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APPLICATION OF OFDM MODULATION ON UP-LINK IN UMTS UTRA-FDD FOR MULTIPLEXING PHYSICAL DATA CHANNELS OF A SAME MOBILE

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Abstract:—OFDM is a modulation technique which allows not only to increase more the bit rates of SISO or MIMO systems but also to fight against the multipath phenomena of the mobile radio channel - due to its frequency and temporal selectivity- by transforming it in a set of sub-channels not selective for frequencies. To benefit of these advantages that it offers, we suggest in this paper to apply it for multiplexing physical data channels of a same mobile given that on the one hand, the UMTS standard plans the situation where a mobile has to emit simultaneously data towards different channels [1] and on the other hand, the multipath phenomena degrade the orthogonality of the codes used in WCDMA. The use of this modulation will allow to simplify the data symbols reception because we shall not have any more as in the case of the RAKE receiver to look for all the path followed by an emitted signal to obtain the received signal. The data emission principle similar to the OFDM which we proposed on the up-link, allowed us to give the emitted OFDM signal expression. We showed that we can have emission bit rates superior or equal to 2Mbit/s if the chip time T_c satisfies equation (24). This OFDM signal is then simulated for a mobile having to send simultaneously one data symbol by channel for a total of four channels.

Keywords:—MIMO, OFDM, RAKE receiver, SISO, UMTS, WCDMA

I. INTRODUCTION

For not having to use a receiver which has to count all the various path followed by an emitted signal to obtain the received signal expression [2] [3] [4], and for not having to be exposed to codes orthogonality degradation effects due to the multipath [2] [3] [4], we suggest improving the UMTS UTRA- FDD system in term of bit rate and simplicity of reception. For that purpose, we adopt on the up-link a modulation similar to the OFDM for multiplexing physical data channels of a same mobile. The implementation of the OFDM modulation eliminates the multipath negative effects for having a simple reception of the sent data; because every sub-channel characterized by a well known carrier has a constant frequency response H(f). Before presenting our OFDM emission principle for a mobile which has to send simultaneously data towards different channels, we call back at first the principles of the OFDM modulation and the baseband emission in WCDMA for deducting the data vector by chip time representing our OFDM symbol. We finish the paper by the simulation of the OFDM signal emitted by a mobile which has to execute simultaneously four different applications.

II. THE OFDM MODULATION

OFDM modulation is a multiplexing technique which consists in transmitting digital data in parallel by modulating them on a large number of narrowband carriers. It allows increasing the spectral efficiency. Also, it transforms a wide band channel very selective in time and in frequency in a multitude of narrow band channels not selective in frequency. This advantage is its implementation in the standards of broadcasting digital sound in mobiles (DAB: Digital Audio broadcasting), of terrestrial digital television (DVB-T: Digital Video Broadcasting- Terrestrial), of high bits rates digital communications, etc……

The OFDM modulation principle is to group N digital data c_k by packet to form OFDM symbols, and then to modulate at the same time the data c_k of a OFDM symbol by orthogonal carriers f_k

If $s_k(t)$ is the modulated signal resulting from a data c_k modulating a carrier at the frequency f_k, then $s_k(t)$ is written :

$$s_k(t) = c_k e^{j2\pi f_k t} \quad (1)$$

The OFDM signal s(t) is the sum of the signals $s_k(t)$:

$$s(t) = \sum_{k=0}^{k=N-1} c_k e^{j2\pi f_k t} \quad (2)$$

If T_s is the time which separates two OFDM symbols, the multiplexing is orthogonal if the variation between two frequencies is $1/T_s$. Then:

$$f_k = f_0 + \frac{k}{T_s} \quad (3)$$

III. CHARACTERISTICS OF THE UMTS UTRA-FDD

UMTS is an European third generation network designed especially to respond to the request of the multimedia services [5]. It is characterized by a radio interface based on a multiple technique access which names the WCDMA [5]. In this multiple technique access, the codes used to spread signals are direct sequences; which means bits sequences called chips which bit rate is very upper to that of the useful data bits and having good properties of autocorrelation and intercorrelation [5]. The spreading consists in multiplying every bit of the useful signal by a sequence of L chips. This gives a resulting signal which spectral band is much wider than that of the original signal. In fact, the spectral band of the coded original signal is appreciably equal to that of the code signal [5]. The code signal is also called the spreading code because having served to spread the original signal spectrum. The spectrum spreading presents some advantages; it decrease the risk of interference with the others received signals while ensuring a certain confidentiality level. A key parameter of a system with spreading of spectrum is the processing gain G which is the ratio between the band width occupied by a bit information after its spreading and the band width occupied by a bit information before its spreading. In fact G represents the capacity of a radio access system with spreading of spectrum to reject interferences. More G is great, more the systems resist to noise.

In the UMTS standard, the frequency band retained for the radio interface is around 2 GHz. It is a frequency band which can be operated in access mode UTRA-FDD or in access mode UTRA-TDD. In access mode UTRA-FDD, the both frequencies sub-bands reserved for the up-link and the down-link are divided into channels (carriers) of 5 MHz of wideness. The up-link carriers are in the sub-band [1920MHz, 1980MHz] [1] [5] and those of the down-link are in the sub-band [2110MHz, 2170MHz] [1] [5]. So, for the UTRA-FDD radio access mode, the physical channel serving for identifying a user is completely defined by the carrier and the CDMA codes which are allocated to him. Two code families are generally used in CDMA:

- The channelization codes which are on the OVSF code family. On up-link they allow to separate data channels of a same mobile [1] [5]
- The muddle codes which are long sequences codes generated from 24 registers. In up-link they allow to separate the flows of various mobiles [1] [5].

IV. BASEBAND EMISSION PRINCIPLE IN WCDMA

The useful information is converted at first in a binary signal. After that, this binary signal is presented on bipolar shape by making correspond to the binary digit (bit) 0 the value +1 and to the binary digit 1 the value -1 [5]. So, the useful information is transformed into a train of binary digit +1 or -1 that we are going to consider as the user data. Consider $S_k(i)$ the i^{th} binary digit emitted by the user k and $1/T_b$ the common bit rate to all users. If we consider that the k^{th} user emits in all Q binary digits, then the baseband corresponding signal is:

$$S_k(t) = \sqrt{2P}\sum_{i=0}^{Q-1} S_k\,(i)C_k(t - iT_b) \qquad (4)$$

P is the baseband power by bit transmitted.

$C_k(t)$ is the spreading sequence (the code) with unit norm formed of L bipolar symbols or chips of duration T_c which values are +1 or -1. It allows to spread the signal of the user k and it satisfies the following equation:

$$C_k(t) = \sum_{n=0}^{L-1} C_k\,(n)g(t - nT_c) \qquad (5)$$

g(t) is a Nyquist root filter for shaping a chip of one unit power. It takes the value 1 in the interval $[nT_c\,,\ (n+1)T_c]$ for n going from 0 to L-1 and the value 0 elsewhere.

Thus the equation (4) becomes:

$$S_k(t) = \sqrt{2P}\sum_{i=0}^{Q-1} S_k(i)\sum_{n=0}^{L-1} C_k(n)g(t - iT_b - nT_c) = \sqrt{2P}\sum_{i=0}^{Q-1}\sum_{n=0}^{L-1} S_k(i)C_k(n)g(t - iT_b - nT_c)$$
(6)

With, $T_b = LT_c$

Then the equation (6) becomes:

$$S_k(t) = \sqrt{2P}\sum_{i=0}^{Q-1}\sum_{n=0}^{L-1} S_k(i)C_k\,(n)g(t - (iL + n)T_c) \qquad (7)$$

V. APPLICATION OF A MULTI-CARRIERS MODULATION WITH ORTHOGONAL FREQUENCIES IN EMISSION FOR MULTIPLEXING THE DATA CHANNELS OF A SAME MOBILE

We have just seen that the emitted signal by a user k of the network is written according to the equation (7):

$$S_k(t) = \sqrt{2P}\sum_{i=0}^{Q-1}\sum_{n=0}^{L-1} S_k(i)C_k\,(n)g(t - (iL + n)T_c)$$

If $S_k(i)$ is the i^{th} binary digit emitted by the user k at the moment $t - iT_b$, let us pose $S_{k\,,i}(t)$ the corresponding signal. $S_{k\,,i}(t)$ is given by:

$$S_{k\,,i}(t) = \sqrt{2P}\sum_{n=0}^{L-1} S_k(i)C_k(n)g(t - (iL + n)T_c) \qquad (8)$$

$S_k(i) \in \{-1, 1\}$ and $C_k(n) \in \{-1, 1\}$

Let us assume:

$$S_{k\,,in} = S_k(i)C_k(n) \qquad (9)$$

It represents the result of the multiplication of the i^{th} bit of the user k by the n^{th} chip of the spreading code $C_k = [C_k(0),\ C_k(1), \dots\dots\dots . C_k(L-1)]$ which is assigned to him.

We see also that $S_{k\,,in} \in \{-1, 1\}$

Then

$$S_{k\,,i}(t) = \sqrt{2P}\sum_{n=0}^{L-1} S_{k\,,in}\; g(t - (iL + n)T_c) \qquad (10)$$

Let us suppose that we have a mobile k which has to emit simultaneously data towards N different channels. Also let us suppose that these data are symbols which can result from a MDA-M, MDP-M, or MAQ-M modulation. We remind that in these types of modulation, the emitted symbols belong to an alphabet with M elements. M is given by the relation:

$$M = 2^p \tag{11}$$

p is the number of bits conveyed by a symbol.
We shall note $A_{k,r}^m$ the symbol delivered by the modulator at the moment mT_s (with m the index of the symbols and T_s the symbol time) to be sent by the mobile k towards the channel r (with r going from 0 to N-1)
If every symbol transports p bits then the symbol time $T_s=pT_b$ where T_b is the bit time.
Let us assume $C_{k,r}$ the spreading code used by the mobile k for the channel r.
Given that we are reasoning on a mobile, we can note $A_r^m = [A_r^m(0), A_r^m(1), \dots\dots A_r^m(p-1)]$ the symbol delivered by the modulator at the moment mT_s and which has to be sent on the channel r, and $C_r = [C_r(0), C_r(1), \dots\dots\dots . C_r(L-1)]$ the spreading code to apply in this channel. As every bit of a symbol A_r^m that we note $A_r^m(i)$ (with i going from 0 to p-1) must be spread by the code C_r , then the elementary information to be sent at every chip time T_c on the channel r is by analogy with the relation (9) :

$$S_{r,in}^m = A_r^m(i) C_r(n) \tag{12}$$

$S_{r,in}^m$ represents the multiplication result of the ith bit of the p bits representing the symbol A_r^m with the nth chip $C_r(n)$ of the spreading code C_r .
If at every time T_c we have to send simultaneously elementary informations $S_{r,in}^m$ to every channel r, and if N is the total number of physical data channels; then we take as OFDM symbol vector the vector S_{in}^m given by:

$$S_{in}^m = \left[S_{0,in}^m,\ S_{1,in}^m,\ S_{2,in}^m, \dots\dots S_{r,in}^m \dots\dots . S_{N-1,in}^m\right] \tag{13}$$

We see that at every time interval T_c is going to correspond a vector S_{in}^m ; and the number of vector S_{in}^m which will be formed during the simultaneous emission towards N physical data channels of their mth symbol A_r^m , is so p.L.
We suppose to have N orthogonal carriers and we suggest applying an OFDM modulation to every elementary symbol $S_{r,in}^m$ of the OFDM symbol vector S_{in}^m.
The output signal of the OFDM modulator at the nth chip time of the ith bits of the mth data symbols A_r^m is then:

$$S_{ofdm}^m(t - mT_s - (iL+n)T_c) = \sum_{r=0}^{N-1} S_{r,in}^m\, e^{j2\pi f_r (t - mT_s - (iL+n)T_c)} \tag{14}$$

$$S_{ofdm}^m(t - mT_s - (iL+n)T_c) = \sum_{r=o}^{N-1} S_{r,in}^m\, e^{-j2\pi f_r (mT_s + (iL+n)T_c)} e^{j2\pi f_r t} \tag{15}$$

In a time $T_b = LT_c$ we have:

$$S_{ofdm}^m(t - mT_s - iT_b) = \sum_{n=0}^{L-1} S_{ofdm}^m(t - mT_s - (iL+n)T_c) \tag{16}$$

$$S_{ofdm}^m(t - mT_s - iT_b) = \sum_{n=0}^{L-1} \sum_{r=0}^{N-1} S_{r,in}^m\, e^{-j2\pi f_r (mT_s + (iL+n)T_c)} e^{j2\pi f_r t} \tag{17}$$

Knowing that a symbol A_r^m lasts a time $T_{s,}$ that it is obtained at the moment mT_s and conveys p bits; then, after the emission of these p bits, the OFDM signal corresponding to the mth symbols is:

$$S_{ofdm}^m(t - mT_s) = \sum_{i=0}^{p-1} S_{ofdm}^m(t - mT_s - iT_b) \tag{18}$$

$$S_{ofdm}^m(t - mT_s) = \sum_{i=0}^{p-1} \sum_{n=0}^{L-1} \sum_{r=0}^{N-1} S_{r,in}^m\, e^{-j2\pi f_r (mT_s + (iL+n)T_c)} e^{j2\pi f_r t} \tag{19}$$

From there, we deduce the expression of the total OFDM signal emitted by the mobile if K symbols must be sent towards every channel r:

$$S_{ofdm}(t) = \sum_{m=0}^{K-1} S_{ofdm}^m(t - mT_s) \tag{20}$$

$$S_{ofdm}(t) = \sum_{m=0}^{K-1} \sum_{i=0}^{p-1} \sum_{n=0}^{L-1} \sum_{r=0}^{N-1} S_{r,in}^m\, e^{-j2\pi f_r (mT_s + (iL+n)T_c)} e^{j2\pi f_r t} \tag{21}$$

Now to find the orthogonal carriers f_r , we are going to subdivide a frequency band wide of $Nf_c = N\frac{1}{T_c}$ into N carriers because every channel r occupies a frequency band $f_c = \frac{1}{T_c}$. So f_r is given by:

$$f_r = f_c + \frac{r}{T_c} \tag{22}$$

Our system bit rate is given by:

$$D = \frac{number\ \ of\ sent\ bits}{sending\ \ time} = \frac{KpN}{KpT_b} = \frac{N}{LT_c} \qquad (23)$$

To obtain bits rates greater or equal to 2Mbit/s which is the maximum bit rate for the UMTS standard, T_c just has to verify:

$$T_c \leq \frac{N}{2.10^6.L} \qquad (24)$$

This is equivalent to:

$$f_c \geq 2.10^6 \frac{L}{N} \qquad (25)$$

VI. SELECTION OF THE USEFUL PARAMETERS FOR THE PERFORMANCE

6.1 The frequency band wide of Nf_c

It remains to see how to select the frequency band which we will divide in N carriers. In fact if we apply the OFDM modulation, it is for addressing against the multipath phenomena and making so that every channel corresponding to a well determined carrier, to be seen as a constant channel. In others words, we want for every channel the transfer function H(f) being constant. Thus we want each channel to be not selective in frequency and consequently to facilitate the reception of the symbols which are sent. For that purpose, a preliminary study of the propagation channel would inform us about its coherence band B_c, which is a frequency band in which the propagation channel is considered constant. Once the coherence band is known, we could deduce a frequency band wide of Nf_c (Nf_c could be chosen less or equal to B_c), what would permit to have the value of f_c knowing N.

6.2 The type and the order of the modulation for a low symbol error probability

For a successful system, the M-ary symbols A_r^m would have to be obtained with an error probability ensuring a good quality of service. Thus, it would be necessary to see for which type and order of modulation, the symbol error probability would be acceptable for the various applications to be simultaneously executed on the mobile.

VII. SIMULATION OF THE OFDM SIGNAL

Consider a mobile which has to send symbols towards four channels. We suppose that every symbol is formed by two bits information. For that purpose, we need four OVSF codes.

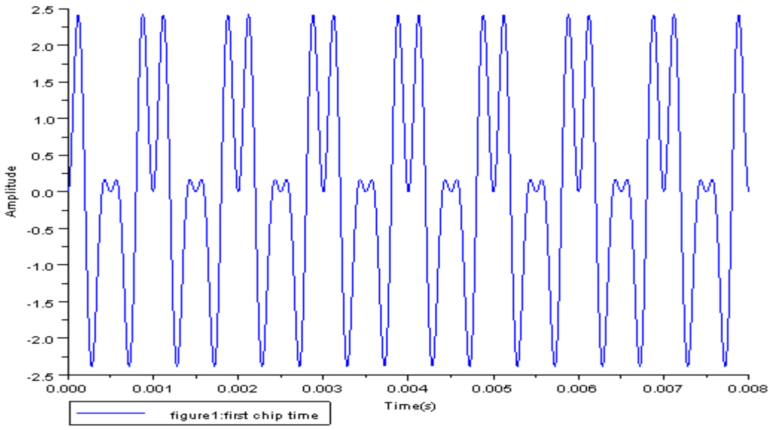
Consider the codes : C_0=[1 1 1 1], C_1=[1 1 -1 -1], C_2=[1 -1 1 -1], and C_3=[1 -1 -1 1].

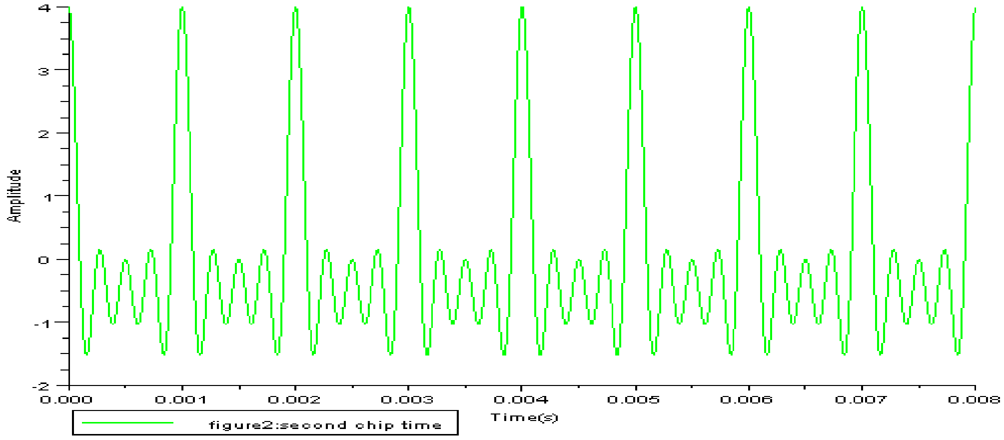
For the simulation, we assume the sending of one symbol by channel; consider the symbols A_0=00 for the channel r=0, A_1=01 for the channel r=1, A_2=10 for the channel r=2, A_3=11 for the channel r=3.

S_1=[1, 1, -1, -1], S_2=[1, 1, 1, 1], S_3=[1, -1, -1, 1], S_4=[1, -1, 1, -1], S_5=[1, -1, 1, -1], S_6=[1, -1, -1, 1],

S_7=[1, 1, 1, 1], S_8=[1, 1, -1, -1] are respectively the OFDM symbols formed at the first chip time, at the second chip time, at the third chip time, at the fourth chip time, at the fifth chip time, at the sixth chip time, at the seventh chip time and finally at the eighth chip time.

The figures (1 to 11) are obtained at a frequency **f_c=1000 Hz**. It follows that **f_0=1000Hz** for the channel r=0, **f_1=2000Hz** for the channel r=1, **f_2=3000Hz** for the channel r=2, and **f_3=4000Hz** for the channel r=3.

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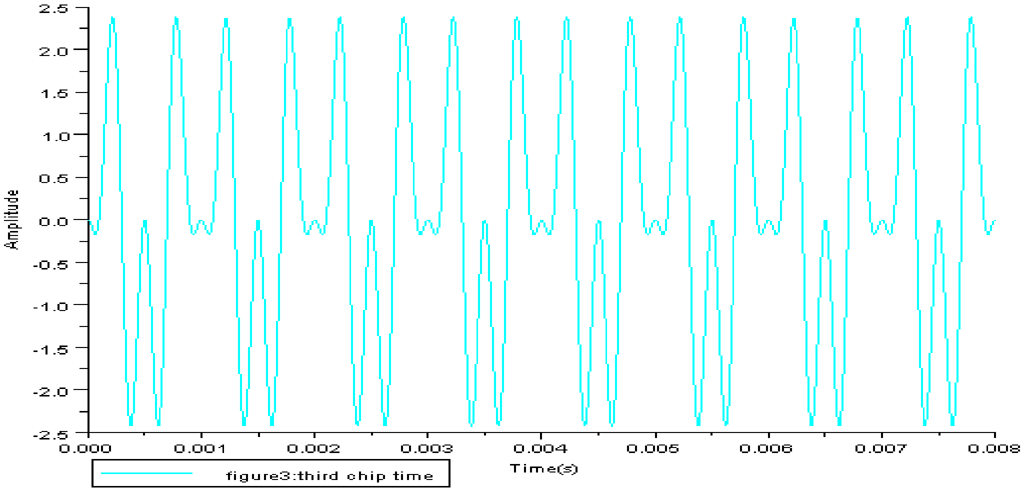
3
2
1
0
-1
-2
Amplitude
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
Time(s)
figure2:second chip time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2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
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-2.0
-2.5
Amplitude
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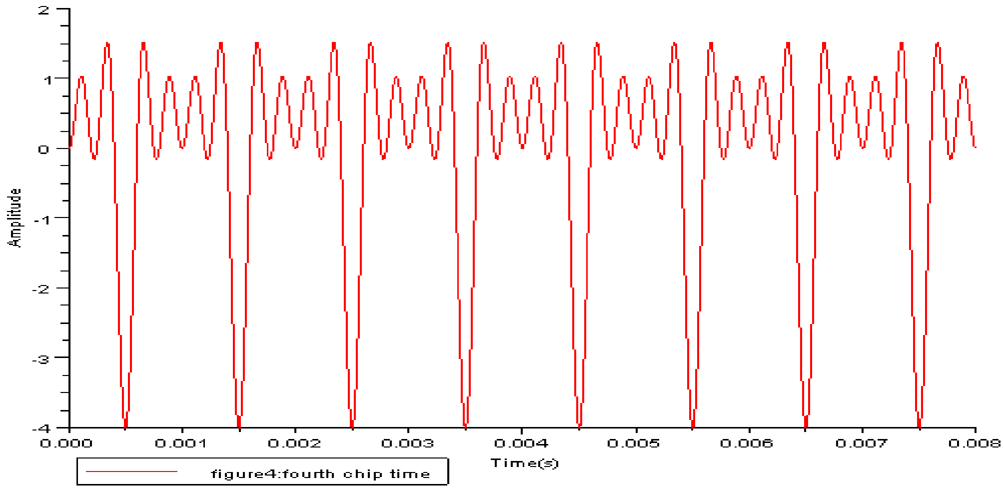
0.005
0.006
0.007
0.008
Time(s)
figure3:third chip time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Amplitude
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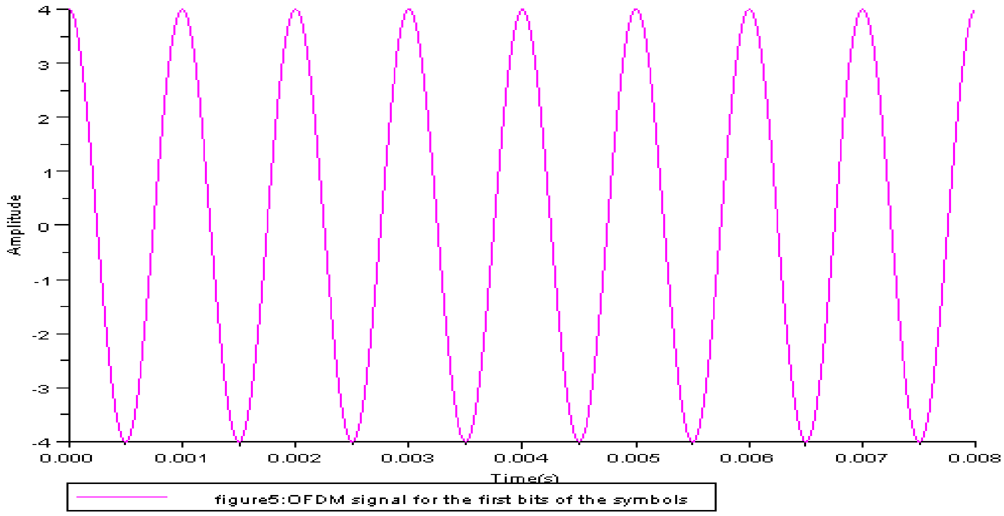
Time(s)
figure4:fourth chip time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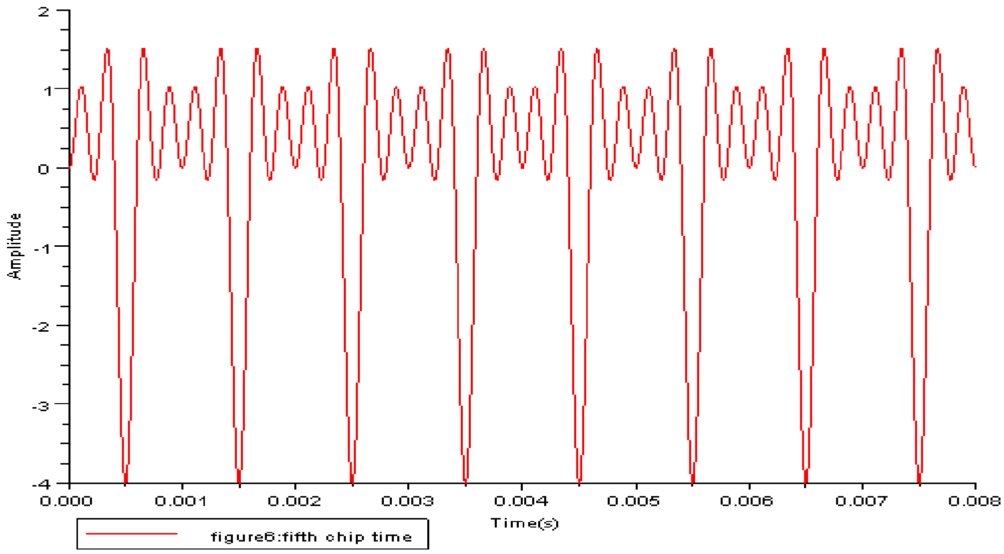
Time(s)
figure5:OFDM signal for the first bits of the symbols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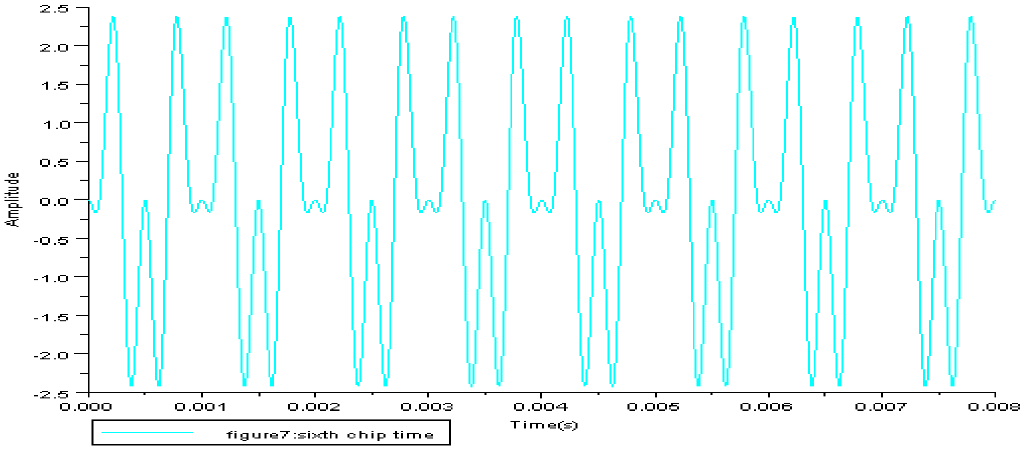
Time(s)
figure6:fifth chip time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Amplitude
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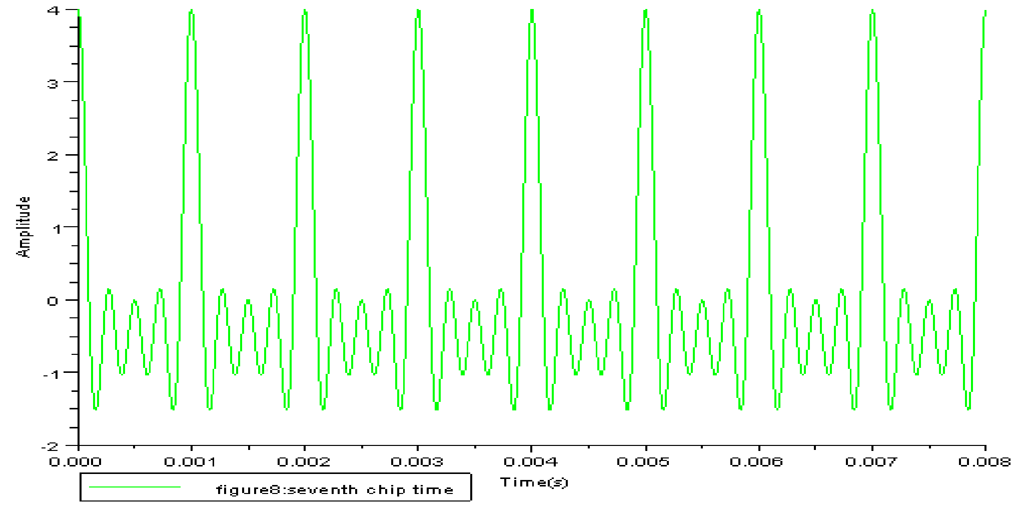
Time(s)
figure7:sixth chip time


Amplitude
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-2
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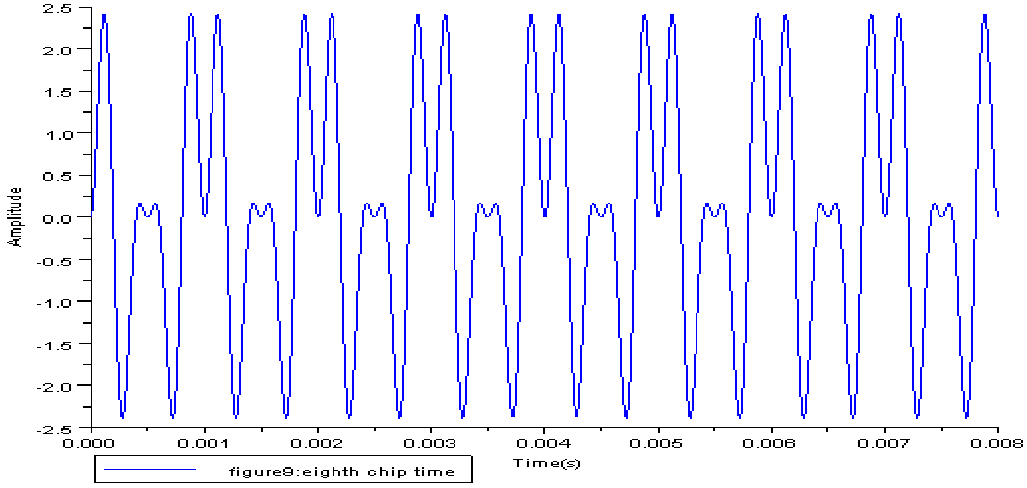
0.008
Time(s)
figure8:seventh chip time


Amplitude
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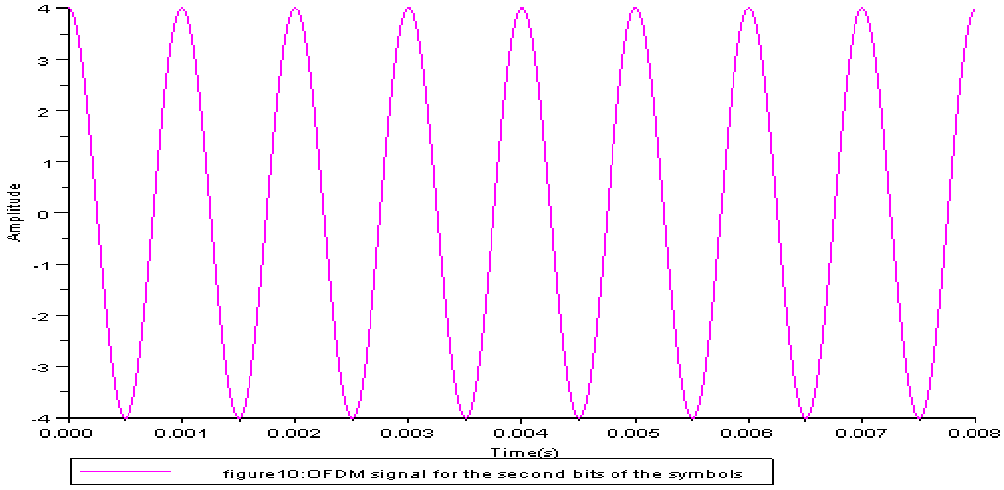
Time(s)
figure9:eighth chip time


Amplitude
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-1
-2
-3
-4
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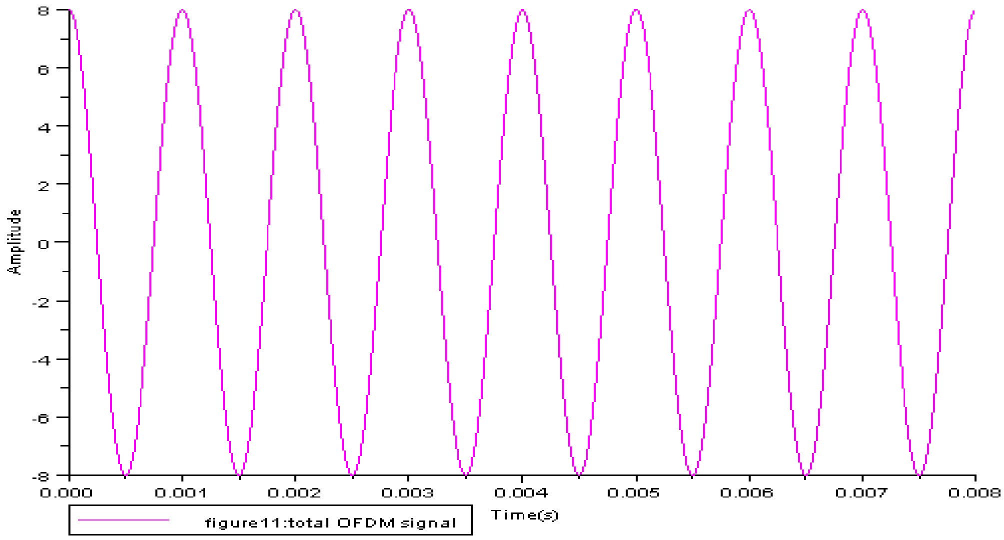
0.008
Time(s)
figure10:OFDM signal for the second bits of the symbols



From the figure 1 to 4, we have respectively the OFDM signals at the first chip time, at the second chip time, at the third chip time and at the fourth chip time. The figure 5 represents the OFDM signal for the first bits of the symbols A_0, A_1, A_2, A_3. Thus it represents the sum of the OFDM signals obtained from the first chip time to the fourth chip time.

From the figure 6 to 9, we have respectively the OFDM signals at the fifth chip time, at the sixth chip time, at the seventh chip time and at the eighth chip time. The figure 10 represents the OFDM signal for the second bits of the symbols A_0, A_1, A_2, A_3. Thus it represents the sum of the OFDM signals obtained from the fifth chip time to the eighth chip time.

Observing these figures, we note that: fig.1 is the same to fig.9 because $S_1=S_8$, fig.2 is the same to fig.8 because $S_2=S_7$, fig.3 is the same to fig.7 because $S_3=S_6$, fig.4 is the same to fig.6 because $S_4=S_5$.

The figure 11 represents the total OFDM signal for the four symbols: It is the sum of the amplitudes in fig.5 and in fig.10.

VIII. CONCLUSION

In this paper, we used an OFDM signal for multiplexing the data channels of a same mobile. What we can gain by using this technique is in first, a reception principle that no more processes multipath because all the mobile channels will be constant in their frequency band and secondly, a bit rate higher than 2Mbits/s if T_c satisfies to the chip time equation at the fifth paragraph. This work is a first phase towards OFDM receivers integration in the UMTS standard for the applications of simultaneous data sending from a mobile towards different channels. The same modulation principle can be used in down-link by forming OFDM symbols by chip time such as we propose it. Now, it remains to see at first, the demodulation of the OFDM signal received at the receiver after crossing of the channel. Secondly, it is the feasibility of this OFDM receivers integration at the level of the node B and the mobile terminals that it would be necessary to see if the frequencies used for the OFDM implementation are different from those of the others applications on the UMTS network using the QPSK modulation.

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