Transmission of Information by Nonsinusoidal Functions

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Abstract

The transmission of information can take place not only on the basis of cosinusoidal and sinusoidal functions but it could also be based on the set of Walsh functions. In CDMA systems the Walsh Codes are used for spreading the spectrum of signal. Walsh codes are perfectly orthogonal binary block codes which have found their use in many popular applications for several decades, including synchronous multi-user communications.

This paper reviews and discusses the application of Walsh functions for designing info communication systems with CDMA.

Key words: Walsh functions, info communication systems, CDMA

1. Introduction

The system requires orthogonal Code Division Multiple Access (CDMA) codes for channel selection. The CDMA System requires orthogonal codes for channel selection.
The ensemble of Walsh functions can serve as an example for ensemble of orthogonal signals. Walsh codes are used for direct spread spectrum (DSSS) systems (such as IS-95, CDMA2000, etc.). They are also used for frequency hopping spread spectrum (FHSS) change selection of starting frequency for the next hop.
Walsh codes are orthogonal codes. Also, if two Walsh codes are correlated, the result is understandable only if these two are identical. As a result, a Walsh encoded signal is received as random noise at the receiver CDMA mobile terminal, except when the terminal uses the same code as that used for the encoding of the input signal.

2. Orthogonal Functions to Spread Spectrum (Walsh Codes)

Correlation of signals with the right spread spectrum involves multiplying the latter with reference copy and then - integration period of the carrier signal. In this regard, one of the useful properties of distributed systems is the range of their mutual orthogonality, mathematically reduced to fulfill the condition

$$\int_0^{T_S} S_i(t) S_j(t)\,dt = \begin{cases} E_s, & npu\ i = j \\ 0, & npu\ i \neq j \end{cases}, \tag{1}$$

where S_i and S_j are functions describing forms of the i and j signal and the period of their establishment T_s, E_s - the energy of the signal (for the purpose of the examination it is simplified and assumes that all signals are equally powerful).

The systems of orthogonal functions following order (numbering) by Walsh, Paley, and the method of Hadamard are well known.

Regardless of the following method, all they are complete system orthogonal functions, while the transition from one system to another is performed through the execution of mathematical operations over their elements.

The defining of a system of Walsh functions using a matrix of Hadamard is most common.

$$H_{2N} = \begin{pmatrix} H_N & H_N \\ H_N & -H_N \end{pmatrix} \tag{2}$$

when H_N - matrix of Hadamard of order N, $H_1 = 1$.

Thus described Walsh functions form a sequence of rectangular impulses with single amplitudes and polarity corresponding to the signs $(\pm)$ of the elements of the rows (columns) of the matrix of Hadamard (2).

The length of each impulse $1/N$ is part of the total range of the function. In fig 1 is given an example of some of the Walsh functions based on a matrix of Hadamard order $N = 8$.

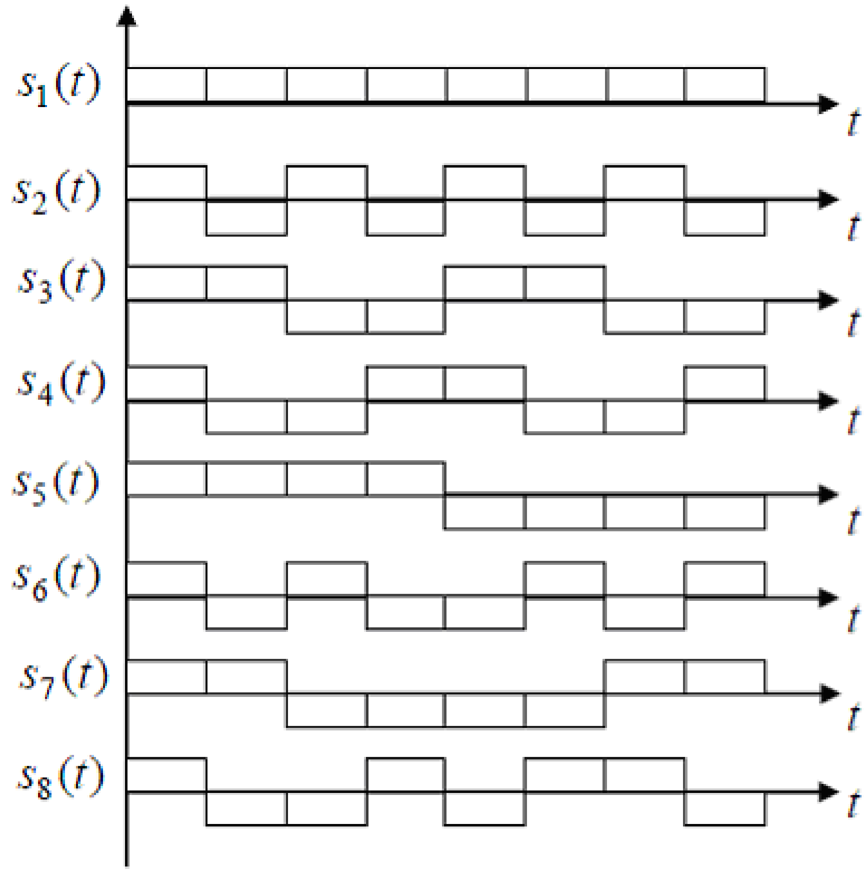

Figure 1. An example of some of the Walsh functions based on a matrix of Hadamard order $N = 8$.

Walsh codes appear complete system of functions "orthogonal in point." At the same time, their correlation properties are not satisfactory. Most of the side peaks of autocorrelation function of the Walsh sequences are rather large . The large side peaks of the cross-correlation function lead to interchannel disturbances in the immediate use of Walsh codes as an address.

Therefore, in order to improve cross-correlation properties the used ensemble of signals in asynchronous channels usually is “scrambled” through a symbol- by- symbol multiplication of the Walsh code with pseudo-random sequence (PRS).

Segments of M-sequences are often used as "scrambling code". For example, in the standard cellular connection CDMA IS-95 the Walsh functions with length $N = 64$ is are multiplied with trimmings of some M-sequence with length $2^{15} - 1$. Moreover, the initial user data is multiplied by one of the Walsh codes, then it is scrambled with PN-BS code and finally is submitted to the carrier frequency.
In the receiver multiplication of the demodulated signal is implemented with synchronous PN-code BS in which the user signal is correlated with suitable function of Walsh.

2.1 General Characteristics of The Standard IS-95 (CMDA One)

The pprotocols for establishing connections in CDMA, as well in other analog and digital standards, are based on the use of logical channels. The structure scheme of the channels in CDMA standard IS-95 is shown in Figure 2.

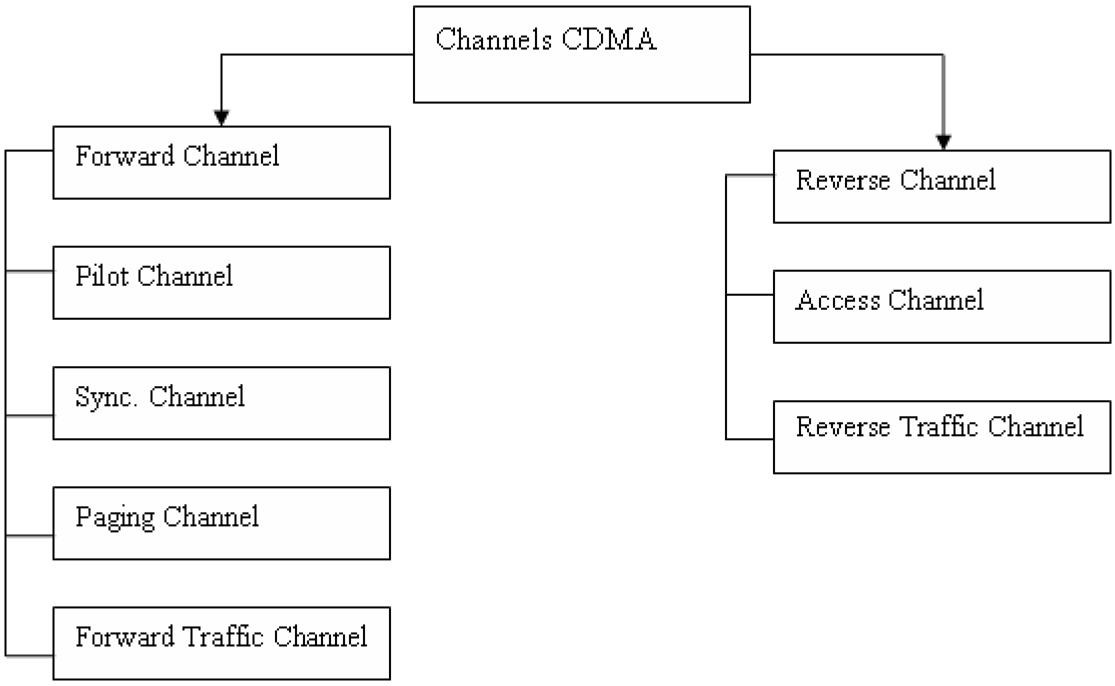

Figure 2. Structure of Channels in the Standard IS-95

2.2 Principles of Formation of the Signal

In the IS-95 standard three groups of codes are used: Walsh, short and long. All these codes are general for the base and mobile stations, however they fulfill different functions (tabl.1) [1].

The base station can simultaneously transmit 64 channels, including channel pilot signal, synchronization channel, 7 Paging Channels (PCH) and 55 traffic channels (TCH).

The signals of all channels are orthogonal, which guarantees the lack of mutual interference between them if they are originating from the same station. The internal system disturbances arise from the transmitters of other base stations operating on the same frequency but with a different cyclic shift of the PRS.

Type of Signal	Code Length	Performed Functions	
		BS	MS
Walsh Code	64	Code Division Multiplexing 64 CDMA	Providing Noise Resistant-Encoded
Short Code	32768	Signal Separation in BS in size of rotation shifting	Short Code Fixed Cyclical Remove Used as Reference Signal in Scrambling
Long Code	$2^{42}-1$ $(4{,}4.10^{12})$	Long Lode to the Removal of Discrete Used as Reference Frequency in Scrambling	Long Code with a Cyclic Shift Used as an Address Sequence

Table 1. Code sequences used in IS-95 standard

In the direct channel (from BS to MS, Fig. 3) modulation of the signal with Walsh functions (binary phase manipulation) is used to distinguish between different physical channels BS, modulation of long PRS (binary phase manipulation)- with purpose for encryption

Communications, modulation of short PRS (quadrate phase shift manipulation of two PRS with equal amounts)- for extending the bandwidth and distinguish signals of different BS. [3]

The zero Walsh function (W_0) is used for the transmission of a pilot signal, while for synchronization – the function W_{32}. In the synchronisation channel the data enters at a speed of 1,2 kbit / s, while by the input of the modulator their speed increases to 4,8 kbit / s. As the speed in the synchronization channel is four times lower than in the Paging or the information channels $(19,2 kbit/s)$, it provides better noise immunity [2].

The synchronization messages contain data for the precise system time, the parameters of the short and the long code and the transmission speed in the Paging channel, i.e for all the parameters necessary to establish the initial synchronization.
All base stations use identical in structure to short codes but with varying cycle move multiple of 64, i.e no more than 511 base stations can operate in the network at any given time.
A proper operation of the BS in the cdmaOne is only guaranteed in the case, when their signals are not superimposed.

In order this requirement to be fulfilled a solid synchronization is necessary, which is currently provided by a satellite navigation system GPS.

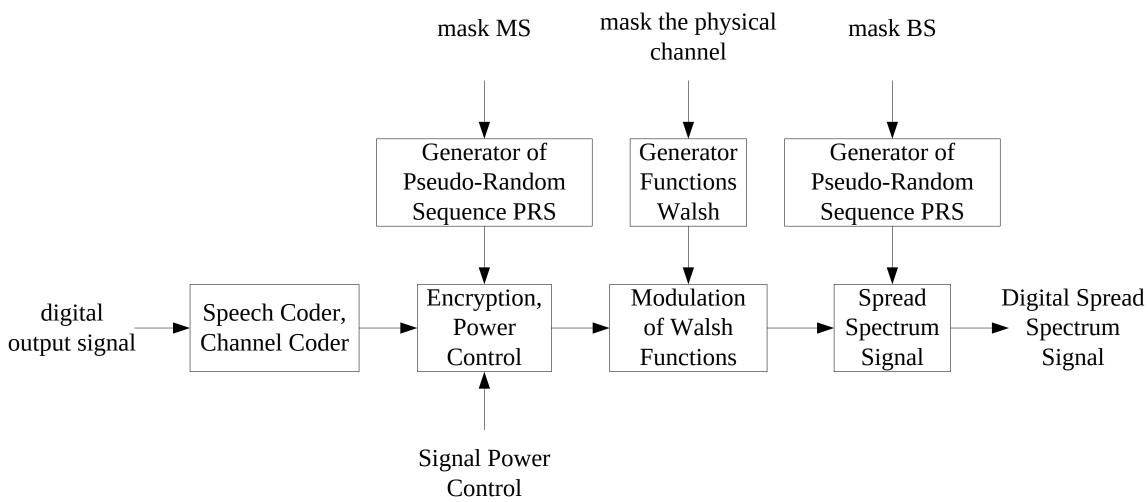

Figure 3. A processing circuit of the signals in the transmit tract at the base station

In reverse channel (from BS to MS, Figure 4) modulation signal short PRS is used to broaden and all mobile stations use the same pair of sequences with the same (zero) shifting. Modulation long PRS, except encrypt messages carry information about MS in the form of its individual number coded and provide different signals from different MS from one cell to account for each individual station moving sequence.

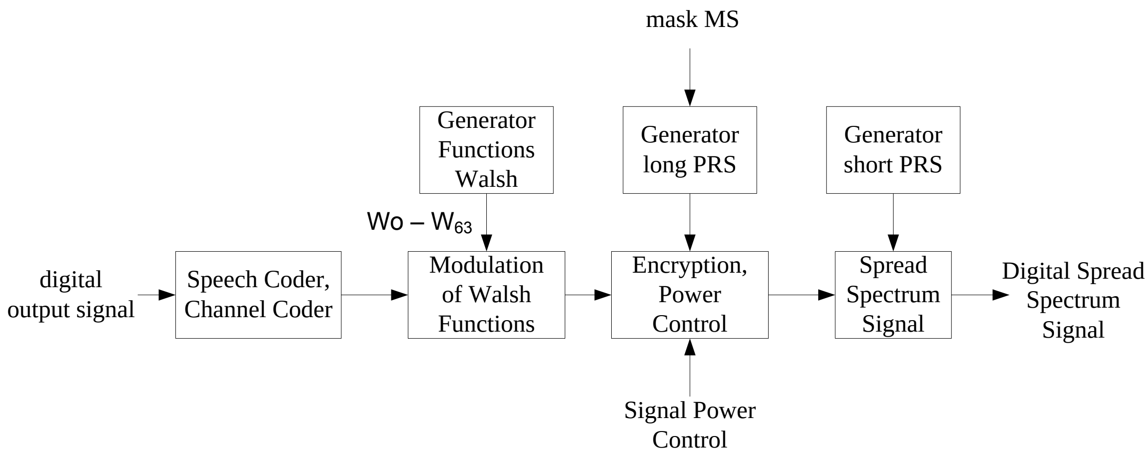

Figure 4. A processing circuit of the signal in the MS

In MS is possible adoption of coherent signals with uptake of the carrier and power control.
The acceptance of the signal in BS takes place with the use of the RAKE receiver having in its composition multiple channels for parallel processing.
After completion of the procedure for synchronization MS is set to channel personalized search and constantly controls it in anticipation of receiving the paging signal.
The adaptive transmission rate varies from 1,2 to 9,6 kbit / s, which allows flexible adaptation to the traffic conditions of radio wave propagation.

The MS uses two types of channels: channel access ACH and channel traffic TCH. The main parameters of channel coding and modulation used in BS and MS in cdmaOne (IS-95), are given in Table 2.

Type of Base Station	Base Station				Mobile Station	
	P1	SYNC	PCH	TCH	ACH	TCH
The Number of Simultaneous Transmission Channels	1	1	7	55	1	1
Input Rate[kbit/s]	-	1,2	2,4 4,8 9,6	2,4 4,8 9,6	4,8	2,4 4,8 9,6
Rate on Coding	-	1/2	1/2	1/2	1/3	1/3
Rate Output of Convolution Coder [kbit/s]	-	4,8	4,8 9,6 19,2	2,4 4,8 9,6 19,2	14,4	3,6 7,2 14,4 28,8
Output Flow Rate Encodings	-	4,8	19,2	19,2	28,8	28,8
Rate After the Code Converter	-	-	-	-	307,2	307,2
Method of Modulations	QPSK	QPSK	QPSK	QPSK	OQPSK	OQPSK

Table 2. Parameters of Channel Coding and Modulation to IS-95

In MS the orthogonal Walsh functions are also used, but for other purposes, i.e not code division of the channels but to improve noise resistance. Each group of 6 bits in transmission corresponds to one of 64 Walsh sequences. During transmission each MS uses long code with individual cycle move, which enables the base station to identify it uniquely. Each MS in network uses the same long code. According to the value of its move, BS differentiates the signals of the serviced subscribers.
The masks of the long codes in direct and reverse channels match.

Standard IS-95 requires the use of the same frequency on all cellular networks. All MS use the same short code, which is in BS. However, the cyclic shift is fixed and identical for all MS. The interference generated by other BS, operating in the same frequency band, eventually determines the limit on carrying capacity.

3. Conclusions

In cdmaOne MS does not transmit a pilot signal and hence the BS is done not coherent processing. This disadvantage is eliminated in the new standard cdma2000, where in the direct channel are transmitted three different pilot signals and in the reverse channel-one. The number of subscribers in SDMA system depends on the level of mutual interference. In order this interference to be reduced, management of the MS transmitted power has been introduced. In the standard IS-95, power control of MS is provided in the dynamic range $84dB$ with increment $1dB$. The data for power management are regularly transmitted at a speed 800bit / s. Upon delivery, they are added to the information symbols.
In this standard separate processing of multiray signals is used with their subsequent aggregation, which provides signal noise $6,7dB$.
Several parallel working channels are used in the case of separate processing of rays. This allows a soft mode switch of MS to take place in the case of transmission from one zone of the link to another.

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