Design of 5G Dual-Antenna Passive Repeater Based On Machine Learning

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Abstract— **In developing communication systems, to achieve diversion, improve network capacity and to get stability, Small Cells is one of the main approaches. Despite the availability of advanced devices there are various problems that are still unresolved. The problem like blind area is considerably high. To solve the problem of blind area, various steps are taken among which one is to cut short the distances between small base stations and users. But this comes up with complex disturbances and large amount of energy consumption. To overcome this, we can come up with the system of dual-antenna passive repeater which consists of a microstrip patch antenna in combination with an algorithm of machine learning. Our proposed system can be used in co-operation with small base stations to replace the function of the small base station in a certain point and achieve wide-angle scattering to realize the blind area signal coverage. The Unsupervised Learning approach in machine learning can be used to calibrate the parameters of antenna. The conclusion of this study can come up with reduced losses and improved signal power.**

keywords: Microstrip Antenna, Yagi Uda Antenna, Repeater, Machine Learning, Regression Model.

I. INTRODUCTION

The upcoming mobile communication system should have improved gain, low power consumption, very high carrier frequencies with massive bandwidths, extreme base station and device densities, and unprecedented numbers of antennas[1]. It is quite obvious that the demand for data traffic grows exponentially, densifying cells is a feasible solution to increase network capacity.

There are multiple locations which come under the blind area criterion, basements of large buildings, shopping malls etc. The developing communication system and requirement of higher density, low power consumption, enhanced cov- erage, blind area coverage and edge coverage, the number of small cell base stations will be 50 times that of 4G. The energy consumption of small cell network base stations is huge. Research statistics show that the energy consumption of the base station accounts for about 60 percent to 80 percent of the entire communication network. When there is less communication data transmission at night, the energy consumption of the base station will account for about 90 [2]. The antenna is a vital part of any repeater installation. Because the function of a repeater is to extend the range of communications between mobile and portable stations,

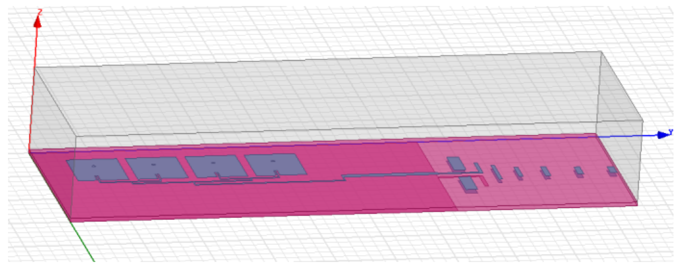

Fig. 1. HFSS Antenna Repeater Design

the repeater antenna should be installed in the best possible location to provide the desired coverage. This usually means getting the antenna as high above average terrain as possible. In some instances, a repeater may need to have coverage only in a limited area or direction. When this is the case, antenna installation requirements will be completely different, with certain limits being set on height, gain and power [3].

In our design we use the four patch microstrip antenna in combination with Yagi-Uda patch antenna. The design is shown in Fig. 1.

A. *Microstrip Patch antenna arrays*

The receiving antenna portion of the dual antenna system, we use a four-element rectangular patch, which is fed with coaxial probe. From the reciprocity of the antenna it can be seen that when the incident wave is irradiated to the patch antenna array, the received electromagnetic wave is transmitted to the Yagi-Uda antenna through the feeding network, and is radiated again, as a result, the direction of the incident wave is changed. The Design of Microstrip antenna is shown in Fig. 2.

B. *Yagi-Uda Antenna Design*

From the reciprocity of the antenna, it can be seen that when the incident wave is irradiated to the patch antenna array the received electromagnetic wave is transmitted to the planar Yagi-Uda antenna through the feeding network, and is radiated again, as a result, the direction of incident wave is changed. The Design of Yagi-Uda Antenna is shown in Fig. 3.

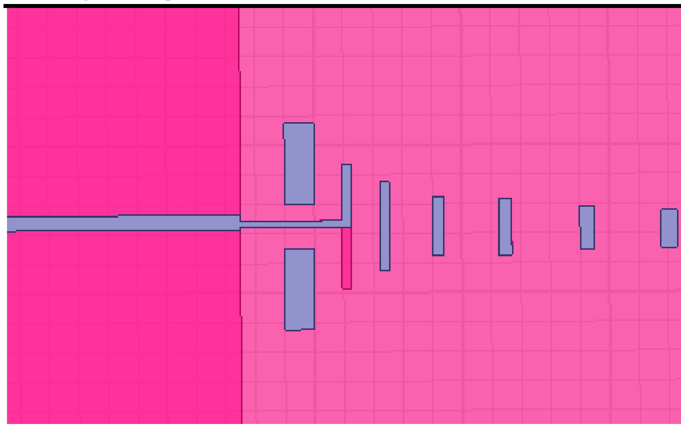

Fig. 2. Yagi-Uda Antenna Design

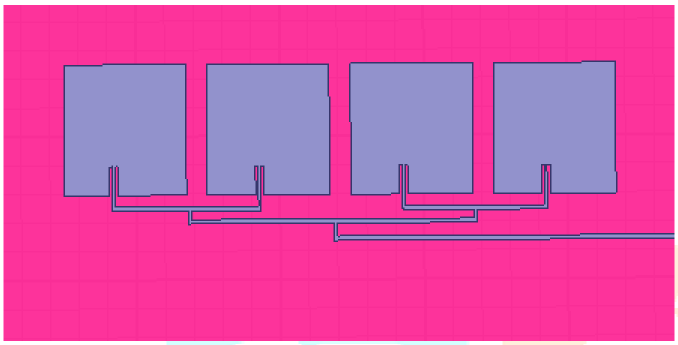

Fig. 3. Microstrip Antenna Design

II. CONCEPT

This project is made to make the availability of network coverage in blind areas. The concept is to try to bend the reflected electromagnetic wave in desired direction. The incident wave is irradiated to the patch antenna array, the received electromagnetic wave is transmitted to the Yagi- Uda antenna, and is radiated again, as a result, the direction of incident wave is changed.

According to the theory of the Yagi-Uda antenna, the director is excited by the induced current generated by the near-field coupling with the driver. At the same time, the induced current of each director also generates a near field and affects other directors. Properly adjusting the distance between the director and the driver can make the phase of the current on the director lag behind with the distance from the driver, so that the maximum radiation direction of the YagiUda antenna points in the direction of the director [4]. In this paper, a set of directors are added on the back of the substrate to better direct the energy generated by the driver to the radiation direction of the antenna, which enhances the directivity and the gain of the antenna.

III. ANTENNA PERFORMANCE

Passive repeaters can be widely used in narrow streets, high-rise commercial areas, multi-walled indoor office areas, shopping malls, subway stations and other terrain complex areas to enhance the signal coverage of blind areas. Taking the indoor wireless propagation model as an example, the propagation of signals within a building is affected by factors such as the layout of the building, the material structure, and the type of buildings.

It is assumed that the transmitter TX and the receiver RX are located at both ends of the corner of the corridor, and the distance from the floor is d0 . The NLOS paths from the transmitter to the receiver mainly include a reflected path, a diffracted path, and a penetrated path. All three paths have high losses. Especially when penetrating obstacles such as walls, the penetration loss can reach 20 dB.

IV. DESIGN PARAMETERS

A. Microstrip Antenna Design

Dimensions:

- Patch :-
X-Size : 9.1 mm Y-Size : 8.5 mm
- Coaxial -
Radius : 0.8 mm Height : 0.64 mm

B. Yagi-Uda Antenna Design

Dimensions:

- Reflectors -
X-Size - 5.5 mm Y-Size - 2 mm
- Directors -
d1 - 0.5λ $d2$ 0.45λ – $d3$ 0.4λ – andsoon...

V. SOLUTIONS

A. Yagi-Uda Results

The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to.

- VSWR: 4.9 dB

B. Repeater performance

An excitation source is simultaneously applied to receiving antennas and transmitting of the antennas to simulate overall gain. A complete pattern of the dual-antenna can be obtained in Fig.6. The total Gain of dual-antenna is 6.1dB. From the reciprocity of the antenna, it can be seen that a certain range of electromagnetic waves received by the patch antenna can be radiated through the planar Yagi-Uda antenna to reach a scattering angle of nearly 60.

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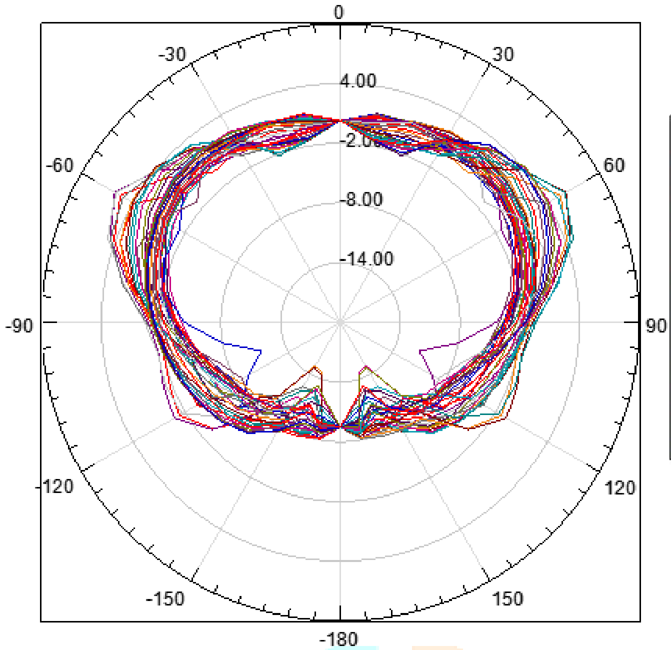

Fig. 4. Radiation Pattern(Gain in DB)

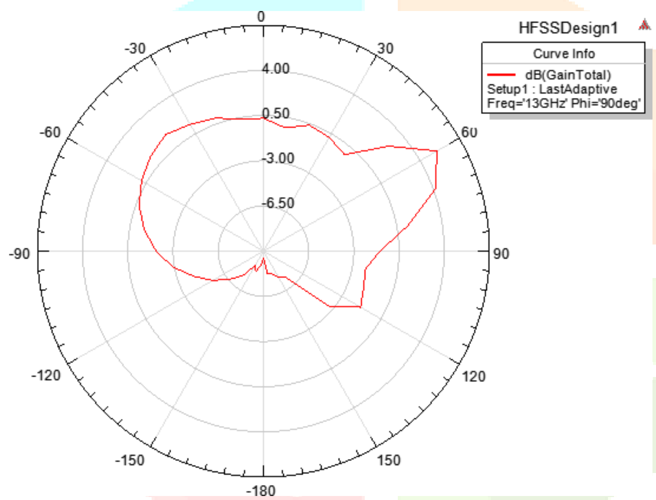

Fig. 5. Radiation Pattern

VI. THE REGRESSION MODEL

Regression analysis consists of a set of machine learning methods that allow us to predict a continuous outcome variable (y) based on the value of one or multiple predictor variables (x).

Briefly, the goal of regression model is to build a mathematical equation that defines y as a function of the x variables. Next, this equation can be used to predict the outcome (y) on the basis of new values of the predictor variables (x).

Linear regression is the most simple and popular technique for predicting a continuous variable. It assumes a linear relationship between the outcome and the predictor variables. Here, in this project we have created a set of data with

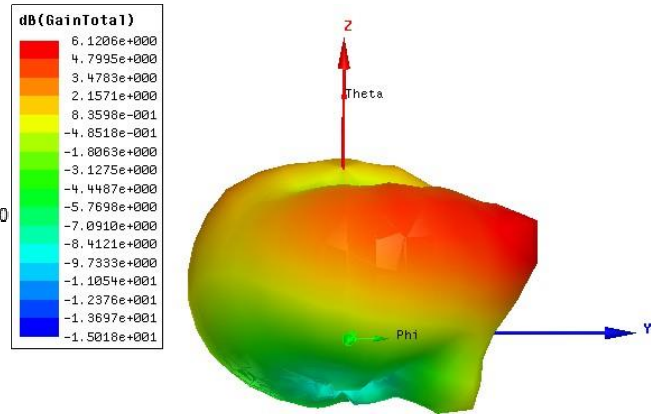

Fig. 6. Polar Plot output

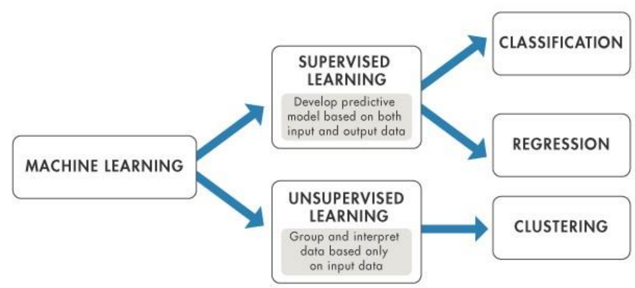

Fig. 7. Machine Learning - Regression model

multiple parameters with different inputs and outputs. We have used Regression model approach to compute the best prediction of antenna design.

VII. REGRESSION MODEL - PYTHON

'Operating Frequency', 'Return Loss', 'Gain in dB', 'Vswr', 'Bandwidth(GHz)', 'Efficiency', 'Directivity', 'Power Radiated(W)', 'Power Accepted(W)' are the parameters used as input for our program. 'Size of Patch (X-Axis) in mm', 'Size of Patch (Y-Axis) in mm', 'Distance between Patches in mm', 'Size of 1st Director (X- Axis)', 'Size of 1st Director (Y-Axis)', 'Distance between Directors', are the outputs that are predicted individually by our model.

VIII. PREDICTIONS - OUTPUTS

As per our calculations the predicted outputs are as fol- lows: Size of Patch (X-Axis) in mm : 1.32 Size of Patch (Y-Axis) in mm : 2.26 Distance between Patches in mm : 6.64 Size of 1st Director (X-Axis) in mm : 2.36 Size of 1st Director (Y-Axis) in mm : 6.80 Distance between Directors in mm : 5.79

IX. CONCLUSION

In this paper, we study the blind area signal coverage problem in 5G communication, and propose a dual antenna passive repeater design. The simulation results show that the design can not only improve the traditional Yagi-Uda antenna, but also can achieve a scattering angle of nearly 60, enhance the receiving power by 2 to 6.1dB under the same transmitting power, which significantly improves the signal quality of the blind areas. Our Machine Learning Regression Model has successfully predicted the appropriate antenna size parameters.

X. ACKNOWLEDGEMENT

This paper can be used to develop Repeater with scattering angle more than 60 and Machine Learning Regression model can be used to design best possible antenna of specific parameters. The authors declare that there is no conflict of interest regarding the publication of this paper. The data used to support the findings of this study are included within the article.

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