Design and Development of Compact CPW Fed Band-notched Antenna for UWB Application using Machine learning

by

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Table of Contents

Introduction I

- Compact CPW Fed Band-notched Antenna is designed for reducing the dimensions of the radiating element without deteriorating its performance over the UWB range.
- Many opportunities for the designers have been developed with the allocation of UWB band. For the wireless application, plannar antennas are the most suitable candidate because of its large bandwidth, low cost and simple design.
- In previous years many UWB antennas for wireless application have been designed.
- Due to the wide frequency range of UWB antennas the major disadvantage with the UWB systems is its interference with the other existing system.
- Therefore, to avoid the interference with the other wireless system it is necessary to notch out portions of the band.

Introduction II

- In previous years many band notched antennas are designed using the various techniques. But all the previously available antennas are big in size with the small bandwidth.
- Therefore the need of antenna a large ultra wide bandwidth with band-notched characteristics increases.
- We apply machine learning techniques to determine the optimal design parameters for the proposed antenna. We compare the results obtained from high frequency structure simulator (HFSS) with those predicted by machine learning algorithms to confirm the accuracy of these techniques.

Motivation I

- Antennas are becoming more and more complex as modern radar and wireless communications evolve at a rapid pace, offering greater degrees of freedom in design, integration, and manufacturing constraints as well as design goal.
- Today, antenna design is mainly based on actual experiments and electromagnetic simulations of the designer.
- Traditional methods are inherently inefficient and computationally intensive, making them unsuitable when a large number of antenna design features need to be optimized, such as 3D printed antennas.
- For solving complex 3D structural design problems, the (ML) approach can be extremely useful.
- Demand for High speed internet is increasing for future 5G era applications

Literature Review I

- In 2010, researchers Lin Guo, Fengyi Huang , Yan Wang, Xusheng Tang studied dipole antennas and proposed a ultra-wideband (UWB) antenna fed by the line. The antenna is an 18 element log periodic dipole antenna. The internal impedance is quite stable and satisfactory. A suppressed narrow band is further achieved in the wide bandwidth by inserting an H-shaped slot in the center feed line of the antenna. The antenna measures 47.8mm by 42mm by 2mm. The simulation results show that the proposed antenna has stable directional radiation patterns, very low configuration and low fabrication cost , which is suitable for the UWB system.

Literature Review II

- Researchers A. Madannezhad, H. Ameri, S. Sadeghi propose a miniature Vivaldi antenna for the proposed UltraWideband (UWB) applications. The antenna is designed to operate in the entire UWB spectrum from 3.1 to 10.6 GHz. The newly modified feed structure is used to miniaturize the Vivaldi antenna. The designed antenna is manufactured and tested. Experimental results show that the antenna's performance on the entire UWB frequency band is satisfactory.

Objective

- Design a Compact CPW Fed Band-notched Antenna for UWB using ANSYS HFSS.
- Then Write script for proposed Antenna.
- Then perform simulation on the thousand antenna design using script file and generate datasets.
- Perform optimisation on the dataset using machine learning techniques to identify the optimal design parameters for the Compact CPW Fed Band-notched Antenna.
- Compare the results obtained from the ANSYS HFSS(simualation result) with the result predicted by the machine learning algorithm to verify the accuracy of these techniques.
- To predict the antenna parameters from the most accurate model.

Methodology

- Antenna design and simulation using High Frequency Structure Simulator (HFSS).
  - Created an python script for multiple antenna model generation.
  - Simulation done after setting up the parametrics in HFSS to prepare the dataset.
- The antenna is Compact CPW Fed Band-notched. It is working on the Ultra Wide Band range for 5G applications.
- Machine Learning in the optimization of design parameters.
- The proposed optimization methods using Machine Learning aims at speeding up the antenna design process. It will also reduce the efforts and final cost of the process.

Implementation Details I

- A Compact CPW-fed UWB antenna with a inverted U-shaped radiator and two rectangular ground plane is proposed.

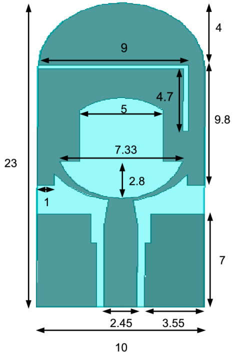


Figure: Geometry of the Proposed CPW-Fed Band-notched UWB Antenna.

Implementation Details II

- Using HFSS We prepared U-Shaped CPW-fed band-notched Antenna.
- We varied some variables for getting optimal design of our Antenna using optimetrics.
- After setting optimetrics and running the simulations for the parameters to be optimized, different data sets are generated for our solution setup.
- The numerical values corresponding to the desired input are saved as comma-separated values (CSV) files with their respective outputs obtained by the simulation to obtain the required dataset.
- After some restructuring of data, it splitted into two parts. first part contains 80% data known as training set and Second part contains 20% data known as test set.
- Model training have been done for these five algorithms:

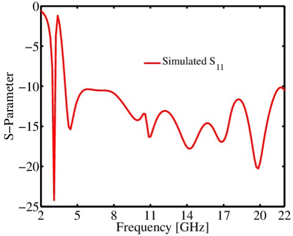
Implementation Details III

- Decision Tree Regression
- Random Forest Regression
- XGB Regression
- K Nearest Neighbor
- Artificial Neural Networks.

- The R2 score and MSE value both are used to evaluate the performance of a regression-based machine learning model.
- Mean Square Error (MSE) have been used as loss function here, which represents prediction in accuracy in regression calculations.
- After selecting the most accurate model, parameters will be predicted by running that regression function for our desired range.

Results I

- The Band-notched Antenna is made of FR_epoxy . The antenna is simulated in HFSS, and the results determined that the studied antenna model is suitable for the 5G applications.



Results II

Figure: Variation of return loss parameter with frequency

- Below table shows the prediction accuracy of the used ML algorithms through the R2 score and MSE value.

	ML Model	R2 score	MSE
1	Decision Tree	0.919	0.933
2	Random Forest (No Tuning)	0.961	0.509
3	Random Forest(Hyper Parameter Tuning)	0.974	0.373
4	XGB Regression	0.939	0.794
5	K-Nearest Neighbor	0.978	0.290
6	Artificial Neural Network	0.924	0.983

Table: Different Model's R2 Score and Mean Squared Error(MSE)

Results III

- both Random Forest With Hyper Parameter Tuning and KNN with n-neighbors=2 give the best prediction accuracy and low MSE value.
  - It gave us the minimum value for S11 equals -35.776 Where Width of L Strip is 0.3mm, Horizontal Length of L Strip is -6.5mm and Vertical Length of L Strip is 10.0mm at the frequency of 19.82GHz. This is the optimal parameter for best antenna design.

Conclusion I

- Based on the results of the comparison with other algorithms, both Random Forest with Hyper Parameter Tuning and K-Nearest Neighbor(KNN) provided more accurate predictions.
- Random Forest with Hyper Parameter Tuning gives R2 score equals 0.974 and MSE value equals 0.373.
- K-Nearest Neighbor with k-neighbors=2 gives R2 score equals 0.978 and MSE value equals 0.290.
- It is difficult to optimize complex antenna designs using a large number of design parameters due to the calculated power limit of the electromagnetic field tool.
- In conclusion, to obtain the optimal antenna design, these modern ML algorithms are more efficient than the traditional method of EM simulation optimization.

Conclusion II

- Through this work, we can say that Machine Learning assisted antenna design methods can play an important role in 5G wireless communication.

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