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AN ANALYSIS AND DESIGN OF A SELF-POWERED MICROSTRIP PATCH ANTENNA USING ARTIFICIAL INTELLIGENCE (AI)

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Abstract

A solar cell circuit design for a self-powered system is connected to the suggested MPA. The 20-W solar panel is immediately linked to the DC/DC buck converter's input in the setup of the system, and the TS5828 transmitter is attached to the converter's output. The system can function as a self-powered wireless surveillance monitoring system since it can operate up to 16.5 meters from the receiver and 15.5 meters from the transmitter.For a desired frequency between 3.5 GHz and 5.5 GHz, a Microstrip Antenna design is presented in this work. When the suggested method's results are compared to those of a full-wave EM solver, they are discovered to be in good agreement. The benefit of the suggested approach is that it eliminates the need for time-consuming, expensive software packages and allows for the quick extraction of the various parameters needed for the design of a specific Microstrip antenna at a given frequency of interest. The rectangular patch geometry is used to illustrate the general design process for Microstrip antennas that is proposed in this study using Artificial Intelligence (AI).

Keywords: patch Microstrip AIAntenna, Artificial Intelligence (AI), Microstrip antenna, mmWave,Solar Panel.

Introduction

Low profile antennas may be necessary in high performance satellite, aircraft, missile, and spacecraft applications where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints. Similar standards are presently used in a wide variety of different governmental and commercial applications, such as wireless communications and mobile radio. Microstrip antennas can fulfill these needs[1,2].These antennas can be manufactured easily and affordably using modern printed circuit technology, are compatible with MMIC designs, mechanically reliable when mounted on rigid surfaces, conformable to planar and non-planar surfaces, and extremely versatile in terms of resonant frequency, polarization, pattern, and impedance when particular patch shapes and modes are used[3,4]. To estimate the resonance frequencies of Microstrip patches of different forms, such as rectangular, triangular, etc., numerous ANN models have been created. Using ANN methods and back propagation as the learning process, numerous designs have been produced. The major objective of the continuing work is to apply RBF neural networks to the fabrication of microstrip antennas. Building an antenna at a particular frequency of interest is typically found to be a time-consuming iterative procedure, particularly when the antenna's attributes depend on numerous variable input parameters[5]. Since it necessitates the determination of several parameters and supports the usage of ANN for its design, the inset feed Microstrip Antenna is employed as a test case. In order to achieve the desired frequency range for an inset feed microstrip antenna between 3.5 GHz and 5.5 GHz, this work creates an ANN model that yields design parameters[6].

Antenna Design:

The radiating edge of the patch antenna is materialized in this work by creating rectangular holes. This is because slot loading antennas outperform conventional rectangular patch aerials in terms of resonant frequency, return loss, and bandwidth cost. Given that one of the main shortcomings of microstrip patch antennas is their narrow bandwidth, the properties of the antenna, including return loss, VSWR, and radiation pattern, have been studied for the 24 GHz band[7]. The following equation can be used to compute the MPA's effective dielectric constant:

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$$\varepsilon_{reff} = \frac{\varepsilon_r + 2}{2} + \frac{\varepsilon_r - 2}{2}(1 + 12\frac{h}{w})^{0.5}$$

Patch length is elongated by ΔL at either end.

$$\frac{\Delta L}{h} = 0.412\frac{\left(\left(\frac{w}{h}+0.264\right)\left(\varepsilon_{reff}+0.3\right)\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{w}{h}+0.8\right)}$$

$$L_{eff} = 2\Delta L + L$$

The ratio of the antenna's maximum and minimum RF voltage levels is known as VSWR. The reflection coefficient is the ratio of the amplitudes of the incident wave and the reflected voltage wave.

$$r = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$$

$\rho = \frac{VSWR-1}{VSWR+1} = |r|$ and VSWR= $\frac{|r|+1}{|r|-1}$

Return loss parameter =-20 log $\left(\frac{VSWR+1}{VSWR-1}\right)$

Here Z_0 is the antenna s characteristics impedance

Self-sufficient microstrip patch antennas (MPAs) (Figure-1) have attracted a lot of interest, especially because of their ability to provide wireless surveillance monitoring systems with a steady, dependable signal and reasonably priced, eco-friendly electricity. Even though MPA is a low-cost, lightweight antenna, its bandwidth and gain are limited, and these two factors are essential to the antenna's functioning. This paper proposes a novel AI-based self-powered MPA design.

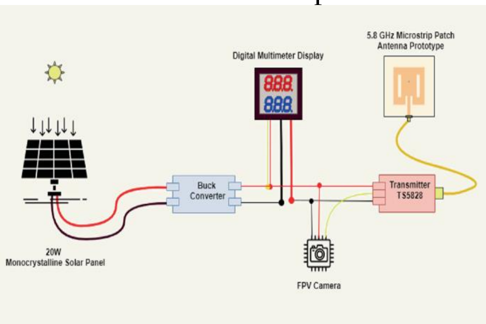

Figure- 1(a) Self-powered solar Patch Antenna[3]

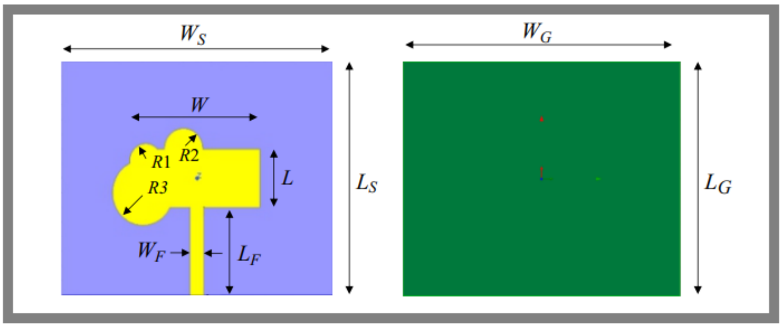

Figure-1 (b) Reference antenna and (c)-ground plane

Slot loading antennas perform better in terms of resonance frequency, return loss, and bandwidth than conventional rectangular patch variations. It permits a resonance frequency reduction of up to 36% and an aerial size reduction of more than 60%. The use of extra slots may contribute to a further expansion of the antenna's bandwidth. High gain can be achieved with a modified slot geometry and a substrate with a high permittivity[8]. This illustrates how the thickness and selection of the substrate are important design factors. In this investigation, a FR4 substrate with a dielectric constant of 4.4 and a thickness of 0.8 mm is used. For the relevant antenna structures in this work, the following assumptions are made:

Consider rectangular substrates with single-layer microstrip antennas. The substrate's entire width and the bottom of the ground plane are considered to be rectangular in shape. Within the constraints of the

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assumed parameterization, the optimization approach determines the ground plane height and the front-side metallization structure. These laws provide a wide range of topologies for antenna constructions. A powerful fully integrated design and analysis tool for RF, microwave, millimeter wave, analogy, and RFIC design is the AWR Design Environment combining Microwave Office and Analogy Office [9]. Users of Microwave Office's EM Sight tool can replicate any multi-layered EM structure. A modified spectral domain technique of moments is used by EM Sight, a full-wave EM solution, in a rectangular enclosure filled with a planar, piece-wise constant stratified media[10]. This method is used to precisely determine the multi-port scattering properties for predominantly planar structures[11]. EM Sight can inspect circuits with an infinite number of layers and ports. However, three-dimensional (3-D) things are not permitted since circuits must be flat. Conductive layers may be connected through vias. The EM Sight solver computes a separate solution for each frequency specified in the frequency range.In general, ANN models have advantageous characteristics that support the resolution of EM tasks[12]. By maximizing the relationship between input and output data, ANNs have the crucial capacity to approximate the mappings of nonlinear input-output data. On the other hand, another important characteristic of ANN is its capacity to adapt to changes in the training environment. The fact that machine learning cuts down on the calculation time seen in CEM techniques is one of its main advantages. This advantage becomes seen when numerous parameters need to be optimized or when a large model structure needs to be built. The established theories of antennas still struggle to effectively address the microstrip antenna geometries, particularly intricate geometrical geometries, or the new model structures[13]. This can be demonstrated by the fact that some of these geometries are not accurate. Machine learning can be applied in real-time to evaluate and enhance the performance of antennas as well as model and predict dispersion issues.

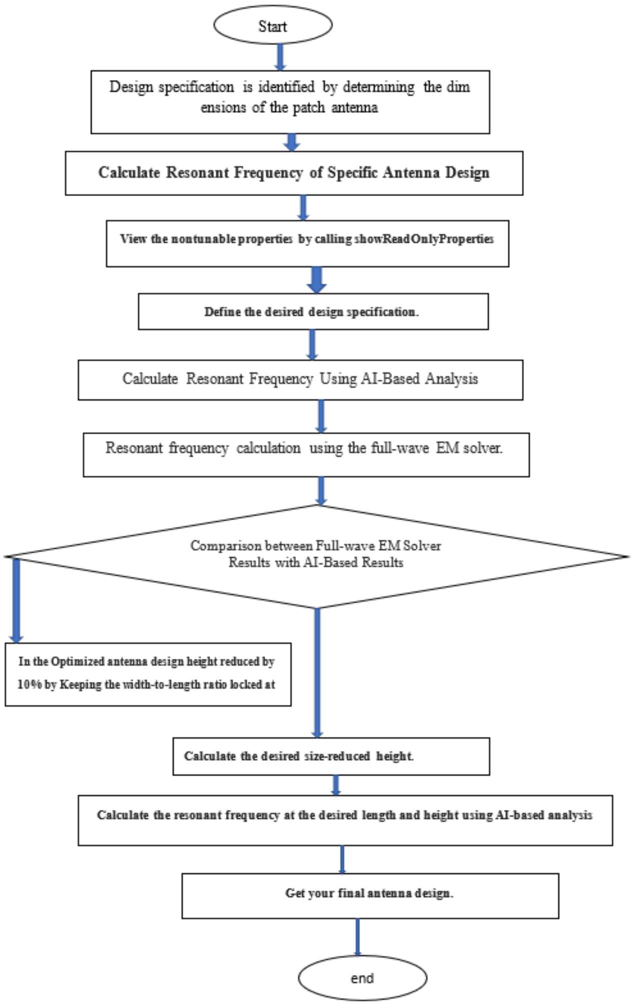

Figure -2 Flow chart for Design of Artificial Intelligence (AI) for Microstrip Patch Antenna

Rapidly characterize and explore antenna across the design space:
Maintain the resonance frequency and width-to-length ratio while lowering the antenna's height by 10%. To swiftly explore this design space and establish the desired time, use AI-based analysis. Higher attenuation coefficients at higher frequencies than at lower frequencies result in greater electromagnetic energy absorption and higher tissue temperatures[14,15]. Due to the significant thermal conduction, this may result in steeper temperature gradients away from the applicator and greater ablation zones[16]. Ablation antennas made to emit at up to 18 GHz frequencies have been the subject of certain studies . The tissue around the applicator is substantially more severely charred and desiccated at higher attenuation levels than at lower frequencies (915 MHz and 2.45 GHz), despite the shorter wavelength being preferable to enable adequate control of the ablation zone length. The relative unpredictability of tissue water vaporization and strong charring at high temperatures, as well as the potential for more complex system design, must be weighed against the possible benefits of operating at high frequencies[17,18].

Results:
The results of the AI-based study are plotted against the full-wave EM solution in Figure 4. The resonance frequency of the AI-based analysis is almost identical to the full-wave EM solution's results. Despite the relative accuracy being less than 1%, the AI-based calculations are performed far more quickly than the full-wave EM solver.

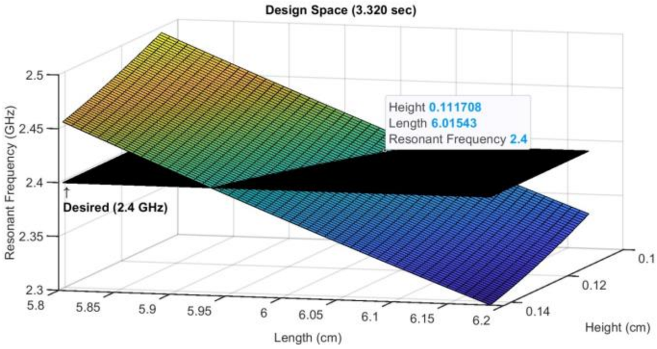

Figure -3 Design space

Figure -3 demonstrates the ability to quickly calculate 50 * 50 = 2500 points in the design space. Due to the significantly greater computing time, using full-wave EM analysis would not have been feasible in this case.

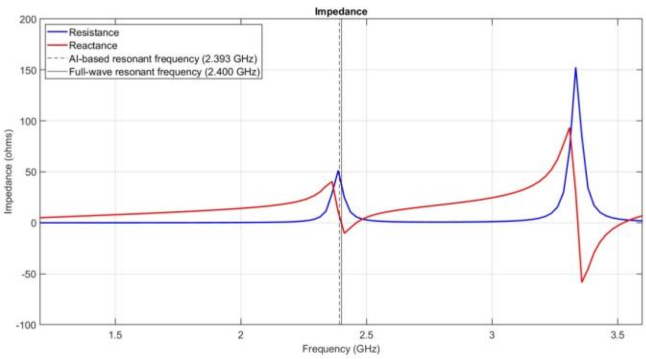

Figure- 4 Resonant frequency full-wave EM solver against the results of the AI-based analysis

Table-1 Time of execution

AI Time	Full wave EM solver Time
0.051sec	186.02 sec

Table-2 Resonant frequency

Resonant Frequency From AI based Analysis	Resonant Frequency From Full wave EM solver Analysis	Initial design frequency	Error In percentage
$2.3848*10^9$	$2.3958*10^9$	$2.48*10^9$	0.098

Table- 3 Tunable parameters in meter

Length	Width	Height
0.0600	0.0781	0.0012

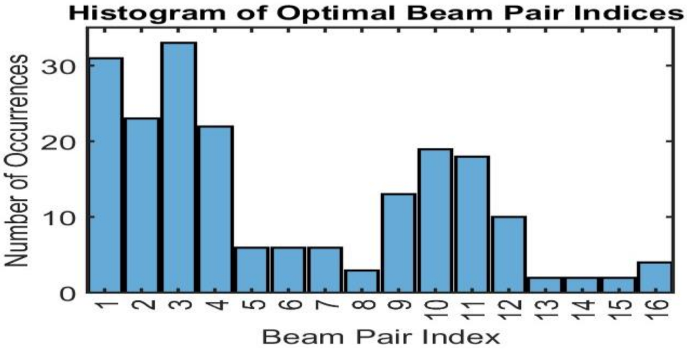

Figure –5 Histogram of optical beam pair indices

The scattered and transmitter locations will determine the actual distribution of the beam pairs, but expanding the training data set to include each beam pair value is still a possibility. The histogram of the optical beam pair indices is displayed in Figure -5.

Conclusion:

AI-based analysis for antenna characterization is conceivable due to its high accuracy and speedier computation times. Maintain the resonance frequency and width-to-length ratio while lowering the antenna's height by 10%. To swiftly explore this design space and establish the desired time, use AI-based analysis. When you first construct the parameters for adjusting the height and length gradually to characterize the space, use default Tunable Parameters to maintain track of the default values. You should specify a narrow tuning range for the length because length is the resonant dimension and your antenna's resonant frequency is already rather near to the target frequency in order to maintain the resonant frequency.

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