EE382C Project Report

System Level Design of Time-Hopping Impulse Modulation

Mohit Jalori

Raghu Raj

May 10, 2000

Abstract

Time Hopping Impulse Modulation (THIM) is an ultra-wideband communication technology in which pulses of very narrow time-width are pulse position modulated (PPM) by pseudo-random codes (PN codes) and data bits. Traditionally, Gaussian monocycle pulses have been used in THIM systems. In this project report we propose new pulse shaping schemes which, we argue and demonstrate, can increase the performance of THIM systems. Another contribution of this project is the modeling and simulation of a THIM system in Ptolemy and Agilent EEsof. This simulation environment greatly facilitates the experimental evaluation of THIM systems. The computational models used for this purpose are described and the theoretical results proposed are justified by simulation results.

1. Introduction and Context of Research

In wireless communications, bandwidth is a major constraint in developing systems capable of supporting multiple users. Extensive research has been carried out in the area of spread spectrum systems, in which every user signal is spread over the entire bandwidth. While CDMA has been the most prevalent spread spectrum technique, another spread spectrum technique, THIM, is gaining recognition. In THIM each transmitter emits a sequence a Gaussian monocycle pulses [2, 3]. Each individual pulse is delayed in time depending on the information signal and the pseudo-random sequence assigned to that transmitter [6, 7]. In Direct Sequence-CDMA, users employ a wide-band pseudo-random sequence to modulate the data signal so that it occupies the entire frequency band. In THIM, the transmitted signal occupies a much larger bandwidth even in the absence of data modulation.

2. Objectives of the Project

In our project, system level design of THIM system, we wanted to create a system level design of the transmitter, receiver and the channel for a THIM system and to come up with a performance analysis for this system. We wanted to simulate this system for different pulse shapes and study its performance in presence of channel impairments.

3. Formal Modeling

We modeled our THIM system using the SDF model because in this system the dataflow does not depend on the data values. The transmitter section in this system periodically generates a frame of 160,000 samples of which 160 samples represent one bit of data. The output samples of all users are combined and the channel section consumes these samples, adds channel impairments and produces the same number of output samples.

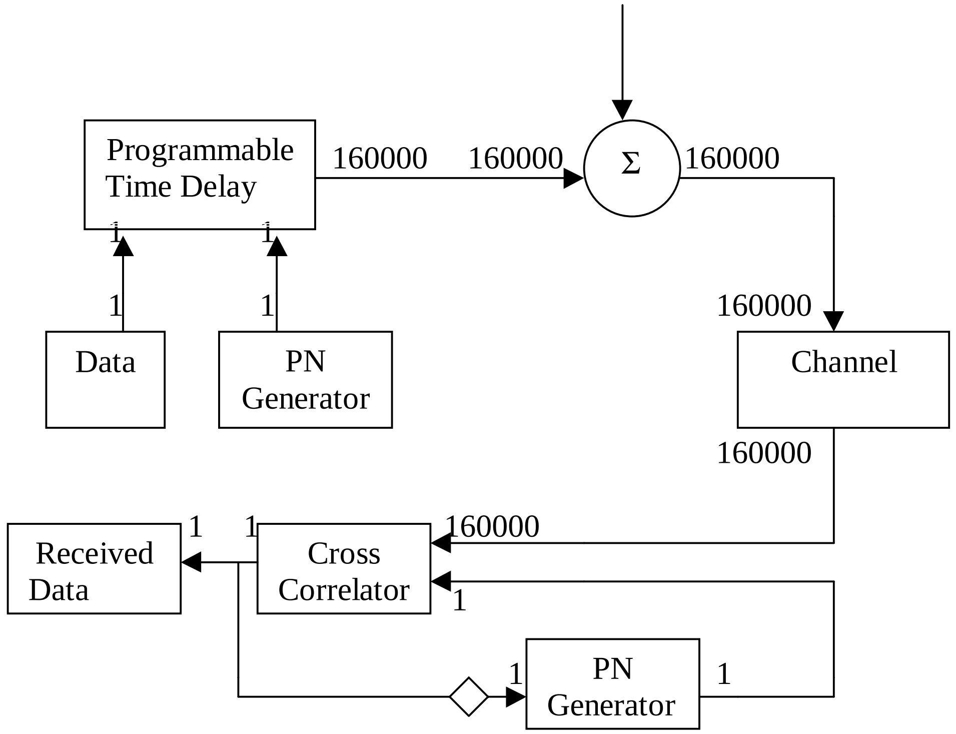

Figure 1: THIM system block diagram.

The receiver section consumes the output of the channel and produces a single data value for the desired user. The block diagram of the system we implemented along with the number of tokens consumed and produced by each SDF actor is shown in Figure1.

4. <u>Implementation</u>

<u>Transmitter:</u> The transmitter section of THIM system consists of a programmable time delay block which produces a train of pulses which are modulated in time depending on the value of data and PN sequence generator. In our project the transmitter transmits a frame of duration 1μsec which contains a pulse representing a bit. The transmitter we designed is capable of transmitting Gaussian monocycle, Gaussian, Raised Cosine and Manchester pulses. The amount of PPM shift given to each pulse is calculated from the value of data and PN sequence. The maximum amount of shift due to data is 300psec (which is a parameter to the programmable time delay block) and the amount of shift due to PN sequence is kept to a maximum value of 25.6nsec [4, 5]. We generate the PN sequence using the product of two 18-stage shift registers having the following

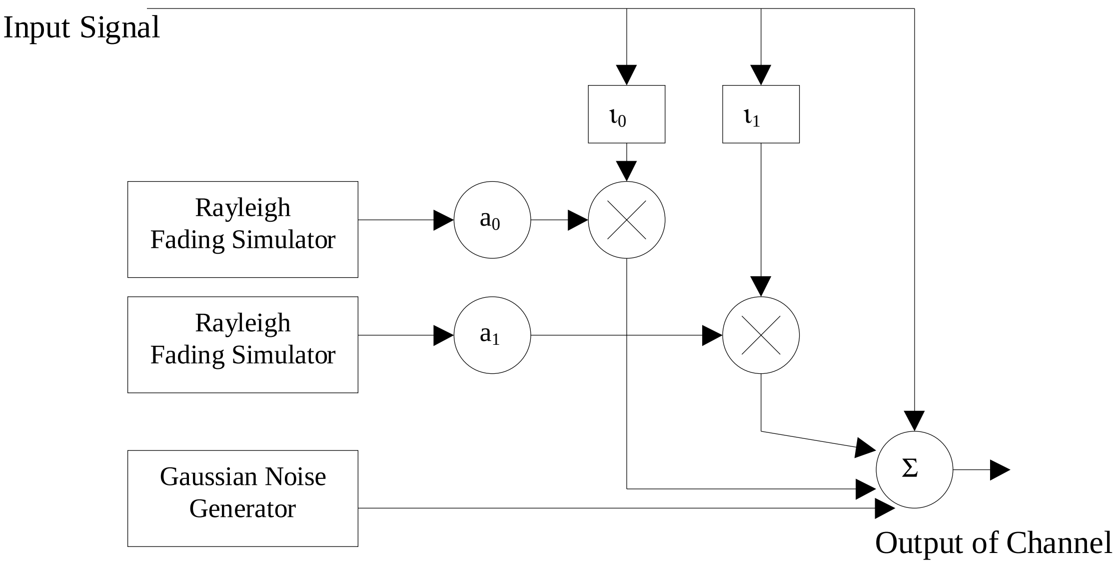

Figure 2: Rayleigh fading channel model

generator polynomial:

$g(x) = g_1(x)\, g_2(x)$, where $g_1(x) = x^{18} + x^7 + 1$ and $g_2(x) = x^{18} + x^{10} + x^7 + x^5 + 1$

Channel: As shown in Figure 2 the channel that we used to simulate our system adds white Gaussian noise and simulates a multipath environment with Rayleigh fading. The variance of the noise is a parameter that is varied to control the signal to noise ratio (SNR) of the system. The channel block is capable of adding upto 7 multipaths with varying attenuation factors, a_N, which are parameters to this block, and Rayleigh fading model is used for each path. The delay on any path, ι_N (which is calculated by a random number generator), varies between 0-10μsec [8].

Receiver:

- Synchronization: In our implementation we transmit a synchronization pulse from the transmitter to receiver every 50μsec [1]. The receiver detects this pulse and, depending on the position of this pulse, estimates the delay due to channel every

50μsec. According to this value of delay the receiver advances or delays the value of its PN sequence generator so as to maintain synchronization with the transmitter.

- Demodulator: The demodulator we have implemented is a sliding cross-correlator which correlates the received signal with a template signal (which is a pulse shifted in time depending on the PN sequence of the user) over a period of 2ns [4, 5]. The receiver section makes its decision on the basis of the position at which the maximum correlation is obtained between the received and the template signal.

5. Simulation Results

For the first set of results we varied the SNR and recorded the corresponding bit error rate (BER). For the second set of results, the SNR was fixed at a moderate value of 3dB and the BER was recorded for different number of multipaths for different signaling schemes. First we will briefly describe the different pulse shapes that have been used. All the pulse shapes that we used have a time duration of 1 ns and unit energy. The spectra of all the pulse shapes used are shown in Figure 3.

- Gaussian Monocycle: The equation of Gaussian monocycle is given by [4, 5]:

  h(t) = $6A\sqrt{\frac{e\pi}{3}}\frac{t}{tau}e^{-6\pi(t/tau)^2}$, where f_c is the center frequency, $tau = 1/f_c$ and A is the amplitude scaling factor.

- Gaussian Pulse: The Gaussian pulse is described by the following equation:

  h(t) = $Ae^{-2\pi(t/\sigma)^2}$, where A is the amplitude and the variance, σ, is chosen to be 2.

- Manchester Pulse: The Manchester pulse of amplitude A is described by the following equation:

  h(t) = A for -0.5 ns $\le t < 0$ns
  -A for 0 ns $\le t \le 0.5$ ns.

- <u>Raised Cosine Pulse</u>: The Raised cosine pulse is described by the following equation:

$$h(t) = \left(\frac{\sin(\pi t/T)}{\pi t}\right)\left(\cos(\pi \alpha t/T) \Big/ (1-4\alpha t/(2T))^2\right),$$ where α is the roll-off factor and T is a measure of the pulse width. In our simulations, we choose α = 0.5 and T = 1nsec.

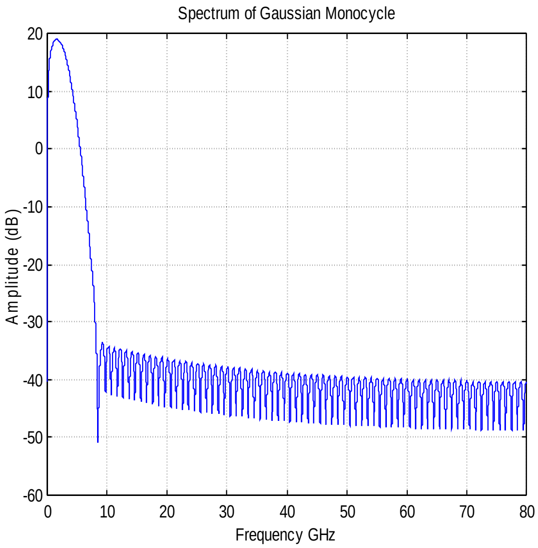

Figure 3(a)

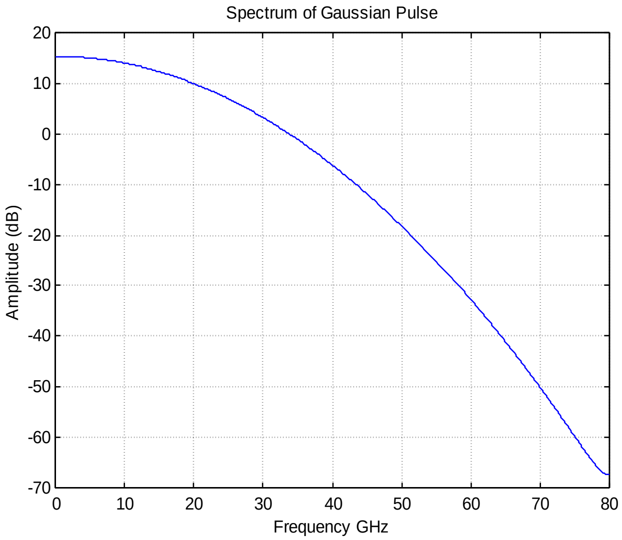

Figure 3(b)

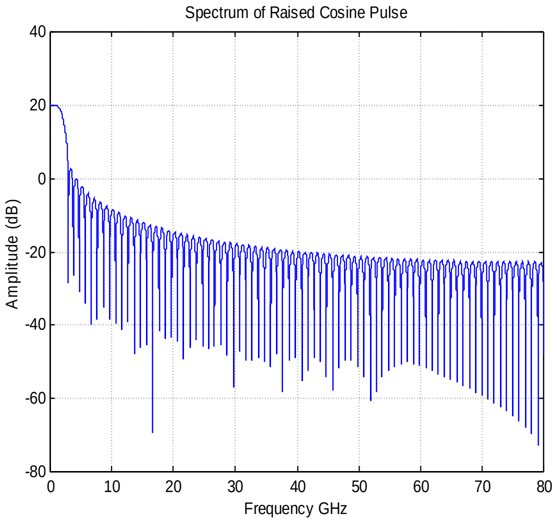

Figure 3(c)

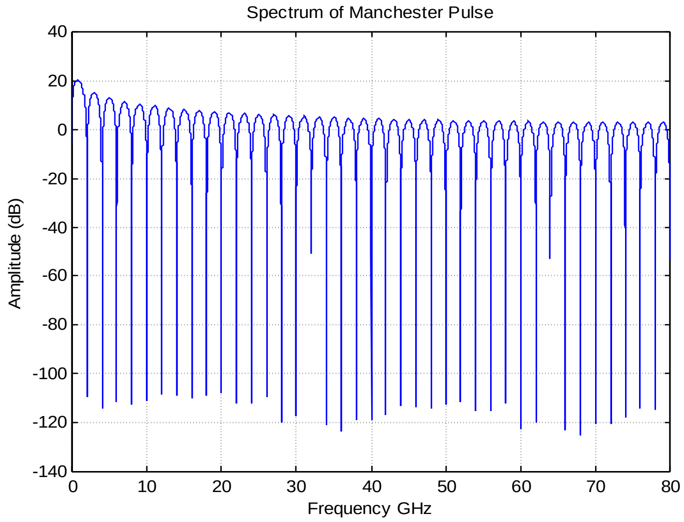

Figure 3(d)

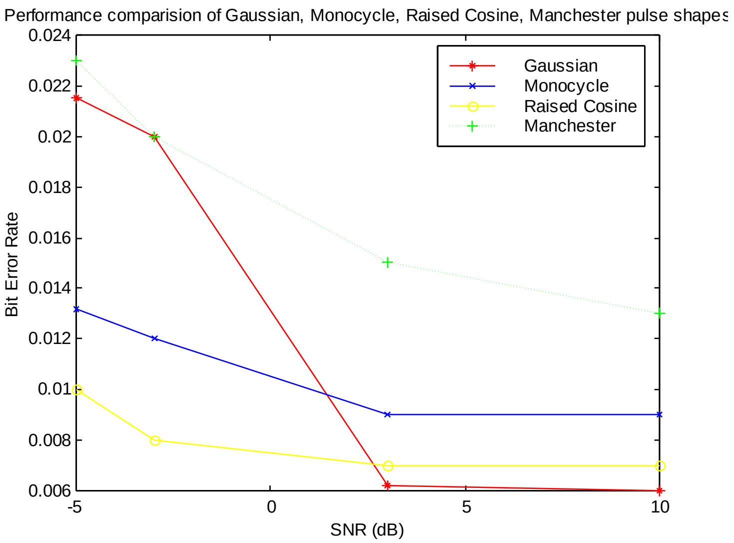

Figure 4(a)

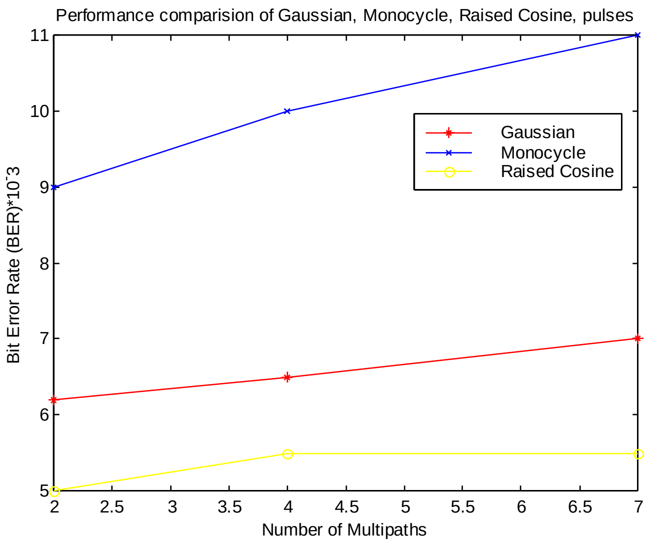

Figure 4(b)

Figure 4(a) plots the BER vs. SNR graph for the various signaling schemes. Figure 4(b) plots the BER vs. number of multipaths graph. We now give a brief explanation of the results we obtained.

6. Discussion of Results

We will briefly consider some of the spectral properties of the various pulses described above. Figure 3 shows the spectra of these pulses.

In low SNR environments, it is favorable for a pulse to have a low bandwidth because, assuming that the noise in the channel is white (i.e. it has uniform density across all frequencies), the pulse will capture lower noise and this improves the BER. It is for this reason that the Raised cosine pulse (with a 3dB bandwidth of 2GHz) performs better than the Gaussian monocycle pulse (with a 3dB bandwidth of 2.5GHz) which in turn performs better that the Gaussian pulse (with a 3dB bandwidth of 15GHz). The Manchester pulse has a lot of significant side lobes which causes degradation of performance at low SNRs.

In the high SNR scenario (low noise environment), the effect of channel noise is negligible compared to the inter-user interference. Thus to minimize the inter-user interference, a good pulse will spread the signal energy uniformly over a wide frequency range so that the signal will appear as noise to the other users.

By inspecting the spectrum of the Gaussian pulse we see that the signal energy is uniformly spread over a very wide frequency range. Consequently, the Gaussian pulse has the best performance in the high SNR regions. In the case of the Gaussian monocycle and raised cosine pulses, we see that the energy of the raised cosine pulse is spread more uniformly than that of the monocycle (since the monocycle has a much sharper cutoff frequency than the raised cosine pulse) and consequently the signal energy density is lower in the former case. This why we observe that the improved performance of the raised cosine pulse over the monocycle. As we observe in Figure 3(d), the Manchester pulse has many side lobes of narrow bandwidth and sharp cut-off frequencies. Hence its energy is not uniformly distributed across the frequencies and so it performs poorly. The results obtained by our simulations (Figure 4(a)) confirm the above analysis.

The graph in Figure 4(b) is plotted for 3dB SNR. The relative performance of the 3 pulses, are in accordance with the graph in Figure 4(a). We see that for all these signaling schemes, the THIM system is very tolerant to multi-path effects which is an important advantage of an ultra-wideband system.

7. Innovations

- The main contribution of this project is the proposal of new pulse shapes (namely Raised cosine and Gaussian) which, we argue and demonstrate, can improve the performance of current THIM systems.
- The contribution to Ptolemy and Agilent EEsof is the addition of a THIM demo.

8. Conclusion

The THIM system was modeled by an SDF graph which was then simulated in Ptolemy and Agilent EEsof. This simulation environment greatly facilitated a detailed performance evaluation of the THIM system for different pulse shapes and multipath scenarios. Finally we demonstrate that the Raised cosine and Gaussian pulse shaping schemes can provide improved performance over the traditional THIM systems which use Gaussian monocycles [2, 3].

References

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