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# Integration of Artificial Intelligence in Micro-patch Antenna Design for AMCA Aircraft

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**Abstract:** Artificial Intelligence (AI) can be utilized in various aspects of antenna design and optimization, including micro-patch antennas. Micro-patch antennas are compact, planar antennas that are widely used in wireless communication systems. AI techniques can enhance the performance of micro-patch antennas by optimizing their design, improving their efficiency, and reducing their size. This paper describes the development of low-cost networked model Aircraft, simulations used to demonstrate two application areas providing the Unmanned Aerial Vehicle (UAV) and enhanced bandwidth using the Micro-patch antenna at the receiver side of the model. The existing method has only 4 channel transmitter, but the proposed system is designed using 6 channel transmitter at the Transmitter side to improve transmission efficiency. The bandwidth from the previous model is 6.35% with return loss of 29dB and gain 8dB, it is enhanced to 14.81% with return loss of 32dB and gain 9.5dB. The HAL AMCA is one of the key components of Indian military industries. In this paper, a research effort is made using the project, HAL AMCA to develop fifth and sixth generation fighter aircraft for Indian air force and the Indian Navy for aviation safety and capacity with AI integrated micro-patch antenna design

***Keywords:*** *Artificial Intelligence, Micro-patch Antenna, Bandwidth, Return Loss, Unmanned Aerial Vehicle*

## 1. Introduction

AI algorithms, such as genetic algorithms or particle swarm optimization, can be employed to optimize the shape, size, and configuration of the micro-patch antenna. These algorithms can explore a large design space and find optimal solutions that maximize antenna performance metrics like bandwidth, gain, and radiation pattern. Machine learning techniques can be used to develop predictive models that link the design parameters of a micro-patch antenna with its performance characteristics. By training these models on a large dataset of antenna designs and their corresponding performance metrics, AI can help identify design patterns, correlations, and optimal configurations for improved antenna performance. AI algorithms can analyze complex electromagnetic field patterns radiated by the micro-patch antenna and identify any deviations or irregularities. This can be useful in detecting and mitigating unwanted effects such as interference, polarization mismatch, or cross-coupling between antenna elements [1][2].

AI can assist in generating new micro-patch antenna designs based on user requirements or specific constraints. By leveraging AI techniques, the design process can be automated, leading to faster and more efficient antenna design iterations. AI models can be trained to predict the performance of a micro-patch antenna based on its physical characteristics and operating conditions. This can enable quick evaluation of antenna designs before prototyping and testing, saving time and resources. By incorporating AI techniques into micro-patch antenna design, engineers and researchers can explore a larger

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design space, optimize antenna performance, and develop novel designs that may not be easily achievable through traditional design methods. These advancements can lead to improved wireless communication systems, better signal reception, and enhanced overall performance [3][4].

The AMCA program, led by the Aeronautical Development Agency (ADA) under the Defense Research and Development Organization (DRDO), aims to develop fifth and sixth generation fighter aircraft for the Indian Air Force and Navy. Known for its performance, stealth, and combat capabilities, the AMCA is designed to replace older aircraft and provide advanced features such as super cruise, stealth characteristics, and integrated electronic warfare systems. This collaborative effort involves organizations like HAL and research institutions, demonstrating India's commitment to indigenous defense capabilities and global aerospace leadership. From the previous generation of RC AMCA it has poor stability, sensitivity and short range. The performance and range of the RC model of the AMCA to be improved and developed. The cost of maintenance to be spent on this model will be reduced compared to the previous models [5][6].

The project aims at increasing the bandwidth of the AMCA from the range of 700 meter to 2 kilometer which will improve the range and speed of the fighter drone aircraft. Detecting the wind speed, atmosphere moisture, and aircraft sensitivity will be adjusted by obtaining the data and improved by using gyroscopic sensor, wave detection sensor. Once the sensor detects the imbalance in the stability and control it checks for the wind speed and controls the propeller to make an adjustment for the aircraft to maintain balanced stability. Improved in the aerodynamics and design to quickly move through any short area like bridge, tunnels, around buildings etc. If this implemented in real-time it can be able to quickly identify the enemy camps and capable to carry 2 air-air missiles & 2 ground-air missiles and able to destroy enemy/terrorists camps easily without taking risks in life of an Indian soldiers. It is a make in India project & the cost used for this aircraft is very low compared to other defense drone aircrafts that’s because its parts are made of recycled plastic and e-wastes [7-8].

## 2. Integration of Artificial Intelligence in Micro-patch Antenna Design

In previous generations of the aircraft, the control systems suffered from poor performance and limited bandwidth [9][10]. To address this issue, a proposed method suggests implementing a 6 channel transmitter using Micro patch antenna techniques. This approach utilizes traffic phase shifting (TPS) and buffering systems to enhance channel utilization. By employing TPS, different traffic flows with varying bandwidth requirements can be accommodated by time shifting their packet release. This technique allows for increased time and granularity in bandwidth assignment, effectively improving the range of available bandwidth. The frequency of operation for the patch antenna is determined by its length, denoted as L. The approximate center frequency is determined based on this length, ensuring optimal antenna performance [11]. Overall, these advancements in antenna design and bandwidth allocation aim to overcome the limitations of previous aircraft generations, resulting in improved control systems and enhanced communication capabilities. . The length L determines the frequency at which the patch antenna will operate. The approximate Centre frequency is:

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \quad (1)$$

Where,

L – Length of even micro patch antenna

W – Width of the patch antenna

k – Free space value of Wave number

$E_\theta$– Normalized Radiation Pattern

$E_\varphi$- Normalized Phase Pattern

According to the equation above, the micro strip antenna within the dielectric (substrate) medium should have a length equal to one half of a wavelength. Input impedance is controlled by the micro strip antenna's width W. Increased bandwidth can also be achieved by using wider widths. The input impedance of a rectangular patch antenna supplied in this way will be in the 300 Ohm range. The impedance can be decreased by widening the gap. To reduce the input impedance to 50 Ohms, however, a very broad patch antenna is frequently required, which takes up a lot of valuable space.

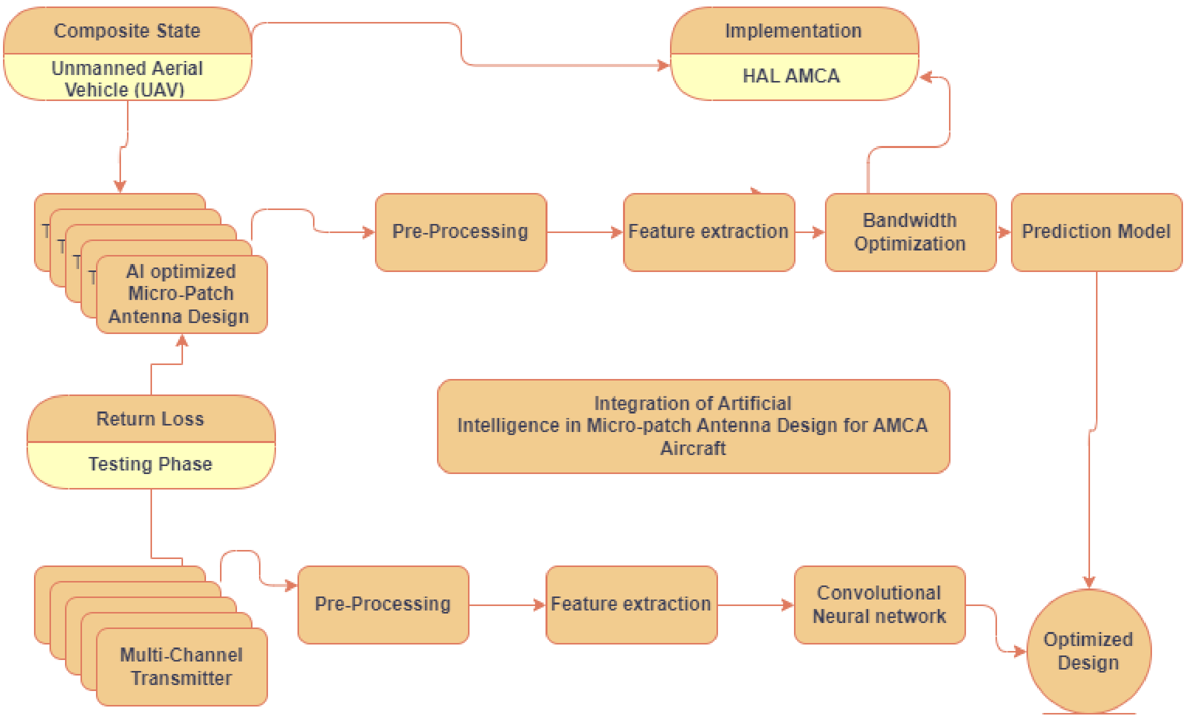


**Fig 1.** Insight on Proposed Methodology

The radiation pattern is further influenced by the breadth. The normalized radiation pattern can be roughly calculated as follows:

$$E_\theta = \frac{sinsin\left(\frac{kW sinsin\theta \sin\sin\sigma}{2}\right)}{\frac{kW sinsin\,\theta sin\,\sigma}{2}} \cos\cos\left(\frac{kL}{2} sin\ sin\ \sigma cos\theta\right) cos\theta \qquad (2)$$

$$\boldsymbol{E_\varphi = -\frac{sinsin\left(\frac{kW sinsinsin\theta \sin\sin\sigma}{2}\right)}{\frac{kW sinsin\ sin\,\theta sin\,\sigma}{2}} \cos\cos\left(\frac{kL}{2} sin\ sin\ \sigma cos\theta\right)\left(\frac{kL}{2} sin\ sin\ \sigma cos\theta\right) cos\theta} \qquad (3)$$

The free-space wave number, denoted by wave number$\frac{2\pi}{\lambda}$, is k in the above equation. The fields' magnitude, as determined by:

$$f(\theta,\phi) = \sqrt{E_\theta^2 + E_\phi^2} \qquad (4)$$

Micro strip antenna is one of the most extensively used antennas in the fryer frequency range and they're frequently used in the millimeter- surge frequency range as well. In this chapter, we will concentrate on the description of the principles of operation of the micro strip patch antenna. There are numerous styles of analysis of micro strip antennas. One of the advantages of the patch antennas is the multitude of ways available to feed the antenna. An aircraft's attitude refers to its relative to the ground. When the aero plane is in a level attitude, its longitudinal centerline is almost parallel to the earth's surface. The horizon will appear to be just about on the nose of the aero plane in this attitude ( i.e. the top of the engine cowling is approximately aligned with the horizon). A nose high attitude occurs when the aircraft's nose is higher than the horizon. The aero plane is in a nose low attitude if the nose is below the horizon.

The weight of the plane, the pilot , the fuel and the equipment is spread evenly throughout the aircraft. The complete weight, on the other hand, may be thought of as being concentrated as a point. The Centre of Gravity is the name given to this place. The plane would be in equilibrium if it were suspended by a rope attached at the centre of gravity (referred to as the CG). A balancing point (called a fulcrum) is located in the centre, with weight on both sides of the fulcrum. The downward pressures on both sides of the fulcrum are equivalent for an aero plane flying straight and level.

## 3. CST Simulation and Results

The design specifications of the micro-strip patch antenna need to be aligned with its intended SAR (Synthetic Aperture Radar) application. Several factors influence the antenna's specifications, which are briefly explained in this section. The frequency band selection is determined based on considerations such as precipitation, de-correlation time, and antenna size. The C-band is often chosen as it offers advantages over higher frequencies (X-band) that are more susceptible to precipitation losses and aliasing of images due to longer de-correlation time. On the other hand, lower frequencies (L-band) require larger antennas. The surface roughness and reflected signal wavelength are estimated based on the Rayleigh criteria and Bragg scattering. Vertical polarization is preferred for maximum reflection from the ocean surface because it allows for the use of identical antennas for both transmission and detection. The available bandwidth obtained from the antenna can be used for transmitting and receiving signals. Therefore, a larger bandwidth provides more capacity for transmission and reception. The Rayleigh criteria and Bragg scattering are taken into account to estimate surface roughness and the wavelength of the reflected signal.The calculation of cross-range resolution and azimuthal resolution, with a bandwidth of 200MHz, yields values of 0.75 meters and 13.5 meters, respectively. These calculated values can then be used to determine the required gain of the antenna.

In summary, the design specification of the micro-strip patch antenna needs to consider factors such as frequency band selection, surface roughness, polarization, bandwidth, and resolution requirements to ensure its suitability for SAR applications.

.Using CST tool we have designed even micro patch antenna to improve the bandwidth of fighter aircraft. The following are the parameters that define the bandwidth of this proposed structure.

(a) The upper patch width (WU)

(b) The upper patch length (LU)

(c) The lower patch width (WL)

(d) The lower patch's length (LL)

(e) The distance between the lower and top patches (GU)

(f) The width of the feed line that connects two patches (WT2)

(g) The aircraft body's curvature (R)

(h) Thickness of the substrate

(I) Substrate substance (Dielectric Constant)

(j) Dimensions of the Bottom Feed line (WT1)

(k) Feed line length at the bottom (LT1)

One parameter is swept about its ideal values in each parametric analysis. The obtained length of the patch determines the resonance frequency, whereas the width determines the patch's edge impedance. The width of the patch can be used to vary the edge impedance. Because the basic even patch is utilized in the parametric analysis, the width and length of the upper and lower patches are considered to be the same. After the upper patch structure has been optimized for the needed bandwidth, the bottom feed length and breadth are also changed.

Similarly, the substrate and thickness are chosen according on the application. As a result, the parametric research includes a total of eight parameters. In each analysis, a specific parameter is swept, while the other values remain constant.

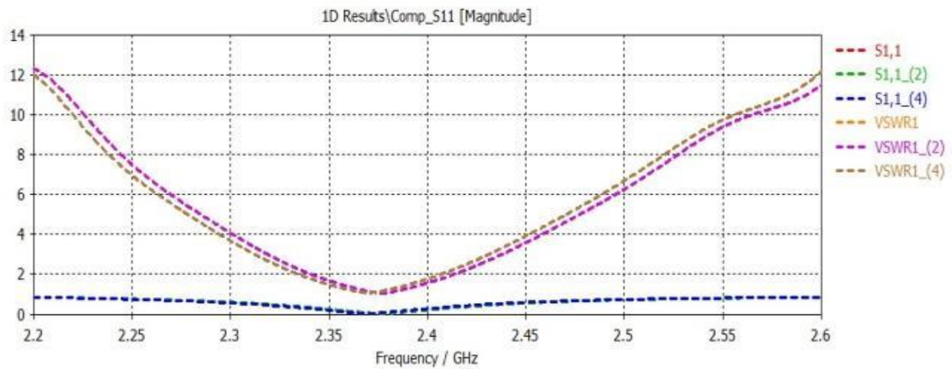


**Fig 2.** Comparison of S11 Magnitude and VSWR

The frequency changes until k value is 2 and it remains constant for all the k value above 2. For k=2, the VSWR decreases gradually until certain point and increases when the bandwidth is increased. For k=4 ,the VSWR decrease gradually until certain point and increase when bandwidth is increased, but greater values then that when the k value is 2.

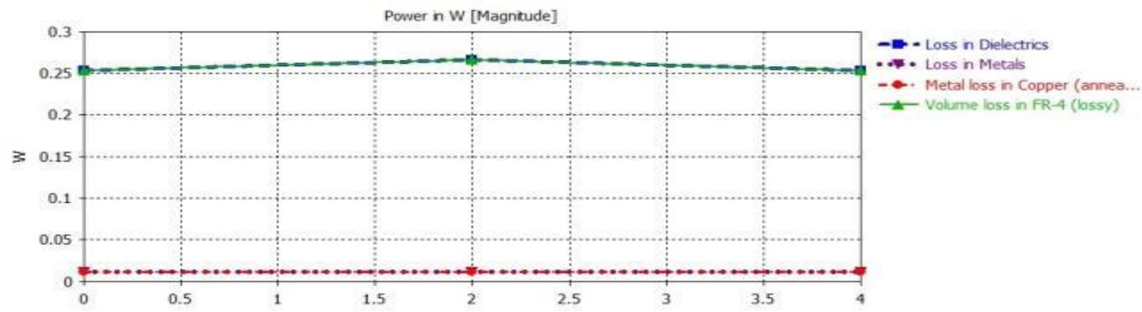


**Fig 3.** Comparison of various Power losses.

Volume loss in FR-4 for lossy material and the loss in dielectrics are found to be same. Similarly, metal loss in copper for micro strip antenna and loss in metal are found to be same.

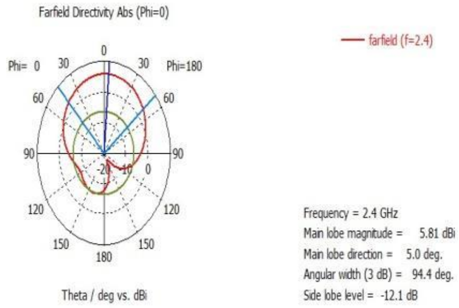


**Fig 4.** Far field Directivity Abs (Phi=0).

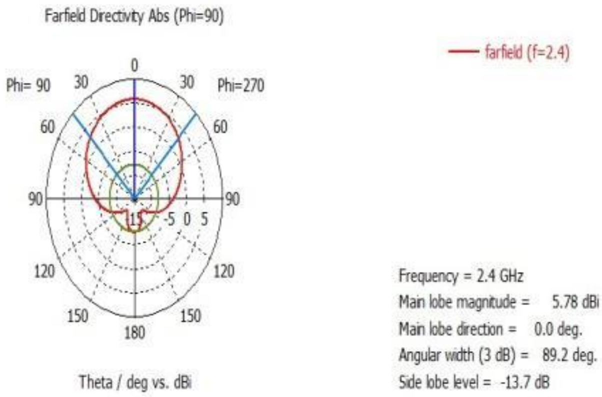


**Fig 5.** Far field Directivity Abs (Phi=90).

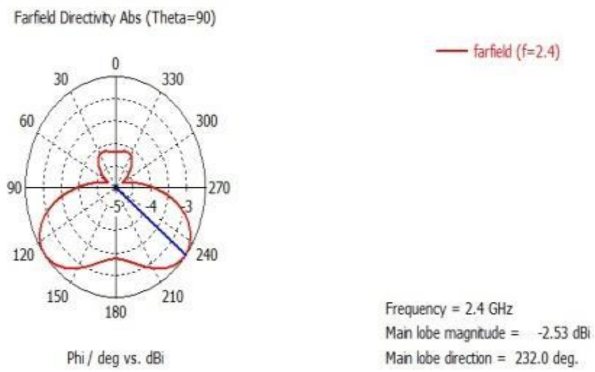


**Fig 6.** Far field Directivity Abs (Theta=90).

From Figure 4, 5 and 6 it is observed that main lobe direction decreases with increase in the values of phi and theta. The hardware implementation of the proposed system is explained. It deals with micropatch antenna, ESC, brushless motor, 6 Channel Transmitter and servo motor. microstrip antenna is used to enhance the bandwidth of aircraft model. Electronic speed control acts as the brain of the model which controls throttling speed and moving direction of the models. Brushless motor uses the throttling power to create the push back force to the model.6 channel transmitter transmits the input signal to the model. Servo motor controls the direction of the aircraft model. Lithium ion battery of 2200 Mah is used to provide source to the model. Receiver which is connected to the micro patch antenna will receive the input signal from transmitter through the micro patch antenna process the signal and sends to the processed signal to the electronic speed control and perform task.

**Table 1.** Comparative analysis of various iterations using AI model

| S.no | Design | Bandwidth (GHz) | Return Loss(dB) | Gain (dB) | Efficiency Improvement |
|---|---|---|---|---|---|
| 1 | Iteration 1 | 0.330 | 29 | 8 | 6.35% |
| 2 | Iteration 2 | 0.762 | 32 | 9.5 | 14.81% |
| 3 | Iteration 3 | 0.954 | 39 | 12.3 | 17.61% |

AI algorithms can optimize the parameters of a micro-patch antenna, such as patch dimensions, substrate material properties, feed location, and ground plane shape. The objective can be to maximize parameters like gain, directivity, bandwidth, or minimize parameters like return loss and cross-polarization. Techniques like genetic algorithms, particle swarm optimization, and simulated annealing can be used to explore the design space and find the optimal configuration. In most of the drone's applications, the spread is constantly rising in a different range of applications which ranges from the hobbyist, industrial and commercial & in most superior military applications. The commercial applications of the drone are many like monitoring buildings, plants, agriculture, shooting areas & delivery of medicines, packages otherwise essential goods. Generally, the high-range of drones mainly equipped with BLDC motors but these motors need cautious & continuous speed regulation for the relative direction of revolution. For that, the ESC circuit is responsible.

## 4.Conclusion

AI algorithms can enable adaptive micro-patch antennas that can dynamically adjust their configuration based on changing environmental conditions or user requirements. This can be achieved through techniques like reconfigurable patches, beam-forming, or tunable materials controlled by AI algorithms. It's important to note that the successful implementation of AI in micro-patch antenna design requires accurate training data, proper validation, and a deep understanding of electromagnetic theory and antenna design principles. Additionally, a multidisciplinary approach involving expertise in antenna design, machine learning, and electromagnetic simulations is often necessary for effective integration of AI techniques into micro-patch antenna development. The improved performance of the HAL AMCA and to improve the technology to sixth generation of the AMCA is the best source that will boost one of the India's defense technologies. Introducing this sixth generation of the technology will lead a way to prove India as one of the best technologically developing countries in the world.

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