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V Slot Loaded Triangular PatchAntenna Analysis Using Ml

Suresh Elagandula, Ananya Etti, Chakali Guru Sai Niharika,
Ireddy Rakesh Kumar Reddy,Mohammed Abdul Farhan
Department of Electronics and Communication Engineering Kakatiya Institute of Technology and Science, Warangal, India

Abstract –
V-slot loaded Triangular patch antenna analysis using Machine learning ANN technique. Initially fractal antenna is designed and analyzed using HFSS tool. The training data is generated from the HFSS tool. Later, training data is applied to ML Random Forest. A triangular patch with a relative permittivity of 4.4 and a thickness of 0.6 mm is developed on a FR4 substrate and mounted 6 mm above the ground plane. With consistent pattern properties, like gain and cross polarisation, within its bandwidth, bandwidth as high as 9.2% are attained. This design technique involves inserting a single feed and two small slots in the shape of a V on the microstrip antenna. The suggested antenna's impedance bandwidth, antenna gain, and return loss are all observed. In order to create an antenna with an impedance bandwidth of 9.2% that is compatible with the Wi-max wireless communication system, a single probe feed triangular patch with a V-shaped slot on the patch can be employed. Antennas with broadband and/or multi-frequency operation modes are necessary for these contemporary communication systems. With the intention of maintaining the compactness criteria, maintaining the overall layout as simply as feasible, and keeping the realisation cost very cheap, these aims have been achieved by using slotted patch for the radiating element.

Keywords: *HFSS Tool, Python, ML-Algorithms, Linear Regression, Decision Tree Regressor, Random Forest Regressor, Elastic net, Lasso.*

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I. INTRODUCTION

Antennas play a crucial role in wireless communication systems. A microstrip patch antenna is one that is created using photolithographic methods on a printed circuit board (PCB). It performs the role of an internal antenna. Microstrip antennas are frequently square, circular, or elliptical, but any continuous design is feasible. The study of microstrip patch antennas has made great strides lately. Compared to conventional antennas, microstrip patch antennas offer greater advantages and better possibilities. They are simpler to build and adhere to, lighter in weight, have a lower volume, cost less, have a lower profile, and are smaller in size. An antenna is a device that converts radiated waves into directed waves or the other way around. The device that "guides" the energy to the antenna is a coaxial wire connecting to it. The radiated energy is determined by the antenna's radiation pattern. A crucial component of communication systems are antennas. A device that transforms an RF signal moving along a conductor into an electromagnetic wave in free space is an antenna, by definition. The intensity in a given direction divided by the intensity that would result from the antenna's power being radiated isotopically (in that direction) is known as the antenna gain. When the antenna's accepted (input) power is divided by four, the radiation intensity that corresponds to the isotopically radiated power is obtained. Otherwise, reception and transmission would be hampered if an antenna was not tuned to the same frequency range as the radio instrument to which it was connected. As a signal is sent into an antenna, a certain type of radiation is emitted and spread throughout space. There are 2 types of microstrip patch antennas isosceles and equilateral antennas using standard electromagnetic simulator HFSS (High Frequency Structural Simulator) software to validate the models. The resonant frequencies of these form antennas have been compared when they have the same patch surface and same physical parameters. The effect of thickness and dielectric constant of substrate on resonant frequency of each antenna has been considered in the implementation. One of the Techniques to design a compact microstrip antenna is cutting slots on the radiating patch to increase length of the surface currents. By cuttingslots from a patch, gain, return loss and bandwidth of MSAcan be improved.

In order to choose the best substrate for the microstrip patch antenna some of the parameters to be considered are

Antenna Gain:

The intensity in a given direction divided by the intensity that would result from the antenna's power being radiated isotopically (in that direction) is known as the antenna gain. The radiation intensity corresponding to the isotopically radiated power is equal to the allowable (input) power of the antenna divided by four.

Antenna Efficiency:

It is described as the proportion of an antenna's total power to the net power received from the connected transmitter. The majority of the time, it is stated as a percentage (less than 100). The total antenna efficiency e0is used to account for losses at the input terminals and within the antenna structure.

VSWR:

Voltage Standing Wave Ratio ranges between 1 to infinity. For better transmission of signal the VSWR value should be below 2.

Radiation Pattern:

An antenna's power radiated out from the antenna is modified by a radiation pattern. A radiation pattern is a graph representing the characteristics of an antenna's far- field radiation. The elevation angle () and azimuth angle ()together determine the geographical coordinates.

Return Loss:

Return loss in communications refers to the loss of power in a signal that is reflected or returned by a break in a transmission line or optical fibre. This break could be brought on either a mismatch with the ending load or a device added to the line. The standard way to express it is as a decibel (dB) ratio.

Beam width:

An antenna's pattern is related to a variable called beam width. The beam width of the pattern is defined as the angle between two equal spots on opposite sides of the pattern limit. An antenna's beam width is a valuable performance indicator that is frequently employed in trade-off with the side lobe level, meaning that as the beam width falls, the side lobe level rises.

Input impedance:

the ratio of voltage to current at two terminals, or the impedance that an antenna exhibits at its terminals. For the proper transmission of the signal without distortion, we match the input impedance.

II. LITERATURE REVIEW

Comparison of resonant frequencies of rectangular, isosceles and equilateral microstrip patch antenna having same patch surface Unconstrained Approach:

The focus of this research is on spectral domain characterization of rectangular, isosceles, and equilateral microstrip antennas. It is used to evaluate the resonant frequency by presenting the problem solution in spectral domain. Then, to ensure a successful convergence of the solution, consider the unique basic feature of each form. Finally, the numerical results were used to compare the resonant frequencies of the three types of antennas when the patch surface and physical parameters were the same. ML Based Methodology:

We used ML based algorithms to find the best substrate which satisfies all the micro strip patch antenna parameters.

Broadband 90 degrees isosceles microstrip patch antenna:Issues Identified:

Human interaction is crucial in all of the aforementioned strategies since they are not independent. Since they frequently require manual intervention, it may affect how accurately they distinguish between trustworthy and false news. In order to categorize which information is false, they also need highly competent experts with extensive understanding of grammar, syntax, semantics, and the relevant facts. Practically no one could possibly be informed of all the details and separate the news. We thus use machine learning algorithms that create models by learning from past datasets and provide greater accuracy.

Broadband Gap-coupled triangular microstrip patchantennas

In comparison to a triangular microstrip antenna, the oscillations in the field distributions at each resonant mode are similar. By altering the isosceles angle, which controls the distance between the patch's first two resonant modes, wideband response can be achieved in an isosceles patch. This work proposes variations of triangular microstrip antennas with angles of 90, 100, and 110 degrees that are gap coupled. Gap coupling between individual patch resonant modes produces wideband response. More than 900 MHz of BW can be produced in a gap coupled setup with patches angled at 110 degrees. A broadside pattern is present in all versions that are gap linked. In 90-degree isosceles patches, bore sight gain of more than 8dBi is obtained.

Broadband 90 degrees isosceles microstrip patch antenna

The analogous equilateral triangular microstrip patch antenna is proposed as a broadband 90 degrees isosceles microstrip patch antenna. A parametric analysis of isosceles angle variance from 50 to 90 degrees is presented. The spacing between the triangular patch's TM10 and TM11 modes is tuned as the angle increases, resulting in broadband response. It is possible to achieve a stimulated and calculated bandwidth of more than 600 MHz This is more bandwidth than an equilateral triangular microstrip antenna can provide. The proposed 90-degree isosceles patch produces a broadside radiation pattern of more than 6dBi gain across the entire bandwidth.

III. OBJECTIVES

The primary objectives of V Slot loaded Triangular Patchantenna using ML Analysis is:

- To more accurately determine the best substrate.
- To design a V Slot Loaded Triangular Patch antenna tomatch the patch surface at similar frequency.
- Using Machine Learning Algorithms to select the bestsubstrate and deploy the model.

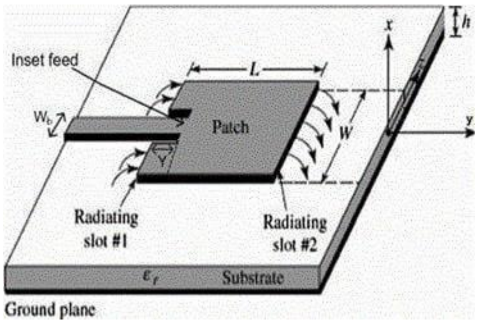


Fig 1: Microstrip Patch Antenna

Many different methods can be used to feed microstrip patch antennas. These procedures come in both contacting and non-contacting varieties. Through a connecting component like a microstrip line, RF power is delivered directly to the radiating patch during the contacting phase. Electromagnetic field coupling is employed in the non- contacting system to transfer power between the microstrip line and the radiating patch. Microstrip thread, coaxial probe (both contacting methods), aperture coupling, and proximity coupling (both non-contacting systems) are the four most widely used feed mechanisms. Utilising either direct or indirect contact, a feed line is utilised to stimulateto radiate.

Microstrip line feed:

Microstrip line feed is one of the most straightforward fabrication techniques because it is just a conducting strip linked to the patch and can be referred to as a patch extension. Because the inset location may be adjusted, it is simple to match. A conducting strip is immediately attached to the edge of the Microstrip patch in this kind of feed technology. Because the feed can be etched on the same substrate as the patch in this type of feed arrangement,a planar structure is produced.

Coaxial Probe Feed:

Coaxial feed, often known as probe feed, is a typical method of feeding microstrip patch antennas. The coaxial connector's outer conductor is connected to the radiating patch, while the inner conductor travels through the dielectric and joins to the ground plane. The feed can be placed anywhere on the patch to match its input impedance, which is the main benefit of this kind of feeding system. Although it requires drilling a hole in the substrate and the connector extends beyond the ground plane, making it non- planar for modelling, it has a limited bandwidth and is challenging to simulate.

Aperture coupled feed:

The ground plane divides the radiating patch from the microstrip feed thread in the aperture coupled feed technique. In order to maximise the outcome for broader bandwidths and reduce return losses, the patch and the feed line are coupled through a slot or aperture in the ground plane, with varied coupling depending on the aperture size,i.e., length and width.

Inset Feed:

The conducting strip's narrower width in the microstrip line feeding approach is advantageous since it enables the feed to have a planar structure. The feed line impedance is changed to the patch input impedance utilising the inset cut in the patch, which eliminates the need for any extra matching components. By making sure that the inset cut's positioning and dimensions are accurate, this can be accomplished. With a planar feed arrangement, the inset- fed microstrip antenna offers an impedance controlapproach.

IV. MACHINE LEARNING ALGORITHMS:

Linear Regression:

One of the most widely used Machine Learning algorithms, logistic regression belongs to the category of supervised learning. This statistical approach is employed in predictive analysis. The relationship between the dependent (output) and independent (input) variables is demonstrated via linear regression. Two varieties of linear regression exist. two types of linear regression: simple and multiple. Because the output in this project depends on a variety of input variables, we use multiple regression.

Random Forest:

The supervised machine learning algorithm includes Random Forest. It can be applied to ML issues involving both classification and regression. Random forest is used to solve a difficult problem and enhance the performance of a certain model. It is based on the idea of ensemble learning, which is a method of merging classifiers. A classifier called random forest, which includes several decision trees, increases the data set's accuracy. Overfitting is prevented by random forest.

Elastic Net:

Elastic net combines the two most often used regularised linear regression models, Ridge and Lasso. The ML model is strengthened by these 2 variations. Dimensionality reduction can be achieved by the use of elastic net regression. Elastic net has greater predictive analysis capability than a linear regression model.

Lasso Regression:

LASSO stands for Least Absolute Shrinkage and Selection Operator. Regression analysis is a technique Lasso is a modification and extension of linear regression that improves prediction accuracy and ML model interpretation by doing both variable selection and regularisation.

V. IMPLEMENTATION

In the proposed method a triangular patch antenna is designed using HFSS software. The antenna is designed using FR4 Epoxy as substrate. After obtaining some parameters at our desired frequency, a v-slot is added and found the parameters graphs and a data set is created which consists of different parameters found in v-slot patch antenna analysis. ML analysis is done based on the data obtained.

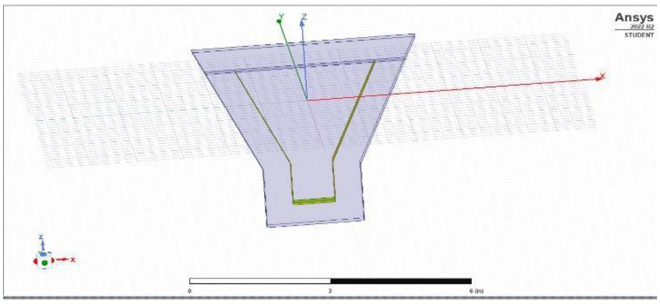


Fig 2: V-slot triangular Patch Antenna

Dataset description:
This is a dataset of different antennadesigns. Columns:
TestFreq (frequency used for testing the signal strength) PatchLength (length of patch antenna in mm) PatchWidth (width of patch antenna in mm)
SlotLength (length of slot in antenna in mm) SlotWidth (width of slot in antenna in mm) Strength (signal strength in dB, higher is better)

Problem:
Is it possible to create a statistical model that can estimate signal strength based on these parameters? Additionally, is it possible to create a model that only use the parameters that are not the test frequency? What are thebest accuracies of your statistical models?

Part a: Is it possible to create a statistical model that can estimate signal strength based on these parameters?

```
models = [LinearRegression, ElasticNet, Lasso, DecisionTreeRegressor, RandomForestI
for model in models:
 reg = model()
 reg.fit(X_train1,y_train1)
 pred1 = reg.predict(X_test1)
 err1 = mean_squared_error(y_test1, pred1) ** .5
 print(f'RMSE of {model.__name__} model is: {err1}')
 print(f'R2 value of {model.__name__} is: {np.mean(r2_score(y_test1, pred1))}')
 print('*'*50)
```

Answer: Yes, it is possible to create a statistical model that can estimate signal strength based on these parameters.

```
RMSE of LinearRegression model is: 2.82613044575275
R2 value of LinearRegression is: 0.3183488945148707
**************************************************
RMSE of ElasticNet model is: 2.896925274079139
R2 value of ElasticNet is: 0.2837703074670552
**************************************************
RMSE of Lasso model is: 2.972590061933514
R2 value of Lasso is: 0.24586728905912647
**************************************************
RMSE of DecisionTreeRegressor model is: 2.722284460666913
R2 value of DecisionTreeRegressor is: 0.36752298954834206
**************************************************
RMSE of RandomForestRegressor model is: 2.7285337847038735
R2 value of RandomForestRegressor is: 0.36461580580809005
**************************************************
```

Part b: Additionally, is it possible to create a model that only use the parameters that are not the test frequency?

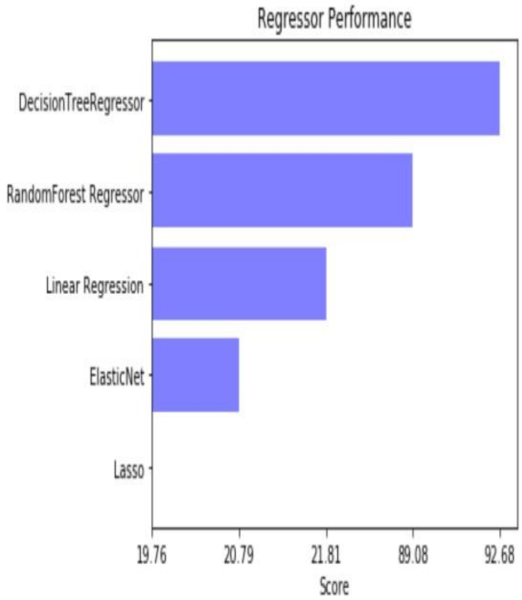
```
models = [LinearRegression, ElasticNet, Lasso, DecisionTreeRegressor, RandomForest
for model in models:
 reg = model()
 reg.fit(X_train,y_train)
 pred = reg.predict(X_test)
 err = mean_squared_error(y_test, pred) ** .5
 print(f'RMSE of {model.__name__} model is: {err}')
 print(f'R2 value of {model.__name__} is: {np.mean(r2_score(y_test, pred))}')
 print('*'*50)
```

Answer: Yes, it's possible to create that kind of model but we will get too much bad results because the variable testfrequency plays a vital role to estimate signal strength.

```
RMSE of LinearRegression model is: 3.030705068398181
R2 value of LinearRegression is: 0.21817698370605798
**************************************************
RMSE of ElasticNet model is: 3.0504608385574814
R2 value of ElasticNet is: 0.20795107483896214
**************************************************
RMSE of Lasso model is: 3.0702426325051335
R2 value of Lasso is: 0.19764512285592062
**************************************************
RMSE of DecisionTreeRegressor model is: 0.9271512990363963
R2 value of DecisionTreeRegressor is: 0.9268318080545291
**************************************************
RMSE of RandomForestRegressor model is: 1.1326453577508342
R2 value of RandomForestRegressor is: 0.8908034292775058
**************************************************
```

Regressor performance:

```
import matplotlib.pyplot as plt2
plt2.barh(y_pos, score, align='center', alpha=0.5,color='blue')
plt2.yticks(y_pos, Regressor)
plt2.xlabel('Score')
plt2.title('Regressor Performance')
plt2.show()
```



Decision Tree Regressor and Random Forest Regressor are the best models among these five models. However Random Forest Regressor model resulted much better their error is pretty low. Moreover 90%+ R^2 is also a good value.

VI. RESULTS

Outputs of V-slot triangular patch antenna

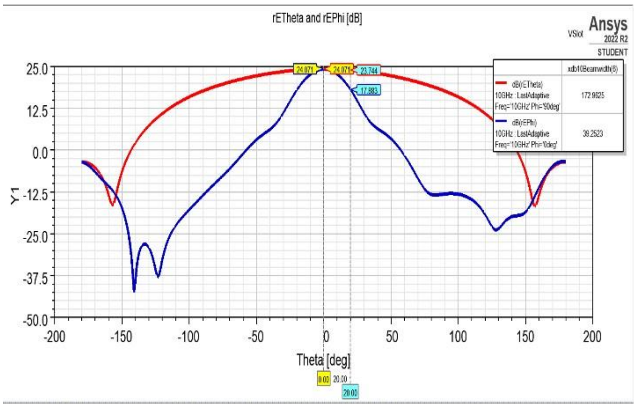


Fig 3

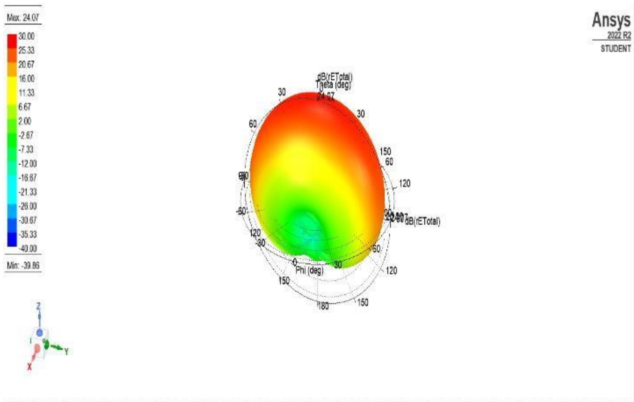


Fig 4

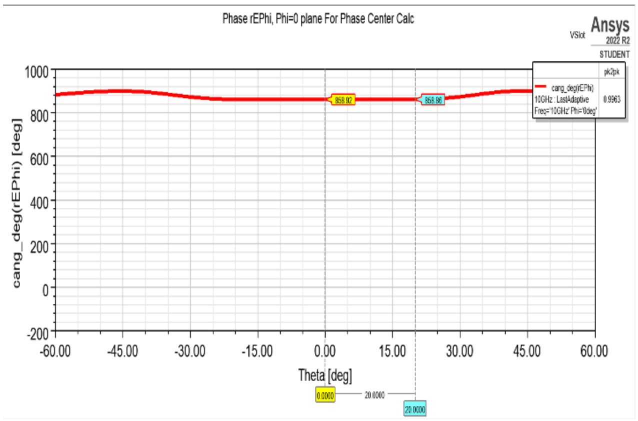


Fig 5

Accuracy scores of machine learning models:

Machine learning model	Accuracy Score
Decision tree regressor	92.68%
Random forest regressor	89.08%
Linear regression	21.81%
Elastic net	20.79%
Lasso	19.76%

VII. APPLICATIONS

- Used in applications of radiation potential.
- Mobile and Satellite Communication
- Radar
- Bio Medical Field
- Radio Frequency Identification
- Air Craft and Ship Antenna

VIII. CONCLUSION

A microstrip patch antenna simulation is carried out. The numerous simulation methodologies are completed. The substrates as well as the patches are made. The patterns of radiation are detected. Ansoft HFSS is used to design V slot Loaded Triangular Microstrip patch antennas at 2.45 GHz. Machine learning is used to train the dataset to find the best accuracy using different machine learning algorithms. The antennas are appropriate for mobile communication, cell phone antennas, and other Wi-Fi applications, among other things.

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