Optimal Physical Layer NB-IoT Design Enhancement for Cellular LTE WAN Network in Smart Healthcare

Amrita Khera[1], JaiKaran Singh [2]
[1,2]LNCT University Bhopal MP India

Abstract—

Recent times NB-IOT is widely emerged to serve high-capacityCellular LTE networks especially in smart health monitoring. The major challenge is the restricted bandwidth constrain offered by NB-IoT networks.The Physical layer is responsible for data communication over the network. Orthogonal-Frequency Division Multiplexing (OFDM) is used as thecommunication standard at NB-IOT physical layer. The prime goal of this paper is to enhance the performance based on the parametric evaluation of LTE-OFDM system for NB-IoT-WAN. The proposed design enhances the performance by setting optimal cyclic prefix (CP)samples and selection of FFT size.It is proposed to use M-QAM for better capacity of data transmission. But it is highly required to evaluate the bit error rate (BER) performance under the higher order modulations to offer distortion less transitions.The optimal phase offsets is taken into account and it is proposed to compare the performance of random and uniform power distributions across the network. Paper compared the uniform and normal power allocation distributions performance. The capacity enhancement is provided by increasing the FFT levels. The BER performance of the M-QAM and M-PSK modulation techniques are compared.Various parameters are optimally selected to enhance system performance including subcarriers, CP samples, and constellation order. The proposed communication design is capable of offering efficient bandwidth utilization. Overall paper considers all aspects to achieve the best system performance and offered BER improvement

***Key Words*—Cellular Network, NB-IOT, Smart Healthcare,M-QAM, LTE-OFDM, H**igher Order Modulation**AWGN, Phase Offset, BER**

DOINumber:10.14704/NQ.2022.20.8.NQ22999 **NeuroQuantology2022;20(8):9807-9822**

I. INTRODUCTION

Wide-area network (WAN) medical applications really hasmain focus of data communication over the cellular networksis achieved by employing NB-IoT (narrow-band IoT) technology [1]. The vast majority of mobile phones can be utilized to employ NB-IoT to transfer medical healthcare data to web servers. When sending information to a database, the NB-IoT is employed as a mediator for creating healthcare information which can be easily obtained during patient healthcare as well as to improve staff quality of service [2, 5].This study simulates the appropriate modulation strategy for long-term testing (LTE) communication systems used to improve the physical layer performance of NB-IoT networks.The physical layer of the IoT network is of great importance and is responsible to communicate information over the network.The abbreviations used are given in the Table 1 along with Notations. Physical layer provides the link between sensors and data servers via Base station (BS) antenna in C-IoT network. The basic architecture of the NB-IoT based healthcare system is illustrated in the Figure 1. There is a centralized main controller used for taking communication decisions. Network has a command and monitoring system along with sensors placed across the healthcare application field. The wireless uplink and downlink communication are part of networks physical layer designs.

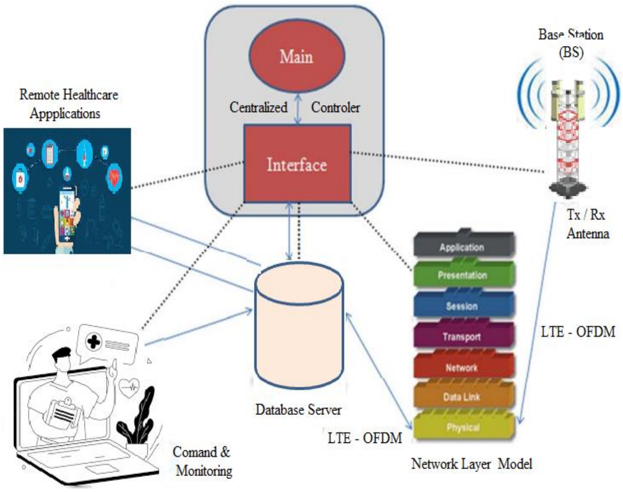


Figure 1 Basic architecture of NB-IoT Health care system

Table 1 Abbreviations and Notations used in the study

Abbreviations		Notations	
AWGN	Additive White Gaussian Noise	$M = L$	Constellation Order
BER	Bit Error Rate	C_r	Linear Power Scale
BS	Base Station	Pwr	Power in dB scale
CE	Channel Estimation	D	Distribution Function
CP	Cyclic Prefix	l	Length of Pwr
FFT	Fast Fourier Transform	$\phi_k(t)$	Base Band Sub-carriers
IoT	Internet of Things	$s(k)$	k^{th} IFFT signal
C-IoT	Cellular IoT	f_k	k^{th} sub carrier frequency
LTE	Long Term Evaluation	N	Number of FFT size
NB-IoT	Narrow Band IoT	n	An integer number
OFDM	Orthogonal-Frequency Division Multiplexing	x_k	k^{th} $transmitt$ Data symbol
PSK	Phase Shift Key	S	Number of total sub carries
QAM	Quadreture Amplitude Modulation	ρ	Phase offset in degrees
SC-FDMA	Single Carrier Frequency-Division Multiple Access	N_{oCP}	Number of CP samples
SVD	Singular Value Decomposition	URD	Uniform ram distribution
LPWAN	Low Power Wide Area Network	NRD	Normal random distribution

Contribution of Work:

The prime contribution of this paper is to optimally design the modulation standards with enhanced capacity and bandwidth efficient performance for NB-IoT uses in healthcare. At the NB-IoT physical layer, OFDM is being used as the communication standard. This article discusses parametric research to improve C-IoTcommunication services' the physical layer modulation capabilities.Subcarriers, CP samples, and constellation order are among the parameters that are optimally chosen to improve system performance.The uniform and normal random power allocation methods are investigated under SNR performance. The proposed methodology improves performance by selecting the optimal FFT size and cyclic prefix (CP) samples.By raising the FFT levels, the capacity is increased. The M-QAM and M-PSK modulation systems bit error rate (BER) performance is compared.Paper also contributed to estimate the optimum phase offset (PO) value which could result minimum BER performance. Overall, five fields of optimal parameters are considered and individually deal to accumulative performance enhancement.

2. Healthcare Applications of NB-IoT

There is wide range of sensing applications of NB-IoT in the Healthcare and hospital management as represented in the Figure 2. Maliket. et al. [1] have presented the various applicationsof the IoT in health care fields. There is a huge scope of sensory systems in medical uses and our aim is on smart applications capable of taking the intelligent decisions. Malik has researched the efficiency of the implementation of NB-IoT in terms of optimal throughput, patients serviced each cell, as well as latency in stand-alone and then in deployments for healthcare surveillance systems. S. Anand et al. [2] have addressed various challenges in NB-IoT network for uses in the healthcare fields. Different biosensors from wireless body area networks are implanted in patients according to A Vinny et al [4] for regularly monitor their health].The impulses' collect attributes are first delivered to gateway allowing data accumulation before being forwarded to remote medical facilities.The 5G empowered a NB-IoT based ambulance service, in instance, instantly connect the patients and ambulance personnel somewhere at accident site, or while in journey, with prepared emergency hospital staff present at remote hospitals [5], A remotely monitoring systemvia using IoT for patient health is proposed by P. S. Akram et al [6]. The IoT is essential for data collection, management, analysis of data, capturing, preservation, and dissemination for remote patients.Akram 9809
monitors the patient's by analysing factors like body temperature, heart rates, and blood pressure (BP), remotely. There are certain hospital service management applications like Smart parking as proposed by Rasika et al [7]. The IoT enabled smart operation theatres are also the future of the smart hospitals. Amrutha et al [8] have used ARM controller for developing the smart handling of operating rooms for hospitals. Therefore, it is highly required to design the high-capacity system for such NB-IoT networks.

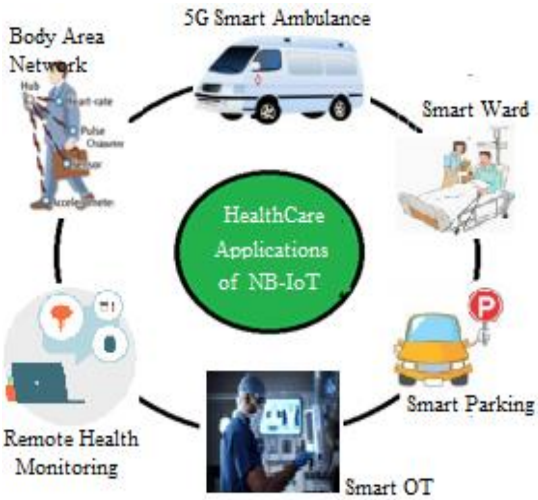


Figure2 Most frequent healthcare applications of NB-IOT networks

Thitapa et al [9] have designed the data transmission system for the use of the healthcare systems using NB-IoT designs. These all applications are together responsible to make the existing healthcare system smarter. This may directly improve the rescue rate of patents.

3. PROBLEMS IN NB-IOT HEALTHCARE

There are a few problematic issues with NB-IOT healthcare. The key problems in design are: insufficient bandwidth; a lack of reliable real-time service delivery [2]. In addition,the unsuitability of the recently present NB-IoT network services is a major issue in for real-time applications. Managing the higher bandwidth requirement for some healthcare applications is required to designing a higher capacity IoT networks. Deployment of low power consuming sensing devices with operated cost is challenging for healthcare WAN applications. Higher FFT size may leads to higher capacity, but it may lead the issues of phase offset errors and requires to address low power FFT design challenges. The tuning of CP samples according to the constellation order M is open field of research. The optimal phase offset selection corresponding to the higher FFT sizes is also open issue and requires experimental tuning for higher BER performance

Solutions: The NB-IOT, also known as LTE-M2, is a mobile network LPWAN technology. It serves as an alternative to the GSM band.Evaluation of communication error rates related to the higher order ofQuadrature Amplitudes Modulations (M-QAM) is the paper's main focus. The use of QAM offers the better Gaussian noise cancelation andalso offers less peak to average ratio and in turn minimizes nonlinear distortions. This paper aims to investigate the inescapable phenomenon of greater sub-carriers and FFT sizes dependent for the NB-IOT system's ideal LTE physical layer content delivery.The predicted increase in communication payload and capacity may be attributed to effective modulation throughout of the physical layer.

The proposed OFDM system solves the LTE requirement for bandwidth flexibility and enables distortion less economically viable solutions for sizable NB-IoT networks expected to operate at consistently highercapacities in future.

3. RELATED WORKS

The physical layer design of NB-IoT is broadly classified as the downlink and uplink designs as shown in Figure 2. The downlink design is reviewed further and is classified according to modulation and channel estimation techniques used are of prime concern in this study. 9810
Performance of BER is proposed to evaluate for these categories.

A. Review of Uplink Design Methods

The NB-IoT uplink design is basically modelled in terms of defining the random-access channels and control channels with variable sub carries spacing's. Arvind Chakrapani [10] has presented a methodology of basic NB-Io uplink design. The mathematical modelling that goes alongside receiver uplink design on NB-IoT channels is described. It was demonstrated how the receiver effectiveness can be enhanced by utilising the time/frequency arrangement of signals. On available commercial Qualcomm, FSM platform the simulation is carried out for link level implementations used to describe the quality of each channel.

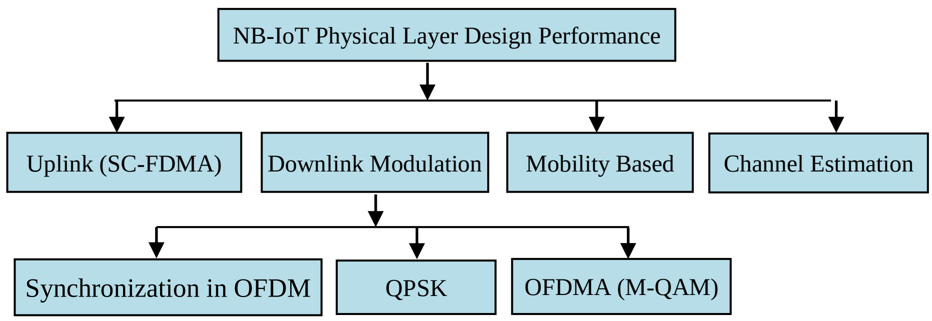


Figure 2 Classification of the Performance Enhancement methods for NB-IOT

Design architecture for the software-defined NB-IoT uplink realisation and prospective use cases were described by AlicjaOlejniczak et al[11] in their article. The platform may be employed in academic settings to create, research, and improve digital transmitter pathways. They gave emphasis of using complex parallel computing and optimization issues for better link design. The NB IoT, LTE, physical layer, as well as digital design are presented by the Basma H. [12] et al. They used single carrier-based frequency division multi access (SC-FDMA) again for uplink design as well as delivered the uplink using BPSK or QPSK as modulation. They have used the FFT block to generate the SC-FDMA data symbols. A non-orthogonal SC-FDMA design was suggested by Bas J et al [13] for NB-IoT optical transmission uplinks. By doing this, the transmission bandwidth can be decreased, which will increase the end-to-end throughput.For cellular IoT and machine-to-machine (M2M) networks, Marwa Chafii, et al [14] has suggested the implementation of index modulation using SC-FDMA uplink transmissions. The suggested SCFDMA using index modulation (SC-FDMA-IM) method is demonstrated for boosting energy efficiency by up to 50%.

B. Review of Channel Estimation Methods

Oruthota, et al. [15] have considered I/Q imbalance for determining the BER formulation of the M-QAM based OFDM modulation system. They have mathematically derived the BER relation and evaluated the performance. The effectiveness of three different CE in combination to equalization techniques was examined in terms of BER.Mwakwata, C.B. et al [16] have provided a survey to give a comprehensive review of a design improvements made possible by the adoption of the NB-IoT specification, as well as the specific research advancements from viewpoints of the physically as well as MAC layersBy using the singular value decomposition (SVD) methodology and dividing the entire channel matrix in to other smaller sub-matrices, Md Khalid et al [17] derive the mathematical framework of said signal for long-term evolution (LTE)-depended NB-IoT downlink structures. They also propose a low complexity LMMSE channel estimation (CE) for the downlink NB-IoT structures. Additionally, they use the overlapped banded methodology to enhance the effectiveness of the suggested channel estimator.According to J. W. Won et al. [18], downlink CE for design NB-IoT is addressed. The three fundamental methodologies employed in IT are the averaged methodology, interpolation strategy, and quasi approach comparing the many NB-IoT CE techniques available might assist establish which the best is as there are numerous of them. The analysis comes to the conclusion that the average method is the most successful. The result makes this quite clear. As a result, this approach is the ideal suggestion for cost optimization, capacity estimation, and batter performance. 9811

C. Review of Mobality based Methods

Y. Moon et al. [19] reported the NB-IoT cell reselection operating parameters. It also provides a method for adjusting cell reselection settings according to the test results. Either an experiment ora real-world working outdoor environment is used to perform the tests. Mobile operators work hard to offer the best NB-IoT services as technology gains popularity. Numerous performance evaluations of NB-IoT mobility have been conducted both an experiment and a real-world network setting. A shortened communication DRX cycle and reselect timer may therefore lead to increased NB-IoT mobility. The quick overview of the Cellular IOT converging is provided by Chen, X.,et al. in their article [20].For the purpose of developing an NB-IOT network, YuxiangLv, et al. [21] suggested a method of channel synchronisation. Low complexity approaches for NB-IOT channel characterization for OFDM-based design have been presented by theYiteng [22] andW. Han [23].

D. Review Recent Advancement

A low-power's split-radix butterfly using 5-2 AC is employed in Guilherme Ferreira, et al [24] FFT hardware architecture. For the dissipated power estimation, that took the activities of the circuit glitching into account, they used a comprehensive methodology. They demonstrated that the proposed split-radix butterfly's structure resulted in significantly less power dissipation when using the FFT.Recent research by F. Li, et al. [25] found that perhaps the phase noise (PHN) produced by local oscillators considerably lowers the dependability of OFDM transmission. Inside this uses sparse Bayesian learning context for OFDM system, an approach to jointly removing NB-IoT interference as well as PHN is described.Prashant Sharma et al [26] have designed a advanced novel very narrow band (VNB) based low power IoT link designs. Method was really bandwidth efficient. The physical layer configuration of LPWA technique has been standardised by Matthieu Kan et al. [28], who also presented a tutorial upon this. They concentrate here on features and indeed the scheduling of such channels for the down and up links over NB-IoT base station interface and at user equipment (UE) transceivers. Overall, it is found that efficient OFDM-LTE design may significantly improve the capacity of IOT networks thus is the focus of this research.

4. Random Channel Realization

The signal power is randomly generated for physical layer transmissions with respect to different SNR in dB.This paper has compared the performance of the physical layer OFDM system under the uniform random distribution (URD) and normal random distribution (NRD) of the power scalein dB as shown in Figure 4. The power is linearly scaled and defined as;

$$C_r = \left|\mathrm{Pwr}/2 * (D_1^{L_{\mathrm{Pwr}}} + jD_1^{L_{\mathrm{Pwr}}}\right|_{abs} \qquad (1)$$

Where;

$$Pwr = 10^{Pwr\_dB/10}{}_1^{i} \qquad (2)$$

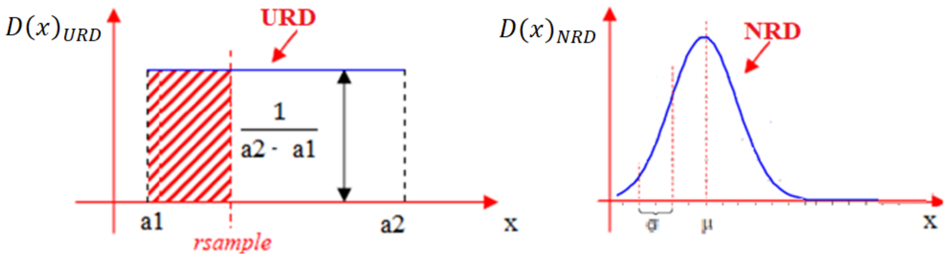
And D is the distribution probability function corresponding to URD or NRD. Let us consider andistribution function given as;

$$D : \epsilon \rightarrow [0,1] \qquad (3)$$

It is such that for random variable x ;$\int xD(x)dx = 1$ (4)

The distribution functions representation for URD and NRD are presented in the Figure 4 a) and b) respectively. The mathematical form of respective URD probability distributions isdefined as;

$$D(x)_{URD} = \begin{cases} \frac{1}{a2-a1} for a1 \leq x \leq a2 \\ 0 \quad for x < a1 \ or x > a2 \end{cases} \qquad (5)$$



a) Uniform Random Distribution (URD) b) Normal Random Distribution (NRD) ,

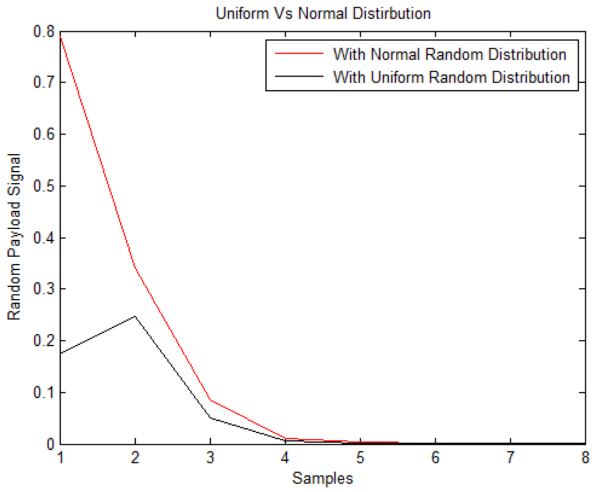


Figure 4 Comparison ofrandom distributed signal power Cr levels for URD and NRD distributions

Where the lower and upper limits of the URD are denoted by the constants a1 and a2, respectively. The values of random variable *x*ranges between $0 \leq x \leq 1$.Given is the probability function for the proposed NRD distribution is ;

$$D(x)_{NRD} = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(x-\mu)^2}{2\sigma^2}} \quad (6)$$

Where the mean of a random variable x is µ and σ is the standard deviation as shown in Figure 4 b). The NRD probability, function, is defined by$D(x)_{NRD}$. The actual random samplesare estimated across the mean valueµ of the *D*. In this paper it is proposed to initialize the signals power levels C_r using these random distributions. Finally, it is concluded from the Figure 4 c) that the Normal random distribution considered the higher signal power across the network and thus is proposed to use in this paper for NB-IoT design.

5. LTE-OFDM WITH CP SELECTION ARCHITECTURE

The proposed methodology is expected to optimaly select the CP samples in combination to higher OFDM FFT lengths and pilot insertion. Figure 5 depicts the proposed OFDM block architecture for the NB-IoT PHY layer. By using first level dense M-QAM based OFDM-modulation, large parallel multi-subcarriers are created, and a variety of information streams are sent orthogonally. It means that, using IFFT as the seconf level modulation, OFDM partitions the channel's bandwidth into k numbers of frequencies sub-carriers which thus appear to be orthogonal with one another. Tehn CP inserton is carried out before being trasmition.

A. M-QAM based Modulation

It is proposed to utilize the M-QAM modulation having major advantage of minimum Euclidean distance amongs the constelation points may reduce the noise impact by increasing the order M of QAM by Bin Zhang et al [31]. The peak-to-average ratio γ is defined as;

*e*ISSN1303-5150

$$\gamma = \frac{P_{max}}{P_{acerage}} \quad (7)$$

The use of QAM offers the mimimum γ values coresponding the less distrotion level for envelope detector. The mathametically the QAM sigis represeted as;

$$v_{M-QAM}(t) = \sum_{n=k}^{M} A_n\, s(t - nT_s) Cos(2\pi f t + \theta_n) \quad (8)$$

Where , $A_n$is amplitude of the every k^th^data signal, θ_n is phase shift and $s(t - nT_s)$ is the delayed baseand signal data. the above equation can be splited to the orthogonal form using the cos(A+B) expansion formula as;

$$v_{M-QAM}(t) = \sum_{n=k}^{M} A_n\, s(t - nT_s) Cos(\theta_n) Cos(2\pi f t) + \sum_{n=k}^{M} A_n\, s(t - nT_s) sin(\theta_n) sin(2\pi f t) \quad (9)$$

These$v_{M-QAM}(t)$ the QAM modulateddata stream are then transmitted using the multi sub-carriers.Every kth subcarrier after the IFFT has the following form:

$$\phi_k(t) = e^{j2f_k^t} \quad (10)$$

The N blocks of lower data rates and parallel data streams are created from the incoming data stream using IFFTas. 9814

$$s(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \emptyset_k(t), \qquad 0 < t < NT, \quad (11)$$

Where, NT is the total frame sample time. The spacing between the each subcarrier frequenciesf_k are equally spaced as $f_k = \frac{k}{NT}$and mathamatically generated using avove equations as;

$$s(k) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k\, e^{j2\pi \frac{nK}{N} t} \qquad 0 < t < NT \quad (12)$$

As a result, the symbol duration has increased.

B. CP Insertion:

As the signal duration rises, the inter-symbol interference (1ST) caused by multipath propagation decreases. Instead of only sending one higher-rate data stream, it is feasible to send several low-rate data streams concurrently. As a result, individual subdata streams also benefit from time savings. To add a cycle prefix (CP), the last samples of the time history signal are copied and appended back to the start of the frame (CP). The CP length must really be greater than the channel's greatest excessive delay in order to prevent ISI, which is once again caused by temporal dispersion.

Theproposed method therefore completely avoided ISI by optimaly selecting the number of CP samples (N_{CP}) to be apended. Mathematical expresion for CP length to be apended in terms of N_{CP} is exoressed as

$$CP_{select} = [N - (\mathrm{N_{CP}}) + 1 : \mathrm{N}] \quad (13)$$

The N_{CP} values are selected to be optimally minimum for better BER performance.

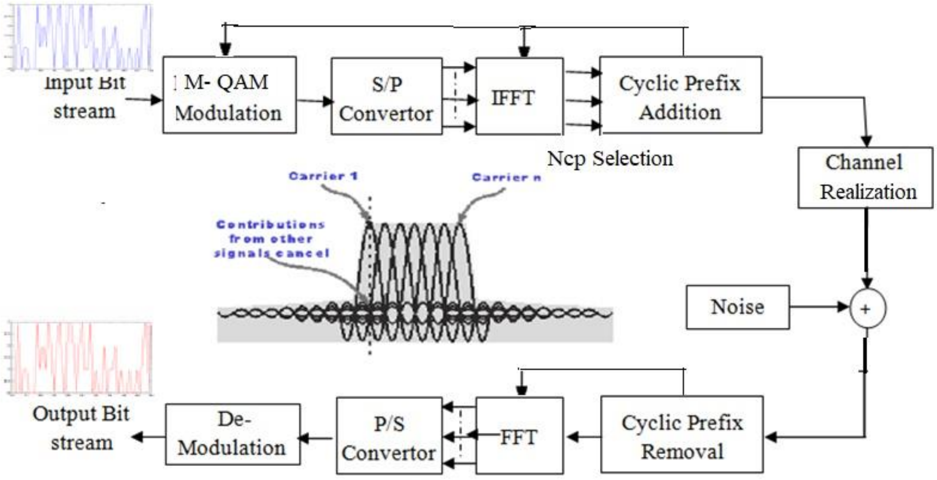


Figure 5 OFDM system architecture for LTE based NB-IOT

The based on the parametric selection and performance feedback the optimum CP and the FFT size is adopted for best BER performance.While, at the receiver initially the CP is eliminated from the data parallel streams. Then the reverse action of Parallel to serial (P/S) conversion using the FFT calculation is carried out and then the serial data stream is de-modulated. As shown in the Figure 5. The sequential flow chart of the NB-IoT proposed physical layer design for the downlink is presented in Figure 6.

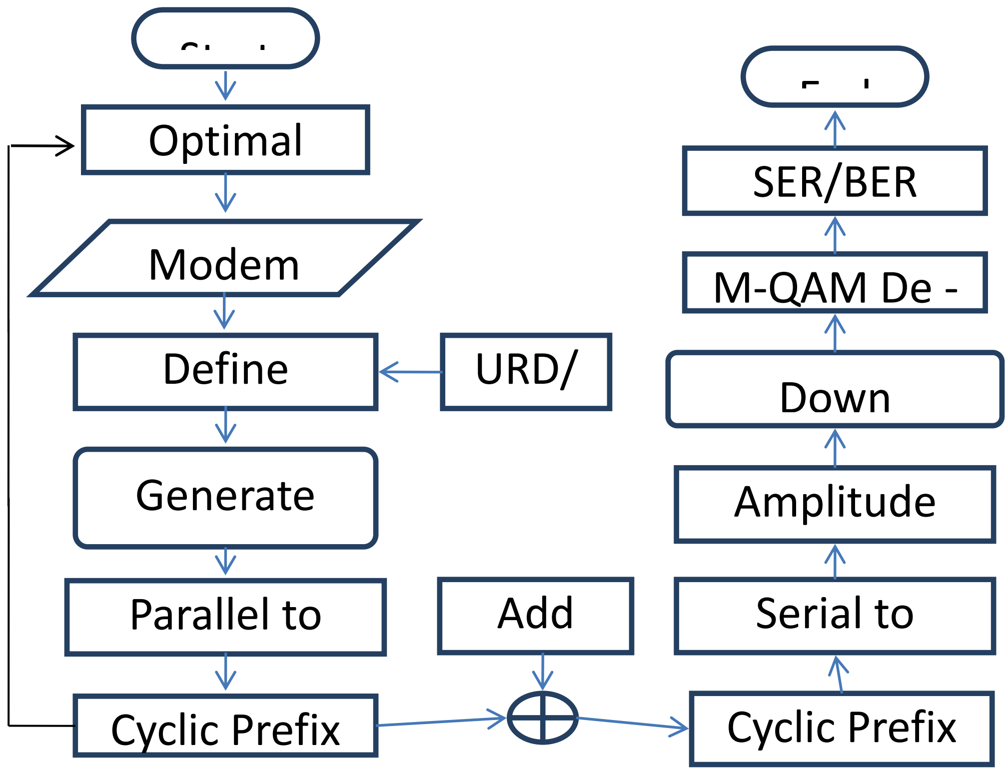


Figure 6 Flow chart ofproposed optimal parametric OFDM with CP insertion for NB-IoT Physical layer

6. Results And Discussion

In this study, several experiments were conducted to create the recommended M-QAM modulation allowing increased OFDM data transmission capability for NB-IoT networks. However, in order to provide transitions with a little less distortion, it is proposed to assess the BER effectiveness with higher order modulations. It is suggested to compare the effectiveness of normal and uniform randomized power distributions over the network while accounting for the optimal phase offsets.

Table 2 provides the range of settings for the best performance. For capacity improvement, the simulation is run with a greater FFT size increased by up to 16 times.

Table 2. Design optimum parameters selected for BER minimization.

S. No.	Parameter Description		
	Details	Notations	Value or the Range
8	Size of the FFT	N	1024-2048
2	Kind of Physical Layer modulation method	/OFDM	For LTE
3	Number of Sub carriers	S	50 and 75
4	Selected Phase Offset	ρ	7.5 degree
5	Number of Castellation for M-QAM or M-PSK order.	M	2 t0 16
6	Range of Cyclic Prefix	Ncep	1or 2

A. Validation of OFDM System

The first experiment is performed for validating the SER and BER using M-QAM modulation for the NB-IoT based LTE-OFDM system. The SNR is varied and keeping the number of FFT levels to N=2048, M=4 and CP samples are restricted to 1 and the number of sub carriers are set to 50 as standard. The validation results are plotted in the Figure 7. It is observed that there is significant BER is achieved by proposed M-QAM based OFDM system but performance is required to evaluate under higher order using optimum parameter selection.

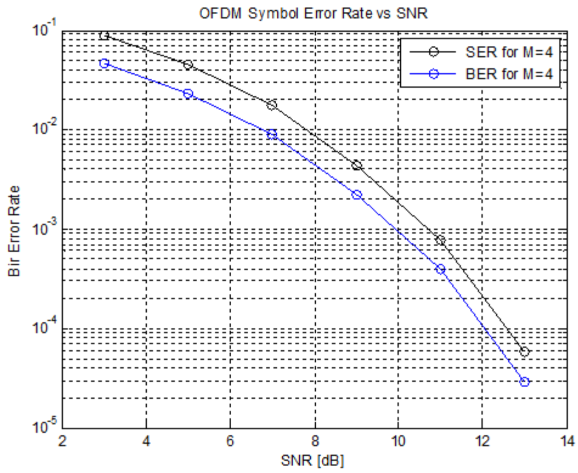


Figure 7 Validation of SER and BER for LTE-OFDM using M0QAM with M=4 for N=2048

B. BER Comparison for M-PSK and M-QAM

Simulation is carried out for comparing the system performance of the M-PSK and M-QAM based modulation techniques keeping the same parameters as used for validation section.

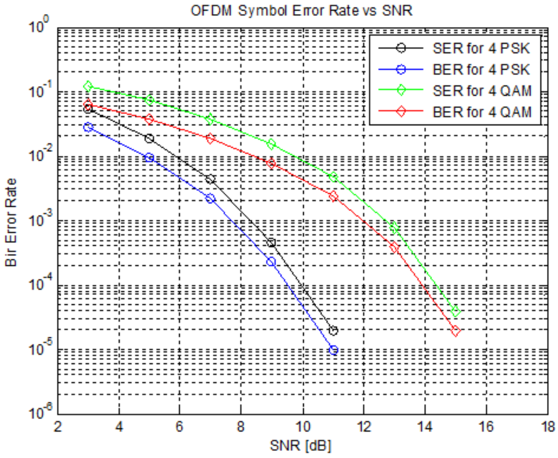


Figure 8 Evaluation of SER and BER for M-PSK and M-QAM for M=4 and NFFT=2048 for LTE-OFDM

The simulated BER of LTE-OFDM is plotted for the evaluation and illustrated in the Figure 8. It is clear that BER is lower in PSK but under the lower SNR (<10 dB) offerings. While the performance of the QAM is good enough at higher SNR even up to 15 dB. The minimum BER is obtained at SNR of 15 dB with order of 0.08 $x10^{-4}$. It needs the significant performance improvement even at the higher SNR levels,but it needs further improvement. Thus M-QAM is considered for further evaluation in this paper.

C. BER for Evaluation under Higher FFT size for M-QAM

To increase the capacity of the NB-IOT system, an experimental simulation is run for various higher order FFT sizes as [2048 and 4096] and greater sub carrier frequencies as 50. The SER/BER is plotted in the Figure 9 for M=4 and CP samples Ncp=4 for phase offset of7.5° for NB-IOT physical layer. The FFT size is increased from 1024 to 4096by 16 times for simulation. It is found that N=4096 offers minimum BER of 4.13 x 10^{-6}. The minimum BER offered is compared in the Table 2 for different FFT sizes.

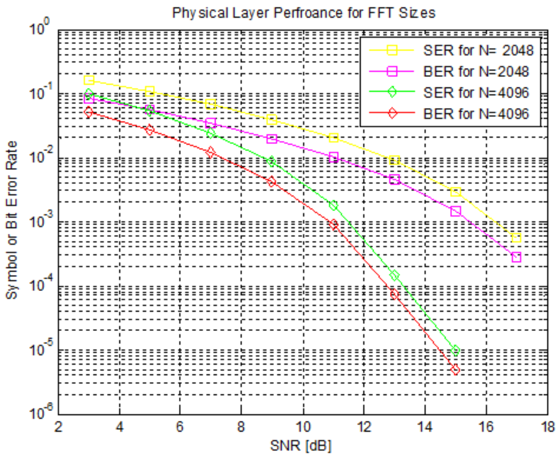


Figure 9 Comparison of BER and SER for QAM order of M=4, Ncp=4 for phase offset=7.5°, for higher FFT sizes varied as 2048 and 4096 for the NB-IoT LTE-OFDM.

Table 2 Performance for minimum SER/BER for the optimum parameters design for simulation

Parameter	N=2048	N=4096
SER	4,12e-04	9.06e-06
BER	1.02e6-04	4,13e-06

D. BER for Evaluation for Random Power Distributions

An experiment is carried out for the evaluation of BER performance of the NRD and the URD based power scaling distributions initializations. The N is kept to 4096 and M=4. The Ncp is kept to unity corresponding to no CP for optimum performance evaluation in this experiment. The BER comparison is given in the Figure 10.

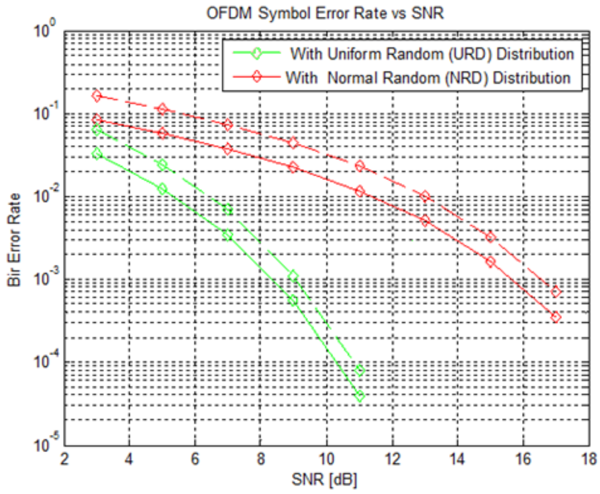


Figure 10 the experimental results of random power distribution for 4096 FFT size and 4 QAM with URD and NRD for LTE-O2FDM in NB-IOT

Although it can be observed that at low SNR the URD distribution gives less BER but in future designs for higher SNR >= 12 dB the NRD distribution is proposed but performance improvement is still a open challenge. Thus in this paper the NRD distribution is preferred over the URD.

E. Impact of CP samples on BER Evaluation

The simulation is performed for analyzing the impact of CP samples Ncp the BER is calculated and plotted in the Figure 11 for the Mcp = [1, 2 and 3]. It can be observed that there is slight lag in the BER as the CP size is increased. The Ncp =1 is corresponds to the no CP and performs. It is observed that increasing Ncp from 1 to 3 may decrease the BER by 8 times. The minimum BER for different Ncp samples are shown in Table 3. The best achievable BER is $4.05 \times 10^{-06}$for Ncp=1.

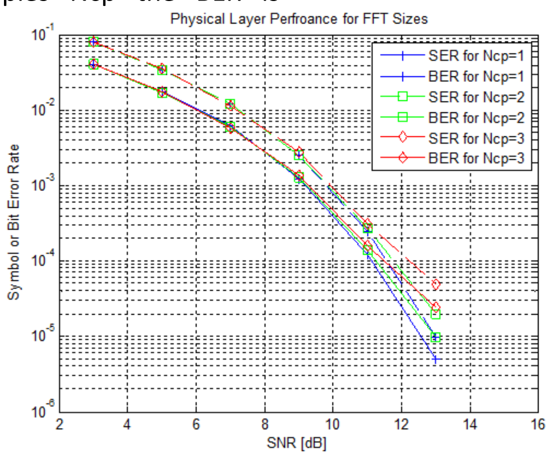


Figure 11 Comparison of BER for different CP samples length Ncp for M=4and sub carriers S=50with phase offset kept constant to 7.5 and the N =4096

Table 3.The performance fordifferent number of CPsamples (Ncp) in terms of BER Simulation

Parameter	For Ncp=1	For Ncp=2	For Ncp=3

Minimum SER	8.302e-06	1.206e-05	4.12 e-05
Minimum BER	4.05e-06	8.35e-06	1.52 e-05

F. Optimum Phase Offset (PO) Selection using BER

For selecting the optimum PO value and its impact the BER and SER performance is evaluated for different PO values. Evaluation results are shown in the Figure 12. During the experiment the design parameters are set as N=2048, M=4, modulation is QAM and Ncp =1. But the PO is varied to [0, 5 , 7.5 and 10] degrees. It is found that PO=7.5 gives the optimum BER of 10^{-6} values. Therefore, in this paper for entire evaluations throughout the experimentation the PO is set to 7.5.

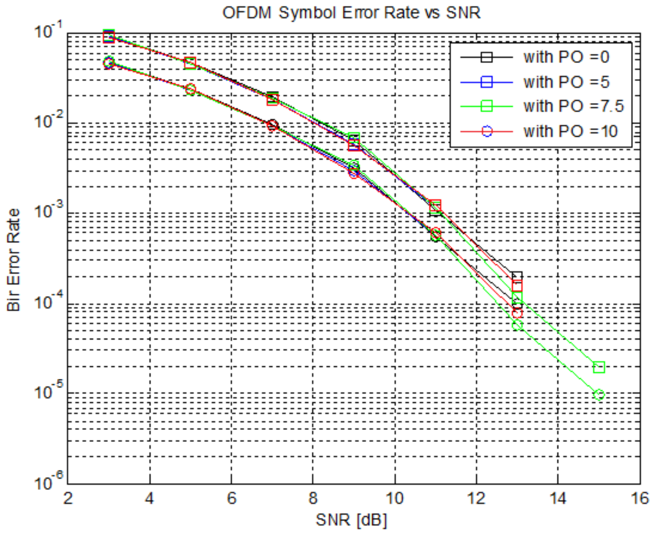


Figure 12Selection of the optimum phase offset (PO) for the NB-IoT LTE-OFDM modulation at the higher FFT size for BER evaluations.

7. Conclusions and Future Works

Paper proposed to improve the NB- IoT's physical layer effectiveness using LTE regulations. By taking into account the larger FFT size up to N=4096 for LTE-OFDM modulation, the system's capacity is significantly increased by 16 folds. Based on a comparison of BER and SER, the effectiveness of OFDM modulation is assessed. The NB-IoT is integrated for the LTE-OFDM system. The first experiment is carried out to validate the SER and BER utilizing M-QAM modulation. The SNR is changed while maintaining N=2048 FFT levels, M=4, 1 CP sample limit, and 50 sub carriers as the LTE standard. At SNR of 13 dB and order of 4.13 x 10^{-4} lowest BER is attained. It needs to perform significantly better. In order to increase the NB-IOT system's capacity, parameters are optimized for various higher order FFT sizes including larger sub carrier numbers.

Paper proposed to design the NB-IOT system with M-QAM modulation which may minimize the non-linear distortions and ICI interferences. For evaluation, the impact of varying phase offset PO's is taken into account. The length of the cyclic prefix (CP) is optimally adjusted to low values for the best BER performance.The effectiveness of the NB-IOT physical layer is improved by selecting the optimal number of CP samples lengths. There is slight lag in the BER as the CP size is increased. The optimally best minimum achievable BER is 4.05 x10^{-06}corresponding toNcp=1. It is found that value of PO=7.5 given the optimum minimum BER values of the order of 10^{-6}.

As an experiment, an assessment of the random probability-based power allocation strategies is conducted. The URD distribution provides reduced BER at low SNR, it is determined, however the NRD distribution is suggested for greater SNR >= 12 dB in future designs. In this study, a good overall performance improvement for the NB-IoT physical layer is obtained.

Although, achieving low power and SNR corresponding to M-QAM and narrow bandwidth is still an open issue to be handle in near future hardware designs. The low power higher order FFT size hardware designs is also open issue for future.

Declaration

1. Funding:-

There is no funding for this research work.

2. Conflicts of Interest:-

The authors have NO affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

3. Availability of data and material:-

Various data repositories are availableFreely in internet for evolution purpose .

4. Code Availability:-

The code for different existing protocol is available at MATLAB library for proposed work the code will be provide on request.

Authors Contribution:-

1) All authors have participated in
(a) Conception and design, or analysis and interpretation of the data,
(b) Drafting the article or revising it critically for important intellectual content, and
(c) Approval of the final version.

REFERENCES

[1] Malik H., Alam M.M., Moullec Y.L., Kuusik A. "NarrowBand-IoT performance analysis for healthcare applications". in the Procedia Computer. Science. 2018; **130**: pp, 1077–1083. doi:10.1016/j.procs.2018.04.156. [CrossRef] [Google Scholar]

[2] S. Anand and S. K. *"*Issues and challenges in healthcare narrowband Io*T',*International Journal of Pharma Medicine and Biological Sciences Vol. 9, No. 1, January 2020486-489, doi: 10.1109/ICICCT.2017.7975247.

[3] N. H. Nguyen, B. Berscheid and H. H. Nguyen, "Fast-OFDM With Index Modulation for NB-IoT," in IEEE Communications Letters*,* vol. 23, no. 7, pp. 1157-1160, July 2019, doi: 10.1109/LCOMM.2019.2917684..

[4] A Vinny Mary and S Jerine, "Wireless body area network transmissions for iot-based healthcare network: a review", IWCASME 2020 IOP Conf. Series: Materials Science and Engineering983 (2020) 012017 doi:10.1088/1757-899X/983/1/012017

[5] Zhai, Yunkai& Xu, Xing & Chen, Baozhan& Lu, Huimin& Wang, Yichuan& Li, Shuyang& Shi, Xiaobing& Wang, Wenchao& Shang, Lanlan& Zhao, Jie. (2020). 5G-Network-Enabled Smart Ambulance: Architecture, Application, and Evaluation. IEEE Network. 35. 10.1109/MNET.011.2000014., 2020.

[6] P. S. Akram, M. Ramesha., S. A. S. Valiveti, S. Sohail and K. T. S. S. Rao, "IoT based Remote Patient Health Monitoring system," 2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS), 2021, pp. 1519-1524, doi: 10.1109/ICACCS51430.2021.9441874

[7] Rasika. P., Sobin.C. C, "An Efficient Security Enhanced NB-IoT Connections In Hospitals", IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 6 Issue 6, June 2019

[8] Amrutha.B.R, Anusha. S, Harshitha. D. S, ArunKumar. S, Nadimpalli Rajkumar, "IoT based Automatic Handling Operation Theatre using ARM7 Processor", International Research Journal Of Engineering And Technology (Irjet) Volume: 07 Issue: 05 May 2020

[9] ThitapaPrompinit, AmonwanJenjirataworn, and SarinpornVisitsattapongse, "Healthcare Data Transmission by Using NB-IoT", International

Journal of Pharma Medicine and Biological Sciences Vol. 9, No. 1, January 2020

[10] Arvind Chakrapani, "NB-IoT Uplink Receiver Design and Performance Study",*in* IEEE Internet of Things Journal, vol. 7, no. 3, pp. 2469-2482, March 2020, doi: 10.1109/JIOT.2019.2957641.

[11] AlicjaOlejniczak, Olga Błaszkiewicz, Krzysztof K. Cwalina, Piotr Rajchowski and Jarosław Sadowski, "Software-Defined NB-IoT Uplink Framework—The Design, Implementation and Use Cases",Sensors 2021, 21, 8234 https://doi.org/10.3390/s21248234

[12] Basma H. Mohamed, Ahmed Taha, Ahmed Shawky, Essraa Ahmed, Ali Mohamed, Manar Mohsen, Rodina Samy, Amr ELHosiny, Ahmed Ibrahim and Hassan Mostafa, "Design of the Baseband Physical Layer of NarrowBand IoT LTE Uplink Digital Transmitter", Journal of Circuits, Systems, and Computers Vol. 29, No. 7 (2020) (16 pages) World Scientific Publishing Company DOI: 10.1142/S021812662050111X

[13] Bas, J., Dowhuszko, A.A. End-To-End Performance of an Uplink NB-IoT Transmission Relayed on a Low-Altitude UAV Platform with Non-Orthogonal Single-Carrier FDMA in the Optical Wireless Backhaul Link. *Mobile Netw Appl* (2022). https://doi.org/10.1007/s11036-022-01991-x

[14] Marwa Chafii, Faouzi Bader, Jacques Palicot. SC-FDMA with Index Modulation for M2M and IoT Uplink Applications. 2018 IEEE Wireless Communications and Networking Conference (WCNC), Apr 2018, Barcelona, Spain. ff10.1109/wcnc.2018.8377028ff. ffhal-01705717f

[15] Oruthota, U., Tirkkonen, O. SER/BER expression for M-QAM OFDM systems with imperfect channel estimation and I/Q imbalance. J Wireless Com Network 2012, 303 (2012). https://doi.org/10.1186/1687-1499-2012-303

[16] Mwakwata, C.B.; Malik, H.; MahtabAlam, M.; Le Moullec, Y.; Parand, S.; Mumtaz, S, "Narrowband Internet of Things (NB-IoT): From Physical (PHY) and Media Access Control (MAC) Layers Perspectives ". ***Sensors*** **2019**, *19*, 2613. https://doi.org/10.3390/s19112613

[17] Md Khalid Hossain Jewel, Rabiu Sale Zakariyya and Fujiang Lin, "On Channel Estimation in LTE-Based Downlink Narrowband Internet of Things Systems".Electronics 2021, 10, 1246. https://doi.org/10.3390/electronics10111246

[18] J. W. Won and J. Min Ahn, "NB-IoT Downlink Channel Estimation," 2020 International Conference on Information and Communication Technology Convergence (ICTC), 2020, pp. 1739-..

[19] Y. Moon, S. Ha, M. Park, D. Lee and J. Jeong, "A Methodology of NB-IoT Mobility Optimization," 2018 Global Internet of Things Summit (GIoTS), 2018, pp. 1-5,

[20] Chen, X., Qi, Q. (2020). Introduction. In: Convergence of Energy, Communication and Computation in B5G Cellular Internet of Things. SpringerBriefs in Electrical and Computer Engineering. Springer, Singapore.,2020

[21] YuxiangLv, Hao Qin, Zhiwei Liu, Yawen Dong, Weiyang Xu, Wenjiang Feng, "An Efficient Synchronization Algorithm in OFDM-based NB-IoT Systems", 2019 IEEE Intl Conf on Dependable, Autonomic and Secure Computing,

[22] Yiteng Wang, Huijie Zhu, "A Low-Complexity Method of NB-IoT Identification", 2018 IEEE 4th International Conference on Computer and Communications, DOI: j978-1-5386-8339-2/18.

[23] W. Han, Z. Dong, H. Xu, Y. Liu and L. Chen, "A Low-Complexity CP-Free OFDM Design For NB-IoT Networks," 2021 7th International Conference on Computer and Communications (ICCC), 2021, pp. 2068-2073, doi: 10.1109/ICCC54389.2021.9674674.

[24] Guilherme Ferreira, Guilherme Paim, Leandro M. G. Rocha, Gustavo M. Santana, Renato H. Neuenfeld, Eduardo A. C. Costa, Sergio Bampi, "Low-power fast Fourier transform hardware architecture combining a split-radix butterfly and efficient adder compressors", IET Computers & Digital Techniques 2021; vol. 15: issue 3. pp. 230–240.**https://doi.org/10.1049/cdt2.12015**

[25] F. Li, H. Zhang and X. Luo, "Joint Cancellation of Phase Noise and NB-IoT Interference in OFDM System," in IEEE Wireless Communications

Letters, vol. 10, no. 2, pp. 436-440, Feb. 2021, doi: 10.1109/LWC.2020.3034461

[26] Prashant Sharma, Daniel W. Bliss, Chair Chaitali Chakrabarti, Thomas McGiffen, “Low-power Physical-layer Design for LTE Based Very NarrowBand IoT (VNB - IoT) Communication”, ARIZONA STATE UNIVERSITY, 2017.

[27] Matthieu Kanj, Vincent Savaux, Mathieu Le Guen. A Tutorial on NB-IoT Physical Layer Design. Communications Surveys and Tutorials, IEEE Communications Society, Institute of Electrical and Electronics Engineers, 2020, ff10.1109/COMST.2020.3022751ff.

[28] Armed Tusha , Seda Doga , Hüsey˙in Arslan, “IQI Mitigation for Narrowband IoT Systems with OFDM-IM”, 2018, IEEE Access, DOI 10.1109/ACCESS.2018.2864892

[29] R, A., N, A.P.,“Fractional wavelet transform based OFDM system with cancellation of ICI”. Journal of Ambient Intelligence Humanized Computing (2019). https://doi.org/10.1007/s12652-019-01191-8

[30] Li, H. (2020). Principle of OFDM and Multi-carrier Modulations. In: Shen, X.(., Lin, X., Zhang, K. (eds) Encyclopedia of Wireless Networks. Springer, Cham. https://doi.org/10.1007/978-3-319-78262-1_164

[31] Bin Zhang, Yuanhang Qu and Min Chen, “Simulation and Performance Study of Quadrature Amplitude Modulation and Demodulation System“, EMCEME 2019, IOP Conf. Series: Materials Science and Engineering 782 (2020) 042048 IOP Publishing doi:10.1088/1757-899X/782/4/042048

[32] Obeidat, H.A., Ahmad, I., Rawashdeh, M.R. *et al.* “Enhanced TOA Estimation Using OFDM over Wide-Band Transmission Based on a Simulated Model”. Wireless Personal Communication **123**, 3449–3461 (2022). https://doi.org/10.1007/s11277-021-09297-z

[33] Zhang, L., Ma, J., Wu, Z. *et al.* Efficient Cross-Correlation Algorithm for Correction of Common Phase Error Employing Preamble for Orthogonal Frequency Division Multiplexing (OFDM) Receivers. *Wireless Pers Commun* **118**, 535–549 (2021). https://doi.org/10.1007/s11277-020-08030-6