Design and Analysis of H-Shape Microstrip Patch Antenna for 5G Wireless Communication Systems

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ABSTRACT- This research paper presents a novel high-gain, wide-band H-shaped slot-loaded microstrip patch antenna. This antenna is printed on a dielectric substrate with a metallic ground plane and is directly fed by a 50 Ω coaxial cable. The antenna was simulated using the ADS software package according to the specified dimensions. The combined effect of incorporating these techniques and introducing the novel slotted patch results in a low-profile, wide-bandwidth, high-gain, and compact antenna element. This printed monopole antenna can be used in wireless communication devices operating in various frequency ranges. In this rapidly evolving world of wireless communication, dual or multiband antennas play a crucial role in meeting the demands of wireless services. An antenna transmits and receives information, making it an essential component for microwave communication. This research paper discusses various feeding techniques used for microstrip patch antennas, which is a key aspect of its design. Achieving a good impedance match between the line and the patch without additional matching components primarily depends on the feeding technique used. After discussing various feeding techniques, this research paper provides an enhanced understanding of the antenna's design parameters and their impact on bandwidth and gain.

KEYWORDS - Microstrip patch antenna, Operating frequency, feeding techniques.

1. INTRODUCTION

The most commonly used microstrip patch antenna is a rectangular patch. A rectangular patch antenna is essentially a section of a rectangular microstrip transmission line, whose length is approximately equal to one wavelength. This antenna uses a dielectric material as the substrate; the length of the antenna decreases as the relative dielectric constant of the substrate increases. When air is used as the substrate of the antenna, the length of the rectangular microstrip antenna is approximately half of the free-space wavelength. A suitably small antenna improves transmission and reception. Microstrip resonators can be divided into two types based on the length and width of the antenna. Resonators with narrow conductors are called microstrip dipoles, and those with wider conductors are called microstrip patches. Resonance occurs when the dimensions of the dipole or patch are equal to half of the guided wavelength. Since they have similar longitudinal current distributions, their radiation patterns and gain are also similar, although other characteristics (such as input impedance and polarization) may differ. When the signal frequency is in the resonance region, a microstrip resonator radiates a broad beam perpendicular to the plane of the substrate. A large portion of the signal participates in radiation, and therefore the resonator acts as an antenna. Since the size of the patch must be comparable to the radio-controlled wavelength, its directivity is quite low; For example, the gain of a half-wavelength dipole is typically 5-6 dB, and the beamwidth is between 70 and 80 degrees. The design of a microstrip antenna begins with determining the size of the patch used for the antenna. Due to the fringing fields that occur at the radiating edges of the antenna, a line extension is added to the patch.

2. LITERATURE SURVEY

A comparison of different feeding techniques is presented. Finally, a microstrip patch antenna was designed at a specific frequency of 1.25 GHz, and simulations were performed using IE3D design software to gain a better understanding of the antenna design parameters and their effects on the radiation pattern and gain. The input data required for the ANN model was generated from the IE3D simulation software. This input data included the variation of the antenna reflection coefficient S(1, 1) and antenna impedance Z(1, 1) with various antenna parameters such as patch length and width, dielectric height, patch offset in the X and Y directions, probe radius, slot length, stub length, probe center, and patch center for S-band aperture coupled microstrip antennas and L-band capacitor coupled microstrip antennas. This dataset was used to train and validate the ANN model.

This technological trend has focused on the design of microstrip antennas with simple geometries. Patch antennas offer several advantages that are not typically found in other types of antenna systems. Microstrip antennas can be easily and inexpensively fabricated using printed circuit board technology. They are very compact and lightweight [1-4].

They are compatible with microwave and millimeter-wave integrated circuits and can conform to both planar and non-planar surfaces. Furthermore, once the patch shape and operating mode are selected, the designs become highly versatile in terms of operating frequency, polarization type, and impedance. The low efficiency, high Q value, poor polarization purity, poor scanning performance, unwanted feed radiation, and extremely narrow frequency bandwidth of a microstrip patch antenna have limited its versatility. However, in some applications where a narrow bandwidth is desirable, such as in government defense systems, microstrip patch antennas are indispensable [5]. However, by increasing the thickness of the dielectric substrate, it is possible to achieve a larger bandwidth (up to 90 percent) and improved efficiency (up to approximately 35 percent) for the desired microstrip antenna [6]. But as the height of the dielectric substrate increases, some energy is lost due to surface waves [7]-[8]. However, to reduce surface waves and the resulting energy loss, while simultaneously maintaining a large bandwidth and improved efficiency, several methods are used, including the cavity method and the stacking method [9].

Furthermore, the ability of a rectangular microstrip patch antenna to exhibit both linear and circular polarization has increased its versatility. Before the revolution in electronic circuit miniaturization and large-scale integration in wireless communication (i.e., before 1970), microstrip antennas, consisting of conductive strips on a ground plane substrate, were underdeveloped. Since then, many researchers have been studying the radiation emitted from the radiating patches of microstrip antennas of various configurations. Munson's early work focused on a low-profile, surface-mounted microstrip antenna for practical applications in rockets and missiles. Due to the increasing demands in communication systems, multiband frequency operation has been achieved using multilayer structures. Various mathematical models have also been developed to improve the performance of these antennas. The research papers and documents related to these antennas published in journals over the past decade highlight their growing importance. It is now one of the preferred methods for antenna designers for microstrip antenna design [10-12].

A wide bandwidth antenna has been achieved, which is 2.5 times greater than that of a conventional edge-fed patch antenna. Furthermore, it has been possible to create an antenna with a smaller physical size but higher output compared to previous research. Chiba and his colleagues presented a dual-frequency planar antenna for handheld telephones. The authors described a dual-band antenna consisting of an outer quarter-wavelength ring-shaped loop with a shorting plane for the lower resonant frequency and an inner quarter-wavelength rectangular patch for the higher frequency response [13]. In this research paper, the authors achieved a 36% impedance bandwidth and an average gain of approximately 7 dBi using an interesting L-shaped probe feed for a thick microstrip antenna. Here, a microwave absorber

3. STUDY OF ANTENNA DESIGNING PARAMETERS

There are three essential parameters for designing a rectangular microstrip patch antenna. Firstly, the resonant frequency (f0) of the antenna must be chosen correctly. For ultra-wideband applications, the frequency range is 3.1 to 10.6 GHz, and the designed antenna should be able to operate within this frequency range. The second important parameter of the antenna is the thickness of the substrate. For this reason, the height of the dielectric substrate used in this antenna design is h = 1.6 mm. The third important parameter for a good antenna design is the dielectric constant (εr) of the dielectric substrate.

A thicker dielectric substrate with a low dielectric constant is desirable. This provides improved performance, wider bandwidth, and enhanced radiation. A lower value of the dielectric constant increases the fringing field at the edges of the patch, resulting in increased radiated power and a reduced quality factor Q. FR-4 epoxy can be used for the new antenna design, which has a dielectric constant of 4.4 and a loss tangent of 0.02. The patch is fed by a microstrip transmission line. The patch acts as a conductor. This antenna structure consists of length L, width W, dielectric substrate height h, and loss tangent. The dielectric constant of the substrate material is a very important design parameter. These are placed on an infinite ground plane. When the patch starts radiating, it forms around a length Lg/2, which is typically associated with a 50Ω impedance. The antenna is usually fed at the isolated edges of width W, as this provides the correct polarization, but its drawbacks include unwanted radiation and the need for impedance matching, which arises due to the typical terminal resistance range of 1500 to 300 ohms for microstrip antennas.

4. APERTURE COUPLING FEED

In a basic aperture-coupled patch antenna, the radiating microstrip patch element is printed on top of the antenna substrate, and the microstrip feed line is printed on the bottom of the feed substrate. As a result, the thickness and dielectric constant of these two substrates can be independently selected to optimize the separate electrical functions of radiation and circuitry. Although the original prototype antenna used a circular patch aperture, it was soon realized that using a rectangular slot would improve the coupling for a given aperture area due to its enhanced magnetic polarization capabilities. The aperture-coupled microstrip antenna has more than twelve components and dimensional parameters, and we summarize the fundamental trends associated with variations in these parameters below: dielectric constant of the antenna substrate, thickness of the antenna substrate, length of the microstrip patch, width of the microstrip patch, dielectric constant of the feed substrate, thickness of the feed substrate, length of the aperture, width of the aperture, width of the feed line, position of the feed line relative to the aperture, and position of the patch relative to the aperture. In this technique, a ground plane separates the radiating patch and the microstrip feed line. Coupling between the patch and the feed line is achieved through an aperture or slot in the ground plane (which is typically located at the center, directly beneath the patch), thereby reducing unwanted radiation.

5. PROPOSED MODEL

Figure 1 shows the structure of the printed patch antenna and the fabricated antenna. The antenna substrate is placed between two copper metal layers. The dimensions of the proposed antenna are given. The aperture and ground plane parameter dimensions are scaled equally in both the X and Y directions. As shown in the figure, a simple rectangular aperture is placed in the ground plane. The aperture placed in the ground plane is constrained at a distance of 6 mm from its top edge and 3 mm from its left edge. The feed point is located at a distance of 2 mm from the bottom edge of the patch and 3 mm from the left edge.

6. FEED LOCATION DESIGN

To radiate electromagnetic waves from the antenna, a feed is used to excite it through direct or indirect contact. Microstrip antennas can have several feed configurations such as microstrip line, coaxial, aperture coupling, and proximity coupling. However, microstrip line and coaxial feeds are commonly used because they are easier to fabricate. The coaxial probe feed is preferred because it is easy to implement, and the input impedance of a coaxial cable is typically 50 ohms. There are several points on the patch where the impedance is 50 ohms. We need to locate these points and match them with the input impedance. When the feed point is selected, it is chosen such that it covers the maximum possible area of the radiating patch at that point.

7. FABRICATION ADVANTAGES

CST software is used to simulate electromagnetic fields across the entire electromagnetic spectrum. All the microstrip patch antennas with varying dimensions mentioned above are fabricated on a dielectric substrate material using conventional milling techniques with the help of a machine. A computer numerical control unit helps in minimizing errors during antenna fabrication. CST is based on the Finite Integration Technique (FIT) and is very popular among antenna designers due to its ease of use in simulations. CST Studio Suite is a high-performance 3D EM analysis software package for designing, analyzing, and optimizing electromagnetic (EM) components and systems. CST Studio Suite contains electromagnetic field solvers for various applications across the entire EM spectrum within a single user interface.

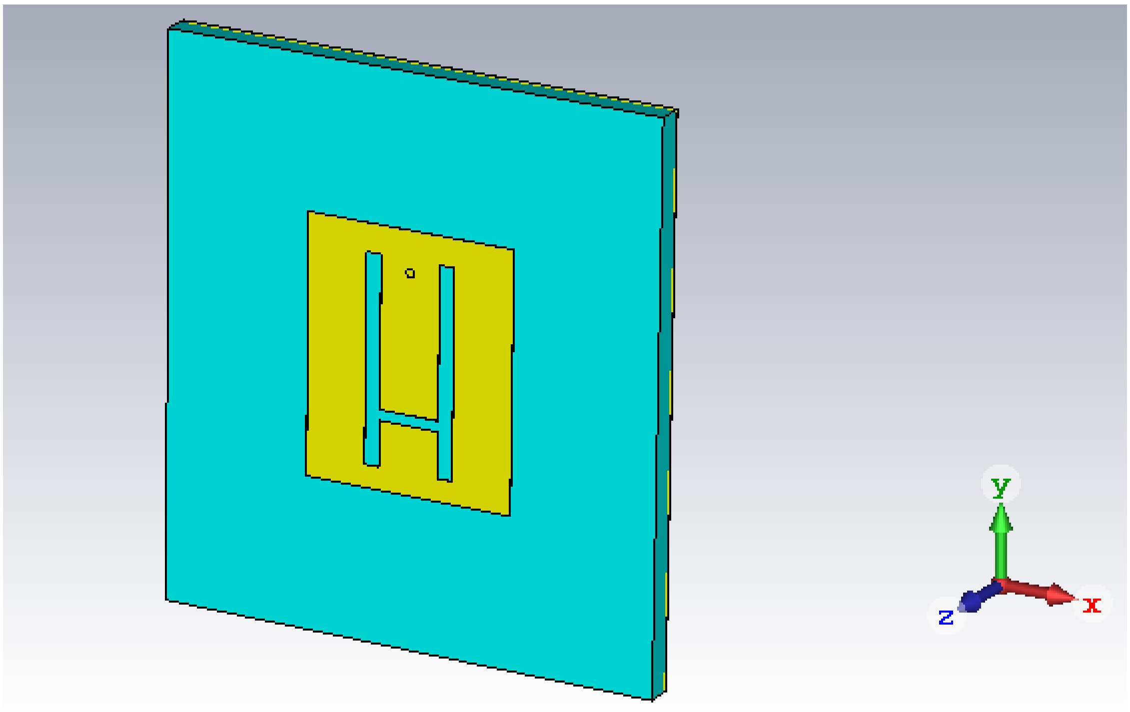

Figure 1. Geometry of microstrip patch antenna with strip

8. RESULTS AND DISCUSSION

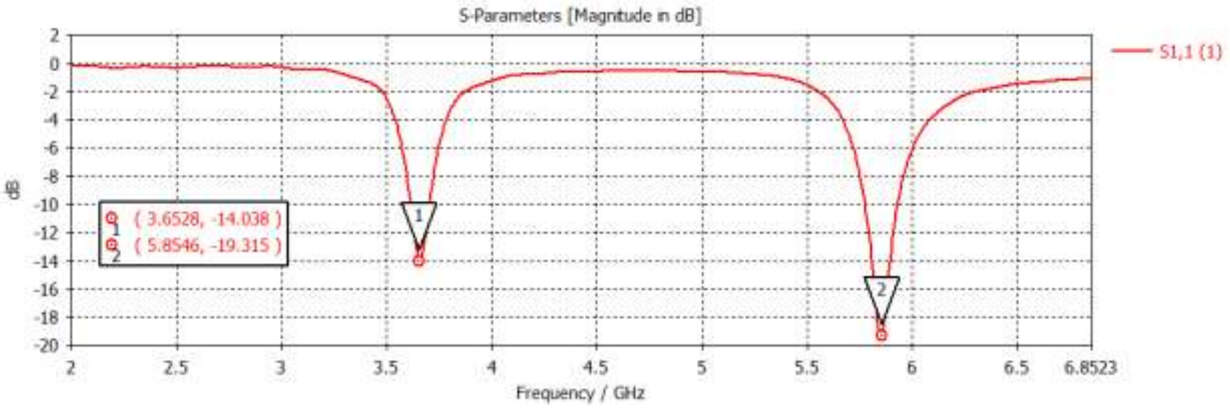

Figure 2. S-factor (S-parameters are a method of describing the characteristics of a device using traveling waveforms instead of voltage and current. They tell us how much of a wave is reflected from or transmitted through a device. For a device like an antenna, there is not just one S-parameter, but rather four S-parameters.

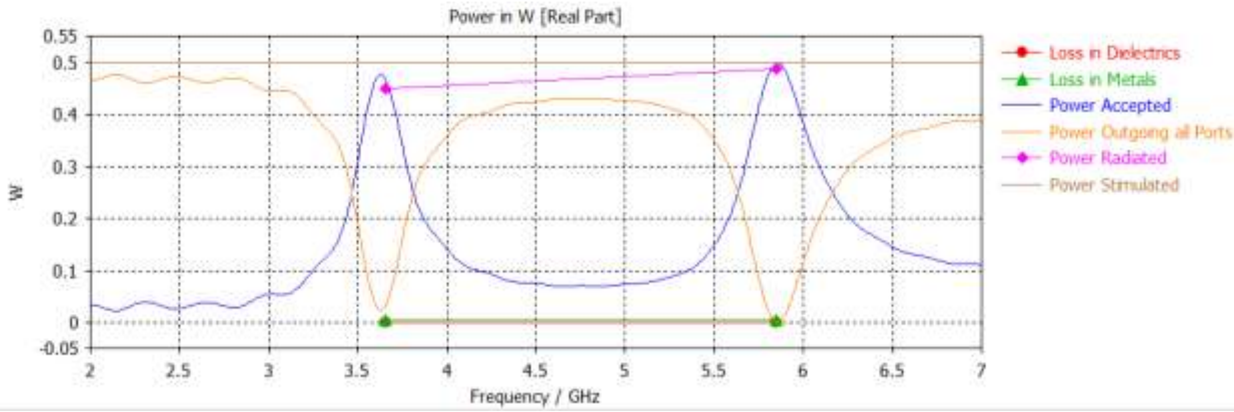

Figure 3. Power (W) (The energy emitted from a unit area is obtained by multiplying Planck's energy density by c/4. Its numerical value can be estimated by multiplying the sum of the values of Planck's radiation intensity by the wavelength period. The region where the interaction of the electromagnetic field begins to transform into radiation is called the radiative near-field or Fresnel zone.

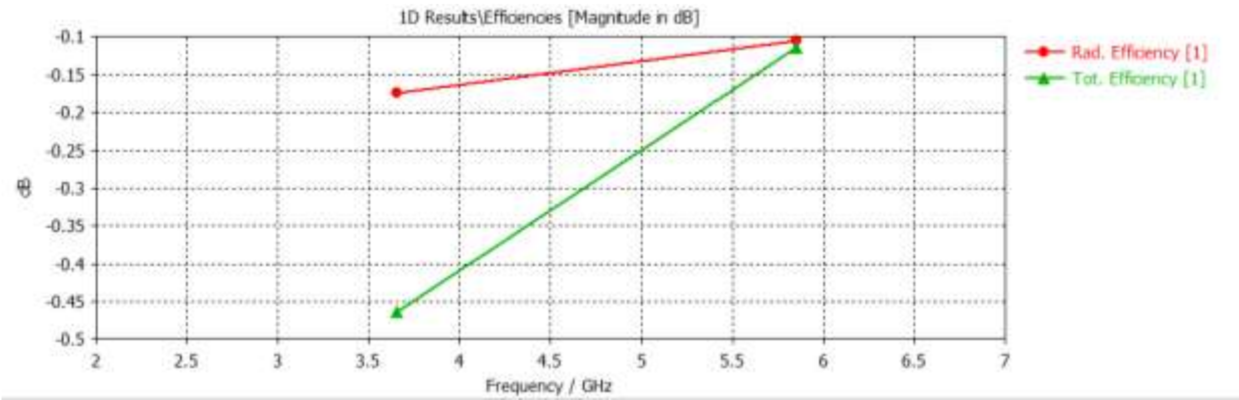

Figure 4. Efficiencies (Antenna efficiency is a parameter that takes into account the amount of losses occurring at the antenna terminals and within the antenna structure.

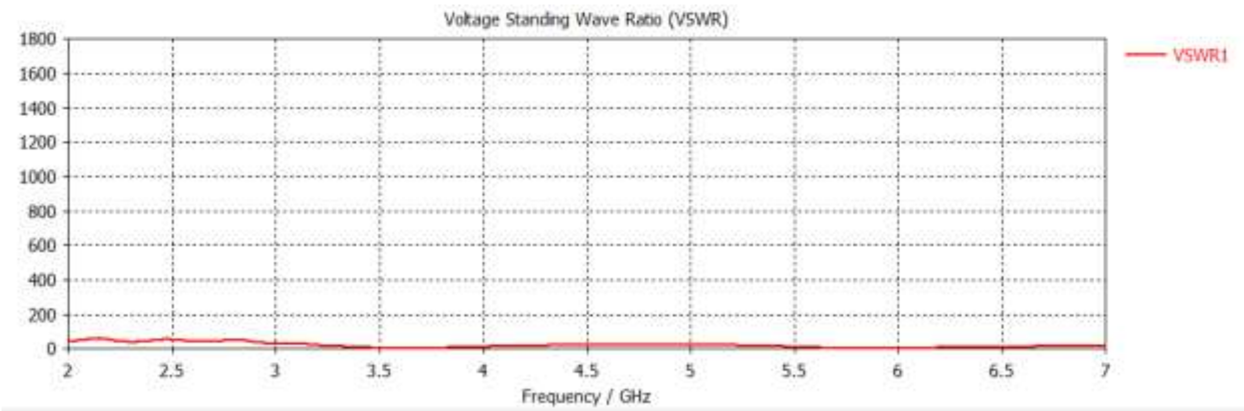

Figure 5. VSWR (The Voltage Standing Wave Ratio (VSWR) is essentially a measure of the impedance mismatch between the transmitter and the antenna. A higher VSWR indicates a greater mismatch.

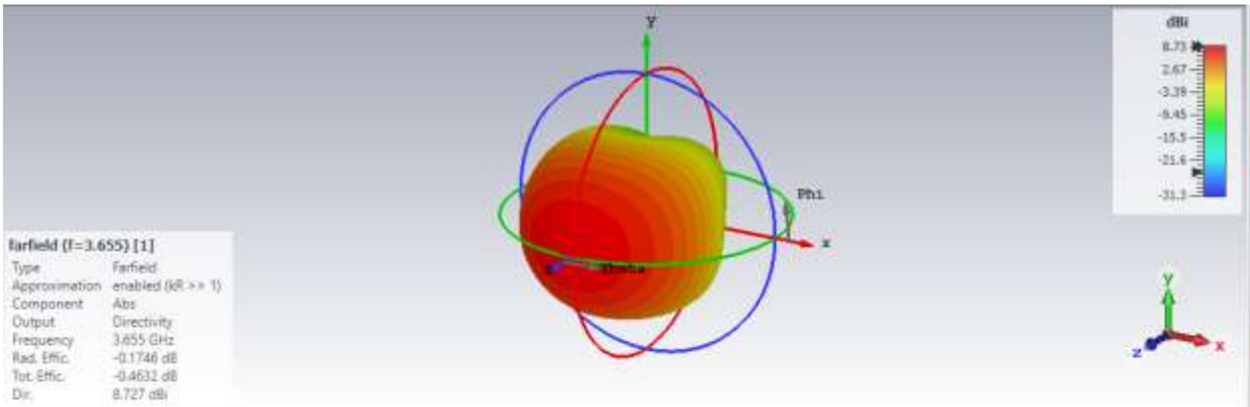

Figure 6. Farfields, one band (Based on the analysis of a transmission line model, a simple formula has been developed to describe the far-field radiation emitted from a rectangular microstrip patch. The current and polarization distributions have been derived using the volume equivalence theorem. Specifically, analytical formulas are provided to describe the radiation pattern in the E-plane and the worst-case cross-polarization level.

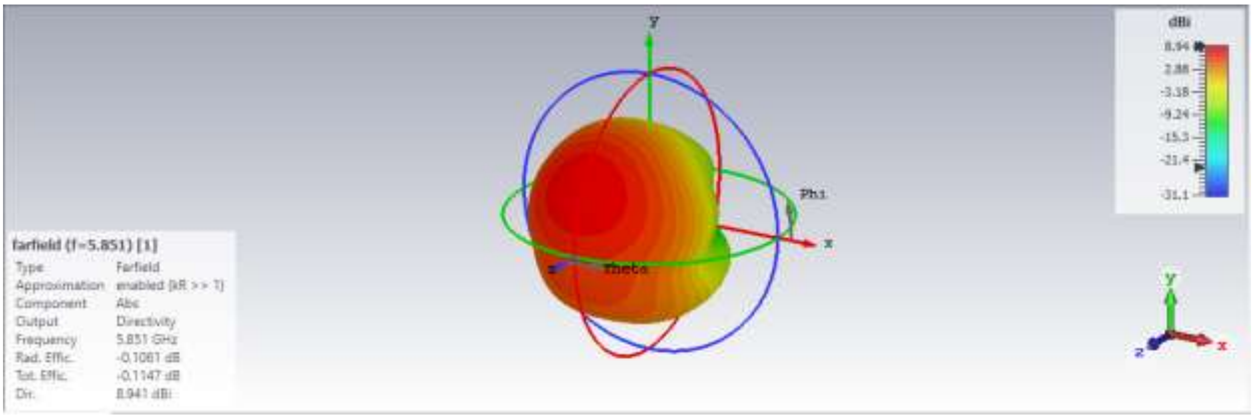

Figure 7. Far fields, other band

9. CONCLUSIONS

We have examined various parameters such as return loss, impedance, VSWR, directivity, gain, bandwidth, and operating frequency, and also studied the effect of physical parameters on the performance of the designed antenna. In our research paper, we first considered the design and simulation of a single-band narrow-band rectangular patch antenna and then extended it to a dual-band narrow-band rectangular patch antenna. Here, we examined various parameters such as return loss, impedance, voltage standing wave ratio, directivity, gain, bandwidth, and operating frequency, and also studied the effect of physical parameters on the performance of the designed antenna. The results obtained from the simulation show that it is an excellent choice for wireless communication systems. In the future, it can be fabricated to compare the simulation results with the actual results. From the simulation, the return loss, gain, radiation efficiency, and S-factor show return losses of -14.038 dB and -19.315 dB, respectively.

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