

Analysis & Implementation of SISO, SIMO, MISO and MIMO in 5G Communication Systems Based on SDR

Meriem DRISSE†
drissimeriem1@gmail.com
University Tunis El Manar

Nabil BENJELLOUN^{2††},
Nabil.benjelloun@esigelec.fr
University Rouen Normandie

Philippe DESCAMPS^{3†††}
philippe.descamps@ensicaen.fr
University Caen
Normandie

Ali GHARSALLAH †
ali.gharsallah@fst.utm.tn
University Tunis El
Manar

Summary

With the rapid growth of new users and massive need for very high data rate in 5G communications system, different technologies have been developed and applied to enhance communication efficiency. One of those technologies is the MISO, MISO and MIMO which transmits and receives information with more reliability by using multiple antennas on transmitter or/and receiver side. This paper presents the latest trends in 5G telecommunications system based on software defined radio, A novel low-cost SIMO, MISO and MIMO using flexibility between USRP and Simulink is implemented tested and validated.

Keywords:

SDR, SISO, SIMO, MISO, MIMO.

1. Introduction

In traditional communications systems, there is only one transmitting and one receiving antenna (SISO) which are faced with challenges such as limitation of available bandwidth, interference, fading and signal loss. However, today's communications services have increasing needs for capacity and reliability. Multi-Antenna Systems is figured out to overcome some of these challenges by using multiple antennas either/both for transmitting and receiving data. By using multiple antennas, it can transmit multiple data streams simultaneously and through various channels, which increases the capacity and reliability of the communication. Multi-Antenna Systems also help to improve the reliability of signal reception, improve signal quality and reduce transmission errors. And this, without increasing either the bandwidth of the bandwidth of the SISO system's receiving antenna, nor the power of the transmitted signal. This paper presents comparison analysis and implementation of the different RF wireless communication systems like SISO systems, SIMO and MISO systems and MIMO systems.

Many researches such [1-2-3-4-5] have proven that Multi antenna systems improve data rates, SNR, BER and quality of signals received compared to the conventional communications [6-7] without proceeding to implementation. And that they are the key technology for 5G systems.

With the emergence of the concept of SDR [8-9], it is useful to combine SDR concept with processing capabilities of multi antennas systems. In this paper, SISO, MISO, SIMO and MIMO systems were properly developed and implemented based on SDR testbed for multiple signals to study and demonstrate the performance of the recommended prototypes. articles such as [10]-[15] are mostly concentrated on simulations and comparative analysis, turning a blind eye to the prototype implementation due to its costly hardware upgrades, limited flexibility, complexity, security, vulnerabilities and power consumption. The SDR has been figured out to meet these limitations because of its rapid prototyping, flexibility, cost-effectiveness, upgradability, interoperability, security in wireless communications standards and protocols. [15]-[18].

We present in a first part, a conception of multilayer antenna dedicated for 5G applications, The rest of this document is organized as follows. In Section II, a multilayer antenna is conceived for transmitting and receiving signals for C band. In Section III, a platform of tests and measurements used for the validation of the results is presented and described. In Section IV, we introduce an overview of our SISO, MISO, SIMO and 2×2 MIMO testbed based on SDR. Then, we define our SISO experimental results while analyzing our results. Even we report our novel model SIMO, MISO and MIMO using AM modulation by studying our system's performance. in section V, the platform of tests and measurements used for the validation of the results. Finally, we come to the end of the article.

2. Multilayer antenna

In the era of the modern world where communication has become indispensable, antennas are rightly considered the electronic eyes and ears of the world because of their undeniable place in communication technology. While seeking to improve the performance of an antenna, it must be adapted to the latest applications. The antenna must also

meet the constraints of diversity and integration into the architecture of the terminals.

Today, multi-antenna technologies are mature enough to become an increasingly common solution in communication systems, to achieve high data rates without increasing the transmission power high data rates without increasing the transmission power and/or the spectral width used. They also ensure reliable connections and good network coverage.

Currently, due to its directional radiation pattern, easy fabrication, high data rates and polarization diversity, Microstrip Patch Antenna array is developed and increasingly. So, compared with [20], optimization compared with research is approved by substituting the rectangular patches by circular patches and also multilayer technology is used to separate and insulate the conductive layers from the dielectric layers. the 4 circular radiating are connected to the corporate feed network by shorting vias [21], to achieve a compact size without sacrificing performance. By using multiple layers, the antenna can achieve a more complex and efficient geometry, which can result in better radiation efficiency and impedance matching, increase gain, perform bandwidth, minimize beamwidth, and keep out the losses.

With using this technology, gain, S11, beamwidth and bandwidth were increased. Moreover, the multilayer antenna with 2x2 circular radiating elements shows better results, the beamwidth covers 0.4GHz bandwidth, the bandwidth a reflection coefficient of -50dB at 3.48GHz and the gain attains 6.4 dB. So, this antenna fulfills the 5G applications requirements. It also offers circular polarization. A suitable gain Multilayer coaxial feed patch antenna has been investigated. Compared to the conventional patch antenna [20], the conceived antenna has the highest gain and the smallest beamwidth as shown in figure 2. Its dimensions also make it suitable for use in DBF antennas. The return loss, gain and beam width demonstrate the applicability of this antenna in 5G applications.

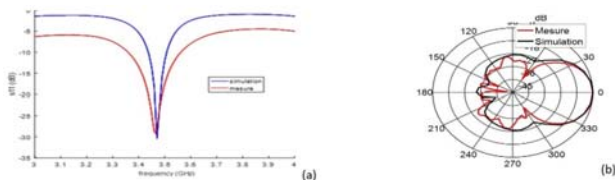


Fig. 1 Comparison between simulation and measurement results (a) S11, (b) Radiation pattern

3. Description of the Agilent platform

The USRP is a versatile platform for software-defined radio, which allows users to build and prototype radio communication systems with a wide range of software tools.[18] was selected for its versatility, modularity, high performance, power consumption and Cost-effectiveness compared to other devices [18] [19], For our testbed, USRP B210 was a top choice because it operates in full-duplex mode, which allows signal to be transmitted and received signals on separate channels and because it has a built-in RF front-end with two receive (RX) and two transmit (TX) channels. Thus, it is possible to study any multi-antenna system by intervening at any stage of the transmission (RF, intermediate frequency or baseband) and provides fully coherent MIMO 2x2 capability.

Within the framework of the development of SDR prototype, the use of test platforms that allow to quickly test and validate the performance of any digital or analog function of the receiver in simulation, but also in measurement, seems quite reasonable. We have therefore developed a test platform based on Simulink and USRP B210 tools [19][20]. This device operates at a frequency of 3.48 GHz, These equipment are connected to multilayer antenna conceived.

The platform of tests and measurements used for the validation of the results were performed in IRSEEM's laboratory without any added elements between the Tx and Rx. Which are spaced at a distance of 1m.

In fact, a sinusoidal signal with frequency of 1MHz generated with Simulink is combined with other Simulink's block and The USRP Toolbox to perform AM modulation with a carrier of 3.48 GHz which is the resonant frequency of multilayer antenna. Connecting Host Pc (MATLAB) to USRP B210 allows users to control, communicate with USRP and provide functions for setting parameters such as the center frequency, sampling rate, and gain. It also includes tools for transmitting and receiving data using different modulation schemes, and for processing and analyzing received signals. The USRP B210 are in turn connected to these conceived antennas which are used as transmitter and receiver.

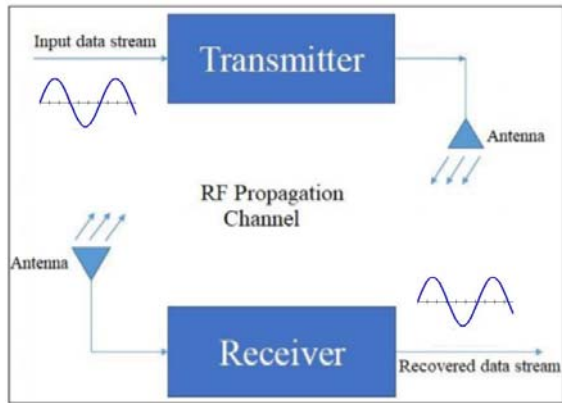


Figure 1: Basic Block Diagram of 5G communication system

4. Measurement testbed and result

The setup has been positioned in the IRSEEM anechoic chamber, it is equipped with 2 USRP B210, octo-clock to assure synchronization between channels, 4 multilayers antennas used for used for transmitting or receiving signals, Host-PC and spectrum analyzer. The setup includes implementation of SISO, SIMO, MISO and MIMO.

4.1 SISO

Transmission

This model describes SISO system which refers to a system in which a single transmitter communicates with a single receiver, based on flexibility and reconfigurability between Simulink and USRP device to implement an AM transmitter and Am receiver.



Figure 2: Implementation of SISO

To transmit and receive RF signals in real time, AM transmitter is built using Simulink, SDR and the following equations.

The amplitude modulation is performed through the equation bellow with $f_p = 3.48 \text{ GHz}$ and $f_m = 1 \text{ MHz}$

$$s(t) = A_c \mu m(t)\cos(2\pi f_c t) + A_c \cos(2\pi f_c t) \quad [1]$$

To build this equation with Simulink, the first part is modelled with Simulink but the second part is done with a block called USRP transmitter which allows to configure the USRP.

To generate this mathematical model, Simulink's block diagrams is used for modelling the first part of equation while the second part is performed with The USRP Toolbox's block called sdru transmitter for setting parameters such as the center frequency, sampling rate, and gain

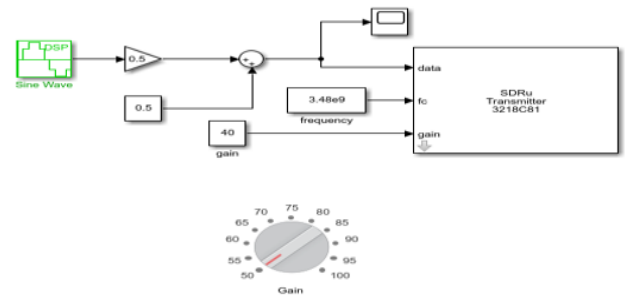


Figure 3 :Transmitter model using Simulink

So, first, we realized AM transmitter using standard blocks and sink blocks of Simulink library to configure gain, center frequency, interpolation, filter and signal data [25][23]. Once the signal has been modulated, a spectrum analyzer called Agilent technologies was applied to verify transmission results in the form of spectrums.

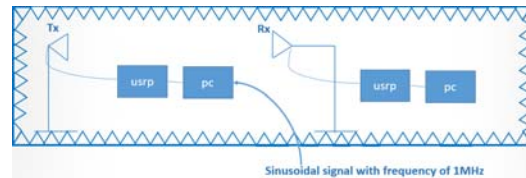


Figure 4: SISO system

Reception

Once the signal is well transmitted, a further multilayer antenna is positioned as receiver. This antenna is interconnected to an additional USRP in order to demodulate and recover the data using the receiver model. So, an AM demodulator is described which includes sdru receiver block to demodulate the signal then passing by low pass filter to eliminate high frequencies.

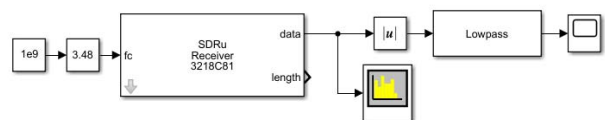


Figure 5: Receiver model

4.2 MIMO

To implement MIMO 2X2 system, pairs of USRP B210, host computer and 4 multilayer antennas complete the MIMO prototype.

The USRP B210 device is mainly including using the following component :

- AD9361 transceiver;
- Xilinx Spartan 6 FPGA;
- The USRP toolbox.



Figure 6: MIMO 2X2 System

The second setup is performed using 2 antennas both at the transmitter and receiver ends; providing fully digital MIMO 2X2.

▪ *Transmitter*

The MIMO transmitter model must keep the same SISO transmitter model with adding a Simulink's block 'called matrix concatenation' and changing channel mapping to [1 2] to transmit the signal simultaneously through USRP transmitters.:

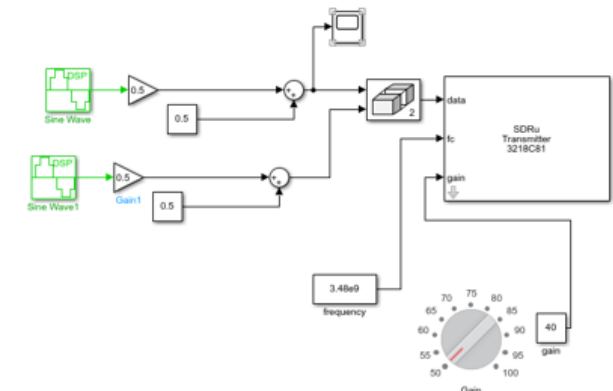


Figure 7: Programming USRP via Simulink

▪ *AM Receiver*

The USRP B210 below describes the hardware implementation framework for MIMO 2x2 model. In fact, for the reception part, the same model of SISO (AM receiver) has been kept, only a slight change with adding a block called select column in order to separate data and to treat each channel separately and simultaneously.

To receive the signals, two antennas are placed as a receiver where a distance of $\lambda/2$ separate both receiver antenna to guarantee the linear independence between channels

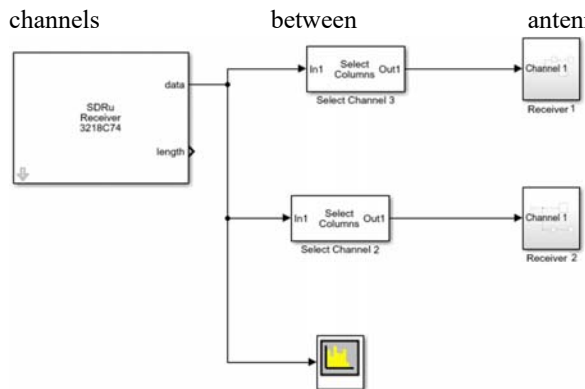


Figure 8: Receiving simultaneously

4.3 SIMO

For the third experiment we used a SIMO 1X2 scheme, with 2 antennas at the transmitter and 1 antenna at the receiver. The two terminals of the first USRP is used for receiving while the other USRP port is used for transmitting.

The conventional SIMO system is fully digital, where all the signal processing techniques are performed at baseband based on Simulink as shown in Figure 10.

▪ *AM Transmitter*

In a data transmission scheme, SIMO system contains a single antenna at the transmitter side and two antennas at the receiver side. This system is also known as receiving diversity.

The transmitter side block consists of essentially the same parameters as the SISO transmitter block.

▪ *AM Receiver*

Once the incoming signal is received by the antennas of the SIMO system, it enters to RF demodulation using UHD and Simulink. The receiver block consists of essentially the same parameters as the MIMO receiver block. In fact, sdr receiver block must be in such a way that we can recover the signal, where the first step is to select the correct platform and the device corresponding to the serial number. The channel mapping is [1,2], as both receiver ports are used. The receiver block receives information from the software radio using UHD.[24][26]

both channels of USRP B210, with setting channel mapping to [1 2] and adding a block called matrix concatenation used as gateway between the block sdr transmitter and the data elements arranged in columns.

▪ *AM Receiver*

The receiver block consists of essentially the same parameters as the SISO receiver block.

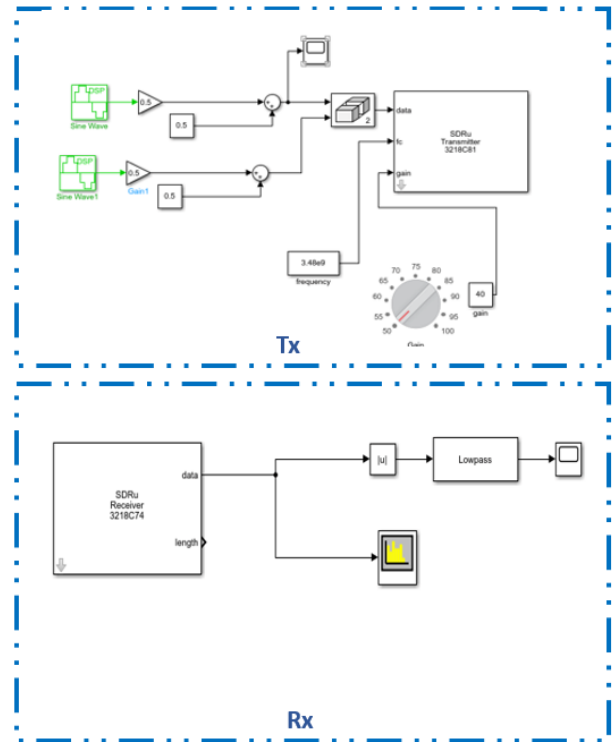


Figure 10: Implementation of MISO using Simulink

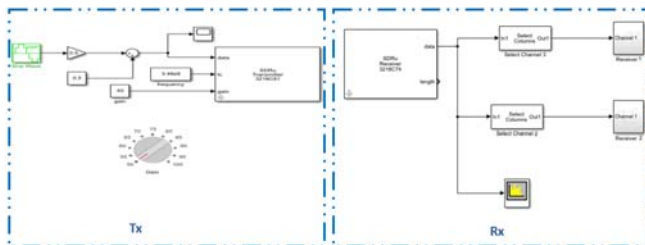


Figure 9: Implementation of SIMO using Simulink

4.4 MISO

For the Final experiment we used a MISO 2X1 scheme, with 2 antennas at the transmitter and 1 antenna at the receiver. Where the two terminals of the first USRP are used for transmitting while the second USRP B210's port is used for receiving.

During data transmission, the same data is transmitted redundantly from both transmit antennas.

▪ *AM Transmitter*

The transmitter side block consists of essentially the same parameters as the MIMO transmitter block. Using



Figure 11: Implementation of MISO

5. Measurement testbed and comparison analysis

After emitting the signal, a verification of AM modulation of the sinusoidal signal's transmission should be executed with inserting a spectrum analyzer on USRP B210's output. As shown in the figure below, the spectrum has the usual presentation, when a strong carrier is on the carrier frequency (3.48Ghz) while the sidebands have a

frequency of $3.48\text{GHz} \pm 1\text{MHz}$. Consequently, The signal has been correctly transmitted.



Figure 12: Frequency spectrum of modulated signal

similarly, To check the signal's reception, a spectrum analyzer block has been inserted into Simulink to check the signal's reception. Also, it produces the regular presentation: two symmetrical sidebands placed on $\pm 1\text{ MHz}$ and the strong carrier is centrally located. So, the sinusoidal signal has been usefully received.

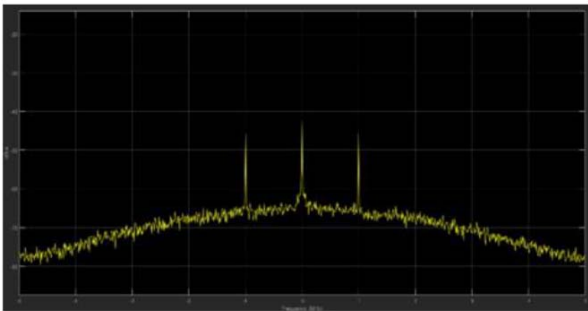


Figure 13: Frequency spectrum of demodulated signal

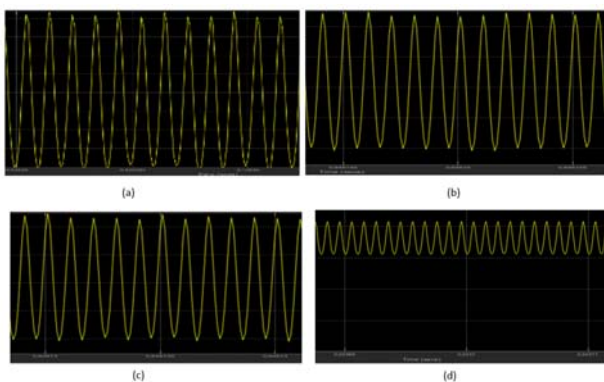


Figure 14: Recovered signal by (a) SISO System, (b) SIMO System (c)MISO system, (d) MIMO System

From Figure 15 of comparison between SISO and various antenna configurations of MIMO systems is carried out. In

fact, multi antenna systems considerably improves the quality of the transmission, through the use of several antennas at the transmitting or receiving end.

It will be illustrated that there is a substantial difference in the performance of MIMO system compared to the others, the MIMO system produced the best sinusoidal signal without fading or distortion. Through enabling the same data transmitting redundantly over the network, problems such as fading caused by lost or dropped packets can be reduced, this will help to recover all of the resulting data.

This paper prove otherwise without proceeding to calculate diversity or BER that MIMO presents the best performance including increased data throughput, improved signal quality, increased range, more efficient use of bandwidth, and increased resistance to interference.

6. CONCLUSION

This paper presents a comparison analysis between SISO and different Multi antenna systems, In fact the performance of SISO system is lower than the other systems. MIMO systems considerably improves the quality of the transmission. Through the use of several antennas at the transmitting or receiving end.

SDR concept combined with multi antenna system is a very interesting approach to develop communications applications that guarantee a robust and versatile transmission. Finally, this system demonstrates great flexibility and scalability to be used in a wide range of applications.

References

- [1] Ashish Kumar Sarangi, Amlan Datta, "Capacity Comparison of SISO, SIMO, MISO & MIMO Systems," 2018 ICCMC, pp. 798-801, (2018)
- [2] A. D. Joshi, and H. H. Joshi, "Spatial diversity techniques for wireless communication - A comparative analysis," International Journal of Latest Trends in Engineering and Technology, vol. 10, no. 3, pp. 93-97, (2018).
- [3] A. K. Sarangi, and A. Datta, "Capacity comparison of SISO, SIMO, MISO & MIMO systems," 2018 Second International Conference on Computing Methodologies and Communication (ICCMC), pp. 798-801, Erode,(2018).
- [4] Ashish Kumar Sarangi, Amlan Datta, "Capacity Comparison of SISO, SIMO, MISO & MIMO Systems," 2018 ICCMC, pp. 798-801, (2018).
- [5] A. D. Joshi, and H. H. Joshi, "Spatial diversity techniques for wireless communication - A comparative analysis," International Journal of Latest Trends in Engineering and Technology, vol. 10, no. 3, pp. 93-97, (2018).
- [6] Bellorado, J., S. Ghassemzadeh and A. Kavcic, Approaching the capacity of the MIMO Rayleigh fading channel with QAM constellations, independent across antennas and dimensions, IEEE Transactions on Wireless Communications, 5(6): 1322 -1332.(2006)

- [7] Wallace, J.W., B.D. Jes and M.A., Jensen, Transmit antenna selection based on outage probability for correlated MIMO multiple access channels, *IEEE Transactions on Wireless Communications*, 5(10): 2945-2955. (2006).
- [8] M. A. Hannan, M. Islam, S. A. Samad, A. Hussain. Performance Evaluation of MISO For RFID Signal Using Software Defined Radio. *Journal of Applied Sciences Research*, ; 7(12): 2031-2035, (2011).
- [9] Zhong S, Feng H, Zhang P, Xu J, Luo H, Zhang J, Yuan T, Huang L. Deep Learning Based Antenna Selection for MIMO SDR System. *Sensors*; 20: 6987. (2020).
- [10] Wang Q, Mu N, Wang L, Safavi-Naeini S, Liu J. 5G MIMO conformal microstrip antenna design. *Wireless Communications and Mobile Computing*; 2017: 1–11. (2017)
- [11] Zhong S, Feng H, Zhang P, Xu J, Huang L, Yuan T, Huo Y. User Oriented Transmit Antenna Selection in Massive Multi-User MIMO SDR Systems. *Sensors*.; 20: 4867. (2020).
- [12] Ali M, Ibrahim M. Design Broadband MIMO Antenna to meet 5G communication systems requirements. in 2021 IEEE 1st International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering MI-STA; 838-842. (2021).
- [13] Prasanna Venkatesan G K D, Ranjitha T, Shimona Neethi C, Swetha S. Optimisation of mimo antenna for 5G applications. *International Journal of Advances in Scientific Research and Engineering (ijasre)*.; 4: 133-139. (2018).
- [14] Gandhiraj R, Ranjini Ram, Soman K P. Analog and digital modulation toolkit for software defined radio. *Procedia Eng*; 30: 1155–1162. (2012).
- [15] Kareem G N, Gbotoso G A, Omogoye . O. MATLAB analysis and Simulink model for amplitude modulation technique. *World Journal of Advanced Engineering Technology and Sciences*; 2: 21-28. (2021).
- [16] Hiari O, Mesleh R. A Reconfigurable SDR Transmitter Platform Architecture for Space Modulation MIMO Techniques. *IEEE Access*; 5: 24214–24228. (2017).
- [17] Molla D M, Badis H, George L, Berbineau M. Software Defined Radio Platforms for Wireless Technologies. *IEEE Access*. 2022; 10:26203-26229.
- [18] Danneberg M, Gaspar I, Matthé M, Zhang D, Leonel Mendes Fettweis L G. Implementation of a 2 by 2 GFDM transceiver for robust 5G networks. 2015 International Symposium on Wireless Communication Systems (ISWCS); 236-240. (2015).
- [19] Nayna T F A, Baki A K M and Ahmed F. Comparative study of rectangular and circular microstrip patch antennas in X band. 2014 International Conference on Electrical Engineering and Information and Communication Technology; 1-5. (2014).
- [20] Chen W, Lin Y. Design of 2X2 Microstrip Patch Array Antenna for 5G C-Band Access Point Applications. 2018 IEEE International Workshop on Electromagnetics Applications and Student Innovation Competition (iWEM); 1-2. (2018).
- [21] Drissi M, Benjelloun N, Descamps P, Gharsallah A. Multilayer antenna dedicated to MIMO Beamforming antenna for 5G telecommunication applications. 2021 IEEE Conference on Antenna Measurements and Applications (CAMA); 183-188. (2021).
- [22] Constantine A. Balanis, *Antenna Theory, Analysis and Design*, New York: John Wiley and Sons. (1997).
- [23] Fokin G , Volgushev D, Kireev A, Bulanov D , Lavrukhin V. Designing the MIMO SDR-based LPD transceiver for long-range robot control applications. 2014 6th International Congress on Ultra-Modern Telecommunications and Control Systems and Workshops (ICUMT); 456-461. (2014).
- [24] Gavrilă C, Popescu V, Alexandru M, Murrioni M, Sacchi C. An SDR-Based Satellite Gateway for Internet of Remote Things (IoRT) Applications. *IEEE Access*.; 8: 115423-115436. (2020).
- [25] Liwski T. AM- ja DSB-modulaatioiden toteuttaminen Simulink- ohjelmistolla USRP- ohjelmistoradioalustalle ,phd thesis, University of Oulu, (2019).
- [26] Drissi M, Benjelloun N, Descamps P, Gharsallah. Designing the MIMO SDR-based Antenna Array for 5G Telecommunication. *Advances in Science, Technology and Engineering Systems Journal (ASTESJ)*; 7: 167-173. (2022).