Turkish Journal of Computer and Mathematics Education Vol.12 No.9 (2021), 2206– 2211

Research Article

Evaluation of Beam Forming Capability of Linear Antenna Array for Smart Antenna System

Sarmistha Satrusallya[a], and Mihir Narayan Mohanty[a]

[a]Department of Electronics and Communication Engineering, Institute of Technical Education and Research, Siksha O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India

Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

Abstract: The increase in the number of users in a cellular network decreases the efficiency of the service provider. Array antenna improves the coverage, capacity and transmission quality of the system. Smart antenna system with digital signal processor has the capability to attain the gain and beam width for linear array in a desired direction. In this work, we analyze and compare linear arrays with 50 and 100 elements with different element spacing to achieve a narrow beam width. It was found that the spacing between the elements with number of elements is essential in determining the gain and First Null Beam Width (FNBW). For 50 numbers of element the gain is obtained as 17.3dB for a spacing 0.75λ and for 100 elements the gain is 20.38dB for a range of 0.6λ to0.75λ.

1. Introduction

Transmission of signal requires an efficient system. Antenna plays an important role to transmit and receive the signal. Basically an antenna is defined as a device through which radio frequency energy is coupled from the transmitter to the free space and free space to the receiver.

With the sudden increase in the number of mobile devices for different application, the necessity of enhanced coverage, improved capacity, and better transmission quality has also increased. However, power and bandwidth have remained costly. Though mobile devices are now available in low power consuming variety, narrow bandwidth is one of the major drawbacks for the system to achieve higher data speed. To increase the bandwidth, array antenna is used in different application. Array antenna is responsible for increase in signal strength, high directivity, low side lobes, high SNR and high gain.

Space Division Multiple Access (SDMA) is used for increasing the capacity of the wireless network. SDMA based system utilize the smart antenna system. In reality antennas are not smart. The digital signal processing capability along with the system makes them smart. The 70's era emphasized the concept of adaptive antenna array. It has its own application in the field of military radar system. The new generation has low cost digital signal processor and innovative software based processing technique to make smart antenna available commercially. The fundamental behind the smart antenna is to improve the performance of the system by increasing the gain in a particular direction. The main lobe of the antenna beam pattern is pointed towards the desired users with a narrow beam width. Different antenna elements are combining with the signal processing capability to optimize the radiation response. This concept is initially used in wireless system where sectoring was used to enhance the coverage area. Sectoring reduced the interference but responsible for increasing the number of hand off. Adaptive array antenna also known as diversity antenna is used to reduce the hand off between beams (Winters, 1998). Wideband smart antennas for wireless communication systems can be realized using three main fundamental approaches: (i) space-time signal processing, (ii) spatial-frequency signal processing and (iii) spatial signal processing (beam forming) (Oluwole et al, 2017).

A switched beam system or phased beam system has a beam-switching hybrid coupler with a phase difference in the output of the arms and the antenna array (Elhiwairis et al, 2011). In this system, highly sensitive multiple fixed beams are formed. After the signal strength is detected, one from the several fixed beams is chosen and switching between beams caters to the changing demands in the sector. Using an adaptive beam forming technique or adaptive array technique, it becomes possible to direct maximum radiation towards the desired mobile user and to introduce nulls at interfering positions (Ameen et al, 2017).

In this paper, the linear arrays are evaluated on the basis of the number of elements and the distance between the elements for beam forming. The paper is further organized into following sections: section 2, describes the previous works in the related area; section 3, represents the system description for the study; section 4, discusses the results and lastly, section 5, summarized the finding of this work.

2. Literature Survey

As wireless communication require higher capacity with lower interference, antenna beam forming with smart antenna increases the carrier to interference ratio in wireless link. Digital enhanced cordless telecommunication is a solution for WLL based communication system. It has degraded performance in multipath propagation. To overcome this smart antenna was used with a specified design and associated signal processing. The direction of arrival was estimated using two algorithms (Razavilar, 1999; Alam, 2010). For wide band in wireless system different signal processing were used with smart antenna. The spatial signal processing also termed as beam forming decreases the interference and estimates the DOA of the array. The BER performance of the smart antenna was analyzed to get an accurate approximation of the error probability. Both the Rayleigh and Rician fading multipath channels were considered to calculate the average probability of error (Oluwole et al, 2017; Haddad, 2010).

Different methods were proposed to control the antenna array for beam forming and element spacing. A comparative study of variable step size normalized LMS algorithm , Simple Matrix Inversion with Recursive Least Square(SMI-RLS) and Least Mean Square with Recursive Least Square(LMS-RLS) was presented for adaptive antenna array used in cellular communication. The methods are useful for reducing the error floor and quicker convergence as compared to LMS and NLMS algorithm (Aghdam, et al, 2016; Roy et al, 2016; Ismail et al, 2020). A Chaotic beam forming adaptive algorithm based on optimization of LMS algorithm using Chaos theory was used for adaption of antenna array radiation pattern. The radiation pattern of linear and circular array was analyzed for different types of input containing noisy reference signals. The algorithm was used for antenna array having less number of elements (Jovanović et al, 2016). Another method known as spatio temporal based approach was proposed for improvement of the performance of LMS, NLMS and VSLMS. The system was assumed to be time varying and the direction of arrival (DoA) was estimated by MUSIC algorithm . To reduce the computational complexity low complexity DoA estimation algorithm was anticipated (Shirvani et al, 2016). For steering the radiation pattern nulls towards the desired signal direction and to achieve a desired low SLL an iterative adaptive beam forming algorithm was studied. The algorithm has the ability to respond immediately in the real time (Gravas et al, 2019). Another robust and improved null-widening approach combining adaptive variable diagonal loading and covariance matrix taper was analyzed in (Li et al, 2017). Authors also reviewed and evaluated analytical techniques of adaptive beam forming systems, level of system performance, optimization approaches and relevant parameters for the deployment of smart antenna (Oluwole et al, 2018).Moth flame optimization for improving far field radiation, adaptive null introducing algorithm for digital and non digital beam forming studied and evaluated for smart antenna system (Das et al, 2018; Nayeri et al., 2018)[17,18]. The methods were useful for enhancing the performance of LMS and reducing the SLL by maintaining a narrow FNBW. Another optimization technique known as Grey Wolf Optimization (GWO) was proposed for beam forming to achieve optimal beam pattern with maximum side lobe reduction. With the increase in number of elements a better beam pattern and with the increase in the distance between the elements a narrow beam width is achieved with a more side lobe numbers (Mohsin et al, 2020).

3. System Design

The antenna array used for smart antenna system required increased gain, narrow beam width and minimum side lobes. The enhancement in gain and focus on directional beam is achieved by changing some of the parameters of the system such as number of antenna elements (N), spacing between the element(d) and steering angle(θ) . But we cannot modify two parameters simultaneously and to minimize the side lobes we need appropriate windowing function.

In this work, analysis is done to find the relationship of the gain and the beam width with the number of the elements and the spacing between the elements. The Hamming window function was applied to power pattern to reduce the number of side lobes.

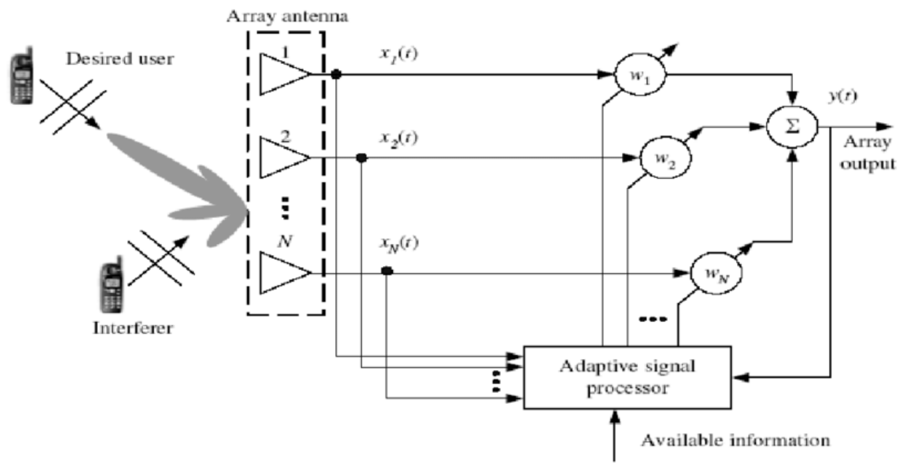

Figure.1. A smart antenna system (Kitindi et al, 2015)

Figure. 1 represents a smart antenna system. It consists of array antenna with adaptive signal processor. The processor is used to phase shift the steering of beam towards the direction arrival of the signal.

To calculate the gain of the array, at first the power radiated due to the array must be calculated. But the power calculation depends on the electric field of the array. For the computation we have to find out the electric field due to single element and multiply with the array factor (AF). Array factor is defined as a parameter which depends on the position of the elements of the array relative to the feed point.

Electric field due to array= [E (single element at ref point)] x [AF] (1)

Electric field due to a single element at the reference point is described as [21]:

$$E_1 = \widehat{a_\theta} j\eta \frac{kI_0 e^{-jkr}}{4\pi r} \quad (2)$$

The array factor (AF) for N-element linear array with uniform distance and uniform excitation amplitude is given by (Stutzman, 2012):

$$AF = \exp\left[\mathrm{j}\ \psi \frac{\mathrm{N}-1}{2}\right]\left[\sin\left(\frac{\psi N}{2}\right)/\sin\left(\frac{\psi}{2}\right)\right] \quad (3)$$

$$\psi = kd\cos(\theta) + \beta \quad (4)$$

The radiated power, P(θ, φ), can be calculated by [40]

$$P(\theta,\varphi) = \frac{1}{2\eta}\{Re \iint \left(|E_\theta|^2 + \left|E_\varphi\right|^2\right) r^2 \sin\theta \, d\theta d\varphi\} \quad (5)$$

The gain function is used to calculate the gain which is given by [21]

$$G(\theta,\varphi) = \frac{4\pi \times P(\theta,\varphi)}{P_{in}} \quad (6)$$

Where P (θ, φ) is the actual power radiated in direction (θ, φ) and Pin is the total accepted power.

The above relation describes the gain of an antenna array depends on number of elements and spacing between them.

The Beam width of the main lobe is defined as the angle from which majority of the antenna power radiates. As gain is related to power efficiency and the directivity of antenna, it is also closely related to the beam width. The presence of side lobes is a major contributor to the interference occurring in the antenna array systems. A reduction in the side lobe level decreases the interference from the unwanted direction and helps in increasing the gain of the main lobe by the law of conservation of energy.

An array of N antenna elements (N = 50, 100) that are arranged linearly with a distance d wavelengths ranging from 0.5 λ to0.8 λ is considered here. The steering angle θ has been varied from -90 degrees to +90 degrees. Two experiments were conducted: varying N with d and θ and varying d with N and θ constant. The antenna gain pattern was plotted with respect to the steering angle.

4. Results and Discussion

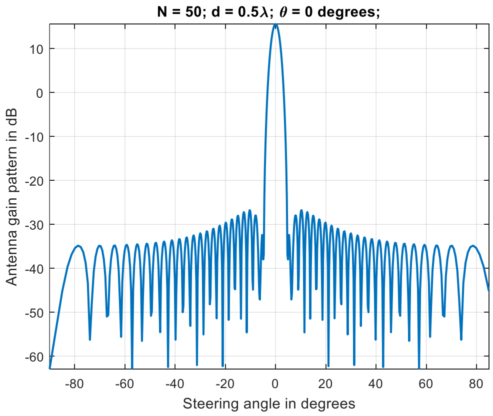

Fig. 1. Antenna gain pattern in dB with N=50, d=0.5λ, θ =0 degrees

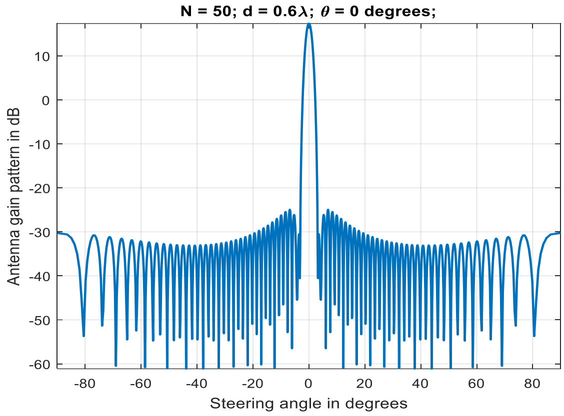

Fig. 2. Antenna gain pattern in dB with N=50, d=0.6λ, θ =0 degrees

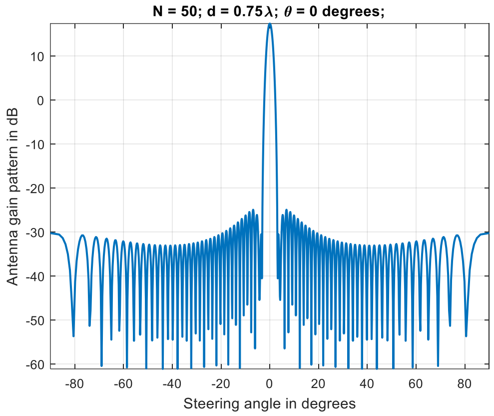

Fig. 3 Antenna gain pattern in dB with N=50, d=0.75λ, θ =0 degree

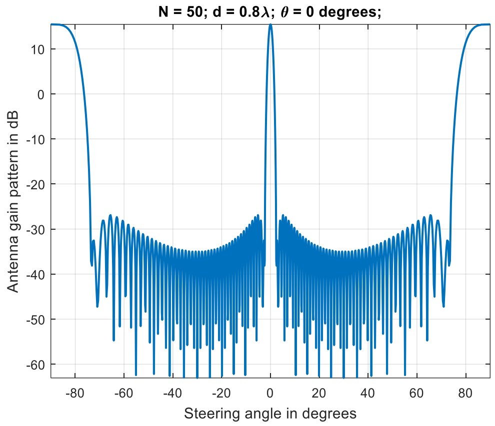

Fig. 4 Antenna gain pattern in dB with N=50, d=0.8λ, θ =0 degrees

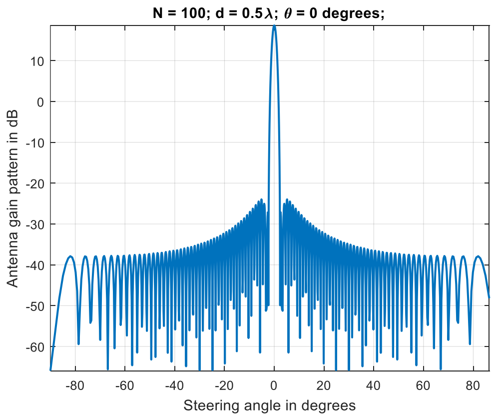

Fig. 5*Antenna gain pattern in dB with N=10, d=0.5λ, θ =0 degrees*

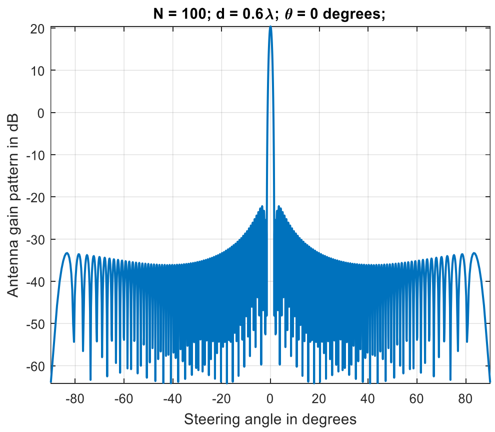

Fig. 6*Antenna gain pattern in dB with N=100, d=0.68λ, θ =0 degrees*

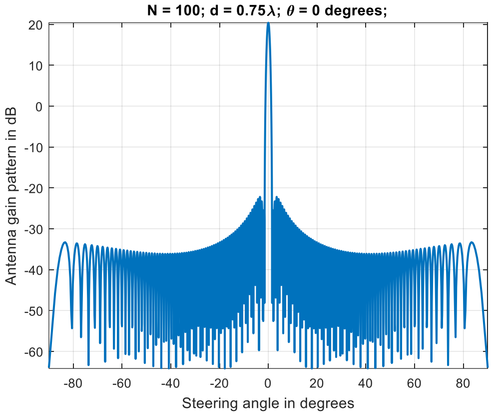

Fig. 7 Antenna gain pattern in dB with N=100 d=0.75λ, θ =0 degrees

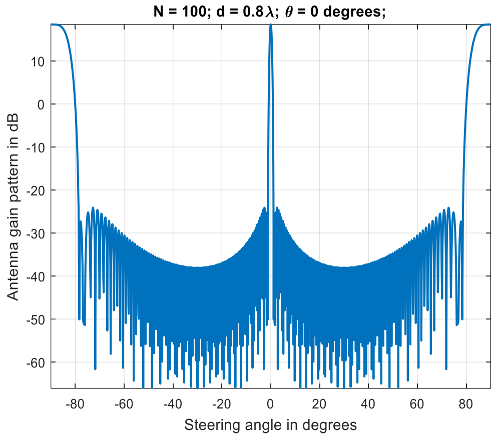

Fig. 8 Antenna gain pattern in dB with N=100, d=0.8λ, θ =0 degrees

5.Conclusion

In this paper, we propose a geo-aware graph partitioning method named heterogeneous adaptive heuristics to minimize the inter-DC data transfer time of graph processing jobs in geo-distributed DCs while satisfying the WAN usage budget. Proposed model incorporates two optimization phases. While the first phase utilizes the one pass streaming graph partitioning method to reduce inter-DC data traffic size when assigning edges to different DCs, the second phase identifies network bottlenecks and refines graph partitioning accordingly. The experiment results on both real geo-distributed DCs and with simulations have demonstrated that proposed is effective in reducing the inter-DC data transfer time with a low runtime overhead. As future work, we plan to extend our techniques to other graph processing models, experiment on graphs with larger sizes and heterogeneous computing environments with GPUs

References

1. Ahamad, S., Rat, P., Jedsada J. and Kittitat, S (2017) Journal of Materials Chemistry C Vol. 5 , pp.4614-4620.
2. Aroulanandam, V.V., Latchoumi, T.P., Bhavya, B., Sultana, S.S. (2019). Object detection in convolution neural networks using iterative refinements. Revue d'Intelligence Artificielle, Vol. 33, No. 5, pp. 367-372. https://doi.org/10.18280/ria.330506
3. Arunkarthikeyan, K. and Balamurugan, K., 2020, July. Performance improvement of Cryo treated insert on turning studies of AISI 1018 steel using Multi objective optimization. In 2020 International Conference on Computational Intelligence for Smart Power System and Sustainable Energy (CISPSSE) (pp. 1-4). IEEE.
4. Babu, T. V (2019) Journal of Innovation in Mechanical Engineering Vol. 2, pp. 27-31
5. Balamurugan, K., Uthayakumar, M., Sankarand, S., Warrier, K.G.K. (2018) International Journal of Machining and Machinability of Materials Vol.19, pp.426–439.
6. ChinnamahammadBhasha, A., Balamurugan, K. Studies on Al6061nanohybrid Composites Reinforced with SiO_2/3x% of TiC -a Agro-Waste. Silicon (2020). https://doi.org/10.1007/s12633-020-00758-x
7. Chinnamahammad Bhasha, A., Balamurugan, K. Fabrication and property evaluation of Al 6061 + x% (RHA + TiC) hybrid metal matrix composite. SN Appl. Sci. **1,** 977 (2019). https://doi.org/10.1007/s42452-019-1016-0
8. Deepthi, T. and Balamurugan, K., 2019. Effect of Yttrium (20%) doping on mechanical properties of rare earth nano lanthanum phosphate (LaPO4) synthesized by aqueous sol-gel process. Ceramics International, 45(15), pp.18229-18235.
9. Evgeni, I., Rumiana, K., Hesheng, X., Yinghong, C., Ricardo, K. D., Katarzyna, D., Anna,D. M. Rosa, P. G., Sossio, C and Verislav, A (2019) Applied Science. Vol. 9, pp. 120-1213
10. Feng, Z., Min, W., Vilayanur, V.V., Benjamin, S., Yuyan, S., Gang W and Chi.,Z. (2017) Nano Energy,Vol. 40, pp. 418–431.
11. Gnanasekaran, K., Heijmans, T., Bennekom, S. V., Woldhuis, H., Wijnia, S. G. and Friedrich, H. (2017) Applied Materials Today Vol. 9 (2017), pp. 21–28
12. Jeyapaul, R. and Shahabudeen, P (2005) International Journal of Advanced Manufacturing Technology, Vol.26, pp.1331-1337.

13. Latchoumi, T.P. and Kannan, V.V., 2013. Synthetic Identity of Crime Detection. International Journal, 3(7), pp.124-129.
14. Lebedev, S. M., Gefle, O. S., Amitov, E. T., Zhuravlev, D. V., Berchuk, D. Y and Mikutskiy, E. A (2018) The International Journal of Advanced Manufacturing Technology 97 , pp.511–518
15. Loganathan, J., Latchoumi, T.P., Janakiraman, S. and parthiban, L., 2016, August. A novel multi-criteria channel decision in co-operative cognitive radio network using E-TOPSIS. In *Proceedings of the International Conference on Informatics and Analytics* (pp. 1-6). https://doi.org/10.1145/2980258.2982107
16. Miguel, A.C., Ignacio, L.G., Nicolette, C. S., Jose, L. L. S., Teodolito, G. G., Juan, S. C .C. and Olga, S. B. (2018) Additive Manufacturing Vol. 22, pp. 157–164.
17. Najera, M. Sandra, J. Michel, K. Kyung and Namsoo (2018) Journal of Material Science & Engineering. Vol. 07, pp. 10.
18. Prakash, K. S., Gopal, P. M and Karthik, S. (2020) Measurement. Vol. 157, pp.107664.
19. Prashantha, K. and Roger, F. (2017) Journal of Macromolecular Science, Part A Vol. 54, pp.24-29.
20. Sheikh, M., Mahmud, T., Wolf, Ch., Glanz, C. and Kolaric, I (2010) Composites Science and Technology, Elsevier , Vol. 70 (16), pp.2253-2259.
21. Tuan, D.N., Alireza, K., Gabriele, I., Kate, T.Q.N. and H. David (2018) Composites Part B Vol. 143, pp. 172–196.
22. Uzair, K. Z., Emilien, B., Ali, S., Mickael, R and Aamer, A. B (2019) The International Journal of Advanced Manufacturing Technology Vol. 101, pp.1215-1226
23. Venkata Pavan, M and Balamurugan, K (2020) Vol.10, pp. 843-852.
24. Zhaobing, L., Qian, L. and Shuaiqi, X (2019) Journal of materials research and academy Vol. 8, pp. 3741-3751