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5G Technology-Principles and Possibilities of Implementation Analysis

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Abstract-5G as the coming fifth-generation wireless broadband technology based on the IEEE 802.11ac standard is expected to provide better speeds and coverage, better interconnectivity, better quality of service and flexibility than the current 4G and it will also fulfill all the requirements of customers who have always wanted advanced features in their cellular phones. This paper explores the benefits of this next generation technology and possibilities of implementing it in our Country. In order to achieve better performance, scientists had proposed several waveforms, among which, the most competitive ones are OFGM (Orthogonal Frequency Division Multiplexing) and FBMC (Filter Bank Multi Carrier Modulation). During this research we have done comparative analysis of these two waveforms based on their Power Spectral Densities (PSD) in MATLAB simulation software. Discussion and analysis of the results are given in the paper.

Keywords- *5G Technology, OFGM, FBMC, Power Spectral Density (PSD)*

I. INTRODUCTION

5G is the fifth generation of wireless technology. It will be known as one of the fastest and most robust technologies the world has ever seen. This means quicker uploads/downloads and more powerful network with a huge impact on our everyday life. The technology will provide a new frequency bands and wider spectral bandwidth. The combination of high speed, quick response and bandwidth, would be able to uncover many potentialities with other popular trends such as autonomous cars, drones, virtual reality and Internet of Things.

Then - how is 5G different from its predecessors (especially 4G)? The answer is - it is not only the increase in bit rate that distinguishes 5G from 4G, but there are advantages in terms of [1,2,3]:

- Lower battery consumption;
- Low latency and high reliability;
- High spectral efficiency;
- High resolution and bandwidth;
- A larger number of connected devices;
- Consistent and flexible connectivity;
- Lower cost of infrastructural development.

In order to achieve all of the listed advantages and more, the network will need a lot of small cell coverage and higher bandwidth spectrum. Also, before evolving to fully standalone network, 5G will operate along with existing 4G network architecture.

II. 5G ARCHITECTURE

A. Overview of the Architecture

As next generation network, 5G is all IP based and uses packet switching for delivering optimized performance and cost. At the beginning, 5G will be integrated with the existing 4G network architecture, in order to provide a continuous connection, low latency applications and faster content. The network architecture has two main components: "Radio Access Network" - RAN and the "Core Network"[1].

RAN consists of the major feature of 5G – small cells, also known as mini base stations, designed for very localized coverage (from 10 meters to a few hundred meters). Other elements that belong to this network are towers, in – building and home systems that connect mobile users and wireless systems to the core network. 5G macro cells will use Massive MIMO (multiple input, multiple output) antennas that have multiple connections for sending and receiving more data simultaneously.

The Core Network manages all of the data, mobile and Internet connections. The way it is designed, allows better integration with the Internet and cloud based services. Also, the distributed servers that are its constitutional elements reduce the response time. In 5G network architecture, all IP based mobile applications and services are offered via Cloud Computing Resources (CCR). Cloud computing allows users to use applications without any installation and to access their personal data at any computer that has Internet access.

B. How Fast will 5G be?

5G is supposed to be 100 times faster than the existing 4G network, with speed of 10 gigabits per second (Gb/s). Faster speeds will allow more high quality data to be transferred and

will give greater opportunities for connectivity and reliability. ITU (International Telecommunications Union (ITU), https://www.itu.int/en/Pages/default.aspx)'s International Mobile Telecommunication System (IMT) - 2020 report shows increased download speeds of 100 Mb/s minimum and a theoretical maximum of 20 Gb/s[4,5,6].

In our country, the mobile operator, Makedonski Telekom, has measured the highest download speed (above 500 Mb/s) in the region.

5G, will also dramatically reduce the latency, which means faster load times and bigger responsiveness when using the Internet. The maximum latency is expected to be 4ms on 5G compared to 20ms on 4G LTE (Long Term Evolution).

C. Opportunities for 5G

The 5G technology is expected to change the way a society works. It will not only provide faster data transfer but it will bring new functionalities and applications with higher social and economic values.

5G is much more that smart phones or faster Instagram opening. This generation of network will open the door to robotic surgeries, self – driving cars, safer transport networks,smart cities, virtual and augmented reality. It will enable the Internet of things (IoT) that will connect billions of devices without human intervention and it will allow businesses to make data driven decisions which will result in reduced costs, better customer experience and long term growth.

5G's extra bandwidth will make services more reliable, allowing more devices to connect to the network simultaneously. It can also act like a cloud server, bringing data storage much closer to devices and offer them a quick access to information.

III. FBMC VS OFDM WAVEFORM CANDIDATES FOR 5G COMMUNICATION SYSTEM

The implementation of 5G will improve the previous generation's performance and adapt the most recent needs, enforced by the new technologies and applications [7,8]. These include the higher speeds and an increased number of users that require more efficient use of the frequency spectrum. In order to achieve these new requirements, several waveforms have been proposed, among which, the most competitive ones are OFGM (Orthogonal Frequency Division Multiplexing) and FBMC (Filter Bank Multi Carrier Modulation).

The OFDM technique with cyclic prefix (CP - OFDM) uses an orthogonal set of subcarriers which makes it the most spread case of multicarrier system. But, its tight timing and synchronization requirement are difficult to obtain in practice. [7].

An FBMC waveform is obtained through the transmission of data through a filter bank, which is the main difference when compared to the existing OFDM waveform. While in OFDM systems an IFFT (Inverse fast Fourier transformation) is used with Cyclic Prefixing (CP), in FBMC this is replaced by a synthesis filter bank.

We can compare these two techniques based on their computational complexity, sub channels, prototype filter, Power Spectral Densities etc. In this case, we will use an example provided by MATLAB simulation software to make a comparative analysis based on their Power Spectral Densities (PSD). MATLAB as a simulation software is well known for its wide range of tools, which include the 5G tool that offers different functions and examples for modeling, simulation and verification of 5G communication systems.

PSD describes the signal's power as a function of frequency. The system parameters are modified in order to explore their influence on the system. Before we define the parameters, we set the "rng" (random number generation) function for repetition. This function puts the settings of the random number generator. Every time we start MATLAB, the generator resets to its default value and any script that calls this function always returns the same result when restarting. We set the value of "rng" this way: s=rng(211). Then we set the following parameters:

```
%% System parameters: user tunable

numFFT = 256;
numGuards = 20;
K = 3;
bitsPerSubCarrier = 4;
numSymbols = 1000;
```

Figure 1. System parameters in MATLAB

where: *numFFT*is the number of FFT points;numGuards represent the empty space between two radio bands; K is an overlapping factor with values between 2, 3 or 4; *bitsPerSubCarriers* with values: 2: 4QAM (transfer of 3 bits per symbol), 4: 16QAM, 6: 64QAM, 8: 256QAM and *numSymbols* is simulation length in symbols.

A. FBMC Modulation

FBMC offers a possibility for overcoming the OFDM limitations, like low spectral efficiency and the need for synchronization. In FBMC, every modulated signal of the subcarrier is filtered [8]. The prototype filter is the basis of the subcarriers. PHYDYAS (PHYsical layer for DYnamic spectrum AccesS and cognitive radio) prototype filter is used because of its better localization and simple equalization of the sender and receiver.

The filter banks are characterized by the overlapping factor - K, which is a number of multicarrier symbols that overlap in the time domain. The prototype filter order can be chosen as 2*K-1 where K = 2, 3, or 4. FBMC uses an N*K length IFFTwhere the symbols are overlapped with a delay of N/2, where N is the number of subcarriers.

In Figure 2 the switch function for prototype filter is shown, where, *L = numFFT-2*numGuards* refers to the number of complex symbols per OFDM symbol. The switch function consists of three statements that evaluate the values of the PHYDYAS filter in the frequency domain for given value of the overlapping factor K (value of 2, 3 or 4). We use MATLAB's function "*periodogram ()*" that estimates PSD for given inputs (Fig. 3)

```
%% FBMC modulation filter

L = numFFT-2*numGuards;
% Prototype Filter
switch K
    case 2
        HkOneSided = sqrt(2)/2;
    case 3
        HkOneSided = [0.911438 0.411438];
    case 4
        HkOneSided = [0.971960 sqrt(2)/2 0.235147];
    otherwise
        return
end
```

Figure 2. Switch function for prototype filter

```
[specFBMC, fFBMC] = periodogram(txSig,rectwin(length(txSig)),numFFT*K*2,1);
sumFBMCSpec = sumFBMCSpec + specFBMC;

txSigAll(:,symbolNr) = txSig;
```

Figure 3. PSD equation with periodigram () function

As we can see from Figure 3, the inputs are:

txSig – constant that stores the calculated IFFT value of the transferred symbol.

It is calculated as: *txSig = scFactor.*fftshift(ifft(X));* where*scFactor = KF/sqrt(KL)* in which KF = K*numFFT and KL = K*L;fftshift ()is a function that is shifting the zero - frequency component to the center of the array (X array) andifft (Y) function that checks if the vector in Y is symmetrical.

rectwin (L) – returns a rectangular window of length L;

numFFT – number ofFFT points;

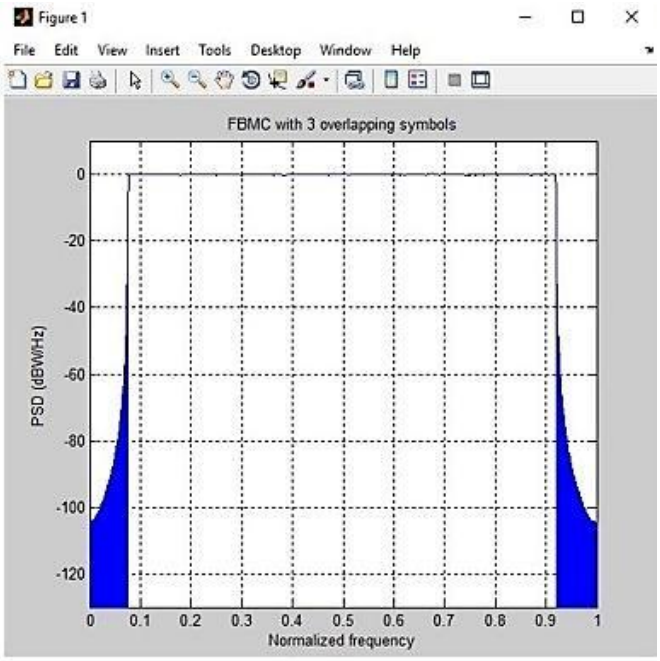
K – overlapping factor;

At the end, the transferred signals for all symbols are stored in the *txSigAll* constant which is calculated with MALTAB*complex ()* function that creates a complex output from two real inputs.

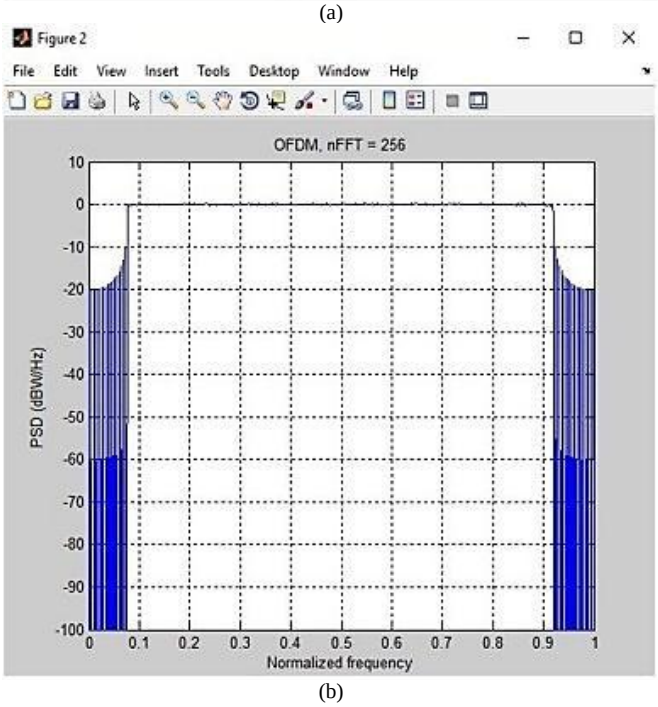
IV. Discussion of the Results

During the simulation, it can be seen the difference between FBMC and OFDM based on their PSDs. The absence of cyclic prefixing in FBMC allows to increase its performance, because CP originates additional overhead and, as a consequence, a loss in bandwidth efficiency. In addition to this, FBMC shows a huge reduction in *out of band* leakage. *Out of band* leakage (OOB leakage) as a transmission of signal outside the designated frequency band plays a big part in the system's spectral efficiency.

In Figure 4 are shown the results of the simulation and as we can see, the side lobes in FBMC are considerably smaller than the ones obtained with OFDM. In FBMC a sub channel only overlaps its neighboring sub channels. That way it is easier to achieve two independent multicarrier signals by leaving an empty sub channel between them.



(a)



(b)

Figure 4. a) Power spectral density of FBMC and b) OFDM

This lets an advanced utilization of the allocated spectrum, leading to higher spectral efficiency. Compared to FBMC, the OFDM PSD curve has higher side lobes and *out of band* leakage.

This shows that the disadvantages of OFDM technique have been addressed and removed in FBMC and these simulation confirms, once again, that the FBMC technique is the most promising waveform contender for future wireless communications specially 5G telecommunications.

V. KEY MEASURES AND ACTIVITIES FOR IMPLEMENTING 5G IN THE REPUBLIC OF NORTH MACEDONIA

In North Macedonia, huge progress has been made during recent years in terms of essential liberalization and development of the communications sector. As a country aspiring to become an EU member, in late 2017, began preparing a national operational plan for the development of next generation networks and started preparations for introducing 5G.

A precondition for introducing the 5G is enabling a sufficient and adequate radio frequency spectrum as early as possible, in order to stimulate innovations, new investments and competition in development of 5G services. In 2018, the Ministry of Information Society and Administration made a decision for creating 4 work groups that will operate towards:

- Determining the activities needed for the introduction of 5G mobile technology;
- Determining free capacities;
- Increasing the interest of citizens for using broadband;
- Providing better coordination of the mapping process on the territory of the Country with existing and future broadband networks

The introduction of 5G will fulfill the requirements in aspect of spectral efficiency, bandwidth capacity and low latency of digital radio infrastructures. In order to achieve this and provide coverage in rural areas, a sufficient amount of appropriate radio frequencies will be required. Nowadays, the operators in our country that offer mobile electronic communications can use the radio frequency spectrum of approximately 1000 MHz, which can also be used for 5G. However, the realization of services with very high data rates (up to 20 Gb/s) requires the allocation of additional radio frequency bands.

As a regulatory body that is responsible for the electronic communications, the Agency for Electronic Communications (AEC) takes special care of the process of frequency allocation according to a well-defined plan. AEC as a part of the created work groups has the following obligations [10]:

- to follow the EU's 5G Action Plan, according to which one major city must be '5G enabled' by 2020, while all urban areas and major terrestrial transport paths must have uninterrupted 5G coverage by the end of 2025;
- to participate in World Radio communication Conferences (WRC: https://www.itu.int/en/ITU-R/conferences/wrc/Pages/default.aspx) where a decision will be made for additional allocation of radio frequency bands for 5G;
- to participate in making changes of law of electronic communications in aspect of telecommunication infrastructure and radio frequency usage

According to the latest statistics, North Macedonia is one of the leaders in the region in using broadband. Successful reforms in the electronic communications sector have been

confirmed in the latest European Commission report. There are positive assessments of Country's progress in using the Internet and the liberalization of the telecommunications market.

VI. Benefits of Introducing 5G Technology in North Macedonia

When we talk about digitization as the fourth revolution, the 5G network is thought to change the way society works, much more than the way the electricity has affected society. 5G technology will not only provide faster data transfer but will bring new functionalities and applications. It is of high importance to point out that 5G technology can be an instrument for transformation i.e. digitalization of traditional industries.

It is crucial, at the very start, to create closer cooperation between vertical sectors, telecom operators and the IT sector. For these reasons, they should be included at the very beginning in the development of 5G. This will further open a field for new businesses, especially for small and medium - sized enterprises. The Ministry of Transport and Communications prepares draft Law on Spatial and Urban Planning, a law that will accurately determine the procedures for preparation of urban plans for areas and objects of state importance. From the aspect of infrastructure, this is the first step in facilitating procedures for the introduction of 5G technology.

From existing operators, Makedonski Telekom is the one that performed the first 5G demo in the country and made one more step towards the introduction of this technology. It has measured the highest data transfer speed so far, of over 500Mbps for downloading [9]. The company will continue to invest and upgrade the network in order to be ready for the commercial launch, planned for 2020.

VII. Conclusion

The implementation of the 5G technology will start in Europe as of 2020 and the complete implementation with all of its advanced functionalities is expected after 2025. Implementing 5G is a challenge for operators, and it will mean better customer service for the end users.

This research shows that in North Macedonia, the introduction of 5G is in the initial phase, but it is realistic and allows increasing the quality of service for the end users. Given the ambitious plans of the operators for the development of the optical network, it is more than certain that our Country will welcome the entry of 5G, well prepared.

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