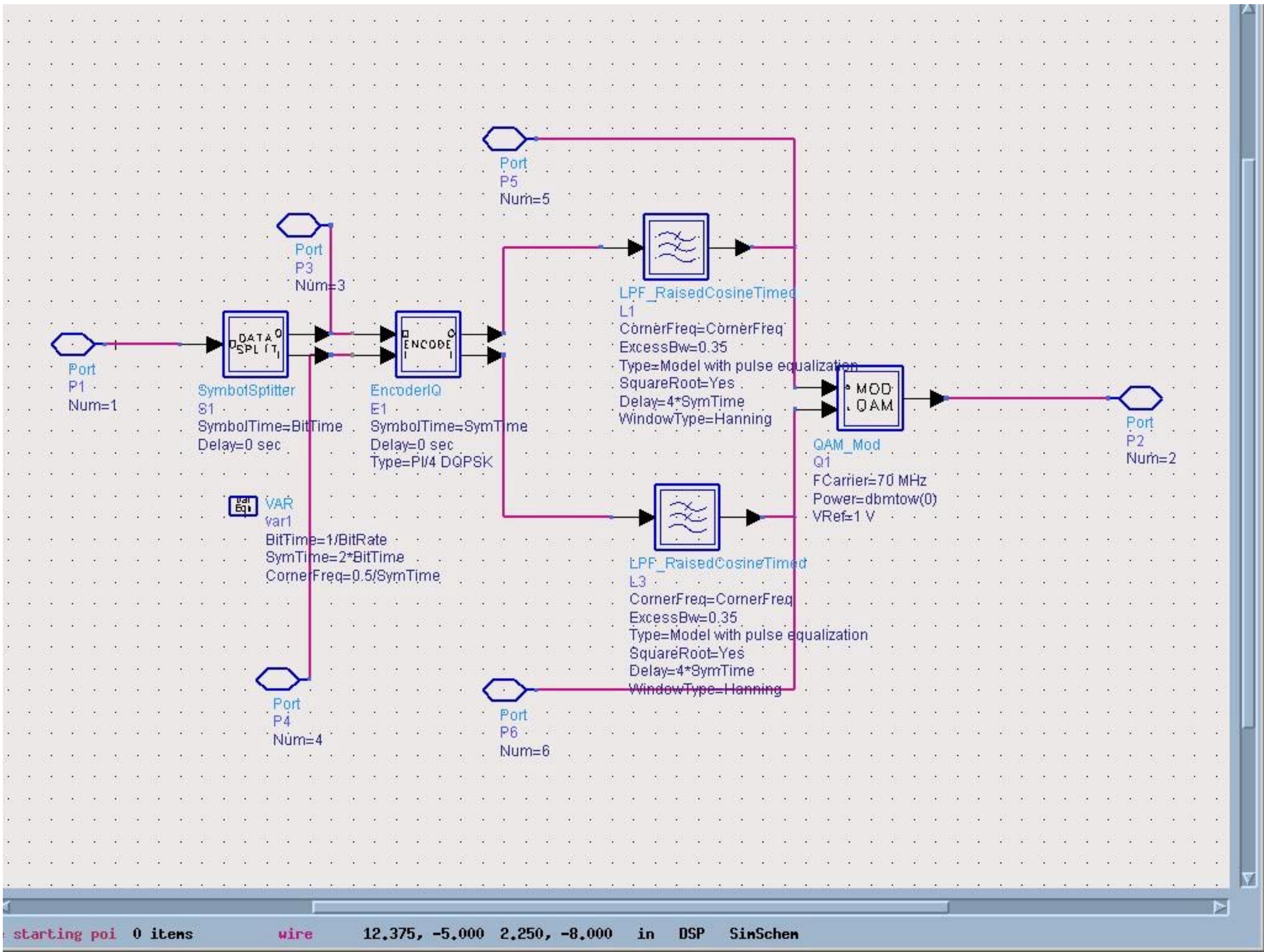



*Illustration 5 The IF modulator*

**The IF module consist of a data spliter, a π/4 QDPSK encoder, two raise cosine low pass filter and a quadrature amplitude modulator.**

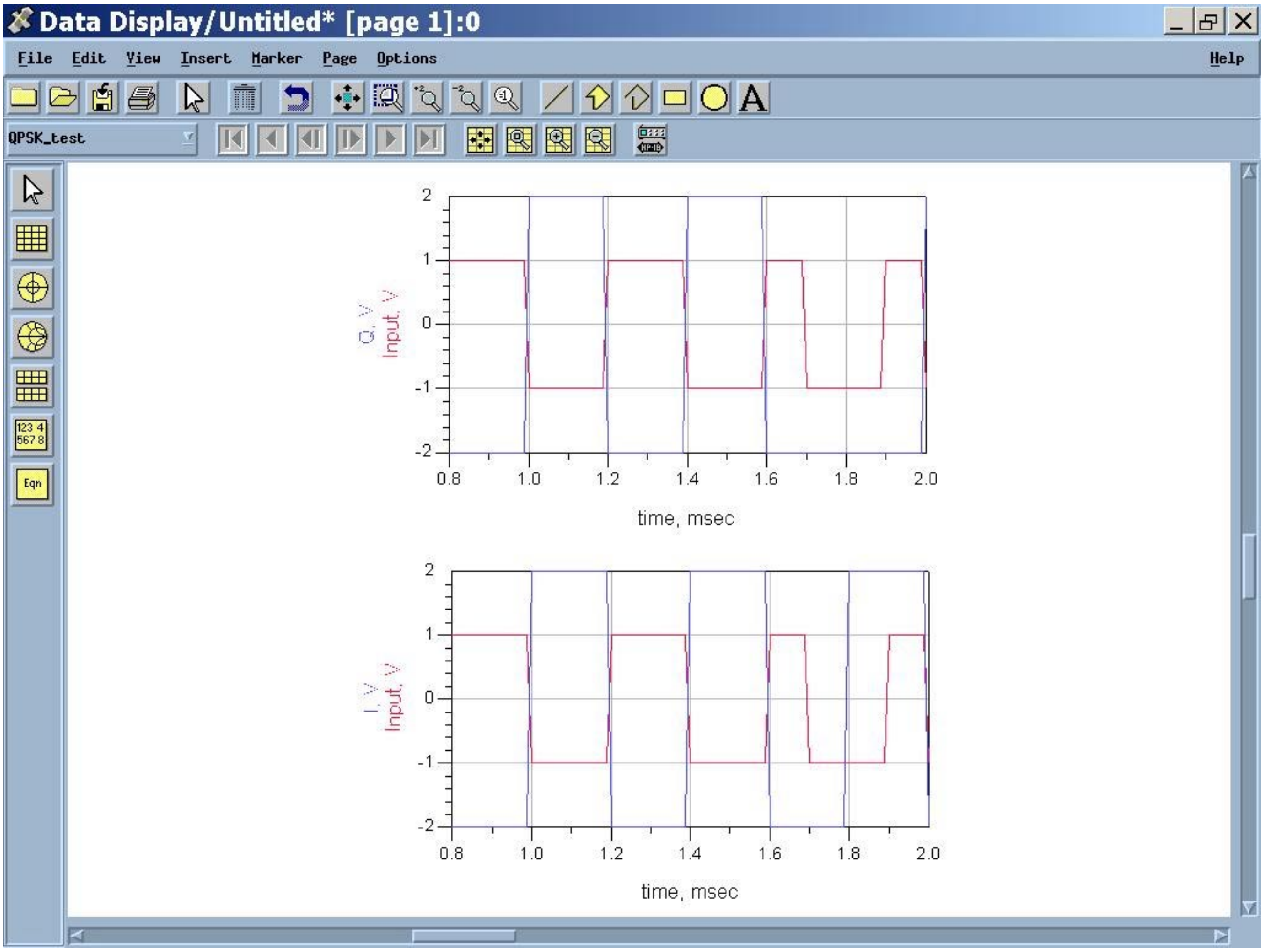



*Illustration 6   Data Splitter Output*

The function of the data splitter is to do a serial to parallel conversion. It takes in two bits from the serial input and output them into I and Q channel. The first bit would be put into the I channel and the second bit would be put into the Q channel. There is a constant delay of two bits time. So, the I and Q channel are only valid after two bit duration. Here is a plot for the outputs of the data splitter. Here the bit time is set to 0.1ms for the ease of understanding. Note the red color trace represent the input data and the blue traces represent the I and Q data outputs.

For each of the data channel, data are modulated in $\pi/4$ DQPSK modulator. PSK modulation is a commonly used technique. It has the benefits of constant envelop and high frequency efficiency. The "D" in DPSK means the coding is a differential coding. It encodes the difference between the current input with the delayed output. The aim of application of DPSK is the recovery of phases without the need for the exact phase of the carrier. In order word, non-coherence detection can be carried out.

Then the Raise Cosine LPF is used to do a pulse shaping. All higher harmonics would be attenuated. The use of Raise Cosine filter is to reduce the possibility of ISI due to limited bandwidth.

The Raise Cosine output needed to be converted into the intermediate frequency. The QAM encoder accepts the IQ input and modulates the IF in amplitude modulation format. But the HPADS would not simulate the high frequency carrier. So, only the information for baseband could be seen. Here is a plotting of the real part and imaginary part of the QAM output. Note, the real part co-responding to the I channel and the imaginary part co-responding to the Q channel.

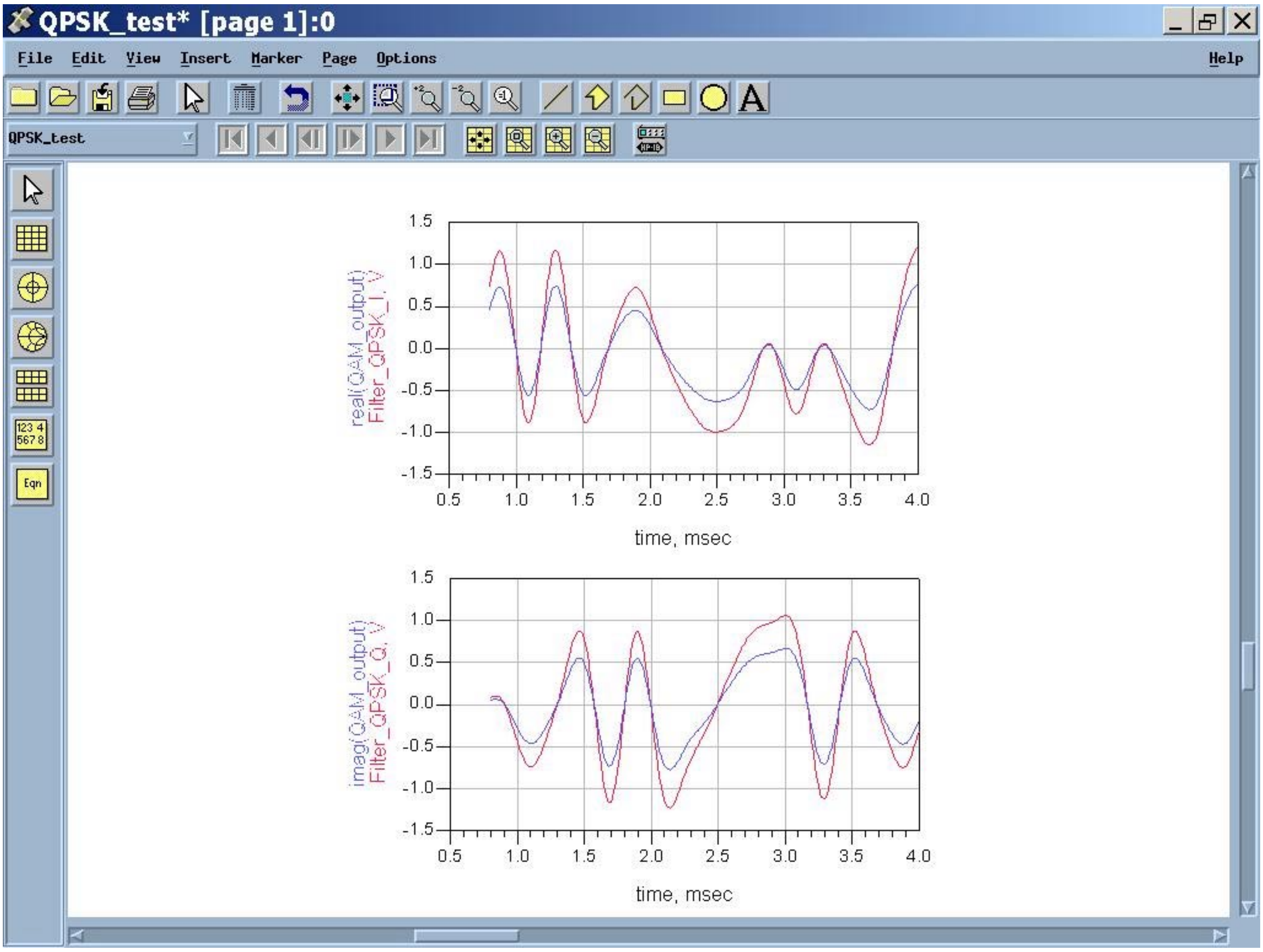



*Illustration 7 The I & Q modulation Input/Output*

By plotting the I and Q channel data on the X-Y plot, the constellation diagram is formed. Here SK ou

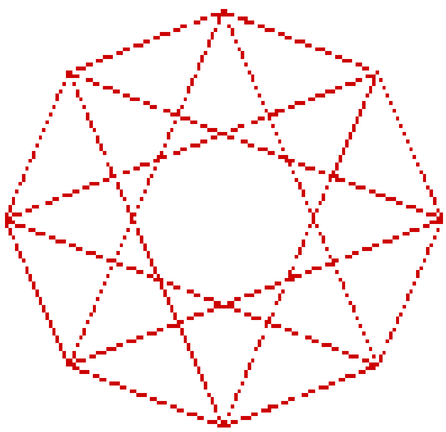


Illustration 8 DPSK_Output_Constellation

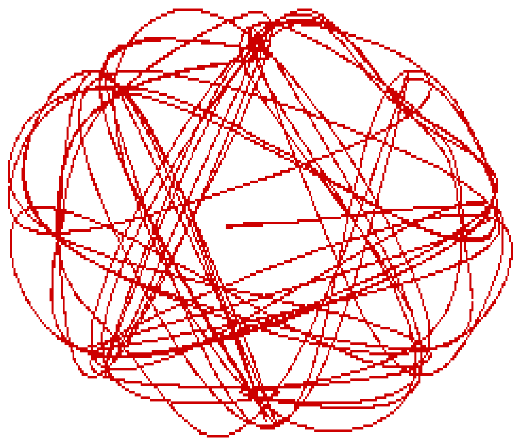


Illustration 9 QAM_Input_Constellation

Here is a graph showing the eye diagram of the QAM output:

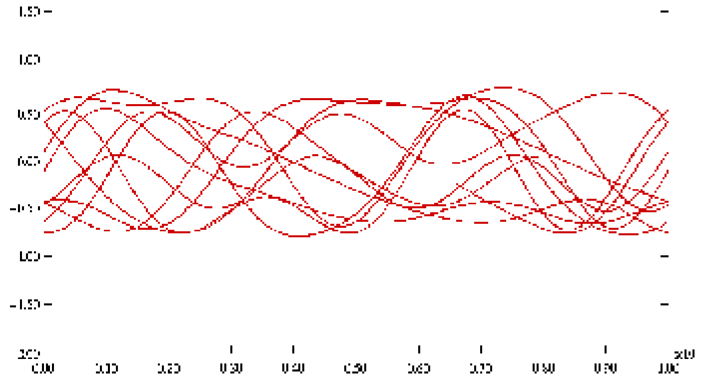


*Illustration 10 QAM_Output Eye Diagram*

The IF-RF module:
It up convert the IF signal into RF band. The current configuration is to up convert the IF of 70MHz into 2.4GHz.

## The Receiver

The receiver consists of a RF to IF converter, a QAM demodulator, 2 Raise Cosine LPF, a π/4 DQPSK decoder and a data combiner. In short, it is a reciprocal design of the transmitter.

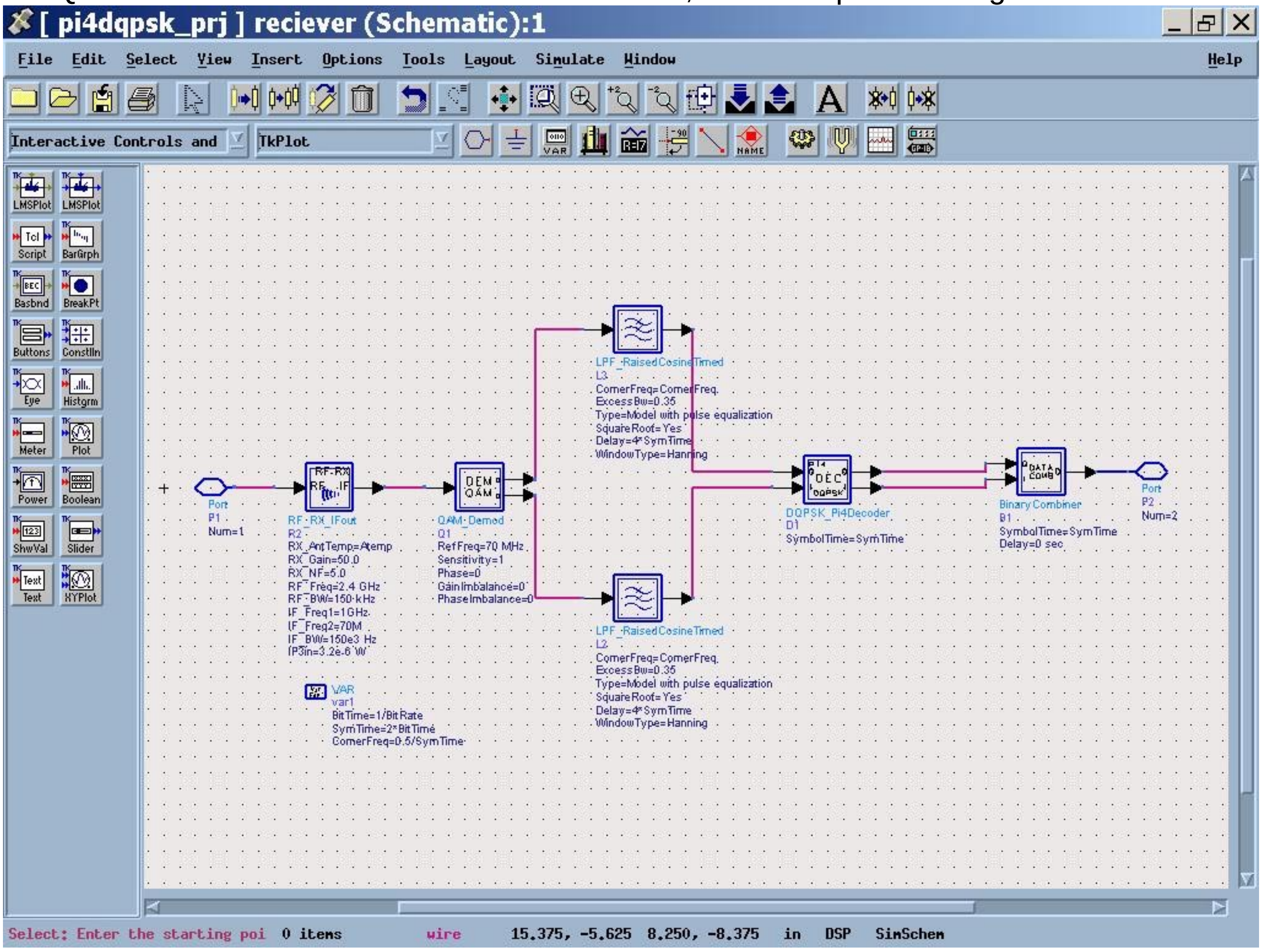



*Illustration 11 The Receiver Design*

The RF-IF module downconvert the RF signal of 2.4GHz into 70MHz IF. Then, the QAM demodulator demodulates the IF QAM signal back into IQ data. The filters do the pulse shaping. Then the DPSK demodulator demodulates the signal into IQ digital data. Finally, the combiner recombines I and Q digital data back into baseband signal.

## System Qualification

The system qualification is performed by the BER block. This block accept two data input channels, then synchronize and normalize them. Then a comparison is made and the rate of mismatch is calculated.

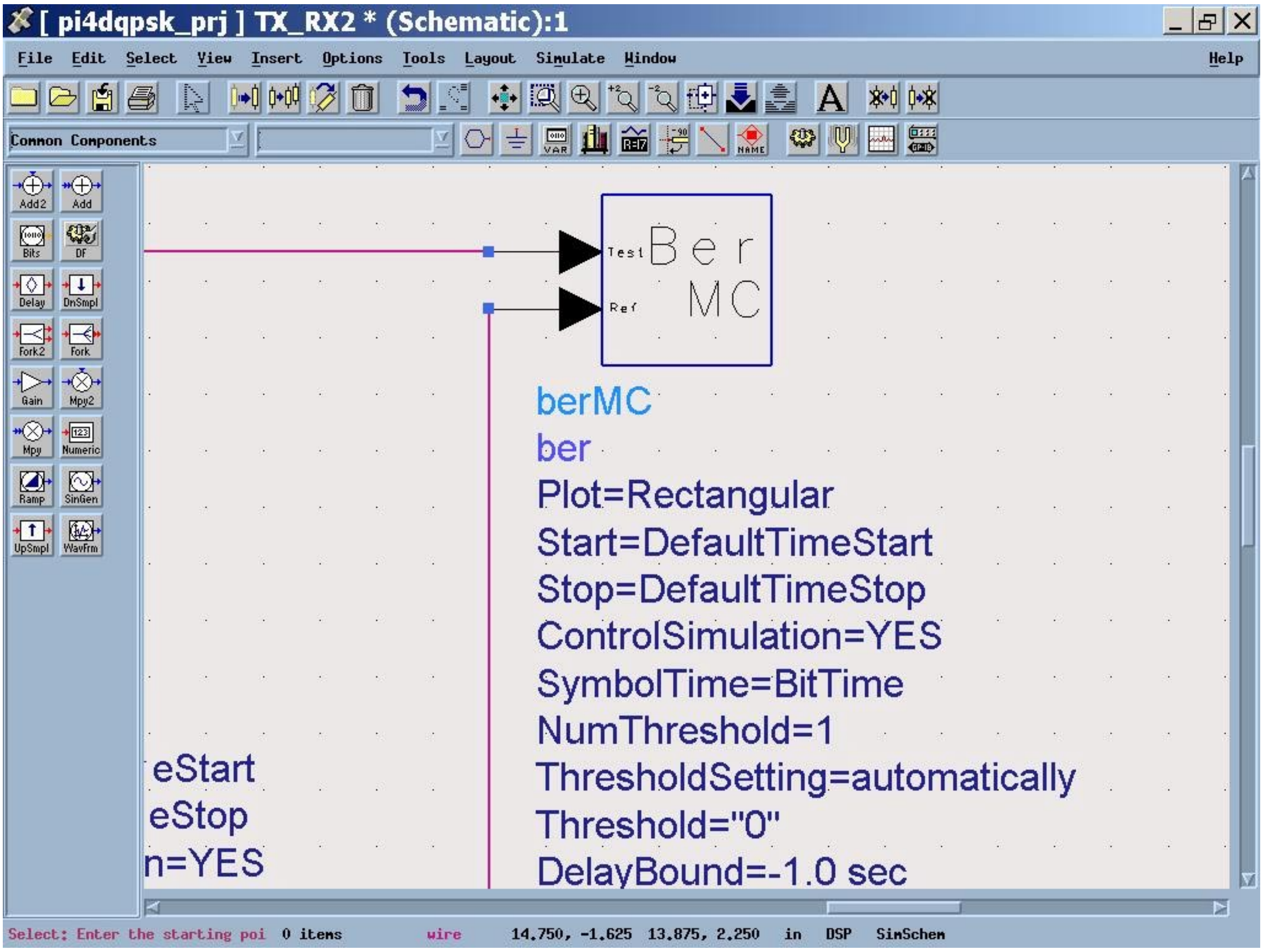



*Illustration 12 The BER block*

Here is a plot of the display for received data, transmitted data and the resultant BER.

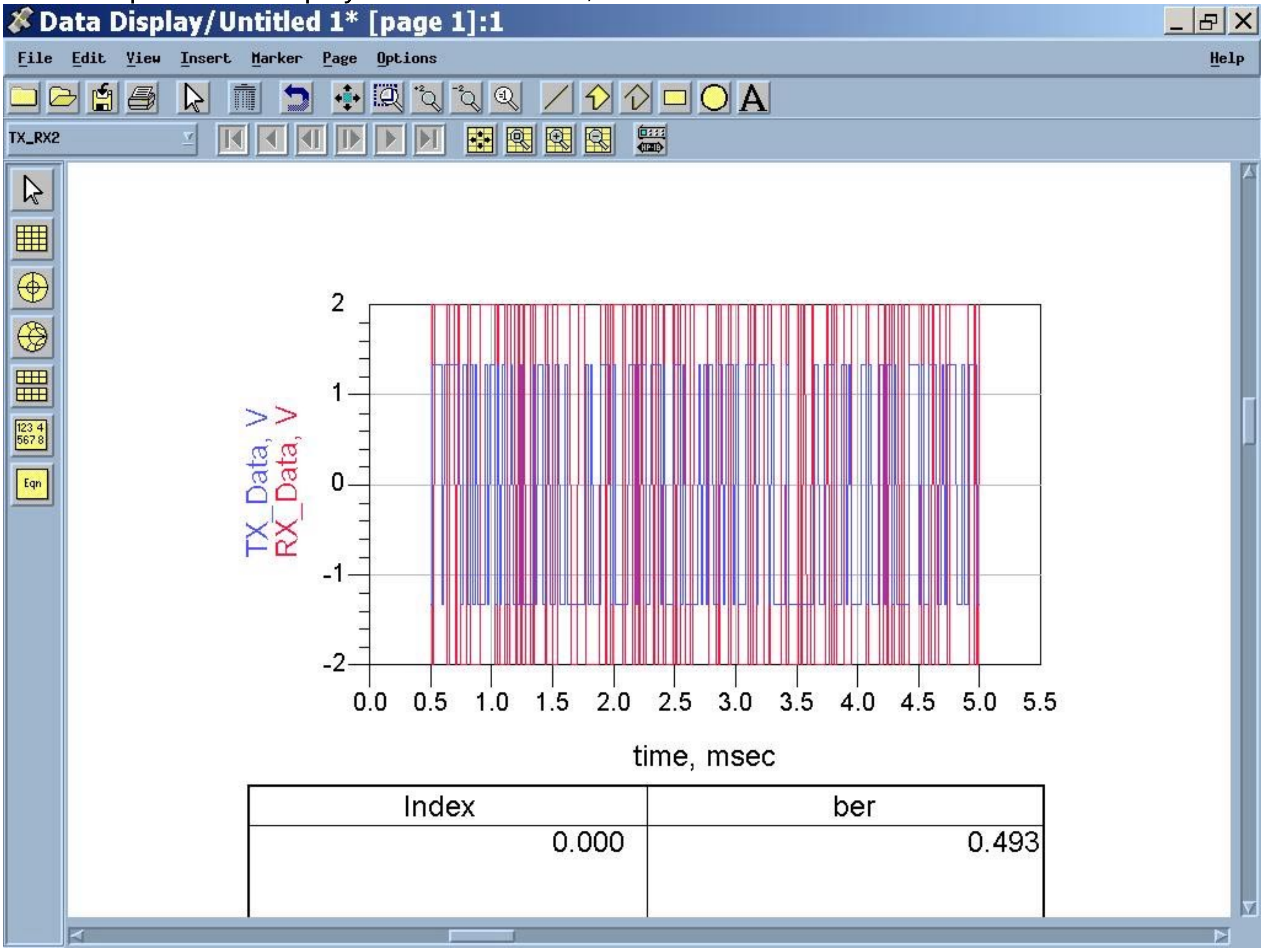



*Illustration 13 The Received Data, Transmitted Data and the Resultant BER*

## Procedures

The transmitter was built according to the project instruction.

The constellation diagrams and eye diagram were plotted to confirm the transmitter performance.

Then the receiver was built by adding components one at a time. Before adding a component, experiment was carried out to examine the function of it. In the same time, the delay time required for synchronization were tested.

The data combiner was connected to the data splitter. It was found that after 4 bit time, the reconstructed data synchronize with the source data.

The $\pi/4$ DQPSK modulator and demodulator were added in between the data splitter and combiner. The data were found reconstructed correctly. (The delay time was not recorded.)

The LPF, QAM modulator and demodulator were added in between the $\pi/4$ DQPSK modulator and demodulator. Data ware reconstructed.

The IF-RF and the RF-IF blocks were inserted in between the QAM modulator and demodulator. The data were reconstructed. The overall delay was found 24 bits time.

The BER block was added to compare the data from the data source and the receiver.

Different channels were insert between the IR-RF and RF-IF blocks.

Simulations were carried out according to different parameter setting.

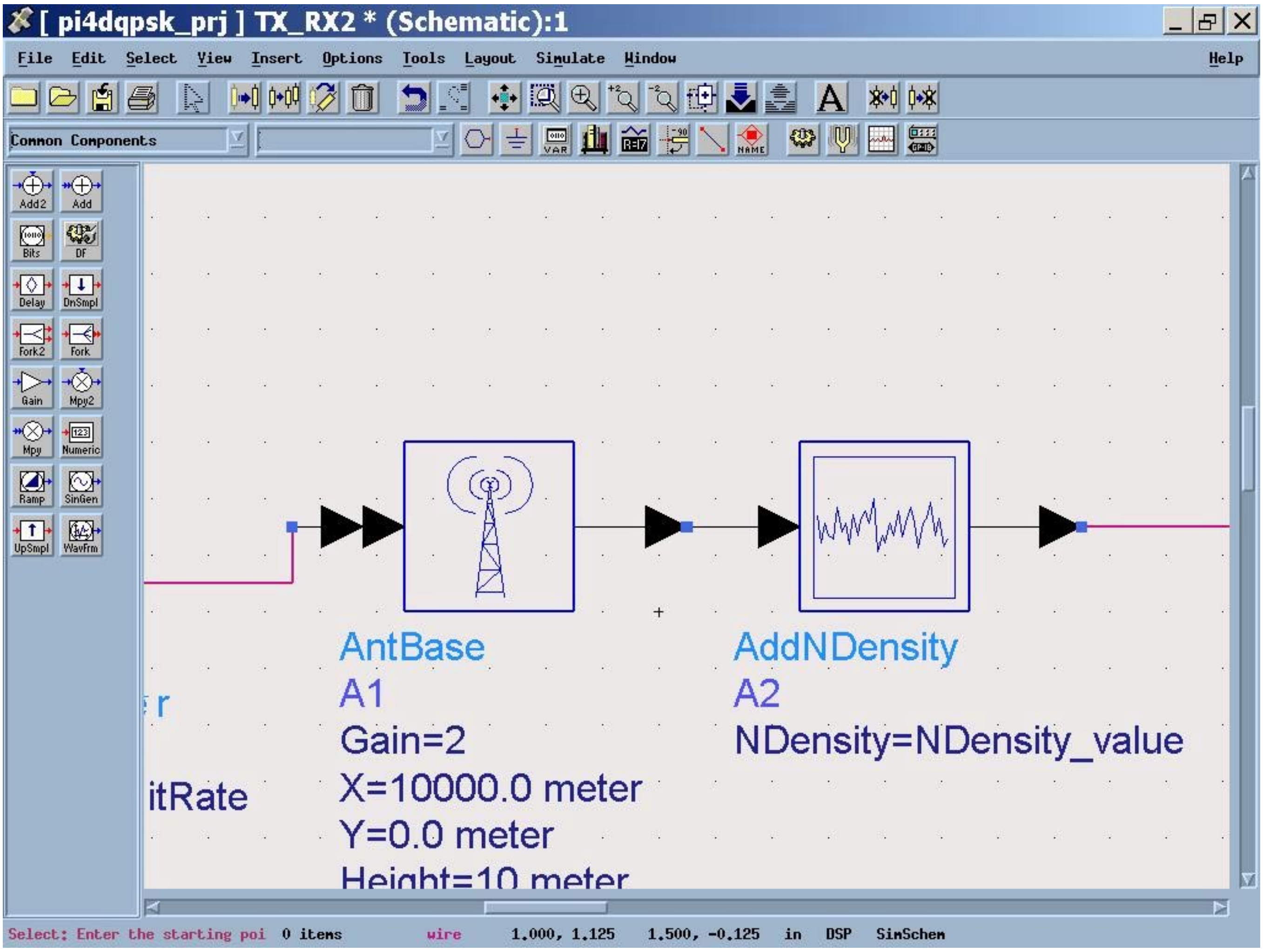
## Results

Three types of channels were tried:

1. Antenna with different gain and noise density.
2. 2. Mobile Channel.
3. 3. Mobile Channel with two antennas.

1. Antenna with different gain and noise density:

In this experiment, the BER for different gain and noise density combination were measured. The gain means the channel gain. The noise density measures in dbm/Hz. The normal thermal noise is at -174dbm/Hz. The higher the value means the higher the temperature.



Here are the results Bit Error rate at different noise density according to different antenna gain. The BER increases with noise density and decrease with the channel gain.

| | BER | | |
|---|---|---|---|
| **Noise Density (dbm)** | **G=2** | **G=1** | **G=0.5** |
| -10 | 0.005 | 0.009 | 0.014 |
| -5 | 0.018 | 0.018 | 0.023 |
| 0 | 0.050 | 0.059 | 0.064 |
| 5 | 0.146 | 0.169 | 0.178 |
| 10 | 0.311 | 0.333 | 0.342 |
| 15 | 0.434 | 0.443 | 0.475 |
| 20 | 0.493 | 0.493 | 0.489 |

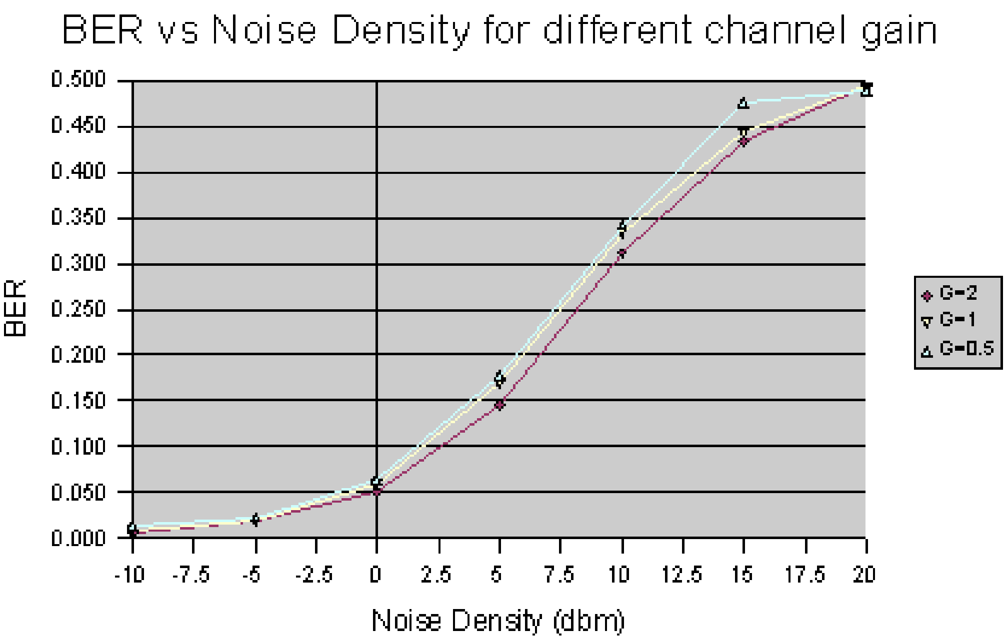


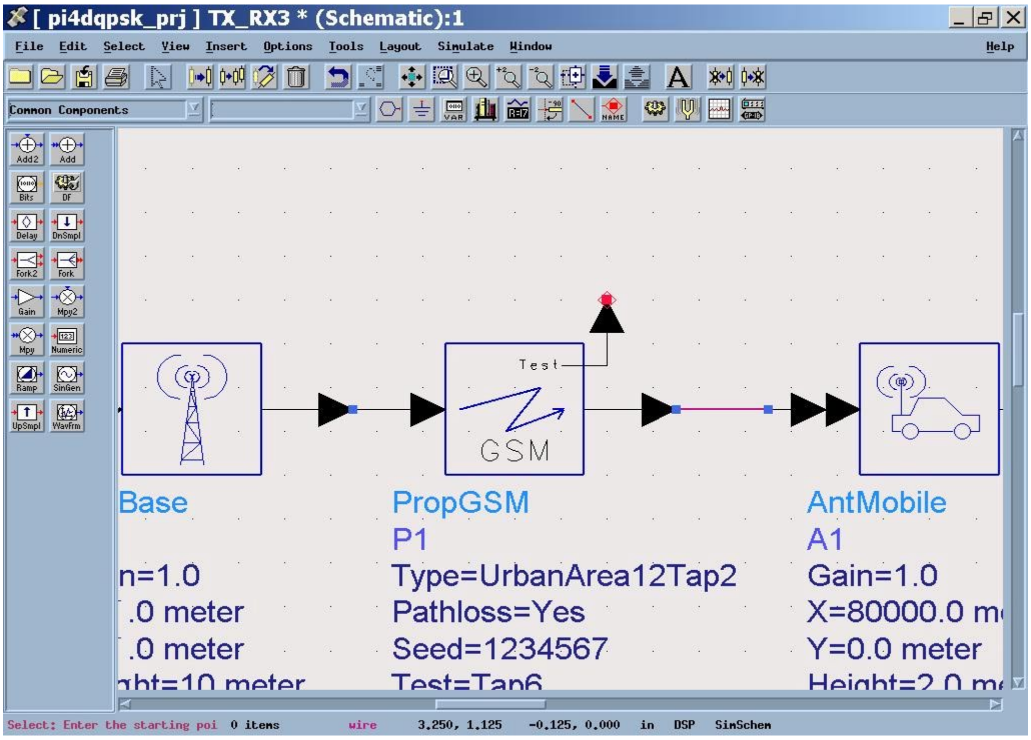

*Illustration 14   BER vs Noise Density @ different channel gain*

2. The Mobile Channel:

The GSM mobile channel simulates multipath delay, fladding and path loss. The mobile antenna simulates distance from the source and the velocity of the mobile.

The Bit Error Rate at two mobile velocities were simulated. The distances from the source ranged from 1Km to 100Km. Here is the result.

The BER increase with distance at the first 15Km. After a peak value, the BER ranges 0.46 to 0.48. The peak BER for higher mobile velocity is higher. The location of the peak locates at a larger distance for the higher velocity.




| | BER | |
|---|---|---|
| Distance (Km) | V=0 | V=100 |
| 1 | 0.000 | 0.014 |
| 5 | 0.027 | 0.037 |
| 6 | 0.100 | 0.055 |
| 7 | 0.183 | 0.123 |
| 8 | 0.288 | 0.242 |
| 10 | 0.393 | 0.338 |
| 15 | 0.484 | 0.466 |
| 25 | 0.447 | 0.498 |
| 50 | 0.443 | 0.466 |
| 80 | 0.466 | 0.466 |
| 100 | 0.475 | 0.466 |

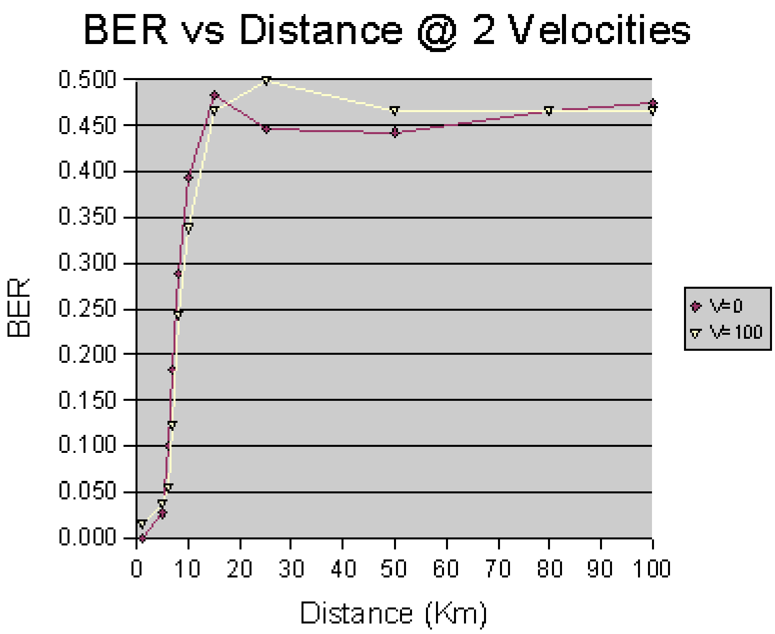
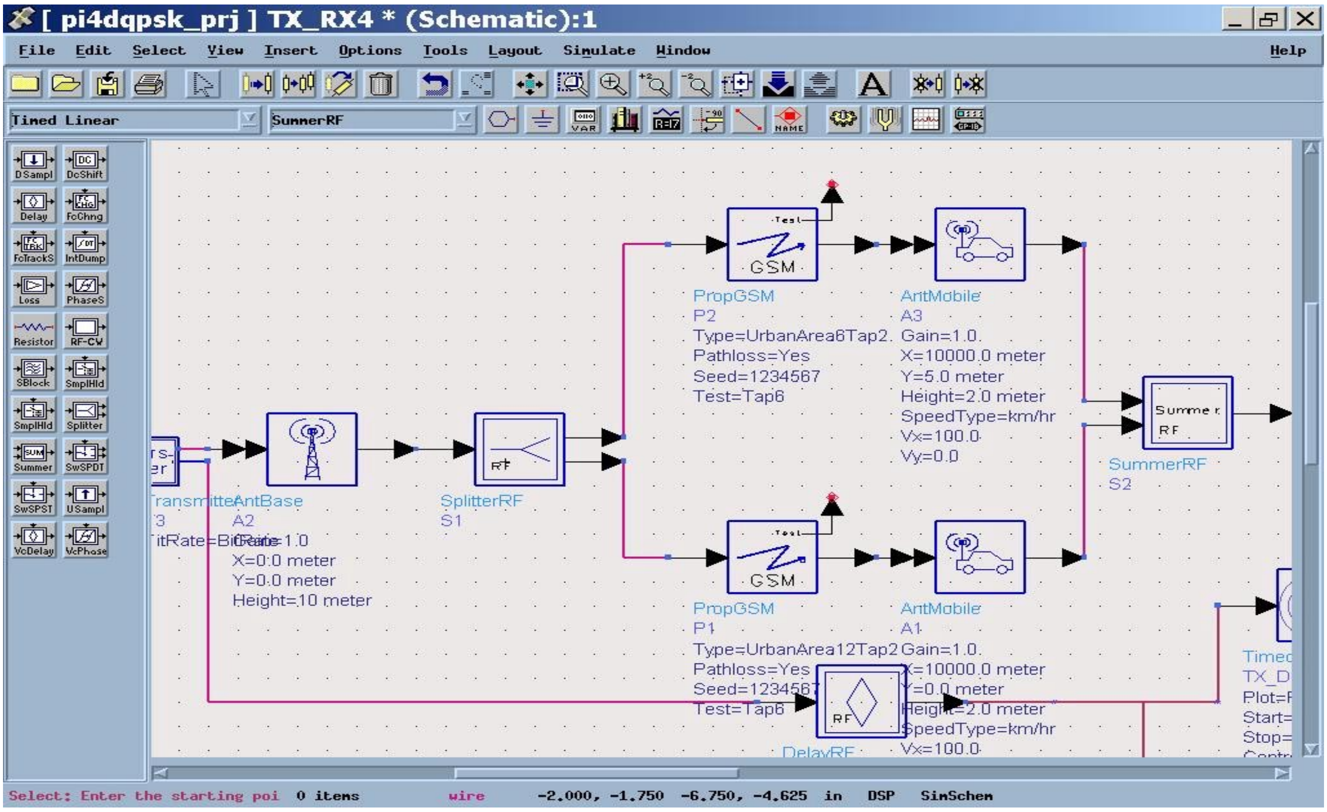



*Illustration 15 BER vs Distance @ 2 velocities*

3. Mobile Channel with two antennas

This objective of this arrangement is tried to check if diversity helps to improve the BER. An extra propagation path and antenna is added. The x-position and speeds of the two mobile antennas are identical. But the y-position of the first antenna is kept at 5m always from the other. The RF splitter is used to split the RF signal into two paths. The RF summer sums up the signal received and feeds the output to the receiver.



Here is the result obtained. The velocity of both mobile antennas are set to 100m/s.

| Distance (Km) | 1-Antenna | 2-Antenna |
|---|---|---|
| 1 | 0.014 | 0.014 |
| 5 | 0.037 | 0.037 |
| 6 | 0.055 | 0.032 |
| 7 | 0.123 | 0.146 |
| 8 | 0.242 | 0.247 |
| 10 | 0.338 | 0.352 |
| 15 | 0.466 | 0.489 |
| 25 | 0.498 | 0.517 |
| 50 | 0.466 | 0.493 |
| 80 | 0.466 | 0.457 |
| 100 | 0.466 | 0.461 |

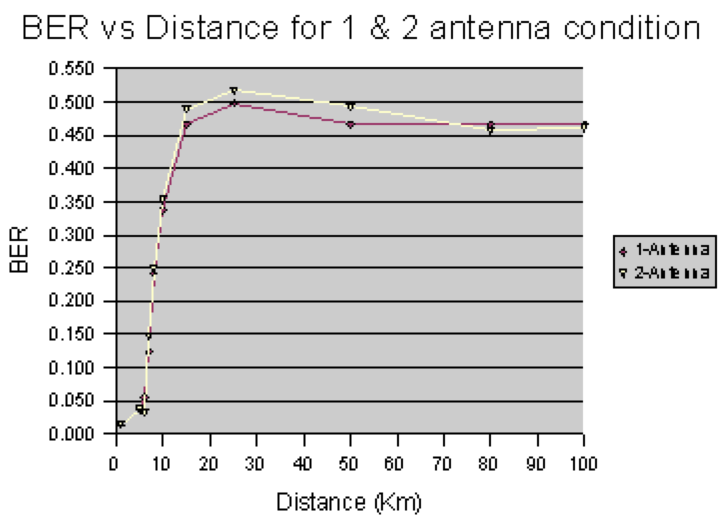



*Illustration 16   BER vs Distance for 1 and 2 antenna condition*

It is quite surprise to see the BER for the 2-antenna case is higher than the 1-antenna case. At the frequency of 2.4GHz, the wavelength is 12.5cm. A distance of 5 meter should be long enough for a diversity setup. Hence the model built here may not really simulating the diversity situation.

## Conclusion

Techniques were learnt how to build a simple TX and RX system.
Three different kinds of channel were tested.
HPADS is a good tool for both system level and board level simulations.
Information and documentation is not sufficient for users to fully appreciate the power of it.