DESIGN AND OPTIMIZATION OF ANTENNA ARRAY USING DIFFERENTIAL EVOLUTION ALGORITHM

A Project report submitted in partial fulfillment of the requirements for

the award of the degree of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

(*Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC with 'A' Grade*)

Sangivalasa, bheemili Mandal, Visakhapatnam dist. (A.P)

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PRAGNANAM BRAHMA

ANITS

CERTIFICATE

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ABSTRACT

An array of antennas is generally used in long distance communication. The observation of celestial objects necessitates a large array of antennas, like the Giant Metrewave Radio Telescope (GMRT). Optimizing this kind of array is very important when observing a high-performance system. The differential evolution algorithm is an optimization solution for these kinds of problems that reconfigures the position of antennas to increase the directivity or decrease the side lobe levels. This paper presents how to design and optimize an antenna array which generates dual-beam patterns using the differential evolution algorithm. A brief explanation about the differential evolution (DE) algorithm and operators used in this paper are provided, results of optimization are discussed. The results shows that the DE algorithm provides efficient and optimum solutions by iteratively trying to improve a candidate solution with regard to achieve the desired array performance as required. The proposed algorithm is able to produce efficient results by increasing directivity in dual-beam patterns. The objective oriented concepts are formulated for implementing this DE algorithm.

LIST OF FIGURES

CHAPTER 1

ANTENNA

1.ANTENNA

In this chapter, the elementary concept of an antenna is provided, and its working is explained. Next, some critical performance parameters of antennas are discussed. Finally, some communal types of antennas are introduced.

1.1 INTRODUCTION:

An antenna is a metallic structure that captures and/or transmits radio electromagnetic waves. Antennas come in all shapes and sizes from little ones that can be found on your roof to watch TV to really big ones that capture signals from satellites millions of miles away. Antennas act as matching systems between sources of electromagnetic energy and space.

1.2 EVOLUTION OF ANTENNA:

An Abridged History of Electromagnetism: Over 2600 years ago (and likely well before that) the ancient Greeks discovered that a piece of amber rubbed on a piece of fur would attract lightweight objects like feathers. Around the same time, the ancients discovered lodestone, which are pieces of magnetized rock.

It took a few hundred years more to determine that there are two different properties of attraction and repulsion (magnetic and electric) likes repel and opposites attract. Another 2000 years passed before scientists first discovered that these two entirely different novelties of nature were inextricably linked. In the early nineteenth-century, Hans Christen Oersted placed a wire perpendicular to a compass needle and saw nothing. But when he rotated the wire parallel to the compass needle and passed a current through the wire, it deflected in one direction. When he passed the current through the wire in the opposite direction, the compass needle deflected in the opposite direction.

Shortly after, Nikola Tesla wirelessly lit lamps in his workshop, demonstrated the first remote-control toy boat, and established the alternating-current system we use to transfer electricity throughout the world today. Less than a full century after Orstead's experiment, Guglielmo Marconi devised a way to send the first wireless telegraph signals across the Atlantic.

1.3 ANTENNA WORKINGS:

In order to know how an antenna radiates, let us first consider how radiation occurs. In physics, radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium. A conducting wire radiates principally because of time-varying current or an acceleration (or deceleration) of charge. If there is no motion of charges in a wire, then no radiation takes place, since no flow of current occurs in the wire. Radiation will not occur even if charges are moving with uniform velocity in a straight wire. However, charges moving with uniform velocity along a curved or bent wire will produce radiation. The radiation from an antenna can be explained with the help of Figure 1.1 which shows a voltage source connected to a two-conductor transmission line. When a sinusoidal voltage is applied across the transmission line, an electric field is created which is sinusoidal in nature and these results in the creation of electric lines of force which are tangential to the electric field. The magnitude of the electric field is indicated by the bunching of the electric lines of force. The free electrons on the conductors are forcibly displaced by the electric lines of force and the movement of these charges causes the flow of current which in turn leads to the creation of a magnetic field.

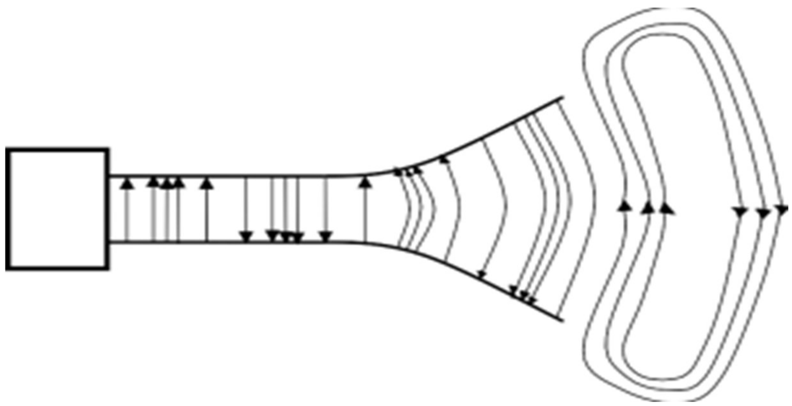

Fig 1.1 radiation from an antenna

1.4 ANTENNA PERFORMANCE PARAMETERS

Now let us understand the characteristics of a typical wireless communication system are dependent on the characteristics of the antenna used in the system.

For example, the operational characteristics of a communication system find back its roots to the directional characteristics of the antenna. Irrespective of the application that an antenna is used in, all the antennas are associated with a few fundamental parameters.

These parameters are sometimes also called as Properties of Antenna or Characteristics of Antenna. Certain basic characteristics of antenna are listed below:

- Antenna Radiation Pattern
- Radiation Intensity
- Directivity and Gain
- Radiation Efficiency and Power Gain
- Input Impedance
- Effective Length
- Bandwidth
- Effective Aperture

Let us understand these properties of antennas one-by-one.

1. Radiation Pattern:

Antenna Radiation Pattern: An antenna radiation pattern or antenna pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates.

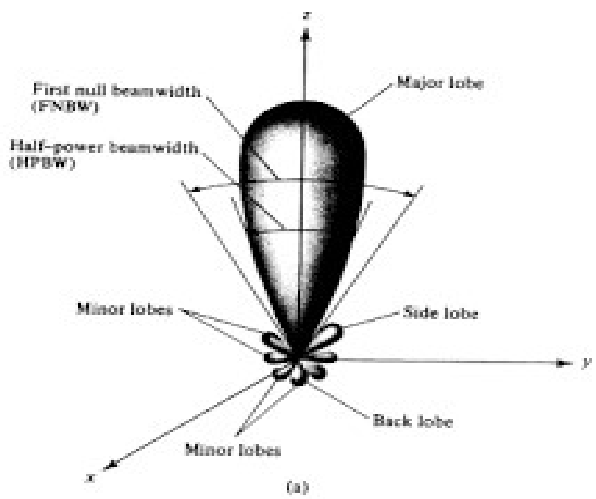

Fig 1.2 radiation pattern lobes

A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity.

- Main lobe
- Minor lobes
- Side lobes
- Back lobes

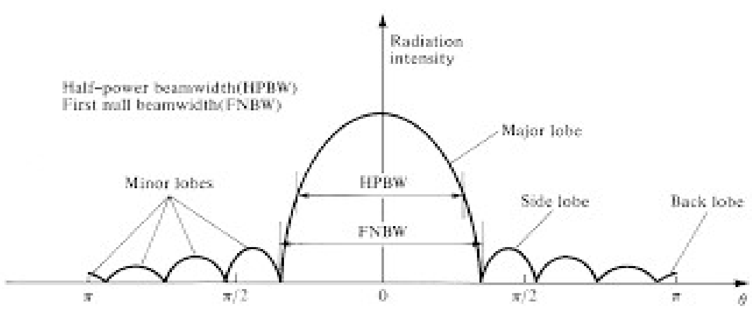

Fig 1.3 radiation pattern

- *Minor lobes usually represent radiation in undesired directions, and they should be minimized. Side lobes are normally the largest of the minor lobes.
- *The level of minor lobes is usually expressed as a ratio of the power den- sity, often termed the side lobe ratio or side lobe level.
- *In most radar systems, low side lobe ratios are very important to mini- mize false target indications through the side lobes (e.g., -30 dB).

Components in the Amplitude Pattern:

There would be, in general, three electric-field components (*Er, Eθ*, *Eφ*) at each observation point on the surface of a sphere of constant radius.

In the far field, the radial *Er* component for all antennas is zero or vanishingly small. Some antennas, depending on their geometry and also observation distance, may have only one, two, or all three components.

Isotropic, Directional, and Omnidirectional Patterns are the types of radiation patterns.

Isotropic Radiator: A hypothetical lossless antenna having equal radiation in all directions. **Omnidirectional Radiator:** An antenna having an essentially nondirectional pattern in a given plane (e.g., in azimuth) and a directional pattern in any orthogonal plane.

Directional Radiator: An antenna having the property of radiating or receiving more effectively in some directions than in others. Usually, the maximum directivity is significantly greater than that of a half-wave dipole.

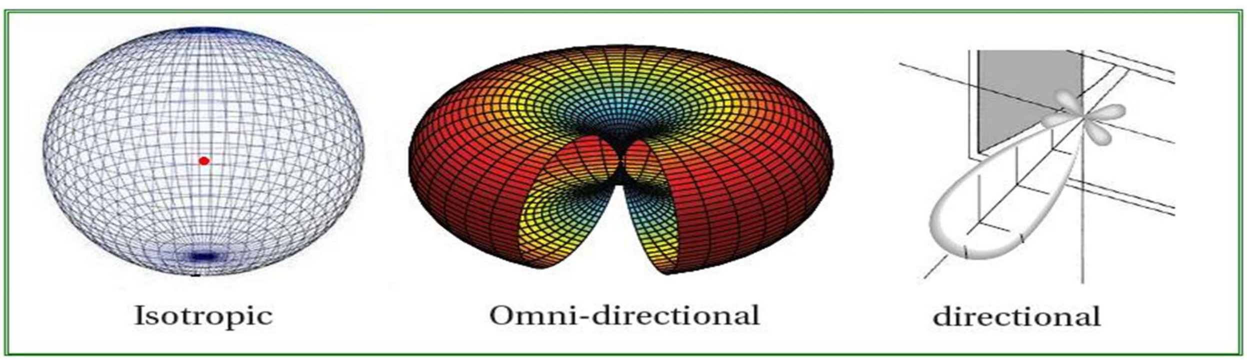

Fig 1.4 reflectors

2. Directivity:

The directivity of an antenna has been defined by as “the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions". In other words, the directivity of a nonisotropic source is equal to the ratio of its radiation intensity in a given direction, over that of an isotropic source. Sometimes, the direction of the directivity is not specified.

Directivity is a dimensionless quantity, since it is the ratio of two radiation intensities. Hence, it is generally expressed in dB. The directivity of an antenna can be easily estimated from the radiation pattern of the antenna. An antenna that has a narrow main lobe would have better directivity, then the one which has a broad main lobe, hence it is more directive.

3. Input Impedance:

The input impedance of an antenna is defined as "the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point". Hence the impedance of the antenna can be written as:

$$Z_{in} = R_{in} + j\,X_{in}$$

Where, R_{in} is the antenna resistance at the terminals

X_{in} is the antenna reactance at the terminal

The power associated with the radiation resistance is the power actually radiated by the antenna, while the power dissipated in the loss resistance is lost as heat in the antenna itself due to dielectric or conducting losses.

4. Return Loss (RL):

The Return Loss (RL) is a parameter which indicates the amount of power that is "lost" to the load and does not return as a reflection. As explained in the preceding section, waves are reflected leading to the formation of standing waves, when the transmitter and antenna.

5. Bandwidth (BW):

The bandwidth of an antenna is defined by as "the range of usable frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." The bandwidth can be the range of frequencies on either side of the center frequency where the antenna characteristics like input impedance, radiation pattern, beamwidth, polarization, side lobe level or gain, are close to those values which have been obtained at the center frequency. The bandwidth of a broadband antenna can be defined as the ratio of the upper to lower frequencies of acceptable operation.

6. Antenna Gain:

The term Antenna Gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. Antenna gain is more commonly quoted than directivity in an antenna's specification sheet because it takes into account the actual losses that occur.

A transmitting antenna with a gain of 3 dB means that the power received far from the antenna will be 3 dB higher (twice as much) than what would be received from a lossless isotropic antenna with the same input power. Note that a lossless antenna would be an antenna with an antenna efficiency of 0 dB (or 100%). Similarly, a receive antenna with a gain of 3 dB in a particular direction would receive 3 dB more power than a lossless isotropic antenna.

Antenna Gain is sometimes discussed as a function of angle. In this case, we are essentially plotting the radiation pattern, where the units (or magnitude of the pattern) are measured in antenna gain.

7. Radiation Intensity

The radiation intensity of an antenna is the power per unit solid angle. It is represented by U and is independent to distance from the antenna. Units of radiation intensity are Watts per steradian (W/Sr).

8. Radiation Efficiency and Power Gain

All practical antennas will have Ohmic losses as they are made up of conducting materials with finite conductivity. Radiation Efficiency is ratio of radiated power to the input power.

$\eta_r = P_{rad} / P_{in}$

Power Gain of an Antenna is the ratio of the power radiated in a direction to the total input power.

9. Effective Length

The length of an imaginary linear antenna with uniformly distributed current is defined as the Effective Length of an antenna such that both these antennas have same far field in π/2 plane.

10. Effective Aperture

Generally, the term effective aperture or effective area is associated with the receiving antenna. Effective Aperture or Area of an antenna is the measure of the ability of an antenna to extract energy from the electromagnetic wave.

Effective Aperture of an antenna is the ratio of the Power Received at the load to the average power density produced by the antenna.

1.5 TYPES OF ANTENNAS

Antennas come in different shapes and sizes to suit different types of wireless applications. The characteristics of an antenna are very much determined by its shape, size and the type of material that it is made of. Some of the commonly used antennas are briefly described below.

1.5.1 Half Wave Dipole:

The dipole antenna is cut and bent for effective radiation. The length of the total wire, which is being used as a dipole, equals half of the wavelength (i.e., $l = \lambda/2$). Such an antenna is called as half-wave dipole antenna. This is the most widely used antenna because of its advantages. It is also known as Hertz antenna.

Frequency range

The range of frequency in which half-wave dipole operates is around 3KHz to 300GHz.
This is mostly used in radio receivers.

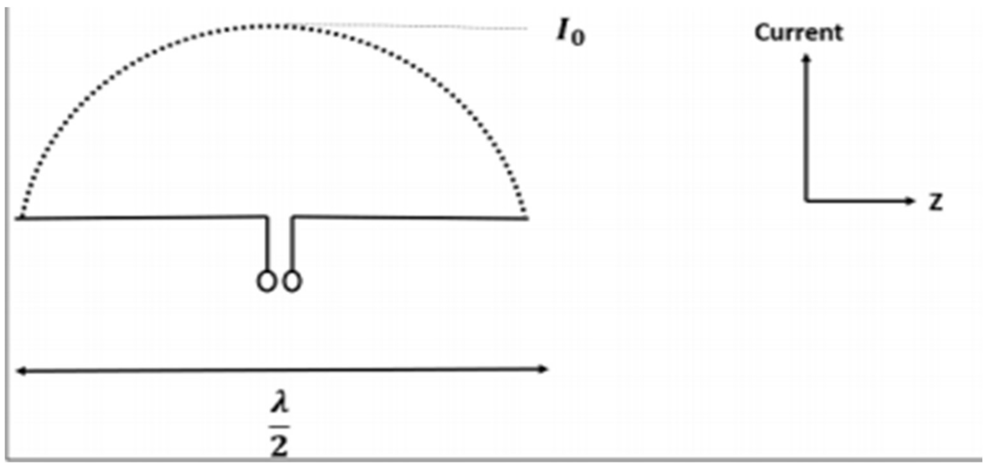

Fig 1.5 Half dipole

The above figure shows the current distribution in half wave dipole. The directivity of half wave dipole is 2.15dB, which is reasonably good. Where, 'i' represents the isotropic radiation.

Radiation Pattern

The radiation pattern of this half-wave dipole is Omni-directional in the H-plane. It is desirable for many applications such as mobile communications, radio receivers etc.

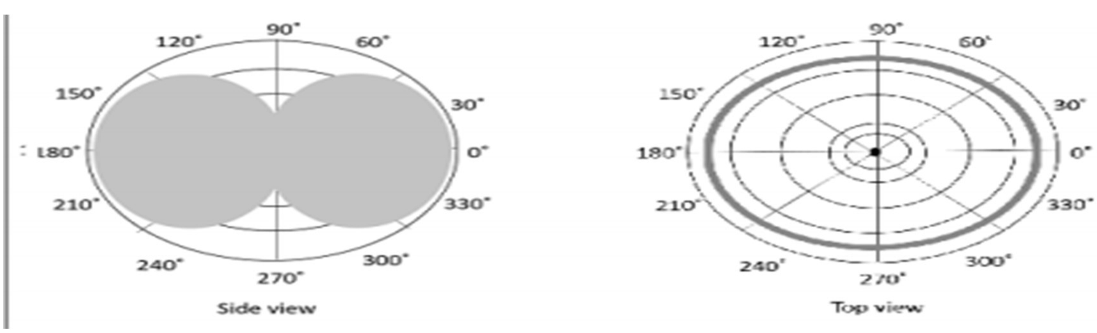

Fig 1.6 radiation pattern for half wave dipole

The above figure indicates the radiation pattern of a half wave dipole in both H-plane and V plane. The radius of the dipole does not affect its input impedance in this half wave dipole, because the length of this dipole is half wave and it is the first resonant length. An antenna works effectively at its resonant frequency, which occurs at its resonant length.

Advantages

The following are the advantages of Loop antenna −

- Compact in size
- High directivity

Disadvantages

The following are the disadvantages of Loop antenna −

- Impedance matching may not be always good
- Has very high resonance quality factor

Applications

The following are the applications of half-wave dipole antenna −

- Used in radio receivers.
- Used in television receivers.
- When employed with others, used for wide variety of applications.

1.5.2 Monopole Antenna

Monopole antennas, as shown in Figure, constitute a group of derivatives of dipole antennas. Here, only half of the dipole antenna is needed for operation. A metal ground plane (ideally of infinite size) is used, with respect to which the excitation voltage is applied to the half structure. The half structure for a regular dipole antenna is called a monopole antenna, in reference to the presence of only one physical side. A similar half structure for a folded dipole antenna is called a folded monopole antenna. The presence of the ground plane allows the monopole antenna to operate as electrically equivalent to a dipole antenna. The ground plane equivalently replaces the lower half by an imaging principle, similar to creating an optical image through a mirror. Notice in Figure1.5 that for the currents in the monopole and dipole structures to be the same, one needs the source voltage of the equivalent dipole antenna to be twice that of the monopole antenna. As a result, the input impedance of the monopole structure is half that of the corresponding dipole structure:

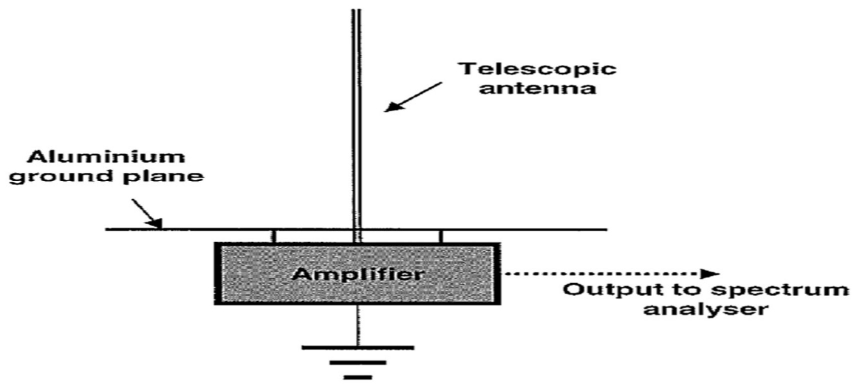

Fig 1.7 monopole antenna

1.5.3 Helical Antenna

Helical antenna is an example of wire antenna and itself forms the shape of a helix. This is a broadband VHF and UHF antenna.

Frequency Range

The frequency range of operation of helical antenna is around 30MHz to 3GHz. This antenna works in VHF and UHF ranges.

Helical antenna or helix antenna is the antenna in which the conducting wire is wound in helical shape and connected to the ground plate with a feeder line. It is the simplest antenna, which provides circularly polarized waves. It is used in extra-terrestrial communications in which satellite relays etc., are involved.

It consists of a helix of thick copper wire or tubing wound in the shape of a screw thread used as an antenna in conjunction with a flat metal plate called a ground plate. One end of the helix is connected to the center conductor of the cable and the outer conductor is connected to the ground plate.The radiation of helical antenna depends on the diameter of helix, the turn spacing and the pitch angle.

Pitch angle is the angle between a line tangent to the helix wire and plane normal to the helix axis.

$$\alpha=\tan-1(S\pi D)$$

where,

- **D** is the diameter of helix.

- S is the turn spacing (centre to centre).
- α is the pitch angle.

Advantages

The following are the advantages of Helical antenna –

- Simple design
- Highest directivity
- Wider bandwidth
- Can achieve circular polarization
- Can be used at HF & VHF bands also

Disadvantages

The following are the disadvantages of Helical antenna −

- Antenna is larger and requires more space
- Efficiency decreases with number of turns

Applications

The following are the applications of Helical antenna −

- A single helical antenna or its array is used to transmit and receive VHF signals
- Frequently used for satellite and space probe communications
- Used for telemetry links with ballastic missiles and satellites at Earth stations
- Used to establish communications between the moon and the Earth
- Applications in radio astronomy

1.5.4 Horn Antenna

To improve the radiation efficiency and directivity of the beam, the wave guide should be provided with an extended aperture to make the abrupt discontinuity of the wave into a gradual transformation. So that all the energy in the forward direction gets radiated. This can be termed as Flaring. Now, this can be done using a horn antenna.

Frequency Range

The operational frequency range of a horn antenna is around 300MHz to 30GHz. This antenna works in UHF and SHF frequency ranges.

Sectoral horn

This type of horn antenna, flares out in only one direction. Flaring in the direction of Electric vector produces the sectorial E-plane horn. Similarly, flaring in the direction of Magnetic vector, produces the sectorial H-plane horn.

Pyramidal horn

This type of horn antenna has flaring on both sides. If flaring is done on both the E & H walls of a rectangular waveguide, then pyramidal horn antenna is produced. This antenna has the shape of a truncated pyramid.

Conical horn

When the walls of a circular wave guide are flared, it is known as a conical horn. This is a logical termination of a circular wave guide.

1.5.5 Log-Periodic Antenna

A log-periodic antenna is also named a log-periodic array. it is a multi-element, directional narrow beam antenna that works on a wide range of frequencies. this antenna is made of a series of dipoles placed along the antenna axis at different space intervals of time followed by a logarithmic function of frequency. a log-periodic antenna is used in a wide range of applications where variable bandwidth is required along with antenna gain and directivity.

1.5.5 Array Antenna

An antenna array (or array antenna) is a set of multiple connected antennas which work together as a single antenna, to transmit or receive radio waves. The individual antennas (called elements) are usually connected to a single receiver or transmitter by feedlines that feed the power to the elements in a specific phase relationship. The radio waves radiated by each individual antenna combine and superpose, adding together (interfering constructively) to enhance the power radiated in desired directions, and cancelling (interfering destructively) to reduce the power radiated in other directions. Similarly, when used for receiving, the separate radio frequency currents from the individual antennas combine in the receiver with the correct phase relationship to enhance signals received from the desired directions and cancel signals from undesired directions. More sophisticated array antennas may have multiple transmitter or receiver modules, each connected to a separate antenna element or group of elements.

The detailed explanation of array antennas is given in the **chapter two**.

CHAPTER 2

ARRAY ANTENNA

2. ARRAY ANTENNA

2.1 INTRODUCTION

An antenna, when individually can radiate an amount of energy, in a particular direction, resulting in better transmission, how it would be if few more elements are added it, to produce more efficient output. It is exactly this idea, which led to the invention of Antenna arrays. An antenna array is a set of multiple connected antennas which work together as a single antenna, to transmit or receive radio waves. The individual antennas are usually connected to a single receiver or transmitter by feedlines that feed the power to the elements in a specific phase relationship.

An antenna array is used to increase overall gain, provide diversity reception, cancel out interference, maneuver the array in a particular direction, gage the direction of arrival of incoming signals, and to maximize the Signal to Interference plus Noise Ratio (SINR).

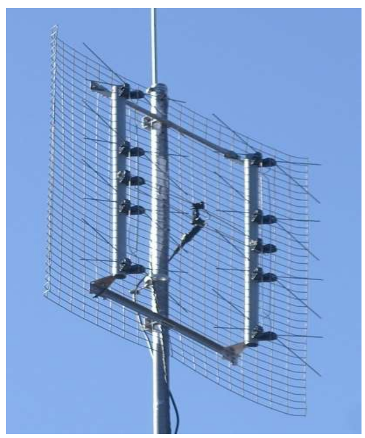

Fig 2.1 array antenna

An antenna array can achieve higher gain (directivity), that is a narrower beam of radio waves, than could be achieved by a single element. In general, the larger the number of individual antenna elements used, the higher the gain and the narrower the beam. Some antenna arrays (such as military phased array radars) are composed of thousands of individual antennas. Arrays can be used to achieve higher gain, to give path diversity (also called MIMO) which increases communication reliability, to cancel interference from specific directions, to steer the radio beam electronically to point in different directions, and for radio direction finding (RDF).

The term antenna array most commonly means a driven array consisting of multiple identical driven elements all connected to the receiver or transmitter. A parasitic array consists of a single driven element connected to the feedline, and other elements which are not, called parasitic elements. It is usually another name for a Yagi-Uda antennas.

A phased array usually means an electronically scanned array; a driven array antenna in which each individual element is connected to the transmitter or receiver through a phase shifter controlled by a computer. The beam of radio waves can be steered electronically to point instantly in any direction over a wide angle, without moving the antennas. However, the term "phased array" is sometimes used to mean an ordinary array antenna.

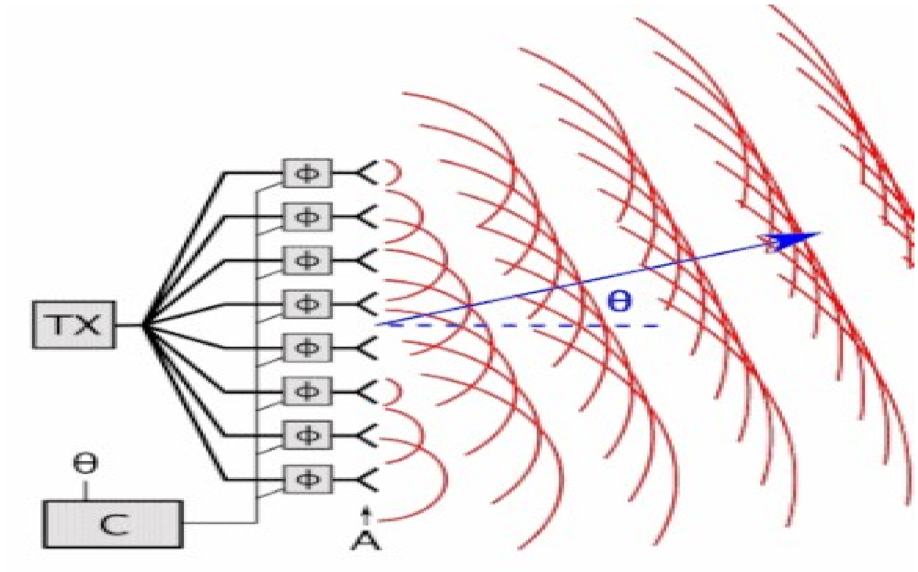

Fig 2.2 Phased array antenna

2.2 TYPES OF ANTENNA ARRAYS

- Two element arrays
- Linear arrays

2.2.1 TWO ELEMENT ANTENNA ARRAY

Suppose two antenna elements to make an array as in figure above. The two elements are fed with current I1 and I2.

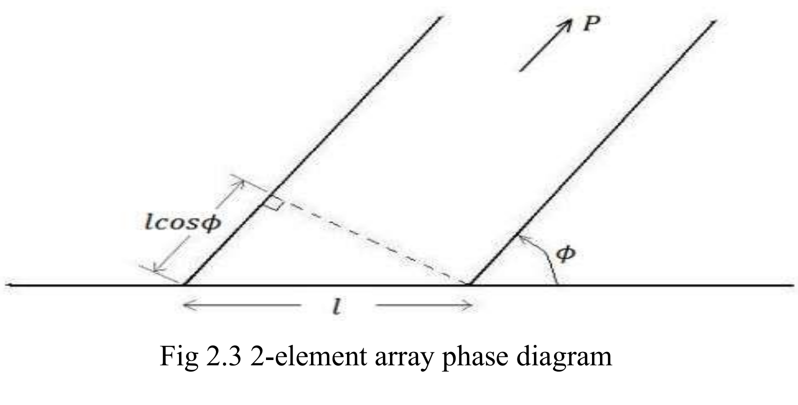

Fig 2.3 2-element array phase diagram

I1 and I2 are equal in magnitude but out of phase:

$$I1 = I1\angle\alpha$$

The point of observation is in the far field, the path length difference is lcos α ,where l the distance between the two elements.

the radiation of element 1 at P will lead the radiation of element 2 with angle Ψ where:

$$\psi = \beta l cos\phi + \alpha$$

β = phase constant of the transmitted wave.

The total field at P is

$$E = E_1[1 + exp(j\psi)]$$

Where E1 is the field at P due to element 1.

The magnitude of the field at P is:

$$|E_\phi| = 2E_1 cos\left(\frac{1}{2}\psi\right)$$

$$= 2E_1 cos\frac{1}{2}(\beta l cos\phi + \alpha)$$

$$= 2E_1 cos(\frac{\pi l}{\lambda}cos\phi + \frac{\alpha}{2})$$

From above equation we can see that for a given phase difference and a given distance we can change the radiation pattern by changing ($\frac{l}{lambda}$).

2.2.2 LINEAR ARRAY

We have studied a simple array consist of two elements, now if we put more elements in the line of our two elements array, we build a linear array.

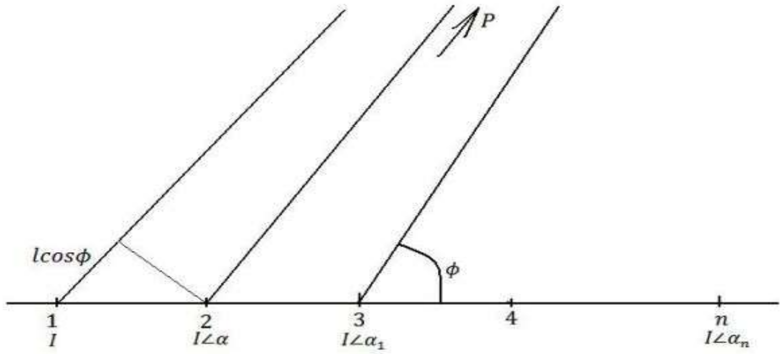

Fig 2.4 linear array phase angle

Now consider figure of a simple linear array with equal separation between elements l and equal current in magnitude and equal difference in phase I

$$I\ , I\angle\alpha\ , I\angle\alpha_1\ , I\angle\alpha_2\ , \ldots\ldots I\angle\alpha_n$$

Field at point P is:

$$E = E_1[1 + e^{j\psi} + e^{j2\psi} + e^{j3\psi} + \cdots e^{jn\psi}]$$

The magnitude of E is:

$$E = E_o \left| \frac{\sin\frac{n\psi}{2}}{\sin\frac{\psi}{2}} \right|$$

$$\text{Where } \psi = \beta l cos\phi + \alpha$$

This quantity is known as the array factor and it determines the shape of the radiation pattern. The equation has a maximum when Ψ=0 so βlcos Ø=-α.

We can now place the maximum as we wish by choosing α correctly. The phase of each element in this array can be controlled by phase shifter, and the amplitude of the elements is adjusted by an amplifier or attenuator.

2.2 RADIATION PATTERNS OF ANTENNA ARRAYS

In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source.

Now let's see the radiation pattern of phased arrays. A "phased array" is simply a linear array of antennas, all equally spaced at a distance d, with the same amplitude applied to each antenna. Sometimes, the phase is also the same, but sometimes we will introduce an intentional phase difference to each antenna. Essentially, we are generalizing the two-element array to have more than two elements.

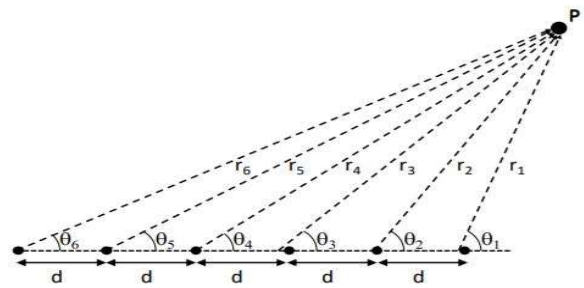

Fig 2.5 radiation pattern of antenna array

Again, if the observation point P is in the far field, then all of the angles θ1-θ6 become approximately equal as the lines become approximately parallel.

Notice, then, that we can apply our "dcosθ" trick from the two-element array to each of the six antennas. This means that each antenna will have a path length that is dcosθ longer than the element to its right. There is also the possibility once again that we will intentionally introduce a phase shift δ to each antenna signal, meaning that the phase difference at the observation point of each antenna compared to the one to its right is the same as it was for the two-element array.

If each antenna has an element factor of E1(θ,ϕ), we can write the total electric field at the observation point as:

$$E(\mathbf{r}) = E_1(\mathbf{r})\left(1 + e^{j\psi} + e^{j2\psi} + e^{j3\psi} + e^{j4\psi} + e^{j5\psi}\right)$$

If we generalize to the case of an array with N elements, this becomes:

$$E(\mathbf{r}) = E_1(\mathbf{r})\left(1 + e^{j\psi} + e^{j2\psi} + e^{j3\psi} + \cdots + e^{j(N-1)\psi}\right)$$

Applying this where q=$e^{j\Psi}$ we can find a closed form of this series:

$$E(\mathbf{r}) = E_1(\mathbf{r})\left[\frac{1-e^{jN\psi}}{1-e^{j\psi}}\right]$$

If we consider only the magnitude of the electric field, this becomes:

$$E(\mathbf{r}) = E_1(\mathbf{r})\frac{sin\left(\frac{N\psi}{2}\right)}{sin\left(\frac{\psi}{2}\right)}$$

By inspection, we can see that the array factor for a phased array is:

$$F_a(\theta) = \frac{sin\left(\frac{N\psi}{2}\right)}{sin\left(\frac{\psi}{2}\right)}$$

The sample Cartesian plot and the polar plot can be shown below:

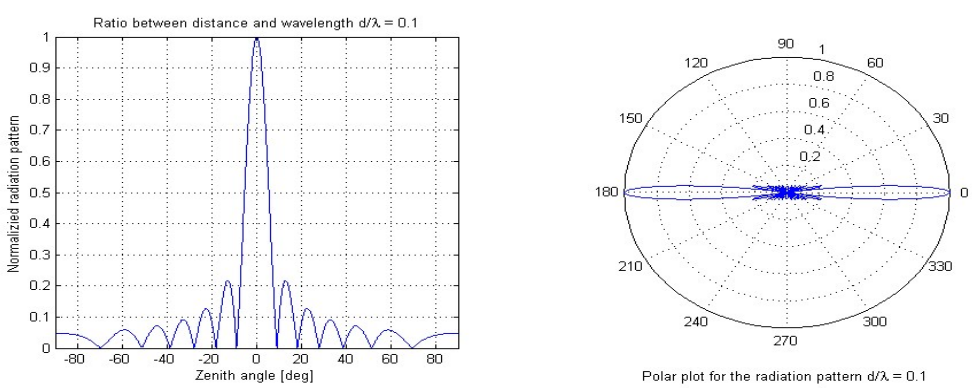

Fig 2.6 cartesian and polar plots

2.3 TYPES OF ARRAYS

The basic types of arrays are −

- Collinear array

- Broad side array
- End fire array
- Parasitic array
- Yagi-Uda array
- Log-periodic array
- Turnstile array
- Super-turnstile array

2.4 USES OF ANTENNA ARRAYS

An antenna array (often called a 'phased array') is a set of 2 or more antennas. The signals from the antennas are combined or processed in order to achieve improved performance over that of a single antenna. The antenna array can be used to:

1. increase the overall gain
2. provide diversity reception
3. cancel out interference from a particular set of directions
4. "steer" the array so that it is most sensitive in a particular direction
5. determine the direction of arrival of the incoming signals
6. to maximize the Signal to Interference Plus Noise Ratio (SNR)

2.5 APPLICATIONS OF ANTENNA ARRAY

One of the interesting applications is direction of arrival estimation. the array will be need to capture the signals and the data will process by signal processing to obtain the direction of the signal. Then, the beam can be steered towards the direction of arrival. This is the concept of smart antenna which smart. The only problem with antenna array is mutual coupling but that can be decoupled.

1. Used as a smart antenna, in turn to align with direction of radiation. This can be novel application. For multiple transmitters at different time and from different direction, you can have only one reception.
2. For a transmission in a different direction user, you can transmit in a a required direction.
3. Any unauthorized persons radiation can be catch hold. This can take care of security aspects (Enemy or another unauthorized person can be captured). This is called application of direction finder.

4. Can be used for path finder or providing guidance to destination for Land, Air or Sea
5. Can find the direction of interference free cone with reference to time or space
6. Used in satellite communications
7. Used in wireless communications
8. Used in military radar communications
9. Used in the astronomical study

2.6 ADVANTAGES AND DISADVANTAGES

The following are the advantages of using antenna arrays −

- The signal strength increases
- High directivity is obtained
- Minor lobes are reduced much
- High Signal-to-noise ratio is achieved
- High gain is obtained
- Power wastage is reduced
- Better performance is obtained

Disadvantages:

The following are the disadvantages of array antennas −

- Resistive losses are increased
- Mounting and maintenance is difficult
- Huge external space is required

CHAPTER 3

DIFFERENTIAL EVOLUTION ALGORITHM

3. DIFFERENTIAL EVOLUTION ALGORITHM

3.1 INTRODUCTION

Differential Evolution (DE) is a population-based metaheuristic search algorithm that optimizes a problem by iteratively improving a candidate solution based on an evolutionary process. Such algorithms make few or no assumptions about the underlying optimization problem and can quickly explore very large design spaces. DE is arguably one of the most versatile and stable population-based search algorithms that exhibits robustness to multi-modal problems. In the field of structural engineering, most practical optimization problems are associated with one or several behavioral constraints. Constrained optimization problems are quite challenging to solve due to their complexity and high nonlinearity.The performance of each DE variant is evaluated by using five well-known benchmark structures in 2D and 3D. The evaluation is done on the basis of final optimum result and the rate of convergence. Valuable conclusions are obtained from the statistical analysis which can help a structural engineer in practice to choose the suitable algorithm for such kind of problems. DE is a popular optimization method used for multidimensional real-valued functions which uses a population of individual solutions. The method does not require gradient information, which means that the optimization problem does not need to be differentiable. The algorithm searches the design space by maintaining a population of candidate solutions (individuals) and creating new solutions by combining existing ones according to a specific process. The candidates with the best objective values are kept in the next iteration of the algorithm in a manner that the new objective value of an individual is improved forming consequently part of the population, otherwise the new objective value is discarded. The process repeats itself until a given termination criterion is satisfied.

Differential Evolution (DE) is a method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. Such methods are commonly known as metaheuristics as they make few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as DE do not guarantee an optimal solution is ever found. DE is used for multidimensional real-valued functions but does not use the gradient of the problem being optimized, which means DE does not require the optimization problem to be differentiable, as is required by classic optimization methods such as gradient descent and quasi-newton methods. DE can therefore also be used on optimization problems that are not even continuous, are noisy, change over time, etc. Differential evolution (DE) has been extensively used in optimization studies since, its development in 1995 because of its reputation as an effective global optimizer. DE is a population-based metaheuristic technique that develops numerical vectors to solve optimization problems. DE strategies have a significant impact on DE performance and play a vital role in achieving stochastic global optimization. However, DE is highly dependent on the control parameters involved.

3.2 NEED OF DIFFERENTIAL ALGORITHM

The main advantage of DE is the fact that it has only three control parameters that the user of the algorithm needs to adjust. These include the population size NP, where $NP \geq 4$, the mutation factor (or differential weight, or scaling factor) $F \in [0, 2]$ and the crossover probability (or crossover control parameter) $CR \in [0, 1]$. In the standard DE these control parameters were kept fixed for all the optimization process. The population size has a significant influence on the ability of the algorithm to explore. In case of problems with a large number of dimensions, the population size needs also to be large to make the algorithm capable of searching in the multi-dimensional design space. A population size of 30–50 is usually sufficient in most problems of engineering interest. The mutation factor F is a positive control parameter for scaling and controlling the amplification of the difference vector. Small values of F will lead to smaller mutation step sizes and as a result it will take longer for the algorithm to converge. Large values of F facilitate exploration, but can lead to the algorithm overshooting good optima. Thus, the value has to be small enough to enhance local exploration but also large enough to maintain diversity. The crossover probability CR has an influence on the diversity of DE, as it controls the number of elements that will change. Larger values of CR will lead to introducing more variation in the new population, therefore increasing it increases exploration. But again, a compromise value has to be found to ensure both local and global search capabilities.

3.3 FLOW DIAGRAM

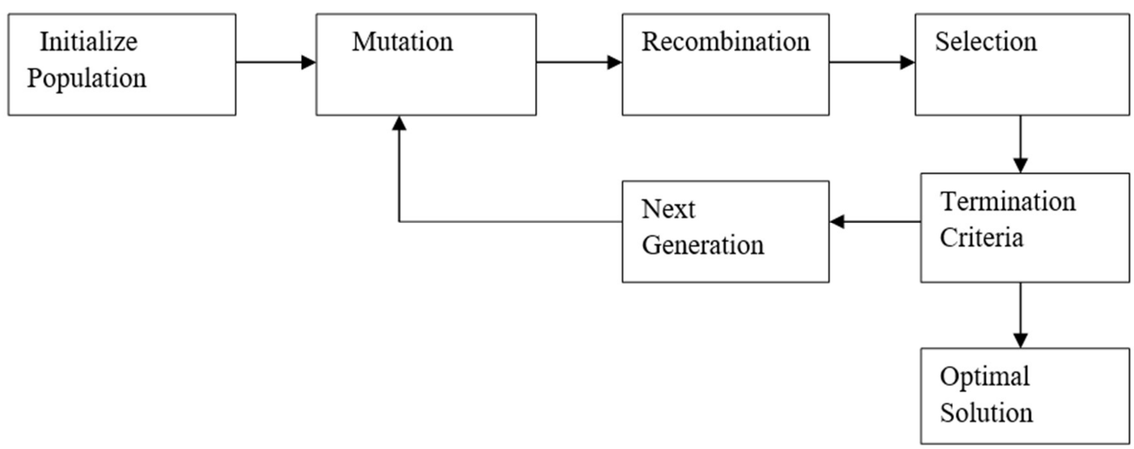

Fig 3.1 flow diagram of DE

1. Initial Population

DE is a population-based optimization technique that begins with the problem solution by selecting the objective function at a random initial population. The following equation is used to develop a random number generator for all vectors from within the predefined upper and lower bounds. The random function Random (0, 1) produces a uniform random number within the range (0, 1).

$$Xn,i = Random(0, 1) . (Xn,i^u – Xn,i^L) + Xn,i^L$$

i= 1,2,3,……..D and n = 1,2,3,……N
Where Xi^L is the lower bound of the variable Xi
Where Xi^U is the upper bound of the variable Xi

2. Mutation:

From each parameter vector, select three other vectors randomly. Add the weighted difference of two of the vectors to the third is called donor vector is generally taken between 0 and 1.
Computing the donor vectors by the formula.

$$V=X_{r1}+F(X_{r2} - X_{r3})$$

Where F = Scaling factor
r1,r2,r3 are random solutions
Where (0<r1,r2,r3<N) And r1≠r2≠r3
Donor vectors are generated without involving the target vector.

3. Recombination:

In this stage, A trail vector is generated from target vector and the donor vector.

4. selection:

The target vector is compared with the trail vector and the one with lowest function value is selected for the next generation.

3.4 ALGORITHM

A basic variant of the DE algorithm works by having a population of candidate solutions (called agents). These agents are moved around in the search-space by using simple mathematical formulae to combine the positions of existing agents from the population. If the new position of an agent is an improvement then it is accepted and forms part of the population, otherwise the new position is simply discarded. The process is repeated and by doing so it is hoped, but not guaranteed, that a satisfactory solution will eventually be discovered.

DE uses some evolutionary operators as selection recombination and mutation operators. Different from genetic algorithm, DE uses distance and direction information from current population to guide the search process. The crucial idea behind DE is a scheme for producing trial vectors according to the manipulation of target vector and difference vector. If the trail vector yields a lower fitness than a predetermined population member, the new trail vector will be accepted and be compared in the following generation. Different kinds of strategies of DE have been proposed based on the target vector selected, and the number of difference vectors is used. In this, we use two strategies, DE/rand/1/bin, described as follows.

For each target vector $x_i(t)$, trail vector $v_i(t)$, i = 1, . . ., NP, let N be the dimension of target vector and G be the G generations. The mutant vectors are generated in these DE/rand/1/bin strategies respectively

For DE/rand/1/bin

$$V_{i,G} = x_{a,G} + F(x_{a,G} - x_{c,G}) \quad (1)$$

Where a, b, c, d $\in [1, \ldots\ldots, NP]$ are randomly chosen integers and $a \neq b \neq c \neq d \neq i.$ F is the scaling factor controlling the amplification of the differential evolution.

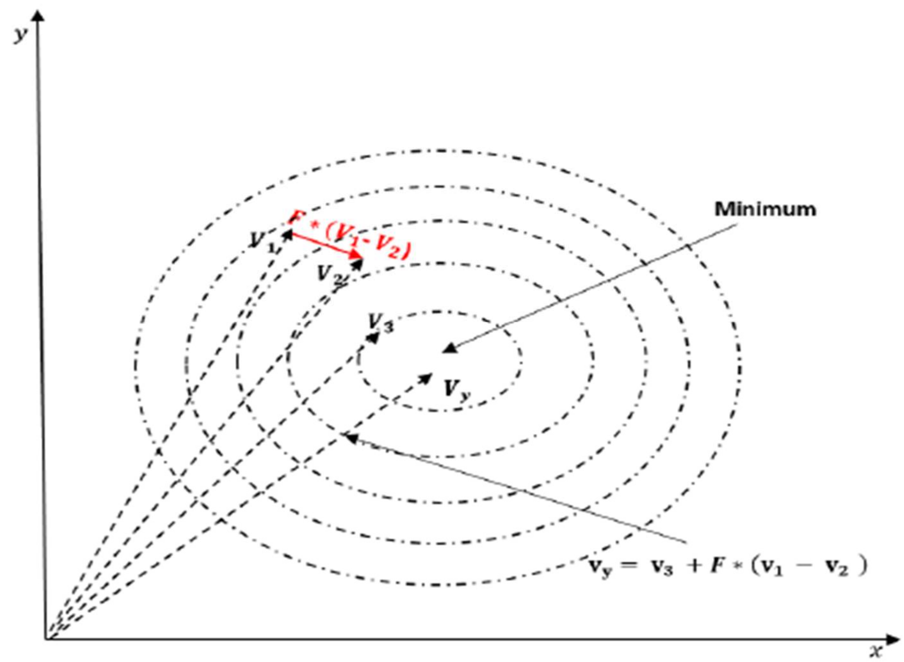

Fig 3.2 Random vectors selected in the mutation strategy (classic differential evolution)

The mutation process is the main distinctive component of DE and is considered the strategy by which DE is carried out. There are different types of mutation strategies, each one distinguished with an abbreviation based on the classic mutation strategy described by equation(1).i.e.,DE/rand/1/bin, where DE represents differential evolution and “rand” represents random, which indicates that the vectors are selected randomly. The number one indicates the number of difference pairs; in this strategy, it is one pair (v1- v2). The last term represents the type of crossover used. This term could be “exp”, for exponential, or “bin”, for binomial. Then, to complement the previous step (mutation strategy), DE also applies uniform crossover to construct trial vectors vTrail, which are out of parameter values that have been copied from two different vectors. In particular, DE selected a random vector from the population, indicated as vx , which must be different to v1, v2, and v3, and then it crosses with a mutant vector vy; the binomial crossover is generated as follows:

$$v_{Trail}[i,j] = \begin{cases} v_y[i,j] \ if \ rand(0,1) < Cr \\ v_x[i,j] \ otherwise \end{cases}$$

(2)

The crossover probability, Cr € (0,1), is a predefined rate that specifies the fraction of the parameter that is transferred from the mutant. Thus, it is used to control which sources participate in a given parameter.

The next operation is selection, in which the trial vector VTrail competes with the target vector Vx. If this trail vector VTrail is equal or less than Vx it changes the target vector Vx in the next generation otherwise Vx is not changed in the population,

$$v_x = \begin{cases} v_{Trail} \ if \ f(v_{Trail}) \leq f(v_x) \\ v_x \ otherwise \end{cases}$$

(3)

where f (x) is the objective function. If the new trail vector f (VTrail) is less than or equal to the target vector f (Vx), it replaces the target vector. Otherwise, the population maintains the target vector value. Therefore, the different DE phases prevent the population from ever deteriorating; the population either remains the same or improves. Furthermore, continued refining of the population is achieved by the trial vector, although the fitness of the trial vector is the same as that of the current vector. This factor is crucial in DE because it provides the algorithm the ability to move through the landscape using a variety of generations.

The standard differential evolution algorithm can be described as the following:

procedure algorithm description of DE algorithm

Step 1: Set the generation counter G=0; and randomly initialize a population of NP individuals X. i Initialize the parameter F, CR.

Step 2: Evaluate the fitness for each individual in P.

Step 3: while stopping criteria is not satisfied do

for i= 1 to NP

select randomly a≠b≠c≠d≠i

for j= 1 to D

j rand = rand (1,0) * D

if rand (0 ,1)≤CR or j= = jrand then

$U_{i,j} = X_{a,j} + F(X_{b,j} + X_{c,j})$

else

$U_{i,j} = X_{i,j}$

end if

end for

end for

for i= 1 to N P do

Evaluate the offspring U_i

if U_i is better than P_i then

$P_i = U_i$

end if

end for

Memorize the best solution achieved so far

Step 4: end while

End

3.5 HISTORY

DE was introduced by Storn and Price in the 1990s. Books have been published on theoretical and practical aspects of using DE in parallel computing, multiobjective optimization, constrained optimization, and the books also contain surveys of application areas. Surveys on the multi-faceted research aspects of DE can be found in journal articles.

The optimization of structures has been a topic of great interest for both scientists and engineering professionals, especially in recent years. Metaheuristic search algorithms are widely accepted as efficient approaches for handling difficult optimization problems. Such algorithms are designed for solving a wide range of optimization problems in an approximate way, without having to adapt explicitly to every single problem. Moreover, they can be generally applied to problems for which there exists no satisfactory problem-specific algorithm.

Shukla et al. (2017) presented a modified mutation vector generation scheme for the basic DE for solving the stagnation problem. A new variant of DE was proposed and its performance was tested on 24 benchmark functions. Abbas et al. (2015) proposed a tournament-based parent selection variant of the DE algorithm in an effort to enhance the searching capability and improve convergence speed of DE. The paper also describes a statistical comparison of existing DE mutation variants, categorizing these varients based on there overall performance. Charalampakis and Tsiatas (2019) compare variants of Genetic Algorithms, Particle Swarm Optimization (Plevris and Papadrakakis, 2011), Artificial Bee Colony, Differential Evolution, and Simulated Annealing in truss sizing structural optimization problems. The authors claim that for the examined problems, DE is the most reliable algorithm, showing robustness, excellent performance and scalability. Mezura-Montes et al. (2006) present an empirical comparison of several DE variants in solving global optimization problems where 13 benchmark problems from the literature were examined and eight different variants were implemented.

3.6 DE APPLICATION

Due to the rapid rise of DE as a modest and strong optimizer, developers have applied the technique in a wide range of domains and fields of technology Yalcin proposed a new method for the 3D tracking of license plates using a DE algorithm, which could be fine-tuned according to the license plate boundaries A color image quantization application using DE was proposed by Qinghua and Hu. The main objective of image processing techniques during the color image quantization phase, is to decrease the number of colors in an image with a low amount of deformation. DE can be used to adjust colormaps and find the optimal candidate colormap. With respect to the bidding market, Alvaro et al. applied DE in developing a competitive electricity market application that finds the optimal bids based on daily bidding activity. Sickel et al. used DE in developing a power plant control application for a reference governor to produce an optimal group of points for controlling a power plant that was produced by. Wang et al. proposed a flexible QoS multicast routing algorithm for the next-generation Internet that improves the quality of service (QoS) of multicasts to manage the increasing demand of network resources. With respect to the electric power systems industry, Ela et al. applied DE to determine the optimal power flow. Goswami et al. proposed a DE application for model-based well log-data inversion to discover features of earth formations based on the dimensions of physical phenomena.

CHAPTER 4

PYTHON

4. PYTHON

In this chapter, an introduction of python programming language then followed by some features of python are discussed then few advantages of python are listed, next simulation work flow of project is discussed then the methodology is explained and next applications of python are listed.

4.1 INTRODUCTION

Python is a widely used general-purpose, high level, interpreted programming language. It was created by Guido van Rossum in 1991 and further developed by the Python Software Foundation. It was designed with an emphasis on code readability, and its syntax allows programmers to express their concepts in fewer lines of code. It supports Object Oriented programming approach to develop applications. It is simple and easy to learn and provides lots of high-level data structures. Python is a programming language that lets you work quickly and integrate systems more efficiently. Python's syntax and dynamic typing with its interpreted nature make it an ideal language for scripting and rapid application development.

Python supports multiple programming pattern, including object-oriented, imperative, and functional or procedural programming styles. Python is not intended to work in a particular area, such as web programming. That is why it is known as multipurpose programming language because it can be used with web, enterprise, 3D CAD, etc. We don't need to use data types to declare variable because it is dynamically typed so we can write a=10 to assign an integer value in an integer variable. Python makes the development and debugging fast because there is no compilation step included in Python development, and edit-test-debug cycle is very fast.

There are two major Python versions: Python **2** and Python **3**. Both are quite different.

4.2 PYTHON 2 VS. PYTHON 3

In most of the programming languages, whenever a new version releases, it supports the features and syntax of the existing version of the language, therefore, it is easier for the projects to switch in the newer version. However, in the case of Python, the two versions Python 2 and Python 3 are very much different from each other.

A list of differences between Python 2 and Python 3 are given below:

1. Python 2 uses print as a statement and used as print "something" to print some string on the console. On the other hand, Python 3 uses print as a function and used as print("something") to print something on the console.
2. Python 2 uses the function raw input () to accept the user's input. It returns the string representing the value, which is typed by the user. To convert it into the integer, we need to use the int() function in Python. On the other hand, Python 3 uses input () function which automatically interpreted the type of input entered by the user. However, we can cast this value to any type by using primitive functions (int (), str (), etc.).
3. In Python 2, the implicit string type is ASCII, whereas, in Python 3, the implicit string type is Unicode.

4.3 HISTORY OF PYTHON

Python laid its foundation in the late 1980s. The implementation of Python was started in December 1989 by Guido Van Rossum at CWI in Netherland. In February 1991, Guido Van Rossum published the code (labeled version 0.9.0) to alt.sources. In 1994, Python 1.0 was released with new features like lambda, map, filter, and reduce. Python 2.0 added new features such as list comprehensions, garbage collection systems. On December 3, 2008, Python 3.0 (also called "Py3K") was released. It was designed to rectify the fundamental flaw of the language. ABC programming language is said to be the predecessor of Python language, which was capable of Exception Handling and interfacing with the Amoeba Operating System.

The following programming languages influence Python:

ABC language.

Modula-3

4.3.1 Why the name python

There is a fact behind choosing the name Python. Guido van Rossum was reading the script of a popular BBC comedy series "Monty Python's Flying Circus". It was late on-air 1970s. Van Rossum wanted to select a name which unique, sort, and little-bit mysterious. So, he decided to select naming Python after the "Monty Python's Flying Circus" for their newly created programming language.

Python is also versatile and widely used in every technical field, such as Machine Learning, Artificial Intelligence, Web Development, Mobile Application, Desktop Application, Scientific Calculation, etc.

4.4 WHY PYTHON

The goal should be clear before learning the Python. Python is an easy, a vast language as well. It includes numbers of libraries, modules, in-built functions and data structures. If the goal is unclear then it will be a boring and monotonous journey of learning Python. The motivation behind learning python can be anything such as knowing something new, develop projects using Python, switch to Python, etc. Below are the general areas where Python is widely used. Python can be used in any of the fields.

- Data Analysis and Processing
- Artificial Intelligence
- Games
- Hardware/Sensor/Robots
- Desktop Applications

4.5 BASIC SYNTAX OF PYTHON

It is the most essential and basic step to learn the syntax of the Python programming language. Python is easy to learn and has a simple syntax. It doesn't use semicolon and brackets. Its syntax is like the English language. But Python uses the indentation to define a block of code. Indentation is nothing but adding whitespace before the statement when it is needed.

For example -

```
def func():
    statement 1
    statement 2
    …………………
    …………………
    statement N
```

In the above example, the statements that are same level to right belong to the function. Generally, we can use four whitespaces to define indentation.

4.6 PYTHON FEATURES

Python provides many useful features which make it popular and valuable from the other programming languages. It supports object-oriented programming, procedural programming approaches and provides dynamic memory allocation.

We have listed below a few essential features.

- Easy to use and Learn
- Expressive Language
- Interpreted Language
- Object-Oriented Language
- Open Source Language
- Extensible
- Learn Standard Library
- GUI Programming Support
- Integrated
- Embeddable
- Dynamic Memory Allocation
- Wide Range of Libraries and Frameworks

4.7 PYTHON INSTALLATION

In order to become Python developer, the first step is to learn how to install or update Python on a local machine or computer. How to install python programming language on the personal computer is given below:

Installation in windows

Visit the link https://www.python.org/downloads/ to download the latest release of Python. In this process, we will install Python 3.8.6 on our Windows operating system. When we click on the above link, it will bring us the following page.

Step - 1: Select the Python's version to download.

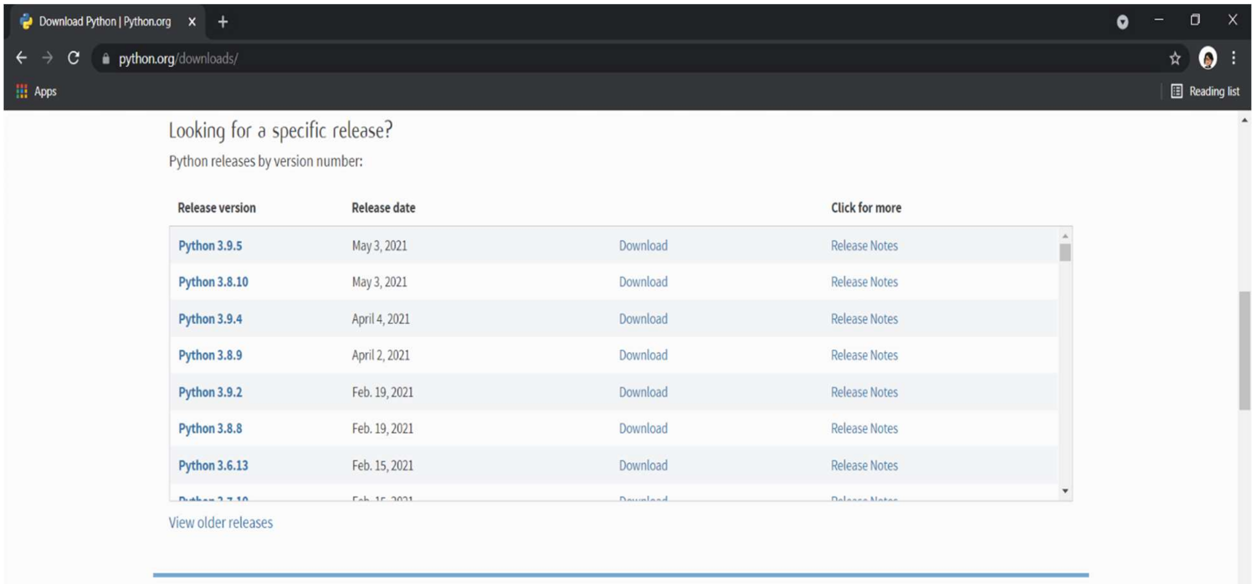

Fig 4.7.1 downloading page

Click on the download button on the latest release

Step - 2: Click on the Install Now

Double-click the executable file, which is downloaded; the following window will open. Select Customize installation and proceed. Click on the Add Path check box, it will set the Python path automatically.

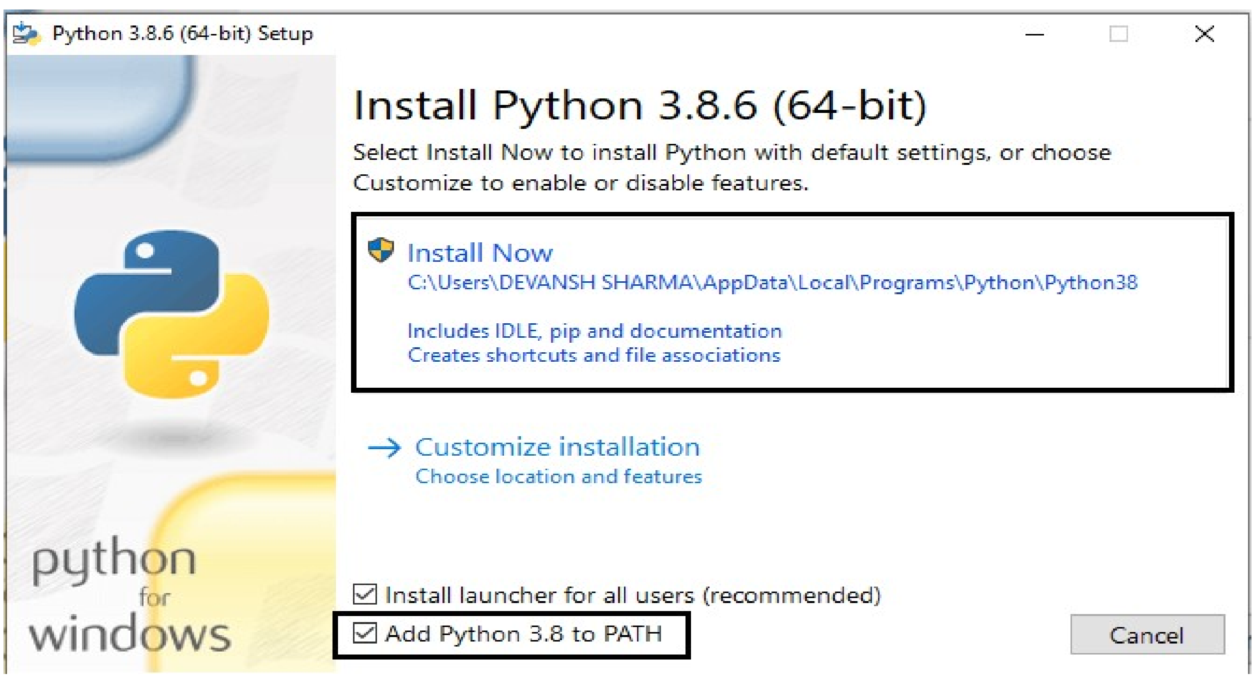

Fig 4.7.2 installation page

We can also click on the customize installation to choose desired location and features. Other important thing is installing launcher for the all user must be checked.

Step – 3: Installation in Process

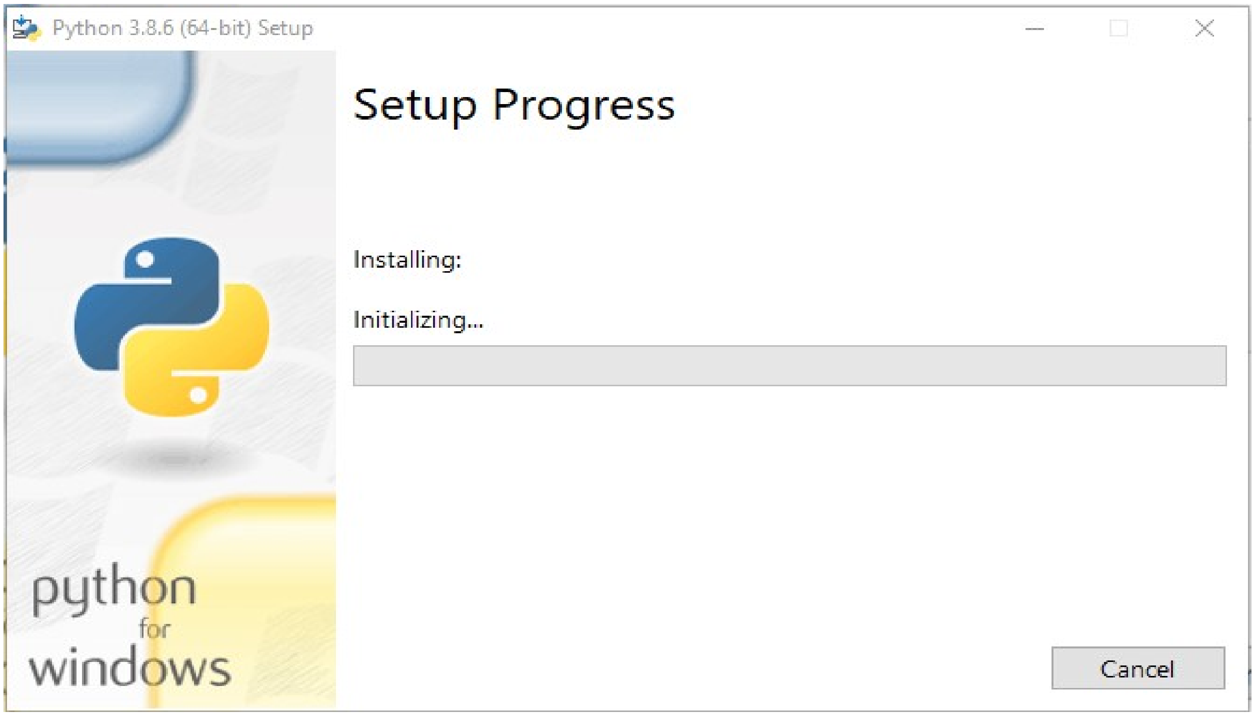

Fig 4.7.3 setup progress

Step – 4: Now, try to run python on the command prompt. Type the command python -version in case of python3.

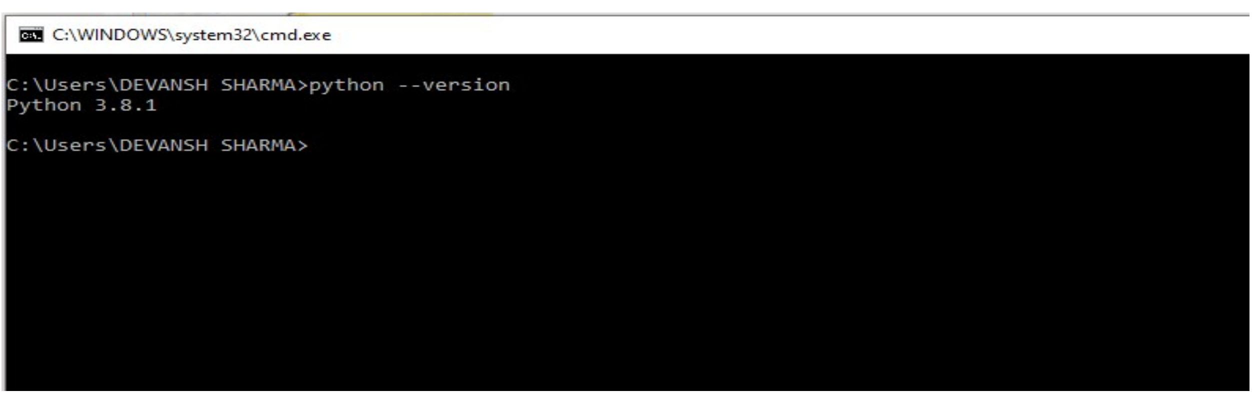

Fig 4.7.4 command prompt

We are ready to work with the Python.

Step – 5: Now open the python IDLE shell and coding part can be done there it looks like below;

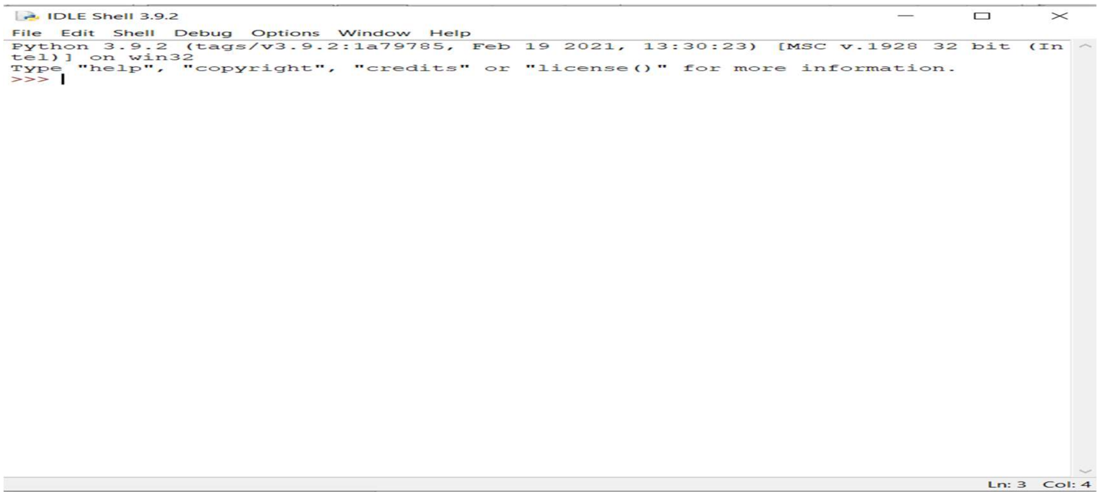

Fig 4.7.5 IDLE shell

4.8 PYTHON APPLICATIONS

Python is known for its general-purpose nature that makes it applicable in almost every domain of software development. Python makes its presence in every emerging field. It is the fastest-growing programming language and can develop any application.

Here, are some application areas where Python can be applied.

- Web applications
- Desktop GUI applications
- Console-based applications
- Software development
- Scientific and numeric applications
- Business applications
- Audio or video-based applications
- 3D cad applications
- Enterprise applications
- Image processing

4.9 METHODOLOGY

Latest versions are always helpful to improve the output. Accurate and better results will be obtained. So, we have simulated our software part by using the latest version of the python software that is **python 3.9**. such that we could use precise inbuild libraries like pyplot, matplotlib, and etc.… for plotting the graphs for changing parameters it can be easy, beam steering can be done accurate with updated syntax of the python 3.9 and this is helpful in improving time complexity also, run time might also depends on the libraries used. here the radiation patterns can be optimized by using trial and error method that is after trying different cases we can get the optimized results.

4.10 SIMLATION TOOL USED

Python programming software version 3.9 is used for design and optimization of antenna array. It is a standard software tool used in many applications. It was introduced in the late 1980s. The implementation of Python was started in December 1989 by Guido Van Rossum at CWI in Netherland.

This software is combination of many libraries which are used develop the required outputs. The code of the other programming language can use in the Python source code. We can use Python source code in another programming language as well. It can embed other language into our code, it can be easily integrated with languages like C, C++, and JAVA, etc. Python runs code line by line like C, C++ Java. It makes easy to debug the code. Which is helpful to improve the radiation patterns outputs with more directivity.

4.11 DESIGNING STEPS OF ANTENNA

1. Import the required libraries.

2. Assign the number of elements that is number of antennas in the array.

3. Give the spacing between the elements in the antenna array.

4. Give the phase angle between the elements.

5. Design equations and array factor equations are formulated and assigned to the variables.

6. Commands for plotting graphs or patterns or outputs are given.

7. Run the software program.

8. Debug the errors if any.

9. Observe the dual-beam radiation pattern of the antenna array obtained.

4.12 STEPS FOR OPTIMIZING AND ANALYZING THE RESULTS OF ANTENNA ARRAY

1. To optimize the results, parameters need to be changed accordingly.

2. check by changing the number of elements in the array.

3. similarly check by changing the spacing and phase angle between the elements.

4. try all the possible cases until we get the optimized radiation patterns with good directivity.

CHAPTER 5

ANTENNA ARRAY DESIGN

5. ANTENNA ARRAY DESIGN

5.1 INTRODUCTION

With recent advancement in simulation technology, many works are presented the synthesis of various size, uniform/nonuniform, linear and planar to achieve higher directivity and low side-lobe level. For design and synthesis of non-uniform arrays, theoretical calculations and approximation are worked out. And the simulation of resulting structure is invoked with 3D EM simulators, such as HFSS, CST, FEKO, IE3D and so on. However, there is no specific tool to develop the synthesis of antenna array design with various polynomial cases, as per authors knowledge. For the benefit of antenna design society, we are presenting antenna array synthesis tool. called ARRAY TOOL. It is free tool developed in Python, and presently available in. ARRAY TOOL has many modules to develop various arrays including phased and conformal array.

5.2 PARAMETERS FOR DESIGNING

The design parameters of antenna array are already mentioned above.As mentioned the following parameters are:

1. Radiation pattern
2. Directivity
3. Side lobe level
4. Bandwidth

5.3 CHALLEGES FACED IN DESIGNING

1. Array architecture study and system level comparison.
2. Silicon based integration concepts for antenna and IC.
3. Design flow to enable co-design and integration of antenna and electronics.
4. Waveform optimization and system-level optimization.
5. Design and realization of a development platform.
6. Develop novel low-cost and energy-efficient array architectures for 5G.

5.4 OPTIMIZATION OF ANTENNA ARRAY

Optimization is defined as the action of making the best or most effective use of a situation or resource. Antenna optimization aims at creating advanced and complex electromagnetic devices that must be competitive in terms of performance, serviceability, and cost effectiveness. This process involves selection of appropriate objective functions (usually conflicting), design variables, parameters, and constraints.

It focuses on optimal synthesis of a linear array to achieve narrower half-power beam width, reduced side-lobe levels, and nulls control as per the need of the design. To accomplish these goals, we considered the optimization of excitation amplitude, phase and inter-element spacing of the array. Since, the optimization problem involved is not convex in nature, so a global optimization algorithm is employed. To achieve this an evolutionary algorithm called differential evolution algorithm have been proposed. It uses more no of iterations to get the optimized solution.

5.5 EFFECTS IN OPTIMIZING AN ANTENNA ARRAY

1. DUE TO NUMBER OF ELEMENTS

Number of elements in an antenna array plays an important role in beam forming, beam steering and interference suppression. In order to observe its effects on radiation pattern of an antenna, we have considered an N element array where array factor, AF is expressed as

$$AF = \sum_{n=1}^{N} e^{j(n-1)(kd\cos\theta+\phi)}$$

Above expression plays a key role in determining the characteristics of an antenna array. This array factor (AF) is multiplied to individual radiator characteristics to get radiation pattern. It is obvious from Eqn. 1 that AF is dependent upon:

(a) Number of elements defining an array i.e. N

(b) Spacing between the elements of the array i.e. d,

(c) Angle of arrival i.e. θ

To study the effects of these variables for an optimum design, a code has been developed using the above Eqn. and AF is observed as a function of various control parameters. As expected, an increase in N decreases the half power beam width (HPBW), while its effect on SLL is negligible. The number of elements needed in an array will be dependent on a particular application. Where wider beam width is required, one can design an array by using lesser number of elements but for narrow beam width, as is required in target localization system, the number of elements should be relatively higher.

2.DUE TO EXCITATION AMPLITUDE

Excitation amplitude for each individual element, commonly known as weight factor, also changes characteristics of an array antenna. Generally, in beam steering experiments, we fix the excitation amplitude say '1', and make use of excitation phase to change the AF. However, it does not mean that excitation amplitude shall always be '1' as a fundamental requirement. By changing its value for various elements of an array, one can change the overall array pattern. An appropriate weight factor for an array radiator allows the designer to have more control on array factor and main lobe beam width with reduced SLL. However, this makes the design more complicated and hardware intensive. But the benefits it gives are significant and thus cannot be overlooked for ordinary reasons.

It is worth mentioning that the amplitude of the signal given at the input of an element defining the array is proportional to the power required for a given communication system. A high power requires components of matching specifications and it also put conditions on power sources feeding such antennas. An antenna with weighted power amplitude to its radiators economizes the overall power of the system and can be truly called as a power efficient design. A comparative analysis of weighted and un-weighted antenna design is presented in given Figure.

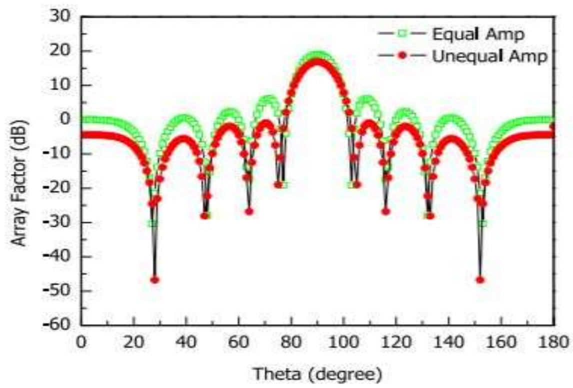

Fig 5.1 weight and un-weight graph

This Figure plots the results for equal and un-equal amplitude excitation where the chosen values of the parameters are N = 9, d = λ/2 and φ = 0◦ . For unequal excitation, the excitation amplitude is 1 for the central element and is reduced by 0.1 per element as we move from center to the edges.

5.6 APPLICATIONS OF OPTIMIZATION

1. Design of civil engineering structures such as frames, foundations, bridges, towers for minimum cost.
2. Design of minimum weight structures for earthquake, wind and other types of random loading.
3. Shortest route taken by a salesperson visiting various cities during one tour.
4. Optimum design in electrical networks.
5. Optimal plastic design of frame structures.
6. Finding the optimal trajectories of space vehicles.

5.7ADVANTAGES OF OPTIMIZATION

1. This method will find the true optimum of a response with fewer trails than the non-systematic approaches or the one-variable-at-a-time method.
2. Yield the best solution within the domain of the study.
3. Require fewer experiments to achieve an optimum solution or the formulation.
4. Can trace and rectify problem in a remarkable easier manner.

5.8 ANTENNA ARRAY DESIGN

Simulation steps are as below:

Step -1: Install python software of version 3.9
Step -2: Open the python IDLE shell 3.9
Step -3: Create a new file by clicking ctrl+N
Step -4: import required libraries they are matplotlib from pyplot, math, pylab.
Step -5: initialize the parameters they are

1. Number of elements i.e. no. of antennas in the array(N)
2. Spacing between the elements(S)
3. Phase angle between the elements(Phi)

Step -6: the design equations and array factor equations are formulated and assigned to the variables.
Step -7: do the normalization for the directivity
Step -8: commands for plotting the graphs/patterns are given according to the syntax.
Step -9: Save the program in the specific location with a name.
Step -10: then run the software program by clicking the fn+f5.
Step -11: debug the errors if any.
Step-12: observe the dual-beam radiation pattern, whether it is with good directivity or not.
Step -13: if normalized directivity is not optimized then by changing the parameters i.e. (N,S,Phi) optimize the patterns this is like trial and error method.
Step -14: once the best directivity is obtained by changing the values continuously that is the optimized output.

5.9DESIGN EQATIONS AND PARAMETERS

Design parameters:

1. FOR SECTOR BEAM

N1 = number of elements(antennas) in array.
S1 = spacing between the elements.
Phi1 = phase angle between the elements.

2. FOR PENCIL BEAM

N2 = number of elements(antennas) in array.
S2 = spacing between the elements.
Phi2 = phase angle between the elements.

Design/array factor equations:

For the dual-beam optimization, the objective is the function for designing an array. The construction of an antenna array will be achieved by array factor equation which must qualify the entire array radiation pattern. The equation is described as follows.

$$AF=\sum_{k=0}^{180} AF[k] + \sqrt{AFR[k]^2 + AFI[k]^2} \quad (5.1)$$

Where AF is array factor equation, AFR is real part of the array factor and AFI is imaginary part of the array factor, here summing-up the values with the previous values is used as the logic, when k is running from 0 to 180 according to dimensions, In general, AFR and AFI are given as;

$$AFR= \sum_{i=0}^{180} \sum_{j=0}^{N-1} AFR[i] + \cos(jSi[i]) \quad (5.2)$$

Where these are formulated equations for dual-patterns, here each and every value are summing-up with previous values, since the output patterns must be sum of all the properties of each element in the array, this is for real part of array factor. The imaginary part is given as;

$$AFI= \sum_{i=0}^{180} \sum_{j=0}^{N-1} AFI[i] + \sin(jSi[i]) \quad (5.4)$$

Here AFR is the array factor imaginary part, where i is running from (0 to 180) and j is running from (0 to N-1), where N is number of elements in the array i.e., no. of antennas in the array, where Si is defined as spacing function, for varying the dual-pattern for changing the spacing between the elements. Si is given as follows;

$$Si= \alpha + \sum_{k=0}^{180} 2\pi S cos[phi[k]\pi/180] \quad (5.4)$$

Here k is running from (0 to 180), phi is for varying the phase in dual-pattern, where S is the parameter for changing the spacing among the elements, and alpha is a parameter for dual-beam generation which is defined as given below;

$$\alpha 1 = -2\pi S1\cos(phi1) \quad (5.5)$$

$$\alpha 2 = -1\pi S2\cos(phi2) \quad (5.6)$$

Where $\alpha 1$ and $\alpha 2$ are parameters for sector and pencil patterns respectively S is the spacing among elements, phi is for varying phase.

Here by varying N, S, Phi parameters optimized dual-beam pattern of the antenna array directivity can be varied.

CHAPTER 6

RESULTS

The designed antenna array results as follows:

1. All (N1, S1, Phi1) values represents sector-beam;
2. All (N2, S2, Phi2) values represents pencil-beam.

- Amplitude and phase excitations varying with no. of elements

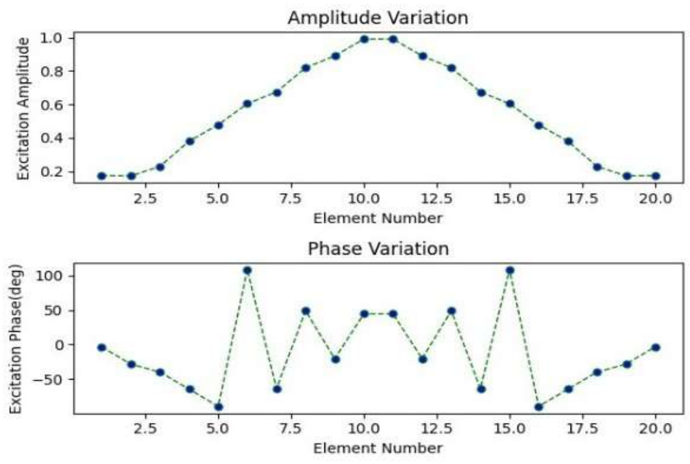

Fig 6.1 amplitude and phase excitations

This shows, in amplitude variation as increase in the number of elements the amplitude excitations are increasing up to certain limit and then decreasing hence with sufficient no. of elements gives maximum amplitude excitations. And phase excitations vary with change in number of elements about the phase in degrees.

Case -1: N1=8, S1=0.30, Phi1=0 and N2=12, S2=0.25, Phi2=0

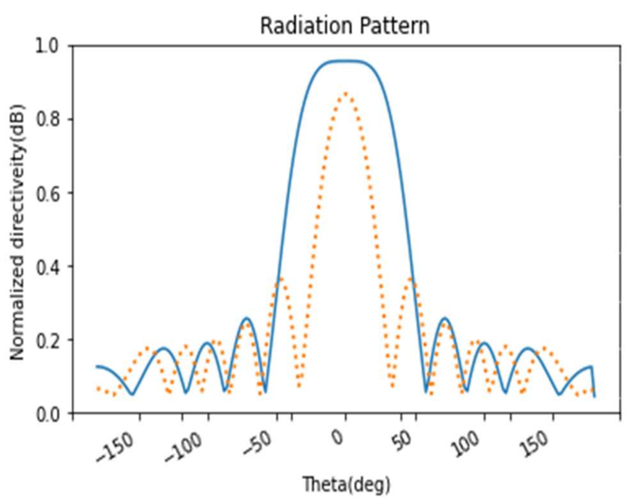

Fig 6.2 optimized output

Case 2: N1=25, S1=0.30, Phi1=0 and N2=5, S2=0.25, Phi2=0

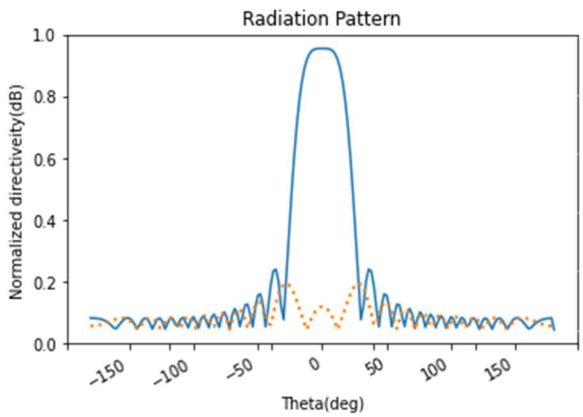

Fig 6.3 change in N1,N2

Case 3: N1=5, S1=0.30, Phi1=0 and N2=10, S2=0.25, Phi2=0

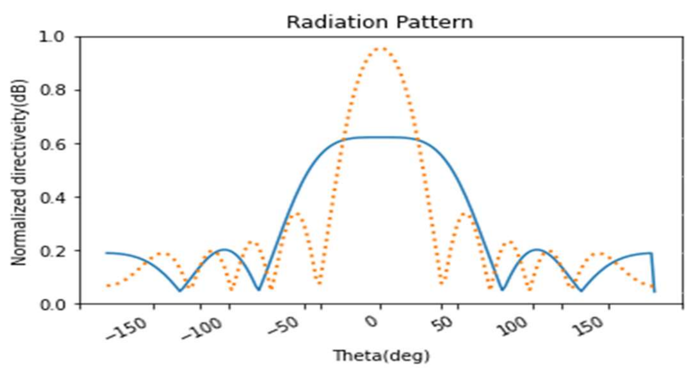

Fig 6.4 change in elements

Case 4: N1=8, S1=0, Phi1=0 and N2=5, S2=0.1, Phi2=0

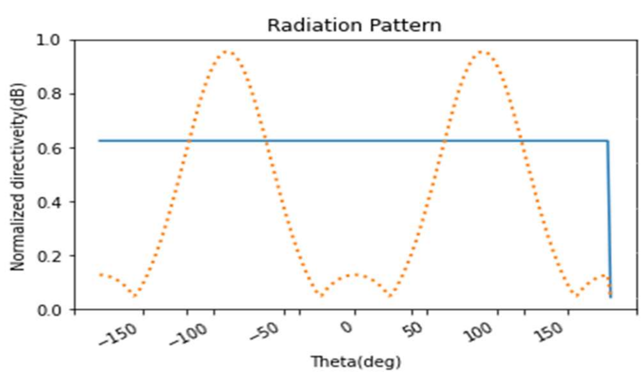

Fig 6.5 change in spacing(S1,S2)

Case 5: N1=8, S1=0.50, Phi1=0 and N2=12, S2=0.3, Phi2=0

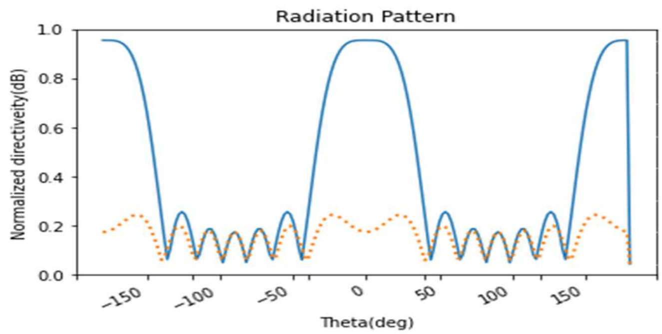

Fig 6.6 change in spacing1(S1,S2)

Case 6: N1=8, S1=0.30, Phi1=30 and N2=12, S2=0.25, Phi2=45

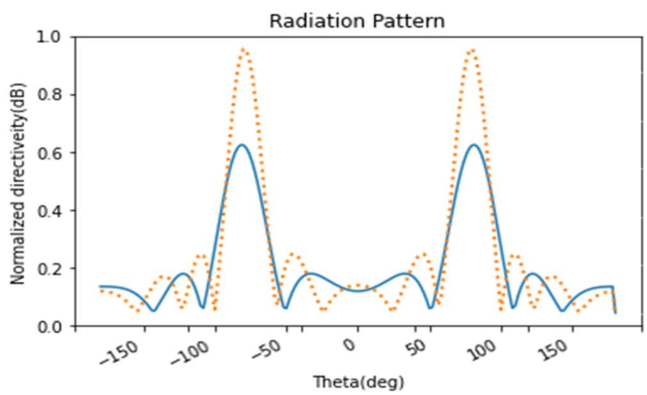

Fig 6.7 change in phase(Phi1,Phi2)

Case 7: N1=8, S1=0.30, Phi1=40 and N2=5, S2=0.25, Phi2=18

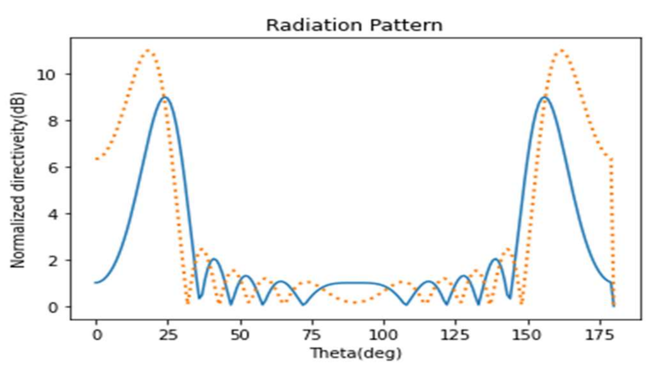

Fig 6.8 change in phase1(Phi1, Phi2)

CHAPTER 7

CONCLUSION

CONCLUSION

This project reports the design and optimization of antenna array. The simulated results shows that the optimized output shows that the antenna array got the normalized directivity at 0.98(approx.), at phase angle around 0 degrees. It can be used at the application where we the antenna beam needs to be changed according to the need of the user like beam steering. When the number of antennas are too many in array the amplitude excitations are abruptly falling down indicating no. of elements should be in limit, and from case 2 with less elements N2=5 is not giving good directivity. When there is no spacing in the elements there will no directivity can see when S1= 0 in case 4. And all the cases tells that the phase angle between the elements must be 0 degrees to obtain optimized outputs. Hence from all the cases we can tell that appropriate values of all three parameter generates optimized outputs. Where (N1=8, S1=0.30, Phi1=0) ;(N2=12, S2=0.25, Phi2=0) are giving the best radiations patterns with good directivity.

CHAPTER 8

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