EE382C Literature Survey

System Level Design of Time-Hopping Impulse Modulation

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Abstract

Time-Hopping Impulse Modulation is an ultra-wideband time domain system that uses pulse position modulation to modulate a train of very short duration Gaussian monocycles. This technology can be used in a wide range of applications including cellular telephones, wireless PBXs/LANs, precision geo-location systems, high performance radar systems and personal communication systems. The objective of our project is to come up with a system level design of a multi-user time-hopping impulse modulation system (THIM) and to study the effect of channel distortion on its performance.

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, where each individual user has the signal spread over the entire bandwidth. While CDMA has been the most prevalent spread spectrum technique, there is another spread spectrum technique, THIM, which is gaining recognition. In THIM each transmitter emits a sequence a Gaussian monocycle pulses, where each individual pulse is delayed in time depending on the information signal and the pseudo-random sequence assigned to that transmitter [1]. In DS-CDMA the users employ a wideband pseudo-random sequence to modulate the data signal so that it occupies the entire frequency band. However in THIM the transmitted signal even in the absence of data modulation occupies a very large bandwidth.

The advantages of THIM system are:

- Multi-User Ultra-Wideband System: THIM has a larger bandwidth than conventional CDMA systems and is capable of supporting more users.
- High Data Rate: Since the Gaussian monocycles have very short duration they are capable of supporting very high data.
- Low Power: Since the THIM systems have a very low duty cycles (typically 0.1%) they require power in the range of few mill watts.
- High Processing Gain: The THIM systems have a high processing gain, which is the ratio of channel bandwidth to the bandwidth of the information signal, because of the wideband nature of the Gaussian monocycles.
- Immunity to multipath fading: In THIM system in order for there to be multipath effects the path length traveled by the scattered pulse must be less than the product of pulse width and speed of light (which is typically 0.3 m) [2,3].

2. <u>Objective of the Project</u>

Our aim in this project is to come up with a system level design of the THIM system in Agilent EEsof. We will be using this design to study the effect of following factors on the THIM system:

- Effect of using different pulse shapes like Gaussian monocycles, rectangular pulses etc.
- Effect of multipath and fading on the performance of the system.
- Effect of different signaling schemes on the system like antipodal signaling, Manchester coding scheme etc.

At the end of the project we plan to come up with a detailed performance analysis of the THIM system.

3. Theory and Implementation

The THIM multi-user system consists of a number of users, N, who simultaneously communicate with their respective receivers on the same frequency band. The system consists of the following sections:

3.1 Transmitter

The output of the transmitter of the k^{th} user is given by [4]

$$s^k(t) = \sum_j w\left(t - jT_f - c_j^k T_c - \Delta d^k_{[j/N_s]}\right). \qquad (1)$$

Here w(t) represents a Gaussian monocycle [6] given by the equation

$w(t) = 6A\sqrt{\frac{e\pi}{3}}tf_c e^{-6\pi(tf_c)^2}$, where A is the peak amplitude of the monocycle and f_c is the center frequency. Figure 1 shows the time domain and frequency domain characteristics of the Gaussian monocycle for A=1 and f_c= 2GHz.

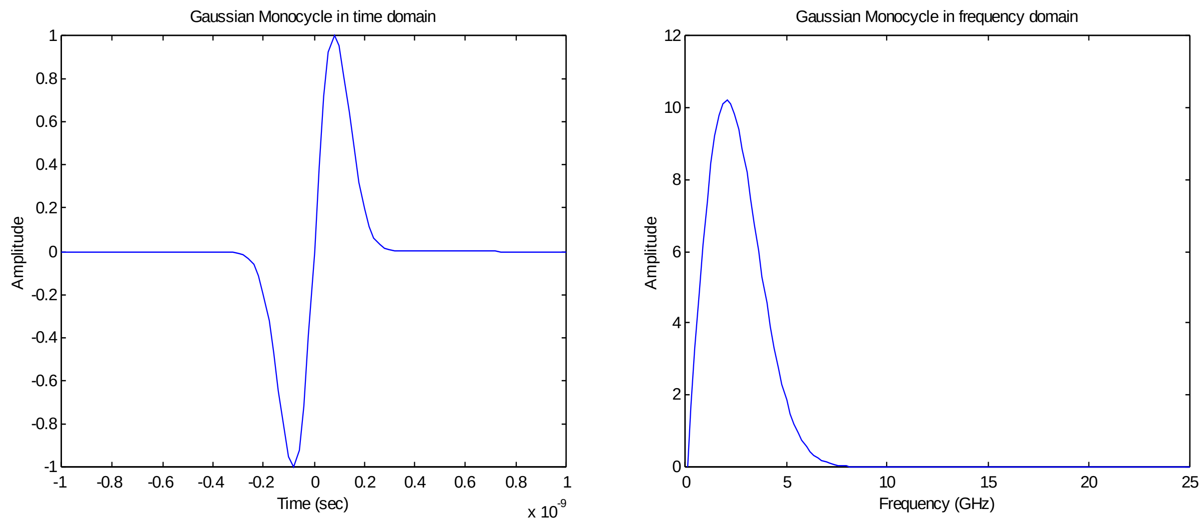

Figure 1

The signal described in equation (1) consists of perturbations of a uniform pulse train of Gaussian monocycles (with period T_f) such that the amount of delay for each pulse depends on the PN-sequence and the input data. The k^{th} user is assigned a unique PN-sequence $\{c_j^k\}$ which is periodic with period N_p. The code element c_j^k delays the j^{th} monocycle of the pulse train by $c_j^k T_c$, where $c_j^k \in [0,N_h]$ and $N_h T_c \leq T_f$. We then encode the data sequence corresponding to the k^{th} user $\{d_j^k\}$ by providing an additional delay of Δd_j^k where $d_j^k \in \{0, 1\}$. Further, a single data bit is used to modulate a block of N_s Gaussian monocycles. The index of the data symbol modulating pulse j is [j/Ns] where [x] represents the integer part of x.

3.2 Receiver

The received signal at the receiver of the k^{th} user is given by [5]

$$r(t) = \sum_{k=1}^{N_u} A_k s^k (t - \tau_k) + n(t)\,, \tag{2}$$

where A_k is the channel attenuation factor for the signal transmitted by the k^{th} transmitter, and τ_k represents the time asynchronism between the clocks of k^{th} transmitter and the receiver. In equation (2) n(t) represents white Gaussian noise. In order to demodulate the received signal for the k^{th} user it is necessary that the receiver for this user accurately estimate τ_k.

4. Current Work

Current work on time-hopping impulse modulation is done primarily by Dr. R. A. Scholtz *et al.* at the Communications Sciences Institute at University of Southern California and at Time Domain Corporation [6]. Time Domain has developed PulseON chipsets and chip designs based upon the Time Modulated Ultra-Wideband (TM-UWB) architecture [6]. Time Domain has built several prototype systems demonstrating the feasibility and application of this technology which include:

- A full duplex radio with an average output power of 250 μW and a variable data rate of either 39 kbps or 150 kbps occupying a bandwidth of 1.3 GHz.
- A full duplex walkie-talkie with an average output power of 2 mW, a data rate of 32 kbps and a range of 900 m.

- A 5 Mbps Wireless LAN that has been tested to a range of 10 m and effectively uses a radiated power of 50 μW.

THIM is also being used for radar applications because it is capable of measuring distance with high resolutions [6]. For example, a 2 GHz center frequency TM-UWB radar that uses 500 ps Gaussian pulses is capable of giving a resolution of 15 cm.

5. <u>Plans for the Implementation</u>

In our project we will be using Agilent EEsof to design and implement the transmitter and receiver section of the THIM system. Figure 2 shows a block diagram of the transmitter section of the THIM system.

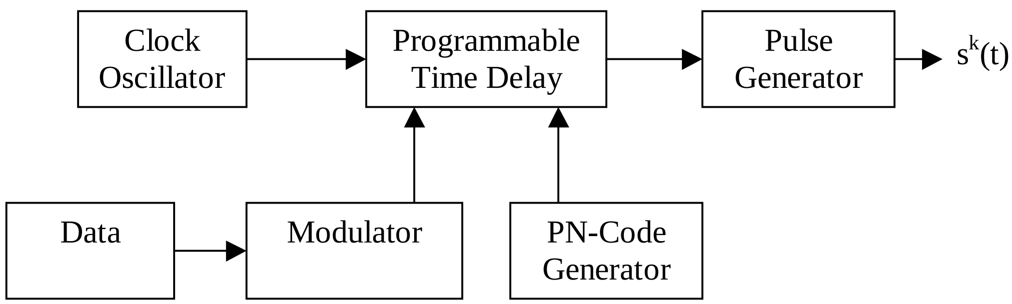

Figure 2

The clock oscillator provides a time base for the system. The analog input data is pulse code modulated into a binary sequence. The output binary sequence along with the PN-code is used to determine the times at which the pulse generator is fired.

Figure 3 shows the receiver section for the THIM system. The receiver is initially in the training mode during which the synchronizer will use the training sequence sent by the transmitter to estimate the channel delay τ. The programmable time delay adjusts the delay of the template signal pulses depending on this value of τ. The pulse generator

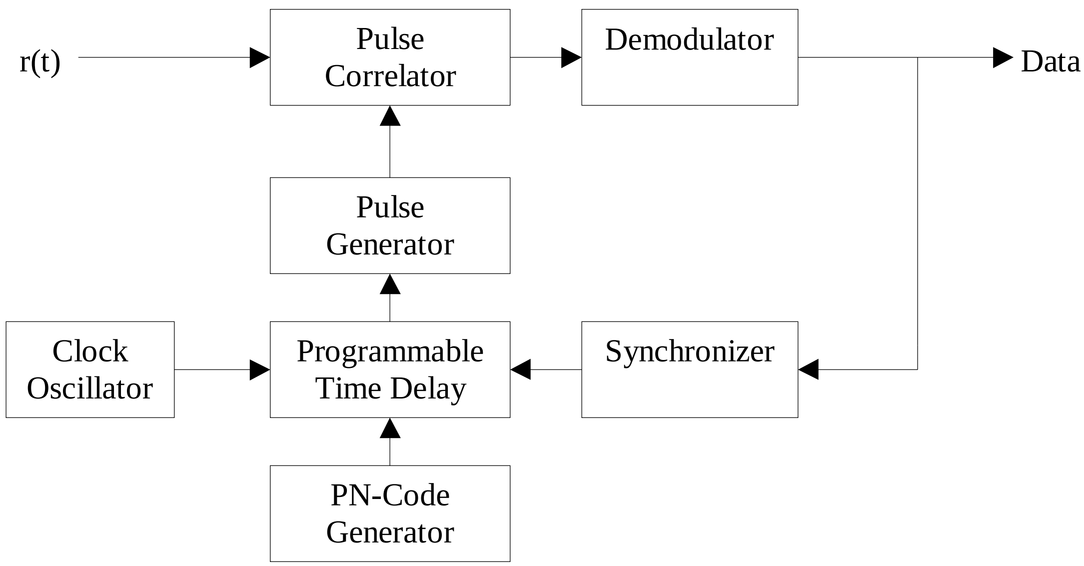

Figure 3

produces template signals corresponding to bits 0 and 1 which are correlated with the received signal. The correlator makes a hard decision as to whether the pulse corresponds to a 0 or 1. The output of the correlator is fed to the demodulator which, after integrating over Ns pulses, decides which symbol was transmitted.

In our project we also plan to implement a channel that will add the white Gaussian noise to the transmitted signal. The effect of multipath fading will be simulated using Agilent EEsof.

Since the dataflow in the system we plan to implement does not depend on the data values, we will be modeling the entire THIM system using the SDF model.

References

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6. Time Domain Corporation, http://www.time-domain.com.