SMART DIVERSITY RECEIVERS FOR DYNAMIC, MULTIPATH, FREQUENCY SELECTIVE FADED FQPSK AND OTHER SYSTEMS

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ABSTRACT

Design, performance Test and Evaluation (T&E) of a novel smart diversity receiver, based on Feher Diversity* (FD) patents over multipath, fast dynamic frequency selective fading channels is presented. A hardware simulator for construction of a frequency selective fading channel has been implemented in laboratory to resemble a telemetry aeronautical channel model, namely the two-path channel model. As an illustrative example, the block error rate (BLER) of a 1 Mb/s rate IRIG 106-00 and CCSDS standardized Feher's patented quadrature phase shift keying (FQPSK) [1][2] with and without diversity in multipath frequency selective fading channels has been tested and evaluated. The experimental results clearly indicate significant performance improvement with the proposed diversity technique even in cases of severely distorted channels.

KEY WORDS

Smart Diversity Receivers, Multipath Frequency Selective Fading, Feher's Patented Quadrature Phase Shift Keying (FQPSK), Feher Diversity.

INTRODUCTION

Within the large class of smart wireless system developments, the described FD is a technique which

* Significant parts of the material in this publication are based on Aflatouni's thesis, Feher et al. patents [1], and other materials which remain property of the authors.

employs a Non-Redundant Error Detection (NRED), also known as pseudo-error on-line monitoring / detection for control signal generation of the diversity branches [1]. The described techniques are suitable for a large class of signals including but not limited to Feher patented GMSK, SOQPSK, FQAM, FQPSK and for other systems such as non-coherently demodulated PCM/FM.

Non Redundant Error Detection (NRED) based FD is used to choose the best receiver diversity branch with the lowest BER while traditional receiver diversity systems that are based on received signal strength measurement techniques choose the branch with the larger C/N ratio even though its performance due to selective fading could be inferior than that of the branch with the lower C/N. This technique is the fastest evaluation technique and leads to hitless choice. By means of pseudo-error detection the error rates that would result from the various available choices (diversity branches) are estimated and compared to select the best change to be made at any time. It could also be demonstrated that for typical aeronautical telemetry RF frequency selective fading channels, having delay spread in 20-200 ns range, the presented receiver diversity technique has significant advantages over other techniques such as adaptive equalization.

In the first part a brief description of the fade simulator as well as the constructed hardware are presented. Pseudo-error detection is introduced in the second part. The implemented hitless switch is described in the third part and the experimental results are presented in the forth part of this paper.

TWO-PATH FADE SIMULATOR CONSTRUCTION

A multipath channel is characterized by more than one path between the transmitter and receiver antennas. One that is often considered in many radio channels is a LOS communication link accompanied by L reflected replicas of the transmitted signal from other links. In most applications, the accuracy of the model improves with increasing L but models with large L limit practical value in simulation and analysis. A good model [5][6] for the aeronautical telemetry channel consists of a LOS signal accompanied by a single strong reflection with attenuation Γ ($0 \leq \Gamma < 1$) whose delay τ relative to the LOS signal is in the range of 20 to 200 nanoseconds (L=1, i.e. two-path model). Figure 1 shows the two-path fade simulator hardware implementation that has been used in the laboratory for this experimental work.

Variable attenuator 1 is used to control the fading notch depth and attenuator 2 in secondary path realizes the fading simulator with either a minimum phase or a non-minimum phase. The delay controls the distance between notches as well as the notch position. The phase shifter is used as the variable delay device and is controlled by a sinusoidal with dc offset.

Figure 2 shows a normal received spectrum of a 1 Mb/s FQPSK and Figure 3 shows a distorted spectrum of a 1Mb/s FQPSK that has been generated by the above fade simulator.

PSEUDO-ERROR MONITORING / DETECTION TECHNIQUE

In the proposed method in this paper, the best diversity branch with the lowest bit error rate (BER) is selected. A pseudo-error detector can be successfully used for the measurement of the BER of a digital communication link. Pseudo-error detection techniques remove the shortcomings of the long evaluation time and requirement to interrupt data traffic and redundancy [7][8]. A pseudo-error detector is implemented in the form of a second detector, which is intentionally more

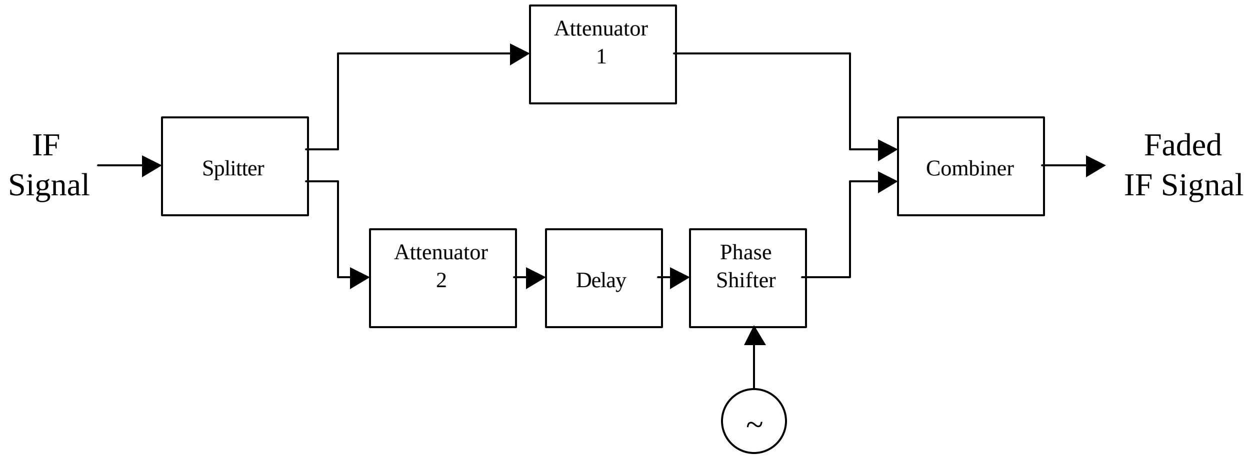

Figure 1) A simple hardware implementation of a two-path fading model

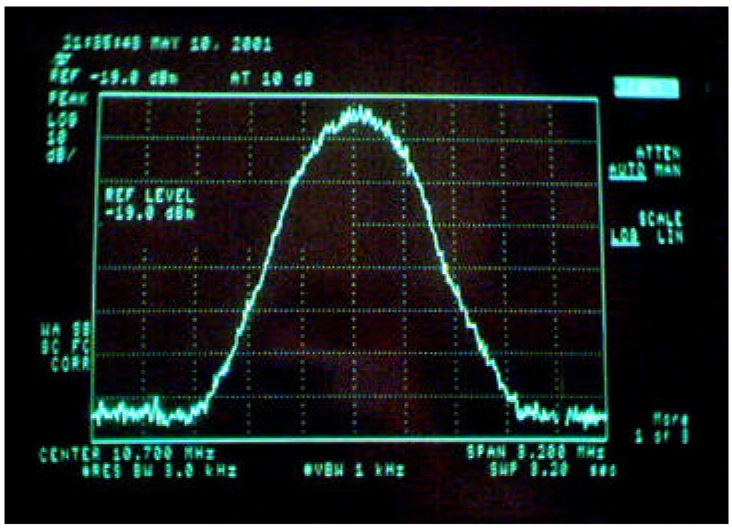

Figure 2) Undistorted spectrum of a 1Mb/s FQPSK

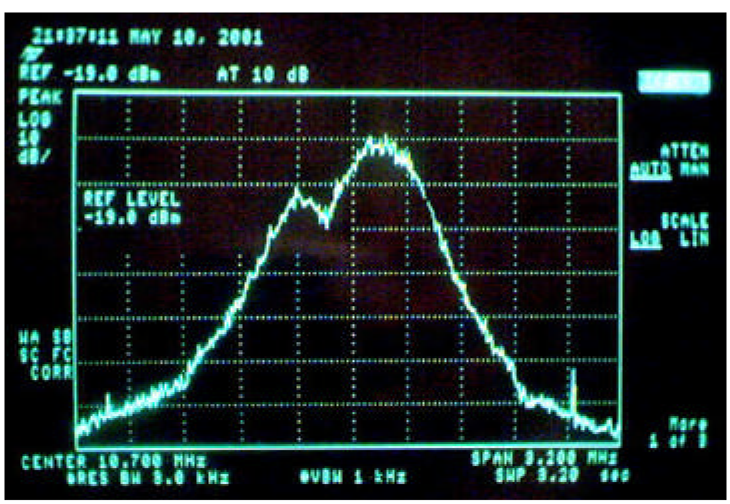

Figure 3) Distorted spectrum of a 1Mb/s FQPSK due to multipath propagation

perturbation sensitive i.e. for a specified signal to noise ration (S/N) or ISI or other impairments it introduces more errors than the primary signal path detector [3][4]. Figure 4 shows the block diagram of the implemented pseudo-error detector in the laboratory. In this method threshold th2 in the secondary path is set higher than threshold th1 in the primary path (shifted threshold method) to achieve the degraded performance as mentioned before.

HITLESS SWITCH IMPLEMENTATION

A simple hitless diversity switch has been implemented and tested in laboratory. Figure 5 shows the block diagram of this hitless switch. Two diversity branches have been assumed for this research. Data 1 and Data 2 are outputs of the demodulators in first and second diversity branches. This switch is controlled by the output of the pseudo-error detector.

PRELIMINARY HARDWARE TEST AND EVALUATION RESULTS

Although preliminary hardware test and evaluation results indicate substantial performance improvement with the utilization of the proposed diversity technique, the final measurement results were not available by the deadline of submitting this paper. The final test and evaluation results will be presented at the ITC 2001 conference. Figure 6 illustrates estimated block error rate (BLER) measurement results with two diversity branches and without diversity for a 1 Mb/s FQPSK system.

CONCLUSIONS

The proposed novel low-complexity smart receiver diversity technique offers substantial performance improvement in frequency selective faded channels. Due to simple implementation of the presented technique compare to other diversity branch combining methods such as maximal-ratio combining and equal-gain combining methods, using the bit error rate as a performance criteria in choosing the best diversity branch, and also employing pseudo-error detector to eliminate redundancy and long evaluation time, this method is very suitable for dynamic fast frequency selective fading environments

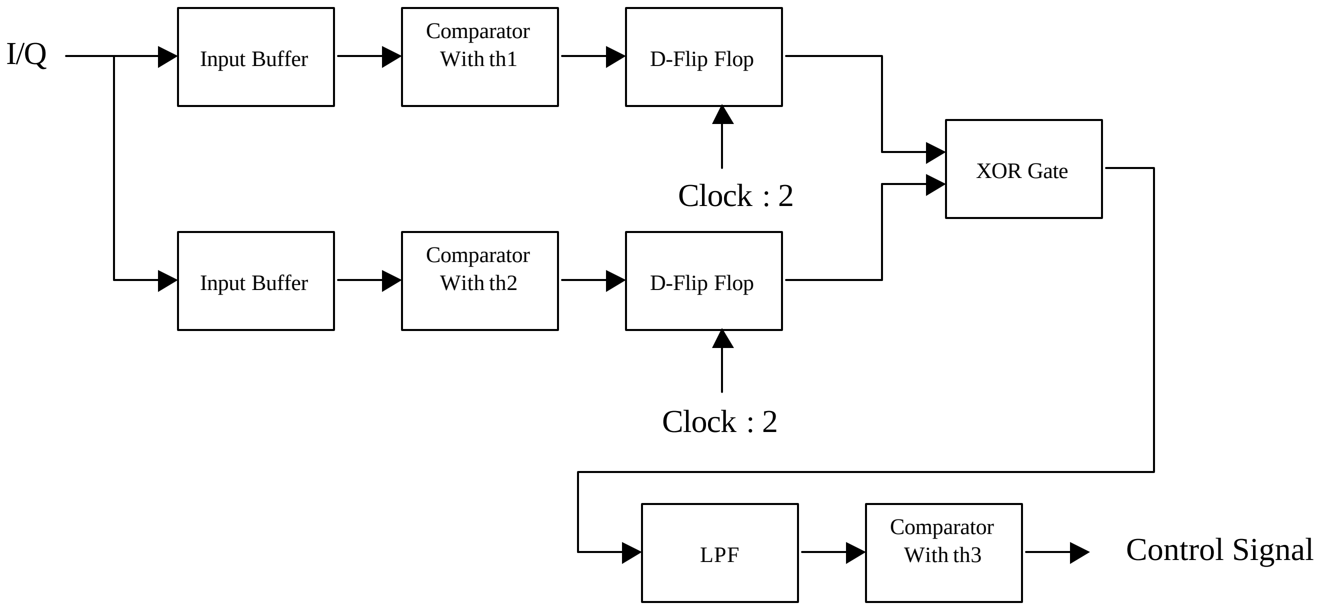

Figure 4) Pseudo-Error Detector Block Diagram

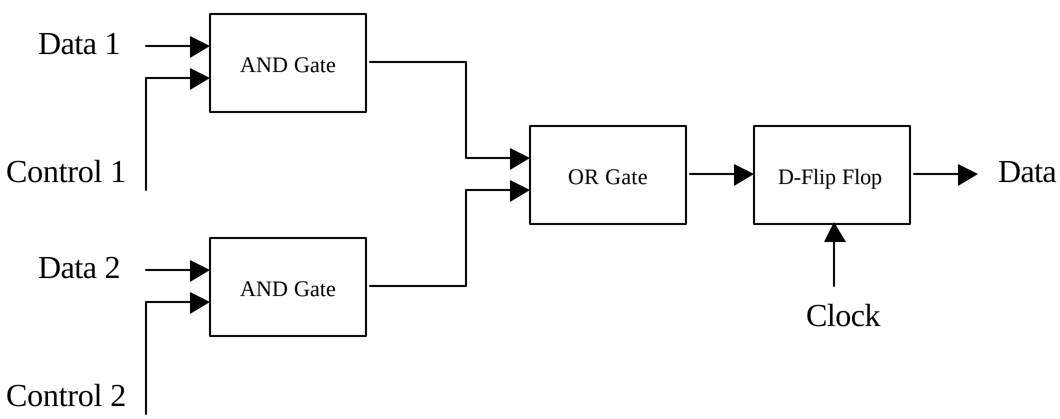

Figure 5) Hitless Switch Block Diagram

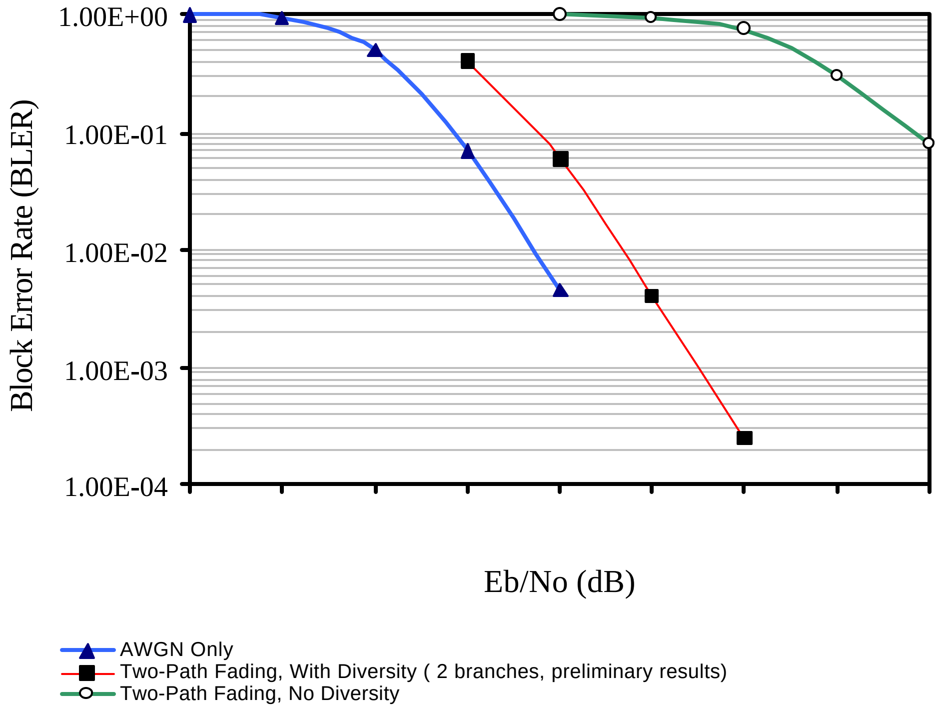

Figure 6) Estimated Block Error Rate (BLER) as a function of available Eb/No (dB) is illustrated with two diversity branches and without diversity for a typical selective fading environment. Numerical values were left blank intentionally as the actual measurements were not completed by the conference paper submission deadline. The actual values will be provided at the conference.

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