International Journal of Electrical and Electronics Engineers
Volume 14, Issue No. 02, July-Dec 2022
ISSN (O) 2321-2055
ISSN (P) 2321 -2045

HALF WAVE DIPOLE ANTENNAS OPTIMIZATION AND CLASSIFICATION APPROACHES :REVIEW

Sonu Rani[1], Dr. Rachna Mehta [2]

[1, 2] Department of Physics, Om Sterling Global University, Hissar (Haryana), India

ABSTRACT

Since last few years, the concept of Machine Learning (ML) has been a go to tool for science and engineering with its omni directional applications in automating difficult and long tasks with exclusive detailing. It is in its infancy but a phenomenon in technology industry with the machine leaning users changing the foundations of hundreds of industries and also research works especially in the field of antenna.We provide a comprehensive summary of the literature on machine learning for antenna design and optimization. This includes an examination of the techniques and algorithms used to generate antenna parameters in accordance with the desired radiation characteristics and other antenna specifications. To aid those interested in working with a certain class of antennas in their machine learning projects, we have categorized the many antennas under study depending on antenna type and configuration.

Keywords:*Dipole Antenna, Machine Learning*

I. INTRODUCTION

In this age of Big Data, ML has become a great head turner in this field [1-3]. Also, ML is showing a well-drawn promise in the optimization of antenna by estimating the behaviour of antenna and also speeding up the optimization with accuracy and efficiency. Antenna being of different shapes, they do not have finite and closed form solutions. So, with approximation of solutions, the physical insight can be gained on design of antenna. Integral equations through Method of moments (MoM) [4] are used for solving the solutions of linear antenna. With the computers advanced form, the possibility to solving Maxwell's equations by integration and differentials. Unknowns are appended for solving more complicated antenna design through differential equations as they can be solved involving larger unknowns. The disadvantages were relative size of memory and CPU usages with structure and parameters of antenna. Development of method called iterative method helped in reducing of the memory and CPU requirements. The common method used in designing antenna is numerical analysis. Numerical analysis methods widely used in exercising and testability of antenna are finite difference time domain for antenna radiation [5], finite element method electromagnetic [6], and Method of Moments applied to antenna [7]. Radiation field of antennas can be observed using optical approximation method. Simulations in antenna require the solving partial differential equations with boundary conditions. These can be done through computers and EM simulators. To reduce these irregularities and increase optimized results, ML is chosen to be a perfect method. ML remains a part of artificial intelligence (AI) emphasizing on extracting information out of data which makes it being used every time for statistical data science field [3,8,9]. This paper provides a detailed survey of few

ISBN : 978-93-91535-36-0

antennae designs which was obtained from the various ML methods. Various designs of antenna are listed basing on the type and their category making it fruitful for beginners to understand the concept and application of ML Techniques. This paper presents an overview on dipole antenna [10-12], with a major focus on investigating its usage in antenna design applications. The concept of machine learning is studied along with its different learning algorithms. Next, an extensive review of several antenna designs is investigated. The methods used to design the antennas using machine learning in each is presented, along with the outcome of each algorithm used.

1.1 Dipole Antenna

It is the simplest and most widely used class of wire antenna. Dipole antenna is also known as doublet or dipole aerial Dipole antenna is categorised into Hertzian dipole, half -wave dipole, small dipole etc. It consists of two conductive elements such as rods or wires as it seen from the name ‘ dipole’ means two poles i.e., two conductive elements [13-15]. The most suitable dipole antenna is one whose overall dimension lies in the range of $3\lambda/2 > l > \lambda/2$ .here λ= free space wavelength. Current flows in these two conductive elements and the current and the associated voltage causes an electromagnetic wave or radio signal to be radiated outwards from the antenna.

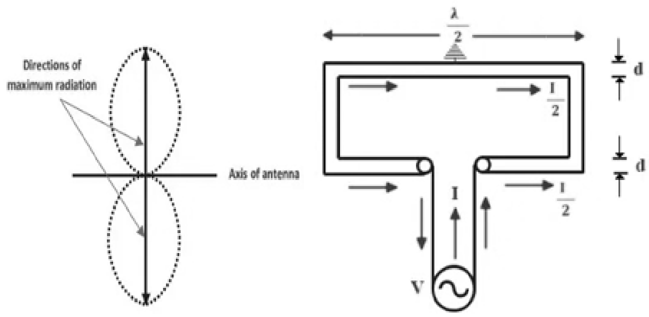

Fig1: Basic dipole antenna and its movement [16]

The antenna wire or rod is split at the center, and the two sections are separated by an insulator, these sections are known as antenna sections. These two antenna sections are connected to a feeder or coaxial cable at the end closest tom the end of antenna. Here wavelengthh is the distance between two consecutive maxima or minima points. In between the two sections of dipole antenna R-F voltage source is applied .the current flowing through the two consecutive elements produces a radio signal or an e-m wave signal to be radiated from the antenna.

- At the center of dipole antenna – current max.
- At the poles or ends of dipole antenna – current min.

In dipole antenna lengthg of the metal wire is approx. half of the max. wavelengthi.e $\lambda/2$ in free space at freq. of operation.

II. DESIGNING OF DIPOLE ANTENNA

2.1 Designing

Dipole antennas operate on HF (high freq) , UHF and VHF bands of radio frequency system.

ISBN : 978-93-91535-36-0

A. Selection of Length of the Dipole Antenna: As we know that the wavelength of a radio wave or any other wave varies inversely proportional to the frequency. it is given by:

$$\lambda \propto \frac{1}{f} = \frac{c}{f} \quad (1)$$

Where, C = velocity of light; f = frequency, in Hertz, λ= wavelength, in meter. Thus,

$$\lambda = \frac{300}{f(MHz)} \quad (2)$$

Now, at a half-wavelength, the length of the antenna is given by,

$$\frac{\lambda}{2} = \frac{300}{2*f(MHz)} = \frac{150}{f(MHz)} = \frac{150*3.28}{f(MHz)} = \frac{492}{f(MHz)} feet$$

$$\frac{150 * 39.37}{f(MHz)} = \frac{5905}{f(MHz)} \; inches \quad (3)$$

Thus, from equation (3) we can say that, if we used a 1 MHz radio transmitter, then the basic length of the antenna wire will be 150 meters or 492 feet or 5905 Inches. This is correct if we neglect the "end effect". This "end effect" is the dielectric effect of the air at the end of the antenna that increases the effective length of the antenna. Due to the end effect, an antenna wire acts as 5% longer than the actual length. This will produce interference between the exciting and oscillating currents and due to that oscillation amplitude may be weakened. To get the practical length of the antenna wire, the value multiplied by a factor K to the basic length of the antenna wire, i.e.,

$$\frac{\lambda}{2} = \frac{492 * K}{f(MHz)} = \frac{492 * 0.95}{f(MHz)} = \frac{468}{f(MHz)} feet \quad (4)$$

The value of K depends on the thickness of the conductor and the operating frequency. This value of K is accurate for antenna wire at a frequency of up to 30 MHz.

B. Selection of the Feed Impedance or Radiation Resistance

The feed impedance of a dipole is defined by the ratio of the voltage and the current at the feed point. It is typically fed at the voltage minimum and current maximum point.

The radiation resistance or an input feed impedance of an ideal dipole antenna in free space can be approximately modelled by a 73 Ω impedance and under practical conditions it varies from 60 Ω to 70 Ω. The antenna impedance can be changed by varying the length or shape of the wires.

- *Dipole antenna:* It can be fed with coaxial cable of 75 Ω two wire which is a good match for a half-wave dipole antenna.
- *Half-wave dipole:* It can be fed with a transmission line of impedances 300 Ω, and 600 Ω open wire line with folded dipoles according to the power handling capabilities.

C. Use of balanced feeder: The dipole antenna is the balanced antenna. Hence, it is necessary to use a balanced feeder. A balanced feeder consists of two parallel conductors. The currents flowing in both the conductors are

ISBN : 978-93-91535-36-0

equal in magnitude but opposite directions. Hence, the radiating field from them cancels out and no powerdissipated. The spacing between the conductors has normally kept about 0.01 wavelengths. If a coaxial feeder needs to be used, then the balanced balun must be used.

D. Strain Insulator: A strain insulator is an electrical insulator that is designed to withstand the pull of a suspended electrical cable or wire. It is inserted between two lengths of the conducting wire, to isolate them electrically from each other. It is used in overhead electrical wire, to support radio antennas and overhead power lines.

E. Coaxial Cable: The most common feeder that is used to feed the antenna is coaxial cable or coax cable. It is often referred to as RF cable. A coaxial cable carries current in both the conductors. These currents are equal in magnitude but opposite directions. Due to that, all the radiating fields are linked within the cable and hence they are canceling out each other. Thus, there is no radiating field outside the cable hence it is not affected by nearby any objects. Therefore, it is best suitable as a feeder to the dipole antenna. Thus, overall design of a 1 MHz dipole antenna is shown in the figure below.

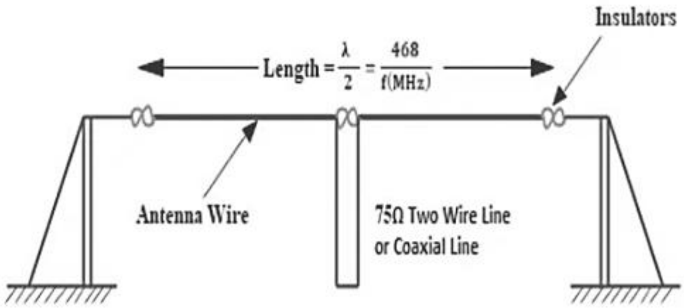

Fig 2: 1 MHz Dipole Antenna Design [16]

2.2 Type of Dipole Antenna

*A. Folded Dipole Antenna:*A folded dipole antenna is an array of the two-dipole antenna. If two dipole antennas are connected in parallel to forms a thin wire loop, then it is called a folded dipole antenna.

- Two-Wire Folded Dipole Antenna: If two dipole antennas are connected in parallel to form a thin wire loop, then it is known as a two-wire folded dipole antenna as represented in fig 1.1. It can be fed with a conventional 300 Ω open-wire transmission line without any matching device.
- *Three-Wire Folded Dipole Antenna:* If three dipole antennas are connected in parallel to form a thin wire loop, then it is known as a three-wire folded dipole antenna or Folded Tripole antenna as shown in fig 1.2. can be fed with a conventional 600 Ω two-wire open transmission line without any matching device.

B. FM Dipole Antenna: FM dipole antenna is defined as the vertically polarized half-wave half dipole antenna. The FM dipole antenna is mostly used as it is to build and it is suitable to provide improved reception of VHF

ISBN : 978-93-91535-36-0

FM broadcast. The FM dipole antenna is shown in the fig 3a(right). The FM dipole antenna is generally used for FM broadcasting frequency range between 88 MHz to 108 MHZ. The FM dipole antenna is generally used for FM broadcasting frequency range between 88 MHz to 108 MHZ.

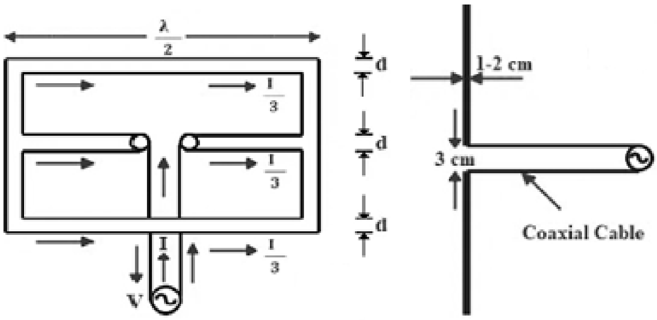

Fig 3a: Folded Tripole Antenna (left) and FM Dipole Antenna (right) [16]

C. Fan Dipole Antenna: Fan dipole or multi-band wire antenna is one in which multiple dipoles are connected with a common feed line, and they are spread out like a fan hence it is called a fan dipole antenna.

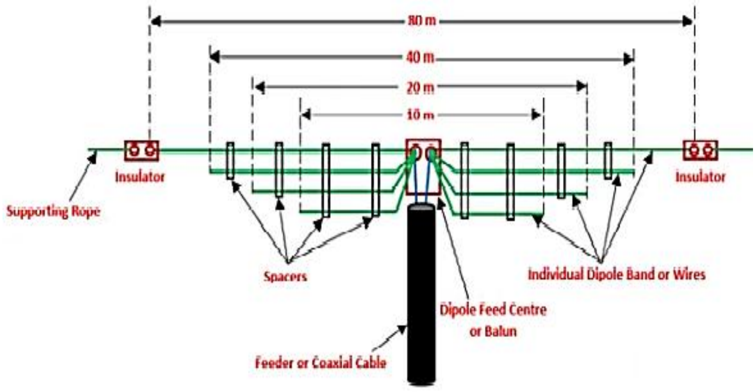

Fig 3b: Fan folded [i16]

The fan dipole antenna is shown in the above figure. It is 4 Bands fan dipole antenna. Here, we used 80 m, 40 m, 20 m, and 10 m multi-band dipole that are connected in parallel with a common feeder line. When 80 m dipole is radiating means the current pass through 80 m dipoles, in this condition, we receive signal only from 80 m bands because it has a lower impedance while other 40 m, 20 m, and 10 m band have a higher impedance compared to the 80 m radiating element. Similarly, when the 40 m dipole is radiating, we only receive the signal from the 40 m bands because it has a lower impedance compared to the other dipole. Note that according to Kirchhoff's Current Law, other dipoles are also radiating but not efficiently.

D. Half-Wave Dipole Antenna: The Half-Wave Dipole Antenna is the most widely used type of dipole antenna. As the name suggests that, the total length of the dipole antenna is equal to the half-wavelength $\frac{\lambda}{2}$ at the frequency of operation. The half-wave dipole antenna can operate around 3 kHz to 300 GHz frequency range;

National Conference on Research Developments in Arts, Science, Humanities & Management
Abhilashi College of Education, Tehsil Balh, Himachal
Date: 29th December 2022
ISBN : 978-93-91535-36-0

hence It is mostly used in radio receivers. The current distribution in the half-wave dipole antenna is approximately sinusoidal along the length of the dipole i.e., a standing wave in nature. The basic half-wave dipole antenna and voltage and current distribution on it are shown in the below figure.

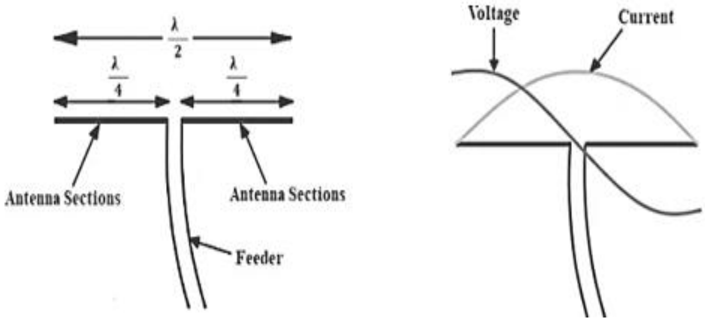

Fig3c: Basic half wave dipole antenna (left) and *I and V* distribution in a half-wave dipole antenna [16]

*E. Short Dipole Antenna:*A short dipole antenna is one in which the length of the wire is less than half of the wavelength Here, the feed impedance starts to increases and its response is less dependent upon the frequency changes. The current distribution in the short dipole antenna is approximately triangular. The length of the short dipole antenna in between $\frac{\lambda}{50}$ ***to*** $\frac{\lambda}{10}$i.e.,$\frac{\lambda}{50} < l < \frac{\lambda}{10}$

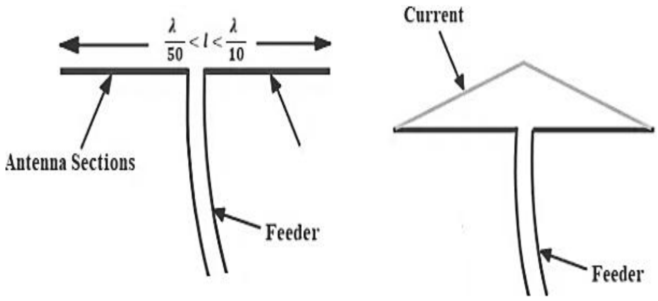

Fig 3d: Short Dipole Antenna (left) and Current Distribution in a Short Dipole Antenna [16]

2.3 Characteristics of Dipole

a. *Impedance of dipoles of various lengths:* The feed point impedance of a dipole antenna is sensitive to its electrical length and feed point position [17]. Therefore, a dipole will generally only perform optimally over a rather narrow bandwidth, beyond which its impedance will become a poor match for the transmitter or receiver (and transmission line). The real (resistive) and imaginary (reactive) components of that impedance, as a function of electrical length, are shown in the accompanying graph. The detailed calculation of these numbers is described below. Note that the value of the reactance is highly dependent on the diameter of the conductors; this plot is for conductors with a diameter of 0.001 wavelengths. Dipoles that are much smaller than one half the wavelength of the signal are called *short dipoles*. These have a very low radiation resistance (and a high capacitive reactance) making them inefficient antennas. More of a transmitter's current is dissipated as heat due to the finite resistance of the conductors which is greater than the radiation resistance. However, they can nevertheless be practical receiving antennas for longer wavelengths.

ISBN : 978-93-91535-36-0

Dipoles whose length is approximately half the wavelength of the signal are called *half-wave dipoles* and are widely used as such or as the basis for derivative antenna designs. These have a radiation resistance which is much greater, closer to the characteristic impedances of available transmission lines, and normally much larger than the resistance of the conductors, so that their efficiency approaches 100%. In general radio engineering, the term *dipole*, if not further qualified, is taken to mean a center-fed half-wave dipole.

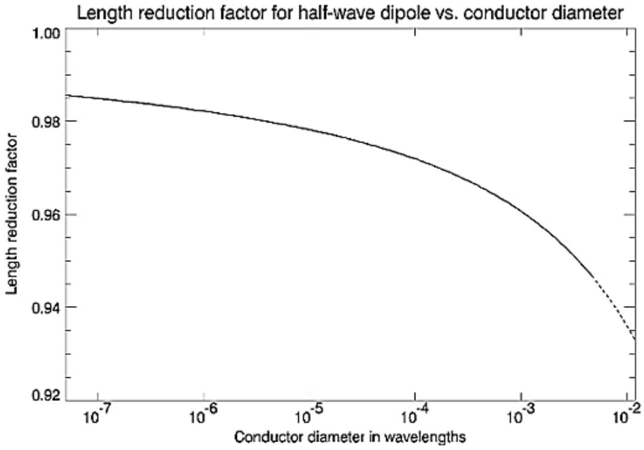

Fig4Impedance of dipoles at different lengths [18]

A true half-wave dipole is one half of the wavelength λ in length, where λ = c/f in free space. Such a dipole has a feed point impedance consisting of 73 Ω resistance and +43 Ω reactance, thus presenting a slightly inductive reactance. To cancel that reactance, and present a pure resistance to the feedline, the element is shortened by the factor *k* for a net length l of:

$$l = \frac{1}{2}k\lambda = \frac{1}{2}k\frac{c}{f} \qquad (5)$$

where *λ* is the free-space wavelength, *c* is the speed of light in free space, and *f* is the frequency. The adjustment factor *k* which causes feedpoint reactance to be eliminated, depends on the diameter of the conductor [20] as is plotted in the accompanying graph. *k* ranges from about .98 for thin wires (diameter, 0.00001 wavelengths) to about 0.94 for thick conductors (diameter, 0.008 wavelengths). This is because the effect of antenna length on reactance (upper graph) is much greater for thinner conductors, so that a smaller deviation from the exact half wavelength is required in order to cancel the 43 Ω inductive reactance it has when exactly λ/2. For the same reason, antennas with thicker conductors have a wider operating bandwidth over which they attain a practical standing wave ratio which is degraded by any remaining reactance.

b. Radiation pattern and gain: A dipole is omnidirectional in the plane perpendicular to the wire axis, with the radiation falling to zero on the axis (off the ends of the antenna). In a half-wave dipole, the radiation is maximum perpendicular to the antenna, declining as $(sin\theta)^2$to zero on the axis. Its radiation pattern in three dimensions (see figure) would be plotted approximately as a toroid (doughnut shape) symmetric about the conductor. When mounted vertically this results in maximum radiation in horizontal directions. When mounted horizontally, the radiation peaks at right angles (90°) to the conductor, with nulls in the direction of the dipole.

ISBN : 978-93-91535-36-0

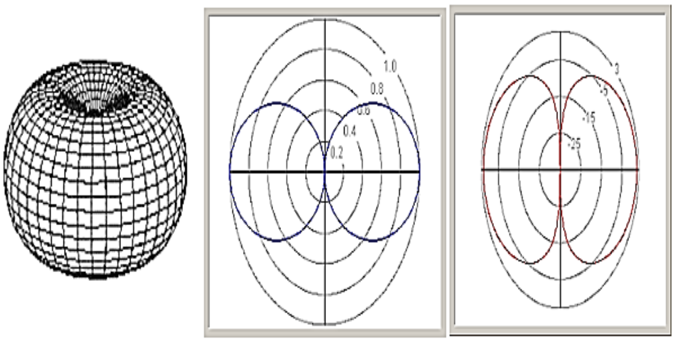

Fig5: 3D radiation pattern of a vertical half-wave dipole antenna (left); Radiation pattern of vertical half-wave dipole; vertical section (center) In linear scale (right) In decibels isotropic (dBi) [20]

c. Feeding a dipole antenna: A balun is required to use coaxial cable with a dipole antenna. The balun transfers power between the single-ended coax and the balanced antenna, sometimes with an additional change in impedance. A balun can be implemented as a transformer which also allows for an impedance transformation. This is usually wound on a ferrite toroidal core. The toroid core material must be suitable for the frequency of use, and in a transmitting antenna it must be of sufficient size to avoid saturation [99]. Other balun designs are mentioned below [21]:

a. Coax balun: A coax balun is a cost-effective method of eliminating feeder radiation, but is limited to a narrow set of operating frequencies.

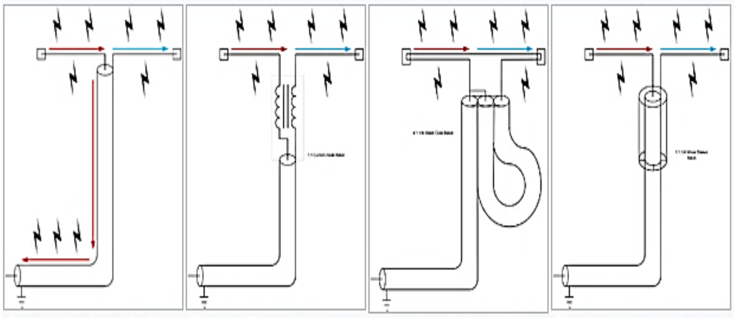

Fig6: Feeding a dipole antenna with coax cable[18]

One easy way to make a balun is to use a length of coaxial cable equal to half a wavelength.

b. Current balun: A so-called current balun uses a transformer wound on a toroid or rod of magnetic material such as ferrite. All of the current seen at the input goes into one terminal of the balanced antenna. It forms a balun by choking common-mode current. The material isn't critical for 1:1 because there is no transformer action applied to the desired differential current. A related design involves two transformers and includes a 1:4 impedance transformation.

ISBN : 978-93-91535-36-0

c. Sleeve balun: At VHF frequencies, a sleeve balun can also be built to remove feeder radiation. Another narrow-band design is to use a λ/4 length of metal pipe. The coaxial cable is placed inside the pipe; at one end the braid is wired to the pipe while at the other end no connection is made to the pipe. The balanced end of this balun is at the end where no connection is made to the pipe. The λ/4 conductor acts as a transformer, converting the zero impedance at the short to the braid into an infinite impedance at the open end. This infinite impedance at the open end of the pipe prevents current flowing into the outer coax formed by the outside of the inner coax shield and the pipe, forcing the current to remain in the inside coax. This balun design is impractical for low frequencies because of the long length of pipe that will be needed.

III. MACHINE LEARNING

Artificial Intelligence and Machine Learning (ML) are often used interchangeably, however, as will be discussed hereafter and investigated in this paper, machine learning is a large subset of artificial intelligence, as shown in Fig. 1.12. In fact, machine learning can be considered as an approach to achieve AI applications. Machine Learning is briefly described as getting useful information out of data, achieved by developing reliable prediction algorithms. These algorithms can be very powerful in optimization, but their success relies on the condition and size of the data collected. Therefore, machine learning is frequently associated with statistics and data analysis [22,24]. As for Neural Networks, they are defined as a type of machine learning algorithms that try to imitate how the human brain works. They consist of layers of interconnected nodes. Each node produces a nonlinear function of its input. Deep Neural Networks (DNNs) are neural networks that have more than one hidden layer [25], usually referred to as Deep Learning. Both of these algorithms are considered as types of machine learning algorithms. This research study presents an overview on machine learning, with a major focus on investigating its usage in antenna design applications. The concept of machine learning is studied along with its different learning algorithms.

3.1 Machine Learning and the Antenna

During the last decade, ML methods have been widely investigated and applied in antenna designs due to their ability to learn from measured or simulated antenna data through a training process and then help to accelerate the entire antenna design procedure. The ML-assisted optimization methods for antenna design can be categorized as a type of surrogate model-based optimization method in which a computationally efficient model is constructed using ML methods to predict the designated characteristics at the possible points in the design space using the training set generated at the sampled points based on the original computationally expensive model. Various ML methods have been introduced for antenna designs such as Gaussian process regression (GPR) [26-28], support vector machine (SVM) [29,30] and artificial neural networks (ANNs) [31]. In this section, the most widely adopted ML methods [32,33][34-37] applied in the antenna modelling field are reviewed.

a. *Artificial neural network:* In the late 20th century, ANNs were firstintroduced to model microstrip antennas. In [37], an ANN was utilized to transformthe design parameters, including thedielectric constant and

ISBN : 978-93-91535-36-0

antenna dimensions,and the design objectives, including the antenna'sdominant-mode resonant frequency to thepatch length.

b. *Support vector machine:* The SVM is able to address both classificationand regression problems [38,39]. Compared with ANNs, the SVM was introduced to the antenna design field due to its improved generalization capability. The SVM has been introduced to model both antenna elements and antenna arrays.

c. *Gaussian process regression:* Recently, the GPR has received extensive attentionin the field of EM engineering, includingfor antenna design. As compared to SVM and ANN, the GPR is able to provide the uncertainty of the predicted results at new design points, which will help designers to explore global optima when few training points are given.

3.2Steps for applying ML in antenna design

In general, in order to apply machine learning in antenna design, the following steps can be done:

- By multiple simulations, the electromagnetic characteristics of an antenna are found out.
- These characteristics are stored in a database and used as a data set for training a certain machine learning algorithm.
- The antenna that gives the closest results is designed by the algorithm after making predictions, depending on the needs of the designer.

IV. RELATED WORK

Zhong, Y., et.al [1] introduce a flexible geometric scheme with the concept of mesh network that can form any arbitrary shape by connecting different nodes. For such problems with high dimensional parameters, the authors propose a machine learning based generative method to assist the searching of optimal solutions. It consists of discriminators and generators. The discriminators are used to predict the performance of geometric models, and the generators to create new candidates that will pass the discriminators. Moreover, an evolutionary criterion approach is proposed for further improving the efficiency of our method.

Table.2 Summaryoftheworksanalyzedbytheresearchers

S. No.	Author's Name	Tool/Method Used	Paper Title	Application Domain	Inferences
1.	Zhong, Y., et.al (2022)	A flexible geometric scheme with the concept of mesh network and an evolutionary criterion approach	*A Machine Learning Generative Method for Automating Antenna Design and Optimization*	Automating Antenna Design	The discriminators are used to predict the performance of geometric models, and the generators to create new candidates that will pass the discriminators.

ISBN : 978-93-91535-36-0

2.	De Melo, M. C., et.al (2021)	Multilayer Perceptron (MLP) artificial neural network with backpropagation	*Computational Intelligence-Based Methodology for Antenna Development.*	Antenna Development	Comparisons of antenna impedance matching obtained by the proposed methodology, numerical full-wave results from ANSYS HFSS and experimental result from the antenna prototype are performed for demonstrating its applicability and effectiveness for antenna development.
3.	Javali, A., et.al (2021)	Review study	*Machine Learning Algorithms in Smart Antenna and Arrays for Internet of Things Applications.*	Internet of Things	MLA for SAA can be a good solution to counter the challenges faced by SAA of the IoT.
4.	Karuppuswami, S., et.al (2021)	Advanced Driving-Assistance System	*Design optimization of a 77 GHz antenna array using machine learning.*	Design optimization of antenna using machine learning	A comparison is shown between traditional GRSM array optimization and optimization coupled with machine learning
5.	Goswami &Goswami (2021)	ANN-ML supervised SDR	*Machine learning supervised antenna for software defined cognitive radios.*	Software defined CRs	The antenna exhibits high radiation efficiency with consideration of tangential losses of FR4 and sustainable gain 2.5 dBi over the complete impedance bandwidth.

Faustino, E. et.al [2] investigates eight machine learning techniques to find which one is more suitable to be used as a surrogate model in the design of antennas. The researchers propose a methodology for comparing and analyzing the techniques using the RMSE as the metric. For the case study, the researchers present the design of

ISBN : 978-93-91535-36-0

a Quasi-Yagi antenna for operating at three resonance frequencies. The results demonstrate that the Gaussian Process model obtained the best performance, achieving an RMSE value of 1.251 in the case study. Goswami&Goswami [8] presents a design of a smart compact wideband patch antenna for SDR in cognitive radios. The fractal slot antenna with electromagnetic bandgap structure is designed on 12 × 18 mm2 FR4 substrate as a primary perception module in the cognitive radio sensor network. The wide operating range of antenna 0.68–12.1 GHz is highly compatible with adaptive learning of SDR to deal with dynamic spectrum variation over a large bandwidth. The proposed five-layered ANN-ML supervised SDR comprises multispectral resolution via coefficient estimation for primary and secondary user and elicits high throughput of proposed antenna during white space spectrum sensing. The data analytics for ANN-ML has modelled on Python 3.0 IDE and the results are validated to justify the candidature of the antenna for wideband sensing as per the Federal Communications Commission standards for CRN. Karuppuswami, S., et.al [23] propose a 77 GHz patch antenna array is presented as a front-end communication tool for Advanced Driving-Assistance System (ADAS). A regression based mathematical modelling algorithm Modified Extensible Lattice Sequence (Mels) is used to develop a supervised machine learning based surrogate mathematical model from the physical array model with very few simulation iterations. Global response search method (GRSM) optimization routine is used for optimizing the surrogate model under a very short time to achieve the design optimization goals. A comparison is shown between traditional GRSM array optimization and optimization coupled with machine learning. Additionally, a simulation-based case study is presented using the optimized antenna array for vehicle-to-vehicle communication in a time-varying autonomous driving scenario. Kumar &Yalavarthi [34] presents a comprehensive review on basic optimization algorithms for micro-strip patch antenna design using machine learning. Classification of machine learning based algorithms: deterministic, stochastic and surrogate model assistant is discussed. Further machine learning models training for optimizing output and for prediction of antenna parameters is presented in this paper. This paper is useful to the readers who work on a particular antenna using the Machine Learning Techniques. Zhang, J., et.al [35] propose a substrate integrated waveguide (SIW) end fire antenna array with zero clearance for 5G mobile applications using machine learning-assisted optimization. In particular, a novel impedance matching architecture that involves three arbitrary pad-loading metallic vias is investigated and adopted for the antenna element. Due to the stringent design requirements, the locations and sizes of the vias and pads are obtained via a state-of-the-art machine learning assisted antenna design exploration method, parallel surrogate model-assisted hybrid differential evolution for antenna synthesis (PSADEA). Keeping a very low profile, the array optimized by PSADEA covers an operating frequency bandwidth from 36 GHz to 40 GHz. The in-band total efficiency is generally better than 60% and the peak gain is above 5 dBi. The beam scanning range at 39 GHz covers from -20° to 35°. Reddy, B. V., et.al [36] provides an approach to design an antenna in an efficient way using machine learning techniques. The process of designing an antenna can be accelerated using ML. Conventional Antenna Design process is very time consuming because of the numerical methods used in the process are complex and computationally heavy. Hence in this work we gave an efficient way to design an antenna and to predict the possible antenna behaviour, reducing the complexities in the traditional approach. Fast prediction of design parameters with reduced number of simulations was achieved by applying ML methods including Random Forests and ANN. In this paper, an enhanced and optimized process of designing an Antenna was discussed which has many advantages over the existing work. The proposed work provides a better computational efficiency with a smaller number of necessary simulations. Javali, A., et.al [38] provided a brief survey on the use of Machine Learning Algorithms (MLA) for Smart Antenna Arrays (SAA) for IoT applications in many fields. As the highly interconnected world of IoT needs many optimizations, stringent analysis and advanced prediction methods MLA for SAA can be a good solution to counter the challenges faced by SAA of the IoT. De Melo, M. C., et.al [40] proposes an efficient and accurate computational intelligence-based methodology for the antenna design and optimization. The computational technical solution consists of a surrogate model application, composed of a Multilayer Perceptron (MLP) artificial neural network with backpropagation for the regression process. Combined with the surrogate model, two multiobjective optimization meta-heuristic strategies, Non-dominated Sorting Genetic Algorithm (NSGA-II) and Multiobjective Evolutionary Algorithm based on Decomposition (MOEA/D), are used to overcome the mentioned issues from the traditional antenna design method. A study of case considering a dipole antenna for the 3.5 GHz 5G band is reported, as proof of the proposed methodology concept. Comparisons of antenna impedance matching obtained by the proposed methodology, numerical full-wave results from ANSYS HFSS and experimental result from the antenna prototype are performed for demonstrating its applicability and effectiveness for antenna development.

V. CONCLUSION

In wireless communication system, antennas designing plays a very critical role for transmitting and receiving the signals. The idea of machine learning and its different ways of learning are studied. Next, a thorough look at a number of antenna designs is done. In each case, the ways that machine learning was used to design the antennas are shown, along with the results of each algorithm.

VI. REFERENCES

[1] Zhong, Y., Renner, P., Dou, W., Ye, G., Zhu, J., & Liu, Q. H. (2022). A Machine Learning Generative Method for Automating Antenna Design and Optimization. *arXiv preprint arXiv:2203.11698*.

[2] Faustino, E., Melo, M. C., Buarque, P., Bastos-Filho, C. J., Cerqueira, S. A., &Barboza, E. A. (2021, October). Comparison of Machine Learning Algorithms for Application in Antenna Design. In *2021 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC)* (pp. 1-3). IEEE.

[3] Akinsolu, M. O., Mistry, K. K., Liu, B., Lazaridis, P. I., &Excell, P. (2020, March). Machine Learning-assisted Antenna Design optimization: A Review and the State-of-the-art. In *2020 14th European conference on antennas and propagation (EuCAP)* (pp. 1-5). IEEE.

[4] Gibson, W. C. (2021). *The method of moments in electromagnetics*. Chapman and Hall/CRC.

[5] Tirkas,P. A., &Balanis, C. A. (1992). Finite-difference time-domain method for antenna radiation. *IEEE Transactions on Antennas and Propagation*, *40*(3), 334-340.

[6] Volakis,J. L., Volakis, J. L., Chatterjee, A., &Kempel, L. C. (1998). *Finite element method for electromagnetics*. Universities Press.

[7] Sarkar, T. K., Djordjevic, A. R., &Kolundzija, B. M. (2001). Method of moments applied to antennas. *Handbook of Antennas in Wireless Communications*, 239-279

[8] Goswami, P. K., &Goswami, G. (2021). Machine learning supervised antenna for software defined cognitive radios. *International Journal of Electronics*, 1-24.

[9] Wu, Q., Cao, Y., Wang, H., & Hong, W. (2020). Machine-learning-assisted optimization and its application to antenna designs: Opportunities and challenges. *China Communications*, *17*(4), 152-164.

[10] Zhang, Z. Y., &Wu, K. L. (2018). A wideband dual-polarized dielectric magnetoelectric dipole antenna. *IEEE Transactions on Antennas and Propagation*, *66*(10), 5590-5595.

[11] Zhou, S. G., Peng, Z. H., & Huang, G. L. (2017). Design of a novel wideband and dual-polarized magnetoelectric dipole antenna. *IEEE Transactions on Antennas and Propagation*, *65*(5), 2645-2649.

[12] Khotimah, K.,Khayam, U., Tai, Y., Kozako, M., &Hikita, M. (2015, August). Design of dipole antenna model for partial discharge detection in GIS. In *2015 International Conference on Electrical Engineering and Informatics (ICEEI)* (pp. 186-191). IEEE.

[13] Santos, P. B., Melo, M. C., Faustino Jr, E., Cerqueira Jr, S., & Bastos-Filho, C. J. (2020, November). A comparison of evolutionary multi-objective optimization algorithms applied to antenna design. In *International Conference on Intelligent Data Engineering and Automated Learning* (pp. 123-134). Springer, Cham.

[14] Alzahed, A. M., Mikki, S. M., &Antar, Y. M. (2019). Nonlinear mutual coupling compensation operator design using a novel electromagnetic machine learning paradigm. *IEEE Antennas and Wireless Propagation Letters*, *18*(5), 861-865.

[15] Zhou, Z., Wei, Z., Tang, Z., & Yin, Y. (2019). Design and analysis of a wideband multiple-microstrip dipole antenna with high isolation. *IEEE Antennas and Wireless Propagation Letters*, *18*(4), 722-726.

[16] Dipole Antenna: What is it? (And the Types of Antennas). Online available at:https://www.electrical4u.com/dipole-antenna/

[17] Stutzman, Warren; Thiele, Gary (1981). Antenna Theory and Design. John Wiley & Sons, Inc. pp. 212–220.

[18] Dipole antenna. Online available at: https://en.wikipedia.org/wiki/Dipole_antenna#cite_note-25

[19] Amlaner, C. J., & Macdonald, D. W. (Eds.). (2013). *A handbook on biotelemetry and radio tracking: proceedings of an International Conference on Telemetry and Radio Tracking in Biology and Medicine, Oxford, 20-22 March 1979*. Elsevier.

[20] Dipole antenna. Online available at: https://en.wikipedia.org/wiki/Dipole_antenna#cite_note-25

[21] Baluns 88-108Hz.Online available at: https://www.m0kwr.com/Downloads/Baluns/88%20-%20108MHz%20Baluns.pdf

[22] Javali, A., Sahoo, A., & Gupta, J. (2021, March). Machine Learning Algorithms in Smart Antenna and Arrays for Internet of Things Applications. In *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)* (pp. 297-301). IEEE.

[23] Karuppuswami, S., Mondal, S., &Chahal, P. (2021, June). Design optimization of a 77 GHz antenna array using machine learning. In *2021 IEEE 71st Electronic Components and Technology Conference (ECTC)* (pp. 1199-1204). IEEE.

[24] Mohri, M., Rostamizadeh, A., & Talwalkar, A. (2012). Foundations of machine learning.

[25] Jiang, R., Wang, X., Cao, S., Zhao, J., & Li, X. (2019). Deep neural networks for channel estimation in underwater acoustic OFDM systems. *IEEE access*, *7*, 23579-23594.

[26] Liu, B., Akinsolu, M. O., Ali, N., &Abd-Alhameed, R. (2019). Efficient global optimisation of microwave antennas based on a parallel surrogate model-assisted evolutionary algorithm. *IET Microwaves, Antennas & Propagation*, *13*(2), 149-155.

[27] Akinsolu, M. O., Liu, B., Grout, V., Lazaridis, P. I., Mognaschi, M. E., & Di Barba, P. (2019). A parallel surrogate model assisted evolutionary algorithm for electromagnetic design optimization. *IEEE Transactions on Emerging Topics in Computational Intelligence*, *3*(2), 93-105.

[28] Xiao, L. Y., Shao, W., Jin, F. L., & Wang, B. Z. (2018). Multiparameter modeling with ANN for antenna design. *IEEE Transactions on Antennas and Propagation*, *66*(7), 3718-3723.

[29] Zheng, Z., Chen, X., & Huang, K. (2011). Application of support vector machines to the antenna design. *International Journal of RF and Microwave Computer‐ Aided Engineering*, *21*(1), 85-90.

[30] Chen, M., Challita, U., Saad, W., Yin, C., &Debbah, M. (2017). Machine learning for wireless networks with artificial intelligence: A tutorial on neural networks. *arXiv preprint arXiv:1710.02913*, *9*.

[31] Xiao, L. Y., Shao, W., Jin, F. L., & Wang, B. Z. (2018). Multiparameter modeling with ANN for antenna design. *IEEE Transactions on Antennas and Propagation*, *66*(7), 3718-3723.

[32] Wu, Q., Cao, Y., Wang, H., & Hong, W. (2020). Machine-learning-assisted optimization and its application to antenna designs: Opportunities and challenges. *China Communications*, *17*(4), 152-164.

[33] Alzahed, A. M., Mikki, S. M., &Antar, Y. M. (2019). Nonlinear mutual coupling compensation operator design using a novel electromagnetic machine learning paradigm. *IEEE Antennas and Wireless Propagation Letters*, *18*(5), 861-865.

[34] Kumar, N. S., &Yalavarthi, U. D. (2021, July). A Comprehensive Review on Machine Learning Based Optimization Algorithms for Antenna Design. In *Journal of Physics: Conference Series* (Vol. 1964, No. 6, p. 062098). IOP Publishing.

[35] Zhang, J., Akinsolu, M. O., Liu, B., & Zhang, S. (2021). Design of Zero Clearance SIW Endfire Antenna Array Using Machine Learning-Assisted Optimization. *IEEE Transactions on Antennas and Propagation*.

[36] Reddy, B. V., Krishna, D. V. S., Sharma, A., &Ranjan, P. (2021, June). Accelerated Antenna Design Assisted by Enhanced Machine Learning Techniques. In *2021 International Conference on Intelligent Technologies (CONIT)* (pp. 1-4). IEEE.

[37] Mishra, R. K., & Patnaik, A. (2003). Designing rectangular patch antenna using the neurospectral method. *IEEE transactions on antennas and propagation*, *51*(8), 1914-1921

[38] Liu, J., Chen, Z. X., Dong, W. H., Wang, X., Shi, J., Teng, H. L., ... & Feng, P. F. (2019). Microwave integrated circuits design with relational induction neural network. *arXiv preprint arXiv:1901.02069*.

[39] Chen, M., Challita, U., Saad, W., Yin, C., &Debbah, M. (2017). Machine learning for wireless networks with artificial intelligence: A tutorial on neural networks. *arXiv preprint arXiv:1710.02913*, *9*.

[40] De Melo, M. C., Santos, P. B., Faustino, E., Bastos-Filho, C. J., &Sodré, A. C. (2021). Computational Intelligence-Based Methodology for Antenna Development. *IEEE Access*, *10*, 1860-1870.

[41] Javali, A., Sahoo, A., & Gupta, J. (2021, March). Machine Learning Algorithms in Smart Antenna and Arrays for Internet of Things Applications. In *2021 International Conference on Artificial Intelligence and Smart Systems (ICAIS)* (pp. 297-301). IEEE