A Review on Machine Learning in Smart Antenna: Methods and Techniques

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***Abstract* - According to several research circles, it is predicted that future wireless systems that employ smart antenna techniques would be more effective at using available spectrum and at building new networks at lower cost, while also improving service quality and allowing for cross-technology operation. These systems require constant monitoring in order to function properly, allowing users to apply machine learning algorithms to analyse large amounts of data from various antenna settings. Machine learning is a technique in which a machine learns and improves on its own, based on past data. These techniques enable the smart antenna target to be learned in an efficient, reliable, and adaptive manner. In this paper, the antenna array and antenna developed for the Internet of Things applications were highlighted. In this paper, we review how machine learning techniques can handle these applications effectively and what the concept of adaptive antenna is and when it can be used in this day and age characterized by the rapid development of information technology.**

***Keywords* – smart antenna, wireless, spectrum, machine learning, antenna, adaptive antenna.**

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1. Introduction

Antenna systems used in traditional wireless systems are either Omni-directional or sectored [1]. A wide range of 'smart' antenna technologies have been offered as viable solutions to improve modern wireless communications in recent years [2]. The antenna is a crucial component of both civil and military radio systems, serving as an electromagnetic (EM) transducer by converting guided waves to free-space waves and vice versa. Antennas can be used to increase or decrease the quantity of energy supplied or received in specific directions, depending on the application. A well-designed antenna may help minimize system requirements while increasing overall system performance [3]. Historically, wireless systems have either used omnidirectional or sectored antenna systems. The downside of such antenna systems is that the electromagnetic energy needed by a particular user in a particular direction is needlessly disseminated across the cell, producing interference for other users. Smart antenna systems have been explored and developed in order to mitigate this form of interference and guide energy to the intended user [4]. Smart Antenna Networks (SAS) have swiftly become one of the most important technologies for achieving high efficiency and improved wireless communication systems. The SAS has gotten a lot of attention in recent decades because it can dynamically enhance system capacity by adjusting interference and targeting the intended user. Intelligent antenna technology has a significant impact on spectrum efficiency, service quality optimization, network configuration reduction, and operational transparency across multi-technology wireless grids when used in communication systems [5]. Intelligent antennas maximize power efficiency. Depending on the clever antenna employed in a communication system, the clever antenna does not always cover an area while waiting for new members. A single user beam can be sent by intelligent antennas. A smart antenna, on the other hand, isn't perfect because some signals sent to users can heavily interfere with other signals bouncing off nearby physical structures. Machine learning has gotten a lot of attention as a way to identify better answers in several fields, and it's expected to play a big role in our future technology and with its omnidirectional uses in automating complex and long processes with specialized detailing, has become a go-to tool for science and engineering [6]. It is still in its infancy, but it has become a phenomenon in the technology business, with machine-learning users altering the foundations of hundreds of industries and research projects, particularly in the field of antennas. In this era of Big Data, machine learning (ML) has emerged as a major player. ML is also showing promise in antenna optimization by estimating antenna behavior and speeding up the optimization process with accuracy and efficiency.

2. Smart Antenna

Smart antennas rely on electronic beam scanning, or switching, as a key component of sophisticated wireless systems [7]. Satellite communications, intersatellite linkages, radars, sensor systems, mobile communications (5G and beyond), local area networks (LANs), GNSS, and wireless power transmission all rely on smart antennas, also known as adaptive arrays or intelligent antennas . Electronic beam scanning, or switching, is one of the most significant elements of a smart antenna. Smart antennas allow wireless devices to achieve optimal performance and channel throughput by electronically directing their maximum emission in the required directions while creating nulls against interfering sources [8]. The system of intelligent antennas is based on spatial processing. The area of coverage and transmission quality have expanded as a result of the rising number of users and demands; smart antennas help to meet all of these needs. When it comes to our human body systems, the functionality of smart antenna systems is well understood [9]. A human signal processor, the brain calculates where the speaker is coming from depending on the time delay between the sound waves heard by each ear. The brain determines the sound's direction by combining the strength of the signals received from each ear. When there are several speakers, the brain is able to block out the background noise and concentrate only on the topic at hand. In order for a listener to respond in the same direction as the intended speaker, they must point their transmitter (mouth) toward the speaker. Similar to human ears, except instead of ears, two antennas are used in smart antenna systems. Instead of the brain, a digital signal processor is used. The antennas' weights are adjusted to drive the main lobe in a certain direction while nulls are positioned in interference directions, using smart antenna design [10, 11]. The next figure (Figure 1.) showing the stretcher of Smart Antenna:

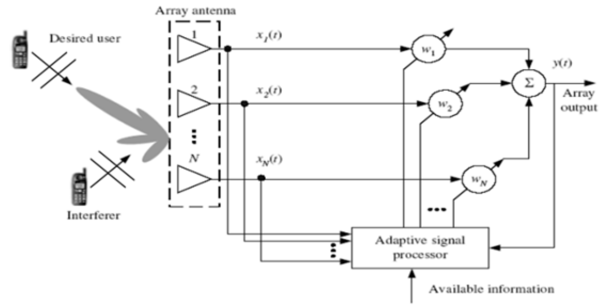


Figure 1. The stretcher of Smart Antenna [12].

The first smart antenna systems were developed for military uses, where they were used to reduce interfering or jamming signals from the adversary. In FDMA, TDMA, and CDMA networks, these smart antenna systems often have active multi-beam technology and give significant performance increases [12].

2.1. Smart Antenna System Features and Benefits

It has many advantages that radiate its use in the field of communications and can be summarized in the following points [5]:

- To achieve interference rejection, an antenna pattern is directed toward co-channel interfering sources, therefore boosting the signal-to-interference ratio of received signals by a factor of two. As a result, there is an increase in capacity.
- As the radio environment changes, Spatial Division Multiple Access adjusts to the new conditions by providing each user with the highest quality uplink and downlink signals possible, and by distributing frequencies based on which users are most concentrated in a given geographic region. RF pollution and interference are reduced as a result of lower power usage (ease health hazard).
- The use of Smart Antennas in cellular communication might result in a considerable reduction in fuel use.

2.2. Configurations for Smart Antennas

It is possible to get reuse signal gain by combining the inputs from many antennas in order to enhance the amount of power available to cover a given region. To achieve interference rejection, an antenna pattern is directed toward co-channel interfering sources, improving the signal-to-interference ratio of received signals [8]. As a result, the capacity is increased. Spatial Division Multiple Access (SDMA) adjusts to the radio environment by giving each user with the finest quality uplink and downlink signals and, owing to Smart Antenna, is capable of changing frequency allocation to the place where the greatest number of users are located. RF pollution and interference are reduced as a result of reduced power usage (a health hazard). The adoption of Smart Antenna in cellular connectivity will dramatically minimize diesel usage [13]. The next figure (Figure 2.) showing Type of Configurations Smart Antennas.

These two types of research are thought to be among the most fertile ground for researchers to conduct and expand their work. The following is a table (Table 1.) showing the most important differences between these two tables and how they work:

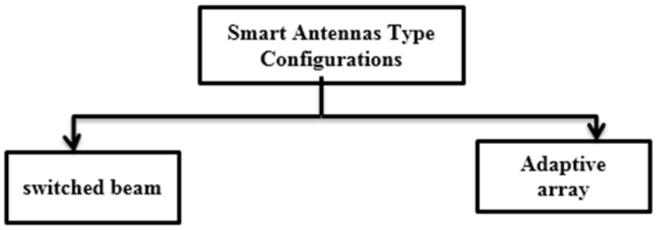
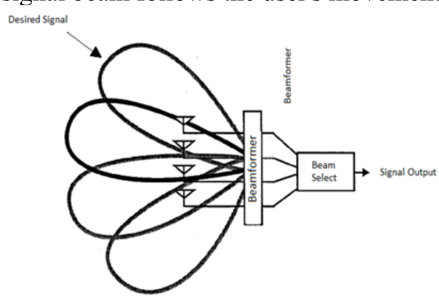
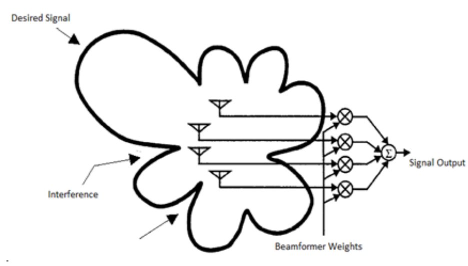


Figure 2. Type of Configurations Smart Antennas [14]

Table 1. Most important differences between switched beam and adaptive array [10], [15]

Switched Beam Antennas	Adaptive Array Antenna
Definition: A multi-beam antenna, often known as a phased array antenna, is a switched-beam antenna. It's an antenna array that, based on predetermined weights assigned to each received signal, forms a large number of fixed beams in various directions.	Definition: In this kind of antenna, the directions of arrival from users are calculated first, and then the weights of the beam formers are set in accordance with the supplied directions. The received signals will be weighted and then blended to optimize the desired signal to interference ratio [S/N], in addition to the signal and noise power ratio [S/N]. The beam pattern will change as the intended user moves since the device is flexible. The null beam is focused towards the interferer, while the main beam is aimed at the intended user. As a consequence, since the needed signal will be in the path of the main beam, interference will be balanced.
Example: The Figure bellow shows how beams direct in certain fixed discrete directions. One beam will turn on or be guided towards the targeted user among numerous others. A switch is used to pick the optimal beam for receiving a specific signal, resulting in the highest possible received strength. To put it another way, the desired signal beam follows the user's movements. 	Example: An adaptive array antenna's beam pattern. While canceling out the interfering signal, the antenna may easily steer the main beam in any direction. The figure bellow shows how the Direction of Arrival method may be used to estimate the direction of the beam. 
Benefit: Can be summarized in tow general point ▪ **Simple:** To choose a certain beam, all that is required is a beam forming network, an RF switch, and control circuitry. ▪ **Economical:** Because all processing takes place in the RF domain, just one signal needs to be translated to baseband and processed there. This is a significant benefit because down conversion circuits are among	**Benefit:** Can summarized in five general point ▪ The number of people who utilize the service has grown. The targeted nature of smart antennas may allow frequencies to be reused, hence increasing the number of consumers who can benefit from them. Because more users are using the same frequency space, the network operator incurs lesser operational expenses in terms of frequency space acquisition,

the most expensive components in today's wireless systems.	resulting in lower operating costs for the network. ▪ Range Expansion: In order to expand the range of operation, the smart antenna concentrates its gain on the connected device. As a result, the area covered by a smart antenna may become more extensive. This has the potential to save money for network operators since they will not require as many antennas or base stations to provide coverage. ▪ Safety and security: Due to the fact that signals are not broadcast in all directions as they would be with a traditional Omni-directional antenna, smart antennas automatically provide increased security. ▪ Interference is lessened: Interference from signals that radiate in all directions is less likely to occur as a result of the directionality of the intelligent antenna. This boosts the system's ability to reuse frequencies as well as its range, which both benefit from this. ▪ Broadband expansion: The bandwidth available increases as frequencies are reused, as well as in adaptive arrays, which can take advantage of the multiple paths that a signal can take to reach its destination.
Not Benefit: Can be summarized in tow general point ▪ **Limited Flexibility**: Because the primary beam can only be focused in specific set directions and the user does not have to be in the path of any one beam, the gain in the user's actual direction may not be the maximum feasible amount. ▪ **Limited Interference Reduction:** In this system, nulls cannot be pointed in any direction, and the number and position of nulls are fixed. As a result, the null cannot be formed in the direction of the unwanted signal (interferer), making interferer nulling ineffective. Switched-beam antennas appear to be more suited to CDMA applications, where signal amplification is crucial, rather than SDMA applications, where interference suppression is critical.	**Not Benefit: Can be summarized in fore general point** ▪ Complex: Smart antennas have the disadvantage of being significantly more intricate than regular antennas. This means that flaws or problems may be more difficult to detect and occur. ▪ It's a Little More Expensive: Smart antennas are significantly more expensive than ordinary antennas since they are incredibly sophisticated and need cutting-edge processing technology. ▪ Larger Dimensions: Smart antenna systems are substantially larger than standard antenna systems because to the antenna arrays that are used. Antennas might be perceived as unattractive or unappealing in social situations, which can be a concern. ▪ Placement: For best operation, smart antennas must be placed in strategic locations. Because of the directional beam that a smart antenna emits, places that are ideal for a standard antenna are not ideal for a smart antenna.

2.3. Machine Learning in Smart Antenna

Machine learning is an application of artificial intelligence (AI) that enables users to gather and evaluate data from their surroundings. Machine learning enables software to progressively learn and adapt to a given job without human intervention, allowing it to make data-driven judgments [6]. Machine learning works through statistical techniques, among other methods. Over the last decade, antenna designs have been extensively examined and used machine learning (ML) techniques because they can learn from antenna data collected or simulated through a training process, and they can subsequently assist in speeding up the entire antenna design process [16].

2.4. Evolution in Machine Learning

In order to calculate the predation efficiency, we have used a statistical measures [17]:

- Mean absolute error (MAE) according to equation (3)
- Mean absolute percentage error (MAPE) based on equation (1)
- Root mean square error (RMSE) Equation according (3).

For performance evaluation of LMST and GRU deep learning algorithms. In the performance estimation of the algorithms, performance indexes were used to compare target values with actual values. These metrics have a single value to calculate the accuracy of machine learning algorithms. Different approaches to measuring the results of machine learning models are [17]:

$$MSE = \frac{1}{n}\sum_{t=1}^{n} e_t^2 \tag{1}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2} \tag{2}$$

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |e_t| \tag{3}$$

2.5. *Machine Learning Odels in Smart Antenna*

Machine learning is based on data-driven algorithms without using rules-based programming [18]. It can generally be split into three main categories: supervised learning, non-controlled learning, and strengthened learning. Other less often used scenarios include: semi-supervised, transudatory, online, and active education [19]. The various learning algorithms in each category have been included. A model captures the core of the discovered knowledge in some formulation. Using a model will assist in our understanding of the world. Models may also be used to make predictions. Data mining can be quite rewarding for the data miner to discover new knowledge and build models that correctly predict the future, which is entirely used in smart antennas. The common steps thus include data planning, data mining, pattern validation, and the representation of information. Any important preprocessing of data is introduced during the data preparation stage, so the implementation of the data mining algorithms is most successful. Knowledge patterns are then extracted using the relevant machine learning algorithm [20]. In the phase of pattern analysis, the goal is to measure the achievable patterns of information and to minimize and summarize those patterns obtained to only the patterns of affective knowledge, thus collecting all the knowledge necessary for implementation. Knowledge production is about developing the required information in a form that is convenient for the needs of users, which should be easy to understand, test, and use in other applications if appropriate [16].

2.6. *Approaches in Smart Antenna*

The fundamental research criteria in smart antennas is to identify spatial signatures. Then, the intelligent antenna calculates beam forming vectors using these spatial signatures, which are used to track and locate a moving or target antenna beam. Two approaches are used in intelligent antennas: switched beam systems and adaptive systems [21]. A switched beam antenna contains several predefined radiation patterns, and a system requirement is based upon the appropriate radiation beam pattern. While the antenna spatial dimension is used, the primary ray occasionally cannot accurately indicate the interest signal (SoI), as illustrated [9]. The pattern of the beam is designed by altering the excitability of the individual antenna elements in a comparatively adaptive antenna system that offers beam orientation in all directions. Furthermore, these excitations might be adjusted in the direction of no interest (SNoI) to decrease radiation (b). Thus, the intelligent antenna can maximize spatial utility through adaptive beam shaping. The most frequent applications for intelligent antenna systems are acoustic signal processing, radar track and scan, and cellular systems like 5G and LTE. The primary distinction between reconfigurable antennas and intelligent antennas is that reconfigurable antennas are antennas with single elements instead of antenna arrays [22]. In spite of the tireless efforts of researchers, the key challenge of smart antennas with data learning and analysis still remains unsolved. One of the major reasons for this outcome is that it recognized the most significant signal of interest for further analysis within a reasonable time and cost [3].

The primary benefit of smart antenna systems is their ability to simultaneously increase the amount of usable signal received and decrease the degree of interference, thus increasing the SIR ratio in densely populated areas. In essence, intelligent antennas can filter out background noise generated by other system users, allowing for the clear transmission and reception of critical signals. Furthermore, because smart antennas are more focused than omnidirectional and sectored antennas, they may be able to direct their energy in non-essential directions toward the intended users rather than squandering it in non-essential directions. This enables base stations to be further split, such as in less densely populated regions.

This application of smart antenna can be created by using different simulation tools to study microscopically and monoscopically different conditions. Table 2. gives a summary of these simulators to produce and analyze real-life scenarios.

Table 2. Smart Antenna tools [24].

Tools	Descriptions	Programming language and operating system
Yagi Calculator	Calculate the dimensions of the antenna components using this online calculator.	windows
VHF/UHF Yagi Antenna Design	The term "antennas for VHF UHF bands" refers to antennas for the vhf and uhf radio bands.	Java script
Antenna Scatterers Analysis Program	Antenna analysis software for numerical electromagnetic antenna design, modeling, and analysis is available for free.	windows
4NEC2 antenna modeler	For both the beginning and seasoned antenna modeler, 4nec2 is a fully free Nec2, Nec4, and Windows-based program for constructing, evaluating, optimizing, and testing 2D and 3D type antenna geometry structures, as well as generating, displaying, and/or comparing near/far-field radiation patterns.	Windows
Antenna Designer	Interactively construct, visualize, and analyze antennas in the Antenna Toolbox library. Using this application, choose antennas depending on their overall characteristics or their antenna performance.	MATLAB

2.7. Conception of SA and Previse Studies

Nowadays, demand for antennas for applications is expanding dramatically when virtually every electronic instrument uses wireless signals. That means changeable functions, smart antennas, and the smallest possible size. An antenna design must, therefore, necessarily be intelligent and efficient. One of the most difficult components for future wireless communication and sensing is the antenna, which serves as a vital interface between propagating electromagnetic waves and electrical signals processed or created by integrated circuits [25]. The need for ever-shrinking physical size and weight for actual IoT applications, adequate efficiency for power and thermal concerns, and sufficient bandwidth for optimal data rate and sensor resolution are only a few of the competing factors in antenna design. Consider a common smartphone [16]. To build the data set for antenna designs, numerical simulations for various inputs and combinations can be used extensively. The geometric characteristics of intelligent technology utilizing a microstrip antenna must be studied design goals (e.g., resonance frequency, orientation, and efficiency) (e.g., slot and gap). The next table (Table 3.) showing the most popular studies in antennas researcher**.**

Table 3. Most popular studies in antennas researcher

Refers	Year	Description	Limitation	Result
[20]	2015	In order to categorize network traffic, the suggested article investigated a number of classification approaches and machine learning algorithms. Among the classification strategies, he selected nine appropriate classifiers: Some of the most common algorithms are BayesNet, Logistic, IBK, J48, PART, JRip, Random Tree, Random Forest, and REPTree, to name a few. And examined the accuracies of several machine learning approaches such as Boosting, Bagging, and Blending (Stacking). The WEKA tool was used to compare these algorithms, and the results are shown below by performance metric. To mimic these classification models, a 10-fold cross validation procedure was applied. For this simulation, WEKA was used using a data set based on NSL-KDD.	Only two algorithms out of 9 were tested and based on this mini experiment (two out of 9) they proved that they are the best and for ease of classification use a ready-made tool for classification	A higher a quires (91.523) in random forest And A higher precision (0.962) in Bayes net
[11]	2016	Three successful adaptive blind beam formers for smart antenna systems were created using the popular constant modulus approach in this proposed system, which was based on the constant modulus technique (CMA). The slow convergence rate of conventional CMA makes it unsuitable for	The proposed system has not been evaluated by any classification methods, i.e., on the percentage of	When compared to earlier blind beam formation algorithms, the proposed KW-CMA achieves the greatest reduction in

		use in wireless communication applications where channel conditions are constantly changing and evolving. In order to solve this difficulty, we first created a step size adjustable approach in order to increase the convergence rate of the CMA algorithm. As a result, the CMA will reach convergence after 10 iterations. To reduce the side lobe level (SLL), we employed three distinct windows: hanning, hamming, and kaiser, and these algorithms are referred to as H-CMA, HW-CMA, and KW-CMA, respectively. Simulated	accuracy, error, or precision	PSLL while maintaining rapid convergence capabilities. It also saves a significant amount of energy due to the elimination of side lobes.
[26]	2017	Ultra-wideband radio transmissions Interferometry based on Doppler radar is a well-known technique that allows for the provision of high-resolution images while utilizing a small antenna array. When many moving targets with comparable Doppler velocities are present in the same range bin, the method suffers from visual anomalies. In order to overcome this difficulty, we use a combination of Doppler interferometry and Capon techniques. We demonstrate, through numerical calculations and tests, that the suggested technique considerably increases performance in a variety of situations.	In order to improve accuracy, this approach requires a lot of flying.	When compared to an image acquired using a combination of the UWB Doppler radar interferometry imaging technique and the false image rejection method, the recommended methodology has a high accuracy of 26 mm and improves imaging accuracy by 47 percent.
[13]	2018	L0-norm constrained normalized least-mean-square (CNLMS) adaptive beam-forming approach for controlled sparse antenna arrays is described in this paper. As a restriction on the sparsity of the antenna array, the CNLMS technique makes use of a l0- norm penalty, which is defined as The advantages of the CNLMS algorithm are carried over into the suggested beamforming approach. It is possible to apply the l0-norm constraint to limit the number of antennas to a specific number, which may be used to manage sparsity. When compared to existing sparse array beamforming approaches, the proposed strategy speeds the convergence process; the speed with which it achieves convergence is illustrated in this work.	To address all array beamforming applications, an adaptive beamforming algorithm with low complexity, low SLL, and good performance should be created.	Using this strategy, a sparsity of 19.8 percent, 49.5 percent, and 19.8 percent is achieved, which corresponds to the required parameter t being 0.2, 0.5, and 0.2, respectively.
[27]	2019	Using the proposed methodology, Support Vector Machines (SVMs) with low degree polynomial kernels are trained on datasets that have been generated using a variety of sampling procedures. The study is validated using simulations of random array configurations with an increasing number of components, in order to determine whether the SVM approach proposed here can be used on big antenna arrays.	The influence of a single element on the amplitude of the far-field pattern diminishes as the size of an arbitrary array increases. This means that for large antenna arrays with thousands of components, the current SVM technique may be unable of detecting even a single faulty element.	The following setups yielded SVM kernel results: (a) (25 element dense regular array, 326 classes), (b) (18 element irregular array, 988 classes), and (c) (25 element irregular array, 326 classes) (8 element dense regular array, 988 classes).
[10]	2021	In this system that has been proposed. For efficient wireless energy transfer in IoT	The proposed system relied on	A test is configured to function at 915 MHz

		applications, adaptive array processing algorithms are presented. The computational cost is reduced by using a simple channel model and cost-effective estimate approaches. Continuous energy tones are broadcast at the same time as a common clock. The energy harvester receives this energy and uses it to calculate the best RSSI signal. The average harvested power, gain convergence, and average RSSI statistics for numerous antennas with varied iteration and distance ranges are visually represented.	listing its results only on the plans without addressing the details of the scheme.	with the help of the Universal Software Radio Peripheral (USRP), and energy is sent at that frequency.

As result we can summarize the above table as the following Table 4.:

Table 4. Summarized of previse studies

Refers	Year	ML	DL	Traditional antenna	Smart antenna	Single antenna	Multiple antennae
[20]	2015	✓	☒	✓	☒	☒	✓
[11]	2016	✓	☒	☒	✓	☒	✓
[26]	2017	☒	☒	☒	✓	☒	✓
[13]	2018	✓	☒	✓	☒	☒	✓
[27]	2019	✓	☒	✓	☒	✓	☒
[10]	2021	✓	☒	☒	✓	☒	✓

The appropriate ML method can be used (e.g., nearest neighbor, linear regression clustering, neural networks, etc.). This is the most crucial stage involving data processing and extracting information that can tie the output modification to the change in the input mode. This helps build a behavioral model that predicts or explains a specific numerical value based on several previous data [18].

The next generation of antenna technology and production technology could be inspired to carry out future work to enhance the IoT industry [10]. The projected results can enable automatic and robust design and production of future antennas for several wireless, medical, and aeronautical applications [28]. Table 5. displaced a summary of current machine learning solution proposed for smart antenna.

Table 5. Summary of machine learning solution in Smart Antenna

Author	ML methods	Scope
Errıcolo et al. [29]	ANN, Deep Learning	Machine learning and its applications to a variety of electromagnetic challenges, including radar, communication, imaging, and sensing
Sharma [16]	nearest neighbor, linear regression clustering, neural network	IoT and next generate Antenna
Kumar et al [30]	ANN + Gradient Descent algorithm, synonym GD for optimization	Prediction for Antenna parameters
Gampala and reddy [31]	Algorithm for optimizing generic machine learning with the Global Response Search Method (GRSM)	Built with a slotted patch antenna for GPS applications
El Misilmani and Naous [6]	ANN + Full-Wave analysis	Generic Antenna
Wu et al [3]	Artificial neural networks (ANN) and support vector machines (SVM)	Radar Antenna
JP Geers [32]	ML	Smart antenna
Mahdi et al [33]	NN	Forecast the opening antenna form
Liuet al [34]	ANN	Forecast the opening antenna form

2.8. Antenna Array

Increasing an antenna's electrical dimensions can be accomplished by combining the radiating components in the geometric and electrical design, rather than increasing the size of each individual element. This innovative multi-element antenna configuration of the arrays are mostly the same. It is not required, but it is more straightforward, more practical, and more convenient. In a single antenna array, the constituent elements could be of any kind (wires, microstrip, apertures, etc.). When the current in each antenna is equal to the current in the isolated antenna, which implies that the antennas are not coupled, the vector addition of the fields radiated by each element establishes the wide range of the antenna array. When the current in each antenna is equal to the current in the isolated antenna, which implies that the antennas are not coupled. This is the best-case scenario, and the performance is reliant on the manner in which the components come together and split from one another. Constructionally, interfering fields from elements in the array should be used to produce directed radiation patterns and to demolish all other elements and objects in the surrounding space. The application of antenna array can be summarize in the following table (Table 6.):

Table 6. Machine Learning Approach in Antenna Array

papers	Refers	ML methods	Performance
de Lange et al.	[27]	CNN	Prediction for Antenna parameters
Gampala and reddy	[31]	Generic ML with Global Response Search Method (GRSM) optimization algorithm	suited for GPS use a slotted patch antenna
El Misilmani and Naous	[6]	ANN + Full-Wave analysis	Generic Antenna
Wu et al	[3]	Artificial neural networks (ANN) and support vector machines (SVM) (ANNs)	Radar Antenna
Geers [53]	[3]	ML	Smart antenna
Mahdi et al	[28]	NN	Forecast the opening antenna form
Liuet al	[33]	ANN	

3. Open Research Problem

Today, it is necessary to design and pack several antennas covering different cellular belts, Wi-Fi, GPS, etc., in an esthetically very narrow space without affecting their performance. The development of machine learning (ML) specialized accelerators has been the dominant trend in all kinds of computer systems. Embedded device machine learning at the edge continues to grow. To date, most research efforts (Table 7.) have concentrated instead of integration into the overall system-on-chip design on the accelerator design in isolation (SoC). However, ML accelerators should be combined with accelerators for other algorithms, such as signal processing or feedback control, in order to develop novel embedded systems for areas such as robotics. As ML applications' complexity continues to develop, it is also considered challenging to integrate numerous accelerators in design time and handle the shared resources of the intelligent antenna during operation. The application of ML techniques can ameliorate this scenario [12]. An embedded control chip could be designed to automatically save lost signals for certain destinations and report the most significant properties of the system of such service to other distant within the same domain. The intelligent embedded chip will be used to perceive the reason for its existence in the universe (i.e., the smart antenna) [22], [23].

Table 7. Open doors for future research concern

Research Domain	Specific Topic	Future work
Smart Antenna	Array of Antenna	Using machine learning to enhance linear array coverage, capacity, and beamwidth in the desired direction
The smart array of antenna	Beamforming antenna	adaptive beam by using ANN
Smart antenna with circular	Indoor localization system	Low-cost modeling
V2X Antenna	5Gand V2x	Autonomous vehicles Application
IoT	Secure smart Antenna	monitoring level
Antenna Design	Antenna gain for beamforming for 5G mmWave networks	Through optimal antenna gain augmentation, hybrid methods that improve the more efficient use of bandwidth are used.

4. Conclusion

This research presents information on how machine learning approaches for the efficient operation of smart antennas are implemented. The assessment is examined based on various viewpoints, such as communication and performance. Throughout this article, we examined in depth the confluence of machine learning and intelligent antenna technology. The integration of machine learning and smart antennas is being investigated in terms of yearly improvement and communication enhancements, among other factors. We looked into a variety of characteristics of smart antennas, which are devices that might benefit from machine learning concepts. In smart antenna appliances, it turns out that neural network technologies are commonly used. However, for sensing failures, the SVM system is best known for various applications, including intelligent antenna design, k-NN, and deeper learning. Overviews reveal that because of its success in numerous AI fields, machine learning in smart antennas has considerable space for evaluation. Finally, although different ML and DL strategies have been presented, it is still an open question to choose the most suitable one for a particular electromagnetic problem and in the end, a table of previous studies was made that included the time period (2015-2021) for the most prominent studies on the topic.

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