2016-09-08

Investigation and analysis of the effects of geometry orientation of array antenna on directivity for wire-less communication
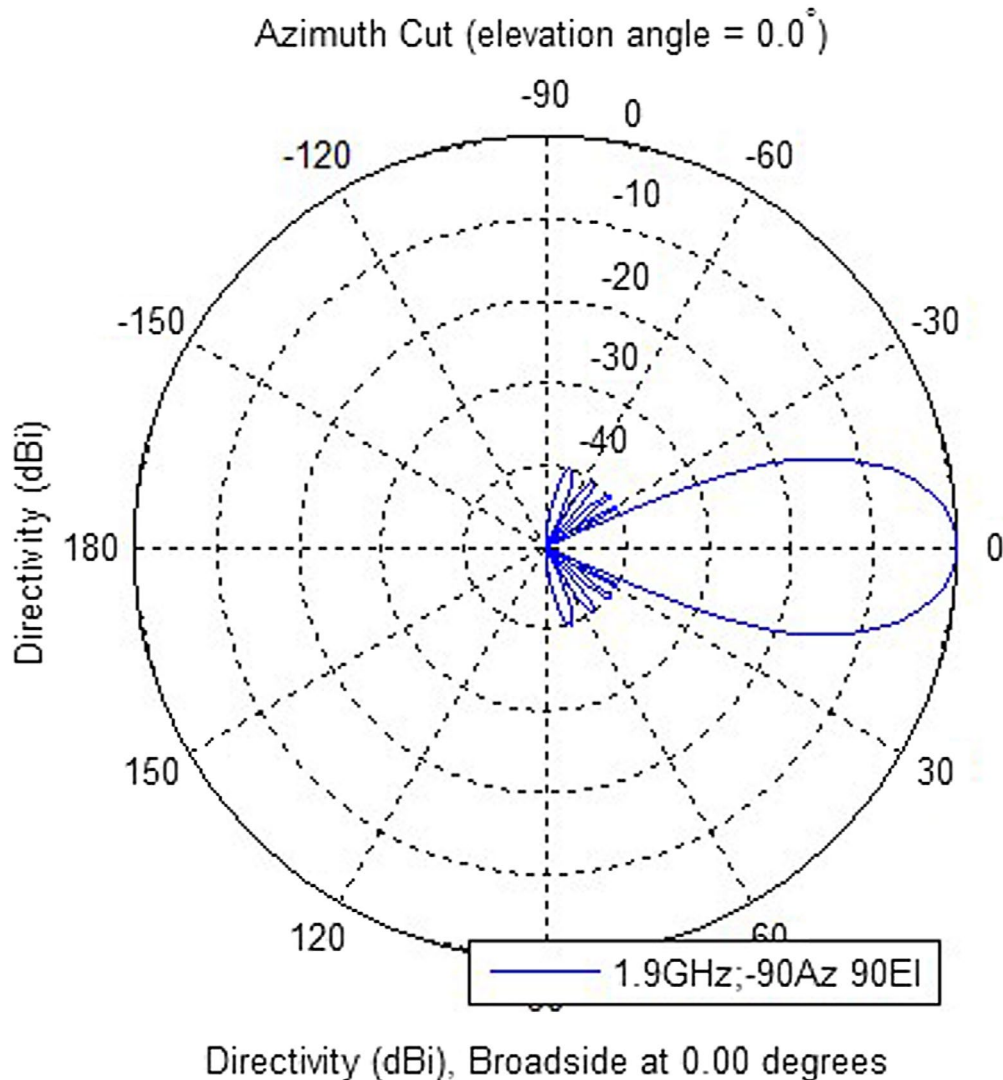
Kazema, Twahir

Cogent Engineering

Provided with love from The Nelson Mandela African Institution of Science and Technology

Azimuth Cut (elevation angle = 0.0°)

Directivity (dBi), Broadside at 0.00 degrees

Legend: 1.9GHz;-90Az 90El

Investigation and analysis of the effects of geometry orientation of array antenna on directivity for wire-less communication

Twahir Kazema and Kisangiri Michael

cogent
engineering

ELECTRICAL & ELECTRONIC ENGINEERING | RESEARCH ARTICLE

Investigation and analysis of the effects of geometry orientation of array antenna on directivity for wire-less communication

Twahir Kazema[1]* and Kisangiri Michael[2]

*Corresponding author: Twahir Kazema, Electronics and Telecommunication, Nelson Mandela African Institution of Science and Technology, Arusha, United Republic of Tanzania
E-mail: twahirkazema@gmail.com

Abstract: Array antennas offer a wide range of opportunities in the variation of their directivity patterns through amplitude and phase control. Directivity is one of very important parameters when optimizing Antenna. This paper intends to investigate the effects of different geometries of array antenna on directivity and side lobe levels. A six by four antenna array was chosen for investigation with uniform element spacing between the elements and the results were presented for each selected geometry, Array elements of dipole and patch antenna were chosen for the investigation and analysis. An analysis of the effect of the chosen antenna array was done by investigating its response when an incident emw (electromagnetic waves) from a mobile phone impinge on the array antenna where the tapering and beam-forming techniques were used for analysis and results presented.

Subjects: Digital & Wireless Communication; Radio, Satellites, Television & Audio; Telecommunication

Keywords: array geometry; directivity; side lobe

ABOUT THE AUTHOR

Twahir R.S.B. Kazema is currently a PhD student in Electronics and Telecommunication Engineering at Nelson Mandela African Institution of Science and Technology majoring in Communication Science and Engineering.

He received Master of Science in Information and Communication Science Engineering at Nelson Mandela African Institution of Science and Technology in 2013. He received a BE (Hons) degree in Electronics and Communication Engineering from St Joseph University in Tanzania (SJUIT) in November 2009. He worked with Kaluta Institute of Vocational Education and Training as the Telecommunication and Electronics Instructor 2009-2010, he also worked with Pee Pee Tanzania Limited (PPTL) as an Instrumentation Engineer 2010-2011 before he joined nelson Mandela African institution.

His interest includes Antenna Design and Optimization using Evolutionary Algorithm, Biomedical Engineering, Data Transmission and Wireless Telecommunications.

Twahir R.S.B. Kazema

PUBLIC INTEREST STATEMENT

Communication affects all the people worldwide, this makes Wireless communication very important in our everyday communication life. Antenna which are used for transmitting & receiving information are mostly important of all. With the challenges facing Antennas, Array antennas offers a wide range of opportunities for the tackling the challenges of the wireless communication. Directivity is one of very important parameters when optimizing Antennas, however sidelobes are not needed in wireless communication systems. Properly optimization of Array antenna will improves the directivity and reduce the side lobe to the minimum required. The mentioned performance metrics can efficiently tackled by clearly understanding and experimenting the geometry (orientation) effects of the array antenna on the mentioned metrics. This study has taken into consideration of dipole & patch as array elements which will help the designer to choose which element will be suitable for addressing the mentioned performance metrics for the purpose of improving QoS.

cogent··oa

1. Introduction

An antenna is used to radiate electromagnetic energy efficiently and in desired directions. Antennas act as matching systems between sources of electromagnetic energy and space. An antenna array is an assembly of radiating elements. Radiation pattern of a single element is relatively wide, each element provides low values of directivity (Mendolia et al., 2004). However, in many applications we require antennas with very high directive characteristics. The directive characteristics of the antennas can be improved by increasing the electrical size of the antenna. One way to increase the dimension of the antenna without necessarily increasing the size of the individual elements is to form an array of antenna elements. The total field of the array is determined by the vector addition of the fields radiated by the individual elements. The elements of the array need not be identical, but it is often convenient and simpler to design such arrays when the individual elements are considered to be identical. Therefore, here we will consider an array with identical elements. In designing arrays we have several controls such as geometrical configuration of the overall array, distance between the elements, excitation (amplitude and phase) and pattern of individual elements.

2. Array antenna review

An array of antennas mounted on vehicles, ships, aircraft, satellites, and base stations is expected to play an important role in fulfilling the increased demand of channel requirement for these services, as well as for the realization of the dream that a portable communications device the size of a wristwatch be available at an affordable cost for such services. Description on how the different shape parameters of the DETSA impact antenna performance was discussed (Greenberg, Virga, & Hammond, 2003). The potential advantages offered by fiber-optic delay lines and the concept of true-time-delay steering for phased array antennas and its advantage over phase shifters in broadband applications were described with particular emphasis by (Ng et al., 1991). Multiple layer dipole array that provides for a multi-frequency band phased array antenna. Several layers of dipole pair arrays, each tuned to a different frequency band, are stacked relative to each other along the transmission/reception direction (Wong, Lee, & Tang, 1996). An array of antennas mounted on vehicles, ships, aircraft, satellites, and base stations is expected to play an important role in fulfilling the increased demand of channel requirement for these services, as well as for the realization of the dream that a portable communications device the size of a wristwatch be available at an affordable cost for such services (Godara, 1997). An adaptive parasitic array antenna system having properties of directive gain, self-pointing and interference rejection was provided including an adaptive parasitic array antenna comprising at least one active element and one or more parasitic elements coupled to controlled impedances (CI). The system further comprises a transceiver, a content-based optimization criterion computation module (Kezys, 2002).

Computationally efficient global optimization method, the differential evolution algorithm (DEA), was proposed for the synthesis of uniform amplitude arrays of two classes, i.e., unequally spaced arrays with equal phases and unequal phases. Phase-only synthesis and the synthesis of uniformly exited unequally spaced arrays (position only synthesis) are compared and it is seen that, by using the unequal spacing, the number of array elements can be significantly reduced for attaining reduced side lobe levels. From the DEA-based synthesis of unequally spaced arrays with uniform amplitudes and unequal phases, it is found that a tradeoff exists between the size of the unequally spaced arrays and the range of phases for the same radiation characteristics. The proposed synthesis technique using uniform amplitudes, unequal spacing, and unequal phases (position-phase synthesis) not only decreases the size of the array for the same SLL compared to both the phase-only synthesis and position-only synthesis but also retains their advantages (Kurup, Himdi, & Rydberg, 2003).

By etching longitudinal slots on the top metallic surface of the substrate integrated waveguide (SIW), an integrated slot-array antenna was created. The whole antenna and feeding system are fabricated on a single substrate, which takes the advantage of small size, low profile, and low cost, etc. The design process and experimental results of a four-by-four SIW slot array antenna at *X*-band are presented by (Yan et al., 2004).

The DETSA is created by taking a Vivaldi radiator and tapering the outside edge of the slot line conductors. The shape of the outside edge of the slot line conductors adds additional antenna design degrees of freedom. A simulation environment of array antenna encompasing realistic propagation conditions and system parameters was employed in order to analyze the performance of future multi-gigabit indoor communication systems at tetra hertz frequencies. The influence of high-gain antennas on transmission aspects is investigated. Transmitter position for optimal signal coverage was also analyzed. Furthermore, signal coverage maps and achievable data rates are calculated for generic indoor scenarios with and without furniture for a variety of possible propagation conditions (Piesiewicz, Jacob, Koch, Schoebel, & Kurner, 2008).

New reconfigurable antenna array was demonstrated for multiple input multiple output (MIMO) communication systems that improves link capacity in closely spaced antenna arrays. The antenna system consists of an array of two printed dipoles separated by a distance of a quarter wavelength. Each of the dipoles can be reconfigured in length using PIN diode switches. The switch configuration can be modified in a manner adaptive to changes in the environment. The configuration of switches effects the mutual coupling between the array elements, and subsequently, the radiation pattern of each antenna, leading to different degrees of pattern diversity which can be used to improve link capacity. The PIN diode-based reconfigurable antenna solution is first motivated through a capacity analysis of the antenna in a clustered MIMO channel model.

A new definition of spatial correlation coefficient was introduced to include the effects of antenna mismatch and radiation efficiency when quantifying the benefit of pattern diversity. Next, the widespread applicability of the proposed technique was demonstrated, relative to conventional half wavelength printed dipoles, using computational electromagnetic simulation in an outdoor and indoor environment and field measurements in an indoor laboratory environment. An average improvement of 10% and 8% is achieved in link capacity for a signal to noise ratio (SNR) respectively of 10 dB and 20 dB in an indoor environment compared to a system employing non reconfigurable antenna arrays (Piazza, Kirsch, Forenza, Heath, & Dandekar, 2008). An investigation into beam synthesis for small circular and semicircular arrays is presented. Array antennas of this type are likely to become a core component in future wireless LAN systems architecture. They offer additional spatial diversity as a means for combating multipath interference, necessary for high speed data communications, and user mobility. Beams are synthesized using co-phasal and adaptive algorithms. Beam widths of 19° and −20 dB side lobe levels are attainable from an array of three wavelengths diameter. A semicircular array of this type can maintain a gain of approximately 10 dBi over a look direction angular range of ± 50° (Fletcher & Darwood, 1998). The impact of mutual coupling between neighboring radiators in an imaging array configuration in the presence of a dielectric super-layer was investigated. The super-layer generally aims at increasing the directivity of each element of the array. However, it was shown that the directivity of the embedded element patterns are reduced by a high level of mutual coupling. Thus a trade-off between directivity enhancement and close packing of the array elements must be found depending on the bandwidth and the pattern requirements (Llombart, Neto, Gerini, Bonnedal, & De Maagt, 2008).

It was demonstrated how a magnetic permeability enhanced Meta material can enhance the antenna array of a multiple-input multiple-output (MIMO) communication system. The performance of a rectangular patch antenna array on a Meta material substrate was studied relative to a similar array constructed on a conventional FR4 substrate. Differently spaced arrays were analytically compared using array correlation coefficients and mean effective gain as performance metrics. Achievable channel capacity were obtained through channel measurements made on a MIMO test bed. While results show that arrays on conventional FR4 substrates have higher capacity due to gain and efficiency factors, arrays can be made smaller, and have less mutual coupling and correlation coefficients, when using a meta material substrate, but the antenna built on the meta material substrate can be made more efficient through the use of better host materials. This was reflected in the analysis of both antenna arrays normalized to remove efficiency and gain differences where they showed

similar performances. Hence, meta material substrates are a cost-effective solution when antenna miniaturization is a key design criteria compared to conventional substrates that achieve the same miniaturization factor without significantly sacrificing performance (Mookiah & Dandekar, 2009).

As the growing demand for mobile communications constantly increases, the need for better coverage, improved capacity, and higher transmission quality rises. Thus, a more efficient use of the radio spectrum is required. Small antenna systems are capable of efficiently utilizing the radio spectrum and, thus, hold a promise for an effective solution to the present wireless systems' problems, while also achieving reliable and robust high-speed high-data-rate transmission. Although numerous studies for smart antennas have already been conducted using rectilinear arrays, including mostly uniform linear arrays (ULAs) and uniform rectangular arrays (URAs), not as much effort has been devoted to other configurations. The performance of smart antennas with uniform circular arrays (UCAs) was examined. A profound justification for this selection is the symmetry possessed by uniform circular arrays. This property provides uniform circular arrays with a major advantage: the ability to scan a beam azimuthally through 360° with little change in either the beam width or the side lobe level. With the use of uniform circular arrays, the two main issues related to smart antennas - estimation of the direction of arrival from incoming signals and beam-forming were both examined (Ioannides & Balanis, 2005).

Results from an investigation into methods of modeling the radiation patterns of phased arrays that include the effects of radiative mutual coupling were examined. The approaches were based on either the principle of pattern multiplication or the use of active element patterns. Theoretical derivations of the various active element pattern methods were presented. A new method, the hybrid active element pattern method was introduced. It accurately predicts the patterns of small and medium-size arrays of equally spaced elements. Example arrays of center-fed dipoles were analyzed to verify and illustrate the representations. The results are general and can be applied to arrays of any type of element. The array patterns computed using both the classical pattern multiplication approach and the methods based on active element patterns were compared to those computed using accurate numerical codes based on the method of moments (Kelley & Stutzman, 1993).

As a complementary imaging technology, coincidence imaging radar (CIR) achieves super-resolution in real aperture staring radar imagery via employing the temporal-spatial independent array detecting (TSIAD) signals. The characters of TSIAD signals are impacted by the array geometry and the imaging performance are influenced by the relative imaging position with respect to antennas array. The effect of array geometry on CIR system is investigated in detail based on the judgment criteria of the effective rank theory. In course of analyzing of these influences, useful system design guidance about the array geometry is remarked for the CIR system. With the design guidance, the target images are reconstructed based on the Tikhonov regularization algorithm. Simulation results are presented to validate the whole analysis and the efficiency of the design guidance (Zha, Wang, Yang, Cheng, & Qin, 2016).

The design of non-uniformly spaced linear array antennas using Particle Swarm Optimization method was considered by (Mukherjee, Hajra, Ghosal, Chatterjee, & Chatterjee, 2014). The purpose is to match a desired radiation pattern and improve the performance of these arrays in terms of side lobe level. This performance criterion determines how well the system is suitable for wireless communication applications and interference reduction. Two approaches are considered: in the first, the design of element placement with the constraint of array length being imposed is performed. The second is based on element position perturbation starting from a uniform element distribution. Many examples are treated to show the effectiveness of the designs and the effect some other parameters might have on the overall performance of the array (Recioui, 2012), the examination of various aspects of beam steered linear array of isotropic radiators with uniform inter-element spacing in order to control beam broadening and to achieve SLL reduction in beam steered array, a novel method has been proposed by (Mukherjee et al., 2014) modifying primarily the search space definition for Particle Swarm Optimization. Tschebyscheff polynomial and PSO has been used to develop the proposed method. Search space for PSO has been defined using Tschebyscheff polynomial for an

amplitude taper beam steered linear array. PSO with the information of where to search finds the optimum excitation amplitude of the beam steered linear array to either achieve reduced SLL and narrow beam width within the beam steering range (Mukherjee et al., 2014).

The design problem of imposing deeper nulls in the interference direction of uniform linear antenna arrays under the constraints of a reduced SLL and a fixed first null beam width (FNBW) is modeled by (Goswami & Mandal, 2013) as a simple optimization problem. The real-coded genetic algorithm (RGA) is used to determine an optimal set of current excitation weights of the antenna elements and the optimum inter-element spacing that satisfies the design goal. Many studies have taken into consideration of linear array and only few have considered other geometries, the purpose of this article is to take a further step of investigation by taking into consideration the patch and dipole elements.

3. Directivity
In electromagnetics, directivity is a figure of merit for an antenna. It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power.

Equation 1: Directivity (Huang & Boyle, 2008)

$$D = \frac{U_{max}}{P_{rad}/4\pi}$$

where $U_{max} = (E_{max} \cdot E_{max}{}^*)$: Maximum radiation intensity, P_{rad}: Radiated power.

Equation 2: Array pattern equation (Huang & Boyle, 2008)

$$E_{tot}(\theta, \phi) = \sum_{n=1}^{N} A_n F_n(\theta_n, \phi_n) e^{-j(ko|r_n|+\beta_n)}$$

where $E_{tot}(\theta, \phi)$: Total E-field at point P in linear volts, $F_n(\theta_n, \phi_n)$: Element pattern function, A_n: Amplitude, $|r_n|$: Distance, β_n: Propagation constant, $ko = \frac{2\pi}{\lambda_0}$: Phase constant.

3.1. Microstrip patch antenna
Below are the equations which are used for calculating the total Electric field of a microstrip patch antenna for φ and θ degrees (Figure 1).

Figure 1. Patch antenna.
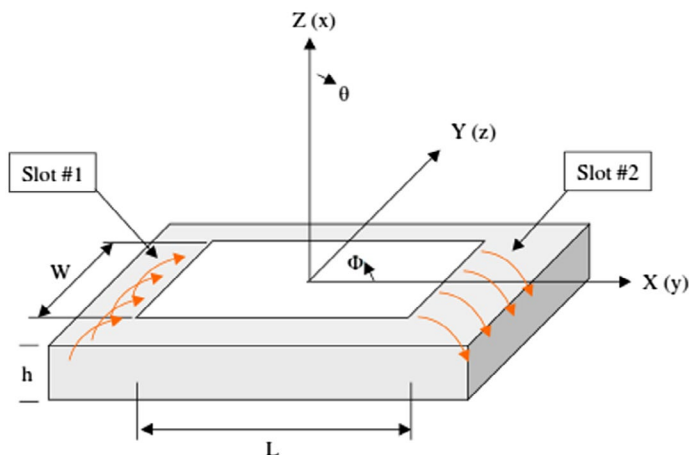
Equation 3: Electric & magnetic field (Huang & Boyle, 2008)

$$E_\varphi total = \left\{ sin(\theta) \frac{sin\left(ko.h./_2 \, sin(\theta)\right) sin\left(\frac{ko.W}{2} \, cos(\theta)\right)}{sin\left(ko.h./_2 \, sin(\theta)\right) sin\left(\frac{ko.W}{2} \, cos(\theta)\right)} \right\}$$

$$E_\phi total = \left\{ \frac{sin\left(ko.h./_2 \, cos(\phi)\right)}{ko.h./_2 \, cos(\phi)} \right\} cos\left(\frac{ko.le \, sin(\phi)}{2}\right)$$

Equation 4: Patch electric field

$$ko = {}^{2\pi}/_{\lambda_0}$$

$$L_e = L + 2 \cdot \Delta L$$

$$\Delta L = h(0.412) \frac{\left(E_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(E_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$

$$E_{reff} = \frac{E_r + 1}{2} + \frac{E_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-0.5}$$

Investigation using the rectangular patch antenna for using in an array antenna was conducted. The parameters which were considered first for the patch itself are as follow:

The value for permittivity (Er = 1)

Height of the patch (h = 0.01)

Length of the patch (L = 0.01)

An array of 24 elements with an element spacing of (0.7 * λ) (Figure 2).

Directivity pattern for rectangular array using rectangular patch antenna was conducted. The directivity for the array was found to be 21.68 dB for specified φ value, however the θ maximum SLL value was found to be 8 dB (Figure 3).

Directivity pattern for circular array using circular patch antenna was conducted. The directivity for the array was found to be 23.23 dB for specified Φ value, however the maximum SLL value was found to be 11 dB (Figure 4).

Directivity pattern for cylindrical array using rectangular patch antenna was conducted. The directivity for the array was found to be 22 dB for specified Φ value, however the maximum SLL value was found to be 8 dB, however the side lobes are very wide and big compared to the other geometries (Figure 5).

Directivity pattern for rhombic array using Rectangular patch antenna was done and found 19.01 dBi for specified Φ value, however the maximum SLL value was found to be 9 dB.

Figure 2. Results for rectangular geometry.
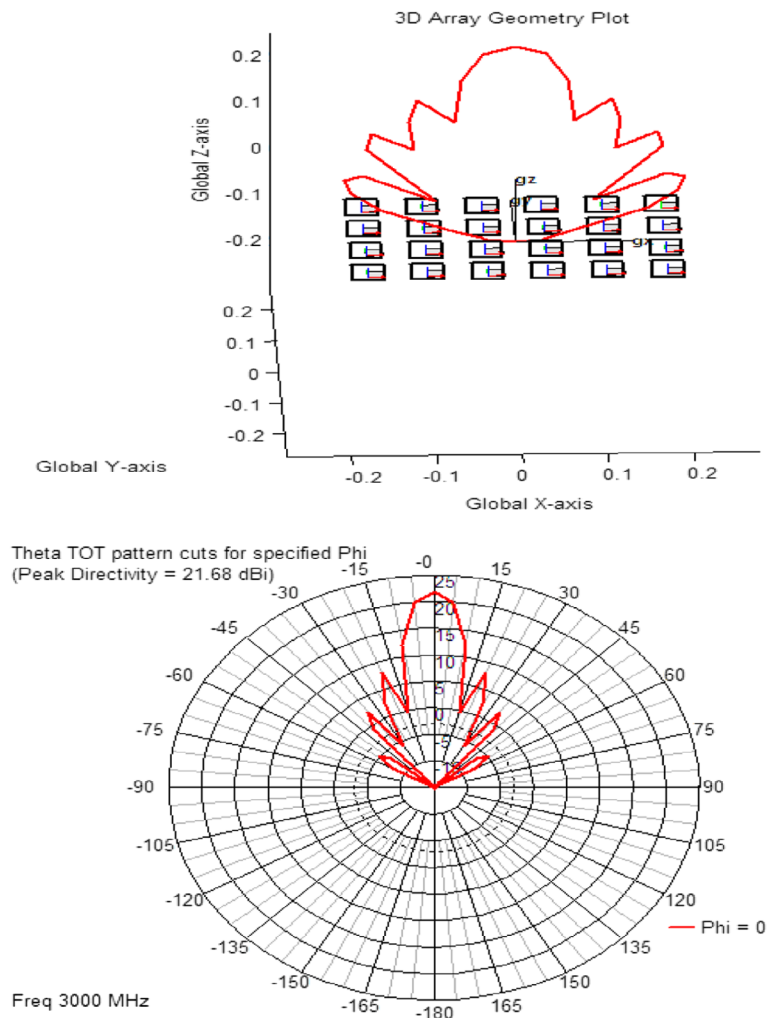
3.2. Dipole

For a dipole Antenna the electric field is expressed as follow:

Equation 5: Electric field for a dipole (Figures 6 and 7)

$$Edipole = \left\{ \frac{\cos\left(\frac{ko.l}{2}\cos(\varphi)\right) - \cos\left(\frac{ko.l}{2}\right)}{\sin(\varphi)} \right\}$$

Directivity pattern for rectangular array using dipole antenna using Rectangular patch antenna was calculated and found 19.54 dBi for specified Φ value, however the maximum SLL value was found to be −2 dBi (Figure 8).

Directivity pattern for circular array using dipole antenna was calculated and found 19.85 dBi for specified Φ value, however the maximum SLL value was found to be 7 dB (Figure 9).

Directivity pattern for cylindrical array using dipole antenna was calculated and found 18.86 dBi for specified Φ value, however the maximum SLL value was found to be 6 dB (Figure 10).

Figure 3. Results for circular geometry.
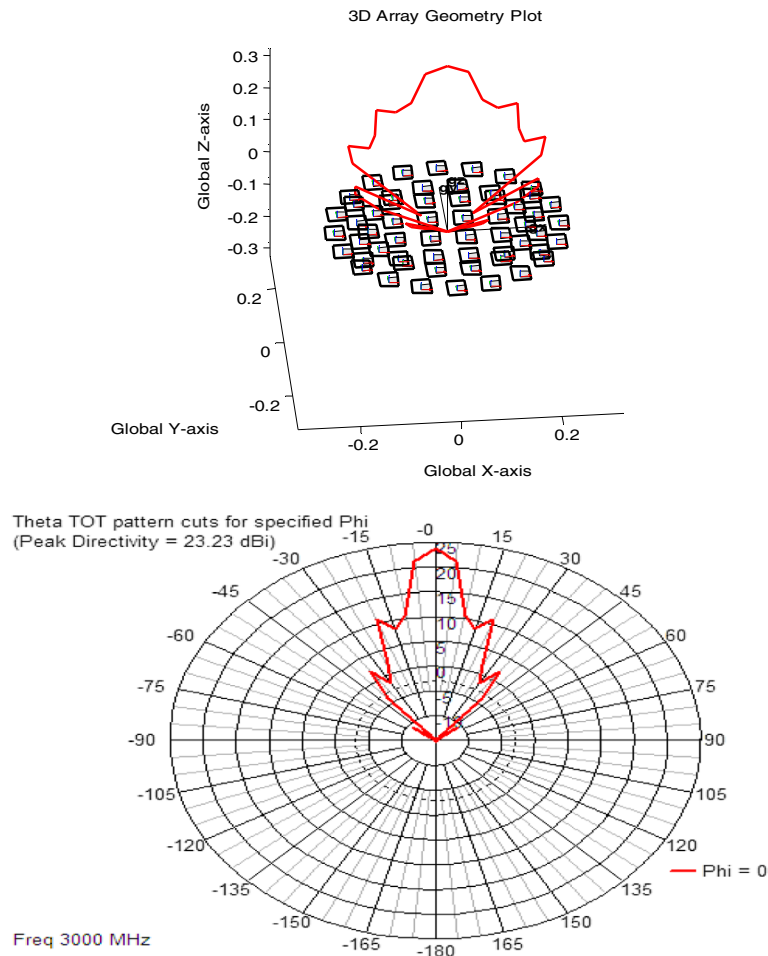
Directivity pattern for rhombic array using dipole antenna using dipole antenna was calculated and found 15.21 dBi for specified Φ value, however the maximum SLL value was found to be −3 dB.

3.3. Analysis of the results
First the analysis started with putting data on the table, the analysis was done by considering the magnitude of radiation intensity which accounts for directivity and SLL which also counts for interference (Table 1).

3.4. Recommendations
From the data presented on the analysis stage above, it is concluded that; rectangular geometry is giving substantial results compared to the others for the given metrics. The rectangular geometry gives −2 dB for side lobes and a directivity of 19.54 dBi while, the geometry consisting of patches is gives a side lobe of 8 dB and a directivity of 21.68 dB (Figures 11–14).

3.5. Array tapering and beam forming techniques analysis
In this section two techniques have been applied, the tapering technique and beam-forming techniques. The tapering technique is applied for radiation purposes while the beam-forming technique

Figure 4. Results for cylindrical geometry.
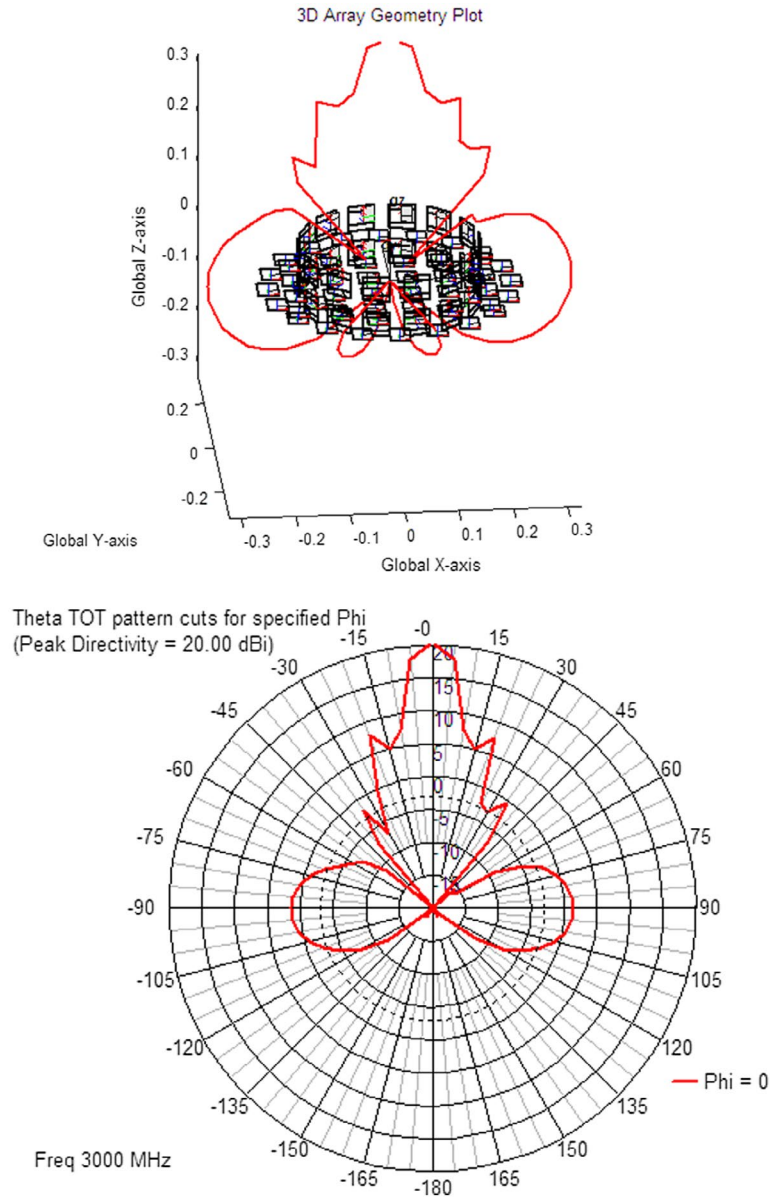
is applied for testing the interference and response of the Array Antenna when there's incident emw from the mobile.

Peak side lobe levels may be reduced via amplitude control or weighting across the array aperture. In this section tapering techniques is applied on four by six rectangular-patch array which is designed for wireless communication on a Base Station Transceivers'.

Figure 15 shows the results of the tapering of the geometry and compares the results before and after tapering.

The results above shows that a reduction of around 6 dB of a SLL from the tapered and non-tapered URA responses for power normalization. The term beam forming refers to an array processing

Figure 5. Results for rhombus.
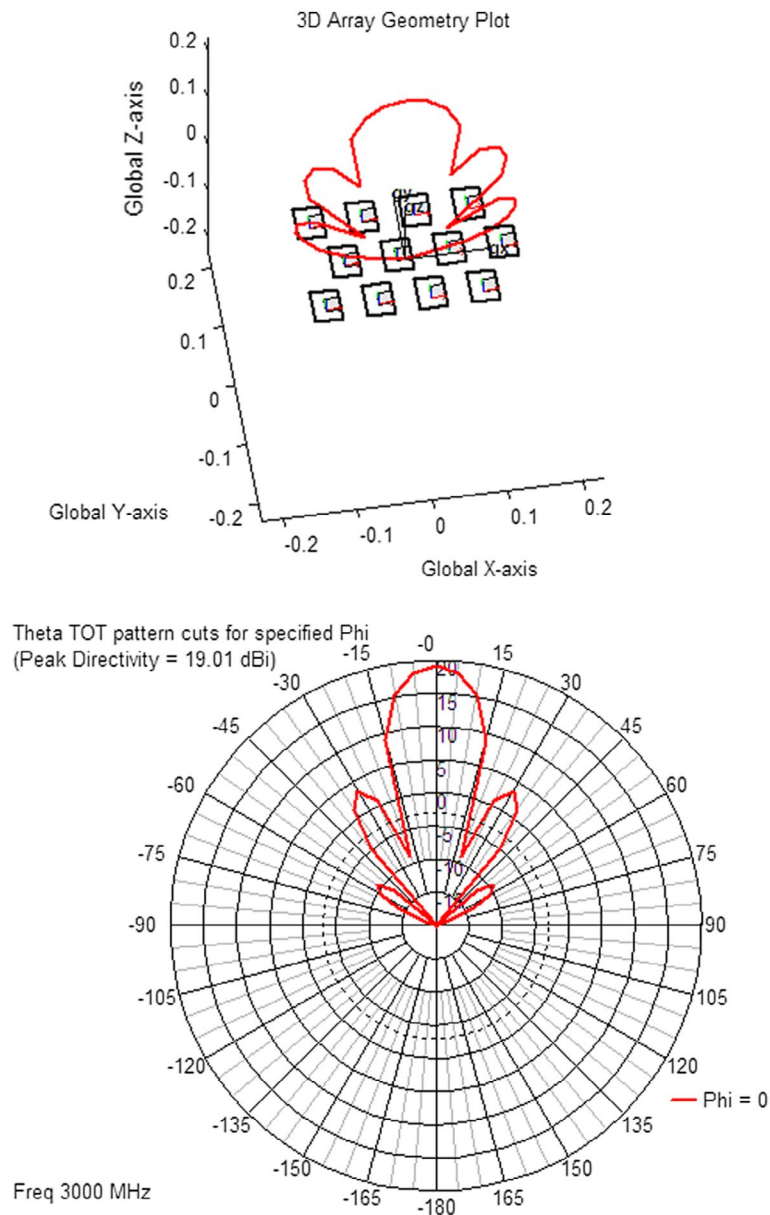
technique for estimating one or more desired signals. Beam-former can be used to spatially filter the arriving signals. Attenuating signals that arrive from specific directions helps you distinguish between signals of interest and interfering signals from other directions.

Beam forming technique uses the weighting method, one of the basic trades-offs when implementing amplitude weighting functions is that a trade between low side lobe levels and a loss in main beam directivity always results. The following graphs shows the results of the Beam-forming technique when an incident signal referred as a mobile-phone signal incident at 30° azimuth and 30° elevation angles on a Rectangular-Array which is assumed to be BTS (Figure 16).

Figure 6. Geometry of the dipole.
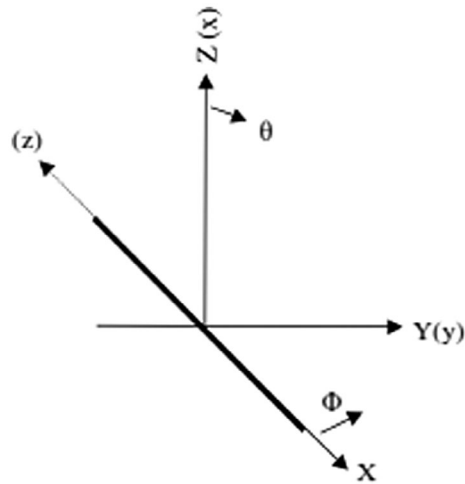
3.6. Before optimization array response

Initial geometry structure of the rectangular array antenna with all elements activated. As shown in figure, the array antenna has 24 elements with each element numbered (Figure 17).

The polar plot shown in Figure 18 shows the antenna array response when all the elements are activated. The pattern shows that; there is a presence of huge Side Lobes on the Antenna radiation pattern, though the directivity of the antenna is very big greater than that of Andrew BTS antenna which is used for wireless communication but still the presence of SLL weaken its performance as interference will occur.

Output characteristics of the array

Progressive phase shift in *x*-direction = −2.0247e−30°

Progressive phase shift in *y*-direction = −3.3065e−14°

Directivity based only on the fields above the *xy*-plane

Directivity = 17.5827 dB

Directivity = 30.7803 dimensionless

Directivity based on the fields above and below the *xy*-plane

Directivity = 20.52 dB

Directivity = 61.5607 dimensionless

Evaluation plane: Number of maxima between 0 and 18° = 2

HPBW for maximum #1 17.5593° thmax = 0°

HPBW for maximum #2 15.5593° thmax = 181° (Figures 19 and 20)

Figure 7. Results for a rectangular array dipole.
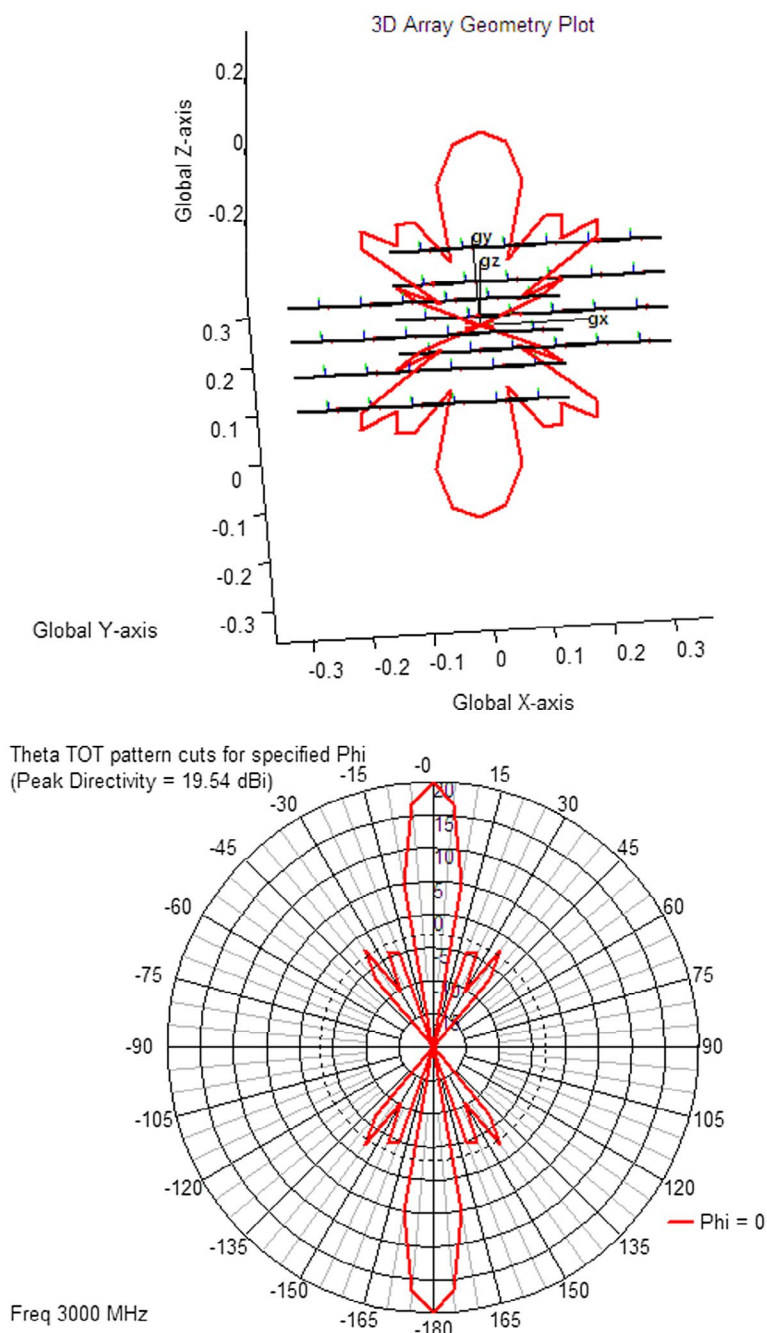
Figure 8. Results for a circular array.
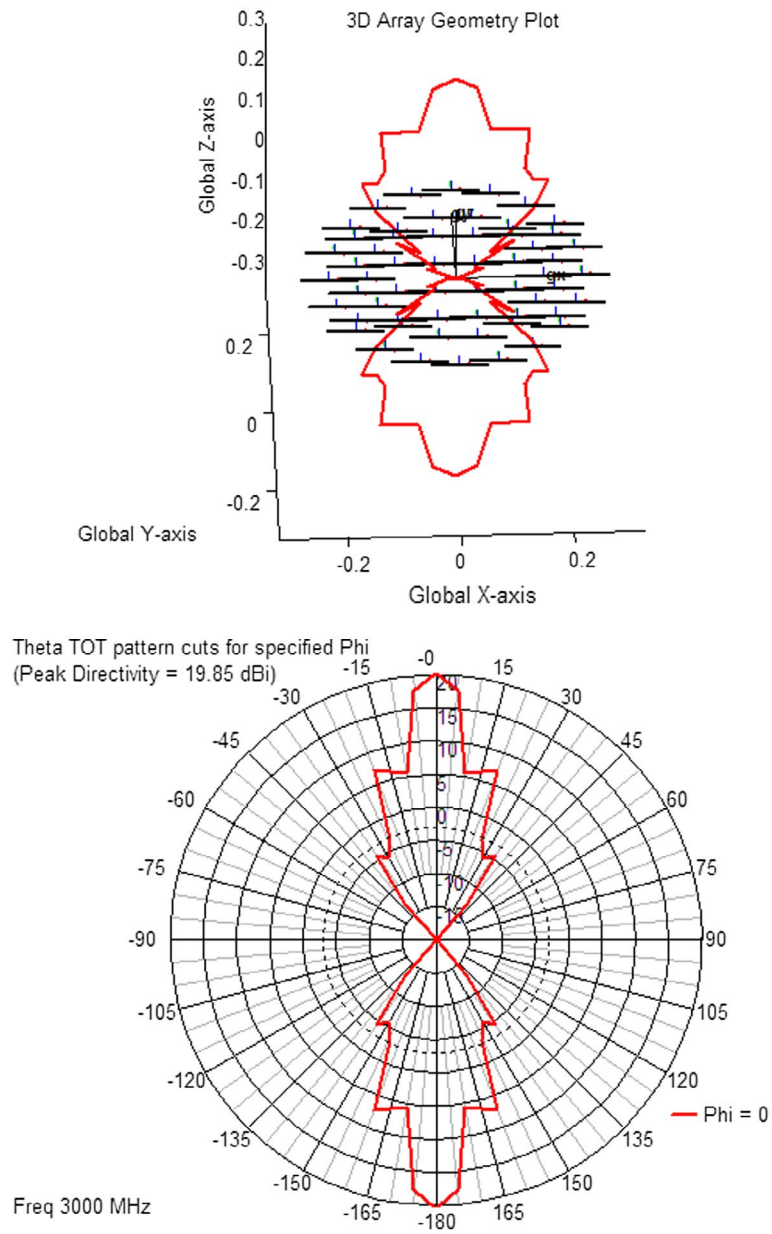
Figure 9. Results for a cylindrical array.
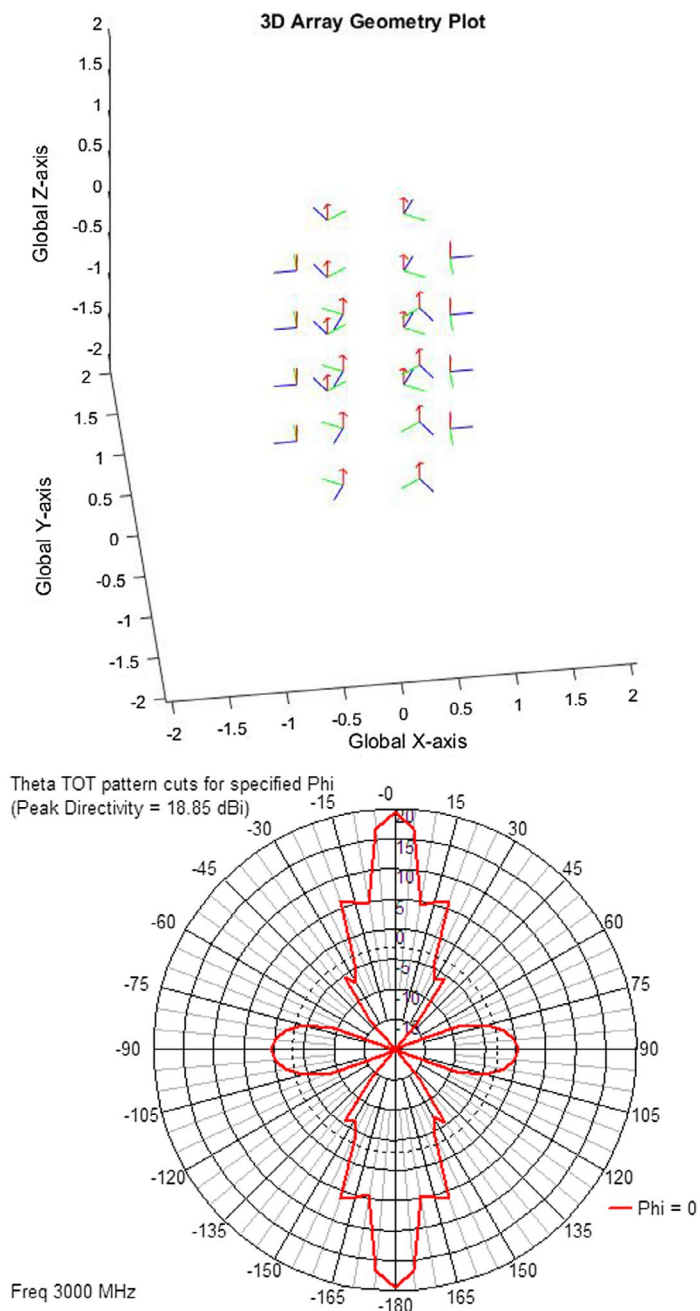
Figure 10. Results for a rhombic array.

S. No.	Geometry	Parameters	Dipole (dBi)	Patch (dB)
1	Rectangular	Directivity	19.54	21.68
		SLL	−2	8
2	Circular	Directivity	19.85	23.64
		SLL	7	11
3	Cylindrical	Directivity	18.85	22.17
		SLL	6	10
4	Rhombic	Directivity	15.21	22.53
		SLL	−3	9
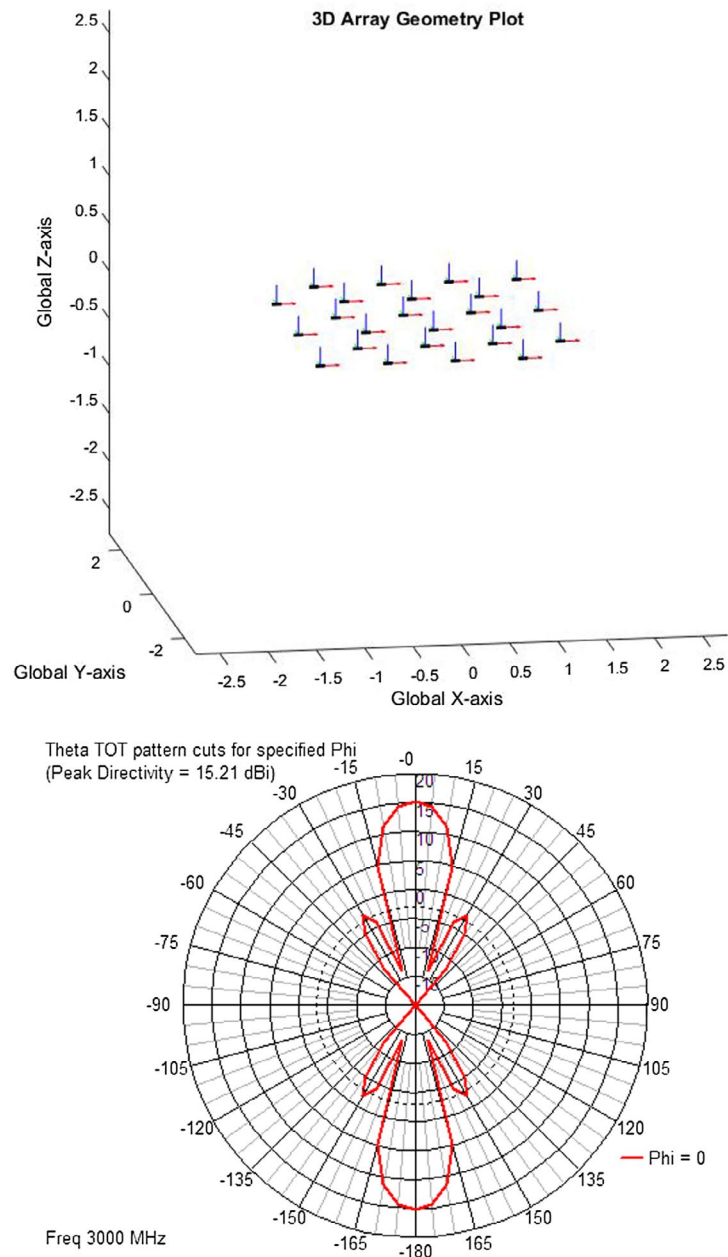
Table 1. Summary of the results

Figure 11. Results of rectangular array analysis.
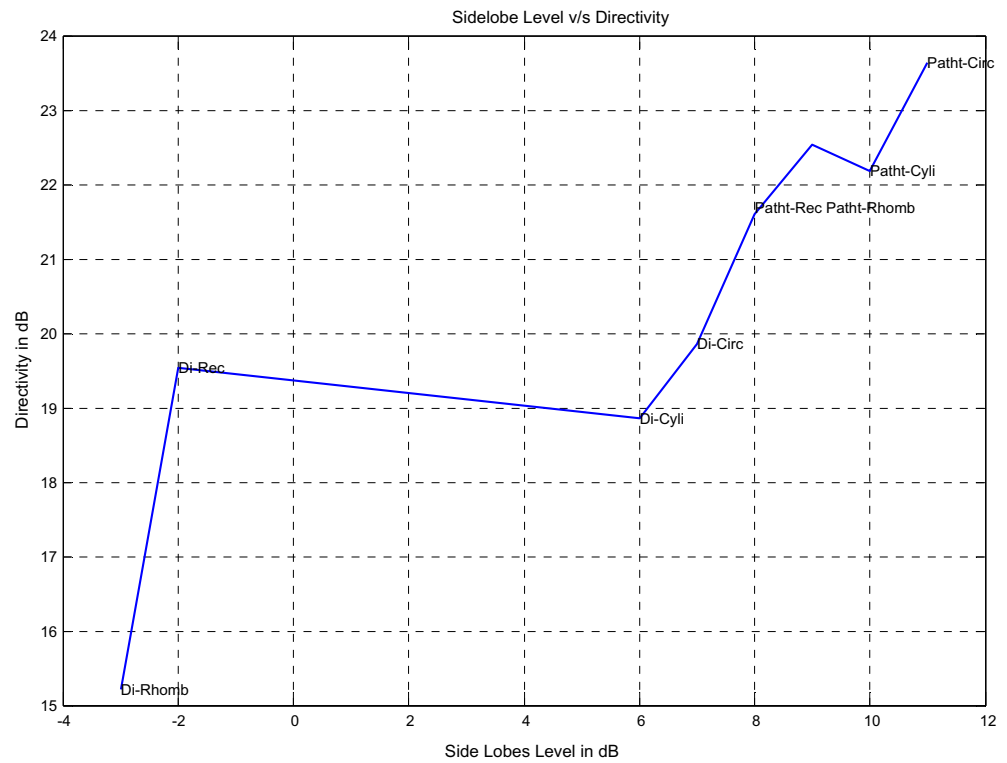
Figure 12. Impedance vs. frequency.
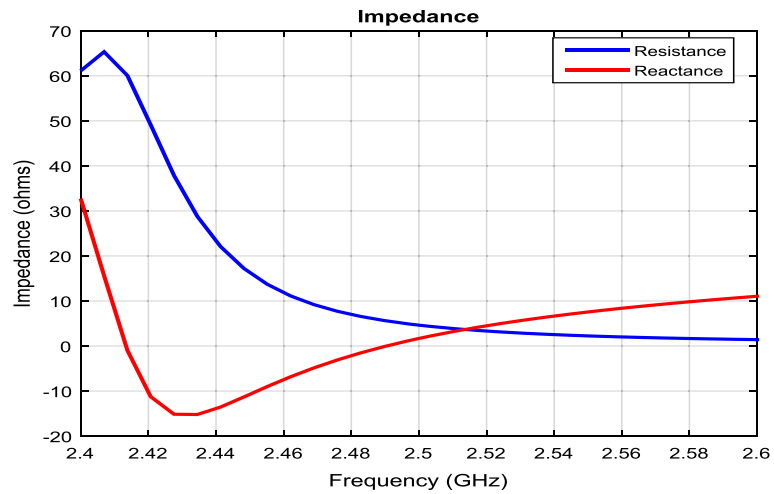
Figure 13. Magnitude vs. frequency.

cogent • engineering
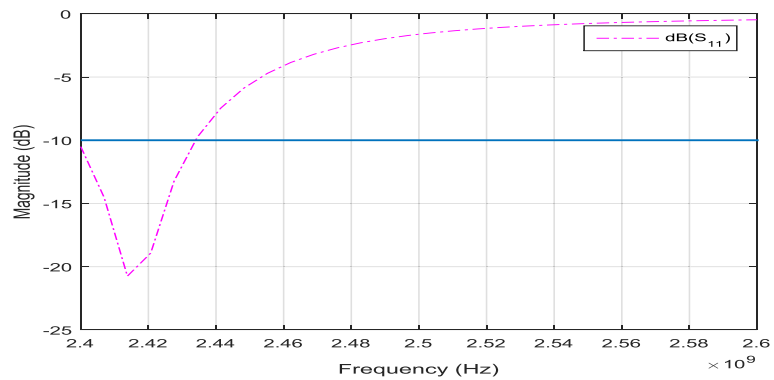
Figure 14. Return-loss vs. frequency.
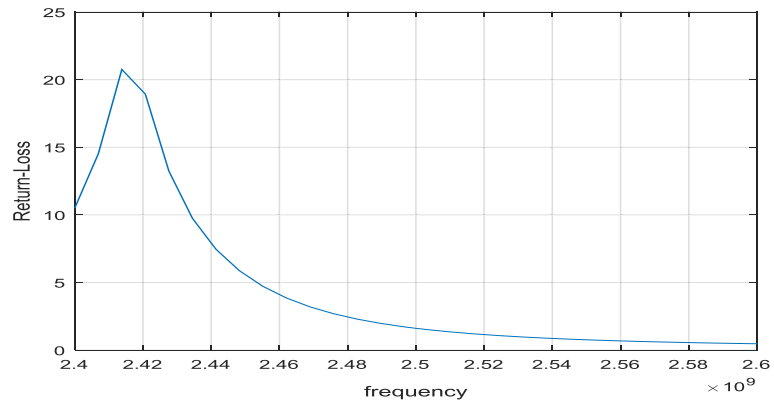
Figure 15. Tapering response.
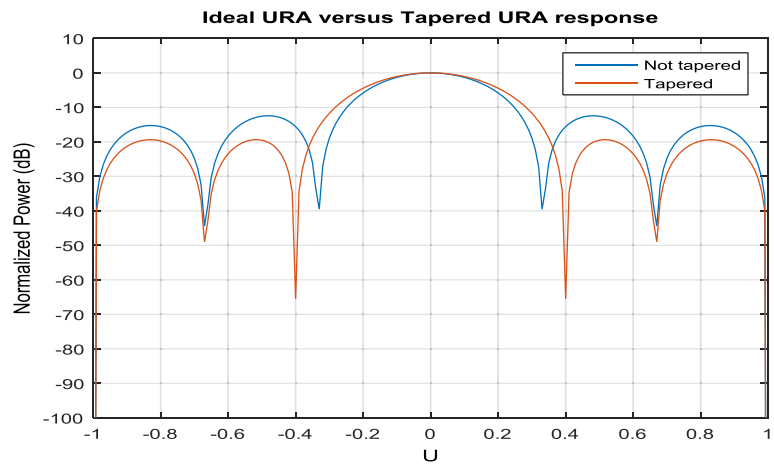
Figure 16. Array response with and without beamforming weights.
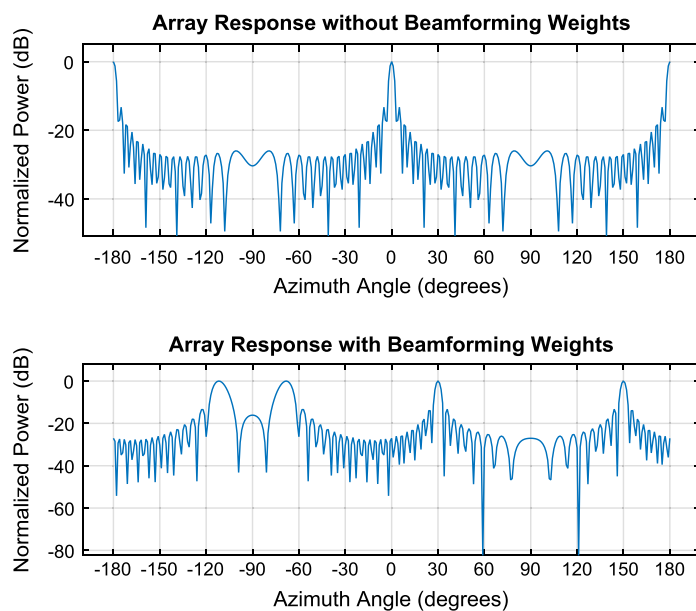
Figure 17. Array antenna with elements.
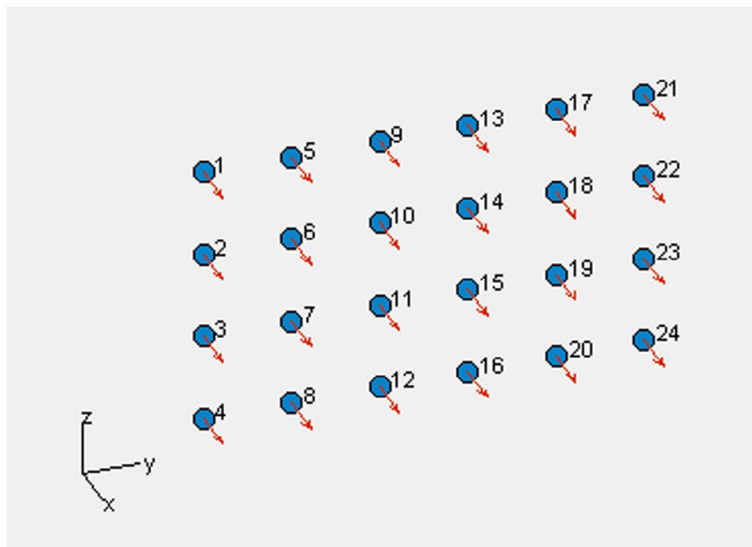
Figure 18. Antenna radiation pattern.

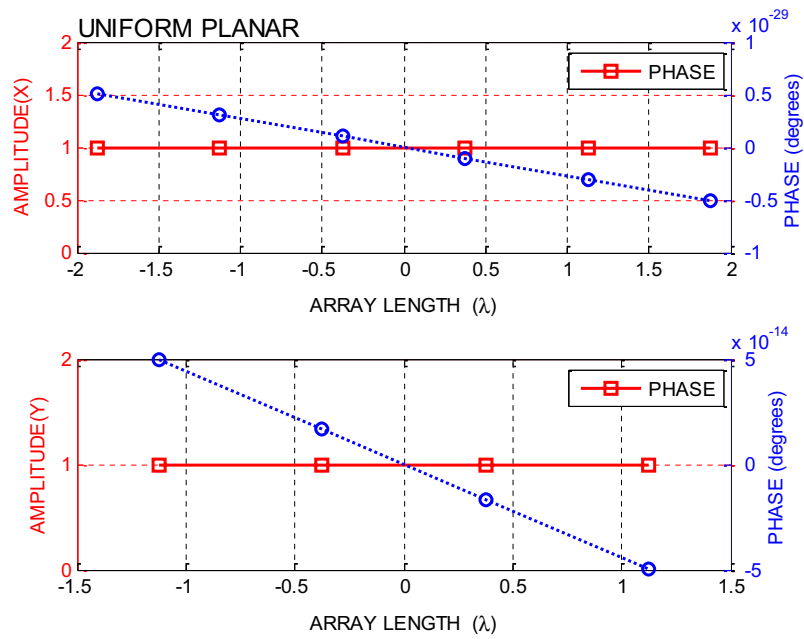Note: Directivity is 20.52 dB.
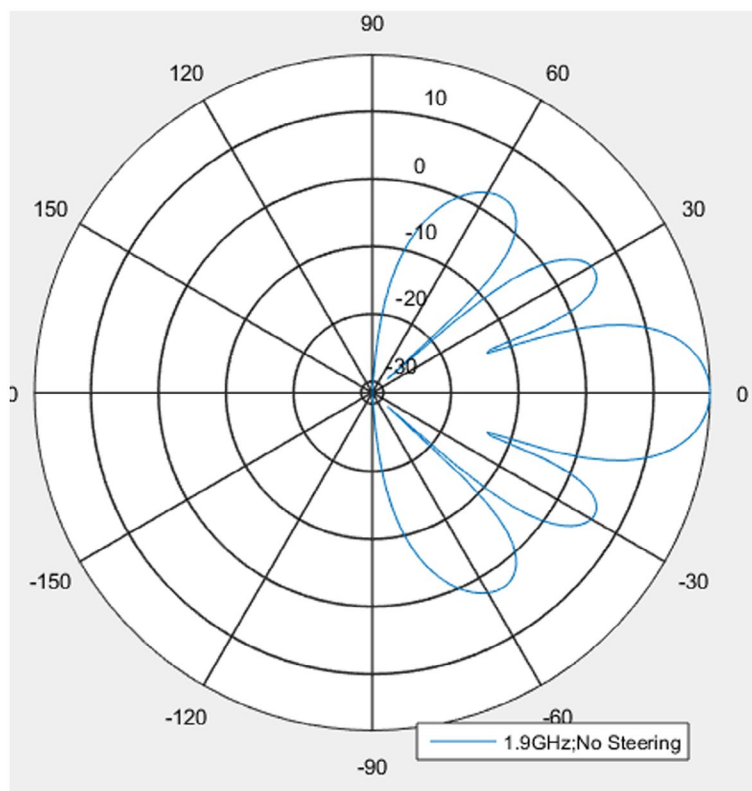
Figure 19. A_factor vs. φ.
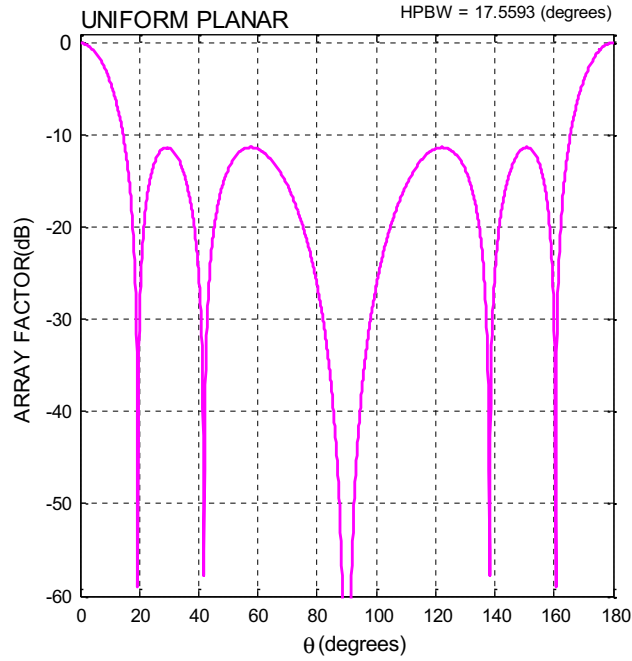
Figure 20. Array scanning responses.

4. Optimization

This part deals with optimization of the above array antenna which is designed for BTS applications. The results shows a substantial improvement on the reduction of the SLL of the array Antenna but with a trade-off of gain reduction, a 4 dBi has been reduced with the optimization of SLL reduction (Figures 21 and 22).

4.1. Particle swarm optimization algorithm

This part shows the results of the optimization conducted by the particle swarm algorithm with a maximum SLL achievement of −55 dB, a maximum of 1,000 iterations were set and a particle swarm value of 500 (Figure 23).

4.2. Genetic algorithm optimization

This part shows the results of the optimization conducted by the particle swarm algorithm with a maximum SLL achievement of −55 dB. A maximum of 1,000 iterations were set with a population of 500 as shown below.

Figure 21. Tapered array radiation pattern.
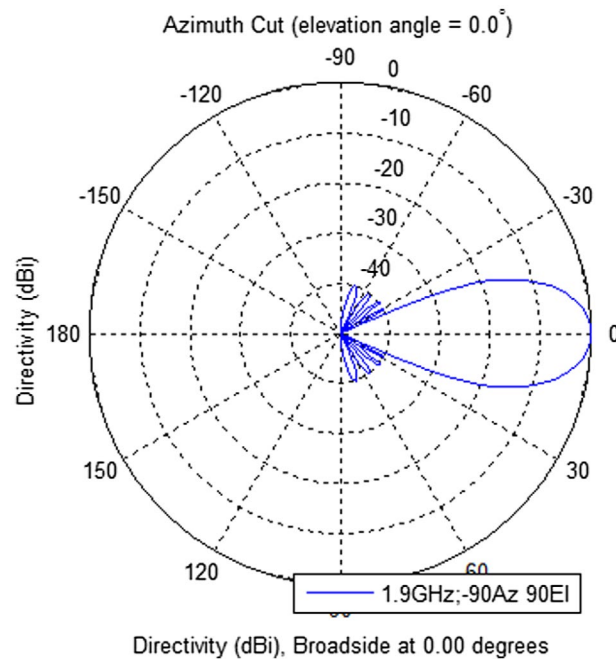
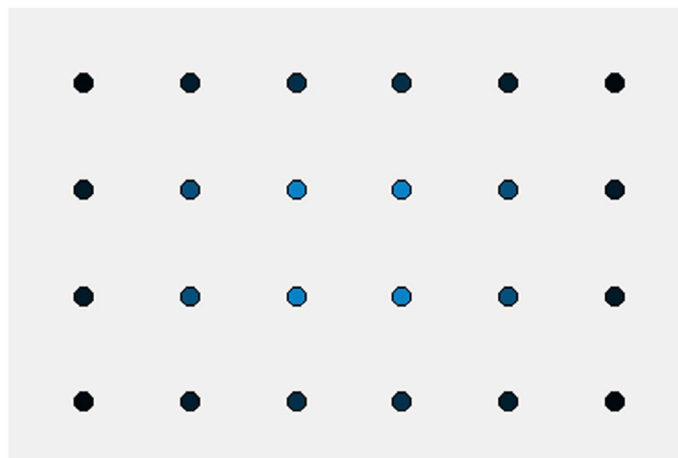Note: Directivity 16.30 dBi.

Figure 22. Tapered geometry structure.
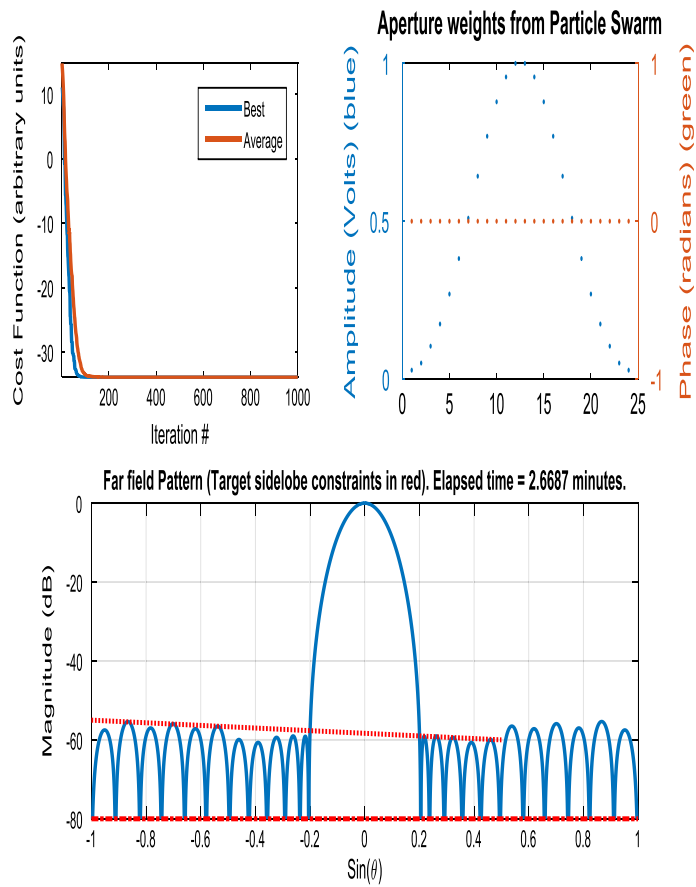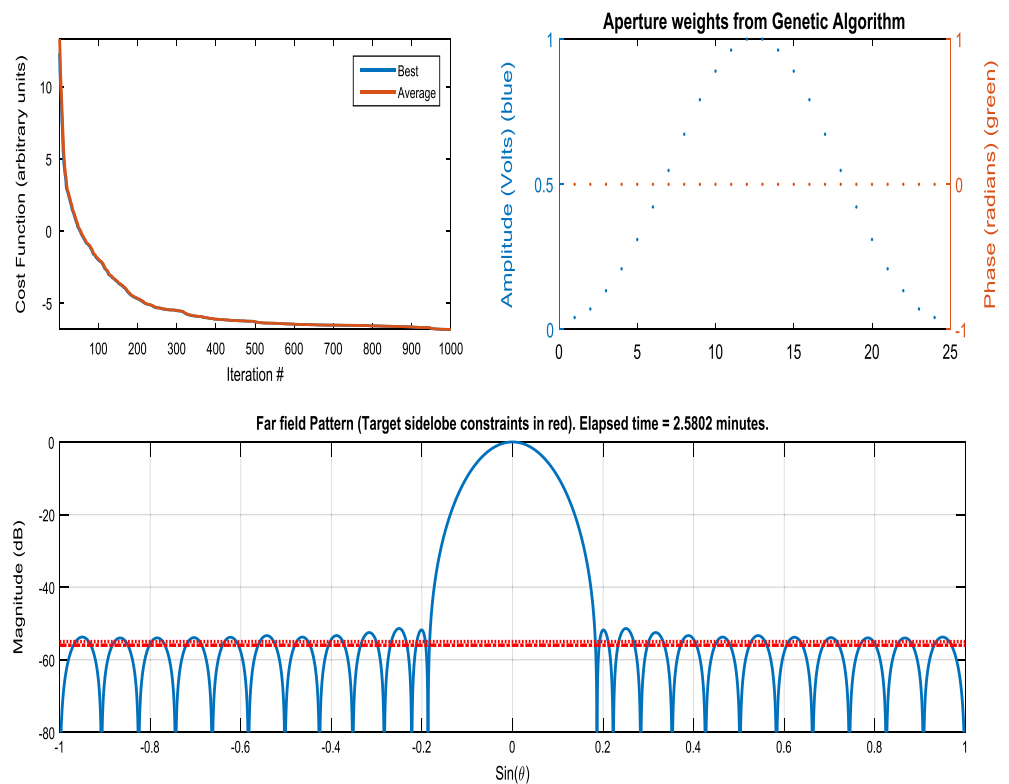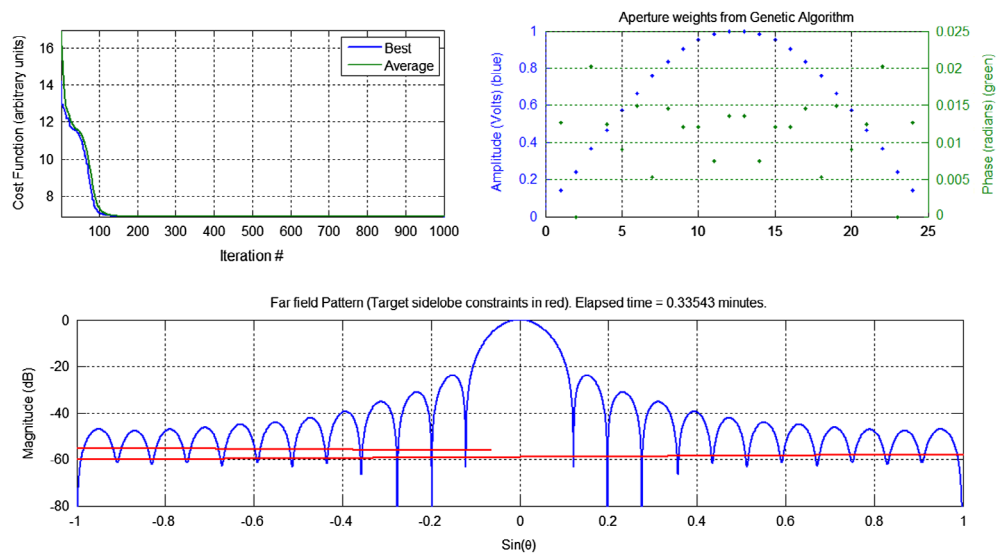
Figure 23. PS optimization results.

Figure 24. GA optimization results.

Figure 25. Optimization using element phase control.

N iterations = 1,000

N population = 500

N marriages = 250

Tournament eligible = 10

Tournament competitors = 5

N crossovers = 2

Mutation probability = 0.04

Mutation range max = 0.25

Figure 24 presents the results optimization using aperture weights whereby Figure 25 presents the results of optimization using phase control of the antenna elements.

5. Conclusion

An investigation on the effects of the geometry orientation of the antenna for wireless communication is conducted in this paper. A base station array antenna was designed particularly for wireless communication and array tapering and beam forming techniques were employed so as to see its performance based on directivity and SLL results. The investigation done for all the selected geometries with rectangular patch element and dipole elements shows that; the array antenna having a rectangular geometry produces a substantial ratio between the maximum directivity relative to the maximum value of the SLL with the dipole elements giving the minimum possible SLL and a difference of 2.14 dBi with the one having patch elements. The results, shows that; there is a need of investigating the effects of the array antenna responses by considering different angles of incidence from a far transmitters as this paper consider only a single angle however still there is a need of using advanced techniques such as G.A and PSO for designing the base station Antennas for improved performance of the Base station Antennas. The study suggest the design of an Array Antenna with improved performance of the gain with minimum SLL but also to produce multiple beams using the same Array antenna pointing in different direction.

cogent ••engineering

Author details
Twahir Kazema[1]
E-mail: twahirkazema@gmail.com
Kisangiri Michael[2]
E-mail: kisangiri.michael@nm-aist.ac.tz
[1] Electronics and Telecommunication, Nelson Mandela African Institution of Science and Technology, Arusha, United Republic of Tanzania.
[2] CoCSE, Nelson Mandela African Institution of Science and Technology, Arusha, United Republic of Tanzania.

Cover image
Source: Authors.

References
Fletcher, P., & Darwood, P. (1998). Beamforming for circular and semicircular array antennas for low-cost wireless lan data communications systems. *IEE Proceedings-Microwaves, Antennas and Propagation, 145*, 153–158. http://dx.doi.org/10.1049/ip-map:19981658

Godara, L. C. (1997). Applications of antenna arrays to mobile communications. I. Performance improvement, feasibility, and system considerations. *Proceedings of the IEEE, 85*, 1031–1060. http://dx.doi.org/10.1109/5.611108

Goswami, B., & Mandal, D. (2013). A genetic algorithm for the level control of nulls and side lobes in linear antenna arrays. *Journal of King Saud University-Computer and Information Sciences, 25*, 117–126. http://dx.doi.org/10.1016/j.jksuci.2012.06.001

Greenberg, M. C., Virga, K. L., & Hammond, C. L. (2003). Performance characteristics of the dual exponentially tapered slot antenna (detsa) for wireless communications applications. *IEEE Transactions on Vehicular Technology, 52*, 305–312. http://dx.doi.org/10.1109/TVT.2003.808796

Huang, Y., & Boyle, K. (2008). *Antennas.* Chichester: John Wiley & Sons. http://dx.doi.org/10.1002/9780470772911

Ioannides, P., & Balanis, C. (2005). Uniform circular arrays for smart antennas. *IEEE Antennas and Propagation Magazine, 47*, 192–206. http://dx.doi.org/10.1109/MAP.2005.1589932

Kelley, D. F., & Stutzman, W. L. (1993). Array antenna pattern modeling methods that include mutual coupling effects. *IEEE Transactions on Antennas and Propagation, 41*, 1625–1632. http://dx.doi.org/10.1109/8.273305

Kezys, V. (2002). *Content-based adaptive parasitic array antenna system.* Google Patents.

Kurup, D. G., Himdi, M., & Rydberg, A. (2003). Synthesis of uniform amplitude unequally spaced antenna arrays using the differential evolution algorithm. *IEEE Transactions on Antennas and Propagation, 51*, 2210–2217. http://dx.doi.org/10.1109/TAP.2003.816361

Llombart, N., Neto, A., Gerini, G., Bonnedal, M., & De Maagt, P. (2008). Impact of mutual coupling in leaky wave enhanced imaging arrays. *IEEE Transactions on Antennas and Propagation, 56*, 1201–1206. http://dx.doi.org/10.1109/TAP.2008.919223

Mendolia, G., et al. (2004). *Antenna system and method.* Google Patents.

Mookiah, P., & Dandekar, K. R. (2009). Metamaterial-substrate antenna array for mimo communication system. *IEEE Transactions on Antennas and Propagation, 57*, 3283–3292. http://dx.doi.org/10.1109/TAP.2009.2028638

Mukherjee, P., Hajra, A., Ghosal, S., Chatterjee, S., & Chatterjee, S. (2014). Side lobe reduction and beamwidth control of amplitude taper beam steered linear array using tschebyscheff polynomial and particle swarm optimization. In *Advanced Computing, Networking and Informatics-Volume 1* (pp. 661–668). Springer. doi:10.1007/978-3-319-07353-8_76

Ng, W., Walston, A. A., Tangonan, G. L., Lee, J. J., Newberg, I. L., & Bernstein, N. (1991). The first demonstration of an optically steered microwave phased array antenna using true-time-delay. *Journal of Lightwave Technology, 9*, 1124–1131. http://dx.doi.org/10.1109/50.85809

Piazza, D., Kirsch, N. J., Forenza, A., Heath, R. W., & Dandekar, K. R. (2008). Design and evaluation of a reconfigurable antenna array for mimo systems. *IEEE Transactions on Antennas and Propagation, 56*, 869–881. http://dx.doi.org/10.1109/TAP.2008.916908

Piesiewicz, R., Jacob, M., Koch, M., Schoebel, J., & Kurner, T. (2008). Performance analysis of future multigigabit wireless communication systems at THz frequencies with highly directive antennas in realistic indoor environments. *IEEE Journal of Selected Topics in Quantum Electronics, 14*, 421–430. http://dx.doi.org/10.1109/JSTQE.2007.910984

Recioui, A. (2012). Sidelobe Level reduction in linear array pattern synthesis using particle swarm optimization. *Journal of Optimization Theory and Applications, 153*, 497–512. http://dx.doi.org/10.1007/s10957-011-9953-9

Wong, N. S., Lee, K. M., & Tang, R. (1996). *Multi-frequency band phased-array antenna using multiple layered dipole arrays.* Google Patents.

Yan, L., Hong, W., Hua, G., Chen, J., Wu, K., & Cui, T. J. (2004). Simulation and experiment on SIW slot array antennas. *IEEE Microwave and Wireless Components Letters, 14*, 446–448. http://dx.doi.org/10.1109/LMWC.2004.832081

Zha, G., Wang, H., Yang, Z., Cheng, Y., & Qin, Y. (2016). Effect analysis and design on array geometry for coincidence imaging radar based on effective rank theory. In *2nd ISPRS International Conference on Computer Vision in Remote Sensing (CVRS 2015)*. Xiamen: International Society for Optics and Photonics.

Cogent Engineering (ISSN: 2331-1916) is published by Cogent OA, part of Taylor & Francis Group.

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com