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THE EFFECTIVENESS OF 6T BEAMFORMER ALGORITHM IN SMART ANTENNA SYSTEMS FOR CONVERGENCE ANALYSIS

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ABSTRACT: Recently, the need for more capacity in wireless networks has motivated this current research towards the creation of standards and algorithms that selectively take advantage of space. The development of smart antenna arrays and related beamforming algorithms has received a lot of attention. Cell Planning is an important process in networking, which is used to ensure coverage and avoid interference. Also, cell planning plays a vital role in the placement of base stations in a network. The communication between the base station (BS) and mobile station can happen either using a single antenna or an array of antenna elements. In the case of using a single antenna, if the Electromagnetic (EM) wave has low SNR, then BS cannot decode the data and drops the signal. Conversely, when an array is used, a signal with low SNR also falls on the base station, and due to multiple delayed copies of the same signal, the data gets decoded successfully. With Space Division Multiple Access (SDMA), the frequencies allotted for mobile communication are reused to provide channel access to multiple users at the same time preserving the allowable reuse distance in network architecture, thus increasing the channel capacity and facilitating multiple users separated by a distance at the same time with frequency reuse. The smart antenna system at the base station performs the transceiver function. The transmission phase uses the output from the reception i.e., the detected user direction radiates a beam towards the desired user for communication to narrow the beam. The proposed 6T Beamformer method is a six-tap-based system with three taps having fixed step sizes and the other three having variable step sizes. With the execution of each tap or module, better convergence and quality of service are achieved. In the result analysis, the proposed method is compared with existing high-performing algorithms like LMS, Griffiths, and VSSLMS against Mean Square Error (MSE) to show that it converges faster at the 9^{th} iteration which is better than others in all the probabilities.

ABSTRAK: Dewasa ini, keperluan terhadap lebih kapasiti dalam rangkaian tanpa wayar menjadi motivasi kepada kajian terkini dalam membentu piawai dan algoritma yang menjimatkan ruang. Pembangunan tata susun antena pintar dan algoritma pembentukan pancaran telah mendapat perhatian ramai. Merancang sel adalah proses penting dalam jaringan, bagi memastikan liputan terhasil dan mengelak dari gangguan. Juga, merancang sel memainkan peranan penting dalam menempatkan tapak stesen dalam rangkaian. Komunikasi antara stesen pusat (BS) dan stesen bergerak dapat berlaku samada menggunakan antena tunggal atau elemen tata susunan antena. Dalam kes antena tunggal, jika gelombang Elektromagnetik (EM) mempunyai SNR rendah, BS tidak dapat menafsirkan kod data dan signal akan terabai. Sebaliknya, apabila susun atur digunakan, signal dengan gelombang SNR rendah akan terus ke stesen pusat dan disebabkan beberapa gelombang sama yang tertunda, data dapat ditafsir dengan sempurna. Melalui Capaian Pelbagai Pembahagi Ruang (SDMA), frekuensi yang ditimbulkan bagi komunikasi bergerak telah diguna balik bagi menyediakan kemasukan saluran kepada pelbagai pengguna pada waktu sama memelihara jarak guna balik yang dibenarkan dalam binaan rangkaian, oleh itu menambah kapasiti saluran dan membantu gandaan pengguna yang dipisahkan oleh jarak dengan kekerapan guna balik pada masa sama. Sistem antena pintar di stesen pusat pula menjalankan fungsi pemancar. Fasa pemancaran ini menggunakan pengeluaran dari penerima iaitu, pengguna yang dikesan dari arah pancaran, akan memancarkan gelombang kepada pengguna yang memerlukan komunikasi, ini dapat mengecilkan jarak pancaran. Kaedah yang dicadangkan ini menghasil pancaran 6T iaitu sistem berdasarkan-enam-tap di mana tiga tap mempunyai saiz langkah yang tetap dan tiga lagi mempunyai saiz langkah berubah. Dengan pelaksanaan ini setiap tap atau modul mempunyai penumpuan yang lebih baik dan servis yang berkualiti terhasil. Dapatan kajian menunjukkan, kaedah yang dicadangkan dapat dibandingkan dengan algoritma berprestasi tinggi sedia ada seperti LMS, Griffiths, dan VSSLMS berbanding min kuasa dua ralat (MSE) bagi menunjukkan ia tertumpu lebih laju pada iterasi ke 9, iaitu lebih baik daripada ke semua kebarangkalian.

KEYWORDS: *beamforming; convergence analysis; mean square error; space division multiple access; weight computation*

1. INTRODUCTION

Communication systems involving 5G not only generate higher performance in convergence, capacity, and data rate but also reduce the latency, computational complexity, and cost. This research proposes a 2-stage suboptimal beamforming method to provide a solution to the problems encountered in the physical layer of the 5G system [1,2]. The role of adaptive algorithms in digital signal processing is pivotal. This study considers the application of the three existing high-performing adaptive algorithms in the quality of voice-over-IP with modifications in the step size, as step size contributes greatly to the convergence speed of the algorithms [3]. The grade of the antenna array will be better if the radiation is sent to the desired user [4]. The grade is directly dependent upon frequency or transmitter usage [5]. All the mobile users in the hexagonal cell will receive the signal with the same frequency at the same time but the angle of variation will distinguish the sources. The new arrays send the narrow beam toward actual mobile users to save an amount of energy [6]. The phase shifts are used to calculate the amount of energy reduced from the initial stage [7]. The concept of scheduler-based transmission will make the antenna array elements rest/constant at regular intervals and assign phase shifts to array elements to form the main beam [8]. The capacity for communication can be increased with the help of intelligent systems [9]. Digital signal processing (DSP) is that crucial determining factor in advancing wireless communications technology and increasing the capacity of limited RF spectrum [10].

Multiple techniques are used to decode the signal based on either summation of signals or by using maximum Signal to Noise ratio (SNR) so that the signal formation is better at the receiving end [11]. During the reception phase, the electromagnetic (EM) waves are obtained as the original signal and delayed versions of the original signal and are added up to get the main signal data. The maximum SNR method will consider each signal, then find the SNR and choose the signal which has the maximum SNR [12]. The phase shifts are computed by taking the actual signal, noisy signal, and jammed signals to form the total signal. The total signal phase shifts are multiplied by the initial set of phase shifts to form the array output. In a legacy system, an array of dipole elements is arranged linearly. The energy wastage is greater whenever the radiation falls in other directions. To overcome that, the following contributions are made:

- The receiving phase's result or the user direction was detected and is used in the transmission phase to guide a beam in the direction of the intended user.
- Then, the 6T Beamformer, a six-tap device used in the suggested technique, has three taps with fixed step sizes and the remaining three with variable step sizes.
- Better convergence is achieved with each tap or module that is executed in the result analysis.

2. LITERATURE REVIEW

Energy Efficient Multicasting via Smart Antennas in Multipath Environments has been proven by Tong and Ramanathan [13]. Nodes can direct their transmission energy in the appropriate directions by utilizing an adaptive antenna array, which allows them to conserve energy. The fact that this work functions in rich scattering surroundings is a noteworthy aspect. The issue was framed as a non-linear issue. Furthermore, it suggested two heuristics that are effective in computing. According to the numerical simulations, the two heuristics can significantly reduce power consumption when contrasted to the single antenna scenario. To fix the design problem and test the performance of the developed approaches, researchers likewise utilized simulation annealing.

Ali and Hassan [14] used a microstrip antenna array to show a hybrid technique. This study contains the theoretical hybrid method, which integrates two methods to boost their effectiveness. This is accomplished by making use of two algorithms' strengths while avoiding their weaknesses. The least mean square and sample matrix inversion methods are those two techniques. The resonant frequency of the microstrip antenna, which operates between 1700 and 1950 MHz, is 1850 MHz.

The influence of different parameters on minimal mean square error has been established by Anjaneyulu et al. [15]. This evaluation considers the Least Mean Square technique settings as well as antenna variables including step-size fluctuation and signal-to-noise variation. The major targets of all parameter changes are mean square error, null depth, convergence speed, and beamforming efficacy. The LMS with suitable antenna input variables resulted in successfully displaying information at the location of the interferers and minimizing the error, as seen in all calculated values.

Mayyas and Aboulnasr [16] presented the sensor which was placed at a distance, d, from each other. The weights are computed by making use of directivity, white noise, and interference ratio. Once the phase shifts were computed using the previous version of phase shifts, step size, reference signal, and error signal, the trace of the autocorrelation was found. From the weights, the maximum value has been found and then normalized phase shifts are obtained.

Saqhib et al. [17]. describes the path establishment process in a wireless sensor network (WSN) for sending data packets and highlights how repeated participation in multiple paths can lead to reduced network lifetime. The paper seeks to provide recapitulation of WSN, the effects of lifetime ratio, and an energy-efficient routing protocol through numerical survey.

Mallaiah et al. [18] demonstrated the Leaky LMS algorithm, which was responsible for finding the phase shifts and then applying the components to create the beam. Leaky LMS was developed on top of the LMS method with the variation in the computation of step size. The step size depends upon the Eigenvalue and then the maximum value of Eigen is found. The new phase shifts were calculated through earlier step size and phase shift.

Beamforming by Small-Spacing Microphone Arrays through Constrained LASSO has been demonstrated by Wang et al. [19]. The Capon approach also determines the cross-correlation between the BS signal and the real reference signal. Toeplitz execution will be used on the phase shifts to discover new phase shifts. Every component of the array was therefore subjected to the phase shifts to create the main beam.

3. SYSTEM MODEL

Consider a uniform linear array that has all dipole elements with each element separated from the other at an equal distance.

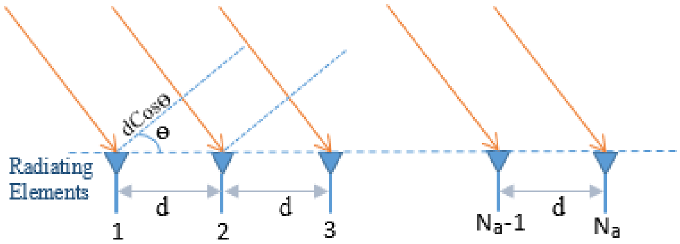

Fig. 1: Uniform Linear Array elements.

Figure 1 shows radiating or antenna elements arranged linearly. Na is the number of antenna elements separated by an equal distance d. The electromagnetic (EM) wave along with the delayed versions falls on the array elements. The representation of the electromagnetic wave will create the delay vector having Na* 1 with Na as the number of elements. The disturbance can be suppressed with the help of multiple wavelengths. The delayed electromagnetic wave vector can be summarized as Eq. (1) below,

$$EM(\theta d) = \begin{bmatrix} 1 \\ e^{-j\pi \sin(\theta d)} \\ . \\ . \\ . \\ e^{-j\pi(N_a-1)\sin(\theta d)} \end{bmatrix} \tag{1}$$

where, Na is the number of array elements, and theta is the direction of impinging electromagnetic wave.

The reference signal is generated for the mobile station which can be a sine or cosine reference signal with Ns number of samples and is provided by the values as Eq. (2)

$$r(i) = cos(pi * i / Ts) \tag{2}$$

where,

i = sample index

Ts = number of samples

The reference signal would be better if the sampling is done using Nyquist criteria in which the sampling period should have a certain minimum value. The sampling frequency should be greater or equal to the minimum value of $1/2*Ts$. The index will be varied between $0 <= I <= Ns$ where Ns is the maximum number of samples.

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The array manifold vector is computed for the set of N users and the combination of direction vectors across interference user's Njammer directions $\{\theta_1, \theta_2, ...\theta_{Njammer}\}$ which is stated in Eq. (3),

$$J_M = \begin{bmatrix} 1 & 1 & .... & 1 \\ e^{-j\pi\sin(\theta_1)} & e^{-j\pi\sin(\theta_2)} & & e^{-j\pi\sin(\theta_{Nj})} \\ . & & & \\ . & & & \\ . & & & \\ e^{-j\pi(N_a-1)\sin(\theta_1)} & e^{-j\pi(N_a-1)\sin(\theta_2)} & & e^{-j\pi(N_a-1)\sin(\theta_{Nj})} \end{bmatrix} \quad (3)$$

The jammer and noise signals are random and can be generated as Nj number of samples. The electromagnetic wave received at the base station will have pure directional vector and reference signal combinations. The jammer signal, along with directional vectors across all the directions and noise signal, can be provided as Eq. (4).

$$\begin{aligned} & BSRS_{signal} = D_v(\theta_0)\, RS + JS * Jm + NS \\ & Where, \\ & D_v(\theta_0) = direction\ vector\ for\ an\ angle\ \theta_o \\ & RS = Total\ reference\ signal\ in\ matrix\ format\ generated \\ & at\ the\ mobile\ station \\ & JS = Total\ interference\ signal\ samples\ which\ are \\ & random\ in\ nature \\ & Jm = Jammer\ Signal\ for\ all\ jammer\ directional\ vectors \\ & NS = Noise\ Signal\ Vector\ Matrix \end{aligned} \quad (4)$$

The BSRS matrix along with the Hermitian BSRS matrix can be multiplied to have an auto-correlation matrix which is represented in Eq. (5)

$$\begin{aligned} & R_{BSRS_{signal}} = BSRS_{signal} * BSRS^H_{signal} \\ & Where, \\ & BSRS_{signal} = total\ recived\ signal\ at\ BS \\ & BSRS^H_{signal} = hermitian\ transpose\ of\ BSRS \end{aligned} \quad (5)$$

The error signal at the base station has been found through the combination of all electromagnetic waves as an array total which is referred to in Eq. (6)

$$\begin{aligned} & AT(n) = Ps^H(n)\ BSRS(n) \\ & Where \\ & Ps^H(n) = hermitian\ transpose\ of\ array\ phase \\ & \qquad shifts\ which\ are\ applied\ to\ individual \\ & \qquad\quad phase\ shifters \\ & BSRS(n) = BSRS\ for\ n^{th}\ sample \end{aligned} \quad (6)$$

The error vector can be obtained using the difference among the reference signal which can be computed as Eq. (7)

$$ev(n) = |BSRS(n) - AT(n)| \tag{7}$$

Each of the methods will have to compute the phase shifts in such a way that the error vector value has to be minimized while considering some of the existing algorithms, such as Least Mean Square (LMS) [16], which is the robust approach to computing the weights. Then, the Griffiths algorithm [20] extracts a particular signal among many signals' incident at BS on the antenna array elements. Finally, the Variable step size Griffiths method [21] is formed by combining LMS along with the VSSLMS method to improve the performance. The step size is varied between 0 and the upper limit so that better and faster convergence can be achieved. The simulation results and their analysis are described in section 5.

4. PROPOSED 6T BEAMFORMER ALGORITHM

Figure 2 shows the functional block diagram of the Smart Antenna system at the BS where the antenna array picks up the signal from the user trying to access the communication channel to establish communication. The user direction is estimated using actual and delayed versions of the signal and the output is passed onto the beamforming block of the system where the advanced signal processing computes the weights for each iteration considering the output feedback and radiates a beam that is maintained sharp and noise-free to the best possible extent for the communication link to be of high quality.

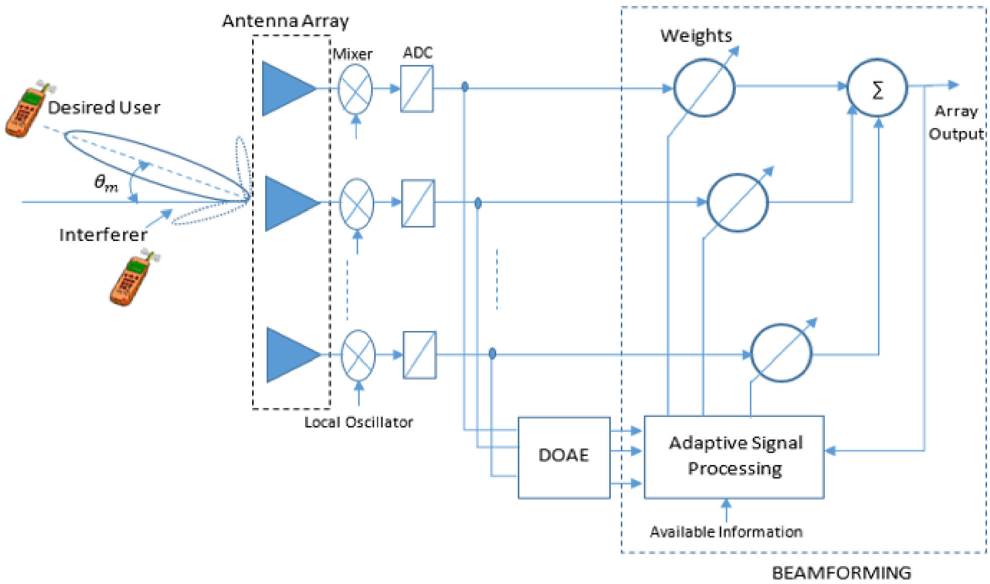

Fig. 2: Overall diagram for Smart Antenna system.

The proposed 6T Beamformer [22] is a six-tap phase shifts method with the combination of leaky Least Mean Square (LLMS) and Variable Step Size Least Mean Square (VSSLMS). Convergence is an important performance parameter wherein the convergence factor is the i^{th} number of iterations at which the mean square error reaches zero. The performance of the algorithm is improved by lowering the iteration count and increasing the convergence factor.

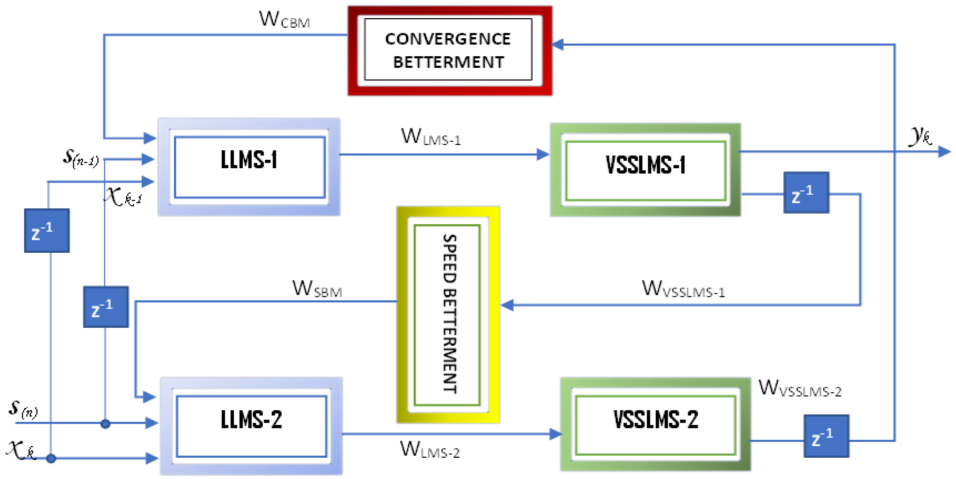

Fig. 3: Six-Tap Phase Shifts Applier.

Figure 3 shows the arrangement of six tap phase shifts applier which can be divided into 7 different blocks. In the first block, the phase shifts are computed using a leaky Least Mean Square (LLMS) method i.e. LLMS (1) to obtain k^{th} phase shifts. A Speed Better module will provide the computation of weights in a better fashion which computes k+1 phase shifts and then it is continued to Variable Step Size Least Mean Square (VSSLMS-1) to compute k+3. It is followed by Convergence Betterment (CB) method which will compute k+4 phase shifts which will then be sent to LLMS (2) and VSSLMS (2) to have k+5, k+6. Due to the execution of the modules, the convergence will be improved and then the error will be reduced to a lower value.

4.1 Leaky Least Mean Square

This method is one of the versatile beamforming methods which makes use of phase shifts that are applied to specific antenna elements followed by the formation of an array factor. But LMS faces certain disadvantages which are a) the rate at which convergence is achieved is quite low and b) drifting of weight causes more error. To overcome these disadvantages, the leaky factor is computed and used in the phase shifts (Eq.(8-9)). The phase shifts of the Leaky Least Mean Square (LLMS) magnitude will be kept within bounded limits so that the drifting issue can be resolved.

The step size for the LLMS module is computed as Eq. (8)

$$SS(n)_{LLMS} = \alpha * SS(n+1)_{LLMS} + \gamma * e(n)^2 \tag{8}$$

where,

α = initial step magnitude between 0 to 1

γ = average square of the error signal

The phase shifts vector used by LLMS can be defined as Eq. (9)

$$ps(n+1) = [1 - 2 * SS(n)]\, ps(n) + e * (n)\ BSRS(n) \tag{9}$$

4.2 Speed Betterment

The convergence speed can be improved using speed betterment-based phase shift computation which will take into consideration cross-correlation, step size, and previous phase shifts, as stated in Eq. (10).

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$$P_{SB}(n+1) = P_{SB}(n) + ([I - 2\mu_{SI} BSRS_{xx}]^{-1}[P(n) - 2\mu_{SI} BSRS_{xs}]) \quad (10)$$

The speed betterment phase shifts are computed using previous phase shifts, the base station received signal and then step size can be computed using Eq. (11).

$$\mu_{SB} = \frac{1}{3tr(R_{SB})} \quad (11)$$

where R_{SB} is the autocorrelation of Base Station Received Signal (BSRS) and $tr(R_{SB})$ is the trace of autocorrelation matrix, which is obtained by performing the square root of the sum of square values of each principal element.

4.3 Variable Step Size Least Mean Square

When the SNR of the signals are varying, the constant value of step size is not helpful. The step size can be obtained using a fast and robust variation of the VSSLMS method by making use of the normalized sigmoid method. It overcomes the convergence by adjusting the step size value in an adaptive fashion which is used in the computation of phase shifts.

The VSSLMS step size is varied to have better convergence which is expressed in Eq. (12).

$$\begin{aligned} SS_s(n+1) &= SS_{supper} \quad if \ SS_s(n+1) > SS_{supper} \\ &= 0 \qquad if \ SS_s(n+1) < 0 \\ &= SS_s(n+1) \ otherwise \end{aligned} \quad (12)$$

where,

SS_{supper} is the upper limit of step size.

The upper limit size is computed by making use of the Eigenvalue computation of auto-correlation which is stated in Eq. (13).

$$SS_{upper} = \frac{2 + ev_m}{AV} \quad (13)$$

where,

$ev_m = \max value\,of\ eigen\,values$

$AV = array\,value\,of\ mean\,square\,error(MSE)$

The phase shifts of the VSSLMS method can be computed using the following Eq. (14).

$$ps(n+1) = ps(n) + SS(n)e^*(n)\ BSRS(n) \ \ldots\ldots \quad (14)$$

4.4 Convergence Betterment

This module helps in increasing the speed at which the error can be minimized by making use of a reference signal to the array output.

The phase shifts are computed using the convergence betterment module by making use of the Aitken Process, which is referred to in Eq. (15).

$$w_{CB1} = L - \frac{Nu_{LLMS}}{De_{LLMS}} \quad (15)$$

where, $Nu_{VSSGMk} = M_k M_k w_{VSSG1} + M_k N_k - M_k\, w_{VSSG1}$

$$De_{LLMSMk} = M_k M_k w_{LLMS1} + M_k N_k - 2M_k w_{LLMS1} - N_k + w_{LLMS1}$$

$L = ACS_k SCS_k w_{LLMS1} + ACS_k CCS_k + CCS_k$ where,

$$ACS_k = I - 2\mu_{CB} R_{xx}$$

$$CCS_k = 2\mu_{CB} R_{xs}\,.$$

5. SIMULATION RESULTS

In this section, simulation results of the proposed 6T Beamformer are discussed in detail along with the comparison of the algorithm against the existing ones to mean square error which is also a measure of the converging speed of the algorithms.

This paper considers a few existing high-performance algorithms such as Least Mean Square (LMS) [15], Griffiths algorithm [19] and Variable step size Griffiths method [20] for comparison of mean square error. The radiation pattern, real phase shifts and imaginary phase shifts are simulated only for the proposed 6T Beamformer as the comparison graph will have the results overlapped. The results are simulated by taking into consideration the probability of a number of jammers from one to many along with varying the number of antenna elements from few to many numbers.

Table 1 shows the probability-1 setup considering fewer array elements and one interference at 30 degrees. Figures 4 and 5 display the real and imaginary phase shifts for the experimental setup considered.

Table 1: Experimental setup for probability-1

Few Antenna Elements- Single Jammer	Values
Number of Array Elements	8
Desired Direction	45
Interference Count	1
Interference Directions	30

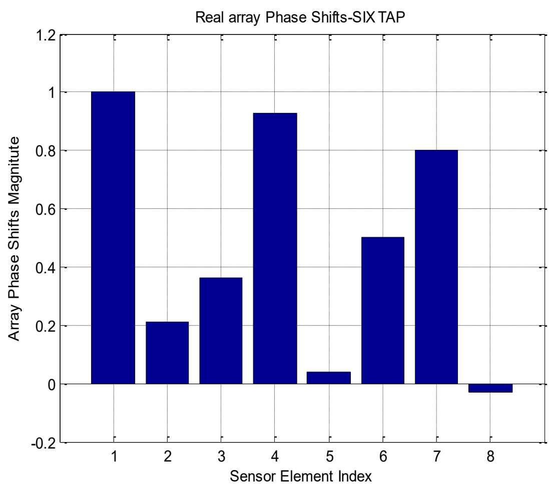

Fig. 4: Real Array Phase Shifts.

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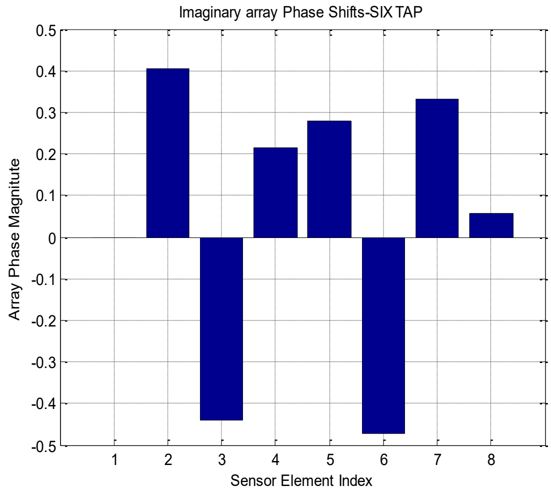

Fig. 5: Imaginary Array Phase Shifts.

Figure 6 Reveals the radiation array pattern for the setup as mentioned in probability-1 of 45 degrees. Figure 7 shows a mean square error comparison plot for probability-1 where the proposed 6T Beamformer algorithm successfully converges faster at run count or some iterations of 11 followed by VSSG, with a run count of 45, Griffiths along with LMS with a run count of 70. Hence the proposed 6T Beamformer performs better than other methods for considering probability-1. Table 2 shows the experimental setup considering a high number of antenna elements and a single interferer at 5 degrees with the desired source at 30 degrees for probability-2.

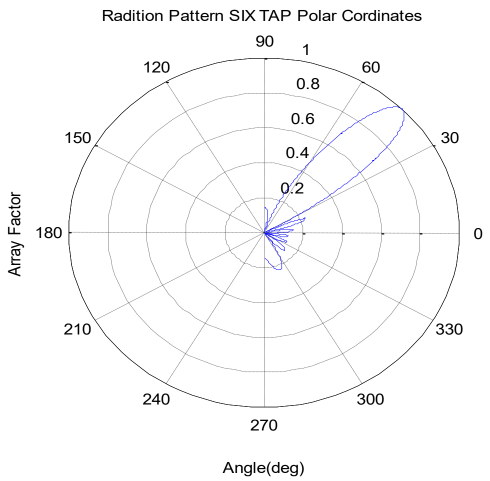

Fig. 6: Radiation pattern for 6T Beamformer at 45 degrees.

Table 2: Experimental setup for probability-2

Many Antenna Elements- Single Jammer	Values
Number of Array Elements	100
Desired Direction	30
Interference Count	1
Interference Directions	5

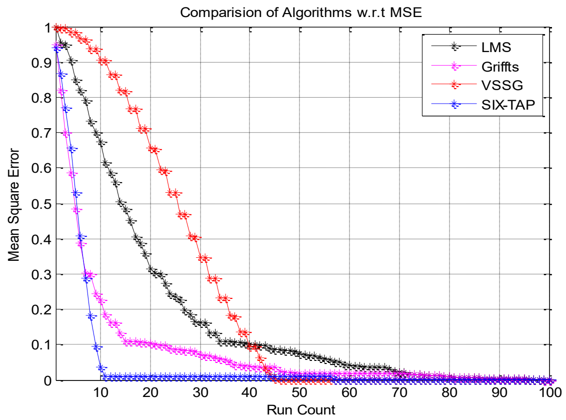

Fig. 7: Comparative analysis of MSE for probability-1.

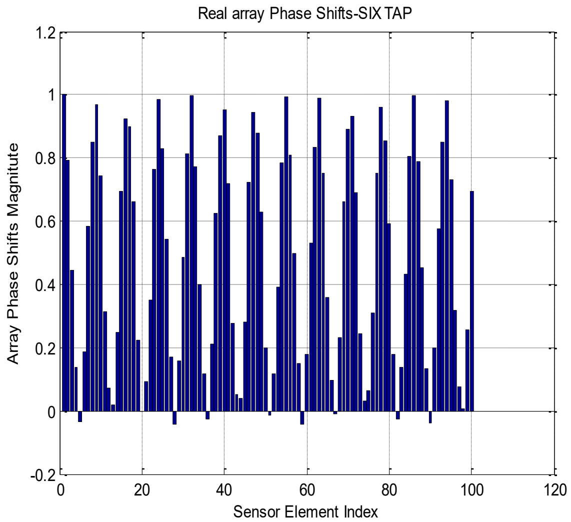

Fig. 8: Real Phase Shifts for probability-2.

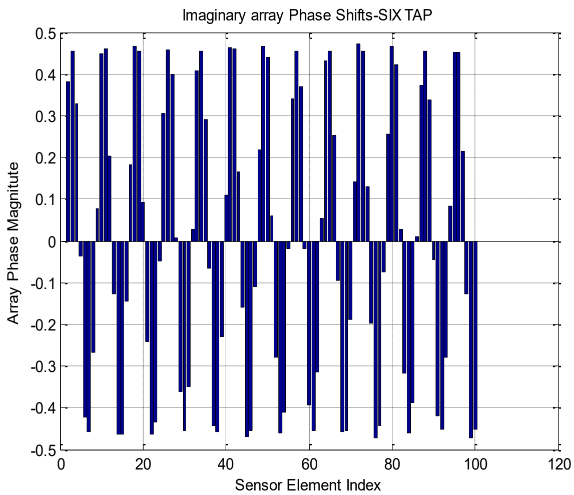

Fig. 9: Imaginary Phase Shifts for probability-2.

Figures 8 and 9 display the real and imaginary phase shifts for the experimental setup considered in probability-2 of 30 degrees. Figure 10 represents the antenna radiation pattern with the main beam at the desired angle of 30 degrees and interferer given no signal strength.

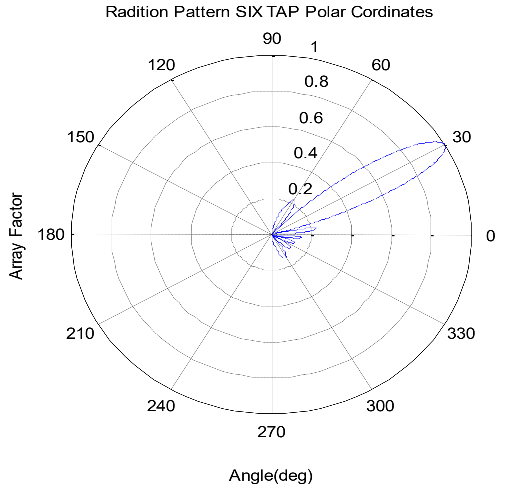

Fig. 10: Radiation Pattern for 6T Beamformer at 30 degrees.

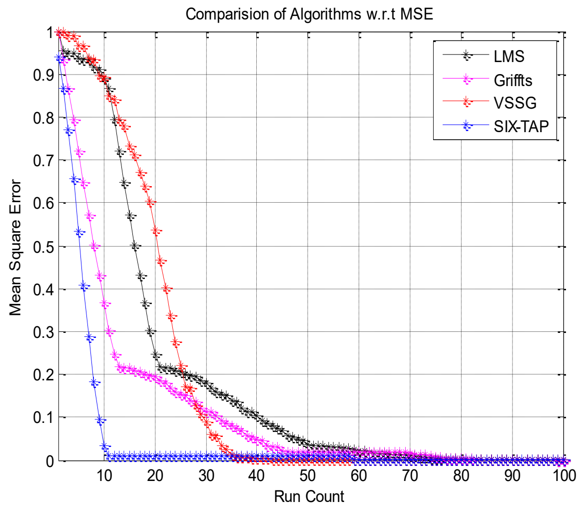

Fig. 11: Comparative analysis of MSE for probability-2.

Figure 11 shows the mean square error comparison graph for probability-2 where the 6T Beamformer converges faster at just 10 iterations which means low MSE followed by VSSG converging in 34 iterations and Griffiths, LMS at 75 each. Table 2 clearly shows that the 6T Beamformer proves to perform better in the desired direction (30 degrees).

Table 3: Experimental setup for probability-3

Few Antenna Elements- Multiple Jammer	Values
Number of Array Elements	8
Desired Direction	60 Degrees
Interference Count	3
Interference Directions	[5 10 15]

Table 3 displays the experimental setup of lesser array elements considering multiple interferers. Here, consider 3 interferers at 5, 10, and 15 degrees each.

Figures 12 and 13 exhibit real and imaginary phase shifts for the experimental setup considered in probability-3. These individual phase shifts are exploited to each element of the array for the formation of the main beam in the desired direction of 60 degrees with multiple

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interferers. Figure 14 shows the radiation pattern for 6T Beamformer forming a mean beam towards the desired user direction of 60 degrees while interferers are treated with nulls.

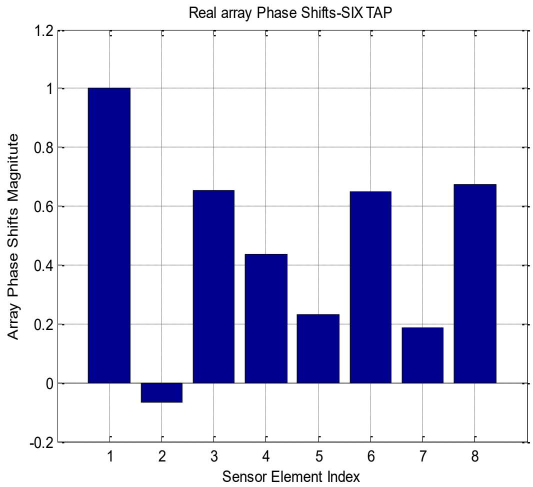

Fig. 12: Real Phase Shifts for probability-3.

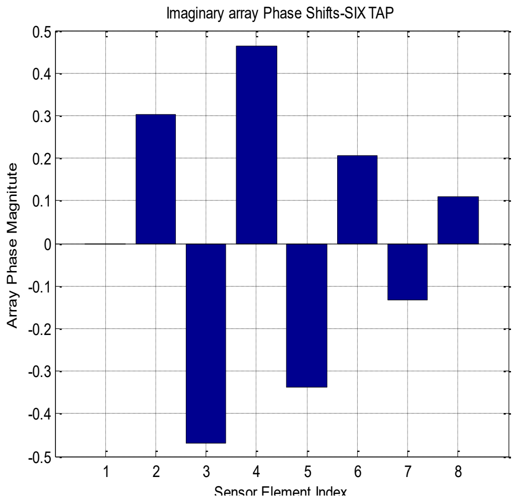

Fig. 13: Imaginary Phase Shifts for probability-3.

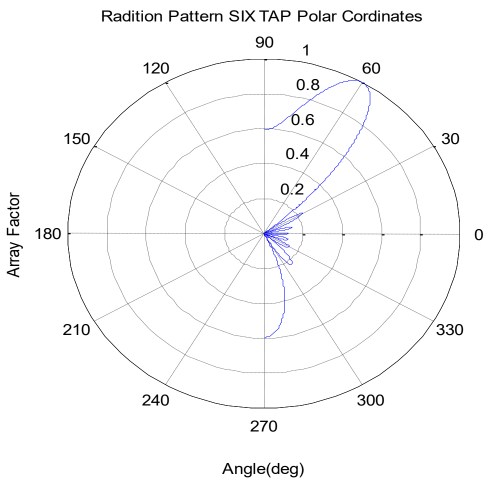

Fig. 14: Radiation pattern for 6T Beamformer - probability-3.

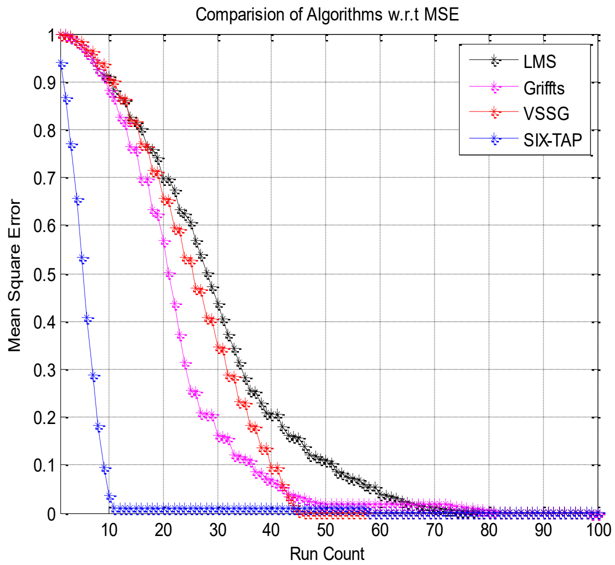

Fig. 15: Comparative Analysis of MSE for Probability-3

Figure 15 shows the mean square error comparison graph for probability-3 where the 6T Beamformer is seen converging faster, at just 10 iterations, giving low MSE followed by VSSG with a run count of 48, Griffiths and LMS converge at a run count of 80 and 78 respectively. Hence, the novel 6T Beamformer performs better than other methods for the considered probability-3. Table 4 displays the experimental setup description wherein a large number of antenna elements and multiple interferers are considered as a probability at the base station.

Table 4: Experimental setup for probability-4

Many Antenna Elements- Multiple Jammer	Values
Number of Array Elements	100
Desired Direction	15 Degrees
Interference Count	3
Interference Directions	[45 50 55]

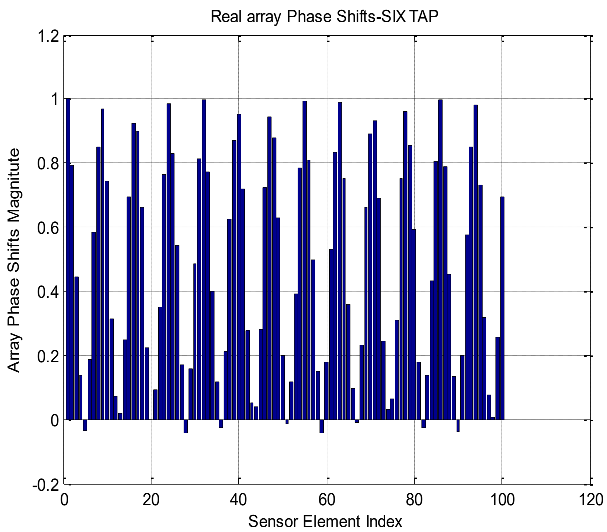

Fig. 16: Real Phase Shifts for probability-4.

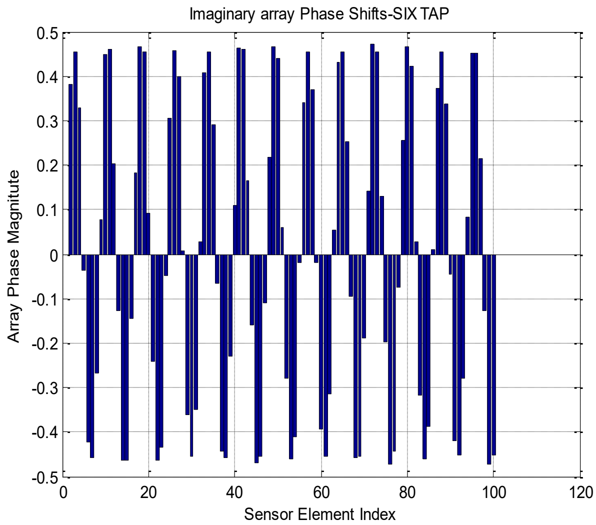

Fig. 17: Imaginary Phase Shifts for probability-4.

Figures 16 and 17 reveal real and imaginary phase shifts for the experimental setup considered in probability-4. Each phase shift is exploited to all sensor elements of the array for the formation of the main beam in the desired direction of 15 degrees with multiple interferers.

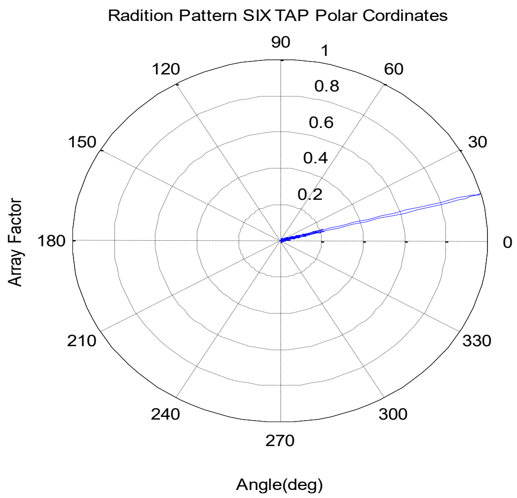

Fig. 18: Radiation pattern for 6T Beamformer - probability-4.

Figure 18 exhibits the radiation pattern for the novel 6T Beamformer Algorithm which excellently forms a narrow main beam towards the desired user direction of 15 degrees. The algorithm works very well with more antenna elements.

Figure 19 shows the mean square error comparison graph for probability-4 where the 6T Beamformer converges at just 9 iterations, implying lower MSE, followed by VSSG with a run count of 40, Griffiths and LMS converge at a run count of 70 and 62 respectively. Hence, the novel 6T Beamformer performs better than other methods for the considered probability-4. Table 5 summarizes the point of convergence obtained from the simulation results. It can be seen that the proposed 6T Beamformer converges faster than other algorithms with the least number of iterations implying low mean square error and high-speed performance of the algorithm.

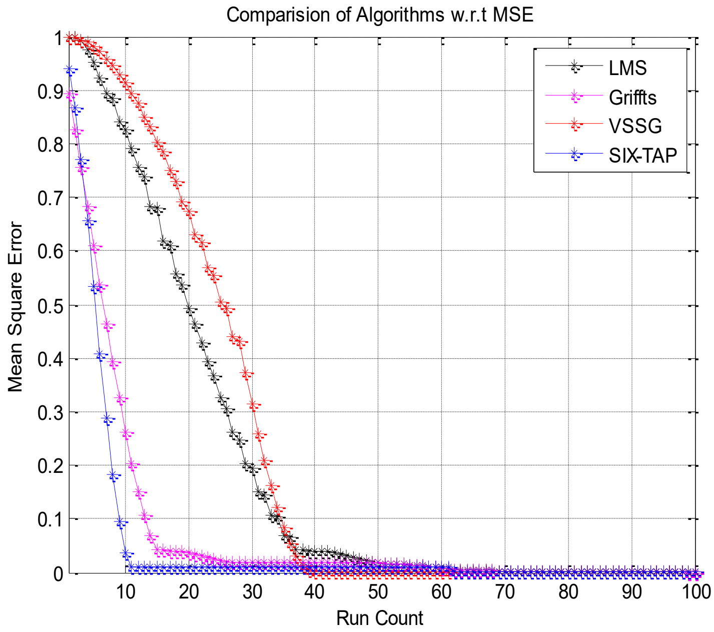

Fig. 19: Comparative analysis of MSE for probability-4.

Table 5: Summarizing the convergence point of all the algorithms.

Array Count	Jammer Count	LMS	Griffiths	VSSG	6T Beamformer
8	1	70	70	45	11
100	1	75	75	34	10
8	3	70	80	48	10
100	3	62	70	40	9

6. CONCLUSION

This research provides a novel beamforming method called 6T Beamformer to improve the converging speed by reducing the mean square error. The novel algorithm makes use of both fixed and variable step size methods along with Speediness Betterment and Convergence Betterment feedback. The feedback of weights is shared between the modules to calculate the phase shifts that are exploited to specific parts to create the main beam for actual mobile users. LMS, Griffiths, and VSSG are described in brief and these methods are then compared to the proposed Six Tap method which outperforms the existing ones for different scenarios of variation in array elements and jammer count. The convergence of SIX-TAP is high compared to other methods. The proposed technique is contrasted with other, high-performing methods in the analysis of the results to demonstrate that it converges more quickly at the 9th iteration and performs better than others in all probabilities. This also implies reduced multipath fading. The algorithm is also efficient in interference rejection and overall increasing the capacity of the RF spectrum. In the future, this research will be further extended by analyzing novel methods with various performance metrics.

REFERENCES

[1] Kabaoğlu N. (2018) Suboptimal Frequency-Selective Transceiver Design for Multicarrier Millimeter Wave MIMO Systems. Electrica, 18(1): 83-89. doi:10.5152/iujeee.2018.1813

[2] Tokan NT. (2019) Array Antenna Feeding Network Design for 5G MIMO Applications. Electrica, 19(2): 120-127. doi: 10.26650/electrica.2019.19004

[3] Hameed AA, Ajlouni N, Orman Z, Özyavaş A. (2020) Investigating the Effectiveness of Adaptive Step Size LMS Algorithms for the Use with VOIP Applications. Electrica, 20(2): 116-123. doi: 10.5152/electrica.2020.19080
[4] Li X, Wang J, Li Z, Li Y, Geng Y, Chen M, Zhang Z. (2022) Leaky-Wave Antenna Array with Bilateral Beamforming Radiation Pattern and Capability of Flexible Beam Switching. IEEE Trans. Anntenas Propag., 70(2): 1535-1540. doi: 10.1109/TAP.2021.3111157
[5] Ghaffar A, Li XJ, Awan WA, Hussain N. (2021) Reconfigurable Antenna: Analysis and Applications. In Matin, MA (eds) Wideband, Multiband, and Smart Antenna Systems. Signals and Communication Technology. Springer, Cham:269-323. https://doi.org/10.1007/978-3-030-74311-6_9.
[6] Kodgirwar VP, Deosarkar SB, Joshi KR. (2020) Design of Dual-Band Beam Switching Array for Adaptive Antenna Applications Using Hybrid Directional Coupler and E-Shape Slot Radiator. Wireless Personal Communications, 113 :423-437. https://doi.org/10.1007/s11277-020-07207-3
[7] Nawaz H, Tekin I. (2020) Ten switched-beams with 2×2 series-fed 2.4 GHz array antenna and a simple beam-switching network. Int. J. RF Microwave Comput. Aided Eng., 30(6): e22184. https://doi.org/10.1002/mmce.22184
[8] Baba AA, Hashmi RM, Attygalle M, Esselle KP, Borg D. (2021) Ultrawideband beam steering at mm-wave frequency with planar dielectric phase transformers. IEEE Trans. Antennas Propag., 70(3): 1719-1728.
[9] Simone M, Fanti A, Lodi MB, Pisanu T, Mazzarella G. (2021) An in-line coaxial-to-waveguide transition for Q-band single-feed-per-beam antenna systems. Appl. Sci., 11(6): 2524. https://doi.org/10.3390/app11062524
[10] Thazeen S, Mallikarjunaswamy S, Saqhib MN. (2022) Septennial Adaptive Beamforming Algorithm. In International Conference on Smart Information Systems and Technologies (SIST): 28-30 April 2022; Nur-Sultan, Kazakhstan. pp 1-4.
[11] Cai Z, Zheng X. (2018) A Private and Efficient Mechanism for Data Uploading in SmartCyber-Physical Systems. IEEE Trans. Network Sci. Eng., 7(2): 766-775. doi: 10.1109/TNSE.2018.2830307
[12] Dakulagi V, Bakhar M. (2020) Advances in smart antenna systems for wireless communication. Wireless Personal Communications, 110(2): 931-957.
[13] Tong L, Ramanathan P. (2004) Energy efficient multicasting using smart antennas for wireless ad hoc networks in multipath environments. In IEEE Global Telecommunications Conference, GLOBECOM '04: 29 November 2004 - 03 December 2004; Dallas, TX, USA. 6: 4109-4113. doi: 10.1109/GLOCOM.2004.1379138
[14] Ali WAE, Hassan AHG. (2014) A hybrid least mean square/sample matrix inversion algorithm using microstrip antenna array. In Science and Information Conference: 27-29 August 2014; London, UK. pp 871-876. doi: 10.1109/SAI.2014.6918288.
[15] Anjaneyulu P, Rao PVDS, Sunehra D. (2021) Effect of Various Parameters on Minimum Mean Square Error and Adaptive Antenna Beamforming using LMS Algorithm. In 6th International Conference for Convergence in Technology (I2CT): 02-04 April 2021; Maharashtra, India. pp 1-5. doi: 10.1109/I2CT51068.2021.9418179.
[16] Mayyas K, Aboulnasr T. (1997) Leaky LMS algorithm: MSE analysis for Gaussian data. IEEE Trans. Signal Process., 45(4):927-934. doi: 10.1109/78.564181.
[17] Saqhib MN, Lakshmikanth S. (2020) Performance Anatomization of Routing Protocols in Wireless Sensor Network. International Journal of Advanced Trends in Computer Science and Engineering, 9(4): 5691-5699.
[18] Mallaiah N, Rao NVK, Ramakrishna D. (2019) RLS Adaptive Beamforming Algorithm in terms of Energy Efficiency For Smart Antenna System. In IEEE Indian Conference on Antennas and Propagation (InCAP): 19-22 December 2019; Ahmedabad, India. pp 1-4. doi: 10.1109/InCAP47789.2019.9134501.
[19] Wang X, Benesty J, Chen J, Cohen I. (2020) Beamforming with Small-Spacing Microphone Arrays Using Constrained/Generalized LASSO. IEEE Signal Process Lett., 27: 356-360. doi: 10.1109/LSP.2020.2971790.

https://doi.org/10.31436/iiumej.v24i2.2730

[20] Roopa S, Narasimhan SV. (2021) Improved stability performance of a feedback active noise control using a Steiglitz-McBride adaptive notch filter and robust secondary path identification based on variable step size Griffiths LMS algorithm. Noise Control Engineering Journal, 69(2): 136-145. https://doi.org/10.3397/1/376914

[21] Shi L, Zhao H, Zeng X, Yu Y. (2019) Variable step-size widely linear complex-valued NLMS algorithm and its performance analysis. Signal Process., 165: 1-6. https://doi.org/10.1016/j.sigpro.2019.06.029

[22] Tuladhar SR, Buck JR. (2020) Unit Circle Rectification of the Minimum Variance Distortionless Response Beamformer. IEEE J. Oceanic Eng., 45(2): 500-510. doi: 10.1109/JOE.2018.2876584.