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Improvement of 5G Telecommunication Network Using Adaptive Artificial Intelligent Based Antenna Technology

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***Abstract* - The swift growth of 5G communication networks necessitates creative approaches to improve dependability, effectiveness, and performance. This paper investigates how to enhance 5G network capabilities through the integration of antenna technology based on adaptive artificial intelligence (AI). Complicated and dynamic settings are frequently too difficult for conventional static antenna setups to handle. Adaptive antennas can dynamically modify their characteristics, such as beamforming and power regulation, in real-time to maximize signal quality and coverage by utilizing AI methods, such as machine learning and deep learning. Using both simulations and in-field testing, the study assesses how AI-based adaptive antennas affect important performance measures including spectrum efficiency, latency, bit-error rate and network throughput. The findings show that 5G networks' capacity and flexibility are greatly increased by AI-based adaptive antenna systems, making them more resistant to changing environmental factors and user density. This technology is expected to play a major role in enabling 5G and beyond network realization.**

Keywords: 5G networks, adaptive antenna technology, artificial intelligence, machine learning, beam forming, network optimization, spectral efficiency, real-time signal processing, telecommunications, dynamic environment adaptation.

I. Introduction

The swift progression of fifth-generation (5G) telecommunication networks has compelled the advancement of sophisticated technologies to fulfill the escalating needs for dependable, high-speed, and low-latency communication systems (Ifeagwu, *et al*, 2011). Traditional antenna systems frequently fail to deliver the necessary performance as 5G networks strive to handle a variety of applications, including large machine-type communications, ultra-reliable low-latency communications, and better mobile broadband (Alor, *et al*, 2022). Researchers and engineers are looking at creative ways to get beyond these restrictions, such as using antenna technology based on adaptive artificial intelligence (AI). Artificial intelligence (AI)-integrated antenna systems provide various benefits over traditional designs. They use machine learning algorithms to dynamically modify important antenna characteristics in real-time. Because of its versatility, the antenna can effectively minimize interference, maximize performance in a variety of settings, and guarantee efficient use of the available spectrum. Antennas with adaptive AI capabilities can improve beamforming, allocate power optimally, and modify radiation patterns to sustain signal quality even in intricate propagation situations like urban canyons and densely populated areas (Ifeagwu, *et al,* 2015a). The goal of this research is to deploy AI-based adaptive antenna technology to enhance 5G telecommunication networks. The main objective is to create an intelligent antenna system that can optimize its setup to improve network performance and can adapt to the radio environment on its own. The suggested system intends to handle issues including multipath fading, high interference levels, and fluctuating user demand by utilizing AI approaches like machine learning, neural networks, and reinforcement learning. This study will assess the effects of AI-based adaptive antennas on important performance parameters like data throughput, network capacity, and signal quality through simulation and experimental validation. The project's results should show a notable increase in 5G networks' overall efficiency, opening the door for more durable and adaptable communication systems that can handle the demands of wireless communication in the future.

II. Adaptive Based Artificial Intelligent Antenna

Only Omni-directional antennas were used in the early stages of wireless communication (Mbachu, *et al.*, 2011a). A basic dipole serves as the antenna's primary component, emitting and receiving electromagnetic waves in the form of signals in all directions. In radio frequency areas, Omni-directional antennas are sufficient even in the absence of user position information. Few of the dispersed signals are able to reach the receiver thanks to the Omni-directional antenna. Interference arises in the same or adjacent cells as the number of users increases. Users fight over the signal energy rather than the Omni-directional antennas' strength for their broadcast.

The omni-directional antenna technique lacks multipath reduction and equalization strength, and it is unable to selectively null signals that interfere with the user's signal (Moraitis, *et al*, 2002). The evolution of the standard sector antenna in use today was prompted by these constraints on the quality, capacity, and coverage of the wireless network (Enebe, *et al.*, 2017).

According to Ohaneme *et al.* (2012), a sectorized antenna is a microwave directional antenna with a sectorized-shaped radiation pattern that is designed to have set directions for transmission and reception. A cellular region is divided into sectors by sectorized antennas, which use directional antennas and the same base station for reference.

The sector antenna can be used for limited-range lengths of roughly 4 to 5 km. It sends signals in a specific direction, covering a larger area than an omni-directional area. In a cellular system, a sectorized antenna system, as opposed to an Omni-directional antenna, maximizes the reuse frequency channel by reducing co-channel interference within the origin cell (Idigo, *et al*, 2011). The fact that each sector of the sector antenna system uses a different frequency to lessen co-channel interference is one of its drawbacks. As we have seen today, handoffs between sectors might occur, which results in a weak signal. The sectorized antenna system's inability to suppress undesired users and provide the maximum beam to intended users is another drawback (Ifeagwu, *et al*, 2015b)

Adaptive based Artificial Intelligent antenna systems were created in mobile communication networks in response to these shortcomings of the sector antenna system now in use (Ifeagwu et al., 2015c).

III. Materials and Methods

3.1 Materials

The materials and techniques used in the creation and assessment of the suggested adaptive AI-based antenna system for 5G telecommunication networks are thoroughly described in this paper. The design and simulation of the intelligent antenna, the choice and application of AI algorithms, performance criteria for assessment, and experimental setting are all included in the research process. The objective is to present a methodical framework for the methodical examination and enhancement of adaptive antenna technology.

(A) Software Tools

(i) The adaptive based AI antenna and its variants are designed and simulated using the Ray Tracer Simulator. RTS offers a thorough environment for electromagnetic study and enables the simulation of intricate antenna configurations.

(ii) MATLAB: Used to implement AI algorithms, including neural networks, machine learning models, and reinforcement learning methods. The computational power of MATLAB is used to mimic the antenna's adaptive behavior.

(B) Hardware Tools

(i) The adaptive based AI antenna: To assess the design parameters, a prototype antenna is constructed using materials like FR4 or Rogers RT/duroid 5880. The antenna can function at a frequency range of 2.5 GHz to 28 GHz, which is appropriate for 5G applications. When combined with AI control systems, it can exhibit adaptive behavior.

(ii) Software-Defined Radio (SDR): In a 5G network configuration, SDR is utilized to test the AI-controlled antenna system's ability to adapt in real time.

(iii) The spectrum network analyzer, or SNA, is used to measure the constructed antenna's gain, bandwidth, and return loss, among other performance measures.

(C) Data source

(i) Simulation Data: AI models are trained and validated using data produced by RTS and MATLAB simulations.

(ii) Empirical Data: The performance of AI-based and conventional antenna systems is compared using data from experimental measurements made with a SNA and SDR setup.

3.1.1 The Equipment Specifications

Equipment specifications:

(i) The base station covered transmitting antenna is a Haewaii 5G device with a 60 (down) slanted, 120 sector type.

(ii) The transmitting antennas have a gain of 16 dBi.

(iii) The mobile station's reception antenna is a horn antenna of the Schwarz Beck BBHA9120 E0899 D69250 Schonau variant.

(iv) The height of the receiving mobile antenna is 1.8 meters. The reception antenna on the mobile device has a gain of 11.3 dBi.

Other details and criteria that are being thought about are:

3.1.2 Spectrum analyzer

(i) Bench top spectrum analyzers are the type used.
(ii) The Agilent B4407 ESA-E Series spectrum analyzer model
(iii) The spectrum analyzer's frequency ranges from 9KHz to 26.5 GHz.
(iv) The spectrum analyzer's resolution bandwidth is 30KHz.
(v) The spectrum analyzer's video bandwidth is 10KHz
(vi) 50ms is the sweep time.

3.1.3 The antenna of Mobile Station (MS)

(i) Type: horn antenna.
(ii) The Model is Gilat CCBH 9120 E0899 D69250.
(iii) The range of frequency is 550 – 5000MHz.
(iv) The isotropic Gains is 5.80 – 18.70dBi.
(v) Antenna factor: 17.50 – 28.03dB/m
(vi) Transmitting power:44.4 dBm
(vii) Transmitting frequency:2.5GHz

(D) Parameters of Base Station

(i) Antenna base station height = 36m.
(ii) Power level reference = 30dBm.
(iii) Frequency = 2.5GHz.

3.2 Method

3.2.1 Experimental Setup

Quality of service metrics that will aid in the system analysis are sought after in order to deliver an excellent analysis of the network system that will guarantee such good quality of service to customers. In order to do this, real-time measurements were made, and the effectiveness of the current infrastructure was determined using the data collected. The base transceiver station that sends out the signals is displayed. Ray tracer is used to gather the transmitted signal strength. Software called ray tracers is designed to show the presence and strength of a signal at a specific location. A ray tracer will determine the intensity of the received signal in any given channel.

The global positioning system measures the distances between the transmitter and the receiver, while the ray tracer indicates the signal strength. The mobile station's angular locations in relation to the transmitting base station can be determined using a GPS. A spectrum analyzer was used to record and examine all of the collected data. The measuring equipment's interconnectivity is depicted in Figure 1.

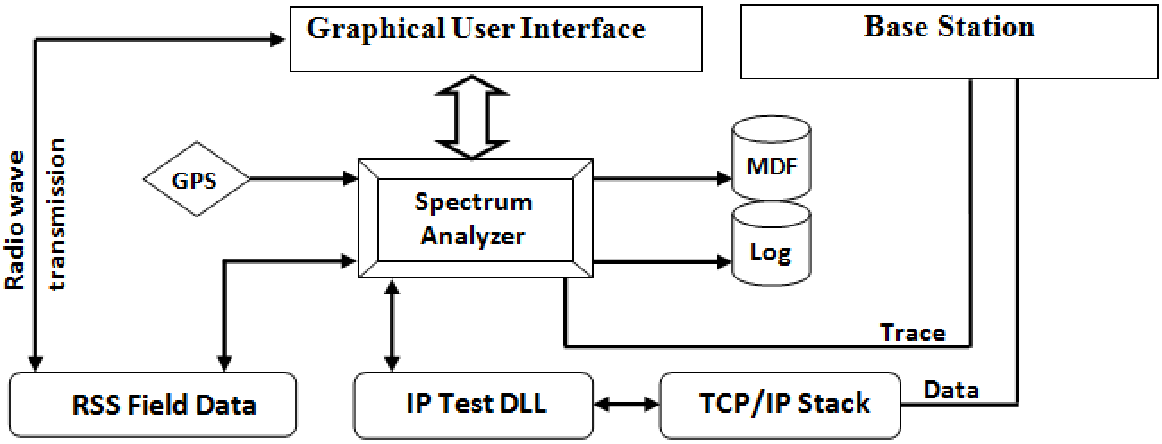

Figure 1: Monitoring equipment Interconnectivity

3.2.2 Environmental Measurement

The drive test measurement route is shown in Figure 1. It comprises little, three to four-story homes with backyards and a poorly developed area. The houses had metal roofs and clay brick walls. There are many bushes in the area and majorly agricultural terrain. At intervals of 100 meters to 700 meters, measurements of the received signal intensity were taken from a reference location on the transmitting base station. The surroundings included little, two- to three-story homes with backyards and a poorly developed area. The homes had metal roofs and clay brick walls. There are hardly many bushes in the area and mostly agricultural terrain. At intervals of 100 meters to 1700 meters, measurements of the received signal intensity were taken from a reference location on the transmitting base station.

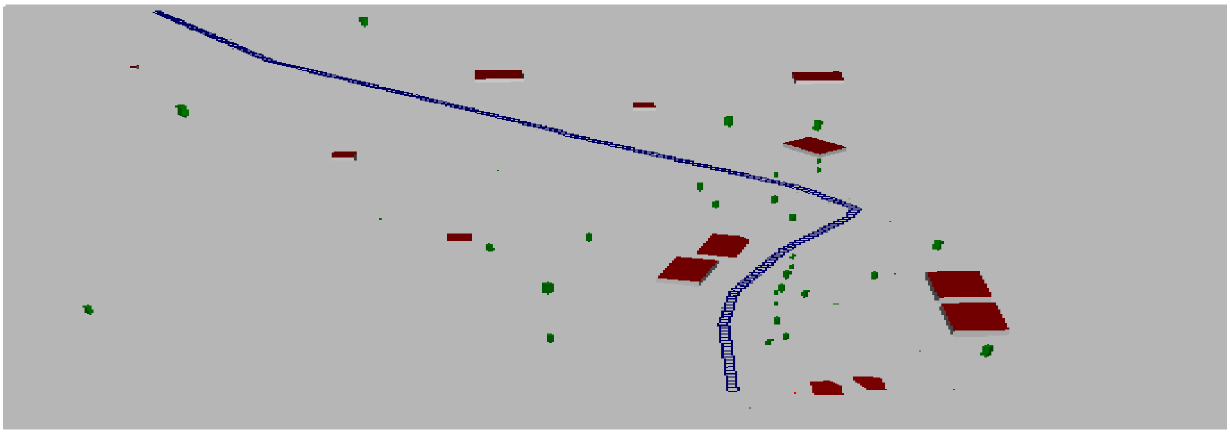

Figure 2: Measurement Route

A base station and a receiver antenna installed on the top of the spectrum monitoring van, which holds the spectrum monitoring apparatus, make up the measurement used on the first scene. An antenna for the base station is 36 meters high, and a mobile antenna was put atop a test van that is 3 meters tall. A 5G network is the base station that was taken into consideration for this inquiry. The network in question uses 2.5 GHz as its carrier frequency.

Even though there were occasional overlaps from two antenna sectors, the test van used for the experiment was driven in the direction of one antenna sector. Test bed transmitter to receiver (T-R) separation distances are measured by the Global Positioning System (GPS), ranging from many multiples of 100m to 1700m.

Four operational base stations were seen during the driving test, and the ray tracer assisted in selecting the network of choice signal from a number of signals from different networks. Setting the right frequency for the desired network to run on allows for this.

The ray tracer assisted in locating the base station that transmits at that specific frequency because it runs at 2.5GHz. On the other hand, the signals' intensities and distances from the base station's reference point were noted at different times. The Global Positioning System was used to determine these kilometers (GPS).

When the van moves away from the base station, a mobile device inside records and monitors the signal it receives in order to do signal-energy measurements. Every day from 9:00 am to 5:00 pm is when measurements are conducted for the duration of the measurement.

3.2.3 Determination of Path Loss Exponent

Pathloss also occurs due to the growth of mobile users Pathloss exponent (*n*) shows the rate of degradation of signal in the concerned area. The pathloss exponent of the testbed environment can be obtained using the average received signal strength in Table 1. To characterize propagation path loss for a specific cell site, values should be established for the path loss at a close-in reference distance, $L_p(d_0)$ and path loss exponent, *n* (Ifeagwu, *et al*, 2017).

Using a reference distance of 100m, $L_p(d_0)$ is 101dB. The path loss exponent *n*, which characterizes the propagation environment in our site of interest, is obtained by method of Linear Regression (LR) analysis. The path loss exponent, *n*, is given in equation (1) as:

$$n = \frac{\sum_{i=1}^{K} \{L_P(d_i) - L_P(d_0)\}}{\sum_{i=1}^{K} 10 \log\left(\frac{d_i}{d_0}\right)} \qquad (1)$$

Where $L_p(d_0)$ is path loss at a close-in reference distance, $L_p(d_i)$ is path loss at interval distance and, *n is* path loss exponent.

3.2.4 Simulation

The software for the radio propagation simulator was used to build the test bed region's prototype. The RPS network was configured using the specifications listed in Table 3.

The environment description geometry, which displays the reflective surfaces in the region and their characteristics, was the first parameter added to the simulator. By determining the coordinates of opposing corners in three-dimensional space, one can determine the locations of walls and other plane structures.

The Radio Propagation Simulator (RPS) network design is made up of transmitters and receivers grouped together with their matching antennas and other parameters including carrier signal frequency, transmitter antenna height, receiver antenna height, and transmitter power.

The transmitter displays the base station's network location. It is distinguished by its height and position. It transmits power and carrier frequency using an antenna that is polarized and oriented in a specific way. Rays are released from the transmitter's antenna during a coverage simulation, and they travel through the surrounding area. Rays emitted from the proposed transmitter antenna propagate throughout the entire simulated environment, and the Radio-wave Propagation Simulator (RPS) results of received signal strength are shown in Table 4. Path analysis along the designated route was used to obtain the received power in the simulated test-bed environment during simulation by deploying simulation parameters in Table 1.

Table 1: Simulation Parameters

Parameters	Values
Base station	One
Type of Transmitting antenna	Sector (tilted 30 degrees)
Height of transmitting antenna	36m
Transmitting Power	47.4deciBelmeter
Polarization	Vertically linear
Carrier Frequency	2.5GHz
Types of receiver antenna	Conventional, AI based Adaptive Base station antenna
Receiver height of antenna	1.6m
Algorithm	3-D

IV. Results and Discussion

4.1 Result Presentation

Table 2 shows the average measurement of received signal strength carried out on Day 1 till Day 8 on the Cell site: BA4601 of Frequency = 2.5GHZ and Transmitting Power is 47.4dBm

Table 2: Average Field Measurement of Received Signal Strength Carried Out On Day1 till Day 8

(Cell site: BA4601, Frequency =2.5 GHz, Transmitting Power =47.4dBm)

Distance from Tx [m]	Received power [dBm]	Average Path loss [dB]
100	-61.89	103.87
200	-64.78	105.80
300	-52.00	94.97
400	-52.80	95.10
500	-80.98	121.00
600	-82.89	124.29
700	-81.00	120.89
800	-94.00	134.69
900	-91.00	133.01
1000	-93.01	133.98
1100	-92.89	133.56
1200	-98.00	138.77
1300	-98.00	138.76
1400	-98.00	141.00
1500	-96.75	138.00
1600	-95.31	136.78
1700	-99.85	140.89

Table 3: Received Signal Strength [dBm] from Simulation (conventional antenna)

Distance from Tx [m]	Received power [dBm]	Average Path loss [dB]
100	-59.98	100.89
200	-60.04	101.89
300	-78.12	117.90
400	-82.98	129.98

500	-82.05	129.57
600	-73.89	114.98
700	-87.89	129.25
800	-89.21	128.97
900	-93.97	135.98
1000	-89.97	130.40
1100	-85.87	125.98
1200	-92.76	139.20
1300	-91.00	132.00
1400	-88.97	129.30
1500	-87.00	128.98
1600	-86.00	128.29
1700	-85.00	125.97

Table 4: Received signal strength obtained from simulation using AI based Adaptive Base station antenna

Distance from Tx [m]	Received power [dBm]
100	-63
200	-65
300	-68
400	-73
500	-82
600	-83
700	-95

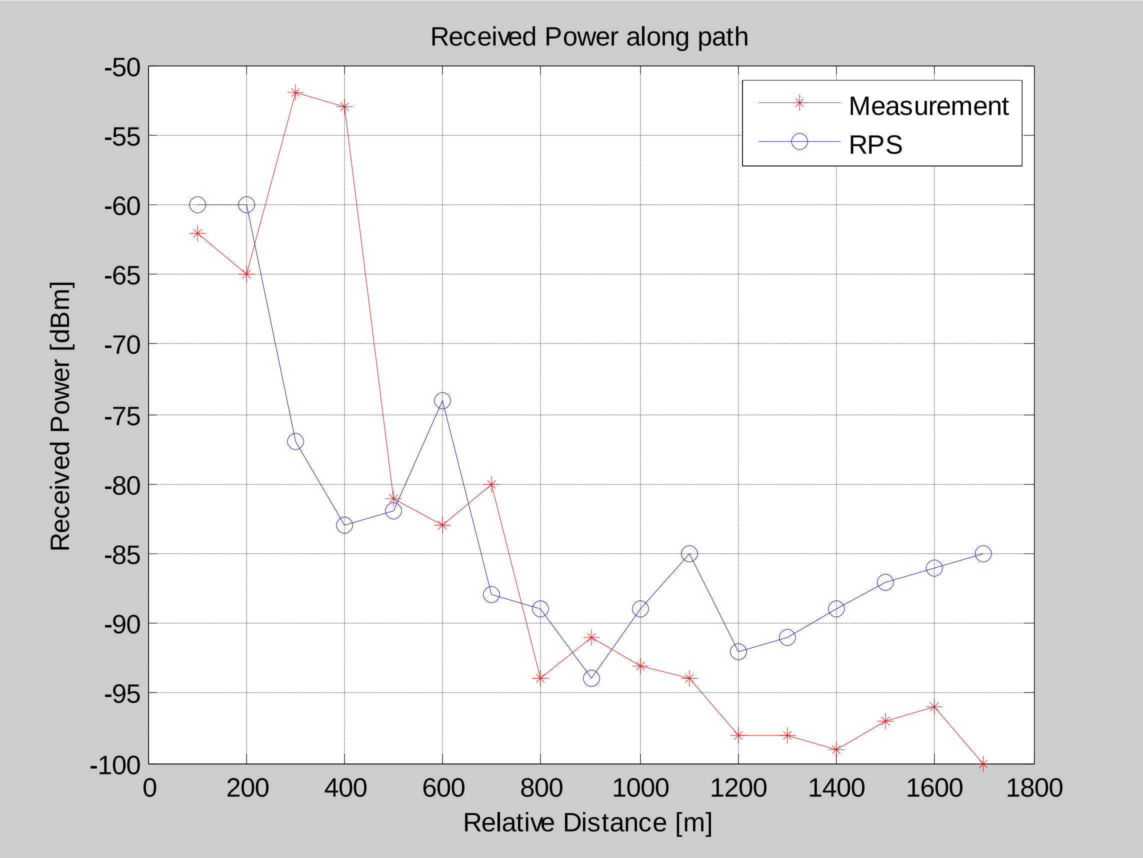

Figure 3: Good correlation between Simulation results and real Measurements

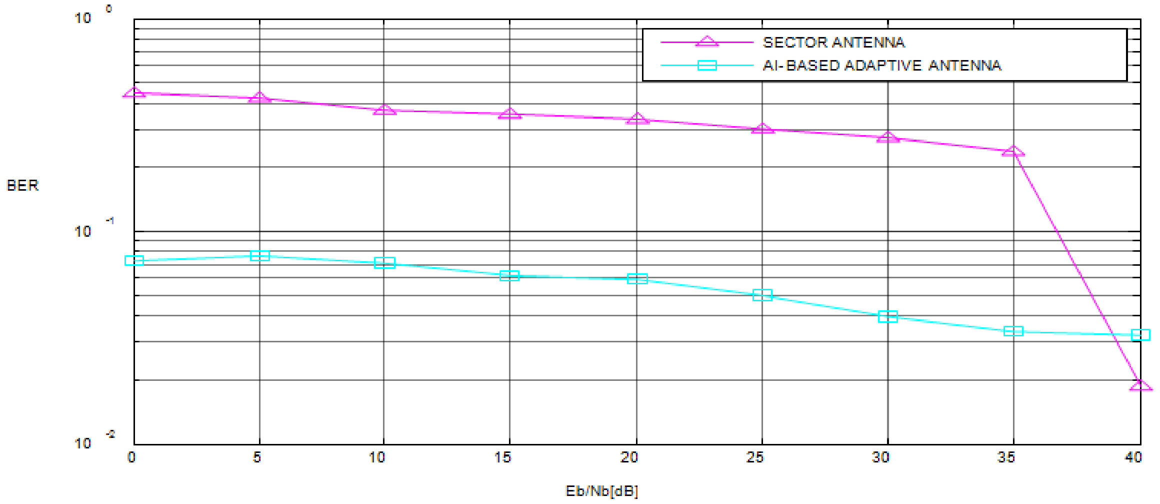

Figure 4: Show the comparison of the receiver average BER performance of 5G network with adaptive artificial intelligent based antenna technology and conventional antenna system

In Figure 4, the comparison of the receiver average BER performance of 5G network with adaptive artificial intelligent based antenna technology and conventional antenna system is shown.

4.2 Discussion

MatLab is used to analyse both Table 2 and Table 3 using equation (1) to obtain path loss exponents of 2.62 and 2.68 respectively. But, using the AI-based adaptive antenna algorithm yielded the received signal strength shown in Table 4 with a pathoss exponent of 2.16.

The fluctuating received signal strength of the mobile devices as they travel away from the transmitter base station is depicted in Figure 3. Additionally, Figure 3 shows how the received signal strength changes as the mobile users walk away from the base station at different places within the cell. Additionally, Figure 3 in particular demonstrates how the topography and multipath effects in the area fluctuate with respect to the RSS at different locations of the mobile users. This further demonstrates that the mobile station experiences varying degrees of interference at different times as a result of multipath and shadow fading, which cause the signal to vary log regularly over the system.

Thus, it can be concluded that Figure 3 illustrates how the transmitter to receiver distances cause the curves to follow the typical decline. But as Figure 3 shows, the mobile station seems to receive worse signal quality at some distant sites than it does at some closer locations.

The mean BER is improved with the adaptive artificial intelligent based antenna compared to the conventional antenna. The BER of the AI-based antenna is of order 10-2 at Eb/No≤ 10Db

In the 5G network, Figure 4 illustrates how adaptive based AI antenna technique can reduce the impact of multipath fading.

V. Conclusion

In the presence of significant interference, adaptive based AI antenna outperformed sector antenna in terms of 5G performance increase. Thus, enhancing an antenna system's ability to reduce interference and noise when significant interferers are present boosts the system's capacity when using such an AI based antenna. As a result, the AI based adaptive antenna used in this paper increases the network's capacity and permits the base station to receive a large number of new users.

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