Penerbit Akademia Baru

Journal of Advanced Research in Applied Sciences and Engineering Technology

www.akademiabaru.com/ submit/index.php/araset/index
ISSN: 2462-1943

Generation and Analysis of 5G Downlink Signal

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ABSTRACT

The evolution of wireless communication technology has provided a viable important concept for the next-generation wireless mechanism. The technology may provide a variety of services for different terminals, such as voice and multimedia data services through a mobile phone, as well as improved packet delivery across cellular networks. Fifth Generation (5G) New Radio (NR) is the most recent radio air interface designed for next-generation wireless communication networks to fulfill the increasing needs of connected devices. It is built to enable a variety of situations, including increased large machine-to-machine communications, mobile broadband, and ultra-reliable low-latency communications. The objective of the study is to generate and analysis the 5G signal. The evolution of wireless communication generation with its advantages, disadvantages and their features are explained and discussed. The requirements of 5G are discussed. The 5G NR signal is generated and analyzed using the various parameters in the waveform generator app in MATLAB. The downlink scenario is considered. The time scope and spectrum analyzer graph of 5G NR signal is discussed. The modulation used here for the generation of 5G signal is 16 QAM modulation and 64 QAM modulation techniques.

Keywords:
New Radio,5G, Downlink, QAM

Received: 21 January 2022 **Revised: 3 February 2022** **Accepted: 3 February 2022** **Published: 7 February 2022**

1. Introduction

In the previous several decades, mobile wireless communication technologies have seen substantial changes. A change in the framework, speed, technology, frequency, data capacity, latency, and so on is referred to as the mobile wireless Generation (G). Each generation has its own set of conventions, talents, processes, and qualities that set it apart from the one before it [1]. The need for high data rates and a huge number of connected devices has risen substantially over time, and in next-generation wireless communication systems known as 5G, the latest needs and expectations are predicted to expand nearly ten times faster than current levels [2–5]. High data rates for the transportation of information can be obtained to some extent by using modern hardware components (e.g., sources, detectors, antennas, and so on) in combination with the latest physical layer solutions. However, present mobile communication systems are unable to match the data rate requirements of 5G, which are estimated to be in the range of 100 gigabits per second

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https://doi.org/10.37934/araset.26.1.2330

(Gbps) or more [6-8]. To address the difficulties raised by 5G, many physical and network layer strategies and solutions have been proposed [9–12].

5G new radio millimeter-wave (5G NR mm-Wave) is a new radio millimeter-wave technology that is being developed as an addition to the existing 4G technology [13–15]. The major goal of 5G is to provide a diverse set of services with high data rates, wide coverage, low latency, low cost, high system capacity, and different connectivity for users all over the world. The performance of 5G cells in the downlink is examined in this work. The first background of 5G is explained with advantages and disadvantages of all generations up to 5G. Secondly, the 5G system components of how 5G data is generated are explained. Then lastly the analysis of 5g signal with 16 QAM and 64 QAM modulation is explained.

2. Background of 5G

The wireless communication system has become more popular due to the fast revolution in mobile technology over recent years. The revolution is taking place as the number of telecommunications subscribers grows. The revolution is stated as follows: 1G represents the first generation, 2G represents the second generation, 3G represents the third generation, 4G represents the fourth generation, and 5G represents the fifth generation.is explained below.

2.1 First generation(1G)

In 1980 first generation was emerged which was an analog system based on the Frequency Division Multiple Access techniques (FDMA). The highlights of the first generation where the speed was up to 2.4 kbps, it allows voice call within one country using analog signal and the capacity was 30 kHz. Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), Improved Mobile Telephone Service (IMTS), and Push to Talk were some of the mobile technologies utilized in the first generation. The drawbacks of first-generation are low voice quality, low capacity, the handset was heavy was not feasible to carry, battery life was poor and spectral efficiency was of the lower level. The communication channel was not secure, and it utilizes analog transmission instead of digital which is less effective in means of transmitting the information.

2.2 Second generation(2G)

To eliminate the drawbacks of first-generation and improve the performance in wireless communication second generation was started during the 1990s. The main advantage of the second generation was it utilizes digital system technology [1], [16]. The benefits of second-generation are the introduction of data services for mobile, the conversations were digitally encrypted and Short Message Service (SMS) text messages were started [8]. The data transmission rate was 64 kbps, with a bandwidth of 30 to 200 kHz.

The technology used in 2G is GSM which provides services like voice and data together. The extended family of 2G is 2.5G and 2.75G. The technology used for 2.5G is GPRS where the data speed was enhanced to 150 kbps. 2.75G utilized the EDGE (Enhanced Data Rate for GSM Evolution) technology, which has a maximum data rate of 384 Kbps. The other technologies used are packet-switched and circuit-switched domain, Code Division Multiple Access (CDMA). The other advantages of 2G are to cover a long distance, less noise compared to the analog signal, longer battery due to radio signals having low power, and provides better quality and capacity compared to the first generation. The drawbacks are no network coverage in any range and weaker digital signal and difficulty handling complex data such as video, large files, etc.

2.3 Third generation(3G)

The third generation uses a Wide Brand Wireless Network through which the data rate is increased. Packet Switching was used to transfer data and voice calls were interrupted through circuit switching [4] [17]. It has a bandwidth of 15-20MHz and is used for applications such as high-speed internet, video conferencing, high QoS (Quality of Service), information security, and others. Voice, SMS, MMS, video, high-speed broadband, and video conferencing services were all introduced. The two main varieties of 3G technology are 3.5G, which boosts downlink data transmission speeds from 8Mbps to 10Mbps, and 3.75G, which boosts uplink speeds up to 5.8 Mbps while reducing the latency between up and downlink. The disadvantages of 3G include the need for more bandwidth, the expensive cost of a 3G mobile phone, the huge size of the phone, the difficulty of building 3G infrastructure, and the high cost of 3G licenses services.

2.4 Fourth generation(4G)

The switching type is utilized in the fourth generation all IP network, and the main network is the internet (3G used packet network, 2G used PSTN). Data speeds with the ultra-broadband internet service range from 100 Mbps to 1.0 Gbps. The characteristics of 4G technology are similar to those of 3G, but it also includes additional services such as Multi-Media Newspapers, the ability to view television shows with improved clarity, and the capacity to carry data much faster than prior generations. Long Term Evolution (LTE) is a kind of 4G technology. Future applications are being developed to meet the QoS and rate expectations of 4G, including wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal voice and data services, and other bandwidth-intensive services. 4G wireless technology should combine many current and future wireless network technologies (e.g., OFDM, CDMA) to provide free mobility and flawless roaming from one technology to the next. The disadvantages are that 4G mobile phones need more battery and that hardware implementation is challenging. Complicated hardware is required, as is an exclusive network.

2.5 Fifth generation(5G)

The fifth generation (5G) is the next step of evolution in mobile communication technology. The expected needs that must be fulfilled to experience 5G are represented in Figure 1, but it can have other different needs based on the demands to satisfy the users.

- **High data rate:** To accommodate the high data traffic the data rate should be as high as 10 Gbit/s.
- **Capacity:** Massive devices connectivity will emerge in 5G due to the Internet of things. The capacity and the number of device connectivity should be high.
- **Energy efficiency:** 5G's overall energy usage in terms of energy/bit must be significantly lower to make it a sustainable technology. To achieve longer battery life, 5G mobile terminals will demand decreased power usage.
- **Mobility:** In high-speed vehicular environments also there an increase in the demand for data rate. In high-mobility conditions with speeds of up to 500 km/h, 5G will need to provide faster data rates.

Journal of Advanced Research in Applied Sciences and Engineering Technology
Volume 26, Issue 1 (2022) 23-30

- **Spectral efficiency:** The reuse of frequency to meet the demands of 5G is also challenging. Hence the use of the range of frequency also plays important role in 5G.
- **Less fading effect:** As the data transfer in 5G is should be secure with less fading effect of the channel. To minimize the fading impact and increase the system's performance, many solutions have been explored and recommended.

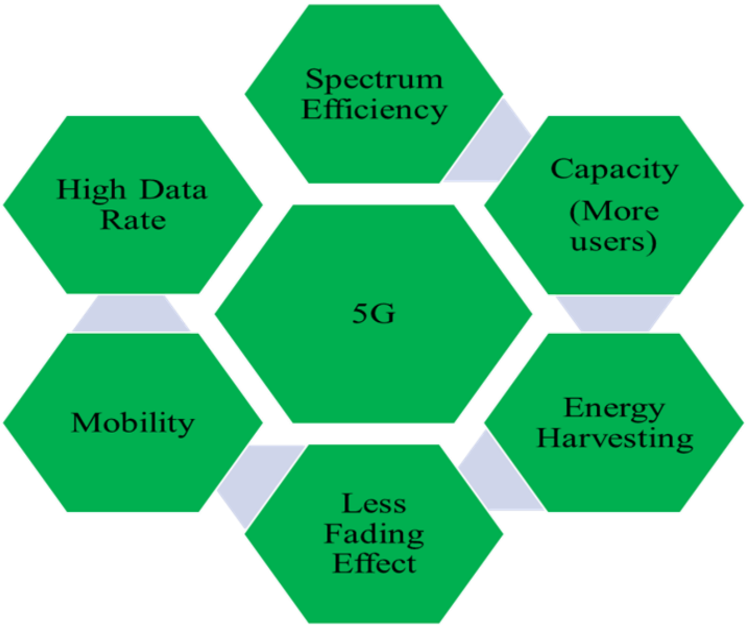


Fig. 1. 5G Requirement

The data rates are increasing as we move from when generation to another generation. The quality of services and applications is also improved. The technology used also changes concerning time and generation to meet the demands of the next generation. Each generation has its advantages and disadvantages as discussed.

3. 5G System Components

The block diagram for 5G NR signal generation is shown in Figure 2.

Fig. 2. An overview of the 5G system simulation

Resource Block: In 5G, each NR Resource Block (RB) has 12 frequency-domain sub-carriers, identical to LTE. The resource block bandwidth in LTE is set at 180 kHz, however, it is not in NR and is dependent on sub-carrier spacing. The NR is expected to operate in the millimeter-wave spectrum with a channel bandwidth of 100 MHz for lower bands up to 6 GHz and 400 MHz for higher bands.

The bandwidth efficiency of NR is expected to grow to 99 percent, up from roughly 90 percent with LTE. (10 percent is allocated in the guard band).

Duplex mode: While frequency-division duplexing (FDD) and time division duplexing (TDD) are commonly employed in 4G mobile wireless networks, they both suffer from low spectrum efficiency due to their half-duplex transmission modes. Here we use FDD with full-duplex mode for 5G waveform generation that will greatly improve spectrum efficiency.

Data Generation: The uniformly distributed random data x(n) is generated using *Randi func* with 10,000 bits.

$$\mathrm{x(n)} = [a_1 - b_1 j, -a_2 + b_2 j \ldots\ldots\ldots\ldots a_n - b_n j]$$

where n = 125856, a and b are decimal numbers from the range 0 to 1. Hence x(n) is the column vector of length 125856.

Modulation: Then the data is modulated using 16 QAM and 64 QAM technique.

Physical Downlink channel: NR embraces a wide range of frequency bands, from sub-GHz to 300 GHz. Due to Path Loss and Channel circumstances corresponding to varied transmission environments, the design shall assure appropriate coverage during transmission. This is a major challenge, particularly in the mm-wave bands, where narrow beamforming is commonly utilized to provide coverage, necessitating the addition of design components to incorporate beamforming implementation at the base station. The Physical Downlink Control Channel (PDCCH) is a physical layer control channel used by 5G new radio (NR) to execute physical layer operations such as scheduling the downlink broadcast. Data transmission, as well as signaling triggers for periodic and aperiodic during transmission or reception. The PDCCH protocol is used to decode Downlink Control Information.

4. Results

The parameters used are shown in Figure 3 for 5G waveform generation. The random bits are used, and the waveform is generated with 16 QAM modulation and with impairments of SNR with 2dB. The real and imaginary part of the signal amplitude with time is shown in the graph of figure 4(a). The spectrum analyzer waveform of the generated waveform is shown in figure 4(b). Similarly for modulation of 64 QAM is shown in Figures 5(a) and 5(b) where the amplitude for both real and imaginary parts vary concerning time. And the spectrum analyzer performance in dB is better for 64 QAM modulation when compared with 16 QAM modulation.

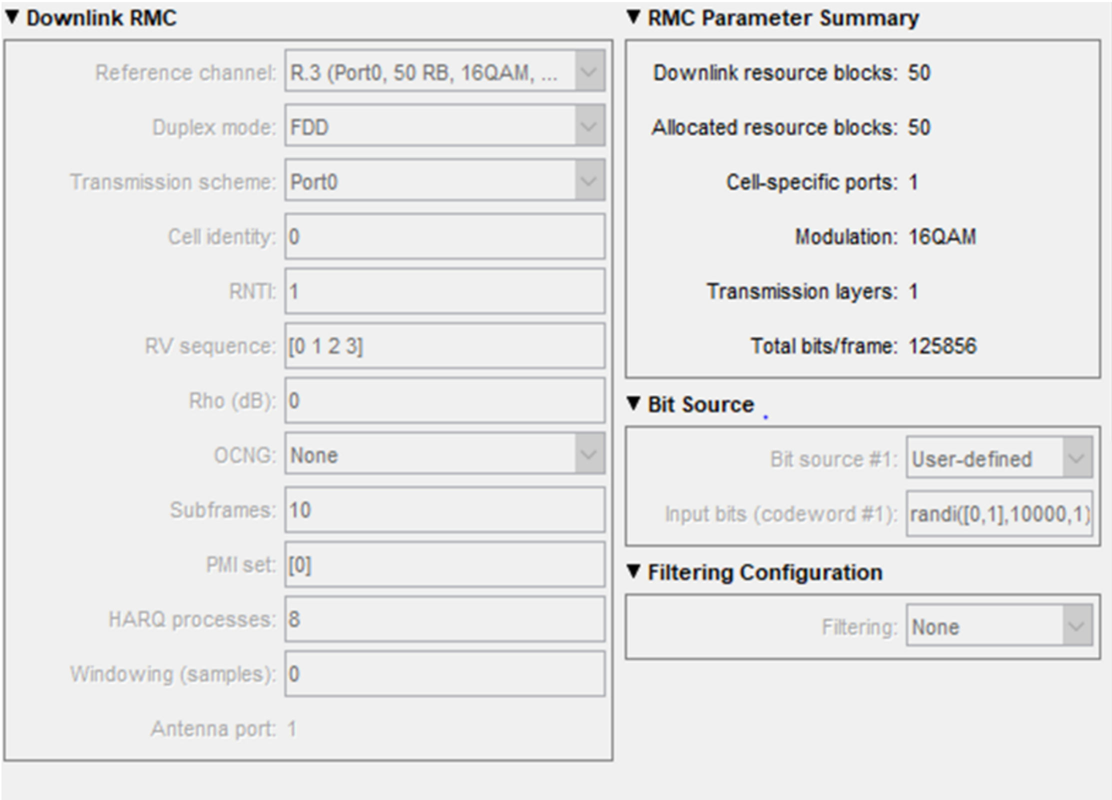
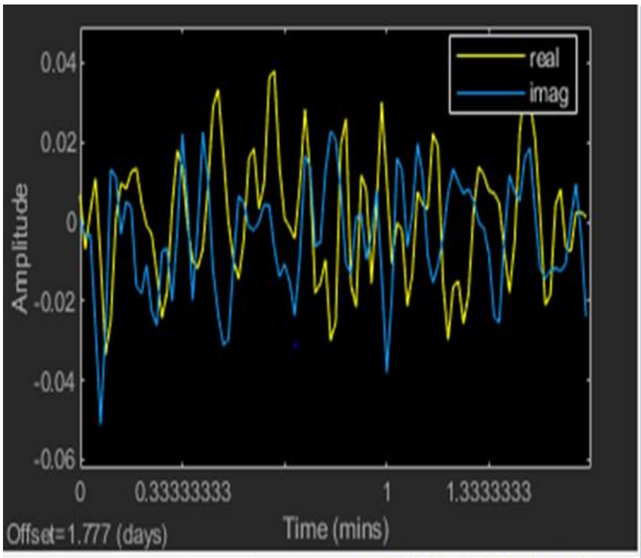


Fig. 3. Parameters used for waveform generation of 5G signal



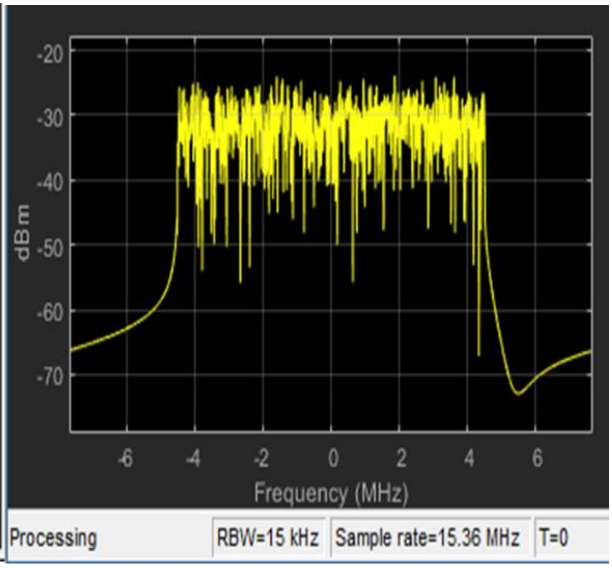


Fig. 4(a). Time Scope for 16 QAM

Fig. 4(b). Spectrum Analyzer for 16 QAM

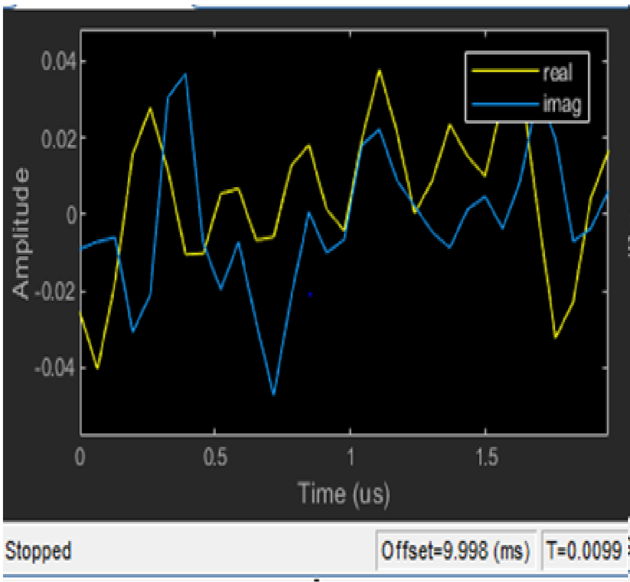


Fig. 5(a). Time Scope for 64 QAM

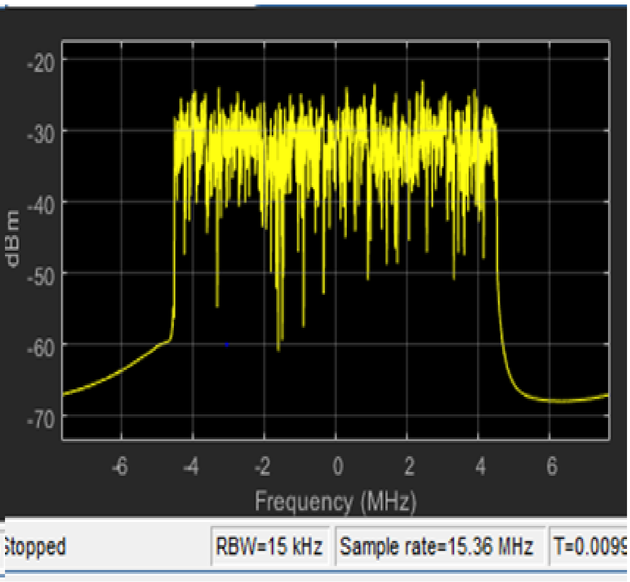


Fig. 5(b). Spectrum Analyzer for 64 QAM

4. Conclusions

The aim of this study is to generate and analysis the 5G signal using MATLAB. Wireless cellular networks are expanding at an unimaginable rate over the world, and it appears that this trend will continue for several years. Wireless communications customers have increased at an exponential rate in recent years. With the advancement of radio technology, more and more new and upgraded services become accessible. Current wireless communication systems are the outcome of a continuous wireless technology evaluation. The evolution of each generation with its advantages and disadvantages is explained. The 5g signal is created and examined in MATLAB's waveform generator using various parameters. The downlink situation is considered. The modulation technology utilized to generate the 5G signal is 16 QAM modulation and 64 QAM modulation. For further analysis, different modulation techniques can be considered.

Acknowledgement
The author Nagma Parveen acknowledge the support of the TFW2020 scheme of Kulliyyah of Engineering, International Islamic University Malaysia. We are also very grateful to the Ministry of Higher education Malaysia for supporting this research under the grant ID FRGS19-055-0663.

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