Appendix A

Uplink Spreading and Scrambling

A.1 Overview

WCDMA uses two level code systems: orthogonal spreading codes and pseudo random (PN) scrambling codes. In order to support variable rates, the WCDMA air interface allows for per-channel selectable spreading factor, and this family of spreading codes is called *Orthogonal Variable Spreading Factor* (OVSF) codes. The use of OVSF codes and scrambling codes is different in the downlink and uplink.

In the downlink, the OVSF codes, also called channelization codes, are used to multiplex different channels transmitted in the same cell. In the uplink, the OVSF codes are used to separate data and control channels from a specific user.

Scrambling, using pseudorandom sequences, is used in addition to spreading. In the downlink, different scrambling codes separate different cells, and in the uplink they separate different users. Note: Spreading and scrambling are applied differently in the uplink and downlink.

A.2 Spreading

Since the ratio of the data symbol rate to the chip is the spreading factor SF. By keeping the chip rate constant, at 3.84 MHz for WCDMA, and by varying the spreading factor for a specific code in the range of 4 to 512, a wide range data rates can be supported. The OVSF codes used for spreading are name $C_{sp,i,j}$, where i is the spreading factor, $i = 2^n, n \in 2, 3, ..., 9$ and j is the index of the spreading factor $j \in \{0, 1, ..., (i-1)\}$. The $C_{sp,i,j}$ are perfect orthogonal sequences such that:

$$\sum_{n=0}^{i-1} C_{sp,i,u}(n) \times C^*_{sp,i,v}(n) = 0 \quad \text{for} \quad u, v \in \{0, 1, ..., (i-1)\} \quad \text{and} \quad u \neq v. \tag{A.1}$$

The method of generation of OVSF codes $C_{ch,i,j}$ is defined as:

$$C_{ch,1,0} = 1, \tag{A.2}$$

$$\begin{bmatrix} C_{ch,2,0} \\ C_{ch,2,1} \end{bmatrix} = \begin{bmatrix} C_{ch,1,0} & C_{ch,1,0} \\ C_{ch,1,0} & -C_{ch,1,0} \end{bmatrix}, \tag{A.3}$$

$$\begin{bmatrix} C_{ch,2^{n+1},0} \\ C_{ch,2^{n+1},1} \\ C_{ch,2^{n+1},2} \\ C_{ch,2^{n+1},3} \\ \vdots \\ C_{ch,2^{n+1},2^{n+1}-2} \\ C_{ch,2^{n+1},2^{n+1}-1} \end{bmatrix} = \begin{bmatrix} C_{ch,2^n,0} & C_{ch,2^n,0} \\ C_{ch,2^n,0} & -C_{ch,2^n,0} \\ C_{ch,2^n,1} & C_{ch,2^n,1} \\ C_{ch,2^n,1} & -C_{ch,2^n,1} \\ \vdots & \vdots \\ C_{ch,2^n,2^n-1} & C_{ch,2^n,2^n-1} \\ C_{ch,2^n,2^n-1} & -C_{ch,2^n,2^n-1} \end{bmatrix}. \tag{A.4}$$

In the uplink, OVSF codes are employed for multiplexing the data and the control channels, and in the downlink they are used to multiplex all the common and dedicated channels to different users within one cell. In the downlink, the physical layer is informed of the code allocation for different channels via higher layer signalling.

A.3 Auto and Cross-correlation Properties of OVSF Codes

The OVSF codes are orthogonal Walsh codes, this class of code loses orthogonality if they are time aligned. This poor cross-correlation causes problems in multipath propagation channel conditions, where the echoes of the downlink signal would interfere significantly with each other. The necessary improvement the signal's auto and cross-correlation properties is achieved by the scrambling code.

A.3.1 Scrambling codes

A.3.1.1 General

Scrambling is applied on top of spreading and does not change the chip rate of the spreading signal. In the uplink, scrambling is used for the separation of users and in the downlink different scrambling is used for the separation of cells.

Scrambling codes are 10 ms long codes formed using shift registers for generation of downlink scrambling codes. Unlike spreading codes, scrambling codes are not orthogonal sequences, but they have good auto and cross-correlation properties.

In the uplink, each mobile terminal is allocated its own scrambling code by the network; this code must be unique in the immediate network neighborhood as it is received by all the cells with which the mobile terminal is in soft handover. The scrambling code selection for common uplink channels like PRACH and PCPCH and their associated preambles are beyond the scope of this selection and are detailed in the 3GPP specifications.

A.3.1.2 Long scrambling sequence

The long scrambling sequences $C_{long,1,n}$ and $C_{long,2,n}$ are constructed from position wise modulo 2 sum of 38400 chip segments of two binary m-sequences generated by means of two generator polynomials of degree 25. Let x, and y be the two m-sequences respectively. The x sequence is constructed using the primitive (over GF(2)) polynomial $X^{25}+X^3+1$. The y sequence is constructed using the polynomial $X^{25}+X^3+X^2+X+1$. The resulting sequences thus constitute segments of a set of Gold sequences.

The sequence $C_{long,2,n}$ is a 16777232 chip shifted version of the sequence $C_{long,1,n}$.

Let $n_{23}...n_0$ be the 24 bit binary representation of the scrambling sequence number n with n_0 being the least significant bit. The x sequence depends on the chosen scrambling sequence number n and is denoted x_n, in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the i^{th} symbol of the sequence x_n and y, respectively.

The m-sequences x_n and y are constructed as:

Initial conditions:

- $x_n(0)=n_0, x_n(1)=n_1, ...=x_n(22)=x_n(23), x_n(24)=1.$

- $y(0)=y(1)=...=y(23)=y(24)=1.$

Recursive definition of subsequent symbols:

- $x_n(i+25)=x_n(i+3)+x_n(i)$ modulo 2, $i=0,...,2^{25}-27.$

- $y(i+25)=y(i+3)+y(i+2)+y(i+1)+y(i)$ modulo 2, $i=0,...,2^{25}-27.$

Define the binary Gold sequence z_n by:

- $z_n(i)=x_n(i)+y(i)$ modulo 2, $i=0,...,2^{25}-2.$

The real valued Gold sequence Z_n is defined by:

$$Z_n(i) = \begin{cases} +1 & \text{if } z_n(i) = 0 \\ -1 & \text{if } z_n(i) = 1 \end{cases} \quad \text{for} \quad i = 0, ..., 2^{25} - 2.$$

Now, the real-valued long scrambling sequences $C_{long,1,n}$ and $C_{long,2,n}$ are defined as follows:

- $C_{long,1,n}(i) = Z_n(i), \quad i = 0, ..., 2^{25} - 2$ and

- $C_{long,2,n}(i) = Z_n((i + 16777232) \text{modulo } 2(2^{25} - 1), \quad i = 0, ..., 2^{25} - 2.$

Finally, the complex-valued long scrambling sequence $C_{long,n}$, is defined as:

$$C_{long,n}(i) = C_{long,1,n}(i)(1 + j(-1)^i C_{long,2,n}(2\lfloor i/2 \rfloor)) \quad \text{(A.5)}$$

where $i = 0, 1, ..., 2^{25} - 2$ and $\lfloor \, \rfloor$ denotes rounding to nearest lower integer.

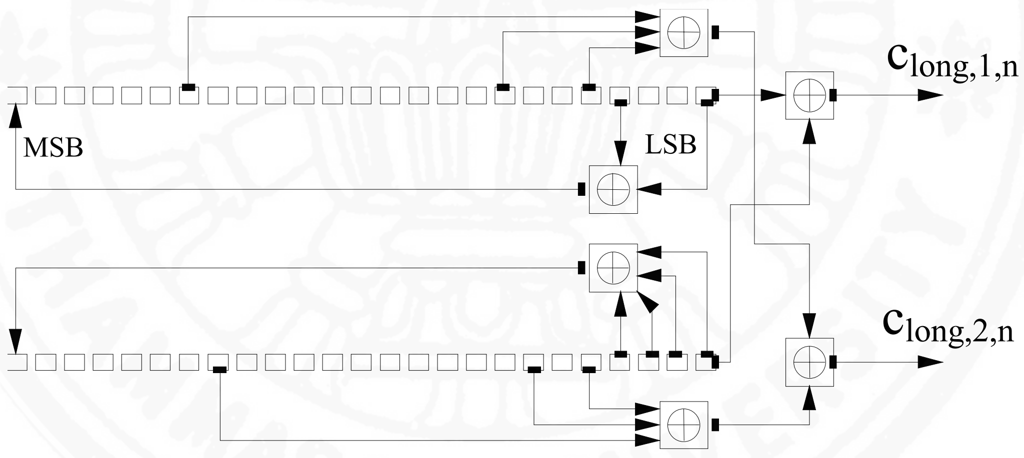

Figure A.1 Configuration of uplink scrambling sequence generator