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Performance Estimation of MIMO-OFDM for New Radio signals IN LTE Networks for Precise indoor signaling

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Abstract: Considering that the radio frontend system for an indoor BS consists of both the RF amplifier circuit as well as the antenna subsystem, it is imperative that the study of compact antennas and their practical implementations becomes further more relevant with the advancement of wireless technological advancements. In this context, the study of high efficiency Single Input Single Output (SISO) antennas has already been carried out for modern wireless BS. Further, efficient Multi-Input Multi-Output (MIMO) antennas are also being used for many high power and medium power BS applications. Additionally, there are popular applications of multi-band antennas for different wireless technologies. In the modern indoor BS, it is becoming a design requirement increasingly to integrate more than one wireless technology, such as Long Term Evolution-Advanced (LTE-A) and Wireless Fidelity (Wi-Fi), into the same hardware. This poses a huge challenge to the hardware and system integration aspect to encompass the multiple MIMO antennas supporting multitechnology requirements while adhering to the high isolation co-existence related radio impairments in a compact form factor. The combined challenge of meeting the high isolation in an efficient and compact size of the radio system is another key focus of this study.

Keywords: Compact Antennas, SISO Antennas, MIMO Antennas, Multi-Band Antennas, Indoor Base Stations (BS), LTE-Advanced (LTE-A), Medium Power Base Stations

INTRODUCTION

Modern wireless technologies have gradually evolved from the initial adoption of the first generation (1G) standards to second (2G), third (3G), and fourth generation (4G) and going forward to fifth-generation (5G) periodically [1-3]. These technologies can be broadly categorized into majorly two types: licensed wireless technology as standardized by 3GPP body of specification standards [4-6] and unlicensed wireless technology as standardized by IEEE 802.11 body of Wi-Fi specification standards [7]. These wireless technologies and standards are the basic foundation on which various wireless technological ecosystems depend upon for their existence and operational compliance [8-12]. Such ecosystems could be a Base Station Subsystem (BSS) or an Access Point (AP). While the radio Base Station (BS) is an integral part of the BSS in a 4G and legacy 3G mobile wireless ecosystem, the APis an integral part of the Wi-Fi fixed wireless ecosystem. To cater to the need of the end-user and various real-world applications, this modern cellular (e.g., 4G, 4.5G, and 5G) wireless radio BSsystems have gone through a transition phase from the traditional outdoor high power macro type to becoming a medium-to-low power in nature for short-range applications. Further, dense and high-capacity applications deploy them for capacity-centric applications instead of targeting the traditional coverage-oriented scenarios [13-14].

These miniaturized versions of the low power base stations are termed as pico and Femto base stations [15-17] and hence can be categorized as smallcell BS. In this regard, the deployments are increasingly gearing up towards the indoor environment with the heterogeneous type of co-existing wireless technologies [18] and standards both in the short-term and also in the futuristic timelines. Since these radio BS systems are used for indoor enterprise and residential deployment scenarios, they are expected to be extremely power efficient regarding their system design.

Additionally, due to the high capacity requirements, these radio BSs incorporate system processing (i.e., hardware and software) components dealing with bandwidth-efficient and high Peak-to-Average Power Ratio (PAPR) modulation schemes compliant with the 4G (or LTE) and advanced 4.5G (or, LTE-A) standards applications [19-20] while maintaining the linearity and efficiency requirements.In this context, the power efficiency and linearity of the RF frontend circuits (e.g., power amplifier) play a major role in optimizing and enhancing the overall power efficiency and linearity of the BS [21-22].

It may be noted here that the RF frontend circuits also comprise of other active circuits such as Low Noise Amplifier (LNA) and switches; however, the major power-consuming component is the Power Amplifier (PA) block.

Hence, it is of utmost importance to focus on the research studies involving RF PA for this low-power indoor BS. Even though several studies have been carried out for the PA efficiency improvements [3-5] as well as linearity improvements [6] for higher power designs, not much work have been done in this regard for the low power and medium power indoor wireless BS to cater to the specific system-related requirements. This is one aspect of this present research work that is focused on the radio PA efficiency improvement while maintaining the required linearity for the lowpower indoor BS system. Through this study, it is proposed to design high-efficiency power amplifier discrete circuits for the low power as well as for the medium power BS system

Further, in any generic wireless radio BS, an antenna element (i.e., the radiating system) is cascaded after the output of the PA stage and plays a critical role in radiating the transmitting signal into the radio channel over free space. Hence, apart from the above-mentioned RF frontend PA circuit, the typicallow-power indoor BS system consists of the radiating antenna elements [9] as an integral system component. It is not adequate to only enhance the efficiency of the PA circuit for the improvement of the overall BS system efficiency, but at the same time, it is very much essential to improve upon the performance aspects of the antenna elementsin a MIMO arrangement of these antennas in the advanced 4G and 4.5G BS system. Additionally, when the co-existing MIMO antenna elements are packed in a compact form factor inside the mechanical enclosure of the indoor BS, the overall radio system performance could degrade due to mutual coupling of the signal from one technology to the other [1-3].Hence, to mitigate this, the isolation among the non-MIMO pair antenna elements needs to be enhanced adequately for a smooth operation of dual wireless technology.

Several antenna isolation techniques for generic SISO BS systems have been reported recently [33-36]; but, these are falling short of addressing the radio system challenges one could face for a MIMO multi-technology indoor radio BS. Hence, this is the second aspect of this present research work which is focused on the radio system performance improvement in terms of enhancing the isolation among the co-existing multi-wireless technology MIMO antennas while maintaining the radio coverage efficiency of these indoor BS antennas. As a natural extension of this study, the indoor radio deployment linked system-level analysis and experimental investigation is undertaken for the designed high isolation antennas.

The overall focus of this work is on two major aspects: a) RF frontend circuits and systems for the BS, covering the study and investigation of the following: i) improving the efficiency of low power and medium power RF power amplifier (PA) circuit, and ii) improving the isolation of multi-technology (i.e., LTE-A and WiFi) MIMO antenna system while maintaining the good radio coverage efficiency, and b) signal-to-noise ratio for the low power indoor wireless base stations.

The proposed improvement in RF performance is aimed to be demonstrated through the actual hardware design implementation (for PA and antenna) and practical investigation such that these should have a better performance than the existing literature and stateof-the-art research

The objective of the work is to elucidate the techniques and means to enhance the efficiency of the MIMO indoor BS through radio frontend design-related improvements for the RF Power Amplifier (PA) as well as the antenna structure.

The author has developed, proposed, and also experimentally validated some meaningful novel techniques for enhancing the linearity and efficiency of RF power amplifiers for low-power indoor BS. This technique has been applied to the typical single-ended amplifier as well as Doherty amplifier structures. For the single-ended RF amplifier configuration, the study and investigation focus on the holistic approach and identification of bias points for enhancing efficiency.

The author shows that there are unexplored bias sweet spots for the single-ended PA, which can be obtained through experimental techniques. For the Doherty amplifier, the author proposes novel modifications to the output circuit configurations for the classical Doherty topology for enhancing efficiency over a larger output power back-off operation. Here, the study shows that with the output matching circuit modifications and altered Doherty transformer circuit, there is a possibility of enhanced efficiency.

This work has implemented, and validated the novel efficient and compact MIMO antennas with high isolation performance while supporting LTE-A and Wi-Fi co-existing technologies and also adhering to enhanced radio system performance, such as radio coverage and signal quality. Apart from the PA circuit, the antenna subsystem plays a major role in transmitting and receiving the signal, and hence in the absence of antenna-related studies, the work is incomplete.

Therefore the author has developed suitable antenna topologies as part of this study. The antennas were developed to use a combination of the Defective Ground Structure (DGS), Slotted Ground Plane (SGP), and polarization diversity to pack multiple planar antennas for high efficiency with high isolation. The designed antennas have been deployed in some of the typical indoor radio deployment scenarios (such as office and enterprise locations), and their performance has been verified. Additionally, in the indoor radio deployment context and using the above-designed MIMO antennas, the author has proposed novel techniques of holistic indoor propagation study mechanisms and procedures for time-efficient and cost-effective radio deployment[12].

The importance of the work is to study and investigate the areas of efficiency improvement for the radio frontend blocks used in the modern low power indoor wireless BS systems supporting LTE-A and Wi-Fi

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technologies[13-15]. The major radio frontend blocks considered in this study focuses on the efficiency of the RF PA and MIMO antenna supported with practical verification of these blocks in the laboratory test bench as well as in the real field deployment. The detailed results presented in this thesis can provide a holistic guide to the radio engineering design efforts for enhancing overall power consumption of the indoor MIMO wireless BS system as well as their efficient field deployment for the end-user (i.e., telecom operators, retail multimedia data subscribers)

LITERATURE REVIEW

Author(s)	Year	Focus/Contribution	Key Techniques/Findings	Implications
Raman Kumar et al.	2024	Overview of 5G compared to previous generations.	Describes 5G functionality, data transmission, and its role in enabling smart cities, autonomous vehicles, and telesurgeries.	Highlights 5G's significance in transforming urban infrastructure and daily life.
Yubo Wan et al.	2024	Robust multi-user uplink channel tracking for massive MIMO in 5G NR systems.	Proposes a sparse Markov channel model and Turbo-CS-based channel estimation with multi-stage successive interference cancellation (MSIC).	Enhances the robustness of channel tracking against system imperfections.
Sahil Sharma et al.	2024	Enhancing NOMA in Cognitive Radio Networks using deep learning and power allocation.	Combines Deep Neural Networks (DNN) and Deep Q-Learning (DQL) for signal identification and intelligent power allocation.	Improves interference management and user recognition in dynamic environments.
Yubo Wan et al.	2024	Channel extrapolation in TDD massive MIMO-OFDM systems for 5G NR.	Proposes a two-stage 2D channel extrapolation scheme using a sparse Markov model and EM-based compressive tracking for imperfection mitigation.	Addresses channel extrapolation challenges in dynamic 5G NR systems.
Huseyin Babaroglu et al.	2024	Digital post-distortion for multi-layer OFDM systems in nonlinear environments.	Proposes ML-DPoI technique for enhancing signal quality under heavily nonlinear power amplifiers, with improved EVM in 5G uplink transmission.	Facilitates sustainable and efficient power usage in millimeter-wave communication.
Anupriya et al.	2023	Evolution from 3G to 5G focusing on waveform techniques.	Evaluates F-OFDM, UFMC, and FBMC waveforms for next-generation wireless systems considering FFT size, filter characteristics, etc.	Identifies efficient waveforms for addressing PAPR and spectrum efficiency issues.

Masaaki Tanio et al.	2022	Delta-sigma RoF system for beyond 5G with improved signal-to-noise ratio (SNR).	Demonstrates a delta-sigma RoF system that embeds a pulse-distortion model, achieving a 6 dB improvement in SNR for OFDM signals after fiber transmission.	Supports enhanced data transmission in beyond 5G networks.
Vikas Chauhan et al.	2022	Comprehensive review of 5G network design, limitations, and future directions.	Explores HetNet, CA, M-MIMO, CR, and high-spectrum access techniques, along with challenges and solutions for 5G network optimization.	Addresses network capacity and throughput challenges for future demands.
Xingqin Lin et al.	2022	Overview of 5G Advanced evolution under 3GPP Release 18.	Highlights diverse advancements such as enhanced performance, new use cases, and technologies introduced in 5G Advanced.	Serves as a foundation for transitioning to 5G Advanced capabilities.

Deployment Of LTE-A In Channel Analysis

This work discusses the importance of channel analysis in LTE-A along with its architecture, features, channels, benefits, and applications. The design of LTE-A aims to deliver faster speeds and a higher data throughput. It provides 100 Mbps in a highly mobile setting and 1 Gbps in a stationary one. Improved coverage, faster speeds within the same spectrum, and seamless handoffs across hexagonal cells are some of its other benefits[21].

Due to the needs of emerging advanced mobile networks like LTE-A, the concept of mobile-based machine-to-machine (M2M) communication, or device-to-device (D2D) communication, has emerged. These networks aim to cover a broad area, provide better dependability, and reduce costs. Because there will likely be a lot of devices that can instantly send compressed data from their applications, M2M communication needs to get better. According to a thorough study by Improved node B manages user devices in a single or many cells, serves the US, regulates handover procedures, and connects with the core network via the S1 interface. Handoff occurs with a longer delay over the S1 interface.

Figure 1 shows the protocol stack (left) and network architecture (right) of LTE – Advanced for E-UTRAN. E-UTRAN also provides home eNB (HeNB) services dedicated to a user within a home for femto cell coverage. Figure 1 (right) shows a high level E-UTRAN architecture.

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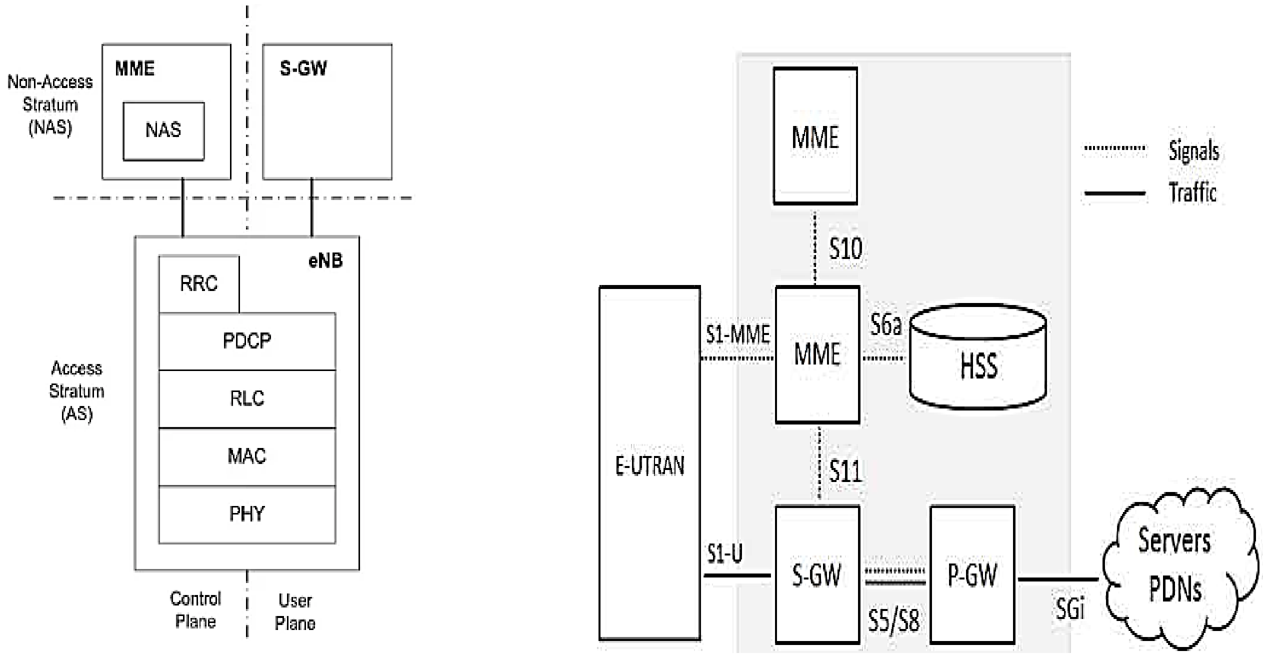


Figure 1 LTE-advanced protocol stack (left) and network architecture (right)

The many gateways in it include the following: Packet Data Network-Gateway (P-GW) and Serving-GW, Mobile Management Entity (MME), S1-MME, improved Node B (eNB), Home enhanced Node B (HeNB), Home enhanced Node B - Gateway (HeNB - GW), relay node, and so on. The P-GW is connected to the S-GW via the S5 interface, and it is linked to the internet protocol operator's services through the SGi network. Users' devices may be linked to packet data networks using this. User devices (mobile phones) are assigned IP addresses by GW. It is possible for a single user to provide access to several PDNs by connecting to numerous P-GWs. Service subscription fee billing, strategy inflict, and packet filtering are all accomplished by it. It establishes the link between (3GPP) LTE/LTE-A and (non-3GPP) WiMAX/CDMA.

When communicating with mobile management entities, the serving gateway makes use of the S11 interface; when communicating with serving GPRS support nodes, it makes use of the S4 interface. It communicates with E-UTRAN via the S1-U interface. Each user's device contributes to the following: inter-3GPP mobility, inter-operators charging, inter-enhanced node B handover, packet routing, and packet forwarding via its unique serving gateway. One component of the LTE-A architecture's control plane, the mobile management entity is responsible for security-related tasks including authorisation, authentication, and signalling. All three of these gateway functions—serving, packet, and packet data network—are supported and controlled by it. Section 1: MME links the upgraded node Bs to the evolved packet core. An interface with user gear or LTE-A mobile phones is provided by the upgraded node B, the fundamental building component of an LTE-A system. Any cellular system, including GSM, may use it as a base station. The X2 interface is the point where two eNBs connect; each eNB is responsible for serving one or more E-UTRAN cells. Indoor areas, such as homes, workplaces, and supermarkets, may have their coverage areas enhanced with the help of Home eNB, a femtocell structure. Connected either directly or via a gateway to the evolving packet core. Controlling all traffic from various HeNBs to the core network, the HeNB gateway links the serving gateway with the mobile management entity. The HeNBs are linked via the S1 interface. When the relay node is functioning well, the whole network benefits[22].

When building frames from binary data, the physical layer (PHY) and the multiple access mechanism play a deciding role. It regulates the coding and modulation process for different control channels and traffic. It also includes the scrambling and layer mapping processes. Both the uplink and downlink systems' reference signals for channel estimation and equalisation are part of this. Among the several tasks performed by the MAC layer are the following: zero padding, prioritising local channels, error correction via HARQ feedback, scheduling information, and multiplexing and demultiplexing RLC PDUs. The radio link control (RLC) layer does many things, such as fixing errors with automatic repeat query (ARQ), sending data in the right order, finding and fixing protocol errors, joining SDUs for the same radio bearer, and dividing transport blocks based on their sizes. Some of the things that Packet Data Convergence Protocol (PDCP) does are header compression, handover sequence delivery and retransmission of PDCP session data units, finding duplicates and cyphers, and protecting the integrity of the data. Radio Resource Control (RRC) is in charge of many things, such as making sure that RRC connections are working, controlling user equipment (UE), managing quality of service (QoS), and sending messages directly between UE and network access servers (NAS) about the non-access tier. Non-Access Stratum (NAS) tasks include authentication, registration, session management between UE and the core network, connection monitoring, location registration management, user context activation/deactivation, and more.

LTE – A FEATURES AND REQUIREMENTS

With the focus of future generations of wireless technologies/standards, LTE-A has a number of key features as follows:

i. Peak data rate of 500 Mbps for uplink and 1Gbps for downlink.

ii. Three times greater spectrum efficiency than LTE.

iii. Peak spectrum efficiency of 15 bps/Hz for uplink and 30 bps/Hz for downlink.

iv. Scalable bandwidth and carrier aggregation.

v. Latency from <50ms to <5ms for one way packet transmission in idle to connected UE.

vi. Two times of cell edge user throughput greater than LTE.

vii. Three times more user throughput than LTE.

viii. Same mobility as in LTE.

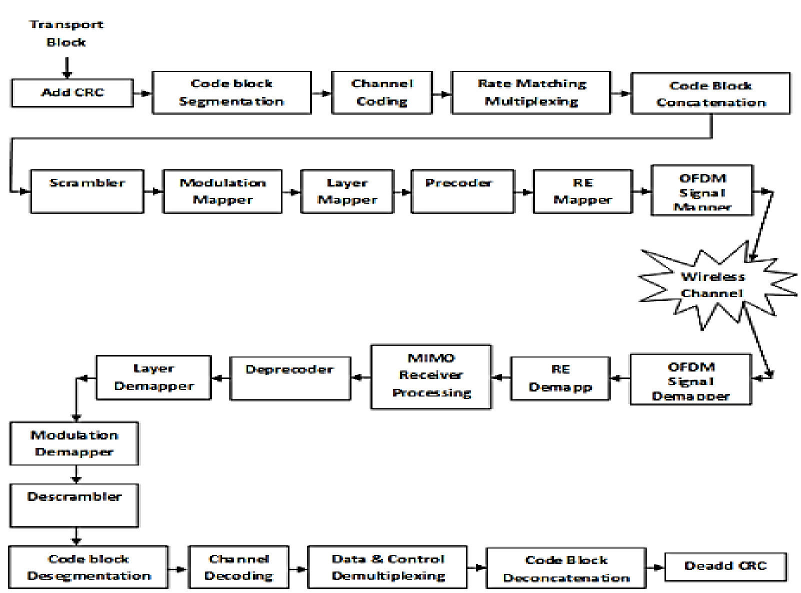
ix. Compatible to LTE and advanced mobile standards.

The many requirements of LTE-A include the following: the capacity to handle peak data rates within a varied range of bandwidth or spectrum efficiency; user throughput; mobility; compatibility with existing or prior technologies; cost and complexity reduction; and so on. A major obstacle in LTE-A downlink deployments is attaining great spectral efficiency while decreasing the mistake probability.

Among LTE-A's promised benefits are universal IP network compatibility, fast data speeds, and minimal latency. Wireless standards rely on four main features: carrier aggregation, multiple-input multiple-output (MIMO) mode, heterogeneous networks, and relaying. Multi-input multiple-output (MIMO) technology aggregates many LTE component carriers into a single LTE network, allowing for a high data throughput of up to 300 Mbps via the use of beam-forming and spatial multiplexing. - A Adaptive modulation and coding methods (AMC) such as 64-QAM, 16-QAM, and QPSK to enhance cellledge coverage and active radio link bit rate, and a physical layer to provide the system bandwidth required to maintain spectrum compatibility The downlink spectral efficiency for 8x8 MIMO should above 15 bps/Hz, and for 4x4 MIMO, the uplink spectral efficiency should be over 7 bps/Hz, according to LTE-A. Antennas for both transmission and reception are more numerous than in LTE. Cell edge coverage and antenna arrays are both enhanced by the beam forming concept in LTE - A. With CoMP, each cell is physically identified and communicated with its own synchronous channel and reference signal via a relay node between the base station and the mobile device. The idea of carrier aggregation allows for an increase in transmission capacity by using several carriers, whether they are adjacent or not. It is important that each component carrier executes its own HARQ retransmission separately. Compared to previous generations of wireless communications, the latency in the signalling and control planes should be lower. Modern methods like as MIMO, OFDMA, AMC, FDD/TDD, and others are essential to increasing the data rate that users may achieve. For LTE to work, higher-order MIMO is essential. A downlink allows for a high data rate. In order to enhance cell edge coverage and decrease overall traffic intensity from macro to micro, pico, or femto cells, HetNet is a deployment technique. In a cost-effective manner, heterogeneous networks provide broadband services. It balances the load as the number of subscribers grows by using pico or femto cells. Both local and broad area relay systems are feasible. LTE-A relay idea enhances both coverage and data speeds.

LTE – A Physical Downlink Processing

The transmission of data from the improved node B at the base station to the user's or mobile device's equipment is a part of LTE, which stands for advanced physical downlink processing. To send and receive data across the downlink shared channel, a physical transceiver is used, as seen in Figure 2. For the purpose of sending transport blocks containing downlink data, the downlink shared channel serves as the transport channel. Precoding allows PDSCH to send code words, which are coded transport blocks, all at once. The first block to use a CRC for transport block error detection is the CRC attachment.



In LTE-A system, Multiple Input Multiple Output (MIMO) is employed to improve the overall data/bit rate by transmitting through two or more antennas as two or more different data streams. The transmission occurs with the help of same resources in both time and frequency but separated by different type of reference signals, received by two or more receiving antennas[23].

The different logical channels for downlink of an LTE-A system and its use are listed in Table 1. The control channels of LTE-A downlink has BCCH, PCCH, CCCH, DCCH and MCCH and the traffic channels for downlink have DTCH and MTCH The transport Channels are distinguished by the way in which the processor of the transport channel influences them. LTE-A downlink transport channels are BCH, DL-SCH, PCH and MCH are given in Table 2

Table 1 Logical channels for LTE-A downlink

Category	Name of the Channel	Function of the channel
Control Channels	Broadcast Control Channel (BCCH)	Provide broadcasting services
	Paging Control Channel (PCCH)	Paging the user/mobile equipment
	Common Control Channel (CCCH)	Common to multiple user equipments
	Dedicated Control Channel (DCCH)	Dedicated to only one user equipment
	Multicast Control Channel (MCCH)	Transmit information for multicast services
Traffic Channels	Dedicated Traffic Channel (DTCH)	Dedicated traffic for a particular user equipment
	Multicast Traffic Channel (MTCH)	Transmit multicast data

Table 2 Transport channels for LTE-A downlink

Category	Name of the Channel	Function of the channel
Transport Channels	Broadcast Channel (BCH)	Carries information and send it to physical broadcast channel
	Downlink Shared Channel (DL-SCH)	Main channel for downlink data transfer, used by logical channels and send information to PDSCH

	Paging Channel (PCH)	Convey PCCH information and mapped to PDSCH, Carries paging information
	Multicast Channel (MCH)	Transmit MCCH information, mapped to PMCH and used for MBMS services.

A large number of physical channels allow data to be sent across the various physical layers in the LTE-A downlink. When information has to be transferred across multiple levels, the physical routes are crucial. Downlink physical control channels and downlink physical data channels are the two main categories into which they fall. Table 3.3 displays the various physical channels and their respective functions as provided by Andre Perez (2015) for the LTE-A downlink system. We have PBCH, PDSCH, and PMCH as data channels. We have PCFICH, PDDCH, and PHICH as our control channels. Also included are specialised control channels for use in heterogeneous networks; these allow for the transmission of control signals such as HARQ, CQI, and RS signals, as well as the incorporation of channel estimation and precoding concepts to counteract interferences, improve reconstruction quality while decreasing error rates, and generally boost system performance.

Requirements Of Channel Estimation

Since wireless channel is more time variant in nature and always changing channel coefficients due to the random change in channel statistics, there is a necessity to design and develop an efficient optimized algorithm to reduce the normalized squared mean error between the original as well as the estimated channel matrix coefficients. The pilot/training based channel estimations LSE and LMMSE were defined. LSE is having easy implementation but has high MSE. LMMSE has low MSE than LSE but highly complex in implementation due to matrix inverse calculation every time the channel statistic changes. To adapt the channel variations and to reduce the MSE, a best channel estimation algorithm is needed. A lot of optimization techniques like ANN, GA,
PSO and ABC were developed but has disadvantages like low convergence speed, more convergence time, not suitable for a global environment like wireless channel and sometime results in premature convergence. Premature convergence is defined as the attainment of false optimum solution before completing the required generations.

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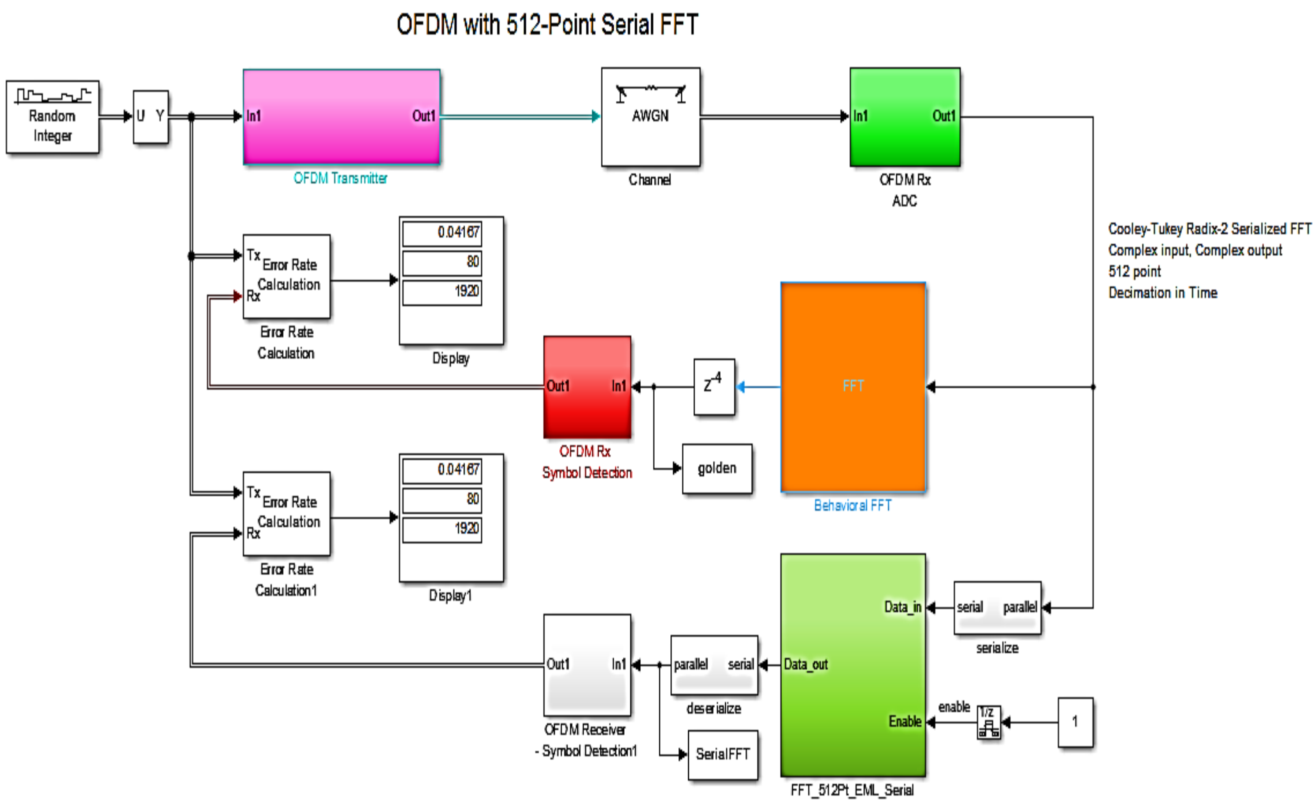

Figure 2.OFDM Communication System with 512-Point Serial FFT Implementation

This Simulink diagram represents an Orthogonal Frequency Division Multiplexing (OFDM) communication system with a 512-point Serial Fast Fourier Transform (FFT) for signal processing. Below is a detailed explanation of its components:

1. Random Integer Generator: Generates random integers, representing the data bits to be transmitted. Connects to the OFDM Transmitter block.
2. OFDM Transmitter Modulates the input data using OFDM by mapping the data onto multiple subcarriers.)Transmits the modulated signal to the channel.
3. AWGN Channel Adds Additive White Gaussian Noise (AWGN) to simulate real-world channel conditions. Receives the transmitted signal from the OFDM Transmitter. Feeds the noisy signal to the OFDM Rx ADC block.
4. OFDM Rx ADC Processes the received signal by converting it into a format suitable for FFT-based demodulation. Passes the processed signal to the Behavioral FFT block.
5. Behavioral FFT Implements a behavioral model of the FFT for demodulating the OFDM signal.

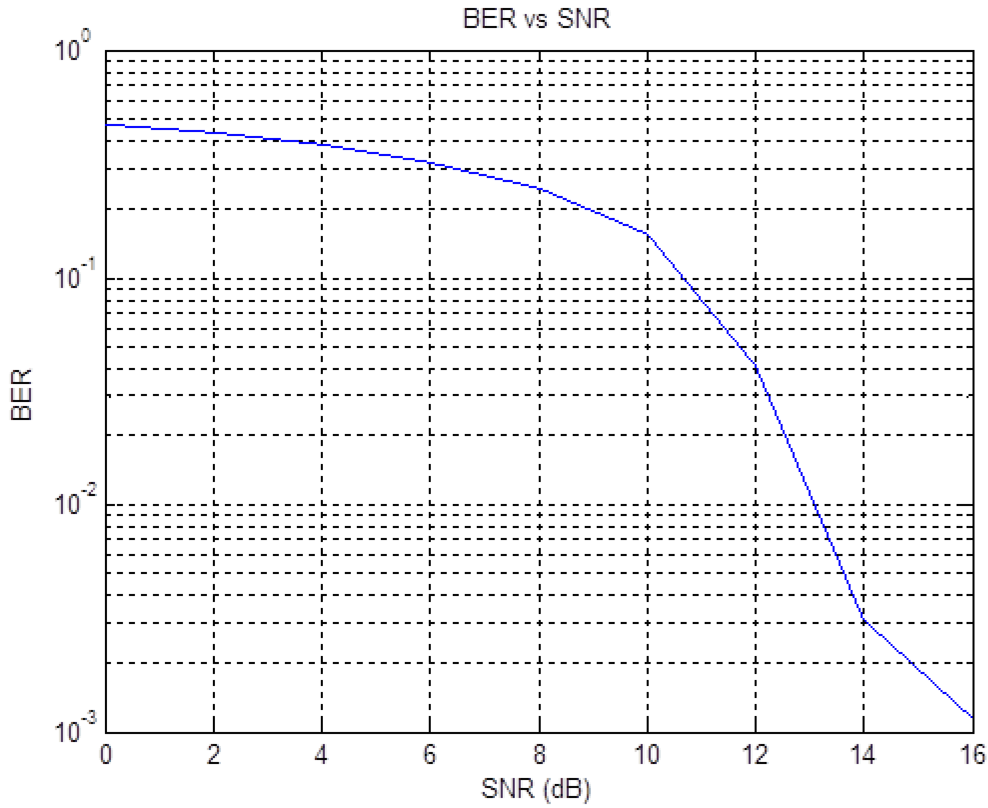

Figure 3. validates the robustness of the OFDM system design, ensuring that it performs well under varying noise levels, as simulated in the associated Simulink model

As shown in figure 3 The steep drop-off indicates that the system's error-correcting mechanisms (like the 512-point FFT) work effectively as SNR improves. The behavior of this curve can be compared with theoretical results or other modulation schemes to assess the system's efficiency.

CONCLUSION

The simulation of channel estimation in MIMO-OFDM systems for 5G New Radio demonstrates its capability for precise indoor signaling and carrier phase reception. The integration of advanced pilot-based estimation techniques ensures accurate channel state information (CSI) under multipath and high-dynamic environments. This enhances spectral efficiency, signal robustness, and throughput in 5G networks. The study reveals that MIMO-OFDM effectively combats indoor signal fading and interference, ensuring reliable data transmission. Carrier phase tracking plays a vital role in maintaining synchronization for precise signal decoding. The adoption of scalable subcarrier allocation further optimizes resource usage. Overall, MIMO-OFDM with efficient channel estimation proves indispensable for supporting the high data rate and low latency demands of next-generation 5G communication systems.

REFERENCES

1. R. Kumar, I. Singh, A. Alkhayyat, A. Joshi, A. Badhoutiya and S. Singh, "5G: Radio Technology Crafted for Wireless Cellular Connectivity," *2024 11th International Conference on Computing for Sustainable Global Development (INDIACom)*, New Delhi, India, 2024, pp. 721-726, doi: 10.23919/INDIACom61295.2024.10499113.
2. Y. Wan, G. Liu, A. Liu and M. -J. Zhao, "Robust Multi-User Channel Tracking Scheme for 5G New Radio," in *IEEE Transactions on Wireless Communications*, vol. 23, no. 6, pp. 5878-5894, June 2024, doi: 10.1109/TWC.2023.3328784
3. Anupriya and V. Nandal, "Evaluation of Multi-carrier Modulation Techniques for 5G Networks," *2023 First International Conference on Advances in Electrical, Electronics and Computational Intelligence (ICAEECI)*, Tiruchengode, India, 2023, pp. 1-6, doi: 10.1109/ICAEECI58247.2023.10370955.
4. M. W. Nichols, A. Gonzalez, E. A. Alwan and J. L. Volakis, "An accordion-folding series-fed patch array with finite thickness: A folding technique for CubeSat arrays", IEEE Antennas Propag. Mag., vol. 65, no. 3, pp. 77-82, Jan. 2023.
5. S. Sharma, A. Kumar and K. Kumar, "A Deep Q-Learning based Architecture for 2 and 4 Users to Optimize Power Allocation and Signal Detection in NOMA Cognitive Radio Networks," *2024 First International Conference on Electronics, Communication and Signal Processing (ICECSP)*, New Delhi, India, 2024, pp. 1-6, doi: 10.1109/ICECSP61809.2024.10698709.
6. M. Tanio, N. Ishii and K. Muraoka, "Wideband Delta-Sigma Radio-over-Fiber Embedding a Pulse-Distortion Model for Beyond 5G," *2022 IEEE 96th Vehicular Technology Conference (VTC2022-Fall)*, London, United Kingdom, 2022, pp. 1-5, doi: 10.1109/VTC2022-Fall57202.2022.10013014.
7. Y. Wan and A. Liu, "A Two-Stage 2D Channel Extrapolation Scheme for TDD 5G NR Systems," in *IEEE Transactions on Wireless Communications*, vol. 23, no. 8, pp. 8497-8511, Aug. 2024, doi: 10.1109/TWC.2024.3351212.
8. H. Babaroglu, L. Anttila, G. Xu and M. Valkama, "Digital Post-Distortion for Multi-Layer MIMO-OFDM," in *IEEE Wireless Communications Letters*, vol. 13, no. 7, pp. 1803-1807, July 2024, doi: 10.1109/LWC.2024.3389695.
9. V. Chauhan and Srinivasans, "A Review on 5G Network System with its limitation and different Approaches to build strong 5G Network System," *2022 3rd International Conference on Intelligent Engineering and Management (ICIEM)*, London, United Kingdom, 2022, pp. 403-410, doi: 10.1109/ICIEM54221.2022.9853134.
10. X. Lin, "An Overview of 5G Advanced Evolution in 3GPP Release 18," in *IEEE Communications Standards Magazine*, vol. 6, no. 3, pp. 77-83, September 2022, doi: 10.1109/MCOMSTD.0001.2200001.
11. Felipe A. P. de Figueiredo, Fabbryccio A. C. M. Cardoso, Ingrid Moerman and Gustavo Fraidenraich, "On the Application of Massive MIMO Systems to Machine Type Communications", IEEE Access, vol. 7, no. 12, pp. 2589-2611, December 2018.
12. Mansoor Shafi, Andreas F. Molisch, Peter J. Smith, Thomas Haustein, Peiying Zhu, Prasan De Silva, et al., "5G: A Tutorial Overview of Standards Trials Challenges Deployment and Practice", IEEE Journal on Selected Areas in Communications, vol. 35, no. 6, pp. 1201-1221, June 2017.

13. A. V. Stenin and A. A. Kalachikov, "Numerical Evaluation of the Channel Estimation in 5G NR Based on Machine Learning", 2022 IEEE 23rd International Conference of Young Professionals in Electron Devices and Materials (EDM), pp. 285-288, 2022
14. H.A. Le, T. Van Chien, T.H. Nguyen, H. Choo and V.D. Nguyen, "Machine Learning-Based 5G-and-Beyond Channel Estimation for MIMO-OFDM Communication Systems", Sensors, vol. 21, pp. 4861, 2021.
15. A. L. Ha, T. Van Chien, T. H. Nguyen, W. Choi and V. D. Nguyen, "Deep Learning-Aided 5G Channel Estimation", 2021 15th International Conference on Ubiquitous Information Management and Communication (IMCOM), pp. 1-7, 2021.
16. S. I. H. Shah, S. Bashir, M. Ashfaq, A. Altaf and H. Rmili, "Lightweight and low-cost deployable origami antennas—A review", IEEE Access, vol. 9, pp. 86429-86448, 2021.
17. T. Wild, V. Braun and H. Viswanathan, "Joint design of communication and sensing for beyond 5G and 6G systems", IEEE Access, vol. 9, pp. 30845-30857, 2021.
18. K. B. Letaief, W. Chen, Y. Shi, J. Zhang and Y. A. Zhang, "The roadmap to 6G: AI empowered wireless networks", IEEE Commun. Mag., vol. 57, no. 8, pp. 84-90, Aug. 2019.
19. M. Pengnoo, M. T. Barros, L. Wuttisittikulkij, B. Butler, A. Davy and S. Balasubramaniam, "Digital twin for metasurface reflector management in 6G terahertz communications", IEEE Access, vol. 8, pp. 114580-114596, 2020.
20. N. Shlezinger, G. C. Alexandropoulos, M. F. Imani, Y. C. Eldar and D. R. Smith, "Dynamic metasurface antennas for 6G extreme massive MIMO communications", IEEE Wireless Commun., vol. 28, no. 2, pp. 106-113, Apr. 2021.
21. R. Chataut and R. Akl, "Massive MIMO systems for 5G and beyond networks—Overview recent trends challenges and future research direction", Sensors, vol. 20, no. 10, pp. 2753, 2021.
22. M. Sakai, K. Kamohara, H. Iura, H. Nishimoto, K. Ishioka, Y. Murata, et al., "Experimental field trials on MU-MIMO transmissions for high SHF wide-band massive MIMO in 5G", IEEE Trans. Wireless Commun., vol. 19, no. 4, pp. 2196-2207, Apr. 2020.
23. A. F. Molisch, V. V. Ratnam, S. Han, Z. Li, S. L. H. Nguyen, L. Li, et al., "Hybrid beamforming for massive MIMO: A survey", IEEE Commun. Mag., vol. 55, no. 9, pp. 134-141, Sep. 2017.