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REDUCTION OF BER IN CELLULAR NETWORK TO ENHANCE THE PERFORMANCE USING ADAPTIVE ANTENNA TECHNIQUE

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ABSTRACT

In this paper, the main attention is on the Reduction of Bit Error Rate (BER) in Cellular networks to enhance the performance using an adaptive antenna method. To accomplish this, the Least Mean Square (LMS) method is adopted. The enormous progression in technology and complexity was witnessed because of the increase in demand for services. In wireless transmission, performance degradation would be observed in the signal transmission and reception due to a high degree of error occurrences. By conducting a drive test the performance of the network is evaluated by measuring the BER. From the results, it is found that the Modified Least Mean Square (MLMS) algorithm generated the lowest BER, equal to 0.0004142, which is very low compared to that of the BER from the drive test. Here in this paper, it is concluded that the MLMS method gave the improved performance along with the lowest BER value that too most effectively reduced than LMS method ensuring improved spectrum usage and optimized channel capacity. This work resulted in the enhancement of the current cellular network, and further work should be done to improve its application in both the horizontal and vertical azimuth directions.

Keywords: bit error rate, recursive least square (rls) algorithm, direct matrix inverse (dmi) algorithm, modified least mean square.

INTRODUCTION

Bit Error Rate (BER) is an important network performance metric. The interest in BER is due to the increase in radio recurrence range used in new strategies to improve range usage [1]. The current radio recurrence band allotted for portable remote correspondence is limited and overpriced and should be administered efficiently [2].

The direction of clients and interferers are assessed by their course of appearance calculation. This calculation is finished, using, MUSIC (Multiple Signal Classification), ESPIRIT (Estimation of Signal Parameters through Rotational Invariance Techniques), Grid Pencil procedure, or their subordinates [3]. They incorporate finding a spatial scope of the receiving antenna show and figuring the DOA (Direction of Arrival) from the pinnacles of the range [4].

Beamforming is the mix of radio signals from a bunch of little non-directional receiving antennas to mimic a huge directional receiving antenna. In beamforming, every client signal is duplicated with complex loads that change the size and period of each signal to and from every receiving antenna. A smart antenna system can change its directional reaction to invalidate the interferer for improving the gathering of the ideal signal [5]. Therefore Adaptive beamforming improves a signal of interest while suppressing the impedance signal and restricting the usage of a variety of sensors through the beamforming algorithm. The calculation method would help in placing the complex loads with the high radiation of the receiving antenna at the required place and the nulls toward the undesirable signals [6].

RELATED WORKS

The work in [7], had discussed improving the channel limit for remote locations by cell sectoring. The main focus was on solving the problem of network congestion using the 6-sectored cell technique. The work was analyzed with the help of Experimental setup (measurements), the System model of the sectored wireless network, and simulation of results. CDMA system is interference inherent, because of which the number of clients might experience the admittance problem to some area/location due to insufficient availability and poor quality of channels. This work gave an appropriate way of upgrading the cell capacity utilizing cell sectoring which enhanced client admittance by utilizing the accessible channels. It also discussed the reduction of interferers by using the sectoring strategy with directional antennas for ideal channel utilization.

RAKE RECEIVER IN CDMA20001x SYSTEM

Code Division Multiple Access (CDMA) 20001x (CDMA20001x) is the key technology used in 3G cellular systems. In the CDMA20001x interface, different data rates that vary in time can be simultaneously transmitted by different users. The physical layer of CDMA20001x can adapt to different service types at a time, especially with respect to low and medium bit rates [8].

In CDMA systems, the chip rate is usually much greater than the flat fading bandwidth of the channel. CDMA spreading code provides a low correlation between successive chips. Because of the propagation delay spread in the radio channel, multiple versions of the transmitted signal at the receiver are raised. If these multipath signals are delayed in time by more than chip duration, they emerge as uncorrelated noise at a CDMA receiver. The multipath signals will carry some important required information and now these CDMA receivers will combine the time-delayed original transmitted signal to improve the SNR at the receiver. This function is carried out by a Rake Receiver. This Rake receiver of CDMA1x cellular systems is a diverse receiver that combines the time-shifted versions of the original signal collected with a separate correlation receiver for each multipath signal. The Rake receiver in Figure-1 consists of different branches equal to the multipath components, and each multipath branch is called a finger [9].

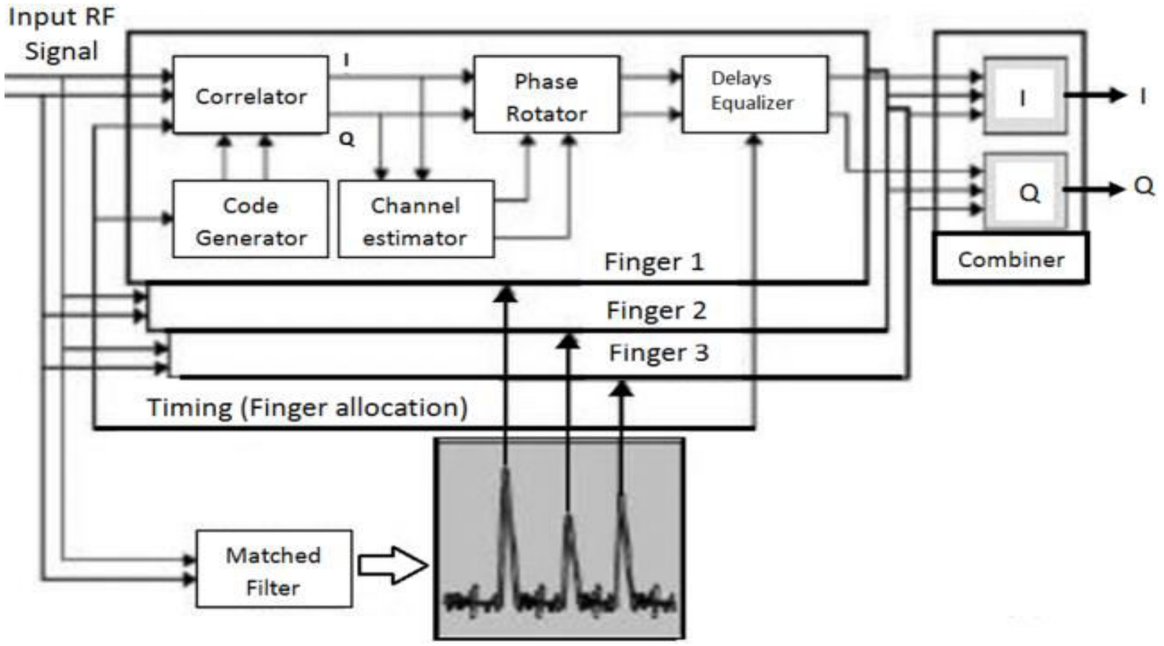

Figure-1. Block diagram of the rake receiver [9].

CHARACTERIZATION OF MOBILE RADIO PROPAGATION ENVIRONMENT

In order to describe a propagation environment the following parameters must be known:

a) Received signal strength obtained from field measurement
b) The path loss exponent n, of the characterized environment
c) An empirical propagation path loss model for the test bed environment.

DETERMINATION OF PATHLOSS EXPONENT (N) OF TESTBED ENVIRONMENT

The path loss exponent n is an experimental constant that is related to the propagation environment. To determine the path loss exponent n of the test bed area measurement were done to see how the signal strength decreases with an increase in distance. It can be manually computed using this equation:

$$P_L(d_i)\ [dB] = P_L(d_0)\ [dB] + n10log10(\tfrac{d_i}{d_0}) \qquad (1)$$

Where n = path loss exponent, the value of n depends on the specific propagation environment.

$P_L(d_0)$ = path loss at known reference distance d_0

$P_L(d_i)$ [dB] = path loss due to transmitter receiver separation distance d_i

The free-space model anyway is an over-elevation, and the spread of a signal is influenced by reflection, diffraction, and dispersing. It is acknowledged based on observational proof that it is sensible to demonstrate the path loss $P_L(d_i)$ at any estimation of d at a specific area as an arbitrary and log-regularly conveyed irregular variable with a separation subordinate mean worth [10]. That is:

$$P_L(di)\ [\mathrm{dB}] = P_L(d0)\ [\mathrm{dB}] + 10n\ \log10(\tfrac{d_i}{d_0}) + S \qquad (2)$$

Where S, the shadowing factor is a Gaussian random variable (with values in dB). The path loss n, is an observational constant that depends upon the environment. To decide the path loss coefficient n of the proving ground territory/climate to actually form it as:

$$n = \frac{\{P_L(d_i)-P_L(d_0)\}}{10log_{10}(\frac{d_i}{d_0})} \qquad (3)$$

If it is a straight return, the estimation of n can be resolved from the information by limiting error R^2as follows:

$$R^2 = \sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10nlog_{10}\left(\frac{d_i}{d_0}\right)\right]^2 \qquad (4)$$

Differentiating equation (30) with respect to n,

$$\frac{\partial \mathrm{R}^2(\mathrm{n})}{\partial \mathrm{n}} = -20\log_{10}(\mathrm{d})\sum_{\mathrm{i=1}}^{\mathrm{M}}\left[\mathrm{P_L(d_i) - P_L(d_0) - 10nlog_{10}}\left(\frac{\mathrm{d_i}}{\mathrm{d_0}}\right)\right]$$

Equating $\frac{\partial R^2(n)}{\partial n}$ to zero,

$$0 = -20log_{10}(d)\sum_{i=1}^{M}\left[P_L(d_i) - P_L(d_0) - 10nlog_{10}\left(\frac{d_i}{d_0}\right)\right]$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - 10nlog_{10}\left(\frac{d_i}{d_0}\right) = 0$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] - \sum_{i=1}^{M}\left[10nlog_{10}\left(\frac{d_i}{d_0}\right)\right] = 0$$

$$\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)] = \sum_{i=1}^{M}\left[10nlog_{10}\left(\frac{d_i}{d_0}\right)\right]$$

Therefore, $n = \frac{\sum_{i=1}^{M}[P_L(d_i) - P_L(d_0)]}{\sum_{i=1}^{M}\left[10log_{10}\left(\frac{d_i}{d_0}\right)\right]}$ (5)

EMPIRICAL PATHLOSS MODEL FOR MOBILE RADIO ENVIRONMENT

The path loss model for free space is given by equation [11]

$Lp_{fs}(dB) = 32.44 + 20\log10(f_c) + 20\log10(d_i)$ (6)

Where

Lp_{fs}	is the free space path loss
f_c	is the carrier frequency in (MHz)
d_i	is the separation between the base station (BS) and mobile station (MS) in (Km).

The Hata path loss model for the metropolitan and rural environment is given individually.

$$Lp_u(dB) = 69.55 + 26.16\log10\,(f_c) + (44.9 - 6.55\log10h_b)$$
$$\log(d_i) - 13.82\log10(h_b) - \alpha\,(h_m) \quad (7)$$

$$Lp_s = Lp_u - 2[\log10\,(\tfrac{fc}{28})]2 - 5.4 \quad (8)$$

Where;

L_{pu}	is the path loss prediction for urban area in dB
L_{ps}	is the path loss prediction for suburban area in dB
$\alpha\,(h_m)$	is the correlation factor for mobile station receiving antenna height in dB
h_b	is the height of BS (km), h_m is the height of MS.

The correlation factor α (h_m) for suburban is given as:

$$\alpha\,(h_m) = [1.1\log_{10}f_c - 0.7]h_m - [1.56\log f_c - 0.8] \quad (10)$$

PROPOSED BER IMPROVEMENT ALGORITHM USING LMS

The proposed system unlike the conventional adaptive antenna system defines an error signal by differentiating the real output and the reference/wanted signal. The error is now being controlled using the modified algorithm which in turn controls the weighting function to enhance the genuine output of the framework.

The BER computational algorithm presents the summarized BER computation and analysis in a flowchart as demonstrated in Figure-2.

The modified LMS is presented as follows:

a) Initialize the dependent variables: weight w and ϕ
b) Form the processes for the BER level computation and the following iterations for the nth time.

a. Form the input signal $x(n) = x(nT_s)$
b. Form the actual output y(n) of the system with the input signal and the adaptive weight

$$y(n) = \sum_{n}^{N-1} w_i(n)x(n-1)$$

c. Form the reference set point

$$d(n) = \sin(2\pi N w_0(n) + \phi(n))$$

d. Compute the error estimator to the adaptive processor from the actual output y(n) and the reference set point d(n)

$$e(n) = d(n) - x(n)w(n)$$

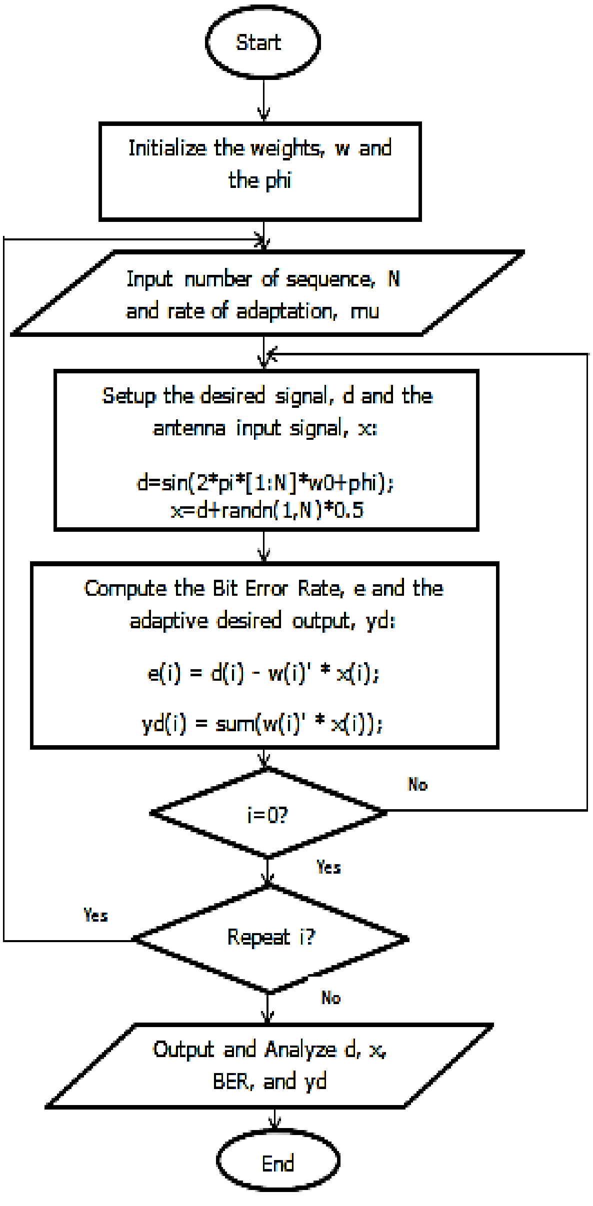

Figure-2. Flowchart of the BER improvement.

This algorithm presents the LMS method for the performance enhancement of the adaptive antenna reception by lessening the spot error rate. The main controlling factors in this approach are the weight w and the real positive constant ϕ. The initial weight w_0 and the ϕ were varied within the limits in order to achieve the desired performance through iterations i [11].

The modification of the LMS algorithm for the network performance which is centered on BER reduction was achieved in this work with the introduction and manipulation of ϕ in the desired signal model. The initial weight function of the adaptive antenna and ϕ at the desired signal was manipulated to start iteration at the beginning of the computation of the LMS program. This was repeated until a desired system performance was achieved.

Where, ϕ is the real positive constant ($0<\phi<1$) and μ is the rate of adaptation ($0< \mu <1$). The number of sequences and the μ was kept constant throughout the experiment.

MEASUREMENT ENVIRONMENT

The field measurement was performed on the existing wireless network of our campus which uses a CDMA20001x base network. The drive test was intended to cover the base station, using a Laptop with data collecting software installed, GPS, a Cellular dongle, a mobile phone, and spectrum monitoring equipment such as ray tracers and spectrum analyzer. Measurements of received signal strength will be made at intervals of 100m up to 700m from a reference point on the transmitting base station.

Cellular Base Station

The base station (BS) is located at a location with Latitude 13.6214 and Longitude: 79.2903. The sectorized antenna of this BS provides coverage for a suburban environment. The base station height is 36m and has a carrier frequency of 878.87MHz.

Drive Test Measurement Procedure

The drive test was conducted on a campus located in a suburban region with hillocks, foliage, and a moderate population for a reliable assessment.

Figure-3. Block diagram of drive test measurement.

The drive test was conducted over a distance covering about 75km. The data was collected during the motion of the vehicle. As shown the Figure-3, the drive test carries a laptop computer connected to two mobile user equipment's. The spectrum analyzer is used for signal measurement, and analysis operations, the results were displayed for interpretation and recording.

During the measurement, the test vehicle was driven in the direction of one antenna sector and there were overlaps from two sectors at some points. In addition, the GPS was used to determine the separation between the base station and the portable station, i.e., the transmitter–receiver (T-R) separation distances starting from 100 meters to several multiples of 100 meters.

During the drive test, four signals from the other functional base stations were also observed and the ray tracer helped to pick the signal from the network of choice amongst the signals from other networks. This is achieved by setting the appropriate frequency on which the desired network operates.

The base station is operated at a frequency of 878.87MHz and the ray tracer locates the base station transmitting a particular frequency. The strength of the signal from various focuses which are being separated from the base stations is recorded. These distances from each focus are obtained using GPS. The signal strength from a base station usually diminishes when there is a separation between the focuses.

The signal-quality estimations were made by observing and recording the signal on a moving vehicle from the base station.

EVALUATION OF FIELD BER OF ADAPTIVE ANTENNA

Here a 6-element adaptive antenna model is used to estimate the BER performance when compared with a sectorial antenna. This is illustrated in the following BER comparison. The procedures are repeated using results obtained from the modified LMS algorithm.

THE RESULT OF USING SECTORIAL ANTENNA MODEL

Table-1. BER vs number of users.

Field BER	Number of Users
0.25	1
0.18	2
0.45	3
1.02	4
0.85	5
1.15	6
1.43	7
0.95	8
1.32	9

1.4	10

Figure-4 represents the BER measurement obtained using the sectorial antenna method.

a) The touch error rate was not steady as the number of connections changed.
b) The spot mistake rate expanded with an increment in the number of associations
c) The least BER measured was 0.25

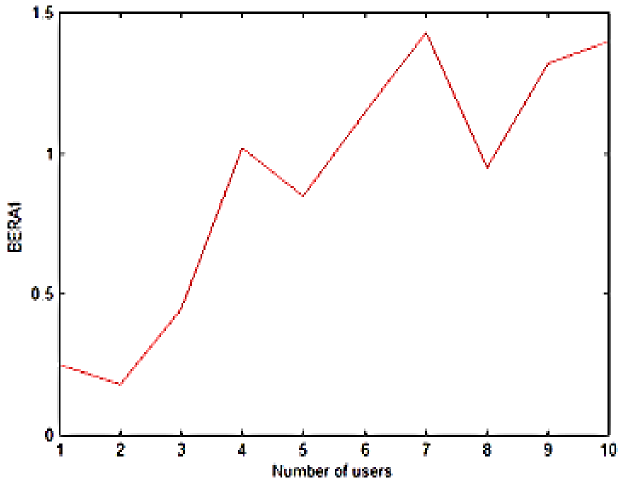

Figure-4. BER performance based on sectorial Antenna model (A1).

As the sectorial antennas uphold high BER values, an increase in interference and fading at both the uplink and the downlink transmission is experienced. To achieve reduced BER values, the multi-element Adaptive Antenna Array model was considered to enhance system capacity.

THE RESULT OF USING 6 ELEMENT ADAPTIVE ANTENNA MODEL

Below Table-2 provides a graphical representation of the BER performance of 6 elements adaptive antenna array

Table-2. BER of adaptive antenna 6 versus number of users.

Field BER	Number of Users
0.125	1
0.1	2
0.225	3
0.51	4
0.425	5
0.575	6
0.715	7
0.475	8
0.66	9
0.7	10

Table-2 represents the BER measurement obtained using the adaptive antenna method.

a) The touch error rate was not steady as the number of connections changed.
b) The spot mistake rate expanded with an increment in the number of associations
c) The least BER measured was 0.125

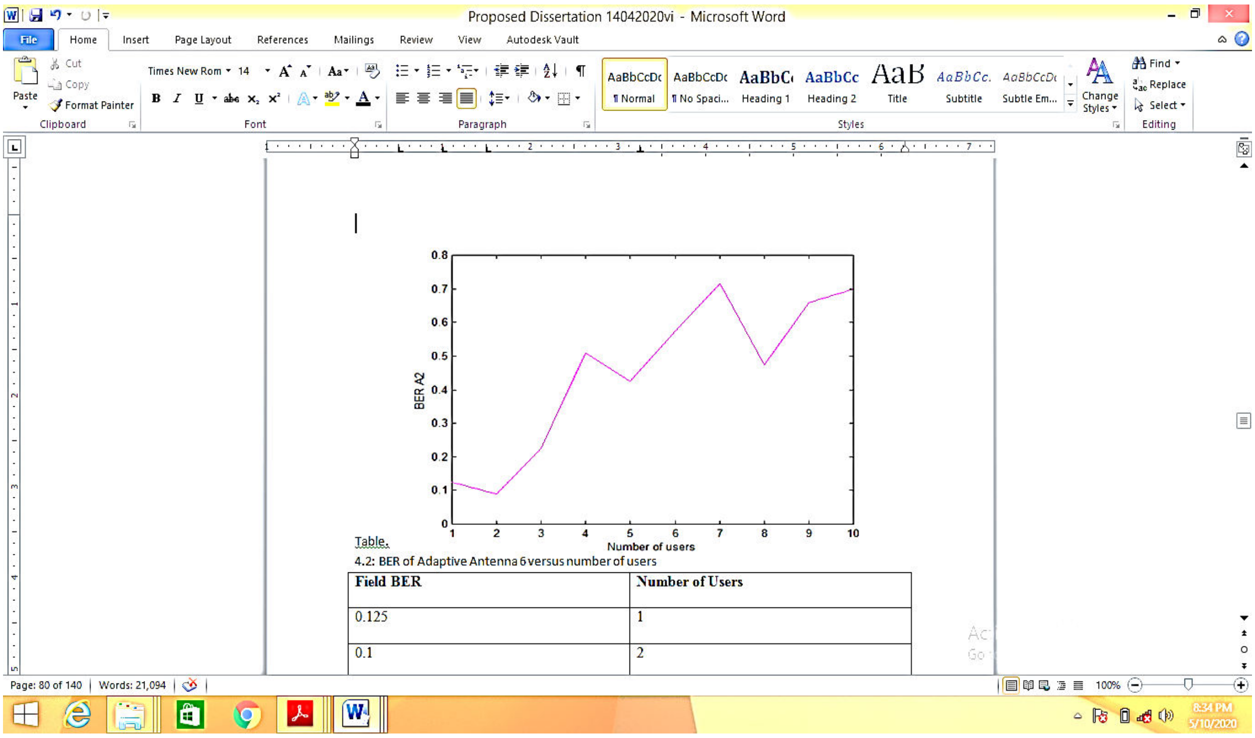

Table.
4.2: BER of Adaptive Antenna 6 versus number of users

Field BER	Number of Users
0.125	1
0.1	2

Figure-5. BER performance based on 6 elements Adaptive Antenna (A2).

The graphic illustration of Figure-5 when compared to the BER performance in figure 4 of the sectorial antenna model represents an improvement in BER and a reduction in interference at values 1.4 and 0.7 respectively. This result represents a significant improvement in BER performance when compared to the sectorial antenna model.

EXPERIMENTAL RESULTS OF THE BER ENHANCEMENT ALGORITHM USING MODIFIED LMS

For the BER improvement experiment, the number of sequence N and the rate of adaptation μ, were kept constant and the values of (w_0) and ϕ were varied. The number of sequence N, for the iteration, was chosen arbitrarily and the rate of adaptation μ, was chosen from the range (0< μ<1), N=11, μ=0.01.

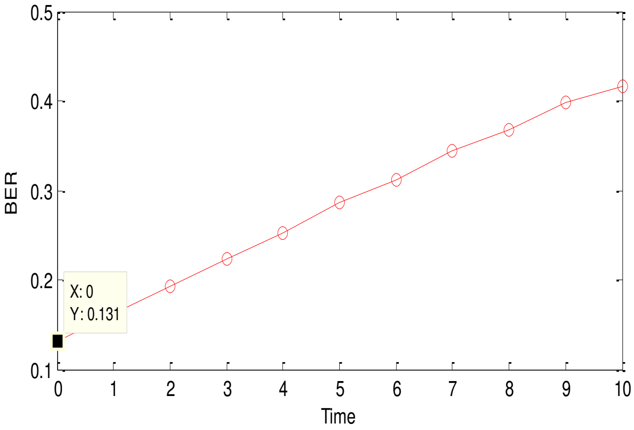

Figure-6. BER graph when w0=0.01 and ϕ=0.1.

The result shown in Figure-6 demonstrates the behavior of the output of the mobile antenna equipment based on the BER level reduction when initial weight (w_0) and ϕ are 0.01 and 0.1 respectively.

a) The least BER level achieved is 0.131 which means that the system performance has not been improved.
b) The BER level increased with the increase in the number of sequence

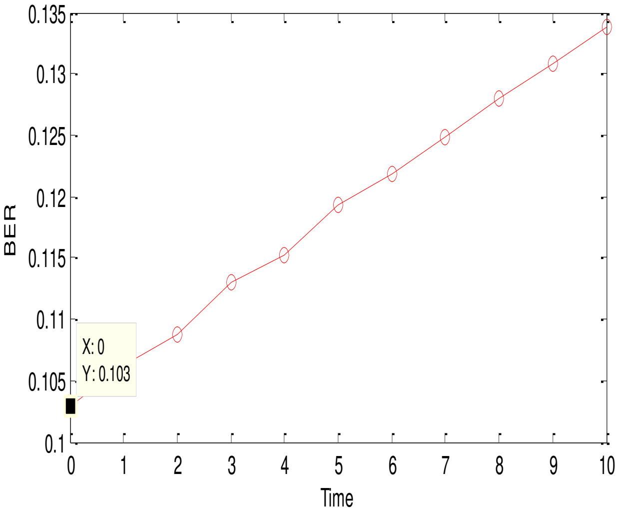

Figure-7. BER graph when w_0=0.001 and ϕ=0.1.

The result shown in Figure-7 demonstrates the behavior of the output of the adaptive receiving antenna based on the BER level reduction when initial weight and ϕ are 0.001 and 0.1 respectively.

a) The least BER level achieved is 0.103 which means that the system performance has not been improved.
b) Little improvement was achieved with the change in the initial weight of the adaptive antenna

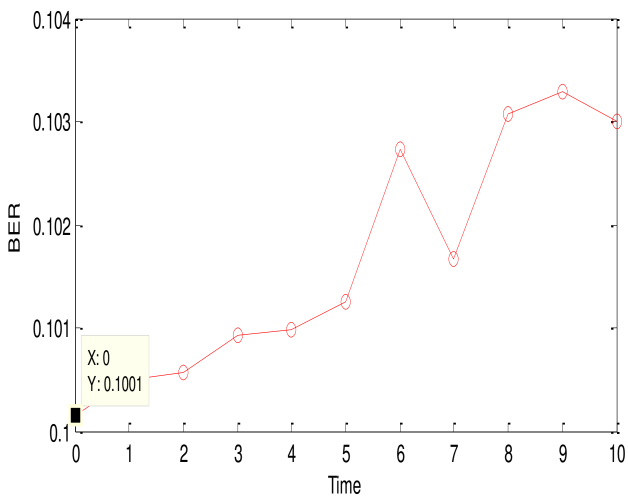

Figure-8. BER graph when w_0=0.0001 and ϕ=0.1.

The result shown in Figure-8 demonstrates the behavior of the output of the adaptive receiving antenna based on the BER level reduction when initial weight (w_0) and ϕ are 0.0001 and 0.1 respectively.

a) The least BER level achieved is 0.1001 which means that the system performance has not been improved.
b) Little improvement was still achieved with the change in the initial weight of the adaptive antenna while keeping the ϕ constant

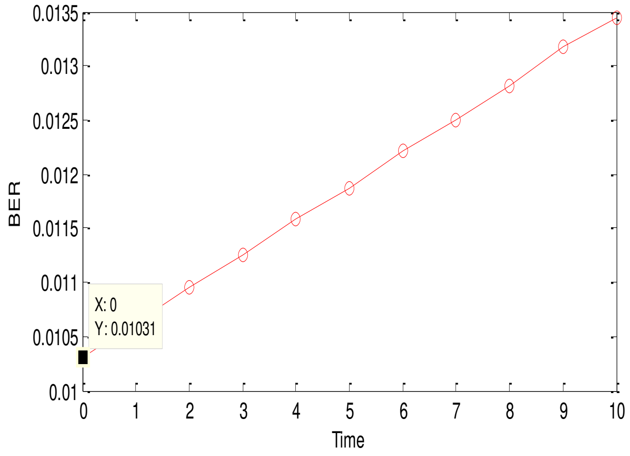

Figure-9. BER graph when w_0=0.0001 and ϕ=0.01.

The result shown in Figure-9 demonstrates the behavior of the output of the adaptive receiving antenna based on the BER level reduction when initial weight (w_0) and ϕ are 0.0001 and 0.01 respectively.

a) The least BER level achieved is 0.01031 which means that the system performance has not improved a little.
b) Significant improvement was achieved with the change in the ϕ while keeping the initial weight of the adaptive antenna constant

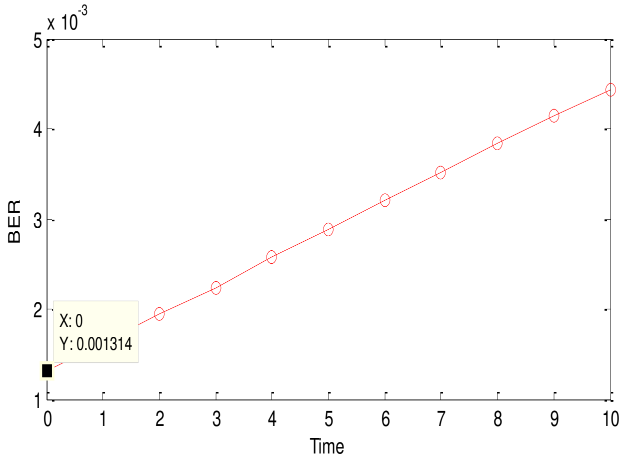

Figure-10. BER graph when w_0=0.0001 and ϕ=0.001.

The result shown in Figure-10 demonstrates the behavior of the output of the adaptive receiving antenna based on the BER level reduction when initial weight (w_0) and ϕ are 0.0001 and 0.001 respectively.

a) The least BER level achieved is 0.001314 which means that the system performance improved significantly.
b) Significant improvement was achieved with more change in the ϕ while keeping the initial weight of the adaptive antenna constant at 0.0001.

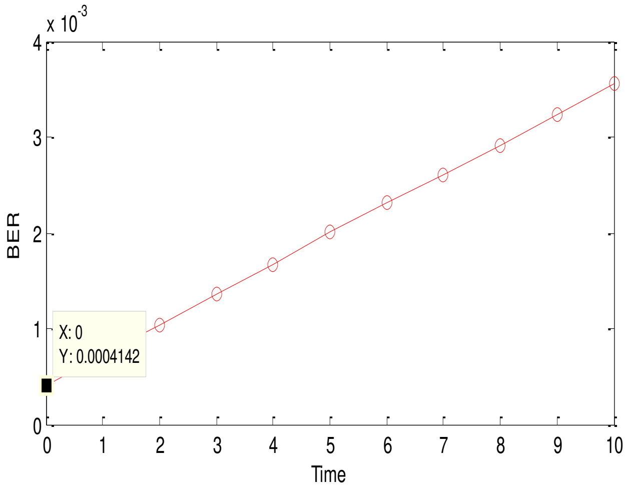

Figure-11. BER graph when w0=0.0001 and ϕ=0.0001.

The result shown in Figure-11 demonstrates the behavior of the output of the adaptive receiving antenna based on the BER level reduction when initial weight and ϕ are 0.0001 and 0.0001 respectively.

a) The least BER level achieved is 0.0004142 which means that the system performance improved significantly.

b) Significant improvement was achieved with more change in the ϕ while keeping the initial weight of the adaptive antenna constant at 0.0001.

Table-3. Summary of the BER improvement results.

S. No	Initial weight (w0)	Real positive constant, ϕ	BER
1	0.01	0.1	0.131
2	0.001	0.1	0.103
3	0.0001	0.1	0.1001
4	0.0001	0.01	0.01031
5	0.0001	0.001	0.001314
6	0.0001	0.0001	0.0004142

The BER improvement experiments results as shown in Figures 6 to 11 were summarized in table 3. From the result, the lowest BER value of 0.0004142 was achieved with an initial weight of 0.0001. This shows a huge improvement in the exhibition of the framework and channel utilization.

RESULTS AND DISCUSSIONS

In this work, the existing adaptive antenna systems were studied based on different areas of consideration for antenna performance improvement which concentrates on the BER of the different adaptive antenna configurations. Two adaptive antenna configurations were considered which are the uniformly spaced antenna element arrays up to 12 (twelve) elements and the odd number of antenna element arrays configurations. These two have been used in many research works and because of the limited arrangement capabilities involved since they are mostly physical arrangements, these methods seem to bring not much improvement other than the extent they have been used. From the reviewed results, the uniformly spaced 12 (twelve) elements antenna array configuration produced a BER of 0.4124 and the odd number antenna element array configuration recorded its best performance at 9 (nine) element arrays with BER of 0.0006453.

However, the adaptive antenna design based on the modified LMS algorithm produced a system performance BER of 0.0004142. Comparing the results of the existing designs having uniformly spaced 12 antenna element arrays and the odd number antenna element arrays configurations with the modified LMS algorithm design, it was confirmed that the modified LMS algorithm design produced the best performance. This means that the adaptive antenna design based on a modified LMS algorithm will guarantee a better BER performance.

Table-4. Comparative BER performance for sectorial antenna, 6 element adaptive antenna array and modified LMS Adaptive Antenna model.

BER (Sectorized Antenna)	BER (Adaptive Antenna)	Number of Users	BER (Modified LMS Adaptive Antenna)	Initial weight, w_0
0.25	0.125	1	0.131	0.01
0.18	0.09	2	0.103	0.001
0.25	0.125	3	0.1001	0.001
1.02	0.512	4	0.01031	0.0001
0.85	0.425	5	0.001314	0.0001
1.05	0.575	6	0.0004142	0.0001
1.01	0.215	7		
0.95	0.475	8		
1.05	0.66	9		
1.09	0.73	10		

CONCLUSIONS

The aim of this work, which is to improve the BER of the framework for the cell mobile network, was successfully achieved using a modified LMS algorithm technique for the adaptive antenna. Two existing adaptive antenna BER improvement methods based on uniformly spaced element arrays and odd numbers of element arrays of 9 elements were studied and the results were used for comparison purposes with the results of the proposed modified LMS algorithm.

REFERENCES

[1] Sarma S., Singh M., Pamula R. 2018 Design of cognitive engine for cognitive radio network using MOGA. In2018 4th International Conference on Recent Advances in Information Technology (RAIT) 2018 Mar 15 (pp. 1-6). IEEE.

[2] Al-Ardi E. M., Shubair R. M., Al-Mualla M. E. 2003. Performance evaluation of the LMS adaptive

beamforming algorithm used in smart antenna systems. In2003 46th Midwest Symposium on Circuits and Systems, (1: 432-435). IEEE.

[3] Godara L. C. 1997. Applications of antenna arrays to mobile communications. I. Performance improvement, feasibility, and system considerations. Proceedings of the IEEE. 85(7): 1031-60.

[4] Chitra K. J., Singh S. K. and Mehra R. M. 2020. Intelligent Antenna System. Journal of Critical Reviews, 7(10), pp.1083-1087, 2020.

[5] Oluwole A. S., Srivastava V. M. 2018. Features and Futures of Smart Antennas for Wireless Communications: A Technical Review. Journal of Engineering Science & Technology Review. 11(4).

[6] Rappaport T. S., Sun S., Mayzus R., Zhao H., Azar Y., Wang K., Wong G. N., Schulz J. K., Samimi M., Gutierrez F. 2013. Millimeter wave mobile communications for 5G cellular: It will work!. IEEE access. 10; 1: 335-49.

[7] García I. F., Moreno M. A., Díaz J. R. 2014. Optimum pumping station management for irrigation networks sectoring: Case of Bembezar MI (Spain). Agricultural Water Management. 1; 144: 150-8.

[8] Singh K., Grewal V., Saxena R. 2009. Fractal antennas: a novel miniaturization technique for wireless communications. International Journal of recent trends in Engineering. 1; 2(5): 172.

[9] Fayadh R. A., Naji M. K., Rhaif S. H., Ali A. H. 2019. Implementation of new combiner for indoor UWB wireless rake receiver. In IOP Conference Series: Materials Science and Engineering. 1, 518(5): 052012). IOP Publishing.

[10] Ertel R. B., Caroieri P., Sowerby K. W., Rappaport T. S., Reed J. H. 2009. Overview of spatial channel models for antenna array communication systems. InAdaptive Antennas for Wireless Communications, (pp. 20-32). Wiley-IEEE Press.

[11] Raheemah A., Sabri N., Salim M. S., Ehkan P., Ahmad R. B. 2016. New empirical path loss model for wireless sensor networks in mango greenhouses. Computers and Electronics in Agriculture. 1; 127: 553-60.