New UMTS Down Link OVSF With Multiple Amplitude Coding

JOÃO S. PEREIRA[1] and HENRIQUE J. A. DA SILVA[2]

[1] Departamento de Engenharia Informática
Escola Superior de Tecnologia e Gestão
Alto do Vieiro, Morro do Lena, P-2401-951 Leiria
Apartado 3063,
PORTUGAL

[2] Departamento de Engenharia Electrotécnica
Instituto de Telecomunicações
Universidade de Coimbra, Polo II, P-3030-290 Coimbra
PORTUGAL

Abstract: - Our investigation is focused on the binary capacity improvement of the Down Link Channel in UMTS (Universal Mobile Telecommunication System). For a WCDMA (Wideband Code Division Multiple Access) system, the use of different channels at the same time, by many users, is possible because these physical channels are orthogonal to each other. For UMTS, these orthogonal codes are called "OVSF (Orthogonal Variable Spreading Factor) Channelization Codes". Each channel has a distinct code that cannot be re-used in the same physical medium at the same time. But there exists a rule of exception that makes possible the use of the same OVSF code in the same transmission medium at the same time: this rule consists on the amplitude variation of the OVSF code. This is a specific multiple level amplitude OVSF code access technique that can increase considerably the quantity of physical channels available. The UMTS DL channel was selected to show the great increase of binary capacity obtained when using a "OVSF With Multiple Amplitude Coding (OVSF-MAC)" Technique. The quantity of new OVSF codes is only dependent on the noise level existing in the transmission channel.

Key-Words: - **UMTS, OVSF code, WCDMA.**

1 Introduction

The European 3rd generation mobile communication system (UMTS) uses many different codes in the Down Link and Up Link channels. For example, a Channelization Code can distinguish a source communication in the same physical medium. These Channelization Codes are also called Orthogonal Variable Spreading Factor (OVSF) codes [1] [2]. OVSF codes produce a variable level of frequency spreading, and at a same time maintain different physical channel codes orthogonal.

The OVSF codes are based on the generation tree represented in Fig. 1. Not all Spreading Factors (*SF*) can be used simultaneously. The UMTS Channelization code management is controlled by the RNC (Radio Network controller) [1]. In Fig. 1 the orthogonal OVSF codes are represented by $C_{ch,SF,m}$, where m is the code number $0 \le m \le SF-1$. Each level of the tree defines a Channelization code with length equal to *SF*.

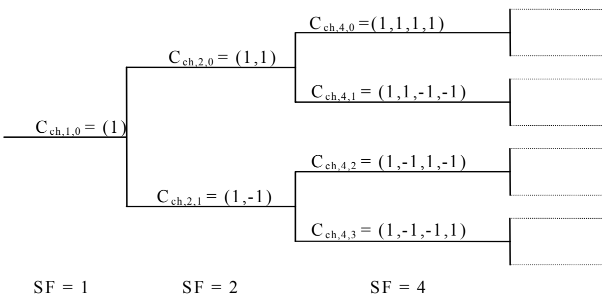

Fig.1 : Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes.

The OVSF codes $C_{ch,SF,m}$ can be obtained by the three mathematical expressions (1), (2) and (3).

$$C_{ch,1,0} = 1 \tag{1}$$

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

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

The leftmost value in each Channelization code word corresponds to the first transmitted chip. The spreading factor can be equal to 4, 8, 16, 64, 128, 256 or 512. Theses values are inversely proportional to the frequency spreading.

For the UMTS Down Link Channel, the $C_{ch,SF,m}$ codes are used for spreading the physical channels, as shown in Fig. 2. The serial data (S) are transformed to parallel data (P) before the spreading operation with $C_{ch,SF,m}$. As can be seen, the real and imaginary parts of the complex data $S_{m,n}$ have the same OVSF code. The last multiplication in Fig. 2 is a scrambling operation. The $S_{dl,n}$ signal is a Gold sequence [3]. This scrambling operation introduces a communication cell separation.

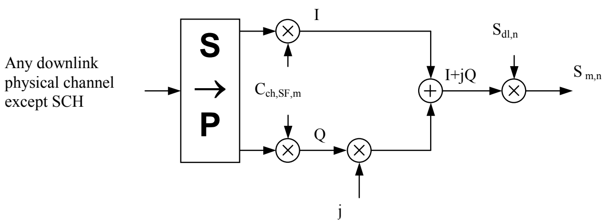

Fig.2 : Spreading for all UMTS downlink physical channels except SCH (Synchronization Channel).

The informative data of a physical channel D_m are divided into two parts; a real part $D_{r,m}$ and an imaginary part $D_{i,m}$. The signal S of Fig. 2 has the expression:

$$S = S_{m,n} = D_m.C_{ch,SF,m}.S_{dl,n} \qquad (4)$$

$$D_m = D_{r,m} + j.D_{i,m} \qquad (5)$$

The sequences $D_{r,m}$, $D_{i,m}$ and $C_{ch,SF,m}$ are real sequences associated to the channel *m*. $S_{dl,n}$ is a complex sequence of a Gold set, used to separate the communication cell *n*.

A base station can transmit up to *m=SF* channels simultaneously. Each sequences *S* can have an amplitude variation without loss of informative data on the receiver equipment. This property may be used to increase the maximum physical channel quantity, *SF*. This is a new access technique that can be designated by OVSF with Multiple Amplitude Coding (OVSF-MAC).

2 OVSF with Multiple Amplitude Coding

The data sequence of a UMTS base station can be expressed by:

$$T_{n,0} = \sum_{m=0}^{SF-1} g_m.S_{m.n} \qquad (6)$$

Besides using all data sequences available, it is possible to add more data sequences to the frame $T_{n,0}$, but there is one condition that should be satisfied: the new frame should not have any value equal to zero inside.

The new codes can be found if we answer the following question: when a UMTS base station is transmitting its maximum binary throughput $T_{n,0}$, how is it possible to add more frames without loss of the decoding capability of previous frames?

One answer can be found in the receiver correlation filters. The decoding capability of a correlation filter is achieved applying an integrator operator to the frame $T_{n,0}$ multiplied by $C_{ch,SF,m}$. The output signal (+ or -) of this integrator operation can be considered as the decoded value. Then, we can easily see that this decoded value is independent of the amplitude of the integrator output. This result is not affected by a g_m amplitude variation because the g_m gain keeps the same signal value. These considerations make possible the introduction of more codes (other frames $T_{n,0}$) in the same physical medium at the same time. But the output of the correlation filter should not be equal to zero. Then, it is possible to add more frames $T_{n,0}$ if this last condition is satisfied and the new frames have a specific amplitude.

The mathematical description of a new frame T_n is given by equations (7) and (8).

$$T_n = \sum_{k=0}^{Q} \frac{T_{n,k}}{2^k} = \sum_{k=0}^{Q} \frac{\sum_{m=0}^{SF-1} g_m.D_{m,k}.C_{ch,SF,m}.S_{dl,n}}{2^k} \qquad (7)$$

$$T_n = \sum_{k=0}^{Q} \sum_{m=0}^{SF-1} g_m . D_{m,k} . C_{ch,SF,m,k} . S_{dl,n} \qquad (8)$$

The new codes are defined by $C_{ch,SF,m,k} = \dfrac{C_{ch,SF,m}}{2^k}$ and may be designated by OVSF with Multiple Amplitude Codes. For the UMTS Down Link channels this new Multiple Amplitude Coding operation may be applied to OVSF codes.

With this method it is possible to increase the maximum binary throughput by a $Q+1$ factor. This value is dependent of the minimum g_m gain and the noise level in the physical medium. The reduction of the amplitude of $T_{n,k}$ frames by a factor $\dfrac{1}{2^k}$ makes possible to add a lot of different new $T_{n,k}$ frames to the original $T_{n,0}$ frame. These new frames do not produce a zero value at the output of the correlation receiver filter because the length of integration is equal to the spreading factor *SF*.

For the down link channel of UMTS, only the $T_{n,0}$ frame is used in the sector *n*. This situation corresponds to the level $k=0$ with $Q=0$. The $T_{n,k}$ frames with $k>0$ are the news frames that can be added to the $T_{n,0}$ frame.

When the system is transmitting multiple frames $T_{n,k}$ with OVSF-MAC, the $T_{n,0}$ frame decoding is achieved by the same method as for a unique frame $T_{n,0}$. The correlation filter works as if the new added frames do not exist, because they have smaller amplitude. It is possible to extract the binary data of the new frames $T_{n,k}$ ($k>0$) with the same correlation filter, using a recursive method. After determining the binary value corresponding to frame $T_{n,k}$ it is possible to know the binary value of the next $T_{n,k+1}$ frame. For example, $T_{n,1}$ can be obtained easily if $T_{n,0}$ is known, by subtracting $T_{n,0}$ from the output of the correlation filter produced by the frame T_n.

3 UMTS simulation results

The proposed coding method has been simulated by software. The communication system elected was the UMTS Down Link channel [1], when maximum binary transmission is used. This situation corresponds to the Spreading Factor $SF=4$, when 4 channels are transmitting simultaneously with 1.92Mbps each (informative data with control data). The maximum binary capacity of the $T_{n,0}$ frame is equal to 7.68 Mbps. Although our simulator allows the consideration of any Spreading Factor, the next example uses SF=4 with Q=1. This is the simpler situation, when only one sub level of OVSF coding is used.

$$T_n = \sum_{k=0}^{1} \frac{T_{n,k}}{2^k} = \sum_{k=0}^{1} \frac{\sum_{m=0}^{3} g_m . D_{m,k} . C_{ch,4,m} . S_{dl,n}}{2^k} \qquad (9)$$

$$T_n = T_{n,0} + \sum_{m=0}^{3} g_m . D_{m,1} . C_{ch,4,m,1} . S_{dl,n} \qquad (10)$$

The $T_{n,0}$ frame is decoded by a correlation filter (matched filter) applied to the T_n frame. The existence of $T_{n,1}$ does not disturb the $T_{n,0}$ decoding if the noise is not significant. This result is possible because the amplitude of the $T_{n,1}$ frame is reduced by a factor of 2.

All $D_{m,0}$ data are decoded normally and the $D_{m,1}$ data are decoded after knowing $D_{m,0}$. After the correlation filter is applied to ($T_{n,0}$ - T_n), the $D_{m,1}$ data can be easily extracted.

Fig. 3 shows the error probability (BER) versus E_b/N_o obtained with a maximum binary throughput of 15.36 Mbps. This is twice the rate used in the UMTS DL Channel.

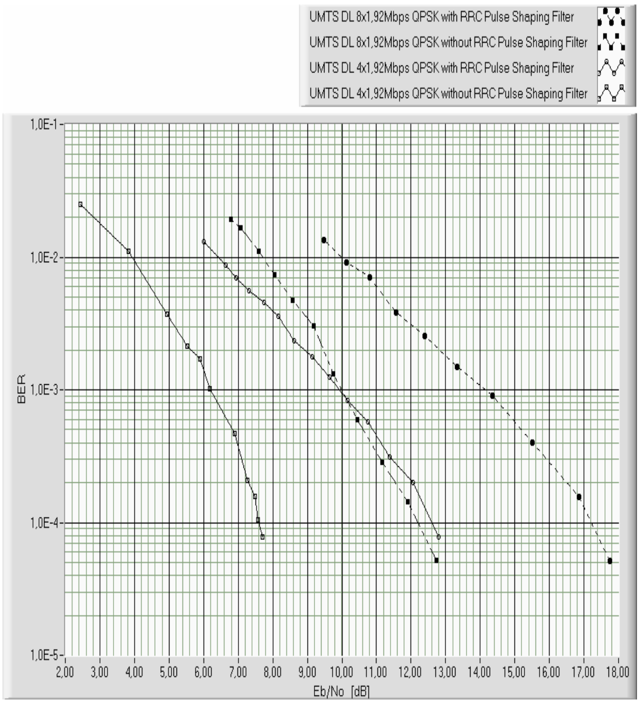

Fig.3 : UMTS DL Channel BER versus E_b/N_o with 15.36Mbps, with and without Root Raised Cosine pulse shaping filter and k={0,1}, compared with UMTS DL Channel BER versus E_b/N_o with 7.68Mbps, with and without Root Raised Cosine Pulse Shaping Filter(k=0).

This simulation was performed considering one cell using 8 channels of 1.92 Mbps. The modulation is QPSK and the noise is assumed Gaussian. The filters (Root Raised Cosine pulse shaping - RRC) [1][4] in the modulator affect the transmission of the $T_{n,1}$ frame when SF=4 is used. For this reason the bandwidth of the RRC filters was increased in order to obtain the maximum transmission bandwidth allowed [4]. Fig.3 includes also the simulation results obtained for a UMTS Down Link Channel with 4x1.92 Mbps and QPSK modulation with and without RRC filtering, for comparison. As can be concluded from this comparison, the OVSF-MAC can be used with an acceptable BER and twice the binary throughput of a UMTS Down Link channel with standard OVSF coding.

The inter symbol interference produced by the Root Raised Cosine pulse shaping filters degrades the BER performance shown in Fig. 3, but may be avoided by using a continuous phase modulation technique, which is now under investigation.

4 Conclusion

The purpose of the multiple access technique presented in this communication, designated by OVSF with Multiple Amplitude Coding, is to increase the quantity of OVSF codes used in the UMTS Down Link Channel. In consequence, it is possible to increase the number of physical channels that can be used in the same cell at the same time. This method may be implemented in UMTS without large modifications, but it is recommended to use a different pre-filtered QPSK modulation.

This method may be compared with a multiple level amplitude modulation. The UMTS mobile phone terminal uses different amplitude levels in the Up Link Channel, with OVSF codes, in order to allow the compensation of the different losses between mobile terminals and base station (near-far effect). In the Down Link Channel this amplitude variation is not necessary. However, its implementation would make possible to increase the number of UMTS Down Link Channels with distinct OVSF codes. Each of the new codes has specific amplitude, and this enables their simultaneous use with the originals codes. The quantity of new OVSF codes is only dependent of the existing noise. In a low noise channel, it is possible to increase, by a factor $Q+1$, the Base Station maximum binary throughput for one cell or sector.

For validation of the OVSF with Multiple Amplitude Coding method, we have presented in this paper some UMTS simulation results. For the simpler case (Q=1) the results obtained show that it is possible to duplicate de maximum binary throughput of the UMTS Down Link Channel. However, it is possible to increase this improvement further if there is low noise in the physical channel. Besides, the new codes are transmitted with a lower power, and this enables their use by the Base Station for nearer terminals.

This new codes (OVSF-MAC) are easily decoded by using a simple recursive method. Each "lower level" code can be decoded after decoding the contiguous "upper level" code. The simplicity of this method may make it acceptable for use in UMTS. The original OVSF codes and the new OVSF-MAC codes can coexist without affecting the decoding of one of them. The solution proposed here can be implemented in the future, when UMTS achieves its maturity and all types of OVSF codes need to be used simultaneously. But the implementation of OVSF-MAC is limited by the Root Raised Cosine pulse shaping filters employed in the QPSK modulation. This limitation is under investigation and may be eliminated by using a continuous phase modulation that does not need to employ raised cosine pulse shaping.

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