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Orthogonal Frequency Division Multiplexing

Michal Sustek, Miroslav Marcanik and Zdenek Urednicek
Faculty of Applied Informatics, Tomas Bata University in Zlin, Zlin, Czech Republic.

Abstract
The contribution serves as a preview of the OFDM modulation signal, which is used in cellular and other wireless networks. We look closer on this problem and we are subsequently discussed general topics. That include an issue of mobile networks in their general concept and also more insight on the network 4 and 5 generations. Within the network 4 generations, namely LTE and LTE-A is approximated architecture and properties of these networks. In a 5-generation networks that reach into realization in the future, we have discussed concepts of architecture and other features.

Keywords: OFDM; modulation; LTE; 5G; cell phone.

INTRODUCTION

Today's technology allows people to communicate over long distances. These technologies capabilities also include cell phones, without which modern society cannot imagine life. People created the cell phones before a long time. It is not surprising that it has already produced several generations of this technology. Its latest version is the fourth generation, known as LTE, but it has been working on the development of the fifth generation, which will first get into application in 2020.

Orthogonal frequency division multiplexing (hereinafter OFDM) is a modulation which uses multi-carrier waves within the allocated radio frequency spectrum [1]. The individual carrier waves are also orthogonal to each other, which means that their scalar product is zero. The Carrier wave is modulated with the help of robust modulation into which we can include QPSK, 16 QAM, and 64 QAM [2]. The channel for the data stream is divided into hundreds of data flows of individual carrier waves. OFDM modulation is resistant to the Multipath because the individual carrier data streams are transmitted at a relatively low speed. This advantage is due to the reduction in modulation rate sub-channels at the same bit rate as in the case of the modulated signal. Interference can be caused by different signal propagation time in the propagation medium between the transmitter and the receiver. The transmission path can be straight or reflected. If the signal is delayed, it will make worse of the signal processing [1].

From the perspective of mobile networks already in its enhanced fourth generation meant a breakthrough. But with the technology and capabilities, which will offer by the fifth generation to receive transmission speed, reliability and speed of service to a whole new level. It is very likely that these networks will be modulated on a similar principle as OFDM.

OFDM

Orthogonal Frequency Division Multiplexing belongs to broadband modulation using frequency division communication channel. The basic difference between OFDM and other modulations with orthogonality are individual carrier waves which have higher spectral efficiency.

OFDM modulation is based on using multiple carrier frequencies (tens, hundreds or even thousands) with a uniform spacing. The transmission is divided into a large number of signals which independently transmits each part of data. The frequency of each carrier is very close to other due to maximum utilization of the available frequency spectrum.

The channel for the data stream is divided into hundreds of data flows of individual carrier waves. OFDM modulation is resistant to the Multipath because the individual carrier data streams are transmitted at a relatively low speed. As part of the transfer is inserted guard interval that does not transmit any information. It allows that the receiving side has interference-free transmission of symbol currently being broadcast. These symbols come to a receiver through multiple paths with different time delays. Therefore, the receiving of same symbol with different time delays means that it is used multiple transmitters. The received power level of multiple transmitters on the receiving side we can aggregate it [1].

Compared to standard analog modulation methods it can be used multiple transmitters on the same frequency in the radio channel. This phenomenon allows receiving a mobile television broadcast and eliminates the need to use directional antennas to prevent echoes.

However, all structural elements are not designed for data transmission in certain moments. These elements are designed on synchronizing the information, which is carried on the data carrier, and equalization allows signal correction in the transmission channel. Other carriers are modulated with simple modulations, in turn, carry information about the system and transmitted multiplex [1].

OFDM modulation itself is very adaptive because it has a large number of independent signals that are involved in transmission. It also does not consider a fixed frequency width of the transmission channels. It can do with channels that are available to transfer. On the other hand, if the channel is wider, this modulation can fit into it. This process increases the actual transfer speed. In addition to these properties, OFDM also has high resistance to interference between symbols ISI (Inter Symbol Interference) and ICI (Inter Carrier Interference) [2]. This protection is guaranteed channel coding applications, mainly by introducing redundancy, which allows you to correct or detect errors resulting in wireless transmission. The second property, which has a significant influence on the resistance of OFDM modulation is bit interleaving, which avoids long clusters of errors in long-term unfavorable condition for the transmission path. In figure 1 we can a see set of orthogonal signals in time.

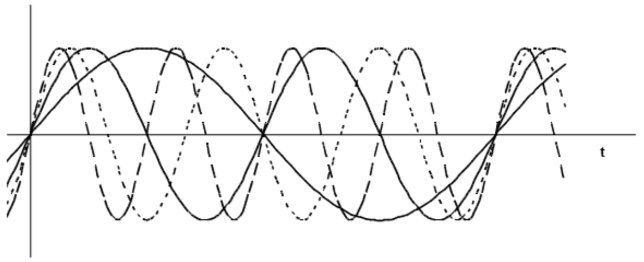

Figure 1: Orthogonal signals [2].

REALIZATION OFDM

Transmitted bytes that enter to the system are first supplied to Serial / Parallel (hereinafter S / P) converter, which is assigned to the groups using a discrete digital modulation method (M-QAM, QPSK), and thereby modulates a large number of simultaneously transmitted signals orthogonal. These groups of blocks then continue to fast inverse Fourier transformation, which leads to their transformation. Individual groups (512, 1024, 2048 bits, depending on the width of the channel) from the frequency spectrum components are transferred to the time domain by IFFT block [2]. The groups are converted into a serial form in the P / S converter and then it is added the protective cyclic prefix, which is formed by the last few samples of the OFDM symbol. Then, through a Digital / Analog (hereinafter D / A) converter is converted into analog form. The blocks on the receiver side have the inverse approach [2].

A. OFDM Use [1]

1) *Signal transmission in ADSL2*
2) *Wireless IEEE 802.11x*
3) *WiMAX*
4) *LTE*
5) *Standards for digital television, DAB and DVB-T*
6) *Communication for energy networks*

B. OFDM Advantages [1]

1) *Good spectral efficiency*
2) *Immune to errors caused by multipath propagation and reflections*
3) *Suppression of interference between symbols*
4) *Resistance selective leaks*
5) *Allows operation SFN*
6) *When the appropriate choice of parameters and modulation topology it can be received by mobile receivers*
7) *Realization of using FFT*

C. OFDM Disadvantages [1]

1) *The volatility envelopes*
2) *Great Value of CF*
3) *United dynamics OFDM requires a dynamic process*
4) *Offset subcarriers*
5) *Challenging sync receiver*

In figure 2 we can see technical realization of OFDM modulation.

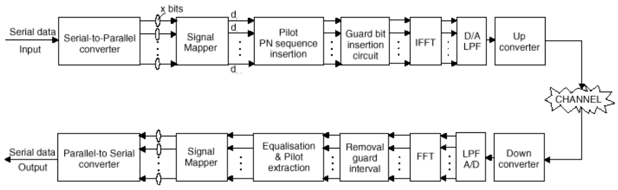

Figure 2: OFDM realization [2].

ELIMINATION OF MULTIPATH

One advantage of OFDM modulation is resistant to multipath. This advantage has based on the reduction in the modulation rate in the individual sub-channels while maintaining the same data rate as the modulation signal. Interference caused by different signal propagation times in the transmission medium between the transmitter and receiver in the case of the direct transmission route (Line of sight, hereinafter LOS), or with reflections (Non-line of sight, hereinafter NLOS) [2]. When the signal transmission is delayed, that will corrupt a process of receiving the signal at the side of the receiver. It means that the next received symbol, which is transmitted by LOS path, is affected by the previous symbol, which was transferred by NLOS path.

In order to suppress undesirable phenomena ICI [2] and ISI [2] are OFDM symbols adjusted using the following methods:

1) *The term of the symbols*
2) *Linear compensation in the utility zone*
3) *Compensation baseband*
4) *Vector encoding / Structured channel signaling*

The most commonly used method is using the guard Interval (hereinafter GI) or CP (Cyclic Prefix).

The principle of the GI is based on the fact that at the time TGI not sent a real useful signal. The receiver has sufficient time to take the symbol in the time TLOS without disturbing the previous symbol received during TNLOS. Thanks to the GI protects against ISI, but no longer to the ICI due to shortening TNLOS [5].

CP prevents interference with ISI and ICI, thereby absorbing the interference ICI and simultaneously forms a guard time on removing the ISI. It consists of the last few samples of the symbol which are copied from the beginning of the OFDM symbol. Forms a guard interval between adjacent transmitted OFDM symbols, maintains orthogonality and synchronization. The length of GI and CP must be longer than the length of the channel impulse response. CP itself is also possible to use for symbol synchronization. The disadvantage is the reduction of GI achievable transmission rate. It is preferable to use it in combination with CP equalization the time-domain received signal to shorten the channel impulse response.

LTE ARCHITECTURE

The architecture of the radio network LTE-A is very similar to the original LTE. It is called E-UTRAN (Evolved Universal Terrestrial Radio Access Network) [3]. The essential difference is the introduction of femtocells and Relay Node. E-UTRAN is responsible for radio equipment UE (User Equipment) and a core network EPC (Evolved Packet Core), which is composed of a large number of the primary base station eNodeB (eNB) and the low power base stations pico-eNodeB (PENB). It forms the backbone of the radio network. The best way to ensure a high data transmission capacity is reducing the cell size, so they were incorporated into this concept home base station (HeNB, femtocells) and repeater RN (Relay Node) [3].

Properties of the network based on the ITU called IMT-Advanced, which was specified in the 10th edition of the general recommendations of the 3GPP. The basic components of the recommendations can be summarized as follows:

1) *Increasing bandwidth and spectrum sharing*
2) *Extension antenna communication system*
3) *Associate repeaters in the radio network*
4) *Heterogeneous distribution network*
5) *eICIC*
6) *The extension properties of terminals*

The physical layer of LTE is designed for the use of OFDM. This modulation is used because it is highly resistant to frequency-selective channels. Other features include the use of adaptive modulation and coding H-ARQ (Hybrid Automated Repeat Request). Within OFDM is used schemes QPSK, 16QAM, 64QAM. At the physical layer are also used in multiple antenna schemes MIMO format to 8x86 [3].

Radio layer of LTE is defined in frequency and time domain. At the highest level is composed of individual frames, which are divided into 10 sub-frames. Each sub-frame is used for the two slots. Each slot consists of 7 OFDM symbols with a CP (six of them contains an extended CP). In the frequency plane, the individual blocks are divided into 12 subcarriers at intervals of 15kHz. The basic element of the physical layer is 12 subcarriers for a duration of one slot (source block). [2] Resource blocks are further divided into the source elements, which are defined on one subcarrier in the duration of one OFDM symbol.

The source elements are the fundamental bearers of user and management information for higher layers. It is divided into several sub-channels.

5G NETWORK

For the introduction of 5G networks in normal operation, it is necessary to partially change the architecture of cells in cellular systems. The current concept of mobile networks involves the use of base stations in the middle of each cell, which communicates with the individual users, regardless of where it is located in an open space or inside buildings. Users who are located inside buildings are faced with the fact that the signal must pass through walls if it wants to communicate from outside the station. The loss of this channel causes considerable losses that significantly affect the transmission speed and spectral energy efficiency.

Architecture

One of the main ideas of design 5G networks is a separation of internal and external users into two segments. The approach of two segments aims to avoid losses resulting signal passing through the walls, or at least minimized. This should help a distributed antenna system and massive MIMO (Massive Input Massive Output) technology, which will be deployed large antenna arrays with tens or hundreds of antenna segments. While the most common MIMO technology serves 2 to 4 antennas. The massive MIMO systems aim to increase your options by antenna arrays [4].

Outside the base stations are equipped with extensive antenna array with antenna elements around the cells. Communication between the base station and the antenna array will be realized by an optical fiber. Outside users are equipped with a limited number of antenna elements, but it can work with others in an extensive virtual network. Array antenna will be installed outside buildings and also allow it to communicate with external base stations.

When we used the cellular architecture where the internal users needing to communicate only with the internal access points (they would not contact the outdoor base station) with a large antenna array. We can use a number of technologies for communicating short range with high transmission speeds (Wi-Fi, UWB, mm–waves communication) [4].

5G network architecture will contain macrocell, microcell, small cell, and transmitter. To ensure adequate coverage, the user who is moving too fast it will also work with mobile femtocells that combine the concept of mobile relays and femtocells.

Massive MIMO

MIMO systems consist, as already mentioned from multiple antennas at the transmitter and receiver. In case we add additional antennas and degrees of freedom (in addition to time and frequency dimensions) may be wireless channels work with a larger amount of data. It leads to significant improvement in performance data, reliability, spectral and energy performance data. The massive variants of MIMO systems have a larger number of antenna elements (tens to hundreds) on the receiver and transmitter side. Transmit antenna may be located in one application or in the form of distributed systems in multiple applications. In practice may be an enormous amount of antennas distributed over several devices, or may also be located in one single device [4].

Next to standard benefits of MIMO systems, massive version can enhance the spectral and energy efficiency. Also, the interference inside the cell can be minimized using a simple linear recording and detection methods.

Spatial Modulation

Spatial Modulation MIMO is a technique that allows an application to be less comprehensive MIMO networks without degradation of their properties. Including the current simultaneous data streams from available antennas. This modulation encodes part of the message, to be forwarded to the positions of transmit antennas in the antenna field. Therefore, this array plays the role of second constellation diagrams which are used to increase the data rate regard to systems with a single antenna.

Only one antenna is active at a given time, the rest waiting. The first information block A is divided into sub-blocks of log2 (Nb) and log2 (M), wherein Nb is the number of transmit antennas and M is the size of the complex signal constellation diagram. The first sub-block identifies active antenna from a number of transmit antennas and second sub-block identifies the chosen symbol from constellation diagram, which will be sent. Spatial modulation is thus a combination of Space Shift Keying (SSK) and amplitude / phase modulation [6]. In figure 3 we can see spatial modulation diagram.

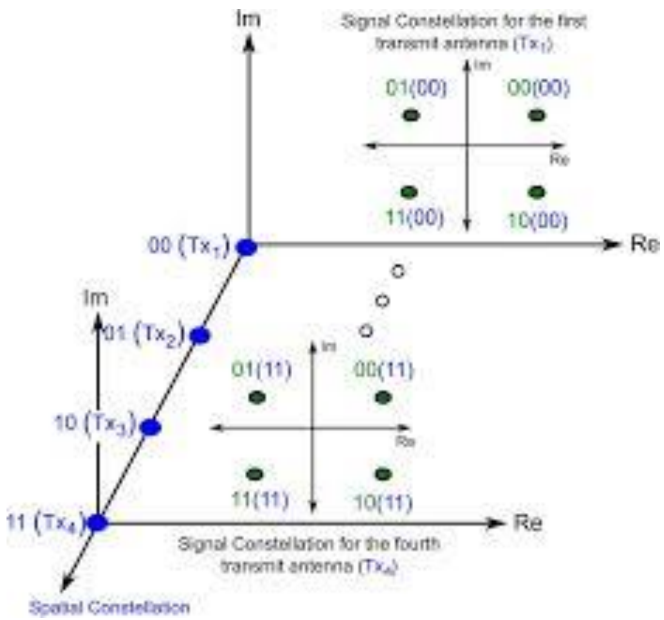

Figure 3: Spatial modulation [6].

CONCLUSION

OFDM technology is based on using multiple carrier frequencies with a uniform spacing. The broadcast is divided into a large number of signals that independently carries different parts information. The supporting frequencies are very close to each to make the most use of the available frequency band. The carrier wave itself is modulated with a robust modulation, among which include QPSK, 16QAM, 64QAM and the subcarriers are orthogonal to each other. A data flow of channel is divided into hundreds of other data flows of individual carriers. As part of the transfer itself inserts into the message the guard interval.

Not all carrier waves are used for data transmission, but there are cases in which the inserted pilot carrier waves are used to synchronize the information which is carried on the data carrier and equalization allowing correct signal distortion arising in the transmission channel. Other carrier waves, which are modulated with a simple modulation, carry system information and transmitted multiplex. The actual OFDM is very adaptive, as it allows a large number of independent signals that participate in the transfer.

Transmitted bits which enter the system are first supplied to S / P converter. These bits are assigned to the groups which using discrete digital modulation methods, and thereby modulates a large number of simultaneously transmitted orthogonal signals. These groups then continue into the block of fast inverse Fourier transformation. Each group consists of frequency components of the spectrum, that is, by using the IFFT block, transferred to the time domain. These groups are then converted into the serial form by the P / S converter and are added protective CP, which is formed by the last few samples of the OFDM symbol. Then, through a D / A converter is converted into analog form. The blocks on the receiver side have an inverse approach.

From the perspective of the fifth generation of mobile networks to be put into practice in 2020, it is necessary to modify the architecture of mobile networks. The planned concept is the separation of the internal and external users into two segments, which together cooperate. The goal is to prevent losses of signal if the signal passing through the walls. This leads to the massive MIMO technology, which deploying a large antenna array with tens or hundreds of antenna elements. The base stations will be connected via optical fibers. Outdoor users will still have limited amounts of antenna elements, but can work with others in an extensive virtual network.

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