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Reducing Blocking Probability of 3G Mobile Communication System Using Time Multiplexing NOVSF Codes

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Abstract

Orthogonal variable spreading factor (OVSF) codes have been proposed for the data channelization in W-CDMA access technology of IMT-2000. OVSF codes have the advantage of supporting variable bit rate services which is important for emerging multimedia with different bandwidth requirements. OVSF codes are employed as channelization codes in W-CDMA. Any two OVSF codes are orthogonal if and only if one of them is not a parent code of the other. Therefore, when an OVSF code is assigned, it blocks entire ancestor and descendant codes from assignment because they are not orthogonal to each other. This code-blocking problem of OVSF codes can cause a substantial spectrum efficiency loss. Efficient channelization code management results it high code utilization and increased system capacity.

The common purpose of all of them is to minimize the blocking probability andthe reallocation codes cost so that more of new arriving call requests can be supported. The probability of code blocking due to the inappropriate resource allocation will be thus minimized using NOVSF code of spread factor 32.[1]

Keywords : OVSF, NOVSF, W-CDMA

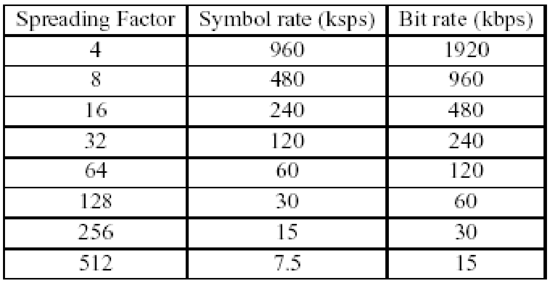
1. Introduction

It is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system, i.e. user information bits are spread over wide bandwidth by multiplying the user data with Quasi-random bits (called chips) derived from CDMA spreading codes. In order to support very high bit rates (up to 2 Mbps), the use of a variable spreading factor and multicodeconnections is supported. The Spreading Factor is the ratio of the chips to baseband information rate. It is the number of chips for each symbol. Spreading factors vary from 4 to 512 in FDD UMTS.Spreading process gain can be expressed in dBs (Spreading factor 128 = 21dB gain)which indicates the process gain. Different spreading factor means different code length. The idea is to be able to combine different messages with different spreading factors and keep the orthogonality between them. We therefore need codes of different length that are still orthogonal.[2]

2.OVSF AND NOVSF CODES

In W-CDMA, all users share the same carrier under the direct sequence CDMA (DSCDMA) principle. In the 3GPP specifications orthogonal variable spreading factor (OVSF) codes are used as channelization codes for data spreading on both downlink and uplink. OVSF codes also determine the data rates allocated to calls. W-CDMA supports data rates up to 2.048 Mbps in 5 MHz bandwidth using variable spreading factors.

Table 3.3 summarizes the spreading factors, symbol rates, and bit rates for W-CDMA physical channels.



Spreading Factor	Symbol rate (ksps)	Bit rate (kbps)
4	960	1920
8	480	960
16	240	480
32	120	240
64	60	120
128	30	60
256	15	30
512	7.5	15

When a particular code is used in OVSF, its descendant and ancestor codes cannot be used simultaneously because their encoded sequences become indistinguishable. Therefore, the OVSF code tree has a limited number of available codes. Because one OVSF code tree, along with one scrambling code, is used for transmissions from a single source that may be a base station or mobile station, the same OVSF code tree is used for the downlink transmissions and therefore the base station must carefully assign the OVSF codes to the downlink transmissions. Since the maximum number of OVSF codes is hard-limited, the efficient assignment of OVSF codes has a significant impact on resource utilization. Any two OVSF codes are orthogonal if and only if one of them is not a parent code of the other. Therefore, when an OVSF code is assigned, it blocks all of its ancestor and descendant codes from assignment because they are not orthogonal. This results in a major drawback of OVSF codes, called **blocking property**a new call cannot be supported because there is no available free code with the requested spreading factor.

OVSF codes can be generated recursively in a binary tree structure using Walsh matrices or applying the following rule recursively: code Cn;i of length n generates the following two orthogonal codes of length 2n: C2n;i = [Cn;i; Cn;i] and C2n;i+1 = [Cn;i; _Cn;i], where _Cn;i denotes the inverted sequence (or binary complement) of Cn;i, n equals SF that is a power of 2, and i is an index[3][4]

3. Downlink Spreading and Modulation

The scope is to establish the characteristics of the spreading and modulation in the FDD mode, and to specify:

- Thespreading (channelization plus scrambling);
- Generation of channelization and scrambling codes;
- Modulation.

After combining the different transport channels into physical channels, data is sent to the downlink base station transmitter antenna in the form of slots. At the transmitter antenna, data is first spread by a real value orthogonal signature code for channel separation that transforms every data symbol into a number of chips, thus increasing the bandwidth of the signal. The number of chips per data symbol is called the Spreading Factor (SF).

It is then scrambled by a complex valued gold code sequence. With the channelization, data symbol on so-called I- and Q-branches are independently multiplied with an OVSF code. With the scrambling operation, the resultant signals on the I- and Q-branches are further multiplied by complex valued scrambling code, where I and Q denote real and imaginary parts, respectively.

Finally, the channels that are also transmitted during a connection are added together with different weights to create the waveform that is sent through the channel after applying the transmitter pulse-shaping filter.[5][6]

3.1 Spreading

Data modulation is QPSK where each pair of two bits are serial-to-parallel converted and mapped to the I and Q branch respectively. The I and Q branch are then spread to the chip rate with the same channelization code cch (real spreading) and subsequently scrambled by the scrambling code Cscramb (complex scrambling).

Spreading/modulation of the CPICH, Secondary CCPCH, PSCCCH, PDSCH, PICH and AICH is done in an identical way as for the downlink DPCH.

Spreading/modulation of the Primary CCPCH is done in an identical way as for the downlink DPCH, except that the Primary CCPCH is time multiplexed after spreading. As illustrated in Figure 6.1. Primary SCH and Secondary SCH are code multiplexed and transmitted simultaneously during the 1st 256 chips of each slot. The transmission power of SCH can be adjusted by a gain factor GP-SCH and GS-SCH, respectively, independent of transmission power of P-CCPCH. The SCH is *non-orthogonal* to the other downlink physical channels.

3.2Channelization Codes

The channelization code for the Primary CPICH is fixed to $c_{256,0}$ and the channelization code for the Primary CCPCH is fixed to $c_{256,1}$.The channelization codes for all other physical channels are assigned by UTRAN.

When compressed mode is implemented by reducing the spreading factor by 2, the OVSF code of spreading factor SF/2 on the path to the root of the code tree from the OVSF code assigned for normal frames is used in the compressed frames. For the case where the scrambling code is changed during compressed frames, an even numbered OVSF code used in normal mode results in using the even alternative scrambling code during compressed frames, while an odd numbered OVSF code used in normal mode results in using the odd alternative scrambling code during compressed frames.

In case the OVSF code on the PDSCH varies from frame to frame, the OVSF codes shall be allocated such a way that the OVSF code(s) below the smallest spreading factor will be from the branch of the code tree pointed by the smallest spreading factor used for the connection. This means that all the codes for UE for the PDSCH connection can be generated according to the OVSF code generation principle from smallest spreading factor code used by the UE on PDSCH.

In case of multicode PDSCH allocation, the same rule applies, but all of the branches identified by the multiple codes, corresponding to the smallest spreading factor, may be used for higher spreading factor allocation.
The OVSF codes can be defined using the code tree of fig 6.1.

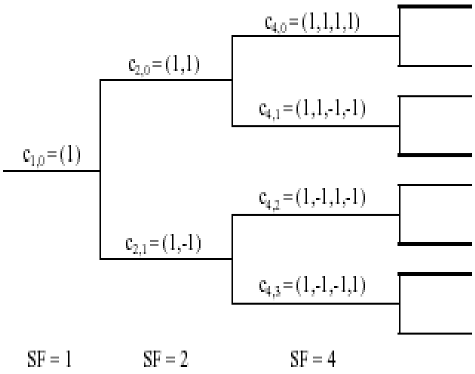


Fig 4.1 Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes.

In Figure 6.1, the channelization codes are uniquely described as $C_{SF,k}$, where SF is the spreading factor of the code and *k* is the code number, 0 <=*k* <=SF-1. Each level in the code tree defines channelization codes of length SF, corresponding to a spreading factor of SF in Figure 6.1.

The generation method for the channelization code is defined as:

$$c_{1,0}=1,$$

$$\begin{bmatrix}c_{2,0}\\c_{2,1}\end{bmatrix}=\begin{bmatrix}c_{1,0}&c_{1,0}\\c_{1,0}&-c_{1,0}\end{bmatrix}=\begin{bmatrix}1&1\\1&-1\end{bmatrix}$$

$$\begin{bmatrix}c_{2^{(n+1)},0}\\c_{2^{(n+1)},1}\\c_{2^{(n+1)},2}\\c_{2^{(n+1)},3}\\\vdots\\c_{2^{(n+1)},2^{(n+1)}-2}\\c_{2^{(n+1)},2^{(n+1)}-1}\end{bmatrix}=\begin{bmatrix}c_{2^n,0}&c_{2^n,0}\\c_{2^n,0}&-c_{2^n,0}\\c_{2^n,1}&c_{2^n,1}\\c_{2^n,1}&-c_{2^n,1}\\\vdots&\vdots\\c_{2^n,2^n-1}&c_{2^n,2^n-1}\\c_{2^n,2^n-1}&-c_{2^n,2^n-1}\end{bmatrix}$$

The leftmost value in each channelization code word corresponds to the chip transmitted first in time.

For the DPCCH and DPDCHs the following applies:
The DPCCH is always spread by code $c_{256,0}$ i.e. $C_{ch,0}$ = $c_{256,0}$.
When only one DPDCH is to be transmitted, DPDCH1 is spread by code $C_{ch,1}$ = $c_{SF,k}$where SF is the spreading factor of DPDCH1 and k= $SF_{d,1}$ / 4
When more than one DPDCH is to be transmitted, all DPDCHs have spreading factors equal to 4. DPDCHn is spread by the the code $C_{ch,n}$ = $c_{4,k}$, where *k* = 1 if *n* Є{1, 2}, *k* = 3 if *n* Є {3, 4}, and *k* = 2 if *n* Є {5, 6}.

3.3 Downlink Scrambling Codes

The downlink scrambling codes are used to maintain cell or sector separation. A total of 2^{18}-1 = 262,143 scrambling codes, numbered 0…262,142 can be generated. However not all the scrambling codes are used. The scrambling codes are divided into 512 sets each of a primary scrambling code and 15 secondary scrambling codes.

The primary scrambling codes consist of scrambling codes n=16*i where i=0…511. The i:th set of secondary scrambling codes consists of scrambling codes 16*i+k, where k=1…15.

There is a one-to-one mapping between each primary scrambling code and 15 secondary scrambling codes in a set such that i:th primary scrambling code corresponds to i:th set of scrambling codes.

Hence, according to the above, scrambling codes k = 0, 1, …, 8191 are used. Each of these codes are associated with an even alternative scrambling code and an odd alternative scrambling code, that may be used for compressed frames. The even alternative scrambling code corresponding to scrambling code k is scrambling code number k + 8192, while the odd alternative scrambling code corresponding to scrambling code k is scrambling code number k + 16384.

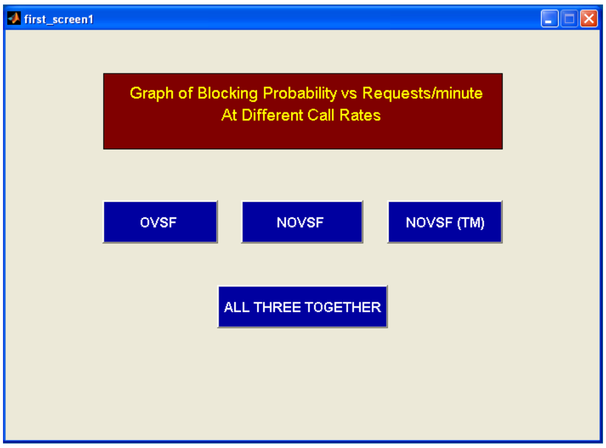
The set of primary scrambling codes is further divided into 64 scrambling code groups, each consisting of 8 primary scrambling codes. The j:th scrambling code group consists of primary scrambling codes 16*8*j+16*k, where j=0..63 and k=0..7.

Each cell is allocated one and only one primary scrambling code. The primary CCPCH is always transmitted using the primary scrambling code. The other downlink physical channels can be transmitted with either the primary scrambling code or a secondary scrambling code from the set associated with the primary scrambling code of the cell. The mixture of primary scrambling code and secondary scrambling code for one CCTrCH is allowable.

The scrambling code sequences are constructed by combining two real sequences into a complex sequence. Each of the two real sequences are constructed as the position wise modulo 2 sum of 38400 chip segments of two binary *m*sequences generated by means of two generator polynomials of degree 18. The resulting sequences thus constitute segments of a set of Gold sequences. The scrambling codes are repeated for every 10 ms radio frame. Let *x* and *y* be the two sequences respectively. The *x* sequence is constructed using the primitive (over GF(2)) polynomial $1+X^7+X^{18}$.

The y sequence is constructed using the polynomial $1+X^5+X^7+X^{10}+X^{18}$

Simulation Results



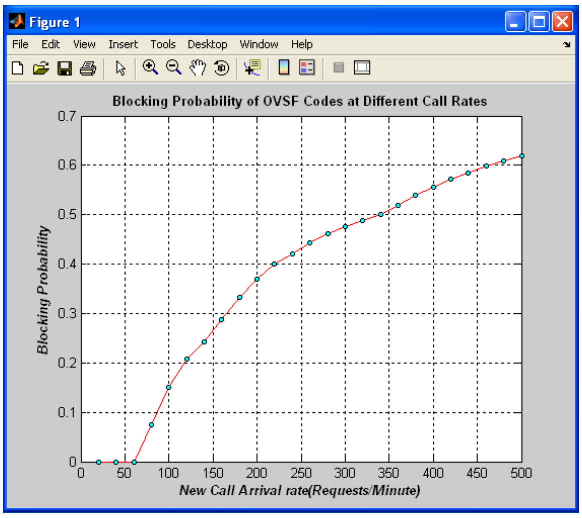


Figure R1: Blocking Probablity of OVSF Codes at Different Call Rates

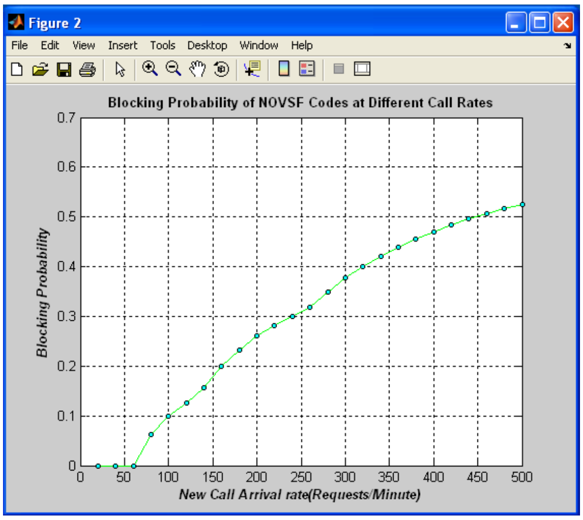


Figure R2: Blocking Probability of NOVSF Codes with Elight Initial Orthogonal Codes at Different Call Rates

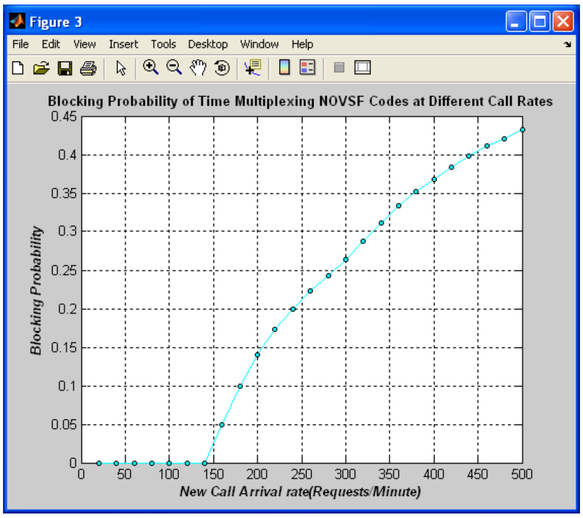


Figure R3: Blocking Probability of NOVSF (Time - Multiplexing) Codes at Different Call Rates

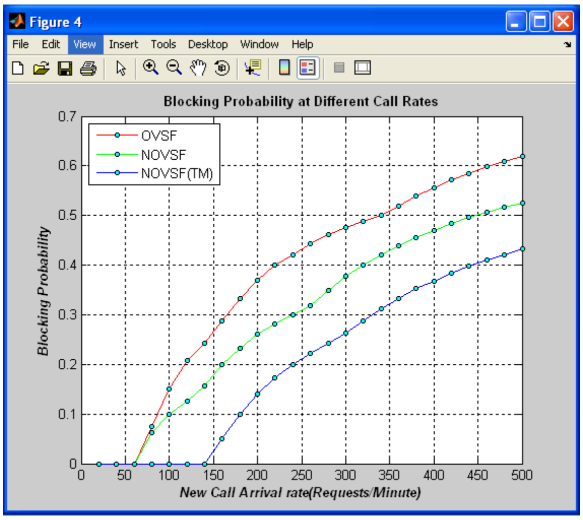


Figure R4: Blocking Probability at Different Call Rates

Conclusions

Proposed use of Non-Blocking OVSF (NOVSF) codes and Time Multiplexing NOVSF codes in the sense that all codes are orthogonal to each other and no code blocks the assignment of any other NOVSF code. An immediate consequence of this Property is that the aggregate rate of all NOVSF codes is the summation of all NOVSF codes rates, as opposed to the OVSF property that the aggregate rate of all OVSF codes can be at most the rate of root code.

As the graphs of Blocking probability Vs New call arrival rate (request/minute) show that Time Multiplexing NOVSF codes produce less code blocking then NOVSF codes with eight initial orthogonal codes at different call rates, which again produce less code blocking than OVSF codes. So NOVSF codes of type-2 and Time Multiplexing NOSF codes lead to increased system capacity and high code utilization. Therefore, Time Multiplexing Non Blocking OVSF codes are better option for channelization codes in W-CDMA system in near future.

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