# Simple CDMA Message Decoding

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***Abstract*—This task deals with decoding a message encoded by a simple code-division multiple access (CDMA) system. The system design consists of 8-ary Walsh channel orthogonal spreading with a maximum-length sequence, oversampling and filtering. Through this decoding procedure, the goal is to understand how a CDMA system transmits bits across the Walsh channel. The decoding steps involve M-sequence generation, determining where the data starts using a generated pilot and cross-correlation, computing frequency and phase offsets, de-spreading over Walsh channels, and decoding the message. The message is found to be a quote from 'A Christmas Story' movie released in 1983.**

***Index Terms*—code-division multiple access, maximum-length sequence, Walsh channel**

## I. INTRODUCTION

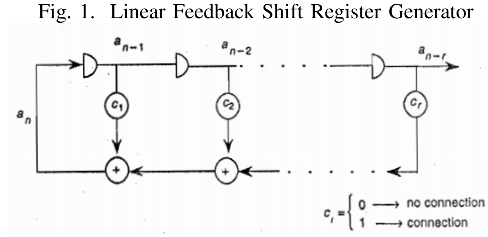
Code-Division Multiple Access (CDMA) is a spread-spectrum based wireless communication protocol that is widely used along with GSM which uses time-division multiple access technique. It has advantages of providing greater bandwidth efficiency and multiple access over a single communication channel. Although the required bandwidth is greater for the spread-spectrum technique, it came to use for the benefit of security and resistance to jamming in multiple access scenarios, especially for military purposes. In CDMA, each data signal is sent over mutually orthogonal channels, and such "Walsh" channels can be constructed with Hadamard transform. An example 8-ary Hadamard transform matrix used in this task is shown in Table I. Each row or column is to be assigned to an individual user and this chipping sequence spreads the signal uniquely for multiple users.

TABLE I
8-ARY HADAMARD TRANSFORM

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| [1 | 1 | 1 | 1 | 1 | 1 | 1 | 1; |
| 1 | -1 | 1 | -1 | 1 | -1 | 1 | -1; |
| 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1; |
| 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1; |
| 1 | 1 | 1 | 1 | -1 | -1 | -1 | -1; |
| 1 | -1 | 1 | -1 | -1 | 1 | -1 | 1; |
| 1 | 1 | -1 | -1 | -1 | -1 | 1 | 1; |
| 1 | -1 | -1 | 1 | -1 | 1 | 1 | -1] |

The maximal length sequence is generated from a linear feedback shift register with the specified polynomial. Figure 1 shows a general approach to generating one [1].

Fig. 1. Linear Feedback Shift Register Generator




## II. APPROACH

The message decoding is performed in the following order: filter and channel parameter initialization from the transmitter, maximal length sequence (M-sequence) generation from the provided polynomial (taps) for the linear feedback shift register (LFSR), pilot generation from the 0th Walsh channel, determining where data frames begin from cross-correlation, correct the frequency and phase shifts, despreading and decoding through the 5th Walsh channel, and finally converting to ASCII characters for each of the 8-bit long sequences.

### *A. Parameters*

The transmitted data matrix, the coefficients for the root-raised cosine filter, chip rate (1 MHz), oversampling rate (4x) and the number of chips per frame (255) are provided. The transmit filter has roll-off factor of 0.75, and the number of taps is 25. We note that each ASCII string is encoded in MSB-first order and each character is spread across 64 chips on Walsh channel 5. There are three characters in each repetition of the M (255)-sequence, and the first and last frames contain only the pilot. The modulation scheme used for encoding is BPSK and the SNR for the data is 20 dB.

### *B. PN Sequence*

The specific taps used to generate the PN sequence used in this system are [8, 7, 6, 1]. This Galois form can be translated to Fibonacci form of [8, 7, 2, 1]. This polynomial is fed into the LFSR with initial state of all one's to generate a PN-sequence, which is later XOR'ed with data to de-scramble.

### *C. Pilot Frames*

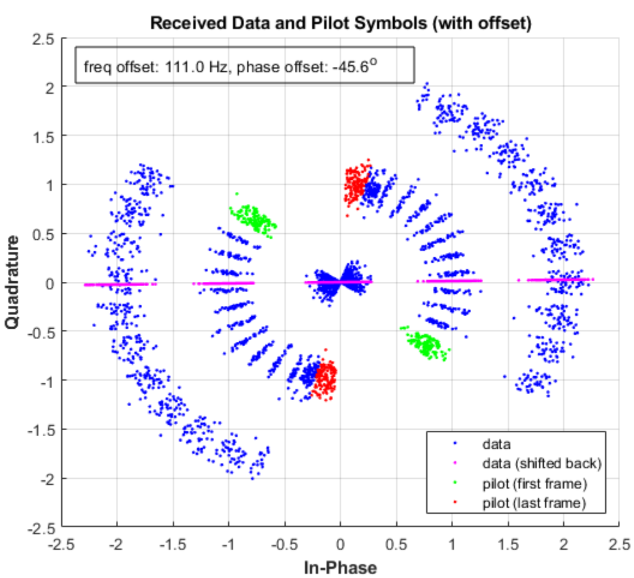
A test pilot is generated from spreading across Walsh channel 0 and BPSK modulating a sequence of zeros. In order to determine where data frame begins, this test pilot is cross-correlated with each frame, and it was found to be the second frame where data starts to appear.

### D. Signal Shifting

Upon receiving the data stream, the opposite of the transmit filter procedure is performed – filtering with the same characteristics and decimating by the same factor. Because there is a constant frequency offset and additional random phase offset in the encoding stage, they need to be taken into account. For this correction, the average of the differential phase angles for each pilot frame in the received data stream is used to determine the frequency offset, and the phase offset is found from the first pilot frame with a carrier with the previously computed frequency offset.

With the estimated offsets in frequency and phase, the received data are shifted, de-spread at Walsh channel 5, BPSK-demodulated, descrambled with the PN-sequence, and translated to ASCII characters. It is found that there is a constant frequency offset of 0.0007 radians per chip, or 111 Hz total, and a phase offset of -0.7956 radians per chip, or -45.6$^o$ degrees total. The decoded message is `Be Sure to Drink Your Ovaltine.` This message comes from a scene in `A Christmas Story` movie back in 1983, where Ralphie gets his decode ring and learns something about the world from this message. The signal constellations for the transmitted data symbols, shifted data symbols, and pilot symbols in the first and last frames are shown in Figure 2.

Fig. 2. Signal Constellations - Data and Pilot frames




## III. Conclusion

The task deals with decoding a secret message transmitted through an 8-ary Walsh channel-based CDMA system, and the decoding procedure takes into account the frequency and phase offsets in the pilot frames to estimate the correct bits. The message is correctly translated into ASCII characters of some meaning.

## References


[1] Andrew J. Viterbi. 1995. CDMA: principles of spread spectrum communication. Addison Wesley Longman Publishing Co., Inc., USA.