Performance Improvement in Smart Antenna Using Adaptive LMS Algorithm

S.Kannadhasan[1], R.Nagarajan[2]
[1]*Assistant Professor, Department of Electronics and Communication Engineering, Cheran College of Engineering, Anna University, Tamilnadu, India,*
[2]*Professor, Department of Electrical and Electronics Engineering, Gnanamani College of Technology, Namakkal, Tamilnadu, India,*
kannadhasan.ece@gmail.com, krnaga71@yahoo.com

Abstract

This paper presents a smart antenna system for modern mobile communication technology in the industrial market of wireless communication. The smart antenna techniques are used to reduce the interference and the performance of the system also improved. The smart antenna technique in wireless communication has expected to adaptive updating of weights linked to the antenna channel. The various channels respond to the variations with the help of Denial of Arrival (DOA) and the beam forming algorithms. This research work presents with the adaptive LMS algorithm which is effective in the design, operation, and mathematical calculations of the smart antenna. The proposed system is analysis the various parameters such as, convergence speed, channel capacity and resolution of the smart antenna. The proposed algorithm is to compare the various parameters of the smart antenna. The results illustrate that the proposed hybrid algorithm has low percentage of error, high accuracy as well as high convergence speed compared with the existing algorithms.

Keywords: Smart Antenna; DOA, Genetic Algorithm (GA), Neural Network (NN), and Adaptive LMS Algorithm.

1. Introduction

A smart antenna system combines multiple antenna elements with a signal-processing to optimize automatically respond to the radiation pattern in the signal environment. In recent years, smart antennas have been considered to be one of the most expected technologies, which are adapted to the demanding high bit-rate or high-quality in broadband commercial wireless communication such as, mobile internet and multi-media services [1], [2]. The diversity technique is used in the smart antenna for wireless communication at both transmitter and receiver [3]. The diversity effect includes the transmission, reception of the channel to increase the speed and reduce the rate of error [4]. Normally wireless communication, a smart antenna is used at the source and destination separately [5]. These types of smart antenna techniques are affected by multipath effects [6]. The electromagnetic field is scattered with the various waveforms and various paths from source to reach the destination [7]. The scattered portions of the signal are for late due to some causes such as fading.

The modern communication system is used for multi-path fading, intersymbol interference, and co-channel interference [8]. This multipath fading technique can reduce the speed and increase in the number of errors that occurred in the channel [9]. The wireless communication, smart antenna systems (or antenna arrays) can be used to suppress multipath fading with antenna diversity and to increase the system capacity by supporting multiple co-channel users in reception and transmission [10]. The smart antenna is used to reduce interference and also improve the system performance at operating high frequencies [11].

The smart antenna is used to require a higher sampling rate in the field of digital signal processing. The beamforming techniques to optimize the array output for the maximum radiated power is produced in the direction of the user and the undesired signal from the co-channel interference [12]. The directions of smart antenna and interference are obtained depends on the beamforming technique in the direction of beams form of arrival that means of DOA algorithm. Adaptive smart antennas are the array antennas whose radiation pattern is shaped according to some adaptive algorithms [13]. Smart essentially means computer control of the antenna performance. The smart antenna radiation pattern directs the beam towards the users of interest only and nulls toward interference to improve the capacity of the cellular system [14].

The smart antenna system is focused on the signal quality for transmission of radio signals to the channel capacity through increased frequencies. [15]. There are many adaptive algorithms have been used in the antenna array elements. The algorithm-based smart antenna is to improve efficiency and system performance [16].

2. Design Process of Smart Antenna

Smart antenna technique with several structures in the form of array elements like linear, circular, polar, planar, disc, square and rectangle are used in the applications of digital signal processing. The various antenna structures with beam patterns normally depend upon the array factor. A linear array considers with uniform inter-element spacing (Δ) and non-uniform for amplitude. An array element with the odd and even number of antenna elements along the Y axis is present in the paper.

$$AF(\theta) = \sum_{n=0}^{2N-1} I_n e^{jn\psi} \quad (1)$$

Where $\psi = k\Delta(\sin\theta - \sin\theta_d)$ and $k = \frac{2\pi}{\lambda}$. Normally, ψ is called progressive phase shift. k is wave numbers and λ is wavelength of the transmitted signal. Magnitude of current for the n^{th} element in array is denoted by I_n. Scanning angle θ is measured about the array axis in the range $[-90^\circ, 90^\circ]$ and θ_d is a squinted angle.

$$AF(\theta) = \varphi^T\, a(\theta) \quad (2)$$

Where $\varphi^T = [I_0, I_1, \cdots, I_{2N-1}]$ is called as the array weights of $a(\theta) = \left[1, e^{j\psi}, \cdots, e^{j(2N-1)\psi}\right]^T$

$$AF_p(\theta) = \sum_{n=1}^{N} I_n \cos[k\,\Delta_n(\sin\theta - \sin\theta_d)] \quad (3)$$

Where, $\Delta_n = \frac{(2N-1)\Delta}{2}$.

3. DOA Estimation Techniques

The smart antenna systems have been attractive solutions to the problem related to spectrum estimation and detection. The two main functions in the smart antenna are the Direction of Arrival (DOA) estimation and adaptive beamforming. The DOA algorithms have been studied for many years in array signal processing technology. Tremendous work has been carried out to estimate the DOA of signals impinging on the antenna array. The DOA estimation is one of the most important research problems in various applications like radar, sonar, communications, etc. Estimation algorithms of DOA depend upon maximum likelihood and subspace decomposition approaches. Subspace-based (or super-resolution) approaches have attracted much attention after the work is computationally simple as compared to the Machine Learning (ML) approach. There are a number of algorithms for subspace DOA estimations.

The objective of the DOA estimation is to utilize the signals received by the antenna array sensors to determine the direction of the signal from the actual users. Thus, the DOA based algorithms which are used for estimation of the angular position of signal effects on the increment of received signal quality. The algorithm of DOA or super-resolution analyzes the antenna array arrangements to better diagnose the received signals and they also can identify multiple locations of targets. In other words, the success of the smart antenna design depends on the precise estimation of angle by DOA algorithms. There are two types of DOA estimation based algorithms available such as conventional and subspace methods.

4. Proposed Adaptive LMS Algorithm

The proposed hybrid Genetic Algorithm (GA) based Neural Network (NN) integrated with adaptive Least Mean Square (LMS) algorithm methodology is used to enhance the performance of the smart antenna. It provides high convergence speed, channel capacity, and resolution of adaptive linear array.

The adaptive LMS algorithm is just a rearrangement of the initial LMS equations. The adaptive LMS filter with increased arithmetic efficiency, the reduction in the number of both multiplications and additions being commanded by the block size. The proposed research work is to reduce the arithmetic complexity of the LMS algorithm without modifying its behaviour: and the algorithm obtained is mathematically equivalent to LMS. The "updating" part generates the next taps is given below.

Adaptive LMS Algorithm

1. Initialize randomly $X(n)$and initialize the desired output $d(n)$.
2. Initialize $W(n) = 0$.
3. Compute the output $Y(n)$and the error $e(n)$.
4. Update μ using Eqn. (1).
5. Assign $\Delta\mu = \mu$
6. ***while***$(MSE > limiting\ error)$
7. Compute $\Delta W(n)$
8. Update $W(n)$
9. Compute the error $e(n)$and MSE.
10. Update μ.

In Adaptive LMS k^{th}stage is implemented by merging two stages of $(k-1)^{th}$ stage such that $\mu_{k-1} > \mu_k$. But choose of $N = 2^p$ limits its applicability. In this algorithm to get the faster convergence rate we propose the step size as,

$$\mu = \frac{A}{g(N)} \qquad (4)$$

Where A is a constant and $g(N)$ is a polynomial of N of degree 1.

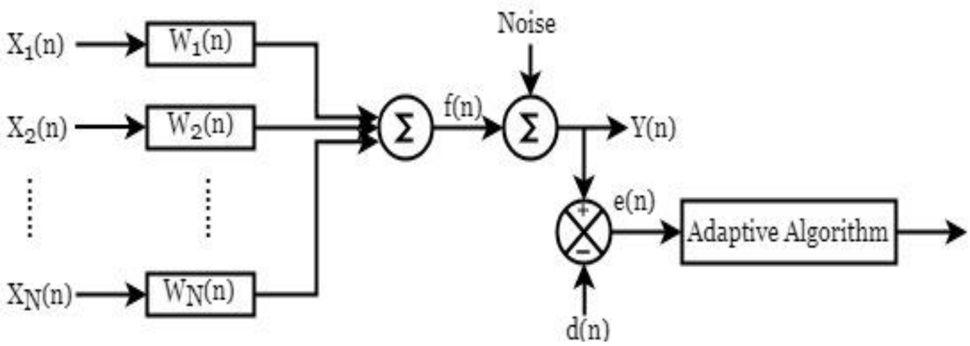

Figure 1: Block Diagram of Adaptive LMS Algorithm

Update $\mu(n)$ depending on the value of Mean Square Error (MSE) as,

$$\begin{cases} \mu(n) = \mu(n-1) - \Delta\mu \ ; \ for\ MSE(n) > MSE(n-1) \\ \mu(n) = \mu(n-1) + \Delta\mu \ ; \ otherwise \end{cases} \quad (5)$$

Same thing is also valid for $\sqrt{MSE}$ case.

The proposed technique, the antenna senses its environment and receives the signal. Then it calculates the direction of arrival. Once its direction has been calculated, it match with characteristics to that stored in memory, if a match is found then it immediately produces the stored response. If a match is not found it runs the algorithm in the routine manner as shown in Figure 1. A signal that impinges on the array elements induces a current in them. The magnitude of induced currents in the array elements will be the same, but with a successive phase difference. We now multiply the induced currents with the weights (randomly assigned through GA) of the array elements and add them. This becomes the cost function which is to be maximized. This is done using the same steps of the GA algorithm i.e. natural selection, cross over, and mutation. The new population thus formed is treated in the same manner. This process goes on until the algorithm is converged. Once it is converged, we select the best chromosome of the last population that gives us the optimized complex weights, giving us the direction of arrival of the user.

Adaptive LMS scanning is performed i.e. match is found in the stored response in the memory. If the DOA is within the stored DOA estimates and magnitude at the interference is within a Specific margin then we can directly provide the stored weights to the array elements instead of running the entire algorithm again. In case a match is not found, then beam forming is done using GA as explained earlier.

5. Implementation Results And Analysis

5.1 Implementation Results

The result shows the implementation of the proposed adaptive LMS algorithm in terms of the relative error, normalized noise level and the number of generations. In this section some of the graphical representation of the proposed hybrid algorithm for the performance enhancement of smart antennas has discussed. Mean response time for various numbers of fixed antennas is compared with the smart antennas.

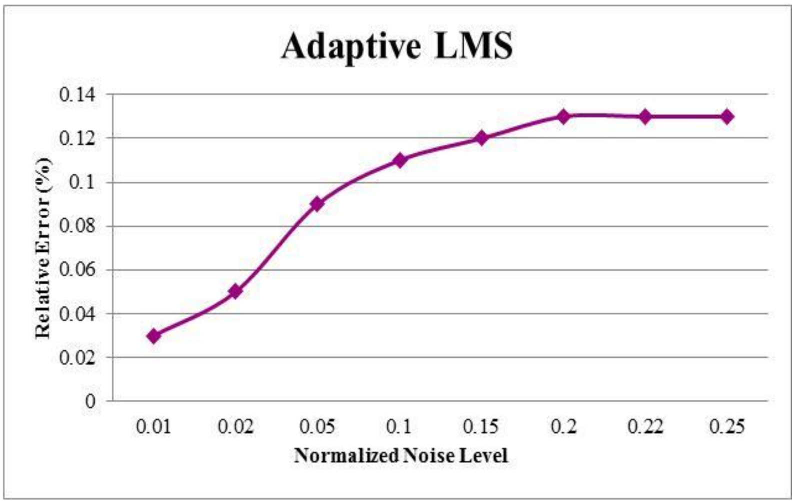

Figure 2: Error Percentage for Various Noise Levels

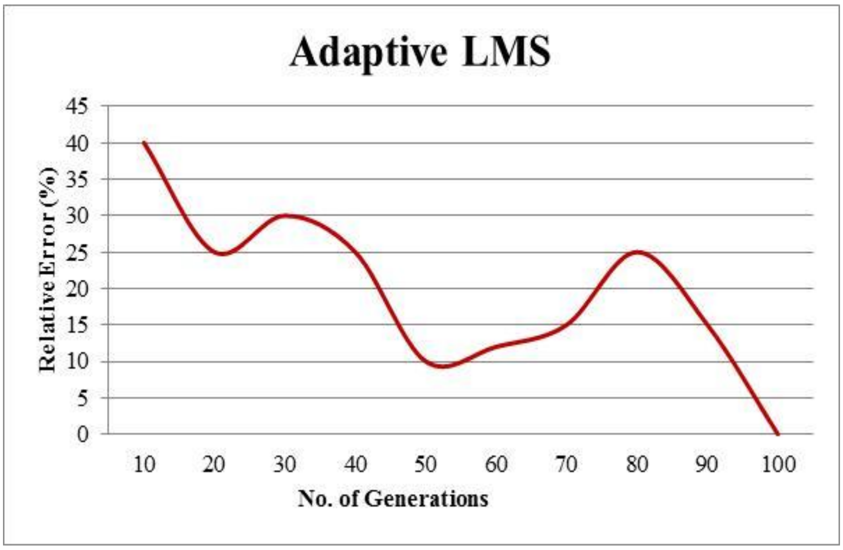

Figure 3: Error Percentage for Various Number of Generations

The results shown in Figure 2 represent the relative error during the normalization of the various noise levels. The noise level of the proposed adaptive LMS is nominal for the relative error. Adaptive LMS denotes its identity in relative error and the noise level relation. Similarly, the improved performance of the Adaptive LMS algorithm has shown in Figure 3. The Figure 3 shows the error percentage of adaptive LMS in terms of number of generations. It illustrates that the adaptive LMS has obtained its optimum error 60-70 generations.

.5.2 Performance Analysis

The proposed algorithm are validated and its performance are enhance such as,

i) Accuracy
ii) Convergence Speed and
iii) Mean Square Error

i) Accuracy

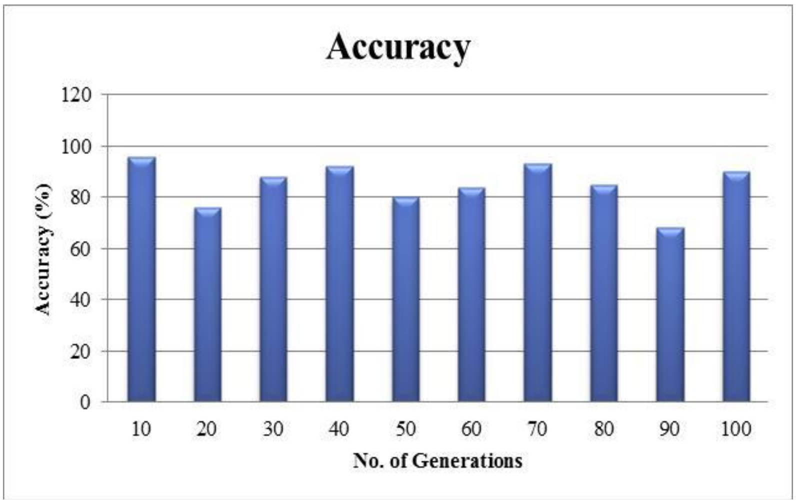

Figure 4: Percentage of Accuracy of the Proposed Algorithm

The accuracy may be determined by calculating the global quantization noise power in the system output. The accuracy is a measure of the degree of closeness of a measured or calculated value to its actual value. The Figure 4 displayed the accuracy of the proposed hybrid algorithm. It is calculated based on the number of generations of the proposed algorithm. In this algorithm it takes 100 generations.

ii) *Convergence Speed*

The speeds of convergence of the means of the coefficient values depend on the eigenvalues λ_i and with the step size μ. In particular, we can define the time constant τ_j of the j^{th} term within the summation as the approximate number of iterations it takes for this term to reach $\left(\frac{1}{E}\right)^{th}$ its initial value. For step sizes in the range $0 < \mu \ll \frac{1}{\lambda_{max}}$, where λ_{max} is the maximum eigenvalue of R_{xx}, this time constant is,

$$\tau_J = \frac{1}{\ln(1 - \mu\lambda_J)} \approx \frac{1}{\mu\lambda_J}$$

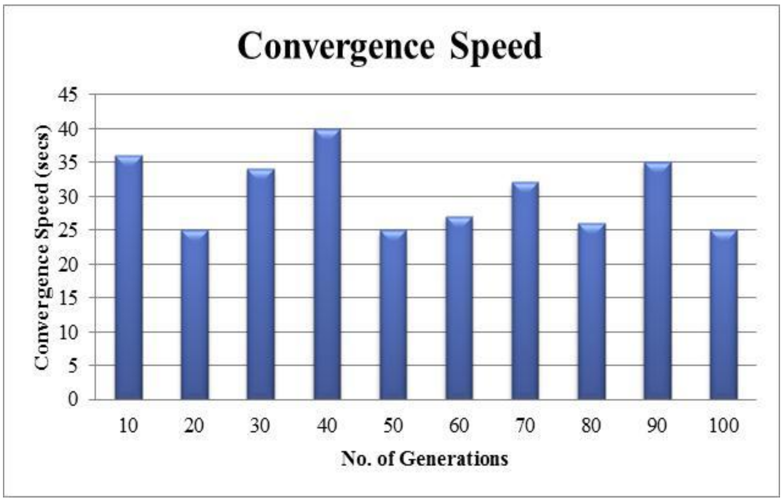

Figure 5: Convergence Speed of the Proposed Algorithm

.

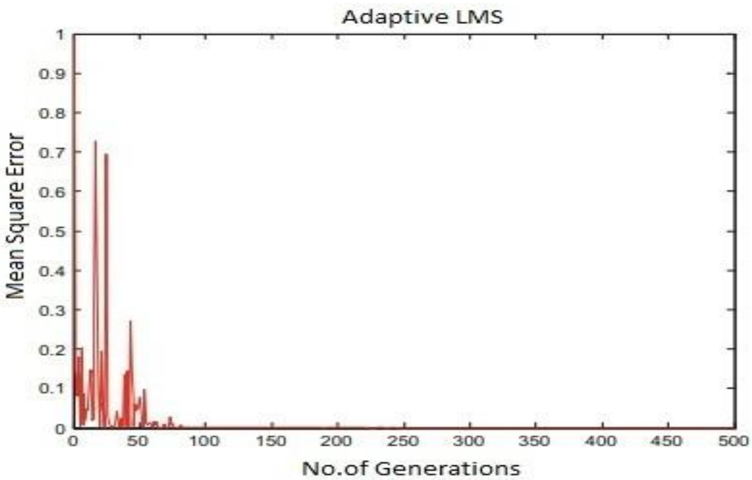

Figure 6: Convergence plot of adaptive LMS algorithm

The Figure 5 shows the convergence speed of the proposed hybrid algorithm. It is calculated based on the number of generations of the proposed algorithm. In this algorithm it takes 100 generations. The Figure 6 shows the convergence plot of the proposed adaptive LMS algorithm.

iii) Mean Square Error

The mean-square error, as a function of filter weights is a quadratic function which means it has only one extreme, which minimizes the mean-square error, which is the optimal weight. The LMS thus, approaches towards these optimal weights by ascending/descending down the mean-square-error vs. filter weight curve. The percent error is the ratio of the error to the actual value multiplied by 100.

$$\%\, error = \frac{error}{actual\ value} \times 100$$

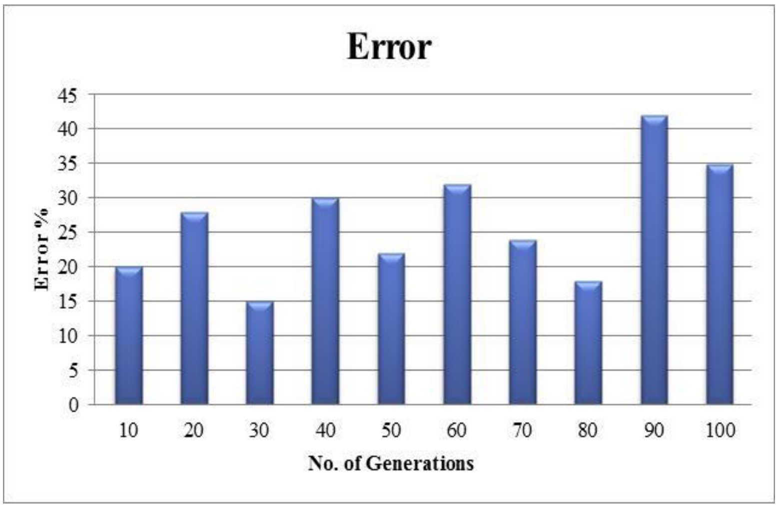

Figure 7: Error percentage of the proposed algorithm

The Figure 7 demonstrated the error percentage of the proposed hybrid algorithm. It is calculated based on the number of generations of the proposed algorithm. In this algorithm it takes 100 generations. The algorithm starts by assuming small weights (zero in most cases) and, at each step, by finding the gradient of the mean square error, the weights are updated. That is, if the MSE-gradient is positive, it implies, the error would keep increasing positively, if the same weight is used for further iterations, which means we need to reduce the weights. In the same way, if the gradient is negative, we need to increase the weights.

5.3 Comparative Analysis

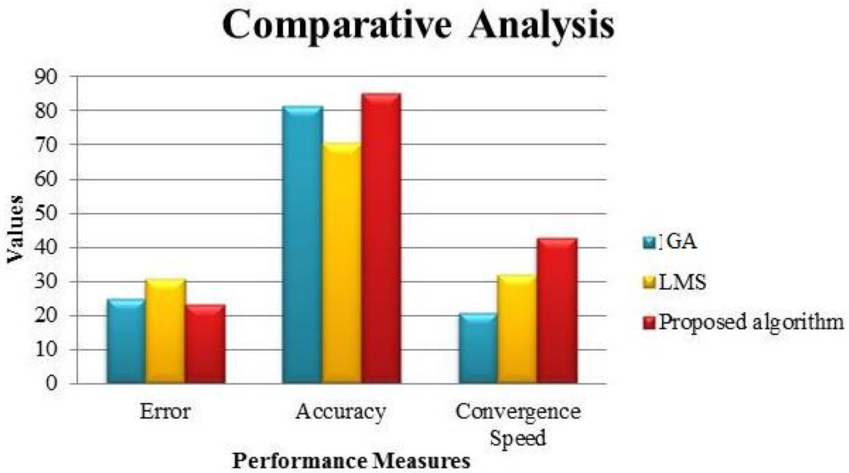

Figure 8: Comparative Analysis of the Proposed Algorithm

The proposed research work novel algorithm parameters are comparing with conventional algorithm such as, MUSIC and the traditional LMS algorithms. The validation of the proposed algorithm has been evaluated based on their performance measures are shown in Figure 8. The Figure 8 illustrates that the proposed hybrid algorithm has DOA estimation superior to other estimation techniques LMS algorithms in view of error percentage, convergence speed and accuracy.

6. Conculsion

The Smart antennas are one of the advancements in telecommunication technologies are though developed using different algorithms, but the urge was felt for improving the technique to increase their efficiency. Therefore this research work presented a new technique that tried to fulfill all the issues of the smart antenna and additionally to improve the performance. This paper proposed a novel hybrid algorithm called hybrid algorithm of Genetic based Neural Network integrated Adaptive LMS algorithm to improve the antenna performance in terms of high convergence speed, channel capacity, and resolution of the adaptive linear array. The performance of the proposed algorithm had measured based on three measures, and the comparison had carried out between algorithms. The results illustrate that the proposed hybrid algorithm has low percentage of error, high accuracy as well as high convergence speed compared with the existing algorithms.

References

[1] Blanz JJ, Papathanassiou A, Haardt M et al (2000) Smart antennas for combined DOA and joint channel estimation in time-slotted CDMA mobile radio systems with joint detection. IEEE Trans VehTechnol 49(2):293–306

[2] Winters JH (2006) Smart antenna techniques and their application to wireless ad hoc networks. IEEE WirelCommun 13(4):77–83

[3] Sundaresan K, Sivakumar R (2006) Ad hoc networks with heterogeneous smart antennas: performance analysis and protocols. WirelCommun Mobile Comput 6(7):893–916

[4] Chen K, Jiang F (2007) A range-adaptive directional MAC protocol for wireless ad hoc networks with smart antennas. Int J Electron Commun 61(10):645–656

[5] Quintero A, Li DY, Castro H (2007) A location routing protocol based on smart antennas for ad hoc networks. J NetwComputAppl 30(2):614–636

[6] Lim C-H, Wan Y, Ng B-P et al (2007), A real-time indoor Wi-Fi localization system utilizing smart antennas. IEEE Trans Consum Electron 53(2):618–622

[7] Roy S, Boudreault J-F, Dupont L (2008) An end-to-end prototyping framework for compliant wireless LAN transceivers with smart antennas. ComputCommun 31(8):1551–1563

[8] Perez-Neira A, Mestre X, Fonollosa JR (2001) Smart Antennas in software radio base stations. IEEE Commun Mag 39(2):166–173

[9] Falletti E, Presti LL, Sellone F (2006) SAM LOST smart antennas-based movable localization system. IEEE Trans VehTechnol 55(1):25–42

[10] Biswas RN, Mitra SK, Naskar MK (2014) A robust mobile anchor based localization system for wireless sensor networks using smart antenna. Int J Ad-hoc Ubiquitous Comput 15(1/2/3):23–37

[11] Constantinescu, M. and Borcoci, E. (2012) Optimization Method for Smart Antenna use in WiMAX Vehicular Communications. 2012 9th International Conference on Communications (COMM), Bucharest, 21-23 June 2012, 263-266. https://doi.org/10.1109/ICComm.2012.6262555

[12] Bao, K., et al. (2016) Diamond-Shaped Mesh Network Routing with Cross-Layer Design to Explore the Benefits of Multi-Beam Smart Antennas. 2016 25th International

Conference on Computer Communication and Networks (ICCCN), Waikoloa, HI, 1-4 August 2016, 1-5. https://doi.org/10.1109/icccn.2016.7568510

[13] Cikovskis, L. (2014) Inter-path Interference Cancelation in Wireless Ad-Hoc Networks Using Smart Antennas. 2014 IEEE 2nd Workshop on Advances in Information, Electronic and Electrical Engineering (AIEEE), Vilnius, 28-29 November 2014, 1-6. https://doi.org/10.1109/aieee.2014.7020329

[14] Hung, L.L., Huang, Y.W. and Wu, S.H. (2014) Transmissions for Delay-Guaranteed Information Using Smart Antenna Systems. 2014 10th International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), Kitakyushu, 27-29 August 2014, 146-149. https://doi.org/10.1109/iih-msp.2014.43

[15] Loh, T.-H., et al (2014) Assessment of the Adaptive Routing Performance of a Wireless Sensor Network Using Smart Antennas. IET Wireless Sensor Systems, 4, 196-205. https://doi.org/10.1049/iet-wss.2014.0066.

[16] S.Kannadhasan and Dr.R.Nagarajan, Performance Improvement of Slot Antenna Using Various Parameters and Band Pass Filter. IEEE International Conference on Circuits and Systems in Digital Enterprise Technology, December 21 and 22, 2018, Saintgits College of Engineering, Kottayam, Kerala. ISBN: 978-15-38605-75-2.