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Simulation of Channelization Codes in 2G and 3G Mobile Communication Services using MATLAB

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Abstract- **This paper presents comparison of different channelization codes between OCSF, OVSF, and NOVSF. The effect of NOVSF codes on blocking probability is analyzed. OCSF codes are used by second generation CDMA mobile communication systems where service is mainly directed towards voice communication with fixed bandwidth utilization. In third generation mobile radio communication, directed mainly towards different multimedia services, WCDMA is selected as technology for use in UMTS terrestrial radio access (ULTRA) FDD operation by ETSI. WCDMA can support mixed and variable rate services. Such flexibility can be given by multiple OCSF codes and OVSF code but still there are some drawbacks of these codes so NOVSF codes are used. This paper will compare and contrast all these codes**.

Keywords: Orthogonal Constant Spreading Factor (OCSF), Orthogonal Variable Spreading Factor (OVSF), Nonblocking Orthogonal Variable Spreading Factor (NOVSF), Wideband Code Division Multiple Access (WCDMA)

I INTRODUCTION

In India, mobile communication has entered in daily life in the past decade. In second-generation (2G) mobile radio communication GSM uses FDMA/TDMA and IS-95 uses CDMA as access technology. These 2G systems cater to voice, facsimile, and low-bit-rate data communication. In IS-95 System, each user is assigned a unique OCSF code.

Beyond 2G systems, WCDMA is used as multiple access technology in third generation mobile radio communication (3G), which supports high data rate, variable bit rate, and different quality of service (QoS) requirements like end-to-end delay, jitter, and packet loss. To support all these requirements of third generation multiple OCSF code or OVSF codes are used.

To support higher data rate in CDMA With multiple OCSF codes, multiple transceivers are required for every user device (Mobile subscriber or Base station). User with small data rates send information by using more number of OCSF codes .It is done to make overall transmitted bandwidth of the system constant hence the hardware complexity is more. Due to this limitation, OCSF_CDMA is not preferred.

IN OVSF–CDMA each user requires a single transceiver unit. This is possible because the number of transceivers is equal to the number of OVSF codes. For higher data rate single OVSF code is assigned to each user and higher data rates are provided by using lower spreading factors. In recent years there is much research is done on the assignment strategies of OVSF codes. Adachi [1] proposed to use OVSF code to allocate bandwidth in CDMA system, OVSF code corresponding to code rate is provided to any service. Minn [2] pointed that false use of OVSF code allocation may waste 25% of OVSF spreading code, and he proposed DCA method to adjust spreading code tree each time a service request is made.

Park [3] used both capacity partitioning and class partitioning methods to allocate resources to different groups of service class. Yang [4] defined a flexibility index to measure the capability of assigned code set to support multirate traffic classes. Saini [5] used code reservation mechanism to assign codes to incoming serviced .Tseng [6] used OVSF code tree placement to resolve code placement problem. These OVSF codes can support 15Kbps, 30Kbps, 60Kbps, 120 Kbps, 240 kbps, 480 kbps and 960 kbps data rates

For requirement of variable data rates fragmented OVSF are required Jang and Lin [7] proposed OVSF code based frame work to support QoS for third generation WCDMA system.

The OVSF codes are generated using a tree structure. One of the important properties of the OVSF codes is that if any code is used in the OVSF code tree ,none of its ancestors and descendants ,which leads to the blocking of ancestors and descendants which gives code blocking in this situation a new call is rejected even though capacity to handle it. The spreading factor (SF) in OVSF codes varies from 4 to 256 for uplink transmission and from 4 to 512 for the downlink transmission.

There are three Non-Blocking OVSF codes that overcome the limitation of OVSF code that orthogonality will not be there in ancestors and descendants codes:-

i) Type 1 NOVSF Codes Employing Time Multiplexing

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The main objective of these codes is to improve the utilization of OVSF codes without the overhead of code reassignments. To achieve this, only a single layer of OVSF codes with SF is taken into consideration and time multiplexing is applied to share them among channels. This implies that both time and code multiplexing are used in NOVSF codes. Note that all OVSF codes of the same layer are orthogonal to each other and, therefore, do not block each other. Each code may be shared in time among more than one channel. The number of time slots in an OVSF code with SF 8 can be variable or fixed.

ii) Type 2 NOVSF Codes

This type of NOVSF codes can be described in three different cases. In all cases, OVSF codes are reorganized in code trees such that all the codes of the code tree are orthogonal to each other. The reason why the codes in the first two cases are orthogonal is as follows: There are initially *X*1; *X*2; : : : ; *Xi* orthogonal codes with the same spreading factor (SF) that is equal to *i*, where either *i* = 4 or *i* = 8. Let code *Xj*, *j* _ *i*, generate *nj* orthogonal codes with the *same SF*, where *n j* is a power of 2. All of these *n j* orthogonal codes with the same SF are placed on the same distinct layer of a code tree. Therefore, all the codes of the resulting code tree are still orthogonal to each other.

iii) Type 3 NOVSF Codes

This type of NOVSF codes are generated systematically when there is no limit on the upper bound of SF. To describe the systematic generation of all orthogonal codes for *SF*_4, we first define BOVSF codes and then NOVSF codes. **BOVSF codes**: *1)* Let *A* = [1] be the root BOVSF code, as *A* = [1] is also the root OVSF code. *2)* Use each BOVSF code *X* to generate two orthogonal codes: [*X*; *X*; *X*; *X*] and [*X*; _*X*], where _*X* is the inverted sequence of *X*.

Using this procedure recursively, generate all BOVSF codes that can be represented as nodes of a balanced binary tree. BOVSF codes have the same property as OVSF codes, that is, *i*) all BOVSF codes of the same layer of the BOVSF code-tree are orthogonal to each other, and *ii*) any two codes of different layers are orthogonal except for the case that one of the two codes is a parent code of the other.

With these non-blocking OVSF codes; blocking probability of OVSF codes is reduced.

II FUNDAMENTALS

OVSF code tree is a complete binary tree. Each OVSF code is denoted by as $C_{SF,X}$ where SF is the spreading factor representing OVSF code length and x is the channelization OVSF code tree. Transmission rates offered by OVSF codes An OVSF code tree is a binary tree with ten layers, labeled from 0 to 9 starting with the root node, such that SF of codes at layer *k* is equal to 2*k*. As stated earlier, 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 to a channel, it blocks its entire ancestor and descendant codes from assignment because they are not orthogonal to each other.

For instance, the assignment of code $C_{4;1}$ shown in Fig.4.1 blocks the assignment of its ancestor codes (i.e., $C_{2;1}$ and $C_{1;1}$) and descendant codes(i.e., $C_{8;1}$ and $C_{8;2}$). The circle and cross signs on the links indicate the assigned and blocked codes, respectively. For instance, the assignment of code $C_{4;1}$ blocks the assignments of $C_{2;1}$, $C_{1;1}$, $C_{8;1}$, and $C_{8;2}$ because they are either ancestors or descendants of $C_{4;1}$. Code $C_{4;4}$ can be prevented from being blocked by freeing $C_{8;8}$ and reassigning code $C_{8;6}$ to the channel of $C_{8;8}$.

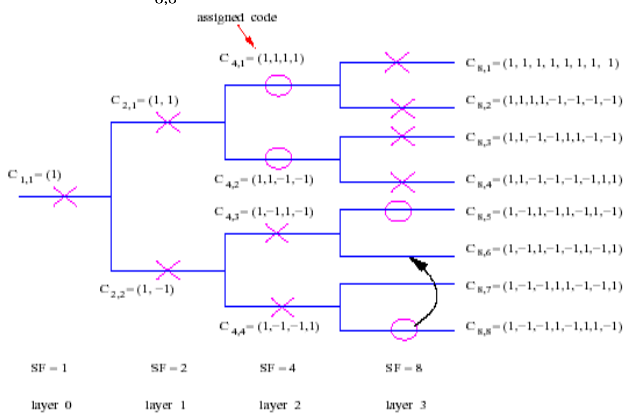

Fig 1 OVSF codes

III PROPOSED CODES

1.1 NOVSF codes using Time multiplexing

Each code may be shared in time among more than one channel. The number of time slots in an OVSF code with SF 8 can be variable or fixed. If it is variable, then we need to introduce a variable, say cycle length, to indicate the number of time slots, which requires that receiver be informed about the cycle length during transmission. We assume that the number of time slots is fixed and equal to 64. In this case, assigning one time slot of an OVSF code with SF 8 would be equivalent to assigning an OVSF code with SF 512 to a channel without any time multiplexing.

Similarly, when all 64 time slots of an OVSF code are assigned to the same channel, the supported data rate becomes the same as the one that would be obtained in case of assigning an OVSF code with SF 8 without any time multiplexing. Thus, if all 64 time slots of a code are not assigned to the same channel, the data over the channel are transmitted intermittently.

Figure 4.3 illustrates 8 OVSF codes with SF 8, namely, *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*. Each code has 64 time slots, each corresponding to a sequence of 8 chips. Hence, there are 64 chip sequences in all 64 time slots, resulting in a total of 512 = 64_8 chips. The date rate supported by each time slot is equivalent to the data rate that an OVSF code with SF 512 can support. Each time slot of the WCDMA standard frame can carry 2560 chips, which implies that there are 5 transmissions of 64 time slots in a frame.

If the date rate supported by a time slot is denoted by *R*, then data rate supported by *K* time slots equals *R_K*. The time slots that are assigned to a channel do not have to be consecutive. Fig.4.3 illustrates how the first 8 time slots of two NOVSF codes, namely, *A* and *B*, may be shared in time among five different channels at some point of time. The data rates corresponding to the OVSF codes with SF 512, 256, 128, 64, 32, 16, and 8 are obtained by 6 assigning 1, 2, 4, 8, 16, 32, or 64 time slots, respectively, that are a power of 2. Indeed, since any number of time slots may be assigned to a channel, many intermediate data rates can be supported in channels when NOVSF codes are employed. Or other solution is code reassignment.

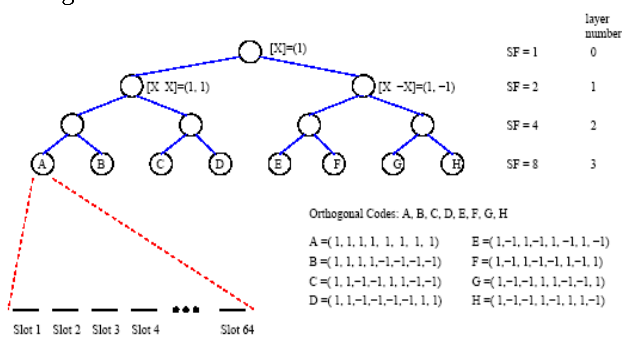

Fig 2 NOVSF code with time multiplexing

1.2 Type 2 NOVSF CODE

These type of codes overcome the limitation of OVSF code. There are three cases of these type of codes:

Case 1: NOVSF codes with four initial orthogonal codes.

In this case, there are initially four orthogonal codes, namely, *A*, *B*, *C*, and *D*. Using these four orthogonal codes, a binary code tree is constructed as follows. Code *A* is made the root code with *SF* 🖬 4 in the layer 1 of the tree. For the tree layer 2, the following two orthogonal codes with *SF* 🖬 8 are generated from code *B*: ☎*B*;*B*➂ and ☎*B*;♉*B*➂. Similarly, four codes are generated from code *C* and are placed on layer 3 of the tree. Finally, eight generated codes from *D* are placed on layer 4 of the tree. What is required is to have a code tree of four layers in this case, but the SF of codes at any one of these four layers can be equal to any power of 2 ranging between 4 to 512, depending on the requested data rates of users. For instance, the SFs of the code tree could be 16, 4, 32, and 64 at some instant of time.

Case 2: NOVSF codes with eight initial orthogonal codes with SF from 8 to 512.

In this case, as shown in Figure 4.5, there are initially eight orthogonal codes, namely, *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*. Using the first seven orthogonal codes, a binary code tree is constructed as follows. Code *A* is made the root code with *SF* 🖬 8 in the layer 1 of the tree. For the tree layer 2, the following two orthogonal codes with *SF* 🖬 16 are generated from code *B*: ☎*B*; *B*➂ and ☎*B*; ♉*B*➂. Similarly, four codes are generated from code *C* and are placed on layer 3 of the tree. As illustrated in Figure 3, codes *D*, *E*, *F*, and *G* generate 8, 16, 32, and 64 codes, respectively, and are placed on layers 4, 5, 6, and 7, respectively. Code *H* can be used as a standby code in any tree layer whenever more codes are needed. Indeed, each one of the eight codes *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*. can have any spreading factor depending on the requested data rates. For instance, if there are eight users.

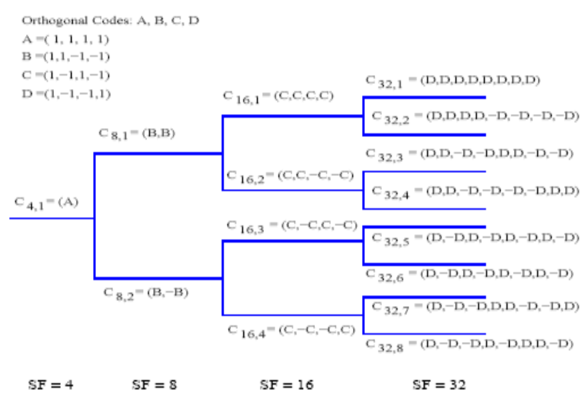

Figure 3: NOVSF codes with four initial orthogonal codes

In this figure, it is assumed that SF ranges from 4 to 32. But, SF can indeed range from 4 to 512. For instance, the SFs of the tree layers may be 4, 8, 32, and 128, requesting codes with *SF* 🖬 8, then each layer is assumed to be assigned a code with *SF* 🖬 8. In general, any layer of the tree can have *X* = 8 orthogonal codes with the spreading factor of *X*, where *X* is a power of 2 ranging from 8 to 512. This implies that, without considering the standby code *H*, there may be at most 64 codes in each layer. When *H* is also considered, one layer can have as many as 128 codes.

Case 3: NOVSF codes with four initial orthogonal codes with SF from 4 to 512.

In this case, there are initially four orthogonal codes, namely, A, B, C, and D as in Case 1. It is the same as Case 1 except that the

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descendants of a code in this case can be assigned more than one layer with the condition that only orthogonal descendants can be assigned.

1.3 Type 3 NOVSF Codes

This type of NOVSF codes are generated systematically when there is no limit on the upper bound of SF. To describe the systematic generation of all orthogonal codes for *SF* ♉ 4, we first define BOVSF codes and then NOVSF codes. BOVSF codes: *1)* Let *A* ◙ [1] be the root BOVSF code, as *A* ◙ [1] is also the root OVSF code. *2)* Use each BOVSF code *X* to generate two orthogonal codes: ☯*X*; *X*; *X*; *X*☸ and ☯*X*; ♉*X*☸, where ♉*X* is the inverted sequence of *X*.

Using this procedure recursively, generate all BOVSF codes that can be represented as nodes of a balanced binary tree. BOVSF codes have the same property as OVSF codes, that is, *i*➂ all BOVSF codes of the same layer of the BOVSF code-tree are orthogonal to each other, and *ii*➂ any two codes of different layers are orthogonal except for the case that one of the two codes is a parent code of the other.

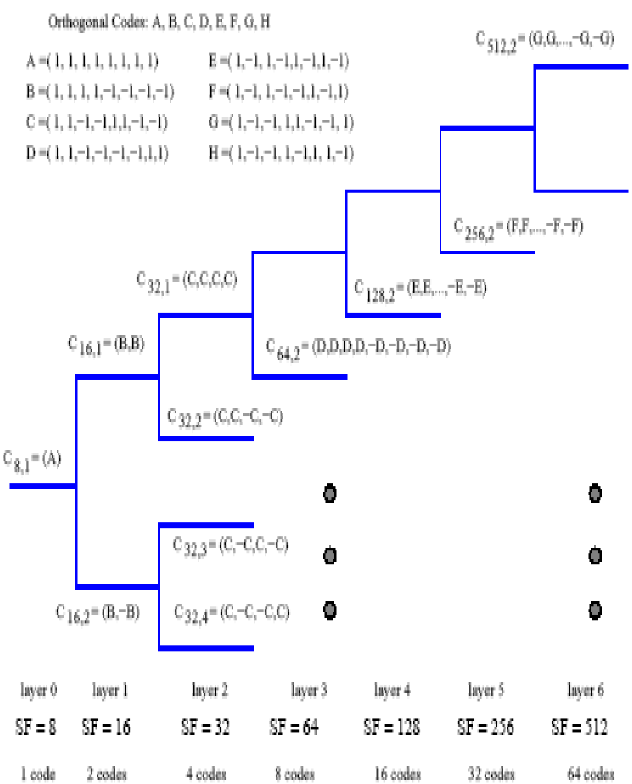

Fig 4: The binary code tree for NOVSF codes with 8 _ SF _ 512. (Only one NOVSF code is illustrated in layers 4 to 7 due to space limitations)

IV SIMULATION RESULTS

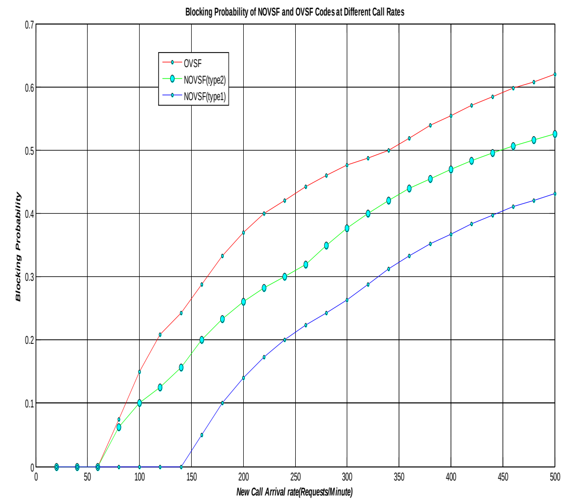

Fig 5 Blocking probability of OVSF and NOVSF codes at different call rates.

Blocking probability for different call rates like R,2R,4R,8R is calculated and graphs are plotted blocking probability vs different call rates using MATLAB 2010 for OVSF,NOVSF(Type1), NOVSF(Type2) codes. It has seen from graph that NOVSF (Type1) with time multiplexing has reduced blocking probability.

V CONCLUSION

OCSF codes used in 2G systems cannot be used for multi-rate data requirements. For multi-rate data requirements in 3G, multiple OCSF codes can be used, but there is hardware complexity involved. OVSF codes with different spreading factor can be used to support variable data rate requirement but these codes should be orthogonal to each other. In this ancestors and descendant codes cannot be used as orthogonal codes. If used, even if system has capacity to provide channel but calls can be blocked for that NOVSF code with time multiplexing can be used which reduces blocking probability by 40% [8] and throughput of non-real-time calls is improved by use of NOVSF codes. Call blocking probability of OVSF ,NOVSF(Type 1)with time multiplexing, NOVSF(Type 2(case 1)) is calculated and comparison is done and it is seen that NOVSF(Type 1) with time multiplexing are best suited for 3G
WCDMA systems which reduces blocking probability. Three different graphs are plotted in MATLAB call blocking probability vs different call rates.

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