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Development of an Algorithm for Optimizing Array Antenna Elements for Cellular Networks Using Evolutionary Computation

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Abstract

The discussion on a number of important issues and the state-of-the-art development of the model for optimizing antenna array element was done. An optimal radiation pattern as well as minimum side lobes levels were obtained for a rectangular antenna array using the hybridization of particle swarm and genetic algorithm optimization technique. A set of normalized complex and phase shift weights were generated by the developed optimization algorithm and the bound constrained fitness function that allows the optimization for non-uniform element spacing was presented. A comparison between the un-optimized pattern and the one optimized for minimization of SLL using the model developed in this research was also presented, the results show that the latter achieves a better and more consistent radiation pattern as well as non-complexity flow of the developed model itself. Lastly the study proposed multi-beam antenna architecture for multi-RAT (Radio Access Technology) interworking which is key enabling technology for 5G vision.

Keywords: SLL, evolutionary computation, multi-beam

1. Introduction

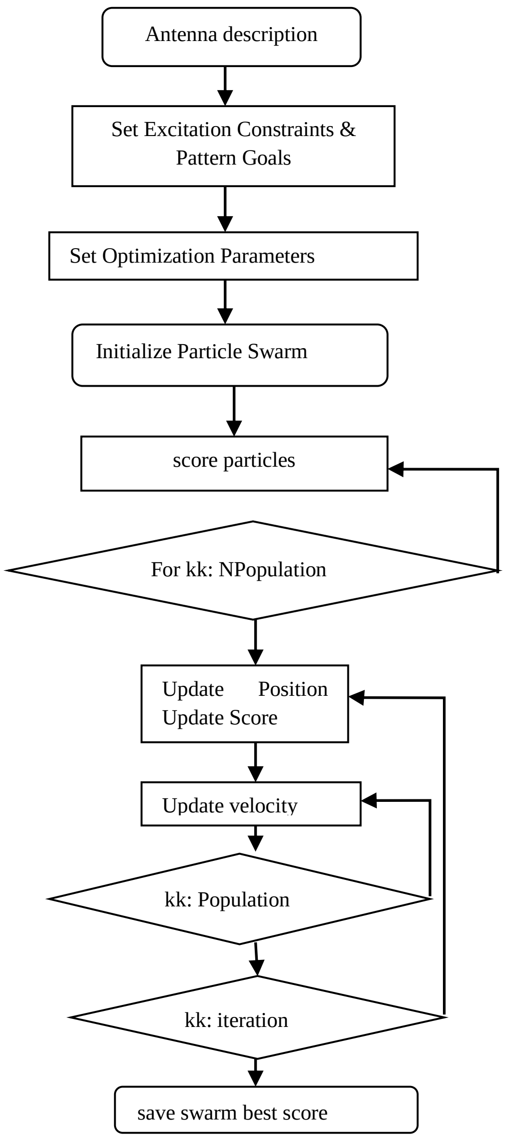
Accelerated by the popularity of smart-phones and tablets, the telecommunication industry has experienced explosive growth over the past decade [1]. Also the telecom industry has experience changes on its generation from 2G, 3G and now to 4G. 4G stands for the fourth generation of the wireless data transmission networks set-up by the mobile phone industry in order to offer more bandwidth and greater speeds for everyday mobile device operations [2]. In the current 4G systems, technique such as MIMO, OFDM are used as an advanced radio interface and link adaptation technologies. 4G wireless telecommunication networks have the ability to support the data rates of up to 1 Gbps for low mobility, such as roaming/local wireless access and for high mobility, a data rate up to 100Mbps is achieved [3]. The fourth generation wireless communication systems have been deployed in many countries. However, with an sudden increase of wireless mobile services and devices, there are still some challenges that cannot be solved even by the 4G, the challenges such as spectrum crisis and high energy consumption[4]. For the last several years, the telecommunications industry and academia have been investing significant amounts of research effort in fourth generation (4G) long term evolution (LTE) to provide higher data rates to end users by improving spectral efficiency, deploying more base stations, and/or aggregating more spectra. Despite the fact that some of the LTE enhancements, such as advanced multiple-input multiple-output (MIMO), heterogeneous networks (HetNets), Co-ordinated multipoint (CoMP), and carrier aggregation (CA), deliver the additional capacity required to sustain the traffic surge for the next few years, none of them is seen as a possible solution to support the hundreds of times more traffic demands foreseen in 2020 and beyond, the so-called 5G era[5]. However, it is expected that in 5G millions more base stations (BSs) with higher functionality and billions more smart phones and devices with much higher data rates will be connected [6]. In 5G mobile communication it is expected to have the presence of higher traffic volume, increased indoor or hotspot traffic, and higher energy [7]. The development of wireless system capacity ever since the invention of the radio right up to the present can be attributed to three main factors: increase in the number of wireless infrastructure nodes, increased use of radio spectrum, and improvement in link efficiency. These three factors continue to be the prevailing drivers of the wireless capacity growth today [8]. As it is stated, two of the factor which contribute to the effectiveness of the wireless communication system (i.e. infrastructure nodes and link efficiency) are closely related to the efficiency of the antenna placed on the base station. Since the future 5G era expect to use small cell technique to achieve higher speed, then this study will concentrate on the design of the base station array antenna through the development of a model for optimization of array elements by using evolutionary algorithms. A rectangular geometry has been selected; and a non-uniform element spacing between the array elements has been used to address the SLL effects on the design.

2. Overview of Evolutionary Computation (GA & PSO)

The evolutionary algorithms (EA) are stochastic optimization techniques, which emulate biologic processes or natural phenomena[9] . Their ability to find a global optimum value, without being captured in local optima, and the possibility to well face discontinuous and nonlinear problems, with many variables, are some advantages of the evolutionary techniques. Moreover, these algorithms do not need to calculate any derivative in order to optimize the cost function and this fact allows them to administer more complex cost functions. In contrast with traditional searching techniques, EAs do not rely strongly on the starting point [10]. Mostly a bad choice of the initial values can slow down the convergence of the entire process, or even drive the convergence towards a wrong solution. However, these algorithms have strong stochastic basis, as a result they need a lot of iterations to get a good result, in particular when the optimization problem has many unknowns[11]. Taking into account Genetic Algorithms and Particle Swarm Optimization algorithms, mostly the PSO have faster convergence rate than GA early in the runs, but they are frequently outperformed by GA for simulation that has long runs, or when the number of unknown variables increases. It is then proposed new hybrid technique, called Hybrid PSGA algorithm consists in a strong co-operation of PSO and GA. It is in the best interest of this study to present the PSGA method that will be applied to minimize the sidelobe levels and improve radiation pattern of a cellular base station array antenna.

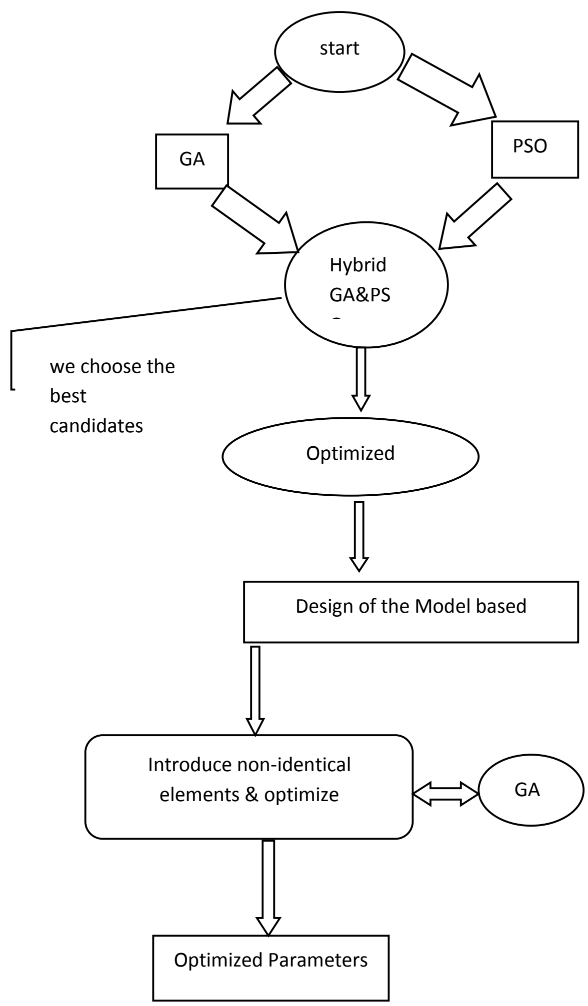
Programming Flow

The flow chart; shows how the particle swarm algorithm was programmed step by step until the best



This section, presents the procedure on which the algorithm/model was developed and then applied and then to optimized to get the optimum solution in wireless communication. To hybrid the algorithm we had several options, the first was to stagnate pbest particles and change their positions by mutation operator of GA. The second was to initialize the population of PSO and assigning its solution of GA. The total numbers of iterations are equally shared by GA and PSO. First half of the iterations are run by GA and the solutions are given as initial population of PSO, the remaining iterations are run by PSO. This study chooses the technique of not to change the gbest particle position over some designated time steps, the crossover operation was performed on gbest particle with chromosome of GA. In this technique both PSO and GA run in parallel, this was done by optimizing independently and then hybridize them to one algorithm. The hybridized algorithm gives best candidates; the obtained candidates were used as a starting point for the development of the model which will be used to introduce the non-identical elements in an array antenna.

Flow Chart



Experiment 1 - Element Weight & Phase Optimization

The experiment started with the optimization of array geometry studied in[12]. The two chosen algorithms were selected for the optimization as shown on the figure 1 and 3. A Matlab software was used for programming the algorithm and presenting the optimized results. Genetic Algorithm (GA) is one of the most effective evolutionary algorithm developed so far; it simulates the natural evolution, in terms of survival of the fittest, adopting pseudo-biological operators such as selection, crossover, mutation, and many other additional operators.

The following parameters were set for the genetic algorithm;

Table 1: Genetic Parameters

Antenna Description	Excitation Constraints	Pattern Goals	Optimization Parameters
Nelements=24; CosineElementFactorExponent=1.2;	MagMin (1: Nelements,1) = 0; MagMax (1: Nelements,1) = 1; PhsMin (1: Nelements,1) = 0; PhsMax (1: Nelements,1) = 1; EnforceSymmetry=1;	UpperSidelobeGoal_u= [-1 -.065]; UpperSidelobeGoal_dB=[-85 -84]; LowerSidelobeGoal_u= [-1 1]; LowerSidelobeGoal_dB=[-86 -86]; AutomaticallyExemptMainBeam=1; NPatternPoints=5120;	Niterations=1000; Npopulation=500; Nmarriages=2500; TournamentEligible=100; TournamentCompetitors=50; Ncrossovers=20; MutationProbability=0.04; MutationRangeMax=0.2; MutationRangeDecay=1.5; Norder=2*Nelements; Nmutations=round(MutationProbability*Norder);

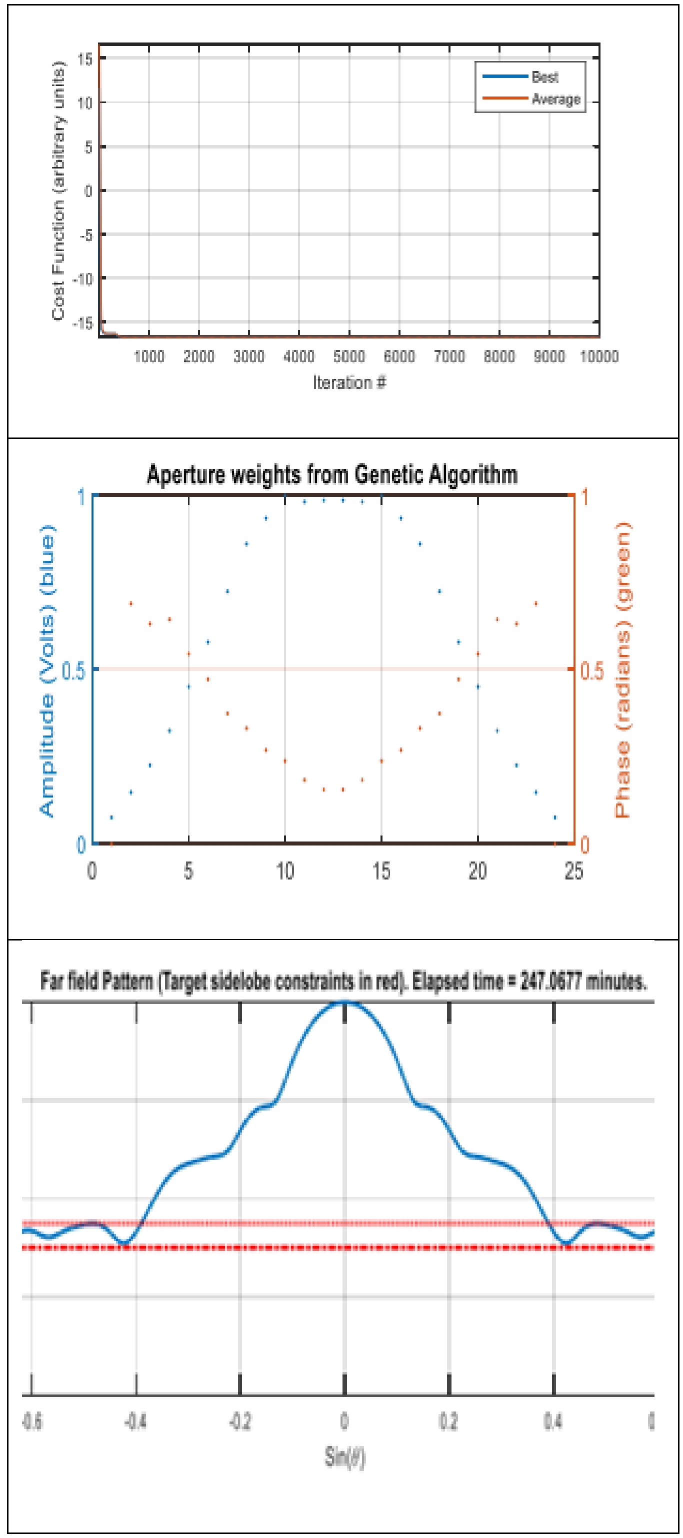


Figure 1: Genetic Algorithm Results

The figure 1 presents the results for sidelobe minimization by optimizing the phase and amplitudes of the array elements using genetic algorithm.

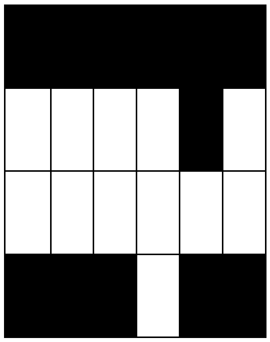


Figure 2:Optimized Array Antenna Structure

The Fig. 2 shows the optimized antenna structure where the black spot presents the off elements and the white space presents the radiating elements. Particle Swarm Optimization (PSO) is one of the more recently developed evolutionary techniques, and it is based on a suitable model of social interaction between independent agents (particles) and it uses social knowledge in order to find the global maximum of a generic function.

Antenna Description	Excitation Constraints	Pattern Goals	Optimization Parameters
Nelements=24; CosineElementFactorExponent=1.2;	MagMin(1:Nelements,1)=0; MagMax(1:Nelements,1)=1; PhsMin(1:Nelements,1)=0; PhsMax(1:Nelements,1)=1;	UpperSidelobeGoal_u= [-1 1]; UpperSidelobeGoal_dB=[-85 -85]; LowerSidelobeGoal_u= [-1 1]; LowerSidelobeGoal_dB=[-86 -86];	Niterations=10000; Npopulation=5000; Phi1=2; Phi2=2; W=.4; VRMSmax=.3;
	EnforceSymmetry=1;	AutomaticallyExemptMainBeam=1; NPatternPoints=512;	Norder=2*N elements;

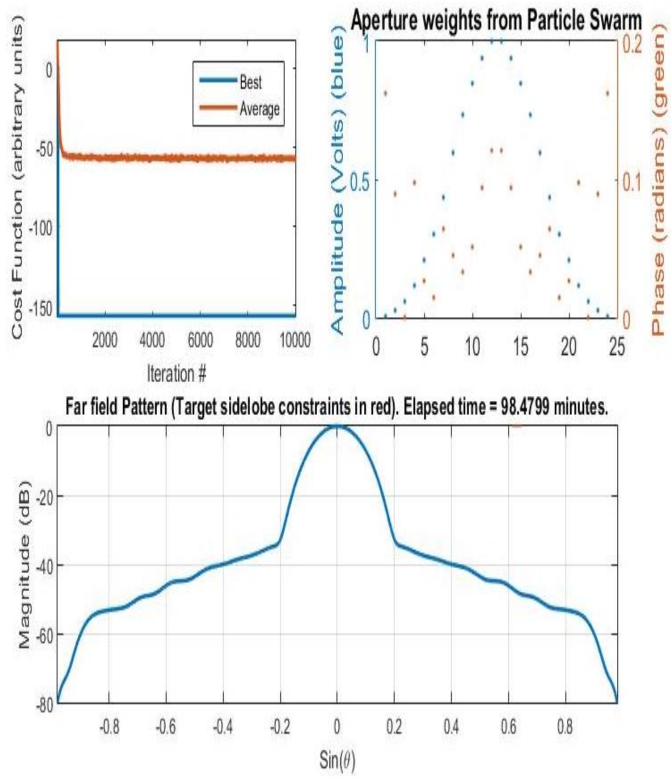


Figure 3:The Particle Swarm Optimization Results

The Fig. 3 presents the results for sidelobe minimization by optimizing the phase and amplitudes of the array elements using particle swarm algorithm.

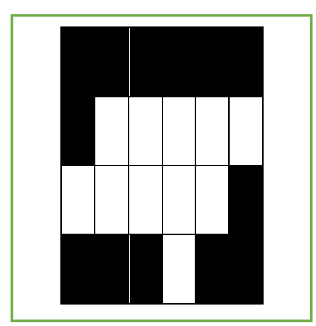


Figure 4: Optimized Array Antenna Structure

The Fig. 4 shows the optimized antenna structure where the black spot presents the off elements and the white space presents the radiating elements. The results show that; the gain of the antenna is 21 dBi but the radiation pattern is poor and not smooth.

Experiment 2 - Effect of Element Structure for SLL (Rectangular V/S Triangular)

The experiment number two was conducted taking into consideration the effect of the element structure. The observation was done by observing the effects on the radiation pattern and gain of the array antenna. The first step was done by considering the element of the array as patch and the next triangular array elements were considered. Feko software was used for simulation and the results were presented as shown on the figure

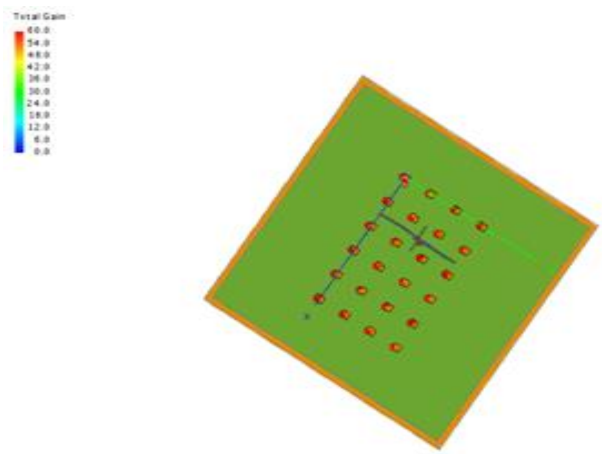


Figure 5: Array with Rectangular Elements

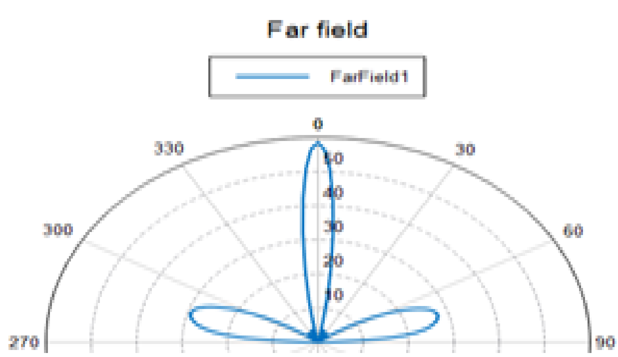


Figure 6: Radiation Pattern of Array with Rectangular Element

The two figures present the simulation results for the array antenna having rectangular elements. The results show that; the radiation pattern produced has major side lobes which are not needed in wireless communication. The next step an element with triangular shape was chosen, the same software (FEKO) was used for observing the experiment results.

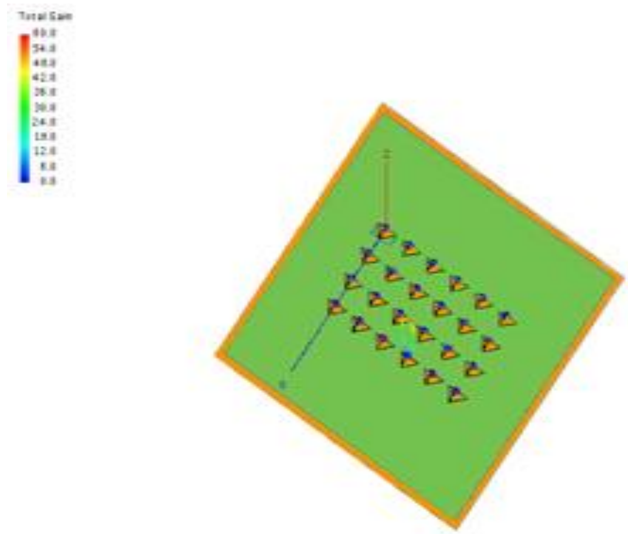


Figure 7: The Array Antenna with Triangular elements

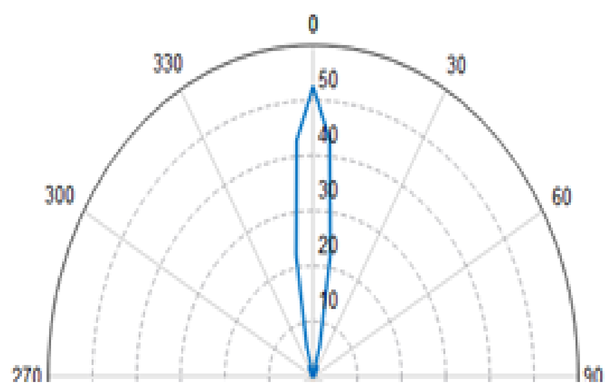


Figure 8: radiation pattern for Array with Triangular Element

The two Fig. 94 present the simulation results for the array antenna having triangular elements. The results show that; the radiation pattern produced has no side lobes which is what we need in wireless communication.

Experiment 3 - Hybridizing the Algorithms

In practice it is very difficult to construct the array antenna having triangular shape, taking into consideration the instrumentation and precision engineering. To overcome this; the research decided to join the two algorithm so as to get the best results. A Matlab program was used to hybrid the genetic algorithm and particle swarm algorithm for the purpose of getting the best optimized results

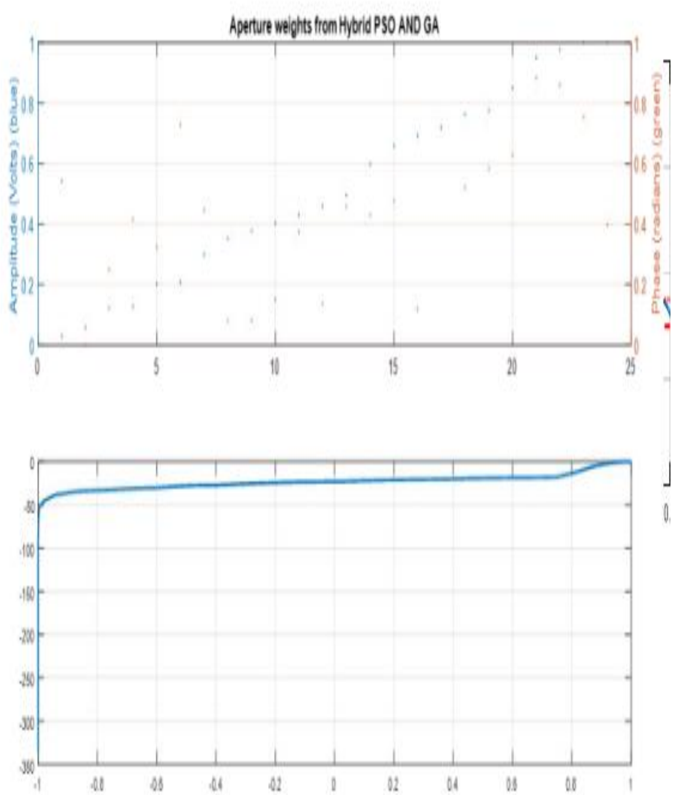


Figure 9: Hybrid Results

The Fig. 9 shows the results for the optimized antenna one using the combination of particle swarm and genetic algorithm. The voltage values which are less than 0.5 are the antenna elements which are switched off by the Algorithm so as to produce the pattern with minimum side lobes level and the one greater than 0.5 are switched on.

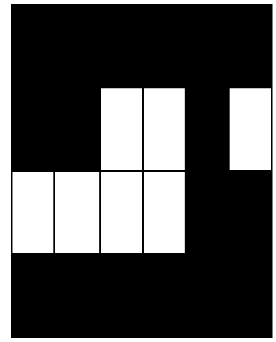


Figure 10: Optimized Antenna Structure

Table 2: Hybrid Parameters

Weights [Normalize]						
0.53 86	0.58 62	0.59 89	0.74 06	0.77 20	0.91 31	1
Phases [Normalized]						
0.64 50	0.79 28	0.93 09	0.71 45	0.79 97	0.85 75	0.91 36

Experiment 4 - K-Factor Parameter

This part of the experiment, contributes to the additional parameter on the development of the optimization model (algorithm). A comparative analysis was conducted between the linear and rectangular array antennas; in this part, the study observes the difference of directivities of the two geometries. Experiment on three Array antennas of different size (i.e. 2by2 3by3 and 4by4) was conducted. The Fig. 99 presents the results of the experiment.

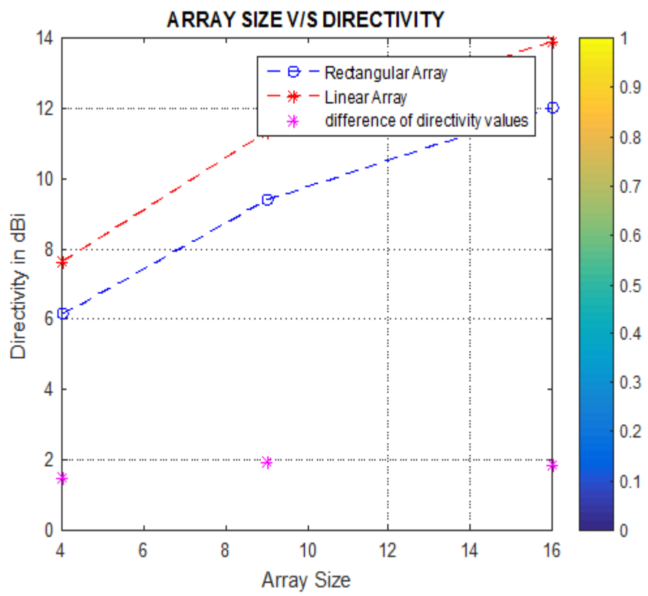
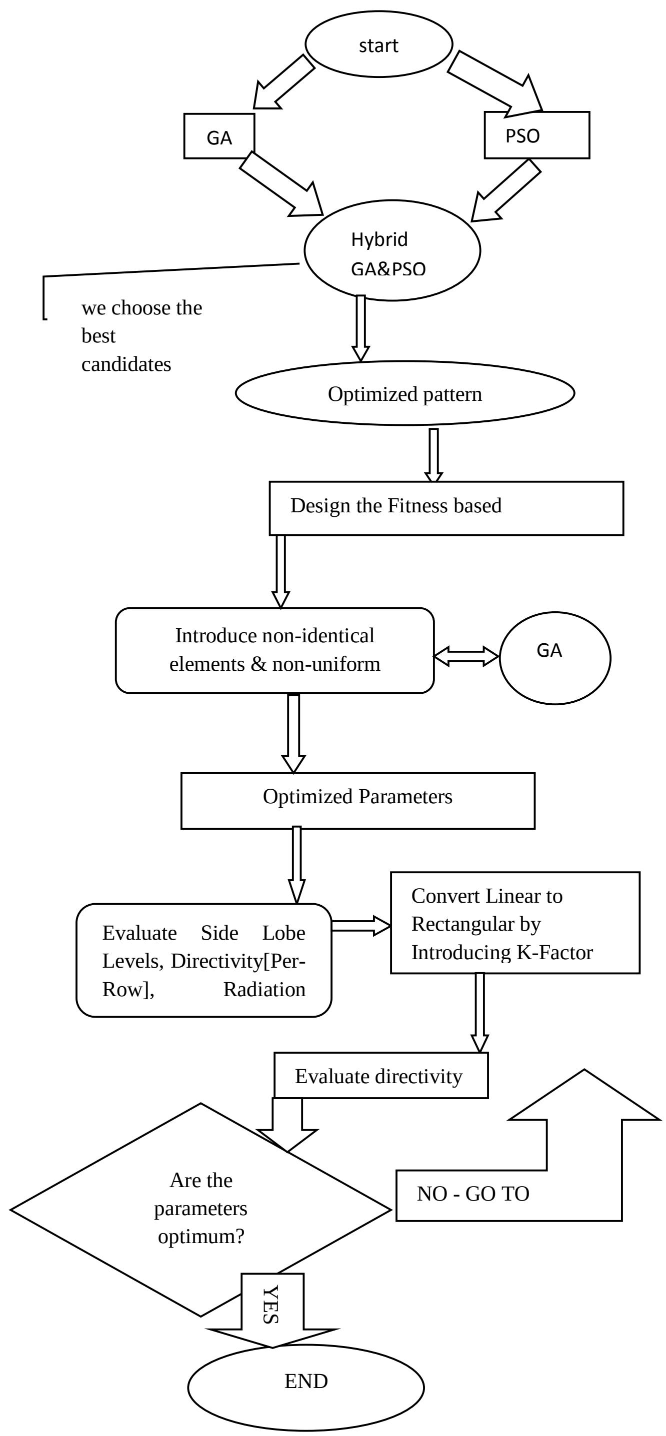


Figure 11: Array Size V/S Directivity

The Fig. 99, shows that; A linear array geometry, regardless of the element type, has a higher directivity compared to the rectangular geometry. The experiment found out that; the difference between the two geometries is averaged around 1.7667. Hence, on the developed optimization algorithm, a factor K=1.7667 dBi is added to it when the model evaluates the directivity of the array antenna. The model developed in this research, treats the columns of the rectangular geometries as individual linear array antenna. This technique not only simplify the difficulty of reaching the optimum convergence but also allows the optimized rectangular array antenna to produce multiple beams.

Flow Chart



Design of the Model started from the Array Factor formular expressed on the equation 14;

Array Factor Equation

$$AF(\vartheta, \varphi) = \sum_{n=1}^{N} E_n e^{jn(kd_1 \cos\theta + \beta)}$$

In this research, non-identical elements are taken into consideration; this means antenna elements are given the same excitation but giving different radiation power in space. Figure 73 will be used for model development

$$AF(\theta,\vartheta) = \sum_{n=1}^{N} W_1 + W_2 e^{jn(kd_1\cos\theta+\beta)} + W_3 e^{jn(kd_2\cos\theta+\beta)}$$

from

$$e^{(kd\cos\theta+\beta)} = 2\cos(kd\cos\theta+\beta) - e^{(-kd\cos\theta+\beta)}$$

Substituting the above expression to the AF equation

$$AF(\theta,\vartheta) = \sum_{n=1}^{N} W_1 + W_2[2\cos(kd\cos\theta+\beta) - e^{(-kd\cos\theta+\beta)}] + W_3[2\cos(kd\cos\theta+\beta) - e^{(-kd\cos\theta+\beta)}]$$

$$AF(\theta,\vartheta) = \sum_{n=1}^{N} W_1 + 2W_2\cos(kd\cos\theta+\beta) - 2W_2 e^{(-kd\cos\theta+\beta)} + 2W_3\cos(kd\cos\theta+\beta) - 2W_3 e^{(-kd\cos\theta+\beta)}$$

Neglecting the exponential components, we get the following expression;

$$AF(\theta,\vartheta) = \sum_{n=1}^{N} W_1 + 2W_2\cos(kd_1\cos\theta+\beta) + 2W_3\cos(kd_2\cos\theta+\beta)$$

$$AF(\theta,\vartheta) = W_1 + 2W_2\cos(kd_1\cos\theta+\beta) + 2W_3\cos(kd_2\cos\theta+\beta)$$

For Linear Array having four Elements; the equation becomes

$$AF(\theta,\vartheta) = W_1 + 2W_2\cos(kd_1\cos\theta+\beta) + 2W_3\cos(kd_2\cos\theta+\beta) + 2W_4\cos(kd_3\cos\theta+\beta)$$

The given; two linear equations a constrained cost function is designed and programmed using Matlab software. Below is a sample program used for optimizing an array element spacing using genetic algorithm multi-objective optimization function. Since the weights and phases of the array elements has already found using previous steps. In this part the values are substituted and the Array Factor equations has only element spacing (d) to optimize.

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Function y=myfitness(d)
y(1)
=0.5386+2*0.5862*cos(39.77*d(1)+0.7928*pi)+2*0.5989*cos(39.77*d(2)+0.9309*pi)+2*0.7406*cos(39.77*d(3)+0.7145*pi);
y(2) =
0.7720+2*0.9131*cos(39.77*d(4)+0.8575*pi)+2*1*cos(39.77*d(5)+0.9136*pi);
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

objfunction=@myfitness;

nvars=5;

LB = [0.007 0.007 0.007 0.007 0.007];

UB = [0.014 0.014 0.014 0.014 0.014];
Consfcn = @myconstraints;
[x, fval] = gamultiobj (objfunction, nvars, [], [], [], [], LB, UB, consfcn);
x, fval
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [x, fval, exitflag, output, population, score] =
generatedcodes1(nvars, lb,ub, PopulationSize_Data)
%% This is an auto generated MATLAB file from
Optimization Tool.
%% Start with the default options
options = gaoptimset;
%% Modify options setting
options = gaoptimset (options,'PopulationSize',
PopulationSize_Data);
options = gaoptimset (options,'CreationFcn',
@gacreationuniform);
options = gaoptimset (options,'CrossoverFcn',
@crossoversinglepoint);
options = gaoptimset (options,'MutationFcn', {
@mutationuniform [] });
options = gaoptimset (options, ‘Display', 'off');
options = gaoptimset (options, ‘PlotFcns', { @gaplotdistance
@gaplotscorediversity @gaplotselection @gaplotstopping
@gaplotparetodistance @gaplotrankhist @gaplotspread });
options = gaoptimset (options,'Vectorized', 'off');
options = gaoptimset (options,'UseParallel', 1 );
[x, fval, exitflag, output, population, score] = ...
```

```
gamultiobj (@myfitness, nvars, [],[],[],[],lb,ub,[],options);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Table 3: Optimized element spacing

Population	Best Candidates	Generations	Problem Type	Avg-distance	Spread
10000	165	1000	Bound Constraints	0.0085	3.5051
d(1)	d(2)	d(3)	d(4)	d(5)	
0.1398	0.1397	0.1399	0.1400	0.1400	

Impedance Improvement [Matching Network Design for Band 38]

The antenna designed has a poor vswr along the bandwidth, this part we design a matching network for the antenna and then optimize the network values using direct search optimization method. First we Specify Frequency and Impedance as we are building a matching network with a band-pass response, so we specify the center frequency and the bandwidth of match as follow.

```
fc = 2165e6;          % Center Frequency (Hz)
BW = 910e6;           % Bandwidth (Hz)
```

We then specify the source impedance, the reference impedance and the load resistance. We modeled load |Zl| as a series R-L circuit.

```
Zs = 50;              % Source impedance (ohm)
Z0 = 50;              % Reference impedance (ohm)
Rl =  40;             % Load resistance (ohm)
L = 1e-8;             % Load inductance (Henry)
```

The code below using fminsearch was used for optimizing the network

```
niter = 250;
options = optimset ('Display','iter','MaxIter', niter);
L_Optimized = [Lvals (1) Lvals(end)];
L_Optimized = ...
   fminsearch(@(L_Optimized) antennaMatchObjectiveFun
(matchingNW, ...
   L_Optimized, freq, Zl, Z0), L_Optimized, options);
```

The values obtained after the optimization are shown on table 24;

L1_Initial = 2.7149e-07	L1_Optimized = 2.7154e-07
L3_Initial = 2.7149e-07	L3_Optimized = 2.6152e-07

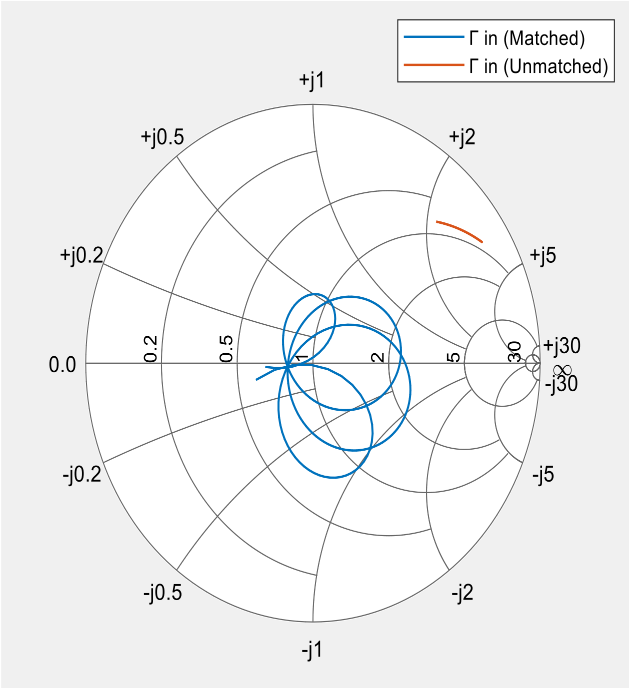


Figure 12: Smith Chart Results

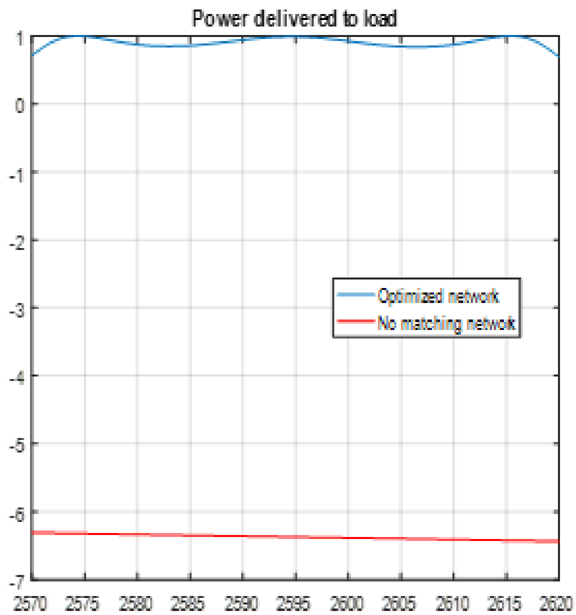


Figure 13:Observed delivered power

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LC Ladder element

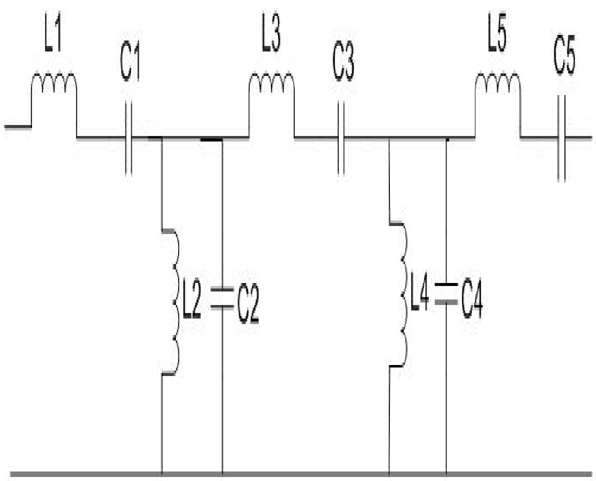
Topology: 'bandpasstee'

Inductances: [2.7154e-07 4.8058e-11 2.6152e-07]

Capacitances: [1.3857e-14 7.8279e-11 1.3857e-14]

NumPorts: 2

Terminals: {'p1+' 'p2+' 'p1-' 'p2-'}



Array Element Design and Algorithm Testing

Testing of the algorithm started with the design of the antenna element, which will be on the testing of the algorithm. The antenna selected is a simple metal strip antenna with a length of 0.0694 meters, and power was fed at mid-point along the x-axis as shown on figure 106.

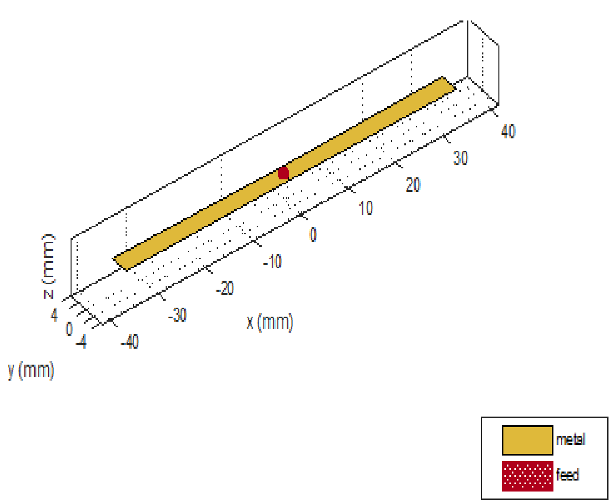


Figure 14: Proposed array element

A number of experiments were conducted so as to improve the electromagnetic features of the proposed array element is shown on table 26. The design was based on the structural bending, element width and length while the observation was based on gain and s-parameters improvement.

Table 4: Experiment results for proposed element

Ex p.no.	Bending angle	length	width	dBs11 (s-parameters)	Gain
1	[45 45]	0.0347, 0.0347	0.0035	-23	1.72
2	[45 0]	0.0347,0.0347	0.0035	-11	2.03
3	[45 0]	0.0347,0.034	0.00035	-16	2.01
4	[30 0]	0.0347,0.0347	0.00035	-14	2.07
5	[30 0]	0.028,0.0347	0.0035	-11	2.02
6	[30 0]	0.028, 0.04	0.0035	-12	2.09
7	[15 0]	0.028, 0.04	0.0035	-11	2.13
8	[10 0]	0.028, 0.04	0.0035	-11	2.13
9	[10 0]	0.028, 0.04	0.00035	-13.5	2.1
10	[5 0]	0.028, 0.04	0.0035	-11	2.13

From the experiments conducted as shown on table 26, it was observed that experiment-1 resulted into a minimum gain but good impedance matching at the given bending angles while experiment 7,8 and 10 gives a maximum gain value but with an average impedance results. From the experiment it was observed that; the value of length and width of the metal structure has a positive result on the gain improvement while the bending of the antenna has a positive result on the impedance matching (s-parameters) of the antenna given the feed-point is where the bending of the structure was done. The results on an experiment-9, was the selected array element since it has good s-parameters and as well as good gain, comparing it with the maximum values obtained from gain and s-parameters of the whole results observations. The simulation results of the selected element are shown on table 27

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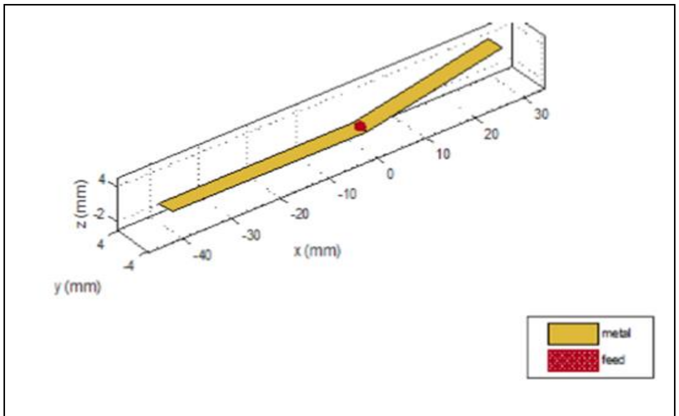
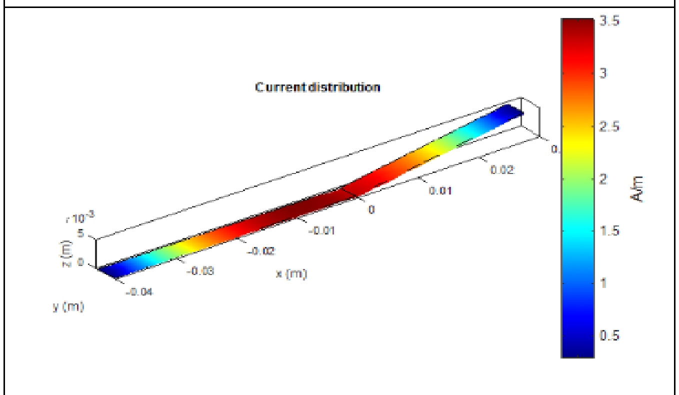
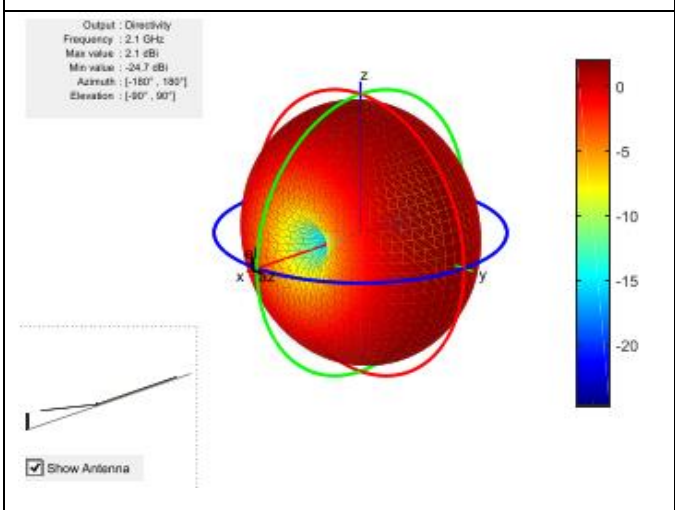
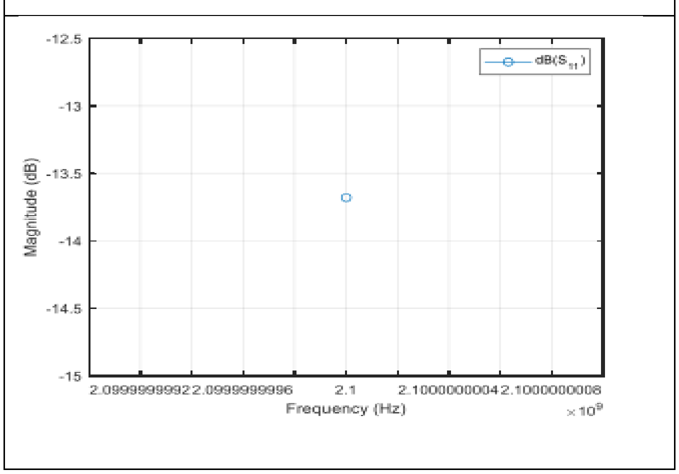
Table 5: Designed array element results



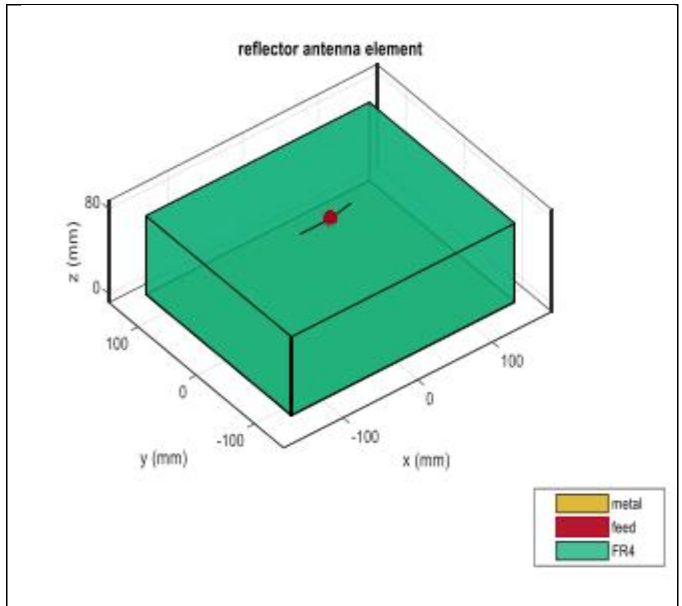
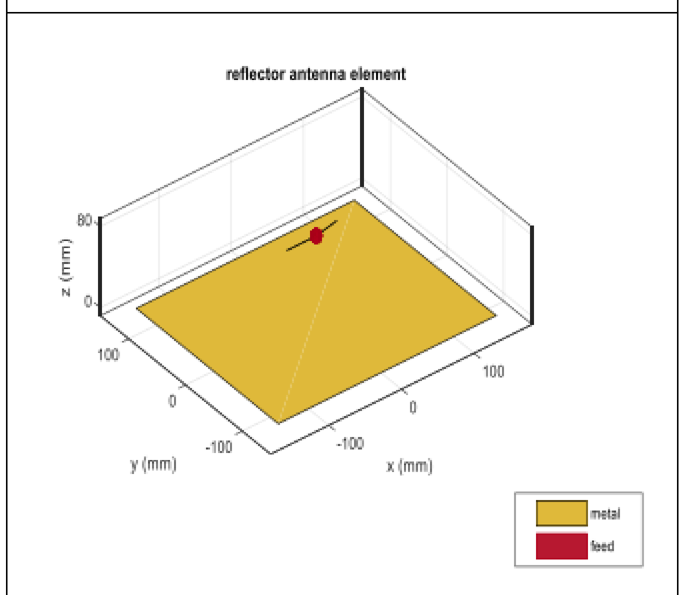






To improve the gain of the selected array element a backed reflectror was added and a dielectric medium was introduced between the array element and the reflector. An assesment as shown on table 28 was done so as to address the effects of FR4 and air dielectric substrates.

Table 6: *Array element with dielectric & reflector assessment*


Dielectric medium is FR4 The radiator wasnot conforming to the surface of the dielectric substrate

Dielectric medium is Air A maximum gain of 6.95 dBi was observed

The designed antenna with the added reflector was used as an array element on the rectangular array antenna and the dielectric medium is air. The array antenna was tested at the latitude of -2.519351 and longitude of 32.8967193, and the height/altitude was set at 20 meters above the ground. To model the phases of each array element and creting dead array elements, matlab 2018a was used to program the task.

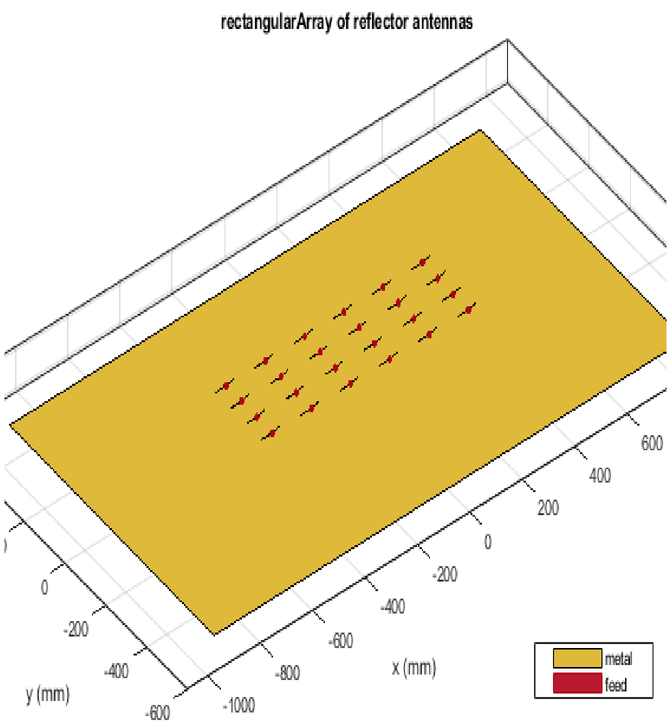


Figure 15: Rectangular Array with designed elements

Figure 16 shows the electromagnetic field strength of the radiation pattern, while figure 17 shows the coverage field strength range from 48 to 56 *dB/mµV/m*. However, for the areas simulated on figure 16 and 17 the array antenna was having no reflectors.

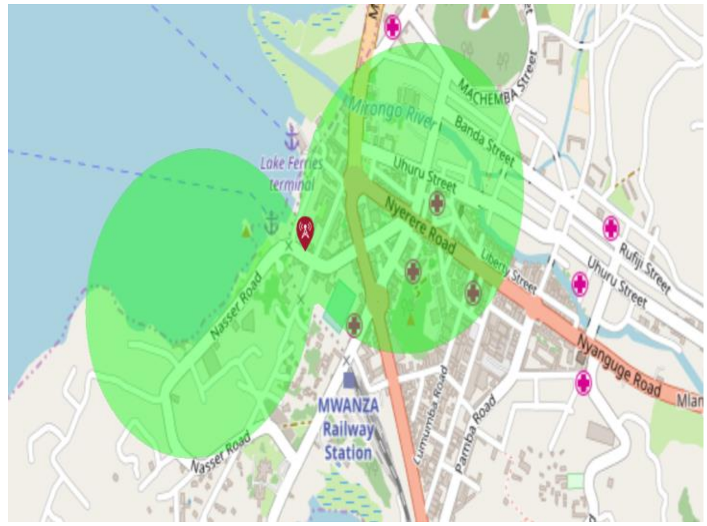


Figure 16: Radiation pattern for 56 dB/mµV/m field strength

Sample matlab codes used to define and set antenna parameters

```
tx = txsite ('Name’,’ Antenna Site', ...
   'Latitude’, lat, ...
   'Longitude’, Lon, ...
   'Antenna', dv, ...
   'AntennaHeight', h, ...
   'AntennaAngle', xyrot, ...
   'TransmitterFrequency', freq);
sigStrengths = [36 48 56];
coverage (tx, 'Type' , 'efield', ...
   'SignalStrengths’, sigStrengths, ...
   'Colormap', 'parula', ...
   'ColorLimits', [36 56])
```

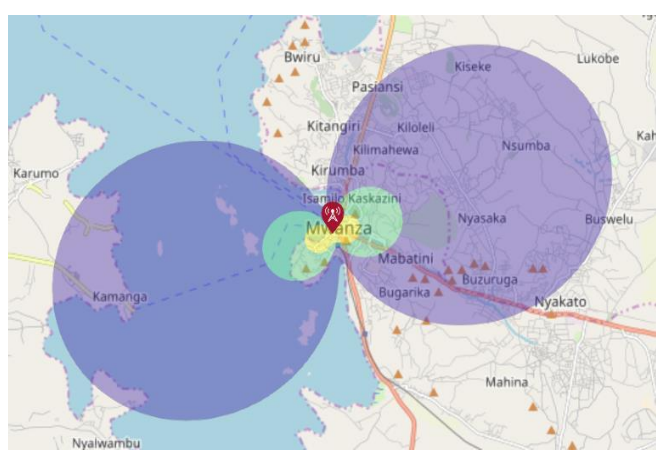


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Figure 17: Radiation pattern for 48-56 dB/mμV/m field strength range

5. Antenna Test in a 5G Macro-Cell Environment

The designed antenna was tested on a 5G urban macro-cell environment and the visualization of the signal-to-interference-plus-noise ratio (SINR) on a map was done. The environment for testing was based on the guidelines defined in Report ITU-R M.[IMT-2020.EVAL] for evaluating 5G radio technologies. The test environment is posta dares salaam which is the urban environment with high user density and traffic loads focusing on pedestrian and vehicular users (Dense Urban-eMBB). The test setting plan for 5G technologies reuse the test network layout for 4G technologies as explained in Report ITU-R M.2135-1. The network layout consists of 19 sites placed in a hexagonal layout, each with three cells. The distance between adjacent sites is named as the inter-site distance (ISD) which depends on the test usage situation. For the Dense Urban-eMBB test environment, the ISD is 200 m.
The center site was programmed as shown on the matlab codes below and the 5G sites locations are shown on figure 110.

centerSite = txsite ('Name', 'Posta Dar es salaam', 'Latitude', -6.8148', 'Longitude',39.2881);

siteDistances = 1×19
0 200.0000 200.0000 200.0000 200.0000 200.0000 200.0000 346.4102 346.4102 346.4102 346.4102 346.4102 346.4102 400.0000 400.0000 400.0000 400.0000 400.0000 400.0000

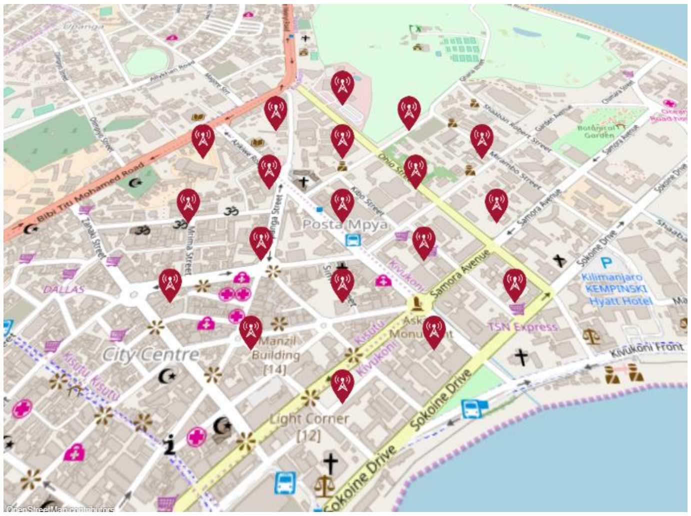


Figure 18: 5G Macro-cell site location at Dar es salaam

On setting the cell parameters, each site was set to have three transmitters corresponding to each cell. The cell towers were sectored into the following angles as shown below. cellSectorAngles = [30 150 270]; The transmitter parameters were defined based on the Report ITU-R M.[IMT-2020.EVAL], given the following parameters

fq = 4e9; % Carrier frequency (4 GHz) for Dense Urban-eMBB

AntennaHeight = 25; % height in meters

txPowerDBm = 44; % Total transmit power in dBm

txPower = 10. ^((txPowerDBm-30)/10); % Convert dBm to W

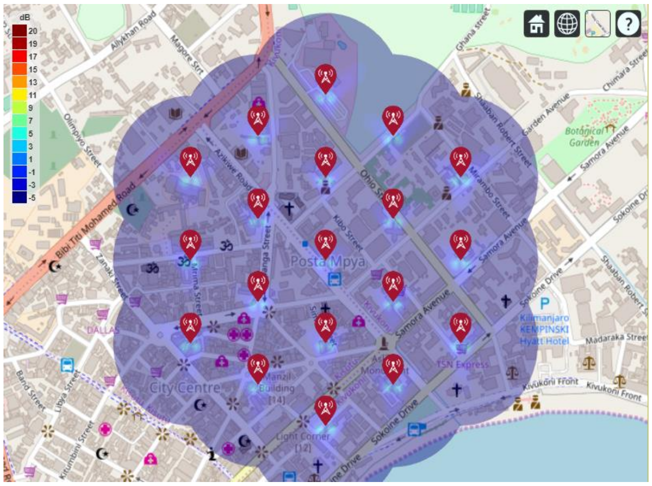


Figure 19: Coverage EMW for 5G Dense Urban Dar es salaam

Antenna array was used to increase directional gain and increase peak SINR. A mechanical down tilt of 15 degrees was used so as to illuminate the intended ground area around each transmitter. To reduce sidelobes, tapering was applied, the matlab codes below were programmed to reduce sidelobe levels of the transmitters antennas.

```
dBdown = 30; taperz = chebwin (nrow, dBdown); tapery = chebwin (ncol, dBdown);    downtilt = 15;
```

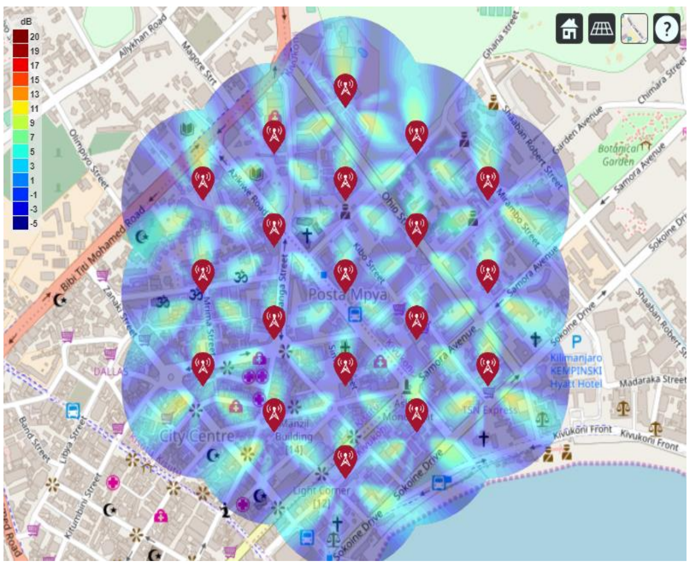


Figure 20: Reduced interference 5G Macro-cell

Visualize SINR for the test scenario using the Close-In propagation model [3], which models path loss for 5G urban micro-cell and macro-cell scenarios. This model produces an SINR map that shows reduced interference effects compared to the free space propagation model. A rectangular antenna array can provide greater directionality and therefore peak SINR values than use of a single antenna element.

Proposed Multi-Beam Scheme

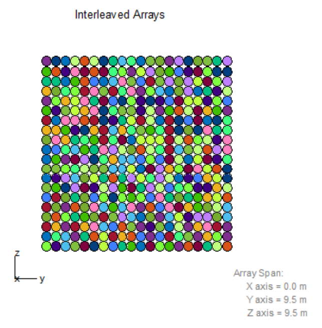
Due to the large bandwidth available in millimeter wave (mm-wave) radio, particularly that operating in the frequency range of 28 to 90 GHz, has been considered as a very promising candidate for 5G cellular communications [13, 14]. Compared to microwave systems, the propagation attenuation of mm-wave is much higher and the realizable radiation power is much lower. This creates the necessity to use high-directivity antennas so as to guarantee the minimum signal power at the receiver for successful signal detection.

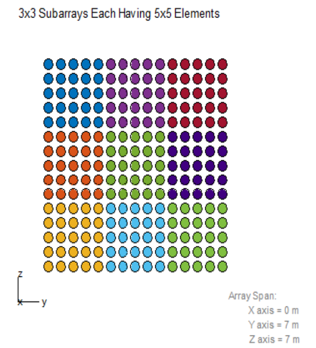
Due to the growing of cities, to support mobile users and users at different locations has become a complex issue[15]. To accommodate those challenges, the antenna needs to have steering characteristics. For array antenna with a wavelength of mm-wave, it is practicable to accommodate a large number of antenna elements in a physically limited space. An array can produce multiple narrow beams towards different directions. For instance, suppose it is desired to form from two or four beams towards the selected steering angles [16]. Hence, in a growing city (changing of environment), where 5G is expected to be deployed a Steerable Multi-beam antenna array is a promising scheme.

6. Architecture and Organization

The table 7 shows the architecture of a hybrid array, where the whole array is divided into many sub arrays. Each sub array is an analog array, consisting of antennas connected with analogue adjustable phase shifters in the RF chain. Each sub array is connected to a baseband processor via a digital-to-analog convertor (DAC) in the transmitter or an analog-to-digital convertor (ADC) in the receiver.

Table 7: Architecture Overview

<table>
<tr><th colspan="2">Weighted Color Coded Array Elements</th></tr>
<tr><td>


</td><td>


</td></tr>
</table>

The architecture proposed in this research is based on the available number and arrangements of un-optimized elements. Given a geometry which is not optimized; using evolutionary computation algorithms not all the element in a geometry will be active after optimization. This research proposes the use of non-active elements in the geometry for creating another radiation pattern (Multi-beams), an intelligent (i.e. Artificial Intelligence techniques) control system must be designed for the proposed system.

7. Conclusion and Discussion

In this study, the Particle Swarm and Genetic Algorithm Optimization method were hybridized to develop a model for optimizing the rectangular array antenna elements. The amplitude weights and normalized element phases were optimized in order to minimize the power of the side lobe level. An experimental study of the effect of the element shape of the occurrence of the sidelobe level was also conducted. The results show that; the array antenna having a triangular shape produces no side lobe levels compared to the ones with a rectangular shape, but also the Model developed in this research proves to be more efficient and reduces the complexity of optimizing antenna having a rectangular geometry; this was done splitting the rows into a separate linear array and then re-joining it by adding a constant factor (K).

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