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Various Correlation Properties of Orthogonal Spreading Codes for CDMA Technique

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ABSTRACT
Spread Spectrum a means of signal modulation, in which the signal frequency is spread over a very wide bandwidth. Spread spectrum technology, which was initially used in military applications, is another approach to achieve multiple accesses. An important multiple-access technique in wireless networks and other common channel communication systems is Code-Division Multiple Access (CDMA). Each user shares the entire bandwidth with all the other users and is distinguished from the others by its signature sequence or code.
The sequences which are used in CDMA should have the following properties:
• There should be a balance in the number of ones and zeroes.
• The autocorrelation must be a sharp two-valued function
• The cross correlation must be as low as possible.
In this paper, we propose the generation of the orthogonal sets of codes which are able to retain the properties of Complete Complementary (CC) codes. The proposed methods can be applied to any sequence with ideal two-level cross-correlation
Keywords - Spread Spectrum, Orthogonal Sequences, Cross-correlation Function (CCF), Spreading Codes.

I. INTRODUCTION

Over the last eight or nine years a new commercial marketplace has been emerging, called spread spectrum, this field covers the art of secure digital communications that is now being exploited for commercial and industrial purposes. In the next several years hardly anyone will escape being involved, in some way, with spread spectrum communications. Applications for commercial spread spectrum range from "wireless" LAN's (computer to computer local area networks), to integrated bar code scanner/palmtop computer/radio modem devices for warehousing, to digital dispatch, to digital cellular telephone communications, to "information society" city/area/state or country wide networks for passing faxes, computer data, email, or multimedia data[15].

"Spread-spectrum radio communications, long a favourite technology of the military because it resists jamming and is hard for an enemy to intercept, is now on the verge of potentially explosive commercial development. The reason: spread-spectrum signals, which are distributed over a wide range of frequencies and then collected onto their original frequency at the receiver, are so inconspicuous as to be 'transparent [2].' Just as they are unlikely to be intercepted by a military opponent, so are they unlikely to interfere with other signals intended for business and consumer users even ones transmitted on the same frequencies. Such an advantage opens up crowded frequency spectra to vastly expanded use [4]. In this paper, we propose the generation of the orthogonal sets of codes which are able to retain the properties of Complete Complementary (CC) codes. The proposed methods can be applied to any sequence with ideal two-level cross-correlation. In 1st section we discuss the background of spread spectrum. In 2nd section we discuss the properties of spread spectrum. In 4th & 5th section we introduced the Orthogonal Sequences & their types. In 6th & 7th we discuss the characteristics and advantages of spread spectrum and finally, brief summaries are given in Section 8th to conclude the paper.

II. Background

Spread spectrum system spreads the transmitted signal over a wide frequency band, much wider, than the minimum bandwidth required to transmit the information being sent. For example, a base band signal with a bandwidth of only few kilohertz is distributed by a spread spectrum system over a bandwidth of many megahertz which is done by modulating with the information to be sent with the wideband encoding signal [5].

Fig.1. shows that spreading is achieved when multiplying the signal with the spreading sequence.

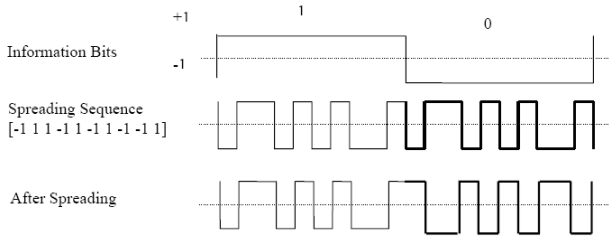

Fig.1. Spreading waveforms.

Some of the properties of spread spectrum systems are,

• Low density power spectra.
• Code division multiplexing which is possible for multiple access.
• Selective addressing capability.
• Interference rejection.

The important forms of spread spectrum modulation are frequency hopping, direct sequence, time hopping, chirping and various hybrid combinations of the above forms though only the first two are the most important ones[10]. Frequency hopping spread spectrum, which is also called multiple frequency, code selected, frequency-shift keying, is one in which a signal is spread by causing it to hop rapidly from one frequency to another according to a predetermined pseudorandom sequence. Direct sequence spread spectrum systems, which are the most widely used systems, are those in which the signal is spread over a continuous range of frequencies [9].

III. Spread Spectrum

One way to look at spread spectrum is that it trades a wider signal bandwidth for better signal to noise ratio. Frequency hop and direct sequence are well-known techniques today. Frequency hopping is the easiest spread spectrum modulation to use. Any radio with a digitally controlled frequency synthesizer can, theoretically, be converted to a frequency hopping radio. This conversion requires the addition of a pseudo noise (PN) code generator to select the frequencies for transmission or reception. A frequency hopped system can use analog or digital carrier modulation and can be designed using conventional narrow band radio techniques [14]. De-hopping in the receiver is done by a synchronized pseudo noise code generator that drives the receiver's local oscillator frequency synthesizer.

To qualify as a spread spectrum signal, two criteria should be met:

1. The transmitted signal bandwidth is much greater than the information bandwidth.
2. Some function other than the information being transmitted is employed to determine the resultant transmitted bandwidth.

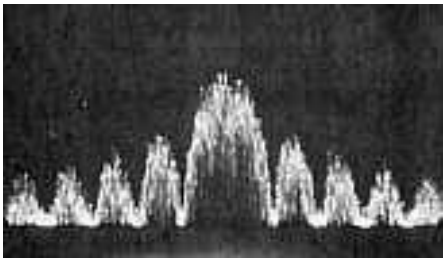

Fig.2. A Spectrum Analyzer Photo of a (DSSS).

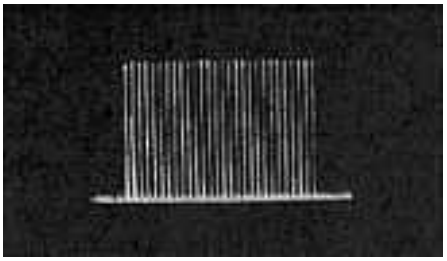

Fig.3. A Spectrum Analyzer Photo of a (FHSS).

Direct sequence systems - Direct sequence spread spectrum systems are so called because they employ a high speed code sequence, along with the basic information being sent, to modulate their RF carrier. Figure 2 illustrates the most common type of direct sequence modulated spread spectrum signal [9, 12].

Frequency hopping systems - The wideband frequency spectrum desired is generated in a different manner in a frequency hopping system.

3.1 Spread Spectrum Properties

- Signal occupies a bandwidth much larger than is needed for the information signal.
- Spread spectrum modulation is done using a spreading code independent of the data in the signal.
- Despreading at the receiver is done by correlating the received signal with a synchronized copy of the spreading code.

There are some more interesting properties to Spread Spectrum, some of them are:

- Good Anti Jamming performance.
- Low Power Spectral Density.
- Interference Limited operation. In all situations, the whole frequency spectrum is used.
- Applying Spread Spectrum implies the reduction of Multi path effects.
- Random Access probabilities. Users can start their transmission at any time.
- Privacy due to the use of unknown random codes. The applied codes are in principle unknown to hostile users, i.e. each user has his own unique code.
- Multiple Accesses. More than one user shares the same BW at the same time.

IV. Background for Orthogonal Sequences

The code-division multiple access (CDMA) standard for U.S. digital cellular services is the IS-95 (Interim standard-95). Cellular systems based on this standard include the personal communication service, or PCS. In such a system, the reverse link (mobile station to base station link) uses [5].

DSSS technique that employs nonbinary orthogonal modulation using Walsh-Hadamard signals. In another application, high-data-rate wireless local-area networks subject to multipath interference also employ DSSS technique along with nonbinary orthogonal modulation using Walsh-Hadamard signals.

4.1 Direct-Sequence Spread Spectrum

One type of direct-sequence spread spectrum communication system employs a form of spread spectrum modulation in which the narrowband information-bearing data signal is spread over a wide range of frequencies through direct multiplication with a pseudo-random binary sequence, which is a sequence of chips, or elemental pulses, valued -1 and 1 and has noise-like properties [16]. Sequences such as the maximal-length linear feedback shift register sequences or m-sequences as they are commonly referred to in the literature, and the Gold sequences are often used as the pseudo-random binary sequences. In the system under consideration, m-sequences are used. Figure 4 gives an illustration of the direct-sequence spreading.

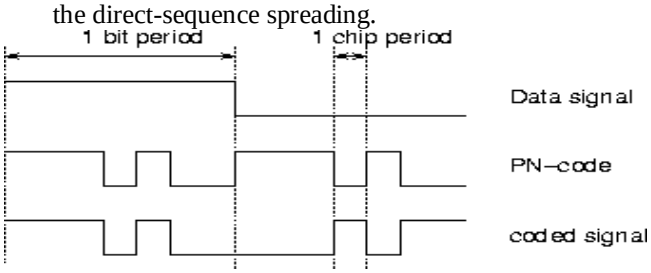

Fig.4. Direct-sequence spreading

4.2 M-Sequence

An m-sequence with period N=2n-1 is generated using a linear feedback shift register (LFSR) with n storage elements. A general n-stage LFSR is shown below in Figure 6.

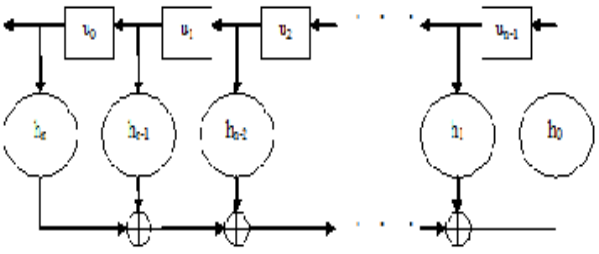

Fig.6. General n-stage linear feedback shift register.

Where h = (h0, h1,…,hn) is called the feedback tap coefficient vector, and each of its elements is either a 0 or 1, with 0 representing no connection to the mod-2 adder and 1 representing a connection to the mod-2 adder. For all LFSRs with n storage elements, h0=hn=1. If hn = 0, then the left-most storage element has no role in determining which sequence is generated; and if h0 = 0, then there is no feedback [13].

A convenient way to represent the n-stage LFSR is by the polynomial,

$$h(x) = x^n + h_1 x^{n-1} + h_2 x^{n-2} + \ldots + h_{n-1} x + 1$$

V. Types of Sequences

5.1 Gold Sequences:

The cross correlation properties are as important in communication systems as autocorrelation properties. Cross correlation is a measure of agreement between the two different codes. The periodic cross correlation between any pair of m-sequences is very high. Such high values of cross correlation are undesirable in CDMA communications. Gold developed new sequences with better cross correlation properties called Gold sequences [16].

5.2 Kasami Sequences:

There are two classes of Kasami Sequences: the small set and the large set. The number of sequences for the small set is $2^{n/2}$, and for the large set is $2^{n/2}(2^n+1)$, where n is the number of stages of the shift register. The procedure for generating Kasami sequences is similar to that used for generating Gold sequences. The maximum cross correlation value for any pair of Kasami sequences is $2^{n/2}+1$. The maximum correlation value of the large set of Kasami sequences is same as that of the Gold sequences [14].

5.3 Pseudo Noise Sequences:

Pseudo noise sequences are binary-valued, noise like sequences. They are generated by feedback shift registers with feedback. They are similar to a sequence of coin tossing where +1 represents a head and -1 represents a tail.

The following characteristics are associated with randomness.

- In every period, the number of +1's is nearly equal to the number of -1's.
- In every period, half the runs have length one, one-fourth have length two, one eighth have length three as long as the number of runs exceeds 1.
- The autocorrelation function is two valued.

Any sequence with the above properties is called a pseudo noise sequence.

5.4 Read Muller codes:

Reed_ Muller codes are some of the oldest error correcting codes. Error correcting codes are very useful in sending information over long distances or

through channels where errors might occur in the message. They have become more prevalent as telecommunications have expanded and developed a use for codes that can self-correct.

VI. Advantages of orthogonal sequences

- High spectral efficiency,
- The information rate that can be transmitted over a given bandwidth in a specific communication system is high.
- Multiple access capabilities,
- A channel-access scheme is based on a multiplexing method that allows several data streams or signals to share the same
- Communication channel or physical medium. Multiplexing is in this context provided by the physical layer.
- Robustness in the case of frequency selective channels,
- The quality of being able to withstand stresses, pressures, or changes in procedure or circumstance is possible for the frequency
- High flexibility,
- Narrow-band interference rejection,
- Simple one tap equalization, etc.

VII. SPREAD SPECTRUM CHARACTERISTICS OF CDMA

A number of advantages are:

- Low power spectral density. As the signal is spread over a large frequency-band, the Power Spectral Density is getting very small, so other communications systems do not suffer from this kind of communications. However the Gaussian Noise level is increasing.
- Interference limited operation. In all situations the whole frequency-spectrum is used.
- Privacy due to unknown random codes. The applied codes are - in principle - unknown to a hostile user. This means that it is hardly possible to detect the message of an other user.
- Applying spread spectrum implies the reduction of multi-path effects.
- Random access possibilities. Users can start their transmission at any arbitrary time.
- Good anti-jam performance.

VIII. CONCLUSIONS

The characteristics of CDMA codes for next Generation wireless CDMA systems include availability of large number of codes, impulsive auto-correlation function, zero cross-correlation value and support for variable data rates.

The properties of Gold sequence, Kasami Sequences, Pseudo Noise Sequences and Read Muller codes have been evaluated for CDMA based wireless systems. To reduce the Multiple Access Interference (MAI) in a synchronous system like the downlink mobile radio communication channel, the spreading sequences, or codes, are chosen orthogonal. From the Spread Spectrum Characteristics of CDMA we observe that it has low power spectral density, privacy is more, and overall good performance.

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