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A KOMUNIKAČNÍCH TECHNOLOGIÍ

DEPARTMENT OF RADIO ELECTRONICS

ÚSTAV RADIOELEKTRONIKY

WEB APPLICATION FOR ANTENNA ANALYSIS

WEBOVÁ APLIKACE PRO ANALÝZU ANTÉN

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

AUTHOR AUTOR PRÁCE	**Štěpán Večeřa**
SUPERVISOR VEDOUCÍ PRÁCE	**prof. Dr. Ing. Zbyněk Raida**

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BRNO UNIVERSITY OF TECHNOLOGY FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

Bachelor's Thesis

Bachelor's study program **Electronics and Communication Technologies**

Department of Radio Electronics

Student:	Štěpán Večeřa	***ID:***	230345
Year of study:	3	***Academic year:***	2022/23

TITLE OF THESIS:

Web application for antenna analysis

INSTRUCTION:

Scripts for a simplified analysis of antenna arrays should be developed. Arrays can consist of dipole or patch elements. Scripts should be programmed in MATLAB or Python. Scripts should compute radiation patterns, radiation resistance, directivity and gain of the array. In Python, web user's interface should be created. Functionality of the whole program should be verified on properly selected examples.

The program should be completed by synthesis routines which can compute amplitude and phase distributions related to requested antenna parameters (side-lobe level, e.g.). Functionality of the synthesis routines should be verified by simulations of selected antennas in a proper electromagnetic simulator. The program should be completed by user's guide containing proper illustration examples.

RECOMMENDED LITERATURE:

[1] Fung Tseng; Design of array and line-source antennas for Taylor patterns with a null. IEEE Transactions on Antennas and Propagation, 1979, vol. 27, no. 4, p. 474-479. DOI: 10.1109/TAP.1979.1142122

[2] C. A. Balanis; Antenna Theory: Analysis and Design, 4th Edition. Hoboken: John Wiley & Sons, 2016. ISBN: 978-1-1186-4206-1

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Supervisor: prof. Dr. Ing. Zbyněk Raida

doc. Ing. Lucie Hudcová, Ph.D.
Chair of study program board

ABSTRACT

A web-based application was intended to be developed for a simplified analysis of antenna arrays consisting of wire dipoles or patch elements. Originally, the computational kernel was expected to be developed in MATLAB and the web interface in Python. A feasibility study showed that a full implementation in Python is beneficial. Developed Python functions for antenna analysis and antenna synthesis are briefly described and their functionality is verified in MATLAB.

KEYWORDS

Wire dipole, patch element, antenna array, radiation pattern, radiation resistance, gain, MATLAB, Python, web application.

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Author's Declaration

Author:	Štěpán Večeřa
Author's ID:	230345
Paper type:	Bachelor's Thesis
Academic year:	2022/23
Topic:	Web application for antenna analysis

I declare that I have written this paper independently, under the guidance of the advisor and using exclusively the technical references and other sources of information cited in the paper and listed in the comprehensive bibliography at the end of the paper.

As the author, I furthermore declare that, with respect to the creation of this paper, I have not infringed any copyright or violated anyone's personal and/or ownership rights. In this context, I am fully aware of the consequences of breaking Regulation § 11 of the Copyright Act No. 121/2000 Coll. of the Czech Republic, as amended, and of any breach of rights related to intellectual property or introduced within amendments to relevant Acts such as the Intellectual Property Act or the Criminal Code, Act No. 40/2009 Coll. of the Czech Republic, Section 2, Head VI, Part 4.

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I would like to thank the advisor of my thesis, prof. Dr. Ing. Zbyněk Raida for his valuable comments and friendly approach. Thanks.

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Introduction

In today's wireless applications, antenna arrays play a significant role allowing the user to shape radiation patterns, adapt antenna properties to current needs implement reconfigurability, control nulls and lobes, increase gain, etc. Fundamental routines are available in MATLAB in a form of inconsistent scripts. Initial planes were focused on the integration of those routines, on the elimination of inconsistencies and on the development of a web interfaces allowing to run the scripts from internet pages.

Due to the license policy of MathWorks, an independent use of MATLAB scripts is rather complicated. Since Python offers strong math libraries, the use of MATLAB is questionable. Pros and cons are discussed in Section 2.1. As a result, a full Python implementation was selected. Hence, inconsistent MATLAB functions have been rewritten to Python implementing a simplified analysis of antenna arrays consisting of wire dipoles or patch elements. The simplified approach neglects mutual couplings among antenna elements. Nevertheless, such an approach is sufficient for an elementary characterization of antenna arrays. Implemented functions are described in Section 2.2. In order to verify a proper function of the developed Python routines, a three-element dipole array and a nine-dipole array were modeled and obtained results were compared with MATLAB. Details are given in Section 2.3.

Synthesis function has been added to the program. Program will now automatically calculate current fed to the antenna array elements based on users requests. Users can choose between changing the width of the main lobe and changing the direction of the main lobe in desired plane.

1 Theory

1.1 Antenna analysis

Antenna analysis involves the study of how antennas transmit and receive electromagnetic waves. This includes determining the radiation pattern, gain, impedance of an antenna and more. Simplified antenna analysis is a method of approximating these characteristics using simple equations and assumptions.

1.1.1 Radiation Pattern

The radiation pattern or antenna pattern is the graphical representation of the radiation properties of the antenna as a function of space [2].It shows how the antenna radiates energy or receives energy in different directions. Antennas radiate energy in all directions to some extent. This means, that radiation pattern is three-dimensional.

The radiation pattern is shaped differently depending on distance of observation from the antenna. These regions are commonly called the reactive near-field region, the radiating near-field (Fresnel) region and the far-field (Fraunhofer) region. In most cases, the radiation pattern is determined in the far field region. Far field region for antenna of maximum length D is defined by [1]:

$$R > \frac{2D^2}{\lambda} \tag{1.1}$$

$$R >> \lambda$$

Radiation patterns are usually plotted in principal planes. Principal planes are azimuth plane and elevation plane. The azimuth commonly represents "the horizon"

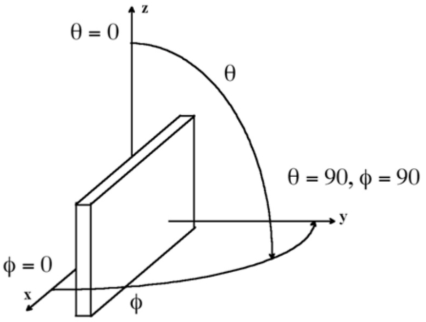


Fig. 1.1: Coordination system.

whereas elevation is used for "the vertical". This representation works if antenna's radiation pattern is well-behaved, meaning that not much information is lost. [2]

We can display radiation pattern in either polar coordinates or cartesian coordinates. Polar coordinates are used more often, because the viewer can more easily visualize how antenna radiates. Plotting the radiation pattern in cartesian (rectangular) coordinates is useful if there are several sidelobes in the pattern and level of these lobes are important. [2]

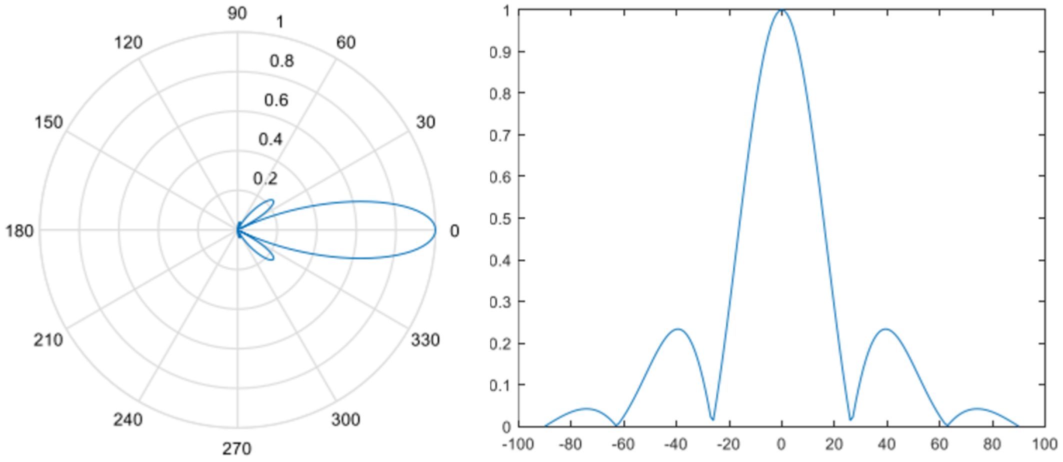


Fig. 1.2: Radiation pattern in polar (left) and cartesian (right) coordinates.

Often are radiation patterns normalized with respect to their maximum value. Radiation pattern is commonly plotted in decibels or on logarithmic scale. This is used, because logarithmic scale is more accurate in displaying parts of the pattern that have low value. [1]

1.1.2 Radiation Pattern Lobes

Different parts of radiation characteristic are called lobes. A lobe can be major lobe, main lobe, minor lobe, side lobe, and back lobe. These names describe in which part are these lobes located. Lobe is part of the characteristic surrounded by relatively weaker radiation - the part that sticks out. The size and shape of the lobes in an antenna's radiation pattern depend on the physical design of the antenna and the frequency of the radiation being emitted. [1]

Major (main) lobe is defined as ""the radiation lobe containing the direction of maximum radiation" [1]. In figure 1.3 and figure 1.2 are main lobes pointing to 0°. There can by more than one major lobe in some antennas, such as split-beam antenna.[1, 2]

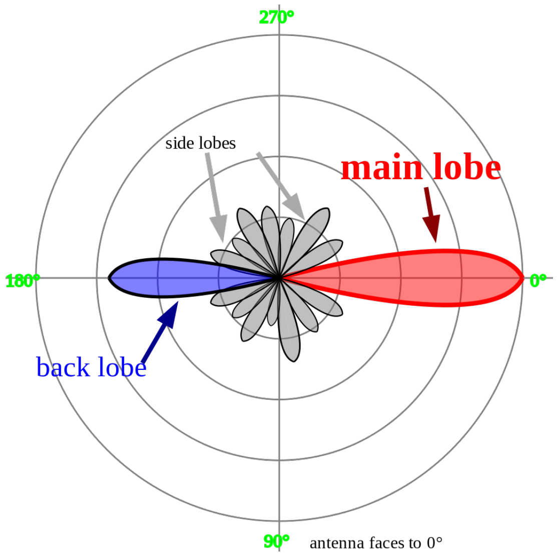


Fig. 1.3: Radiation pattern diagram.

As minor lobe it is referred to all other lobes except major lobe. All lobes in figure 1.3 can be called minor lobes. These are the areas where the power is wasted. [1]

A side lobe is every lobe not in the direction of the intended lobe. [1]

A back lobe is “a radiation lobe whose axis makes an angle of approximately 180 ∘ with respect to the beam of an antenna” [1]. Usually, we can consider as back lobe a minor lobe in an opposite direction of a major lobe. A considerable amount of energy is wasted even here. [1]

In the figure 1.2 we can see radiation pattern of antenna array with reflector. From this figure, we can clearly see, that this characteristic has one major lobe and 4 minor lobes.

Isotropic, Directional and omnidirectional patterns

An isotropic radiation pattern is a theoretical concept that describes a type of antenna or other radiation source that radiates energy equally in all directions. In other words, the radiation pattern is a perfect sphere, with the antenna or radiation source at the center. Isotropic radiation patterns are often used as a reference or baseline when discussing the radiation patterns of other types of antennas or radiation sources. [1]

A directional radiation pattern is a type of radiation pattern that is more focused in a particular direction or directions. This means that the antenna or radiation source will radiate more energy in some directions than in others. These types of antenna can be used for example for long-range comunication. Figure 1.2 is an example of directional radiation pattern. [1]

An omnidirectional radiation pattern is a type of radiation pattern that is relatively uniform in all directions. Omnidirectional radiation patterns are often used in applications where it is important to radiate energy in all directions, such as in wireless communication systems that need to cover a wide area. A common example of omnidirectional antenna is a dipole. Radiation pattern of dipole antenna is displayed in figure 1.4. [1]

1.1.3 Directivity

Directivity is a parameter that tells us how much more directional an antenna is from a reference source, usually an isotropic radiator. It is often used to describe the ability of an antenna to transmit or receive energy in a specific direction. All antennas shows directivity higher than 1 (or 0dB). This directivity is that of an isotropic antenna. Directivity can be calculated from: [1, 4]

$$D = \frac{4\pi}{\int_0^{2\pi} \int_0^{\pi} [f(\theta, \phi)]^2 sin\theta \, d\theta \, d\phi} \tag{1.2}$$

, where $f(\theta, \phi)$ is normalized field pattern.

A high directivity is not always better. For example mobile phones require omnidirectional antennas with low directivity. Antennas with high directivity are mainly used in permanent instalation where transmition over long distances in particular direction is needed. Example of directional antenna is parabolic antenna which radiation pattern is shown in figure 1.5.

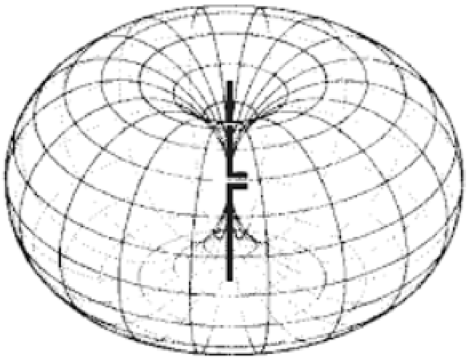


Fig. 1.4: Omnidirectional radiation pattern. [7]

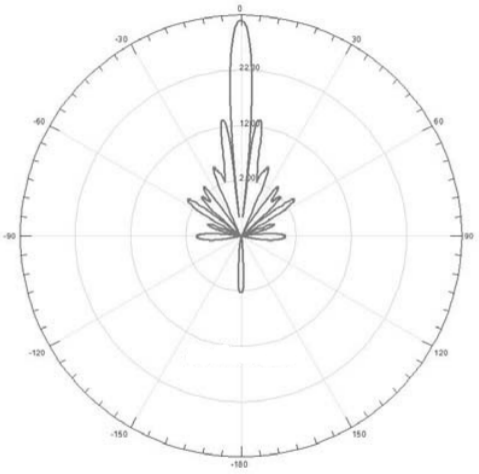


Fig. 1.5: Parabolic antenna radiation pattern. [8]

1.1.4 Gain

Gain is defined as "the ratio of the radiation intensity in a given direction to the radiation intensity that would be produced if the power accepted by the antenna were isotropically radiated" [5]. It is closely related to directivity and also efficiency of the antenna. For practical calculations of maximum gain G_0, formula below is used. [1, 2]

$$G_0 \approx \frac{30000}{\Theta_{1d}\Theta_{2d}} \tag{1.3}$$

, where $\Theta_{1d}\Theta_{2d}$ are angular widths of the main lobe in two perpendicular planes in degrees.

Gain is usually given in decibels instead of dimensionless quantity. The conversion formula is:

$$G_0[dB] = 10log(e_{cd}D_0) \tag{1.4}$$

, where e_{cd} is the antenna radio efficiency and D_0 is maximum directivity.

1.1.5 Efficiency

Antenna efficiency is a ratio of delivered power to the power radiated from the antenna. Efficiency is one of the most important parameters of antenna. Formula for radiation efficiency is given below. [6]

$$\epsilon_R = \frac{P_{radiated}}{P_{input}} \tag{1.5}$$

Usually is efficiency given in percentage or in decibels.

Another term we can encounter is total efficiency. This is antenna efficiency multiplied by impedance mismatch loss M_L when connected to transmission line. [6]

$$\epsilon_T = M_L \epsilon_R \tag{1.6}$$

Given, that M_L is number between 0 and 1, total efficiency is always less than the radiation efficiency.

Antenna efficiency losses are typically:

- conduction losses
- dielectric losses
- impedance mismatch loss

Conduction losses are due to finite conductivity of antenna's metal. Dieletric losses are caused by conductivity of dielectric materials near an antenna.

Efficiency can be close to 100 % (0 dB) for dish antennas or horn antennas with. Mobile phone or WiFi antennas have typically 20 % to 70 % (-7 dB to -1.5 dB) efficiency. [6]

1.2 Antenna arrays

Usually radiation pattern of single antenna is relatively wide. In some applications it is necessary to have antennas with very directive characteristics to be able to communicate over long distances. This can be accomplished by enlargement of the electrical size of the antenna. [1]

To reach the enlargement of the electrical size, we can enlarge the dimensions of the antenna. Another way to achieve this, without changing the dimensions, is to form an assembly of radiating elements in an electrical and geometrical configuration. It is common for all the array elements to be the same. [1]

To achieve required directivity antenna elements fields must interfere constructively in the desired direction and interfere destructively in the remaining directions. This can be only achieved in theory. [1]

In arrays made up of the same elements, there are at least five parameters that affect the radiation pattern of the antenna [1] :

1. The geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.).
2. The relative displacement between the elements.
3. The excitation amplitude of the individual elements.
4. The excitation phase of the individual elements.

5. The relative pattern of the individual elements.

1.2.1 Array factor

The array factor is function of array layout and the excitation phase. It is calculated by equation below. [1]

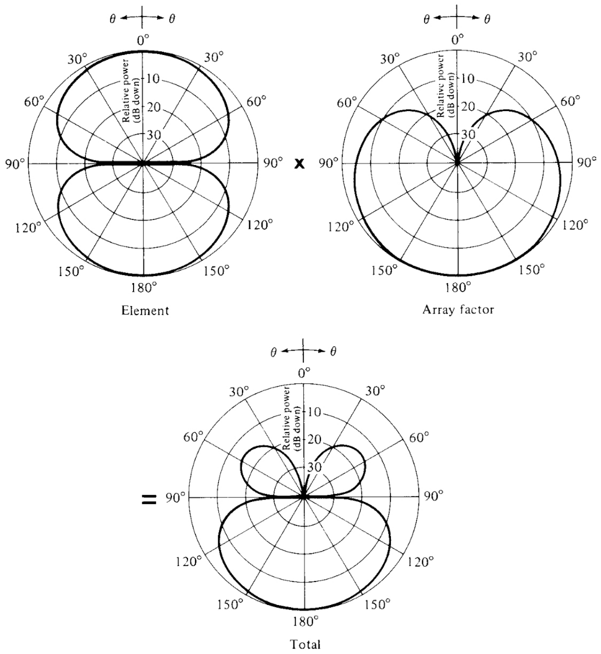
$$AF = 1 + e^{j(kdcos\theta+\beta)} + e^{j2(kdcos\theta+\beta)} + \ldots e^{j(N-1)(kdcos\theta+\beta)} \tag{1.7}$$

$$AF = \sum_{n=1}^{N} e^{j(n-1)(kdcos\theta+\beta)} \tag{1.8}$$

, where d is distance between elements, β is phase shift between elements and θ is elevation angle.

The far-zone field of the element array is product of the field of single element and the array factor:

$$E_{total} = E_{singleelement} \times AF \tag{1.9}$$



Element

Array factor

Total

Fig. 1.6: Influence of array factor on the radiation characteristic. [1]

1.3 Antenna synthesis

Antenna synthesis refers to the process of creating an antenna to meet specific requirements. For example, very common request is to design an antenna, which radiation pattern exhibits a desired distribution, narrow beamwidth and low side lobes. [1]

The main goal is to determine both the antenna setup and its physical measurements and distribution of excitation. The designed system should produce an acceptable radiation pattern, either precisely or approximately. [1]

Antenna pattern synthesis can be classified into three categories.

One group requires that the antenna patterns possess nulls in desired directions. For this method introduced by Schelkunoff can be used. [1]

Second group requires that the patterns exhibit a desired distribution in the entire visible region. This is referred to as beam shaping. This can be accomplished using the Woodward-Lawson methods or Furier transform. [1]

A third group includes techniques that produce patterns with narrow beams and low sidelobes. Commonly used techniques are binomial method and the Dolph-Tschebyscheff method. For antenna arrays, we can use different amplitude distribution. [1]

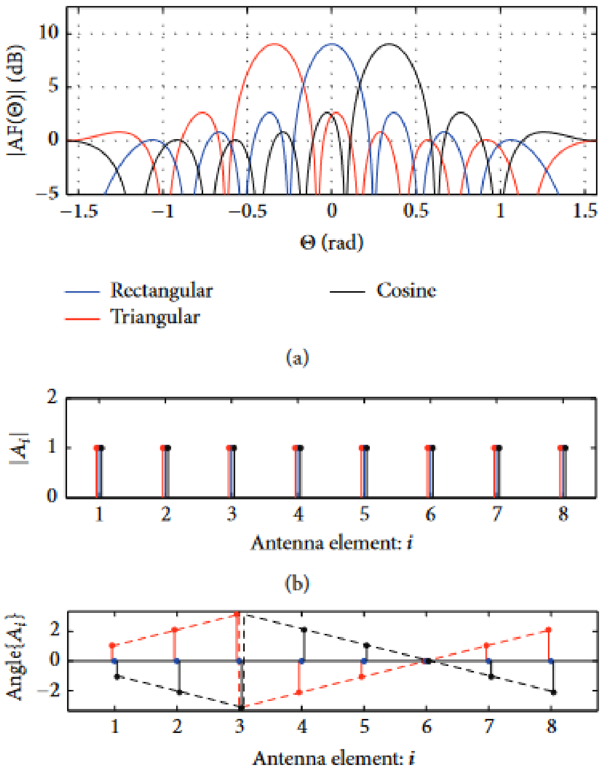
1.3.1 Beam steering

Another way to achieve desired beam angle is through beam steering. It uses phased array to steer main beam in the desired direction. A phased array antenna is an array antenna whose single radiators can be fed with different phase shifts. As a result, the common antenna pattern can be steered electronically. The electronic steering is much more flexible and requires less maintenance than the mechanical steering of the antenna. Main disadvantage is deformation of the antenna pattern. [9]

This can be used for linear and planar arrays. For linear arrays, we determine phase shift between array elements, and then apply them. Usually we set linearly increasing/ decreasing phases, as we can see in the picture 1.8. [10]

For planar arrays, we also determinate the phase shift, and then apply it to the row of antenna parallel to the plain, in witch we want to steer the main beam. Phase shift is same for every element in each column.

This technique was used for the developed program.



(a)

(b)

(c)

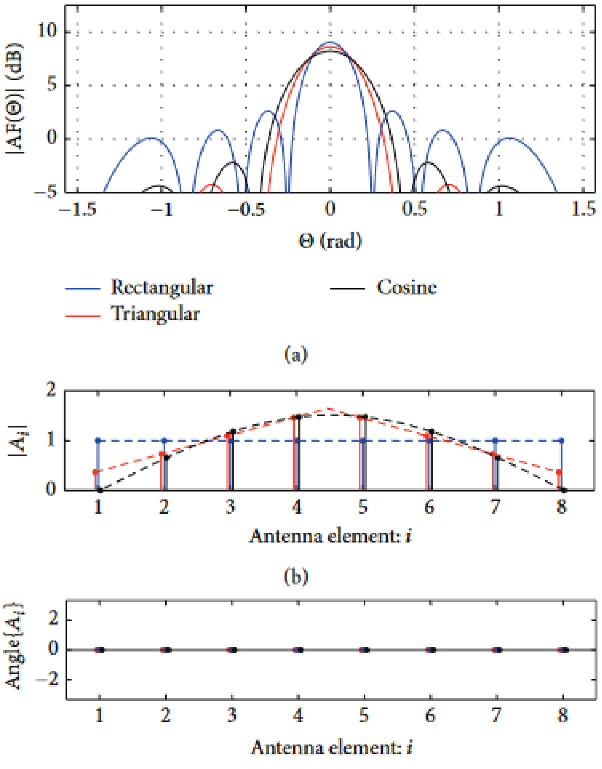
Fig. 1.7: Beam steering through phase control of an 8-element linear array. [10]

1.3.2 Beam shaping

Usually, the process of beam shaping involves the application of varying current amplitudes to the feeding current. [10]

Uniform amplitudes result in the highest gain, this means the main lobe is the narrowest. Modulating the amplitudes of the elements leads to a wider lobe and decreased gain. This also results in the reduced amplitude of the side lobes. [10]

Very common line-source amplitude distributions are triangular, cosine, cosine-squared or Gaussian. The array with the smallest sidelobes is the cosine-squared. The pattern for some of these distributions is summarized in the table 1.9. [1]



(c)

Fig. 1.8: Beam shaping through amplitude control of an 8-element linear array. [10]

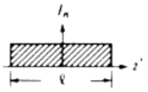
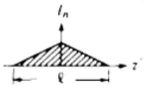
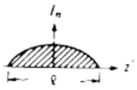
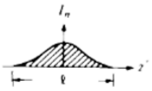
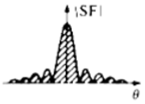
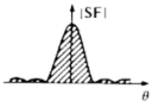
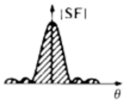
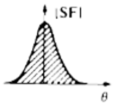
Distribution	**Uniform**	**Triangular**	**Cosine**	**Cosine-Squared**
Distribution (graphical)				
Space factor |SF|				

Fig. 1.9: Radiation characteristics of linear arrays with different distributions. [1]

2 Thesis Results

2.1 Selection of Programming Language

For the front-end part of the application, it was specified to use Python. For the Back-end, it was my choice to choose either MATLAB or Python.

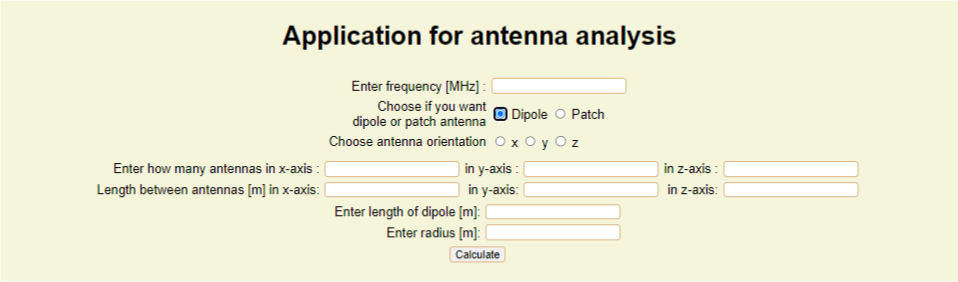
Python is a high-level, general-purpose programming language that is widely used for web development, data analysis, and scientific computing. It is known for its simplicity and readability. One of the main advantages of Python is its large standard library, which includes modules for a wide range of tasks such as connecting to web servers, reading and writing files, and working with data.

MATLAB is a programming language and software environment specifically designed for working with matrices and performing mathematical operations. It is widely used in scientific, engineering, and mathematical fields. MATLAB includes a wide range of tools and functions for working with matrices, complex numbers, and other mathematical data types. One of the strengths of MATLAB is its ability to interact with other programming languages, such as C, C++, and Python.

One key difference between MATLAB and Python is that MATLAB is a proprietary language, while Python is open-source. This means that anyone can use and modify Python for free, while MATLAB is only available to users who have purchased a license.

In the end, i have chosen Python, because of its simplicity and I already had to do Front-end in Python, so i only use one programming language for this project.

Below is application's interface, where user can enter array parameters - length between antennas in each axis and how many antennas are in these axis. If dipole antenna is chosen, user will enter length and radius of the dipole. If Patch antenna is chosen, these parameters will change to width and length of the antenna.



Application for antenna analysis

Enter frequency [MHz] :

Choose if you want dipole or patch antenna ● Dipole ○ Patch

Choose antenna orientation ○ x ○ y ○ z

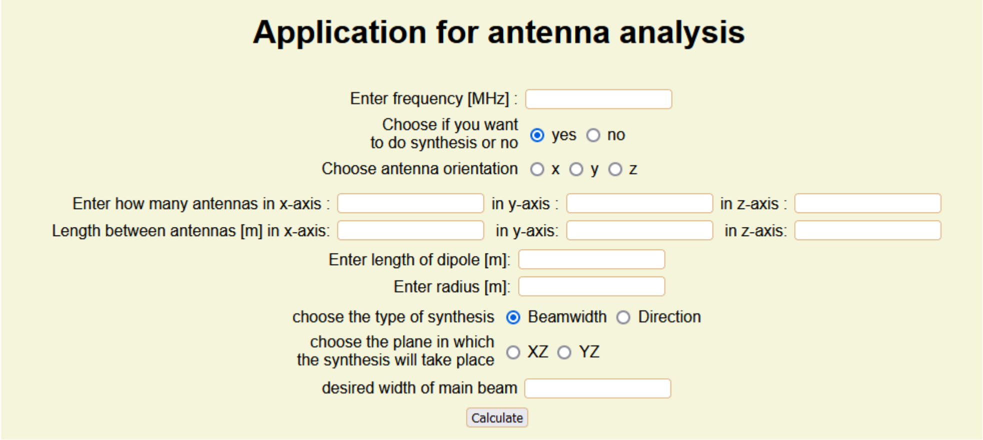
Enter how many antennas in x-axis : in y-axis : in z-axis :

Length between antennas [m] in x-axis: in y-axis: in z-axis:

Enter length of dipole [m]:

Enter radius [m]:

Fig. 2.1: Application interface for antenna analysis


Application for antenna analysis

Enter frequency [MHz] :

Choose if you want to do synthesis or no ● yes ○ no

Choose antenna orientation ○ x ○ y ○ z

Enter how many antennas in x-axis : in y-axis : in z-axis :

Length between antennas [m] in x-axis: in y-axis: in z-axis:

Enter length of dipole [m]:

Enter radius [m]:

choose the type of synthesis ● Beamwidth ○ Direction

choose the plane in which the synthesis will take place ○ XZ ○ YZ

desired width of main beam

Fig. 2.2: Application interface for antenna synthesis

2.2 Implementation

2.2.1 Front-end

Front-end is graphic user interface. This is used for getting antenna information from users.

Combination of HTML, CSS and JavaScript is used for the application's front-end. Specifically HTML to define the content of web page, CSS to specify the layout of web page and JavaScript to program the behavior of the web page.

2.2.2 Back-end

Back-end is used for creating website's structure and overall functionality, allowing site's front-end to exist. There are numerous programming languages for developing back-end, such as Python, Java or Ruby.

Python is used for back-end development with Django, which is high level web framework. The code is divided into functions. What each function does is explained below.

analysis

This function gets information from front-end. Then based on these informations it calculates wave length and calls functions for calculating dipole or patch antenna parameters or antenna synthesis. These parameters are then sent to be displayed on the result's page.

In all calculations for antenna analysis, we assume that every array element is fed by same current with same phase. Current for antenna synthesis is calculated for each dipole in used functions.

plotting, plottingP, plottingS

These function plot antenna layout based on given parameters. Plotting is for dipole antenna. PlottingP is for patch antenna.

Plotly is used as plotting framework. All plotted figures are interactive and web based.

gain2

This part of the code is responsible for calculating gain of dipole antenna array.

First, array factor of given array is calculated according to equation [1]:

$$AF = e^{j(kdx \cdot sin\theta \cdot cos\phi + kdy \cdot sin\theta \cdot sin\phi + kdz \cdot cos\theta)} \tag{2.1}$$

Then we calculate radiated power, which is given by equation below :

$$F = \frac{cos\left(\pi l cos\theta\right) - cos\left(\pi l\right)}{sin\theta} \tag{2.2}$$

This function returns gain. Gain is radiated power multiplied by array factor.

plot3DS

This functions plots 3D radiation characteristic of dipole antenna array.

First, it generates array of elevation angles θ from 0 to π, and array of azimuth angles ϕ from 0 to 2π. These values are then send to Gain2 function. After iterating trough all values, we calculate gain in decibels and normalize it to then plot it in Cartesian coordinates.

gainXY, gainXZ, gainYZ, gainXYPatch, gainYZPatch

These functions calculate and plot normalized gain of given antenna array in azimuth (horizontal), elevation (vertical) and perpendicular plains. These intersecting planes create complementary polar plots that provide a reliable representation of the antenna's performance.

Because we use patch antenna with infinite ground plane, we don't need radiation characteristic of patch antenna in three planes, because the third plot would be empty.

radRes

Function RadRes calculates radiation resistance of antenna array. This is done by formula below.

$$R = \frac{30}{\pi} \int_0^{2\pi} \int_0^{\frac{pi}{2}} F^2 sin\theta \, d\theta \, d\phi \tag{2.3}$$

F is radiation function of dipole antenna [1]:

$$F(\Psi) = \frac{cos\,(klcos\Psi) - cos\,(kl)}{sin\Psi} \tag{2.4}$$

Angles ψ must be expressed by spherical coordinates based on dipole orientation.

$$cos\Psi_x = sin\theta \cdot cos\phi \tag{2.5}$$

$$cos\Psi_y = sin\theta \cdot sin\phi \tag{2.6}$$

$$cos\Psi_z = cos\theta \tag{2.7}$$

gainPatch

This function has the same function as Gain2 but for patch antennas. Array factor is calculated the same. Electric fields are calculated in elevation E_θ[3] and azimuthal E_ϕ[3] fields as equation below shows:

$$E_\theta = sin\left(k\frac{w}{2}cos\theta\right) cos\left(k\frac{l}{2}sin\theta \cdot cos\phi\right) \frac{sin\theta \cdot cos\phi \cdot sin\phi}{(sin\theta \cdot cos\phi)^2 - \left(\frac{wl}{2l}\right)^2} \tag{2.8}$$

$$E_\phi = sin\left(k\frac{w}{2}cos\theta\right) cos\left(k\frac{l}{2}sin\theta \cdot cos\phi\right) tan\theta \left(1 + \frac{(cos\theta \cdot cos\phi)^2}{(sin\theta \cdot cos\phi)^2 - \left(\frac{wl}{2l}\right)^2}\right) \tag{2.9}$$

$$E = \sqrt{E_\theta \cdot \overline{E_\theta} + E_\phi \cdot \overline{E_\theta}} \tag{2.10}$$

E is the total electric field, from which gain is then calculated.

plotPatch3D

This part of the code is responsible for calculating normalized gain and plotting it in Cartesian coordinates.

At the beginning of the function, we generate array of elevation angles θ from 0 to π, and array of azimuth angles ϕ. from 0 to π. We generate ϕ to π because in our calculations we use infinite ground plane dimensions. This means, that our antenna array should only radiate away from ground plane.

gainXYs, gainXZs, gainYZs

These functions calculate and plot normilazed gain in respective plains.

Function gainXYs is calling function phasecoef2 or curcoef to calculate current fed to each antenna element. We call these functions only here, because the called functions are very time consuming.

phasecoef2

This function is responsible for calculating phase shift between array elements. We iterate through numbers from 1 to 360, based on this number is then calculated phase shift. Then with updated current function unigainXZz, unigainXYy or unigainYZ is called, depending on chosen antenna orientation and plain, in witch we want the main beam steering to be in. Based on returned angle of the main beam, we either continue in iterating, or if the main beam is in desired angle we return calculated current to the calling function and set as global variable.

Tolerance for angle is set to 20 degrees.

curcoef

In this function, amplitude fed to each element is calculated. In each iteration of this function, we gradually increase current amplitude on selected antenna elements by the value of 0,5. Then we call one of the functions unigainXZz, unigainXYy or unigainYZ depending on chosen antenna orientation and plain, in witch we want to change the width of the main beam.

Tolerance for beam width is set to 5 degrees.

unigainXZz, unigainXYy or unigainYZ

These functions are basically the same as functions gainXYs, gainXZs, gainYZs. These functions are called, when feeding current is calculated.

These functions return either width of the main beam, or angle of the main beam.

gain2synth

This function is responsible for calculating gain of given antenna array. First, array factor is calculated according to the equation below:

$$AF = \left(\frac{amp}{max\left(|amp|\right)} \times e^{1j(kdxsin(\theta)cos(\phi)+kdysin(\theta)sin(\phi)+kdzcos(\theta))} \right) \tag{2.11}$$

Then radiated power is calculated using equation 2.2.

Gain is then returned.

findnearest

This function returns index of the nearest value to the value given. From index, we can then determine angle.

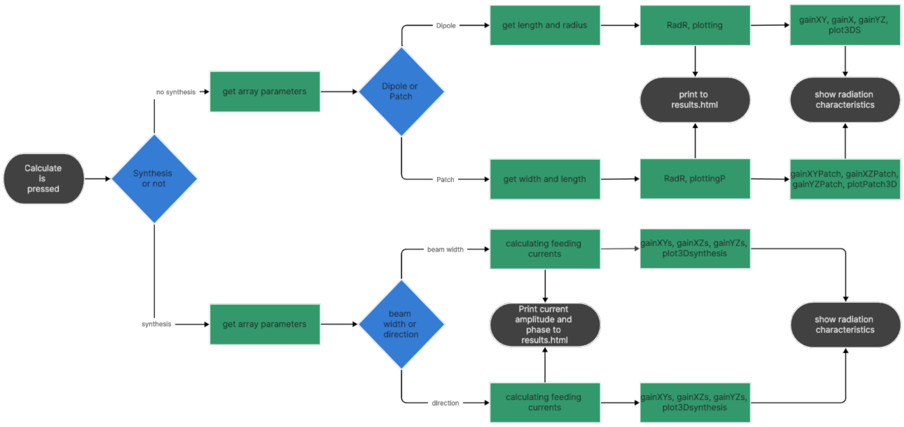


Fig. 2.3: Flowchart of the application.

2.3 Comparison of results

Now i will compare radiation characteristic of dipole antenna array calculated by my application with reference application.

First array consist of three dipole antennas oriented in z axis. Array is oriented in x axis. Dimensions of antennas are length: 0.5 m, radius: 0.001 m. Frequency is 300 MHz.

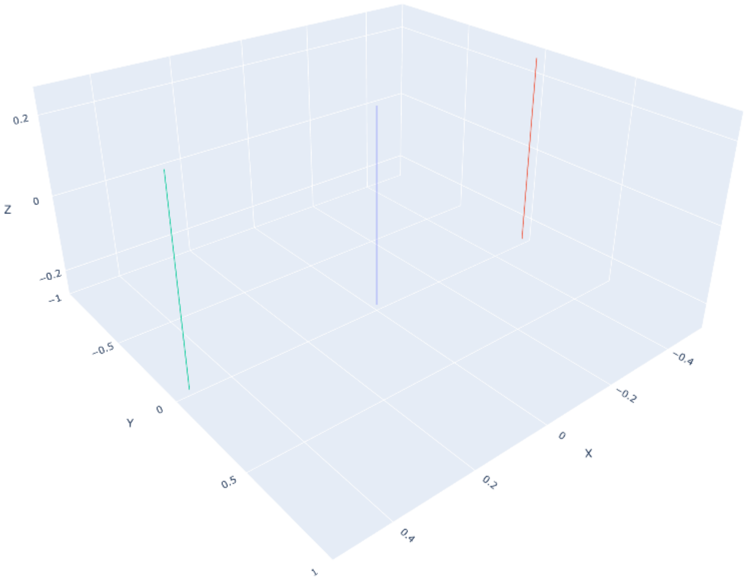


Fig. 2.4: Three-dipole array layout.

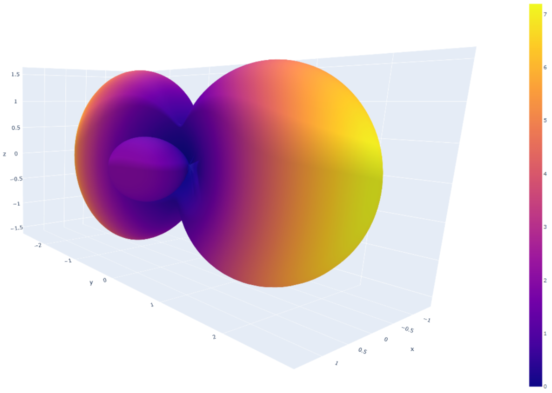


Fig. 2.5: Three-dipole array 3D radiation characteristic.

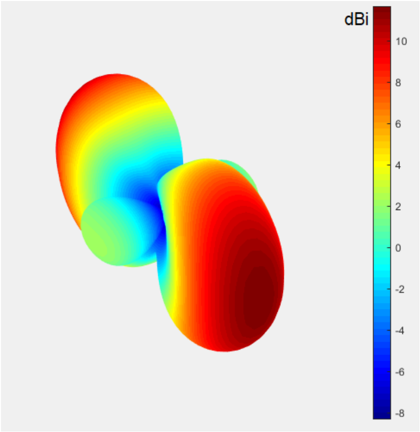


Fig. 2.6: Three-dipole array 3D radiation characteristic from reference app.

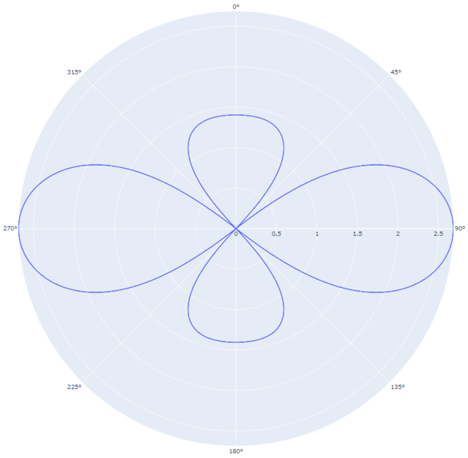


Fig. 2.7: Three-dipole array radiation characteristic in XY plain.

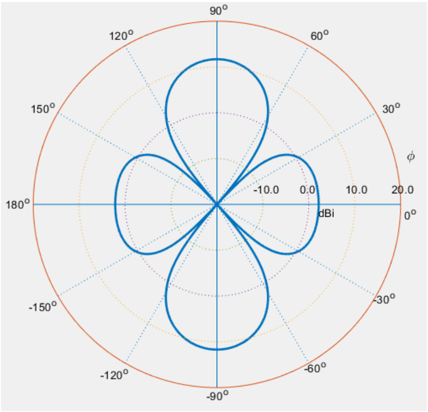


Fig. 2.8: Three-dipole array radiation characteristic in XY plain from reference app.

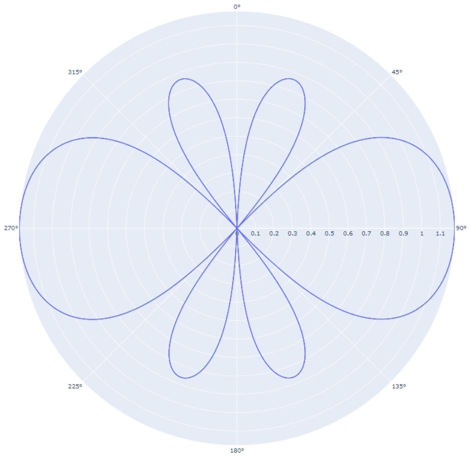


Fig. 2.9: Three-dipole array radiation characteristic in XZ plain.

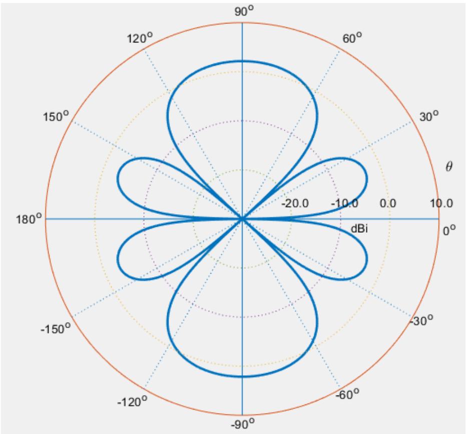


Fig. 2.10: Three-dipole array radiation characteristic in XZ plain from reference app.

Second array on witch i compared results consists of nine dipole antennas in 3x3 layout. Antenna's dimensions are the same as in the first case.

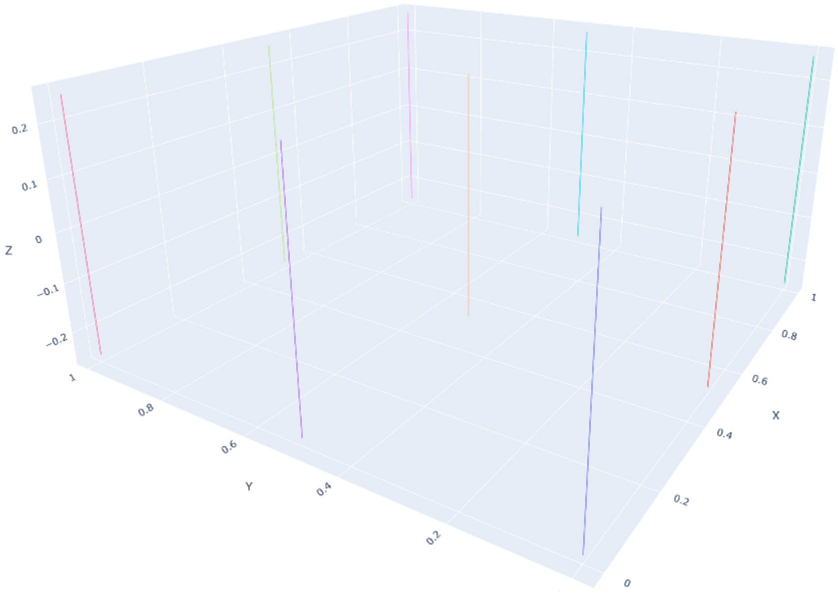


Fig. 2.11: Nine-dipole array layout.

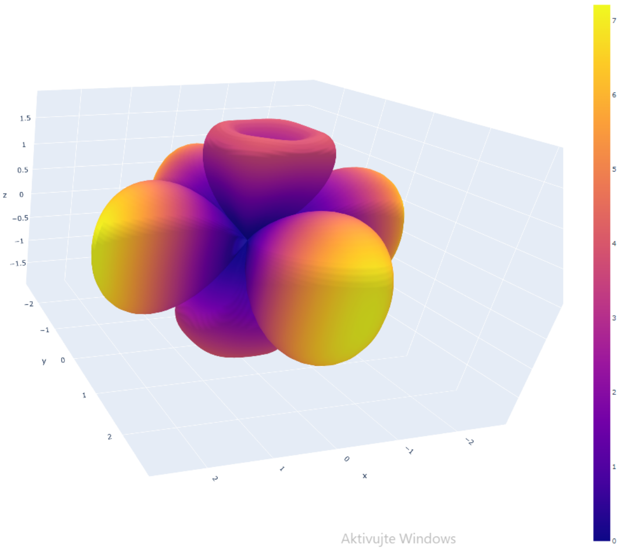


Fig. 2.12: Nine-dipole array 3D radiation characteristic.

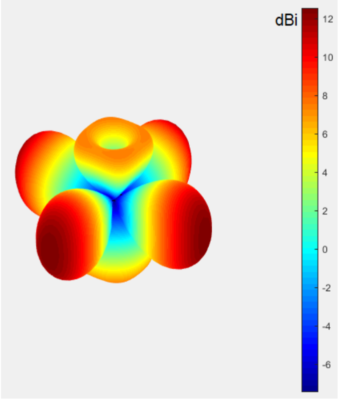


Fig. 2.13: Nine-dipole array 3D radiation characteristic from reference app.

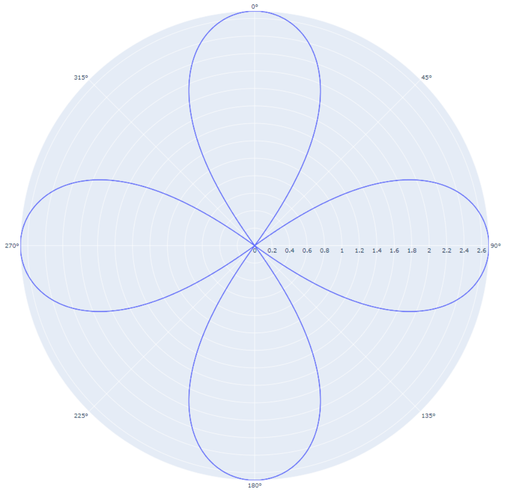


Fig. 2.14: Nine-dipole array radiation characteristic in XY plain.

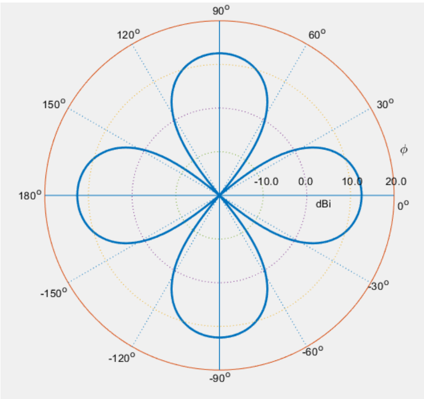


Fig. 2.15: Nine-dipole array radiation characteristic in XY plain from reference app.

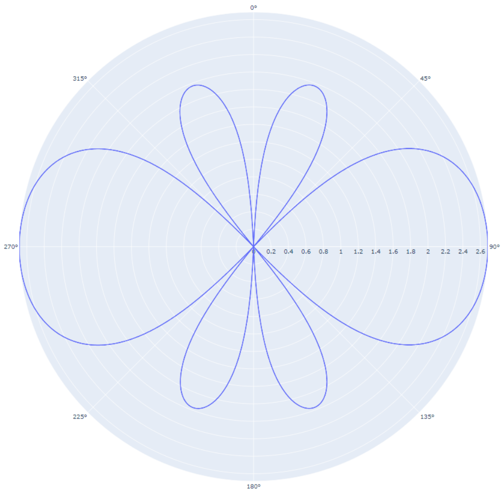


Fig. 2.16: Nine-dipole array radiation characteristic in XZ plain.

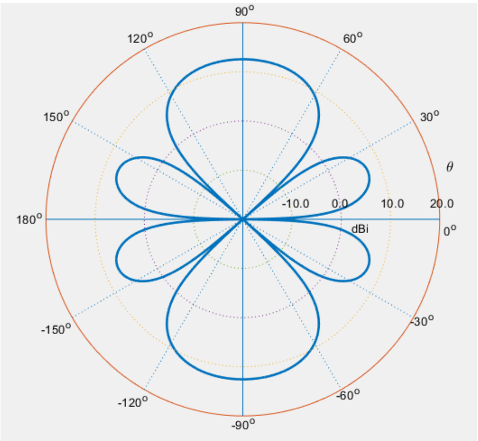


Fig. 2.17: Nine-dipole array radiation characteristic in XZ plain from reference app.

Unfortunately, I couldn't find any application that calculates radiation characteristics of patch antennas arrays so I can't compare results results from my application.

Now we will compare results of synthesis.

First array is 9 dipole array in 3x3 layout. Antennas are oriented in z axis. Dimensions of antennas are length: 0.1 m, radius: 0.002 m. Frequency is 300 MHz. Desired beam width is set to 45° in XY plain. We calculated, that current amplitudes on elements along X axis are 5 A, 1 A and 5 A. Beam width is 48°.

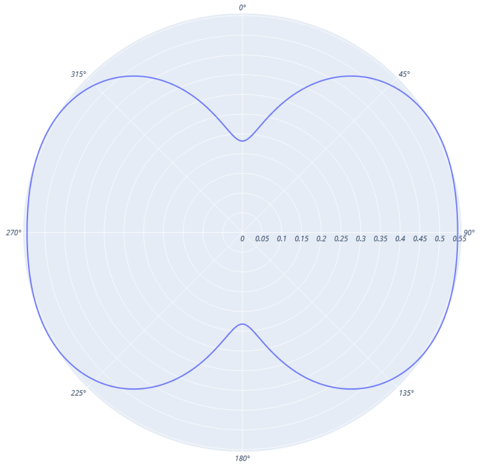


Fig. 2.18: Nine-dipole array radiation characteristic in XY plain.

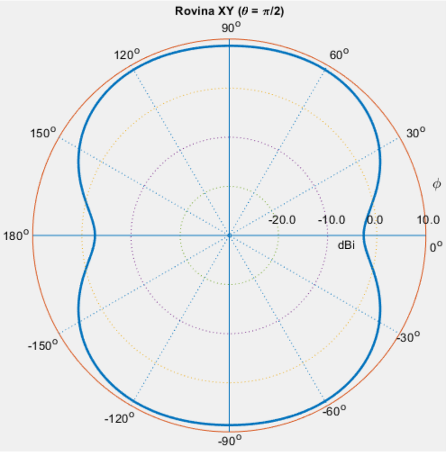


Fig. 2.19: Nine-dipole array radiation characteristic in XY plain from reference app.

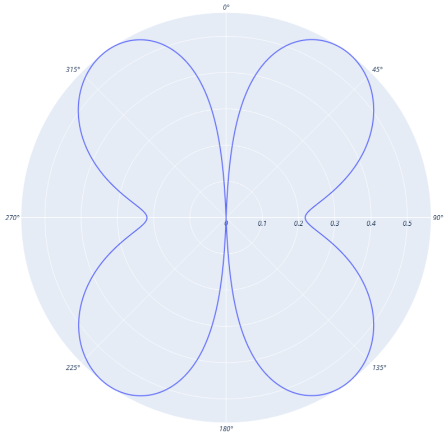


Fig. 2.20: Nine-dipole array radiation characteristic in XZ plain.

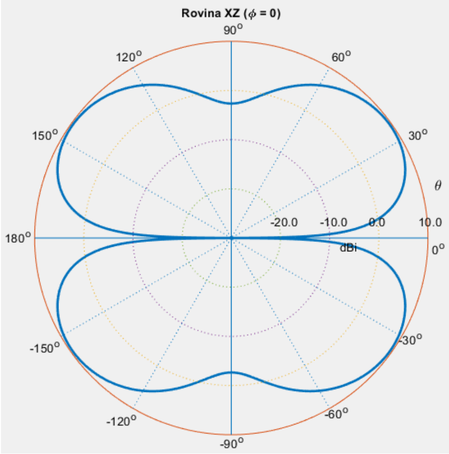


Fig. 2.21: Nine-dipole array radiation characteristic in XZ plain from reference app.

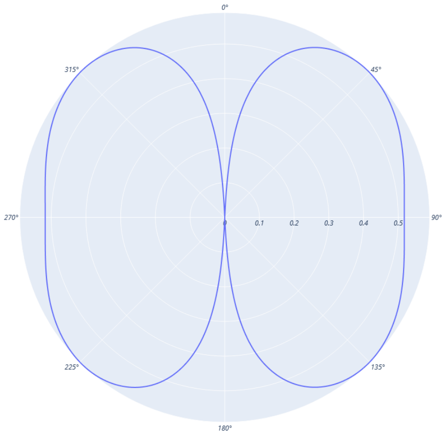


Fig. 2.22: Nine-dipole array radiation characteristic in YZ plain.

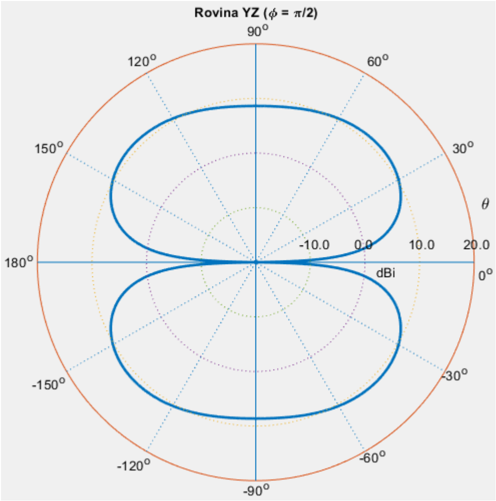


Fig. 2.23: Nine-dipole array radiation characteristic in YZ plain from reference app.

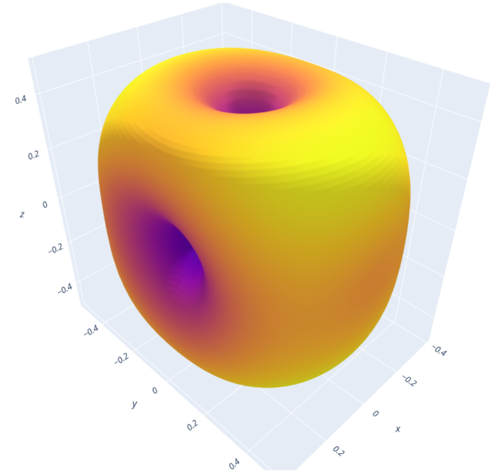


Fig. 2.24: Nine-dipole array radiation 3D characteristic.

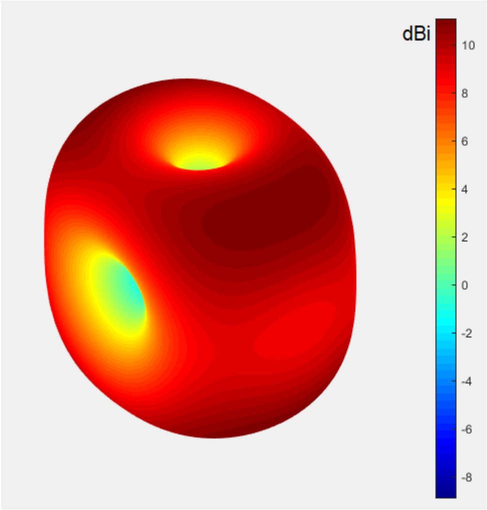


Fig. 2.25: Nine-dipole array 3D radiation characteristic from reference app.

For second comparison of result same array is chosen. Only now we want to do synthesis of beam angle in XY plain. Desired beam angle is 290°.

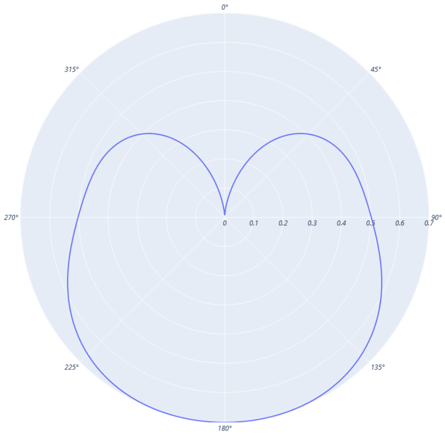


Fig. 2.26: Nine-dipole array radiation characteristic in XY plain.

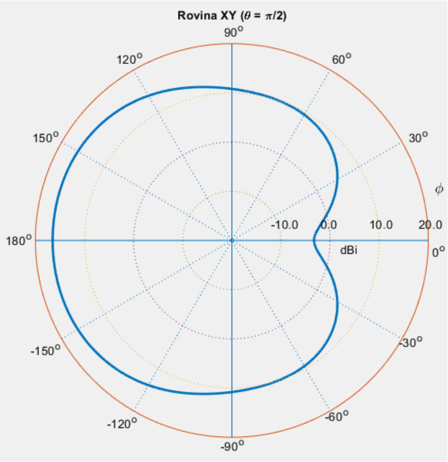


Fig. 2.27: Nine-dipole array radiation characteristic in XY plain from reference app.

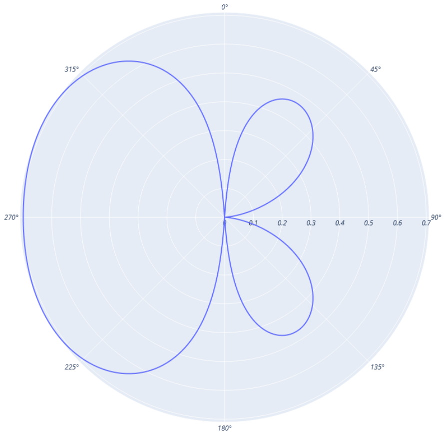


Fig. 2.28: Nine-dipole array radiation characteristic in XZ plain.

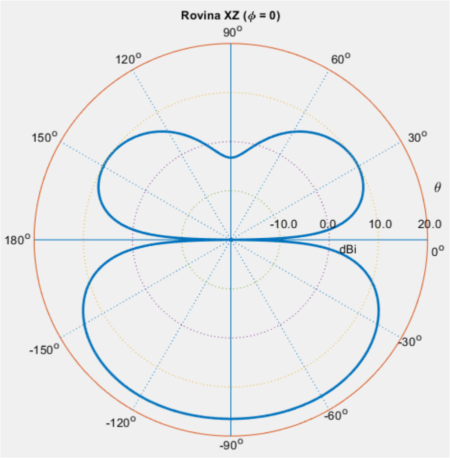


Fig. 2.29: Nine-dipole array radiation characteristic in XZ plain from reference app.

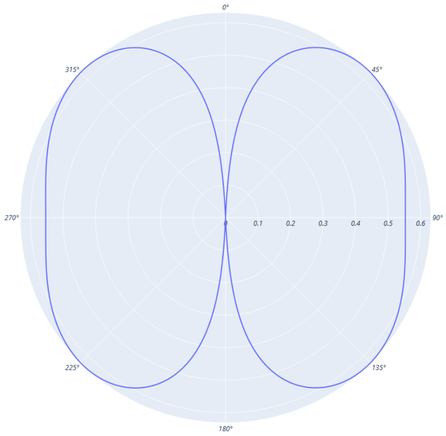


Fig. 2.30: Nine-dipole array radiation characteristic in YZ plain.

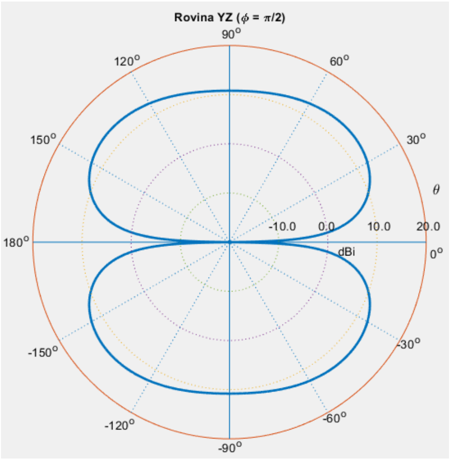


Fig. 2.31: Nine-dipole array radiation characteristic in YZ plain from reference app.

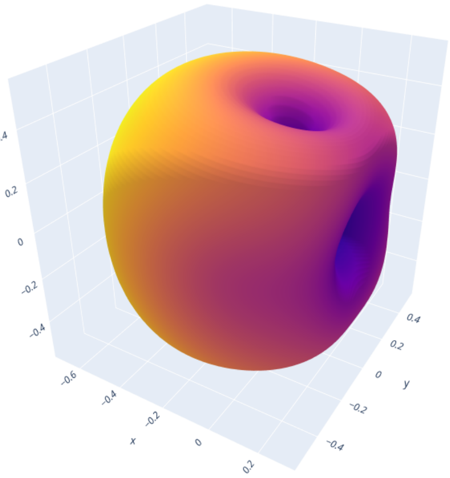


Fig. 2.32: Nine-dipole array radiation 3D characteristic.

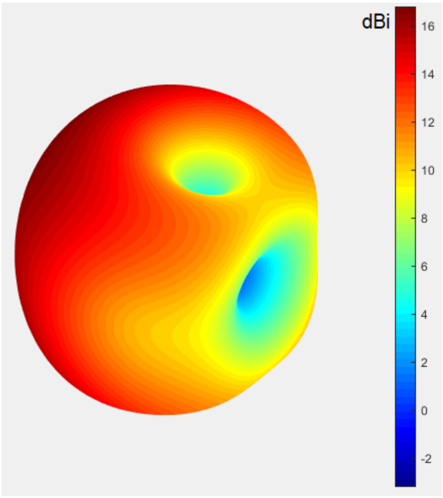


Fig. 2.33: Nine-dipole array 3D radiation characteristic from reference app.

2.4 Future Work

In future I would like to change some things in the application. Most of the changes will be in improving user's experience with the app.

Mainly, the algorithms used to calculate the current are slow and computationally intensive. In the next version, algorithms could be used that would be more efficient, for example steepest descend or newtons method.

Also method of printing calculated amplitudes and phases isn't optimal. The best solution would be to list the results in a matrix that would have the same format as the distribution of the specified antennas in the antenna array.

Then I'd like to secure that application doesn't crash when user's input is something different than integer or floating-point number. This change would be done by conditions in the analysis function.

Next thing I'd like to change is when, there is only one antenna in specific axis, there is no need to ask for length between antennas. This change could be achieved by disabling windows for entering distance between antennas.

Conclusion

In conclusion, the web application for antenna analysis is a valuable tool. Its user-friendly interface and analysis capabilities make it an essential tool for optimizing antenna performance. The results of our evaluation demonstrate that the application functions properly. Overall, the web application for antenna analysis is a valuable contribution to the field.

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