PSEUDO ERROR DETECTION IN SMART ANTENNA/DIVERSITY SYSTEMS

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ABSTRACT

An implementation of a Pseudo Error Detection (PSED) system is presented and its performance in conjunction with smart antenna and smart diversity systems tested and evaluated. Non redundancy, instant response and relative simplicity make the Pseudo Error Detectors excellent real time error monitoring systems in smart antenna and smart diversity systems. Because of the Non-redundant Error Detection mechanism in Pseudo Error Detectors, we can monitor the error quality without any coding or overhead. The output of the pseudo error detector in AWGN, selective fading Doppler shift and other interference environments is directly correlated to the BER and BLER. This direct correlation makes it a great tool for online error monitoring of a system and can have numerous applications

In a PSED the Eye diagram from the demodulator is sampled once per symbol. By monitoring and comparison of the eye at sampled intervals at different thresholds, we would know if an error has occurred. By integrating this result over a period of time we can get the averaged error level. The results provided in this paper were obtained and verified by both MatLab simulations using dynamic simulation techniques and hardware measurements over dynamic channels.

KEY WORDS

Smart antenna, selective fading, Doppler Shift, AWGN, BER, BLER, smart diversity, Pseudo Error Detection, PSED, LEO satellites

INTRODUCTION

In a smart antenna system or smart diversity system it is desirable to be able to monitor the quality of each received branch, instantaneously and in real time. In addition, we not only want to know whether an error is occurring or not but also want to know the level of error occurrence. We have to be able to determine which branch has the best BER performance. In such a system the speed of error detection and error estimation is also important because we want to make a decision for selecting best branch at the bit level. [4]

Of course, the use of coding can be a candidate for monitoring each branch. But considering the mentioned requirements there are a number of issues associated with using coding. First of all coding requires an overhead especially if we want a coding system that estimates not only if there is an error but the level of the error. Such a coding system requires a tangible complexity and overhead. This means that we need to use some bandwidth for the coding. To estimate the error level we need to monitor a proper number of bits and such real time coding for monitoring can be complex and considering that each branch needs its own monitoring system this would make the smart antenna fairly complex. In many cases for examples in some military applications there might be requirements for not using coding or we might not even have access to the transmitter site.

What is presented in this paper is the Pseudo Error Detector (PSED) which has been used in both Haghdad's [4] and Feher's [1] smart diversity systems. There are three major advantages that make the Pseudo Error Detector very suitable for the smart diversity system.

I) Non-redundant error detection system
II) Instant response to error
III) Relative simplicity

In the followings we will briefly review the smart antenna and smart diversity architecture to show the role of the PSED in it. Then we will look at the conceptual definition, hardware and software implementations and results from simulations and measurements.

PSED IN SMART DIVERSITY

Figure 1. shows the use of Pseudo Error Detector (PSED) in a n-branch smart diversity system using Haghdad's Smart diversity architecture[4]. The signals from different antennas are demodulated separately and then the best signal is selected based on the BER quality. This requires a real time monitoring of each branch simultaneously. Monitoring the quality of each branch is done by monitoring the quality of the eye diagram using Pseudo Error Detectors. The output from each Pseudo Error Detector is an indicator of the error level in that particular branch. The outputs from the Pseudo Error Detectors are connected to a decision circuit which decides which branch should be selected. This decision then passed to two hitless switches which select the best branch and its corresponding clock.

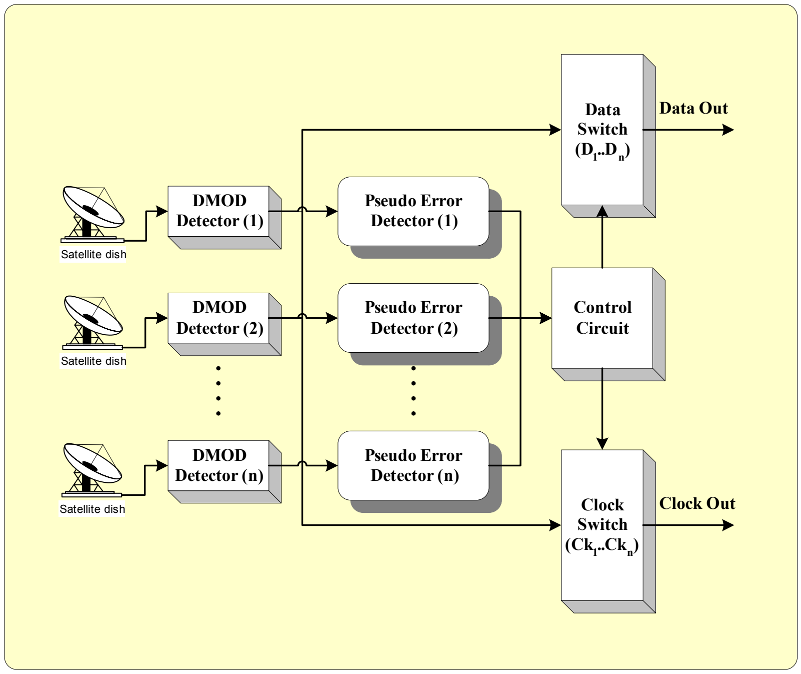


Figure 1. Smart diversity block diagram

PSEUDO ERROR DETECTOR (PSED) ARCHITECTURE

Figure 2. shows the block diagram of the Pseudo Error Detector used in the smart diversity system. The recovered I channel is passed through an input buffer. The signal is then passed via voltage comparators. The threshold for the voltage comparator in the upper branch is set at zero and the lower branch at a little over zero. If the Eye is open and ISI is small then the sampled result of both branches are the same which after XOR it results in output of zero. On the other hand if there is higher level of error and the Eye is closed and ISI is high then the positive value falls below the lower branch threshold and the sample value of the upper branch and lower branch are different. This means that the XOR produces a one.

For any error the XOR result is one and for any good reception the resulting output from the XOR is zero. The more errors the more Ones are outputted by the XOR gate. The LPF with low cut-off frequency of 50Hz acts as an accumulator. The higher the number on ones inputted into the LPF the higher is the signal level. By sending the results from the XOR through a low pass filter it is integrated and we can estimate the error level. The higher is the error rate the higher is the voltage output from the low pass filter.[5][6]

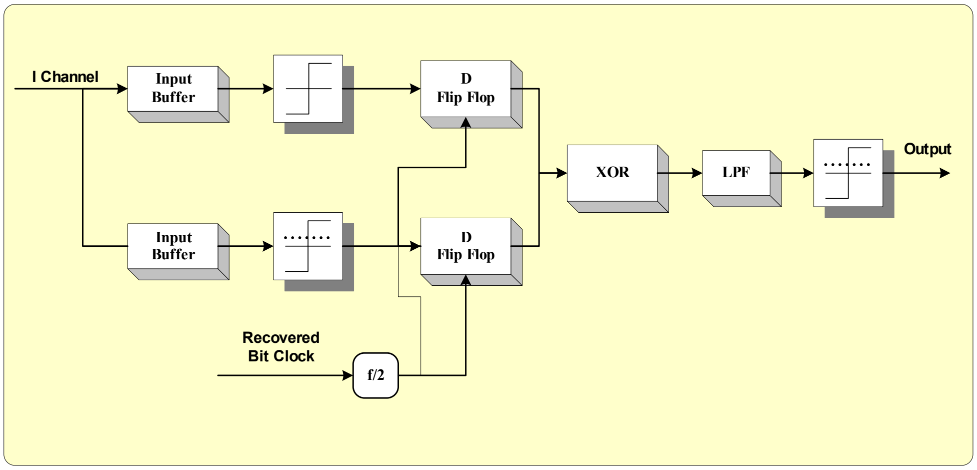


Figure 2. Pseudo Error Detector

HARDWARE IMPLEMENTATION PSEUDO ERROR DETECTION

The concept and the conceptual block diagram of the Pseudo Error Detector were already introduced. Figure 4. shows the block diagram for the hardware implementation and Figure 5. shows the circuit that was implemented in the lab. During the implementation I realized that I was getting a better result if I pre-amplified the eye that is why the voltage regulator is used here and it is adjusted by changing the 5kΩ variable resistor. It is also very important to do the matching of the eye diagram. Mismatch results in disfigured Eyes and it can seriously degrade the performance of the Pseudo Error Detector.

The threshold of the lower branch was set at 0.2 volt and could be adjusted based on the circumstances using 5kΩ variable resistor in the lower branch. The higher the threshold the more sensitive the Pseudo Error Detector and the error output is higher. If the threshold is high then it is constantly showing high error level which is not good. There is an optimum level and I found that 0.2 volt does work in most cases.

Another very important and probably one of the most important things to consider is where to sample the eye. As it is shown in Figure 3. the best place to sample the eye is when the eye is widest open. To adjust the clock in order to get the best sampling point a proper delay and consequently a shift was introduced to the sampling clock of each branch.

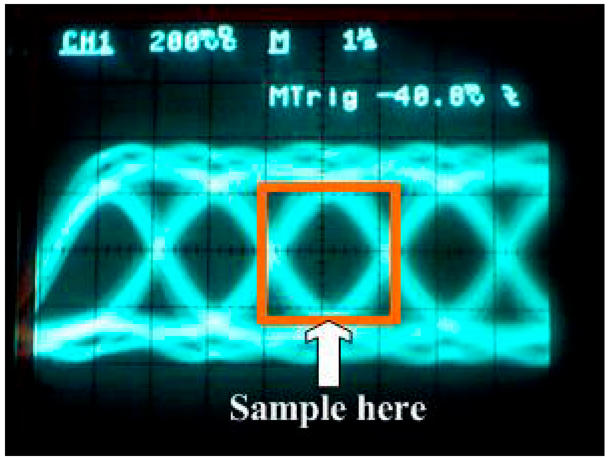


Figure 3. Place to sample the Eye

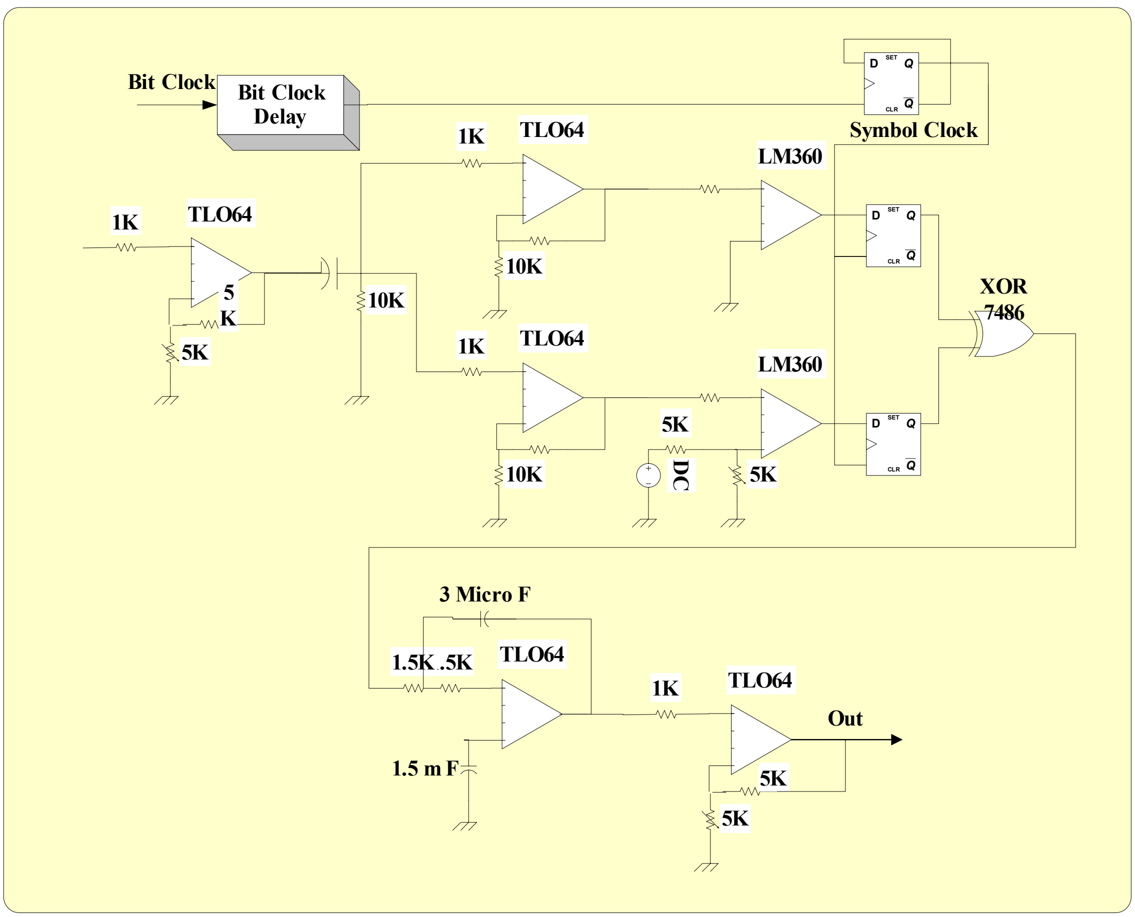


Figure 4. Pseudo Error Detector circuit

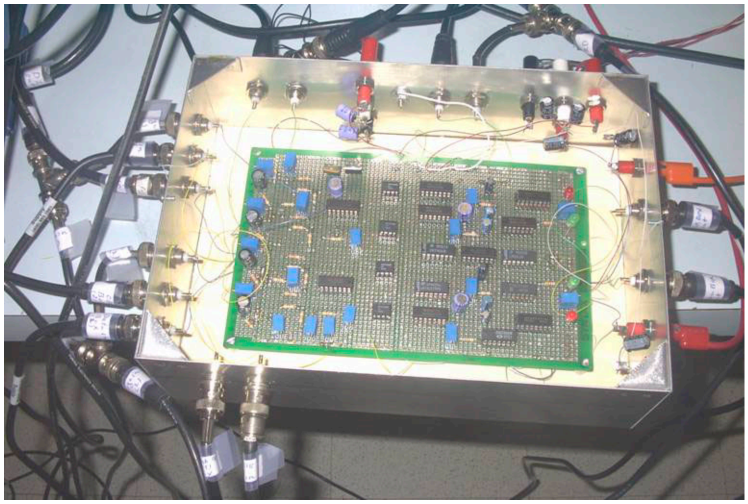


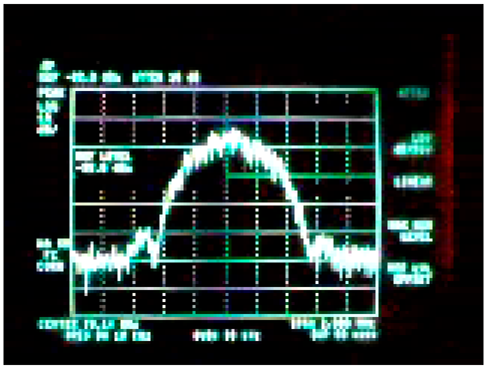
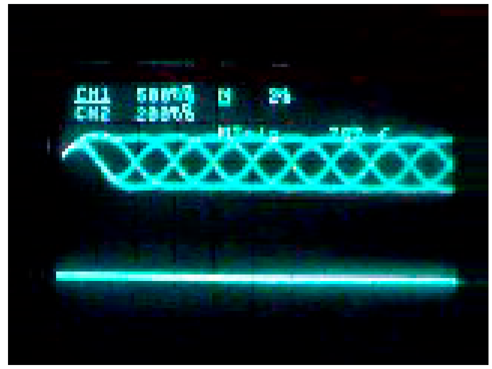
Figure 5. Hardware implementation of the PSED and smart diversity system

PSEUDO ERROR DETECTOR HARDWARE MEASUREMENT RESULTS

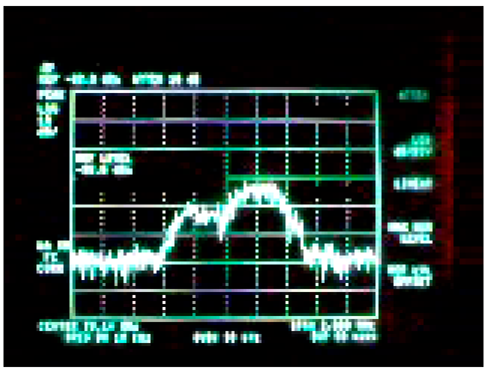
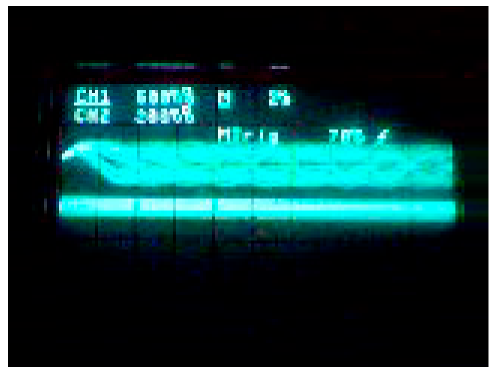
Measuring at IF 70MHz and bit rate of 1Mb/s the following pictures show the picture taken from the spectrum, Eye diagram and the corresponding Pseudo Error Detector output for both branches during low and high Bit Error Rate (BER). The output level is of course depends on a number of factors:

I) The threshold in the lower branch of the Pseudo Error Detector
II) The pre PSED amplification
III) The post PSED amplification
IV) The place where the Eye is sampled

Because it is important to select the best signal under a fair condition, these measures were adopted to ensure equality in both branches. The Eye channels were both amplified to exactly the same level. One of the Eyes was delayed so that both eyes exactly overlap in time. Both were sampled at the same time in the right when the eyes are widest open. The post PSED amplification is calibrated so that for the same eye input they produced the same PSED output level. After the calibration the output overlaps for the same eye quality.

(a) (b)

(c) (d)

Figure 6. Pseudo Error Detectors hardware results obtained for channel (1) at 70MHz and 1Mb/s data rate. (a) Spectrum low error level (b) Corresponding high error level Eye diagram and PSED output (c) Spectrum high error level (d) Corresponding high error level Eye diagram and PSED output

PSEUDO ERROR DETECTOR HARDWARE RESULTS VERSES ACTUAL ERROR RATE

The BER and Pseudo Error Detector are directly correlated. The higher the BER the higher is the output of the PSED. Although this statement is true, the relationship is not linear and it is not directly proportional. The output of the Pseudo Error Detector (PSED) depends on many factors including the threshold levels and the bandwidth of the lowpass filter. Figure 7 shows a measured Pseudo Error Detector (PSED) response at different Bit Error Rates.

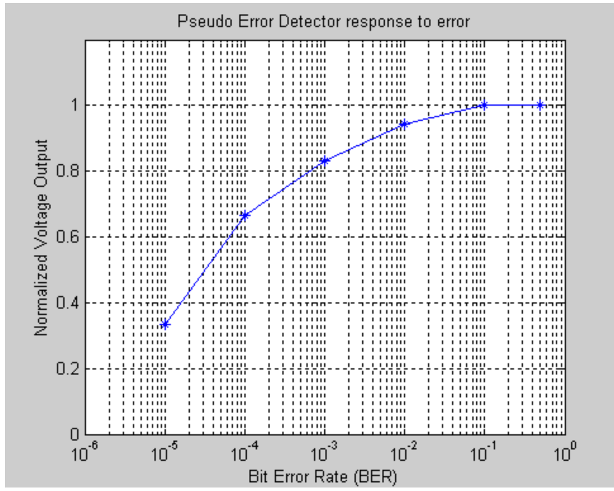


Figure 7. Pseudo Error Detector (PSED) response to error

PSEUDO ERROR DETECTOR SPEED AND RESPONSE TIME

The speed and response time of the Pseudo Error Detector is dependent on the integration of the XOR output. Here a low pass filter was used for the integration of the XOR output. The wider the filter's bandwidth is the faster it responds the lower it is the smaller it is the smoother it is but the response time is slower. If it is too wide then the error level jumps up and down and too much up and down makes the switching and selection process instable. If it is too narrow then the response time is too slow and by the time it switches to the best channel substantial amount of data is lost. So there is an optimum and I found it around 60 to 70 Hz.

PSEUDO ERROR DETECTOR SIMULATION AND RESULTS

The Pseudo Error Detector is a very important component in smart diversity system so here the simulation scheme and results from the Pseudo Error Detector simulator is presented first.
Figure 8. shows the flow chart for the simulator. Using the FQPSK modulator module, the 'I' channel vector and the sample number is passed to this function. It first samples the 'I' channel and then passed through two threshold detectors, simply comparing the values. Then we take the XOR value of the two vectors. Then adding all the ones after XOR and dividing by the length of the vector. Finally the function returns the Pseudo Error Detector value as number. The results that are introduced here are the eye, the sampled eye, the value of the middle steps and finally the error level.

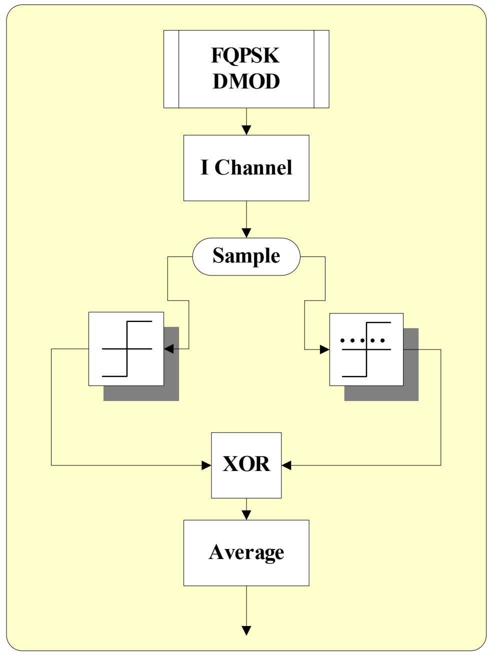
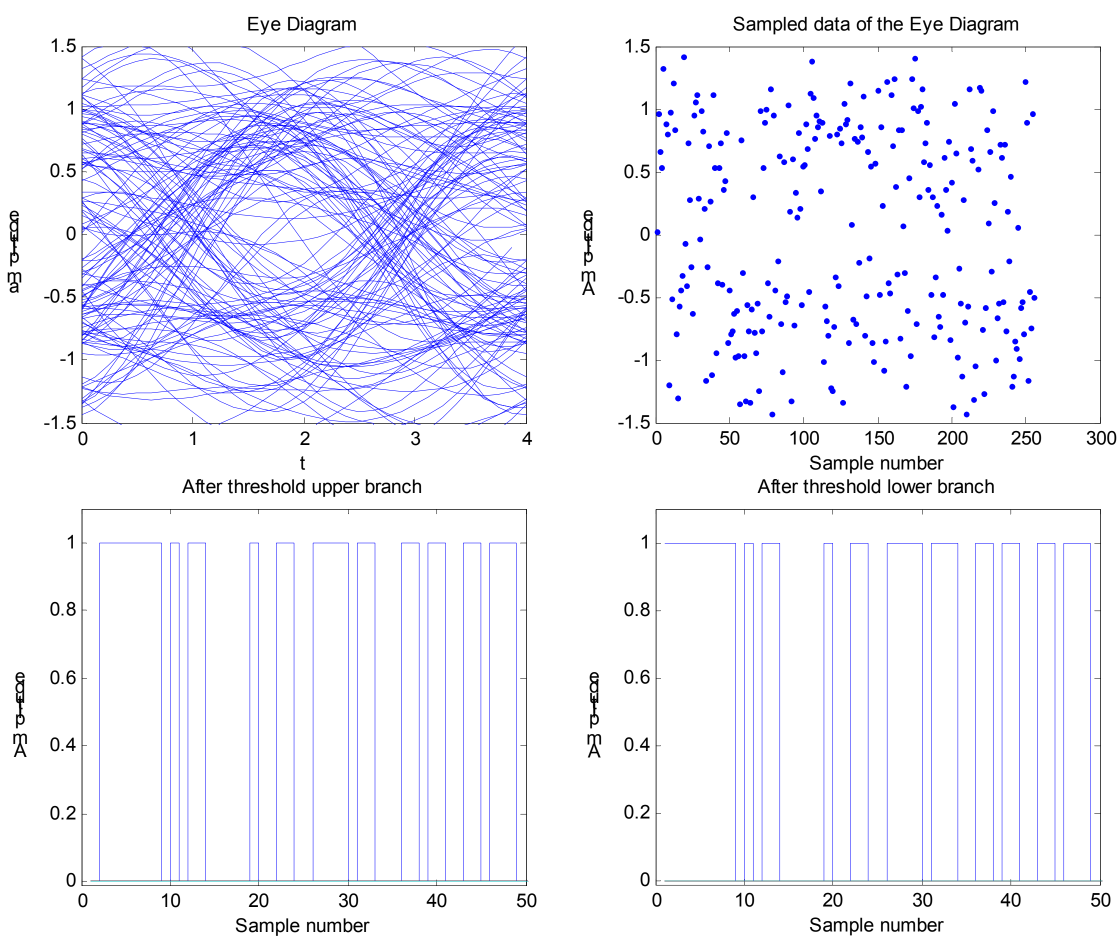


Figure 8. Flow chart of the Pseudo Error Detector simulation



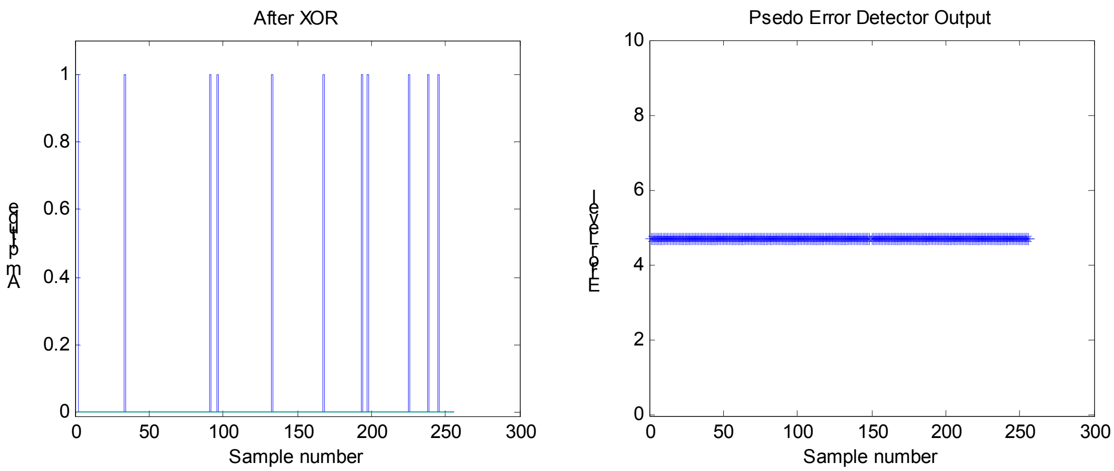


Figure 9. Pseudo Error Detector results for FQPSK modulated signal over a channel with AWGN where $E_b/No=4$ dB and with small selective fading

CONCLUSIONS

A design and implementation of the Pseudo Error Detector (PSED) was presented and its performance was tested and evaluated. We saw that non-redundancy, instant response and relative simplicity make the Pseudo Error Detectors excellent real time error monitoring systems.

One application of the PSED can be in the smart antenna and smart diversity systems. Because of the Non-redundant Error Detection mechanism in Pseudo Error Detectors, we can monitor the error quality without any coding or overhead.

We also established that the correlation between the PSED output and BER/BLER is a direct correlation but not necessarily a linear one. Furthermore, the output depends on many parameters and the PSED can be adjusted to different levels of sensitivity using proper thresholds. The speed of the PSED response can also be adjusted using different integration lengths.

We also looked at some simulation and hardware measurement results. The results show the PSED output can be a good indicator for the Bit Error Rate (BER)/Block Error Rate (BLER). We also showed that we could change the sensitivity of the PSED by changing the threshold levels. It can detect the errors resulting from AWGN, selective fading, Doppler Shift, ACI, CCI and therefore is a valuable error monitoring tool in complex interference environments such as Low Earth Orbit Satellite (LEO) channels.

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