Performance study of the OFDM modulation for the use in Wireless communication Systems of the 4G

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Abstract - ***Communication is ensured by the links between the base station and the different mobiles. It is provided by allocating a channel to each mobile. A channel typically uses two transmission frequencies: one is used to communicate information from the base station to the mobile and called downlink communication; the other is used to communicate information to the mobile station base and is called uplink. The transmission channel is the central issue that must be addressed in different transmission solutions. When a symbol is sent through the channel, it will be received in the form of delayed and attenuated versions superposed which can lead to interference between the transmitted symbols. One remedy would be to increase the time interval between the symbols but at the expense of throughput desired. To maintain high data rates and cancel the interference between symbols, a more sophisticated solution consists of a parallel transmission of data with sufficiently long periods such as OFDM achieves it "Orthogonal Frequency Division Multiplexing. "***

Keywords: *BER, SNR, OFDM, QAM, AWGN.*

1. Introduction:

Digital transmission systems convey information between a source and a destination using a physical medium such as cable, optical fiber or, propagation over a radio channel. The signals may be transported either directly from digital source, such as data networks, or analog origin, but converted to digital form. The task of the transmission system is to move information from the source to the destination with the highest possible reliability.

- The source transmits a digital message in the form of a sequence of binary elements.
- The encoder can possibly remove non-significant bit, or otherwise introduce redundancy in information to protect it against noise and these disturbances on the transmission channel.
- Modulating role is to adapt the spectrum of the signal to the channel on which it is issued.
- On the receiver side, the demodulation and decoding functions are the respective inverses of the functions of modulation and coding located on the transmitter side.

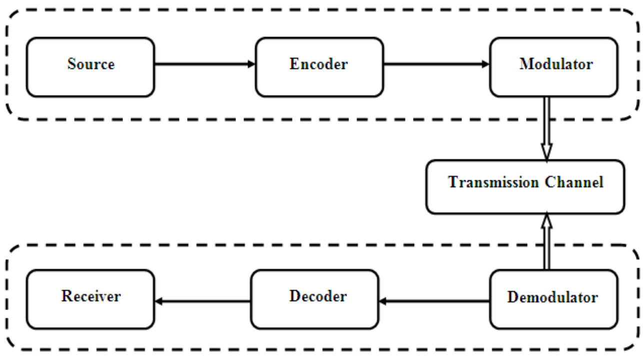

Figure 1: Diagram of a digital transmission system.

Wireless telecommunications is experiencing an interest, always supported for decades and continue to evolve to give us a better quality of service. The propagation channel is one of the key elements of the transmission chain. The propagation channel is the link for transferring information from a transmitter to a receiver. The precise knowledge of the propagation channel is essential for the optimal design of communication systems. The interactions of the propagation channel with the environment cause different physical phenomena that result in a multipath. Reflection, refraction, diffraction, diffusion and effect of the waveguide are the main physical phenomena occurring during the propagation of an electromagnetic wave in an environment.

It is therefore important to predict the operation of the channel in order to assess the impact of noise on the transmission. For digital communication, the SEP (symbol error probability) is most often used to evaluate the performance of a transmission for a given modulation.

The combination of these phenomena generates a multipath propagation, causing the fading effects. There are two types of fading, large and small scale one.

Large-scale fading are the fluctuations in the average power of the measured signal over a sufficiently large distance. Both phenomena that result are shadowing effects and attenuation path.

Large-scale fading is characterized by attenuating the average course and the shading effect. The shading is due to different physical phenomena related to wave propagation and may vary according to the nature of the environment where the spread of the electromagnetic wave occurs.

The small-scale fading is the rapid fluctuations of the received signal power over short distances. Small-scale fading is caused by the multipath signals which arrive at the receiver with random phases, causing rapid changes in the amplitude of the signal over a short distance. The small-scale fading is characterized by three aspects of the channel, are the selectivity time, frequency selectivity and spatial selectivity.

The channel time selectivity is caused by the Doppler Effect. The channel is considered either a fast or slow fading channel, depending on how fast the channel changes occur with respect to the data rate.

The frequency selectivity is due to the dispersion of the arrival times of the multipaths of the transmission signal in the channel which is considered as either flat or frequency selective fading, depending on the size and the width of the strip consistency of the channel relative to the bandwidth of the applied signal.

The spatial selectivity of the channel is caused by multiple paths from the different directions in space and is often characterized by the angular power spectrum.

Main features to compare the different transmission techniques are:

- The error probability per bit transmitted evaluates the quality of a transmission system. It is a function of the transmission technique used, but also of the channel on which the signal is transmitted.
- The spectral occupancy of the transmitted signal must be known to effectively use the bandwidth of the transmission channel. We are forced to use increasingly large modulations spectral efficiency.
- The complexity of the receiver whose function is to restore the transmitted signal is the third important aspect of a transmission system.

Major communications techniques are the mono carrier modulation technique, the main ones, ASK (Amplitude Shift Keying), FSK (Frequency Shift Keying), PSK (Phase Shift Keying), QAM (Quadrature Amplitude Modulation).

Multi carrier modulation technique that presents its advantages over single carrier to see that the use of single carrier modulation uses equalizers provided by low-order filters with limited complexity. This limits the performance of this type of system particularly for channels whose characteristics sustain significant variations. By against the multicarrier systems operate effectively on such channels, since the systems MCM (Multi Carrier Modulation) divide the bandwidth of the transmission channel into several channels and each channel in a narrow bandwidth. Its characteristics remain unchanged (in terms SNR), which makes use of a simple equalizers, both sufficient and efficient. The rest of the paper is organized as follows, the second section explains modulation techniques with these types, and the third section presents the characteristics of OFDM and especially orthogonality. The criteria for performance analysis of digital systems which are the signal to noise ratio SNR, the outage probability, the bit error rate BER, the bit error probability, are reserved for section 4, Simulations and analysis of the results are shown in section 5 , Conclusions are given in Section 6.

2. Modulation techniques:

The modulation aims to adapt the signal to be transmitted to the transmission channel. This operation is to modify one or more parameters of a carrier wave centered on the channel frequency band. The parameters characterizing a carrier wave are amplitude A, frequency f_0 and phase φ_0, and according to the parameter used to encode the information, we have the amplitude modulation, frequency modulation and phase modulation.

2.1 Amplitude-shift keying ASK:

The Amplitude Shift Keying works on the variation of the amplitude of the carrier at the rate of data [1]. The modulation affects the amplitude of the carrier and the signal. The modulated signal is written in the form:

$$m(t) = A(t).\cos(2\pi f_0 t + \varphi_0) \qquad (1)$$

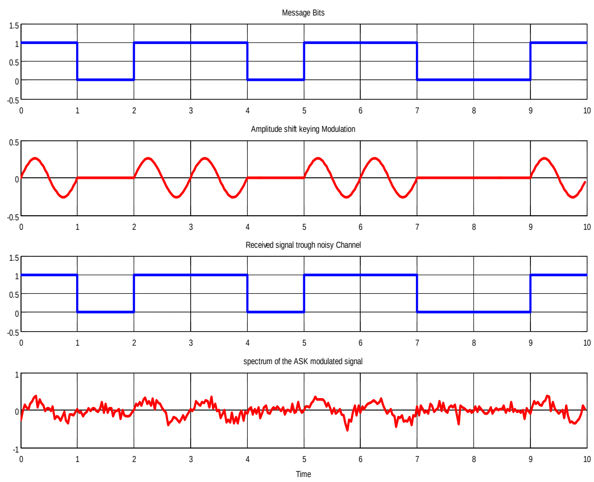

Figure 2: Chronogram and spectrum of a modulated binary signal ASK.

2.2 Frequency-shift keying FSK:

The modulation by frequency shifting, or "frequency-shift keying" (FSK), is to vary the frequency of the carrier when transmitting a 1 or a logic 0 [2].In this kind of modulation there is a derivative of the phase which is a simple way related to the value of symbols to be transmitted. The modulated signal is of the form:

$$m(t) = A_0.\cos(2\pi f(t).t + \varphi_0) \quad (2)$$

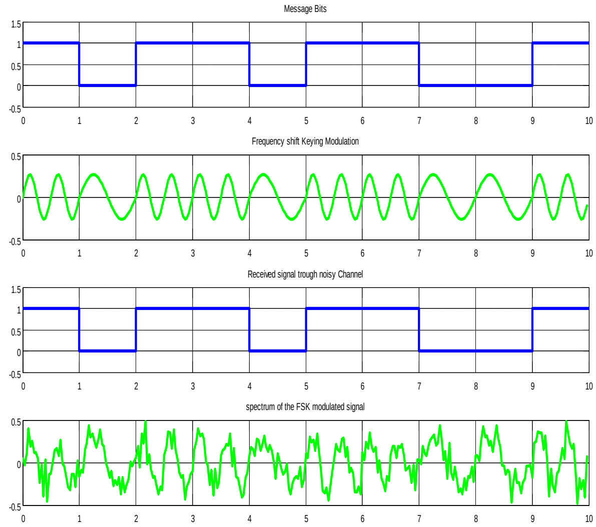

Figure 3: Chronogram and spectrum of a modulated binary FSK signal.

2.3 Phase shift keying PSK:

The modulation by phase shifting, or Phase-shift keying (PSK), varies the phase of the carrier between the transmission of a 0 and a 1 [3].In this technique, it is the phase of the carrier that is modulated by the baseband signal .The modulated signal is written in the form:

$$m(t) = A_0.\cos(2\pi f_0 t + \varphi_0) \qquad (3)$$

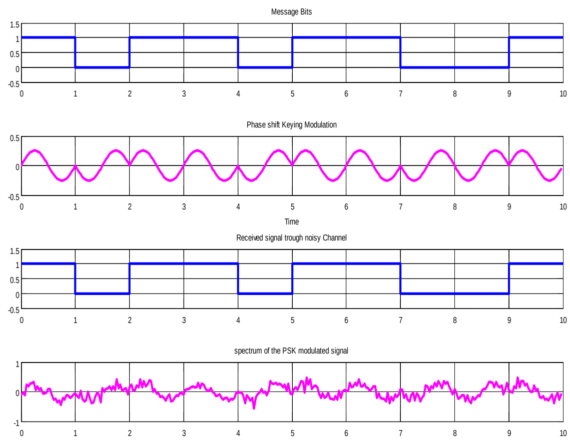

Figure 4: Chronogram and spectrum of a PSK modulated binary signal.

2.4 Quadrature Amplitude Modulation QAM:

The QAM is a mix between the phase modulation for a given amplitude combines word and the phase modulation amplitude for a given carrier associates each word amplitude [4]. To choose a modulation, it should be taken into account various parameters such as the probability of error, spectral occupancy of the modulated signal but also the simplicity of implementation.

3. Orthogonal frequency division multiplexing:

The evolution of digital communications systems is based on several aspects: increasing throughput needs, the mobile nature of the terminal, a congestion context of the spectrum resource. The single-carrier modulations fail to respond optimally to these needs, due to the frequency selectivity of channels and multiple paths that can borrow one signal [4]. For the same frequency spectrum available in the case of multicarrier modulation, the information is spread over a large number of carriers modulated at a low symbol rate. The multi-carrier modulations are now used in various high-throughput applications, whether baseband twisted pair or carrier for wireless transmissions, these applications are based on the same modulation, OFDM (Orthogonal Frequency Division Multiplexing) [5]. The specificity of the OFDM is mutual overlapping of the various sub-carriers, a so-called orthogonal. This orthogonality allows optimal use of spectrum resources and facilitates the digital implementation.

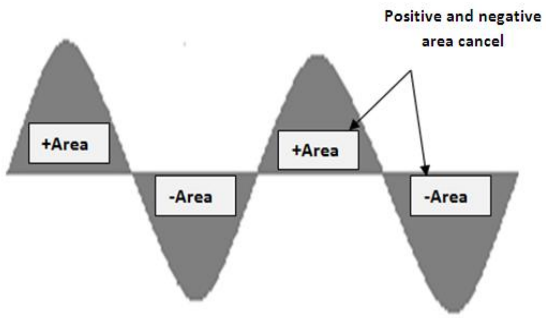

Figure 5: orthogonality of four subcarriers.

Figure 6 shows the spectrum of the OFDM signal. As we can see, the space between each subcarrier allows when the specter between them is maximum, to cancel all other spectrums. So the orthogonality condition is preserved. This orthogonality condition allows an overlap between the spectra of different subcarriers and avoids interference among subcarrier if the sampling is done precisely at the frequency of a subcarrier [6].

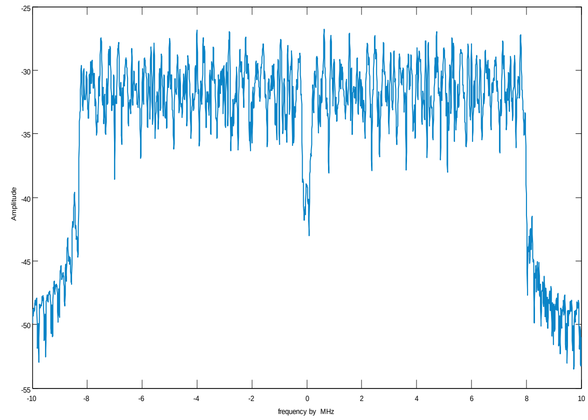

Figure 6: Spectrum of an OFDM signal.

4. Performance Analysis criteria of digital systems:

As performance requirements of a digital signal, the signal to noise ratio, the cutoff probability, the bit error rate and bit error probability are encountered [7].

4.1 Signal to noise ratio (SNR):

Measurements of SNR communications systems are carried out at the receiver and greatly influences the results. Indeed, the noise can enter at any level of the communication system. The communication channel is the entry point of the noise [8].

The SNR can be calculated in two ways and is expressed in decibels. It can be measured directly or indirectly. The first method assumes that it is possible to separately measure the noise power and the signal strength. This first method is direct, to calculate the SNR exactly, but is not achievable in most real cases. [9] The second method, do not try to remove the source of the noise. It measures two powers, the first one of the noise alone and the second one of the signal with the noise.

$$SNR = 10.\log_{10} \frac{SignalPower}{NoisePower} dB \quad (4)$$

This is an estimate of the degradation that the signal has undergone and an indicator of the sensitivity of a device for a given spectral density of noise [10]. The instantaneous SNR is defined by:

$$\gamma = \frac{E_b}{N_0} \qquad (5)$$

Where E_b is instant energy emitted per bit and N_0 spectral density of the noise affecting the transmitted bit [11]. E_b / N_0 can be regarded as a standard measure of the energy per symbol to noise spectral density of power:

$$\frac{E_b}{N_0} = \frac{E_s}{\rho N_0} \qquad (6)$$

E_s is the energy in Joules per symbol and the nominal value ρ is the spectral efficiency (bit / s)/ Hz. E_s / N_0 is also used in the analysis of digital modulation schemes. Both quotients are related to each other according to the following expression [12]:

$$\frac{E_s}{N_0} = \frac{E_b}{N_0}\log_2 M \qquad (7)$$

Where M is the number of possible modulation symbols.
Since the SNR varies depending on the type of radio channel, the average value of the SNR is defined by:

$$\bar{\gamma} = \int_0^{+\infty} \gamma P_\gamma(\gamma)\, d\gamma \qquad (8)$$

Where Pγ represents the SNR probability density through the transmission channel. Through the derivation of the generating function Mγ times (s) of the SNR, the average value of the SNR is expressed by [13]:

$$\bar{\gamma} = \left.\frac{dM_\gamma(s)}{d_s}\right|_{s=0} \qquad (9)$$

4.2 Outage probability:

The outage probability or probability of functioning expresses the probability that a radio link is found in a state where the instantaneous SNR is below a threshold value γth fixed in advance as the transmission longer be possible [14]. This probability is defined by:

$$P_{out} = \int_0^{\gamma_{th}} P_\gamma(\gamma)\, d\gamma \qquad (10)$$

According to the generating function Mγ times (s) of the SNR, P_{out} is defined by:

$$P_{out} = \frac{1}{2\pi j}\int_{\sigma - j\infty}^{\sigma + j\infty} \frac{M_\gamma(-s)}{s} e^{s\gamma_{th}}\, ds \qquad (11)$$

With $s = \sigma + j\omega$ and σ belongs to the area of convergence of the integral.

4.3 Bit Error rate (BER):

The quality of a digital transmission depends on how carefully the bits of the message are returned to the recipient. It is usually measured by evaluating the probability of error per bit, denoted P_b, defined as the probability of taking a wrong decision on a bit [15]. The calculation of the P_b is often very complex .We then use simulations to measure the P_b via a quantity called BER (bit error rate). The measurement of BER is performed by simulating the transmission of a sequence of N bits and evaluating the reception ratio of the number of erroneous bits and the number of transmitted bits [16].The quality of a digital transmission channel can be evaluated by the BER.
In general, the quality of a connection is related to the bit error rate obtained by dividing the number of false bits received by the number of bits transmitted.

$$BER = \frac{NumberOfWrongBits}{NumberOfTransmittedBits} \qquad (12)$$

Binary Error Rate is the ratio of the number of erroneous bits and the total number of bits transmitted. [15] It is defined by:

$$BER = \frac{n_{be}}{n_{bt}} \qquad (13)$$

And n_{be} represents the number of erroneous bits and n_{bt} represents the number of the bits transmitted.

4.4 Bit Error Probability:

The Bit Error Probability (BEP) is a statistical estimate of the BER. This assumes that the BER tends to BEP when the number of transmitted bits approaches infinity [17]. The Probability of Bit Error is defined by:

$$Pb(E) = E\left(\frac{n_{be}}{n_{bt}}\right) \quad n_{bt} \to \infty \qquad (14)$$

Where E is the mathematical expectation. Note that the BEP varies depending on the SNR which itself varies according to the type of propagation channel. We then equates to an average BEP bit error probability defined by:

$$P_b(E) = \int_0^{+\infty} P_b(E/\gamma)\, p_\gamma(\gamma)\, d\gamma \qquad (15)$$

Where, P_b (E / γ) represents the conditional probability of bit error. In general, the BEP is not a linear function of the SNR due to the modulation technique used and the level of detection system [17].

5. Simulation and Results:

There are different modulation for transmitting data in a transmission channel and the influence of the spread on the signal. In an ideal case, there is no attenuation due to the channel and no internal noise that is to say electrical noise generated by the electronic components. So, to recover the original signal and recover the transmitted data, simply perform the inverse method of modulation. But, in a non-ideal case, the signal is disturbed by the channel during the propagation.

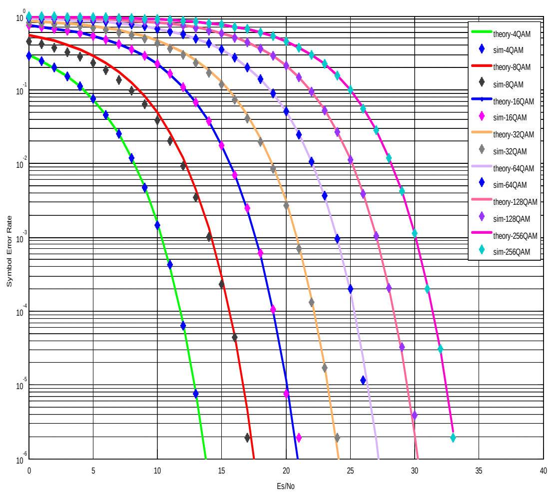

Figure 7: Symbol Error Rate for M-QAM modulation.

In addition, electronic components generating an electrical noise, the signal received is not identical to that transmitted. Thus, it is necessary to quantify the quality of a transmission of binary data. In order to assess the quality, we only count the number of wrong bits received on the number of transmitted bits. This recognition gives the bit error rate (BER). Depending on the type of channel noise power and type of modulation, the BER is changing and it is interesting to predict the performance and robustness of the system without having to make all possible cases.

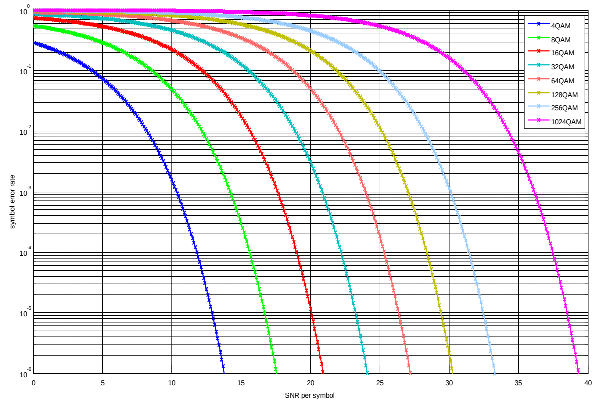

Figure 8: Signal to Noise Ratio by symbol based on the symbol error rate for different modulation orders.

A well-known technique for studying a system of any kind is to model it in order to simulate its behavior in recreating a maximum of cases encountered in reality. Indeed, an almost complete implementation of all the variables being counted in the model gives a good overview of future performance. To draw BER curves simulation, a large number of symbols of achievements channel coefficients and noise samples are generated. The more important achievements and BER curves are typical reality.

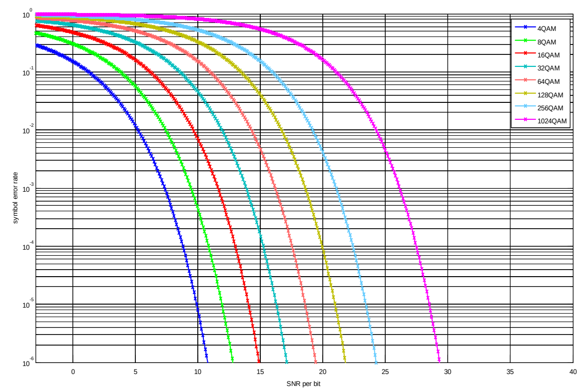

Figure 9: Signal to Noise Ratio by bit based on the symbol error rate for the various modulation orders.

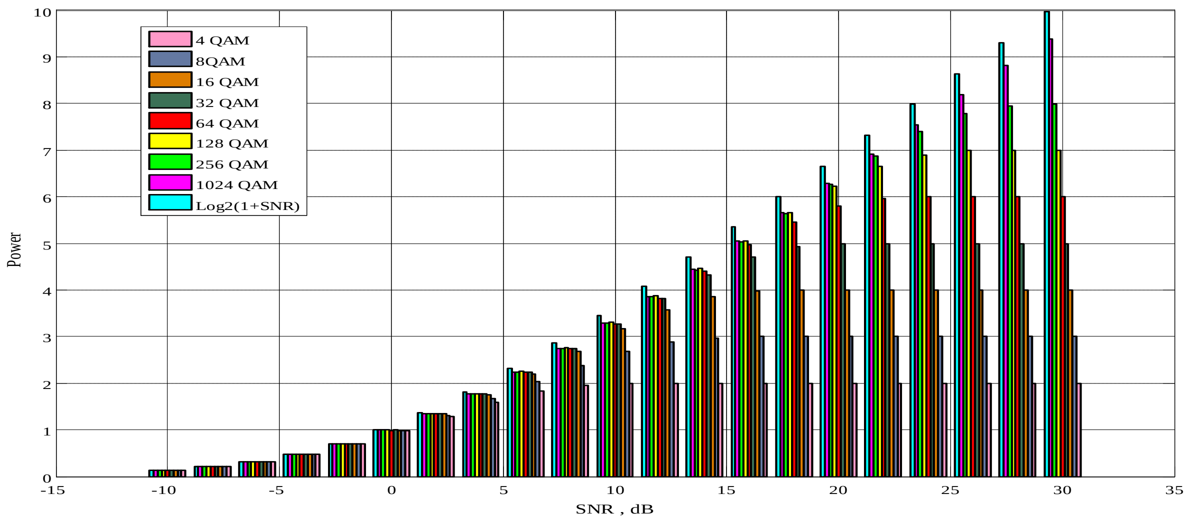

Figure 10: The capacity of a noisy channel

More the signal to noise ratio is high and the degree of modulation QAM is high and so more bits/s and Hz are high to. The points of the constellation of the QAM is more distant from each other and this modulation is more resistant to noise, by against the amplitude of the most distant points is large, thus requiring a more powerful amplifier, so the choice is made according to our priorities, the power amplifier or tolerance to noise. On the other hand, the ratio per bit to noise signal (EbNo) also infects the bit error rate and the number of errors and the following figure shows the bit per signal to noise ratio as a function of bit error rate for various modulation orders (Figure 9).

The figures that we simulate show the crucial importance of different digital transmission techniques supporting. A major advantage of digital transmission is the possibility of their smooth integration in digital integrated networks developing every day .Another advantage is the possibility of keeping the integrity of the information to be transmitted, which is completely impossible with analog transmission. Modern digital communications systems are complex and require modulation and demodulation circuits increasingly sophisticated .We have examined the M-QAM modulation that is frequently used today. It appears that the choice of modulation type is always determined by the constraints of the application. The development of digital transmissions relied on the rapid progress in the field of signal processing integrated circuits.

The performance of a transmission system is mainly evaluated by its ability to withstand shocks, that is to say, to ensure a BER as low as possible and to deliver the most useful information, which is to maximize its capacity or its spectral efficiency.

Table 1: Simulation parameter

Simulation parameter	Value
FFT Size	1024
Subcarrier number	200
Number of bits per symbol	800
Number of OFDM symbol	10000
Modulation type	QAM
SNR	0-33 dB
Channel	AWGN
Guard type	Cyclic prefix
Constellation	4-qam, 8-qam, 16-qam, 32-qam, 64-qam, 128-qam, 256-qam, 1024-qam.

6. Conclusion:

The fourth generation mobile networks offer a variety of services (fast internet access, e-commerce, video conferencing, telemedicine, distance learning, etc.). Each with its special characteristics and constraints quality of service, expressed in terms of bit error rate (BER), allowable delay, delay variation and throughput available through the network .For mobile services of voice, the BER must be less than 10^{-3}, whereas the delay should be less than 300 ms .For data transfer services (email, file transfer), the BER should be less than 10^{-5} through channel .As for multimedia services (video conference), although they can tolerate a relatively high BER (between 10^{-3} and 10^{-7}), they only support relatively low and constant delays. Moreover, the available throughput depends on the environment used. This means that each application can specify the network's QoS (Quality of Service) requirements in terms of the type of traffic, the maximum transfer delay, delay variation, BER and throughput available. Mobile networks must be designed to be flexible and modular, that is to say -to- expandable in terms of services and number of users. This flexibility can also be expressed in terms of adaptability to environments propagation and different traffic variation over time, in terms of ease of management of resources, the ability to interoperate with different systems and accommodate several types of cells and several operators in the same service area.

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