ISSN No:-2456-2165

Beamforming at Quadrature Baseband in 5G mmWave Networks and its Effects on Antenna Performance

[1]Lusungu Ndovi, [2]Charles. S. Lubobya, [3]Ackim Zulu.
School of Engineering, Department of Electrical & Electronics Engineering,
University of Zambia, Box 37392, Zambia

Abstract:- This paper proposes and conceptualizes the use of Quadrature baseband (QBB) beamforming in 5G mmWave Networks as an alternative to Radio Frequency (RF) beamforming. The QBB beamforming is compared in terms of performance to the RF beamforming using antenna gain, throughput and bandwidth as performance metrics. The concept considers beamforming at QBB for four (4) arrayed antennas propagating signals in the mmWave frequencies, at 28GHz.

Keywords:- *Beamforming; Quadrature baseband; Radio Frequency; Antenna performance; 5G Networks;*

I. INTRODUCTION

Beamforming is the process of converging several directional signals in order to create one stronger and directional signal. Quadrature baseband is a term that refers to the generation of in-phase and quadrature components of a signal at baseband. 5G Technology is expected to accommodate billions of devices. In the coming years, an exponential growth of the number of connected devices is expected, as well as the volume of data traffic consumed [1]. The spectrum available for the 5G, allocated by the Third Generation Partnership Project (3GPP), is subdivided into bands below 6GHz and above 6GHz (in this case in millimeter waves, at 28GHz and 39GHz). The 5G networks therefore should have RF front-end systems that allow high versatility to adapt to different scenarios, highly efficient, and integrated . RF antennas are mostly associated with narrow beamwidth with properly aligned beams [2]. Beamforming technique using multiple antennas at the transmitter and the receiver improves signal strength and reduces signal-level fluctuations in fading channels [2]. The use of Beamforming also resolves propagation problems that are observed when operating in the mmWave frequencies. In these high frequency bands, multi-antenna technologies such as massive MIMO and beamforming are used to compensate for the increase in path loss due to high frequency usage [3].

The rest of paper is organised as follows: the next section discusses related work on beamforming in cellular networks, section III discusses QBB and RF beamforming, section IV explains the conceptual frame work of our proposed QBB beamforming while section V gives the methodology of achieving model. The conclusion follows in section VI.

II. RELATED WORK

Tiago *et al* [1]proposed a modular planar microstrip array is presented, designed for the 28GHz frequency band, in a 4x4 configuration, with capability to be connected to a RF front-end allowing beamforming. Kitao *et al* [3]developed a 5G system evaluation using multi-antenna MIMO and beamforming. The tool was able to calculate SINR/throughput based on Shannon capacity. Huang *et al* [4]demonstrates an eight-element multiple input-multiple-output (MIMO) hybrid beamforming receiver array with autonomous millimeter-wave (mm-Wave)/RF frontend beamforming and digital baseband beamforming Hassanien *et al* [5]presents a novel wideband beam steering system using Rotman Lens fed by a wideband microstrip antenna array for use in the future 5G wireless applications is presented. Aliakbarian *et al* [6]presents an implementation of analogue baseband beam steering and its digital counterpart as an attempt to compare between both methods for LEO satellite applications Tae Jo *et al* [2]present an RF proposed the RF beamforming scheme using the discrete phase shifters and the gain controllers in RF chain for MIMO system. Kashavarz *et al* [7] presents a RF beamforming interference cancellation and data rate enhancement solution by using cognitive radio methods. Jin Kim *et al* [8] proposed an architecture and the analog TTD circuit for wide bandwidth and large array antenna system which will be highlighted in future communications. Poudel *et a*l [9] presented the architecture of very large MIMO used for next generation cellular communication networks. They analyzed the ergodic channel capacity of basic multiuser MIMO for different SNR levels.

In this work we propose and conceptualize use of Quadrature baseband (QBB) beamforming in 5G mmWave Networks as an alternative to Radio Frequency (RF) beamforming. We further propose an algorithm that is similar to the earlier authors in [1] but with 5G signals at quadrature baseband (QBB).

III. QUADRATURE BASEBAND AND RF BEAMFORMING

A. Quadrature baseband beamforming

The conversion of an RF signal to quadrature baseband is carried out by the following steps:

- The RF signal is multiplied with a complex carrier in what is referred to as down-mixing.
- The complex down-mixed signal is then lowpass filtered resulting in the quadrature baseband version of the RF signal. [10]

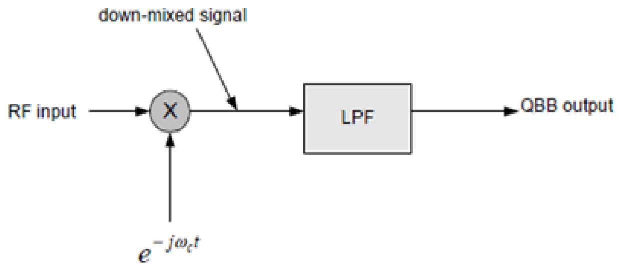


Fig. 1: QBB generation illustration

As explained earlier, the QBB Beamforming process basically involves interfacing the conversional RF beamforming process with the QBB conversion process [11]. The procedure under QBB involves mixing down the incoming signals to quadrature baseband and therefore, entails that the beam pattern is produced after the summing up the quadrature baseband signals before demodulating the summed signal so as to get a maximum value of the output signal and then making a polar plot to get the beam pattern[10]. The block diagram below summarizes the above process.

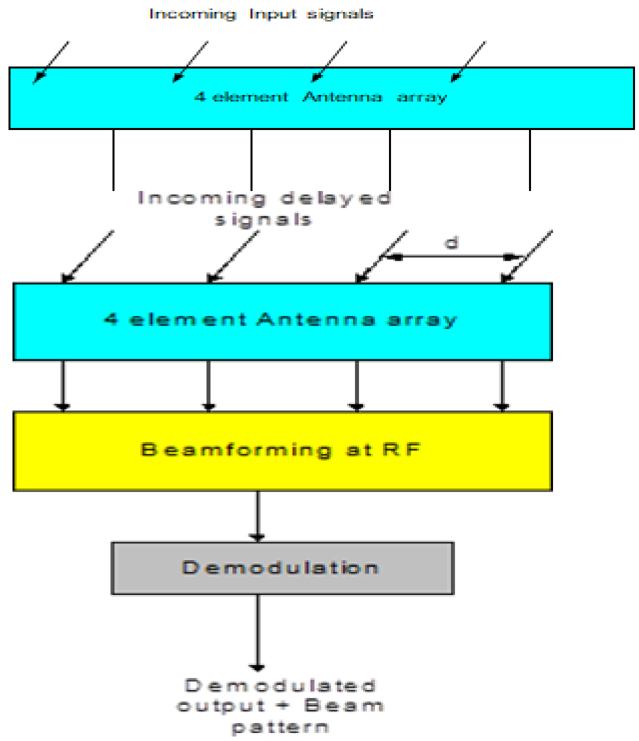


Fig.3: RF Beamforming illustration

IV. BEAMFORMING AT QUADRATURE BASEBAND PROPOSED MODEL

The mathematical model of the proposed system is illustrated using equations (1) to (5). Taking ***s0*** as the reference signal, we generate three other signals with a fixed delay separation in between each signal . Thus we have;

$$s1=s0(t-\Delta t) \quad (1)$$

$$s2=s0(t-2\Delta t) \quad (2)$$

$$s3=s0(t-3\Delta t) \quad (3)$$

The Beamformed signal is thus the summation of the four incoming signals and labeled as

$$s4=s0+s1+s2+s3 \quad (4)$$

The QBB version of signals will be ;

$$s4qbb=s0qbb+s1qbb+s2qbb+s3qbb \quad 5)$$

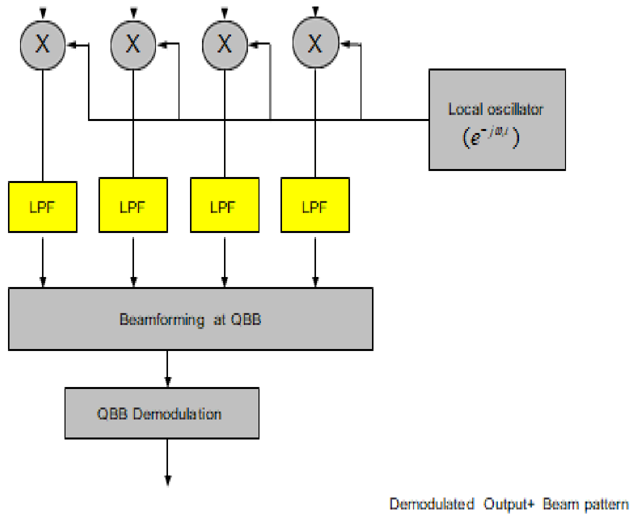


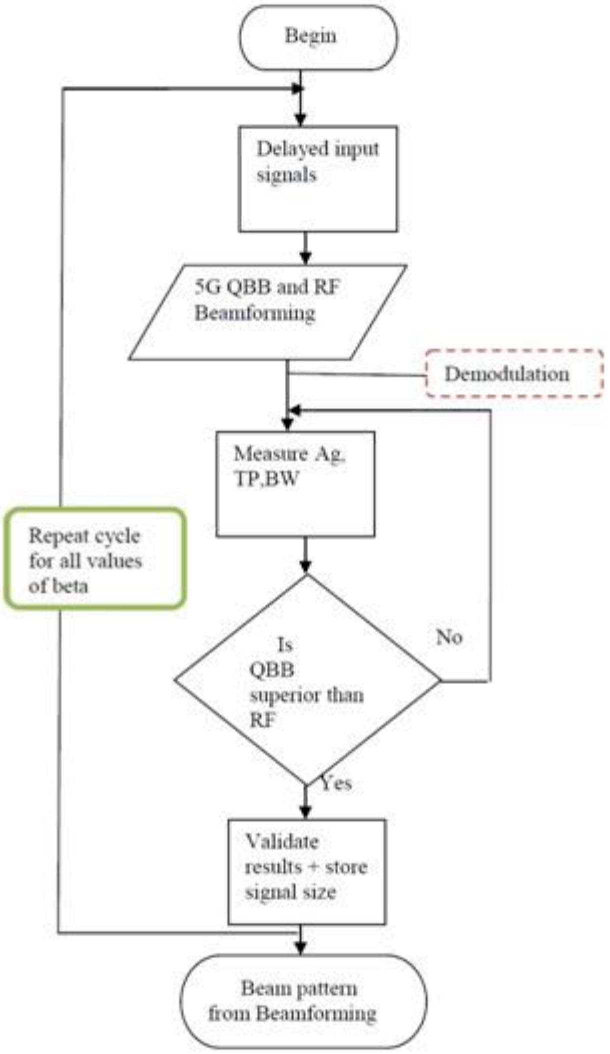
Fig.2: QBB Beamforming illustration

A. RF Beamforming

Beamforming at RF involves summing up the 4 input signals at RF before demodulating the summed-up signal. The beam pattern is produced from the output signal by plotting the maximum value against theta. The block diagram below illustrates beamforming at RF for a 4 antenna array receiver.

Let ***AG*** be the Antenna Gain, ***TP*** the Throughput, ***BW*** the Bandwidth; Thus in our proposed model, we will have a flow chat as illustrated fig.4: It's a simplified model but with results of the analysis being generated, the mathematical models and comparisons of the 3 main parameters will be given and analyzed. A hybrid based QBB model will be generated to ensure the benefits of QBB based Beamforming in enhancing Antenna performance in 5G mmWave networks is demonstrated.

ISSN No:-2456-2165



V. IMPLEMENTATION METHODOLOGY

In carrying out this investigation of beamforming at Quadrature baseband for 5G mmWave networks a 64-bit Laptop computer with an Intel (R), core (TM) 13 CPU processor satellite pro C850-F41K. The computer has been installed with MATLAB version 2020[11]. This version of MATLAB has inbuilt 5G MATLAB tools box functions to generate and propagate the signal.

A. Assumptions and Constraints

In this research, it is assumed that the 5G MatLab [12] tools box will generate the 5G signal and the designed and the designed algorithm for the analysis will have to be synchronized to the inbuilt tools box to carry our the required analysis on the 3 objectives of the expected output results of the 4 antenna array 5G Beamforming at QBB. The synchronization will be an expected constraint but it will be achieved given the background literature review and works done so far from previous works.

VI. CONCLUSION

This paper has proposed and conceptualized the use of Quadrature baseband (QBB) beamforming in 5G mmWave Networks as an alternative to Radio Frequency (RF) beamforming. To implement the proposal and concept, the paper further proposes an algorithm that is similar to the earlier algorithm authors in [1] but at quadrature baseband (QBB) frequencies in the mmWave, 28GHz.

ACKNOWLEDGMENT

This work is supported by the Zambia's Ministry of Higher Education Scholarship research Fund.

REFERENCES

[1]. T. Varum, ―Planar microstrip series-fed array for 5G applications with beamforming capabilities.‖
[2]. K. Jo, ―RF Beamforming Considering RF Characteristics in MIMO system,‖ pp. 403–408, 2010.
[3]. K. Kitao, A. Benjebbour, T. Imai, Y. Kishiyama, M. Inomata, and Y. Okumura, ―5G System Evaluation Tool,‖ *2018 IEEE Int. Work. Electromagn. Student Innov. Compet.*, pp. 1–2, 2018.
[4]. M. Huang, S. Member, T. Chi, F. Wang, and S. Member, ―A Full-FoV Autonomous Hybrid Beamformer Array With Unknown Blockers Rejection and Signals Tracking for Low- Latency 5G mm-Wave Links,‖ *IEEE Trans. Microw. Theory Tech.*, vol. 67, no. 2, pp. 2964–2974, 2019.
[5]. M. A. Hassanien, ―Wideband Rotman Lens Beamforming Technique for 5G Wireless Applications,‖ *2019 2nd Int. Conf. Comput. Appl. Inf. Secur.*, vol. 3, pp. 1–5, 2019.
[6]. H. Aliakbarian, V. Volski, E. Van Der Westhuizen, R. Wolhuter, and G. A. E. Vandenbosch, ―Analogue versus Digital for Baseband Beam Steerable Array used for LEO Satellite Applications,‖ pp. 1–4. **Fig. 4:** Conceptual framework and proposed model Algorithm
[7]. H. Keshavarz, ―International Journal of Electronics and Communications (AEÜ) RF beamforming for MIMO cognitive user,‖ *AEUE - Int. J. Electron. Commun.*, vol. 67, no. 12, pp. 1079–1085, 2013.
[8]. K. Kim and J. H. Kang, ―Hybrid Beamforming Architecture and Wide Bandwidth True-time Delay for Future high Speed Communications 5G and beyond 5G Beamforming System,‖ *2018 IEEE 3rd Int. Conf. Integr. Circuits Microsystems*, pp. 331–335, 2018.
[9]. N. Applications, K. N. Poudel, and S. Gangaju, ―Spectral Efficiency , Diversity Gain and Multiplexing Capacity Analysis for Massive MIMO , 5G Communications System,‖ no. 2, 2017.
[10]. L. Ndovi, ―Benefits to Processor Load for Quadrature Baseband versus Radio Frequency Demodulation Algorithms,‖ no. November, 2008.
[11]. Baseband(2020) retrieved December, 22, 2020 from HTTPS://EN.WIKIPEDIA.ORG
[12]. Zarrinkoub.H, (2018) Retrieved from https://www.mathworks.com on December,22, 2020