**IOSR Journal of Engineering (IOSRJEN)** **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Special Issue || Dec. 2019 || PP 36-41
International Conference on Management Practices, Innovations & Research 2019

# Design of Dual-Antenna Passive Repeater Basedon Machine Learning

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***Abstract:*** *In 5G communications, Small cells are one of the main approaches to achieve data diversion and improve network capacity. The problem of blind area is partially solved by this way, because the distances between small base stations and users are cut short. However, the intensive deployment of small base stations will bring about complex disturbances and large amount of energy consumption. To overcome this challenge, we propose a new approach of dual antenna passive repeater, which consists of a four-element patch antenna array, a feeding network and an improved micro-strip antenna with added parasitic patches. It can be used in co-operation with small base stations to replace the function of the small base station in a certain point, change the beam pointing, and achieve wide-angle scattering to realize the blind area signal coverage. The unsupervised learning which is a branch of machine learning is used to optimize the antenna parameters. Simulation results show that our proposed passive repeater can effectively reduce the path loss and improve the signal power of the receiving end.*

## I. Introduction

THE fifth generation (5G) of mobile communication system should have ultra-high spectrum utilization and ultralow power consumption, and will be significantly improved in transmission rate, resource utilization, wireless coverage performance and user experience, compared with 4G. The demand for future data traffic grows exponentially, and the most feasible solution to increase network capacity is cellular densification. However, more cellular network infrastructures and data lead to a huge energy consumption in mobile cellular networks, and Small Cell Networks (SCNs) technology therefore comes to its way. The small base stations with dense deployment are low in transmission power, close to the users, small in size and low in cost.

Intensive deployment of SCNs can also alleviate the problem of radio blockage in some blind areas. In the macrocellular mobile communication environment, the large penetration loss and reflection loss caused by barrier occlusion greatly weaken the signal level from the base station to the user's Non-Line-of-Sight (NLOS) path, dramatically reducing the efficiency of the data transmission and cutting down the Signal Noise Ratio (SNR). These areas constitute a blind areathatcan'tbeilluminated by the signal. The small base stations can be widely deployed in the narrow streets, high buildings in the commercial area, multiple wall-blocking indoor office areas, shopping malls, subway stations and other complex areas surrounded by walls, forming a full coverage of communication. These small base stations can effectively increase the channel capacity and improve the communication quality while realizing data shunting. However, there are many problems in the intensive deployment of small base stations.

i) The interference between the base stations is very serious and complex, causing severe impact on the user experience in the small cell, especially around the edge. Since the small cell has a smaller coverage radius and is closer to the user, the interference between small cell networks is more serious than that between traditional macro-cells. In a hybrid network, cross-layer interference also exists between small cells and macro-cells.

ii) 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.

Due to the random deployment and resource allocation of small base stations, it is difficult to find a balance between distance and quantity. In order to solve this contradiction, many passive repeaters are designed to be used in cooperation with the small base station to replace the function in a certain position. By installing a passive repeater at the elevation point or at the corner as shown in Fig. 1, a reradiation path is established in the NLOS channel environment causing that beam bypasses the obstacle and points to the desired location of the user. For Multiple-Input-Multiple-Output (MIMO) systems, each antenna transmits and receives signals independently, and the added path can effectively improve the system performance.

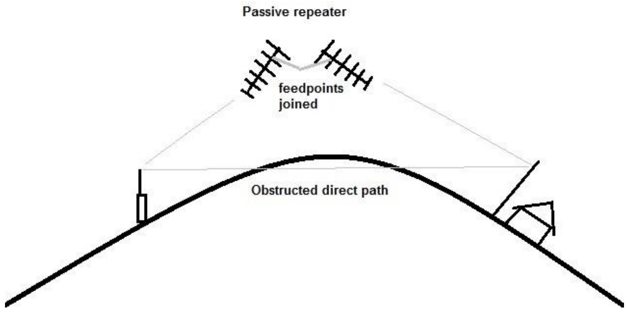


**Fig. 1.** Fig. 1. Passive repeaters used in complex communication environ- ments. (Image reference Google)

Now, there are already many passive repeater designs, but there are problems such as large size and small gain. So we proposed a passive repeater based on a dual-antenna system. It is composed of a four-element patch antenna, afeeding network, and an improved micro strip antenna with added parasitic patches. Traditional antenna design is a process that relies on experience and simulation to continuously approach the optimal solution. Machine learning is a new discipline developed from the field of computer science. It studies and constructs algorithms that can learn and predict complex scenes. Recently, machine learning have been applied in the antenna design process. It can achieve the optimal performance of the antenna more intelligently and more efficiently as well as shorten the design cycle. Here we use the unsupervised learning method which is a part of machine learning to optimize antenna parameters to get the optimal size to meet design specifications. The remaining of this paper is organized as follows. Section II introduces the structure of dual-antenna based passive repeater and the optimization process using genetic algorithm. Section III illustrates the simulation results of the improved microstrip antenna and dual-antenna system . Section IV shows the overall antenna performance assessment, followed by Section V, which concludes the paper.

## II. Passive Repeater design

### *A. Dual-antenna system structure*

In 5G communication, the dual-antenna system structure used as a passive repeater. The repeater consists of three components: a four-element patch antenna array, a feeding network, and an improved microstrip antenna. 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 microstrip antenna through the feeding network, and is radiated again, as a result, the direction of incident wave is changed.

### *B. Two antenna structures*

#### *1) The patch antenna arrays*

For the receiving antenna portion of the dual antenna system, we use a four-element rectangular patch, which is

fed with coaxial probe. According to the relevant formula, we can get the initial size of the patch. As shown in Fig. 2, the four-element rectangular patch antenna array is fed in parallel by a power divider and the incident wave can enter the feeding network and output to the next stage. It is worth noting that the size of the patches is only the initial value,after which we will use the machine learning algorithm to optimize the parameters to make the antenna more satisfying our performance requirements.

#### *2) Improved Microstrip Antenna*

The output of the feeding network is connected to a simplified microstrip antenna. It has a pair of drivers, five pairs of directors printed on both sides of the substrate and a large ground plane as a reflector. The design of the traditional microstrip antenna usually requires a balun structure, so that the input ends of the two arms of the driver have equal amplitude and reverse current, so as to achieve the directional pattern. A simplified feed microstrip antenna was proposed earlier. The front side of the substrate is printed with an arm of an driver and is connected to the feed line via a microstrip line. The other arm of the driver is printed on the opposite side of the substrate in the opposite direction and is connected to the truncated ground plane through another microstrip line. Using the characteristics of the current in the ground plane, the current in the two arms

of the driver is reversed. The complex balun structure is eliminated and the length of the transmission line is greatly reduced. Although the antenna designed can obtainrelativelyhighgain, thebandwidthisnarrow and cannot meet the requirements of modern communications. Therefore, on this basis, making full use of the space on the antenna and adding two pairs of parasitic patches and directors to improve the relative bandwidth of the antenna. In order to reduce the gain loss due to bandwidth expansion, a set of directors corresponding to the front face is added to the back of the substrate. The effect of the director is enhanced, so that the gainof theantennaisim proved.
The center frequency of the antenna is set to 2.45 GHz. The substrate is Rogers RO4350 with a relative dielectric constant of 3.66 and a thickness of 3.175mm. The width of the microstrip can be determined based on the center frequency and other parameters. It can be obtained that the initial length of the driver is dr = 0.5g, the initial value of the director is d1 = 0.45g, and the horizontal distance between the ground plane and the driver is g = 0.25g. The distance between the driver and the director and the spacing between the directors areallequal.Forbetterdirectionality,thelengthofthedirector graduallydecreases.
From the theory of microstrip antennas, it can be seen that adding a parasitic patch near the driver can effectively change the resonant mode to a multi-resonant point, thereby broadening the bandwidth of the antenna. According to the theory of the microstrip 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 microstroip antenna points in the direction of the director. 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 enhancesthedirectivityandthegainoftheantenna.

### *C. Size selections using unsupervised learning mothod*

The antenna size we obtained above is the initial value obtained by experience. Every parameter change in the model will affect the performance of the antenna. In reality, due to the large number of parameters, and each parameter has a variety of values, it is difficult to obtain a set of optimal solutions based on experience or simple sweeping. Recently, machine learning algorithm is widely used in the communi- cation system and antenna parameter selection process, and the results can be constantly modified through data analysis. Therefore, we choose a typical unsupervised learning method in the field of machine learning to optimize the parameters of the antenna to obtain the appropriate parameter values that meet the requirements of the index. Unsupervised learning method is a method to search for the best by simulating the natural evolutionary process. It simultaneously processes multiple individuals in a population and evaluates multiple solutions in the search space through a fitness function. New solutions are continuously generated by the genetic operators until a set of optimal solutions satisfying the constraints is found. The search does not rely on gradient information and has strong robustness. Therefore, it has been widely used in the field of electromagnetic engineering, especially antenna design. The specific process is shown in figure below.

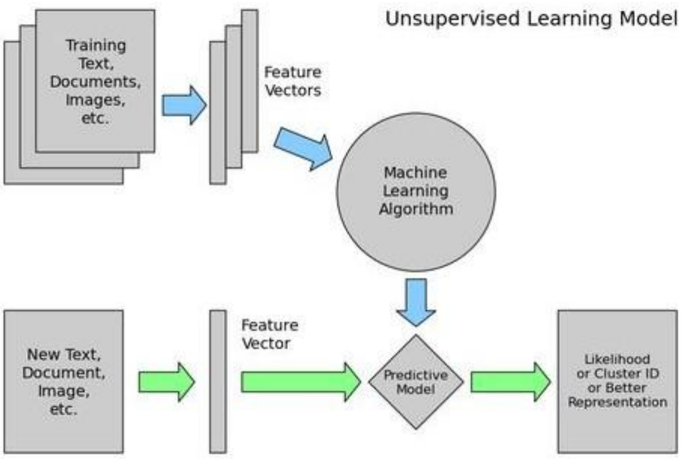


**Fig. 2.** Using Machine Learning to select antenna size (Image reference Google)

Through the selection and optimization of antenna param- eters by algorithms in Unsupervised learning method, we can found more suitable antenna size values.

## III. Simulation results

### *A. Improved microstrip antenna simulation*

Our improvement on the antenna is mainly to add dou- blesided director and parasitic patch, and optimize the antenna parameters by machine learning algorithms. So we use the op- timized parameters for antenna simulation. From the patterns in figure below, it can be seen that the problem of the deviation of the traditional Microstrp antenna pattern is solved because of the double-sided printing has a strong directivity.

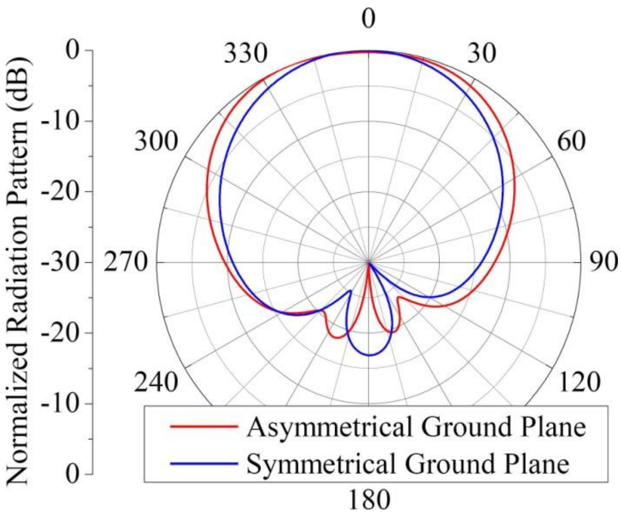


**Fig. 3.** Gain of microstrip antenna (Image reference Google)

As shown in Fig.6, when the return loss is lower than -15 dB, the antenna obtains a bandwidth more than 300 MHz due to the increase of the parasitic patch.

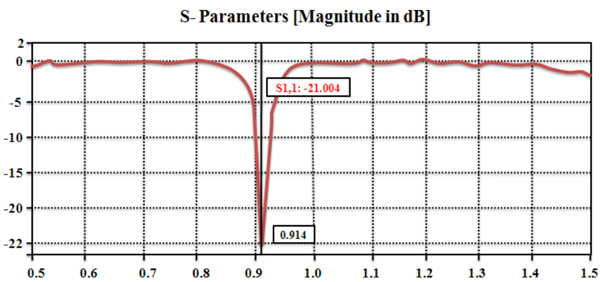


**Fig. 4.** Return Loss (Image reference Google)

### *B. Dual-antenna System Gain*

An excitation source is simultaneously applied to the re- ceiving antennas and the transmitting antennas to simulate the overall gains G1 and G2. A complete pattern of the dual- antenna can be obtained, as shown in Fig. 7 and Fig. 8. It can be seen that the patch antenna and the Yagi-Uda antenna have good directivity, and the patterns do not interfere with each other and can achieve a gain of G1 = 7.4dB and G2 = 5.4dB. 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 microstrip antenna toreachascatteringangleofnearly90.

## IV. Antenna Performance Evaluation

Passive repeaters can be widely used in narrowstreets, high-risecommercialareas,multi-walledindoorofficeareas,shopping malls, subway stations and otherterraincomplexareastoenhancethesignalcoverageofblindareas. Takingthe indoor wireless propagation model as an example, the propagation of signalswithinabuildingisaffected byfactorssuchasthelayoutofthebuilding, thematerialstructure,andthetypeof buildings.ItisassumedthatthetransmitterTXandthereceiverRXarelocatedatbothendsofthecornerofthecorridor,andthedistancefromthefloorisd0. TheNLOSpathsfromthetransmittertothereceivermainlyincludeareflectedpath,adiffractedpath, and a penetrated path.Allthreepathshavehighlosses.Especiallywhenpenetratingobstaclessuchaswalls,thepenetrationlosscanreach20dB.Thepassiverepeaterdesignedinthispaperisplacedhori-zontallyatthecorner,withadistanceoftrfromtheTXandrrfromtheRXhasareceivegainofG1andatransmitgainofG2.Thepatchantennareceivingsurfaceisperpendicularto the incident direction, and the microstripantennapointsto the receiving antenna, as shown in Fig. 9. The shadedpartindicates the wall. When the reisapassiverepeater, anindependentre-radiationpathisadded.ForMIMOsystems, the increased path helps improve system performance.

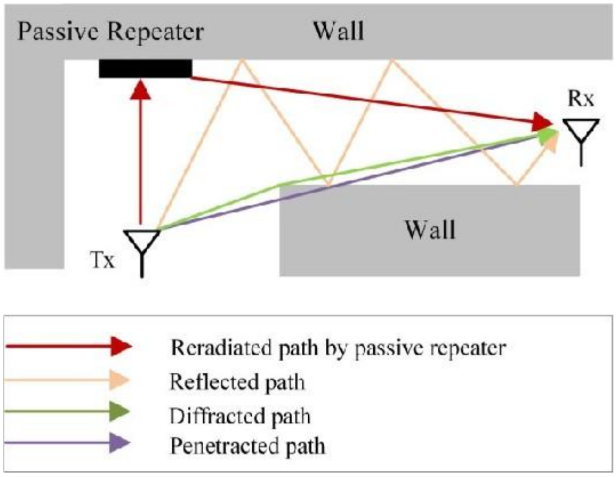


**Fig. 5.** Passive repeater applied to indoor environment (Image reference Google)

Compared with the penetration loss, the passive repeater itself has small losses and can be ignored. When it is present, the path from TX to the passive repeater and from the passive repeater to RX can be viewed as a free-space propagation model.

## V. Conclusion

In this paper, we study the blind area signal coverage problem in 5G communication, and propose a dual antenna passive repeater design based on genetic algorithm. The sim- ulation results show that the design can not only improve the traditional Yagi-Uda antenna, but also can achieve a scattering angle of nearly 90, enhance the receiving power by 6.8 to 12.8 dB under the same transmitting power, which significantly improves the signal quality of the blind areas.

## References

[1]. J. G. Andrews et al., ”What Will 5G Be?,” in IEEE Journal on Selected Areas in Communications, vol. 32, no. 6, pp. 1065-1082, June2014.

[2]. M. Wollschlaeger, T. Sauter and J. Jasperneite, ”The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0,” in IEEE Industrial Electronics Magazine, vol. 11, no. 1, pp. 17-27, March2017.

[3]. G. A. Akpakwu, B. J. Silva, G. P. Hancke and A. M. Abu-Mahfouz, ”A Survey on 5G Networks for the Internet of Things: Communication Technologies and Challenges,” in IEEEAccess,vol.6,pp.3619-3647,2018.

[4]. P. Gandotra, R. K. Jha and S. Jain, ”Green Communication in Next Generation Cellular Networks: ASurvey,”inIEEEAccess,vol.5,pp.11727-11758,2017.

[5]. A. Kiani and N. Ansari, ”Edge Computing Aware NOMA for 5G Networks,” in IEEE Internet of Things Journal,vol.5,no.2,pp.12991306,April2018.

[6]. J. Ni, X. Lin and X. S. Shen, ”Efficient and Secure Service-Oriented Authentication Supporting Network Slicing for 5G-Enabled IoT,” in IEEE Journal on Selected Areas in Communications,vol.36,no.3,pp.644-657,March2018.

[7]. J. Zhang, Peilin Hong, Kaiping Xue and Hao Zhang, ”A novel power control scheme for femtocell in heterogeneous networks,” 2012 IEEE Consumer Communications and Networking Conference (CCNC), Las Vegas, NV, 2012, pp. 802-806.

[8]. P. Wang, M. Liu, Z. Cheng, Y. Yang and S. Zhang, ”Key technology research on 5G mobile communications power system,” 2017 IEEE International Telecommunications Energy Conference (INTELEC), Broadbeach, QLD, 2017, pp.142-148.
[9]. L. Li, Q. Chen, Q. Yuan, K. Sawaya, T. Maruyama,
[10]. T. Furuno, and S. Uebayashi, “Novel broadband planar reflectarray with parasitic dipoles for wireless communication applications,” IEEE Antennas Wireless Propag. Lett., vol. 8, pp. 881–885, 2009.
[11]. J. Huang, ”Analysis of a microstrip reflectarray antenna for microspacecraft applications,” TDA Progress Report42-120,pp.153173,Feb.1995.
[12]. L. Li, Q. Chen, Q. Yuan, K. Sawaya, T. Maruyama, T. Furuno, and S. Uebayashi, ”Frequency Selective Reflectarray Using Crossed-Dipole Elements With Square Loopsfor
[13]. Wireless Communication Applications,”IEEE Trans. Antennas Propag., vol. 59, no. 1, pp. 89-99, 2011.
[14]. X. Wang, L. Gao, S. Mao and S. Pandey, ”CSI-Based Fingerprinting for Indoor Localization: A Deep Learning Approach,” in IEEE Transactions on Vehicular Technology, vol.66,no.1,pp.763-776,Jan.2017.
[15]. H. Huang, J. Yang, H. Huang, Y. Song and G. Gui, ”Deep Learning for Super-Resolution Channel Estimation and DOA Estimation Based Massive MIMO System,” in IEEE Transactions on Vehicular Technology, vol. 67, no. 9, pp. 8549-8560, Sept.2018.
[16]. X. Gao, L. Dai, Y. Sun, S. Han and I. Chih- Lin, ”Machine learning inspired energy-efficient hybrid precoding for mmWave massive MIMO systems,” 2017 IEEE International Conference on Communications (ICC), Paris, 2017, pp.1-6.
[17]. A. Alkhateeb, S. Alex, P. Varkey, Y. Li, Q. Quand Tujkovic, ”Deep Learning Coordinated Beamforming for Highly-Mobile Millimeter Wave Systems,” in IEEE Access, vol. 6, pp. 37328-37348, 2018.
[18]. K. Carver and J. Mink, ”Microstrip antenna technology,” in IEEE Transactions on Antennas and Propagation,vol.29,no.1,pp.2-24,Jan1981
[19]. G.Zheng,A.A.Kishk,A.W. GlissonandA. B. Yakovlev, ”Simplified feed for modified printed Yagi antenna,” in Electronics Letters, vol. 40, no. 8, pp. 464-466, 15 April2004.
[20]. NI Guo-qi, ZHANG Tao, NI Wei, LI Shu-bin, ”Amelioration of the Quasi-Yagi Antenna,” in Journal of Microwaves, 2013,(1);51-54
[21]. Y. Qian, W. R. Deal, N. Kaneda and T. Itoh, ”Microstrip-fed quasiYagi antenna with broadband characteristics,” in Electronics Letters, vol. 34, no. 23, pp. 2194-2196, 12 Nov1998.
[22]. Kai-Fong Lee, S. R. Chebolu, Wei Chen and R. Q. Lee, ”On the role of substrate loss tangent in the cavity model theory of microstrip patch antennas,” in IEEE Transactions on Antennas and Propagation, vol. 42, no. 1, pp. 110-112, Jan1994.
[23]. J. F. Lin and Q. X. Chu, ”Enhancing Bandwidth of CP Microstrip Antenna by Using Parasitic Patches in Annular Sector Shapes to Control Electric Field Components,” in IEEE Antennas and Wireless Propagation Letters, vol. 17, no. 5, pp. 924-927, May2018.
[24]. N. Kaneda, W. R. Deal, Yongxi Qian, R. Waterhouse and T. Itoh, ”A broadband planar quasi-Yagi antenna,” in IEEETransactionsonAntennasandPropagation,vol.50,no. 8, pp. 1158-1160, Aug 2002.
[25]. K. Deb, A. Pratap, S. Agarwal and T. Meyarivan, ”A fast and elitist multiobjective genetic algorithm: NSGA-II,” in IEEE Transactions on Evolutionary Computation, vol. 6, no.2,pp.182-197,Apr2002.
[26]. J. Du, D. Chizhik, R. Feick, G. Castro, M. Rodr´ıguez and R. A. Valenzuela, ”Suburban Residential Building Penetration Loss at 28 GHz for Fixed Wireless Access,” in IEEE Wireless CommunicationsLetters.
[27]. J. Huang, C. Wang, R. Feng, J. Sun, W. Zhang and Y. Yang, ”MultiFrequency mmWave Massive MIMO Channel Measurements and Characterization for 5G Wireless Communication Systems,” in IEEE Journal on Selected Areas inCommunications,vol.35,no.7,pp.15911605,July2017.
[28]. N.S.Perović,P.Liu,M.DiRenzoandA. Springer, ”Receive Spatial Modulation for LOS mmWave Communications Based on TX Beamforming,” in IEEE Communications Letters, vol. 21, no. 4, pp. 921-924, April 2017.
[29]. J. Ryan, G. R. MacCartney and T. S. Rappaport, ”Indoor office wideband penetration loss measurements at 73 GHz,” 2017 IEEE International Conference on Communica- tions Workshops (ICC Workshops), Paris, 2017, pp.228-233.