A Comparative Study of Spread Spectrum Technique based on Various Pseudorandom Codes

By Vandana Nath & Abhishesh Kumar

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A Comparative Study of Spread Spectrum Technique based on Various Pseudorandom Codes

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Abstract - This paper presents a comparative study of Frequency Hopping Spread Spectrum and Direct Sequence Spread Spectrum techniques. The Transmitter and Receiver have been implemented using MATLAB. Maximum-length sequences, Gold Sequences and Walsh Codes have been used as the pseudorandom codes for transmission. Finally received signal have been evaluated on the basis of Bit Error Rate for all the used codes.

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I. Introduction

Spread Spectrum is a modulation method that spreads a narrowband signal over a wide range of frequencies at the transmitting end and then de-spreads it into the original data bandwidth at the receiving end. The Spread Spectrum technique increases the bandwidth of the transmitting signals to a value much larger than is needed to transmit it. Thus, the power per unit bandwidth is minimized[1]. Spread signals are intentionally made to be much wider band than the information they are carrying to make them more noise-like. As the Spread Spectrum Signal is more noise like, this is the reason that they are harder to detect, intercept or demodulate. It is harder to determine the actual presence of the Spread Spectrum signal[1]. Further, Spread Spectrum signals are harder to jam (interfere with) than narrowband signals. These Low Probability of Intercept (LPI) and anti-jam (AJ) features are why the military has used Spread Spectrum for so many years. Spread spectrum technology allows to bring a number of the same information as that can be transmitted using the narrowband carrier signal and spreaded the signal on a frequency range much greater. Spread Spectrum uses wide band, noise-like sequences called Pseudorandom sequences binary sequences (PRBSs) or pseudo noise (PN) or m-sequences. The PN sequences are semi random sequences i.e. it appears random during its code length and the entire sequence repeats indefinitely. They are generated with the use of Linear Feedback Shift Register (LFSRs)[2].

II. Dsss

In Direct Sequence-Spread Spectrum the baseband signal is combined with a code word,which is known as chipping code. The combined signal is then used to modulate the RF carrier signal. In this way the narrowband signal is spread over the large bandwidth. The original receiver is able to retrieve the correct signal if and only if it knows the correct chipping code (i.e. PN code). The PN is obtained using a PN generator. Frequency of the PN sequence is chosen higher than that of the data signal. This generator consists of a Linear Feedback Shift Registers (LFSRs), and a logic circuit with feedback that determines the PN signal. After spreading, the signal is modulated using a digital modulation technique and then transmitted. BPSK (Binary Phase Shift Keying) is the most widely used modulation scheme in Spread Spectrum Systems. The equation that represents this DS-SS signal using BPSK as modulation is:

$$S(t) = \frac{\sqrt{2E}}{T}\, m(t)p(t)\cos(2\pi f_c t + \theta) \qquad (1)$$

Where $S(t)$ is the transmitted DSSS signal, m(t) is the data sequence, $p(t)$ is the PN spreading sequence, f_c is the carrier frequency, and θ is the carrier phase angle at t=0. Each symbol in m(t) represents a data symbol and has a pulse duration of Ts . Each pulse in $p(t)$ represents a chip sequence, and has duration of Tc. The transitions of the data symbols and chips coincide such that the ratio Ts to Tc is an integer.

III. Fhss

In Frequency Hopped Spread Spectrum, the data is directly modulated onto a carrier frequency. That carrier frequency hops across a number of channels within the RF band using a Pseudo random hopping pattern. That pattern is nothing but the list of different frequencies that is maintained in a table called Hopping table. It is this hopping table by which the carrier jumps from on frequency to another at a specified time interval. The advantage of using this scheme is that the signal sees a different channel and a different set of interfering signals during each hop. This avoids the problem of failing communication at a particular frequency, because of a fade or a particular interferer. The number of frequencies over which the signal may hop is usually a power of 2, although all these frequencies are not necessarily used. The frequency hopping is accomplished by means of a digital frequency

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synthesizer, which in turn is driven by PN code generator. The M sequence ,i.e. c chips will produce $M=2^c$ frequencies for each distinct combination of these digits.

PN sequence in the receiver should be an exact replica of the one used in the transmitter, with no delays, because this might cause severe errors in the incoming message.

IV. PSEUDORANDOM PN SEQUENCE

Pseudo random binary sequences ,also known as pseudo noise(PN) or maximal length binary sequences (m sequences) are widely used sequences in the Spread Spectrum systems. In a truly random sequence the bit pattern never repeats, however generation of such a sequence is difficult as it is not practical. The data should appear randomly to the channel and but be predictable to the user. This is therefore the PN sequences are used in the applications. A pseudo random sequence is a semi-random sequence in the sense that it appears random within the sequence length, fulfilling the need of randomness, but the sequence is not actually random. Instead the entire sequence repeats itself indefinitely. To a unintended observer or receiver the actual signal appears as a noise like structure. However the user who is aware of the original PN sequence and its properties will be able to retrieve the correct transmitted signal at its end. The PN sequences are generated by using the Linear Feedback Shift Register (LFSR). An LFSR is most often a shift register whose input bit is driven by the Exclusive OR (XOR) of some bits of the overall shift register value. The initial value of the LFSR is called the seed, and because the operation of the register is deterministic, the stream of values produced by the register is completely determined by its current (or previous) state. Likewise, because the register has a finite number of possible states, it must eventually enter a repeating cycle. However, an LFSR with a well-chosen feedback function can produce a sequence of bits which appears random and which has a very long cycle. If there is 'n' number of flip-flops in the LFSR the code length will be '2^n-1'.

V. GOLD CODES

A Gold code, also known as Gold sequence, is a type of binary sequence, have small cross-correlations property within a set, which is useful when multiple devices are broadcasting in the same range [3]. A set of Gold code sequences consists of 2^n-1'. A set of Gold codes can be generated with the following steps. Gold sequences help generate more sequences out of a pair of m-sequences giving now many more different sequences to have multiple users. Pick two maximum length sequences of the same length '2^n-1' such that their absolute cross-correlation is less than or equal

to '$2^{(n+2)/2}$' , where 'n' is the size of the LFSR used to generate the maximum length sequence. The set of the '2^n-1' exclusive-ors of the two sequences in their various phases (i.e. translated into all relative positions) is a set of Gold codes. The highest absolute cross-correlation in this set of codes is '$2^{(n+2)/2}+1$' for even 'n' and '$2^{(n+1)/2}+1$'for odd 'n'.

i.e $\qquad = 2^{(n+2)/2}+1 \qquad\qquad$ for 'n' is even

$\qquad\quad = 2^{(n+1)/2}+1 \qquad\qquad$ for 'n' is odd

The exclusive or of two Gold codes from the same set is another Gold code in some phase. Within a set of Gold codes about half of the codes are balanced - the number of ones and zeros differs by only one.

VI. WALSH CODE

Walsh code provides useful code sets for CDMA wireless systems as all the codes of the sets are orthogonal to each other. Walsh functions are generated by mapping codeword rows of special square matrix called Hadamard matrix[4]. The length N of a Walsh code is of power 2, i.e. $N=2n$ (n is any positive integer). The matrix contain one row of all zeros and the other rows each have equal number of ones and zeros. Walsh codes can be generated by following recursive procedure:

$$W^1 = [0]$$

$$W^2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

$$W^4 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

i.e.

$$W^{2n} = \begin{bmatrix} W^n & W^n \\ W^n & \overline{W^n} \end{bmatrix}$$

Where, N is a power of 2 and over-score implies the binary complement of corresponding bits in the matrix. So, N length Walsh code can provide N number of codes which can serve maximum N number of users. These codes are orthogonal to each other and thus have zero cross-correlation between any pair.

VII. IMPLEMENTATION

The models for the each Direct Sequence and Frequency Hop Spread Spectrum are designed and simulated. MATLAB is the tool in which all the simulation is done and the graphs are plotted. The DSSS system

is implemented using BPSK modulator. The m-sequences, Gold Sequence and the Walsh code are generated and used as the PN sequences at the input of the DSSS system. The signal is transmitted through AWGN channel. Finally the BER for each case is calculated. The FHSS is also implemented using BPSK modulator. The modulated signal is then derived by each the PN sequence, Gold Sequence and the Walsh Code. The signal is then transmitted along a channel with AWGN. Also the BER of the FHSS for each case is plotted.

VIII.   SIMULATION RESULTS

The DSSS and FHSS transmitter and receiver is simulated for each m-sequence, GOLD, and Walsh Sequence using the MATLAB in the presence of the noise. The various waveforms are obtained during the different stages. Finally the BER(bit error rate) is plotted for each case.

Fig. 1, Fig.2, Fig.3 shows the PN Sequence, Gold Sequence and Walsh Codes respectively. These are the three types of codes that are used for the simulation and are generated using blocksets.

Fig. 4 and Fig. 5 shows the transmitted and received signal during the DSSS system using PN sequences. The signals indicates itself that it appears as noise during the transmission.

Similarly, Fig. 6, Fig.7 and Fig. 8, Fig. 9 shows the transmitted and received signal during the DSSS system using Gold sequences and Walsh Codes respectively.

Fig. 10 shows the BER (bit error rate) of DSSS using all the codes. The bit error rate remains same for all the used codes in DSSS.

Fig. 11,12, Fig. 13,14 and Fig. 15,16 shows the transmitted and received signals of FHSS using PN sequence, Gold Sequences, and Walsh Codes respectively.

Fig. 17 is the BER of FHSS of PN sequence, Gold Sequence, and Walsh codes.
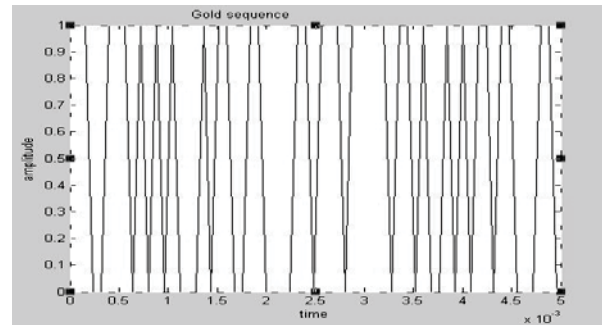
Fig. 2 : Gold Sequence

Fig. 3 : Walsh Code
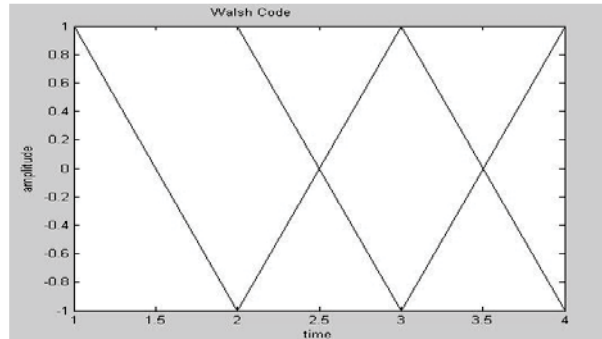

Fig. 4 : DSSS transmitter signal for PN sequence

Fig.1 : PN sequence

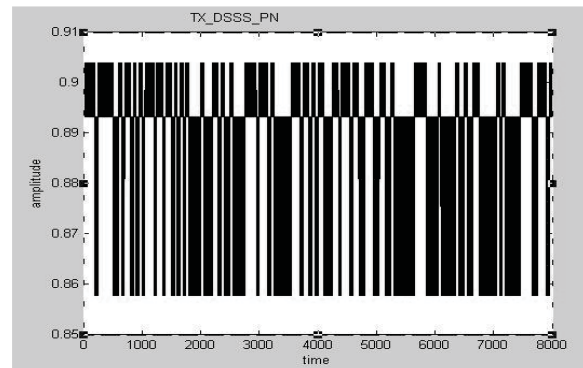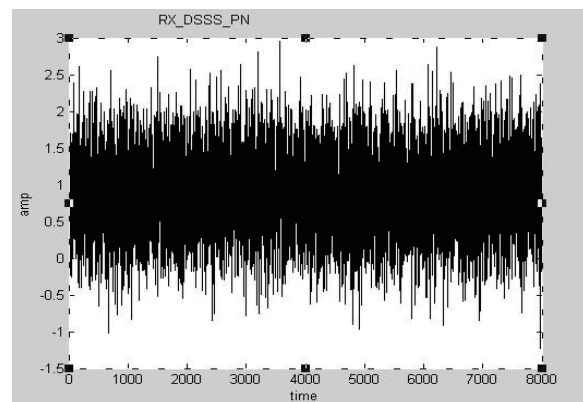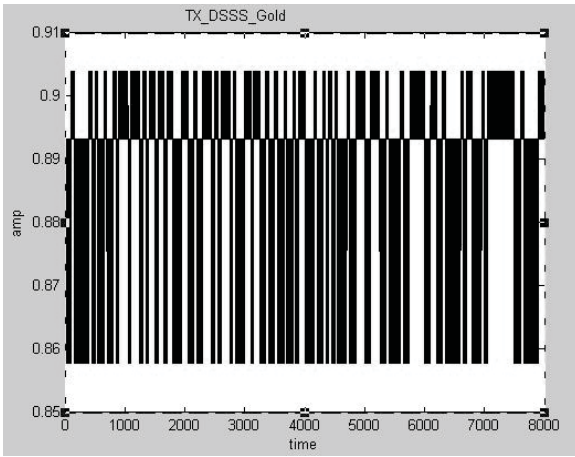*Fig. 5 :* DSSS Receivers signal for PN sequence

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Fig. 6 : DSSS transmitter signal for Gold sequence

Fig. 7 : DSSS receiver signal for Gold sequence
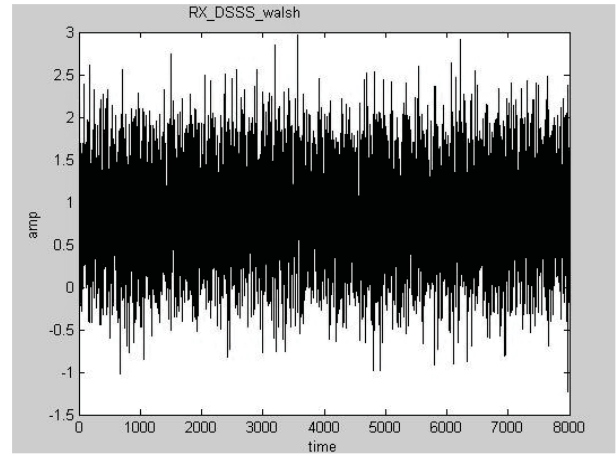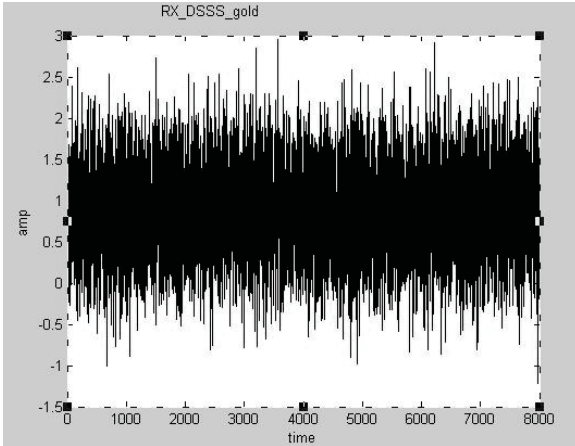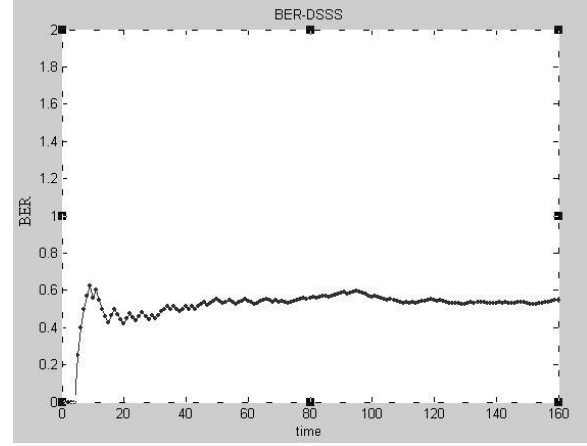

Fig. 8 : DSSS transmitter signal for Walsh

Fig. 9 : DSSS Receivers signal for Walsh sequence

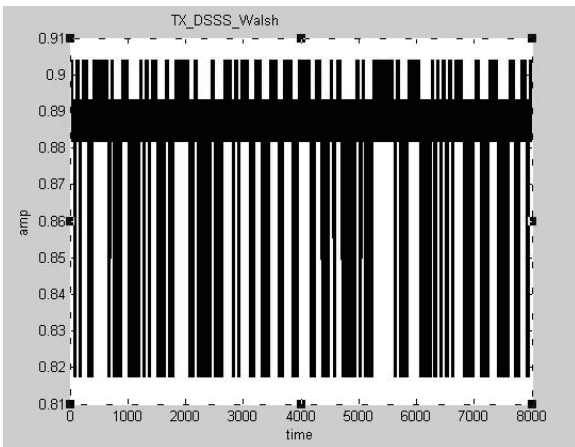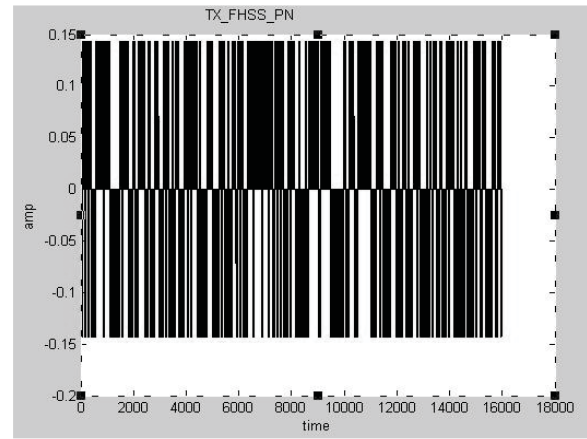*Fig. 10 :* BER for DSSS

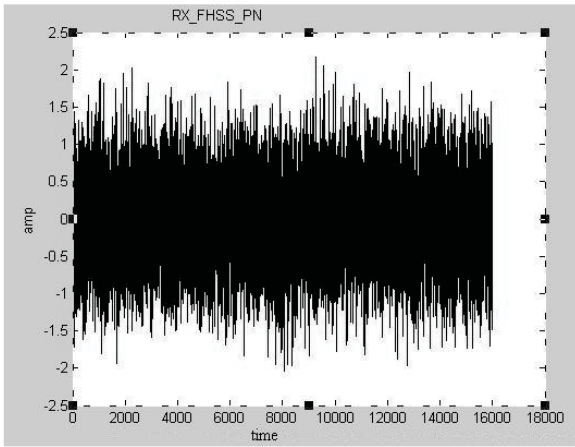*Fig. 11 :* FHSS transmitter signal for PN sequence
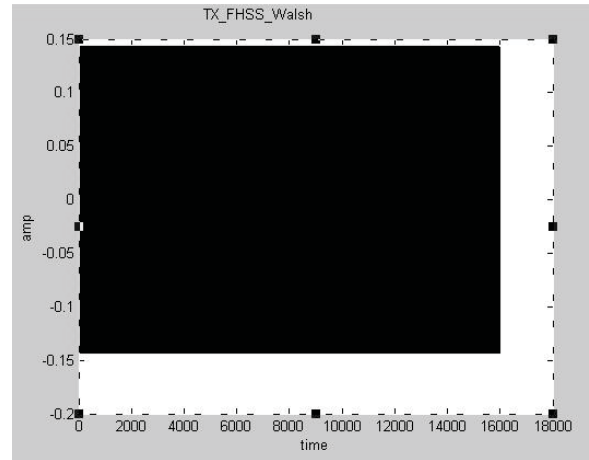
Fig. 12 : FHSS Receiver signal for PN sequence

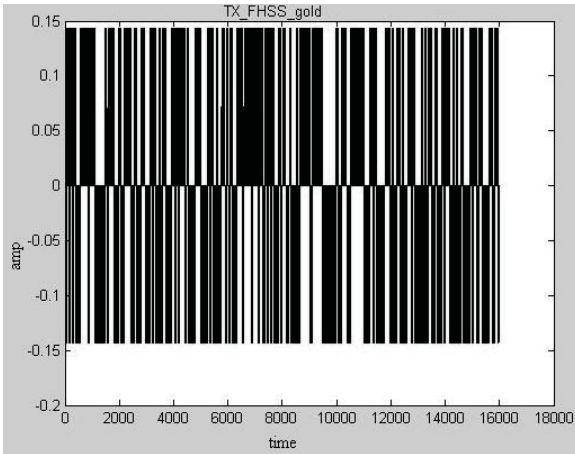Fig. 15 : FHSS transmitter signal for Walsh

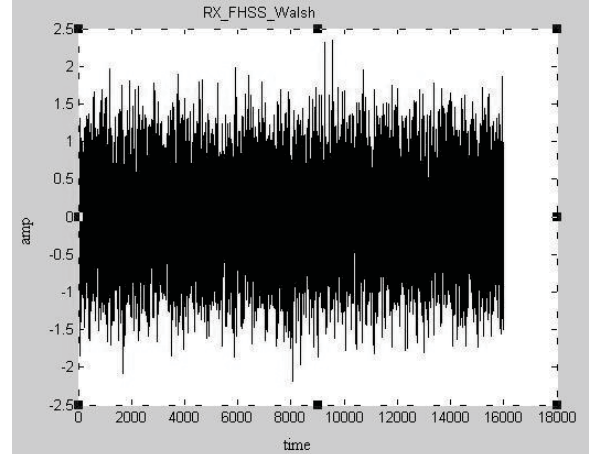Fig. 13 : FHSS transmitter signal for Gold sequence
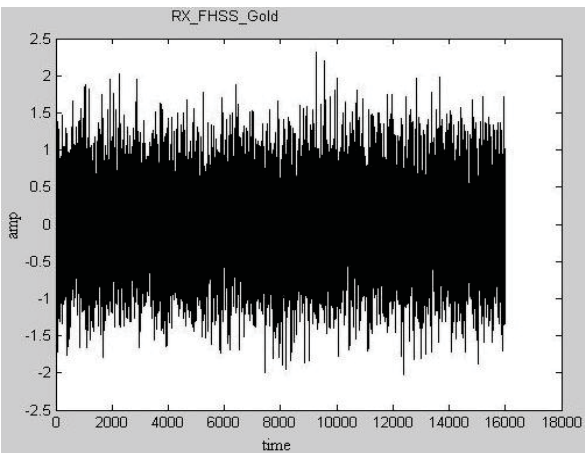

Fig. 16 : FHSS Receiver signal for Walsh
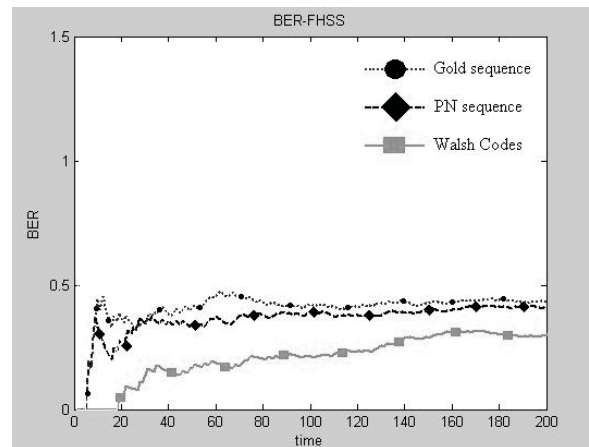

Fig. 14 : FHSS Receiver signal for Gold sequence

Fig. 17 : BER for FHSS

IX. Conclusion

The result of the MATLAB simulation of the Direct Sequence Spread Spectrum (DSSS) system shows that the if the different codes (i.e. m sequences, Gold Codes, Walsh in this case) are used to implement the DSSS system there is no effect on the BER(bit error rate) of the system. The MATLAB simulation of the Frequency Hop Spread Spectrum (FHSS) system shows that the if the different codes are used to implement the FHSS system the PN sequences shows the large BER. This is due to the non orthogonality of the codes. Whereas the orthogonal code i.e. the Walsh code shows the least BER among all three codes in FHSS system. Walsh code gives the much better performance in FHSS as it shows the less Bit error rate if walsh code is used in place of PN sequences.

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