CMOS Microstrip Antenna Design for Wireless Sensor Network Applications

Dr. Swastika
Research Scholar Eklavya University Damoh(MP)
Department of Electronics & Communication Engineering

Abstract
Using the standard 0.18 m CMOS technology, a methodical design approach for a compact circularly polarised microstrip antenna is put forth in this study. The in question antenna is relatively small. The antenna's performance in terms of return loss, axial ratio, impedance matching, gain, and radiation pattern has been adjusted for use in the 2.4 GHz ISM band. The antenna's electromagnetic simulations were carried out using the ANSYS High Frequency Structure Simulator (HFSS). The antenna is 6 mm by 5 mm in total. According to the simulation's findings, the operational band has a peak gain of 1.8 decibels, an axial ratio of 3, and an S11 of -10 dB. The antenna is suitable for WSN applications that need communication lines that are insensitive to direction for higher connection since it has good characteristics for circular polarization. This is due to the fact that these applications demand a stronger connection. Wireless sensor nodes can be easily integrated into the CMOS compatible architecture, allowing for the creation of WSN modules that are both small and reasonably priced.
Keywords; ANSYS High Frequency Structure Simulator (HFSS), CMOS compatible architecture

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Introduction :

Modern technologies like wireless sensor networks (WSNs) have the potential to revolutionise a number of sectors, including healthcare, environmental monitoring, industrial automation, as well as smart homes and buildings [1]. Temperature, pressure, vibration, motion, pollution, and other related conditions are examples of these. It is now possible to deploy WSNs on a large scale using nodes that are both small and affordable thanks to the development of low cost and low power wireless modules. Each sensor node is equipped with the parts required for sensing, processing, communication, and power supply [3]. It is now possible to create sensor nodes that are compact, battery-powered, and have constrained wireless communication and processing capabilities [4] Within specific constraints, these sensor nodes can also communicate wirelessly. Wireless sensor networks (WSNs) are able to be extremely flexible to the requirements of a wide variety of applications despite having limited power, memory, and processing resources [5]. This is because they have distributed sensing intelligence.

Because it is in charge of creating wireless connections, the communication module is a crucial part of the sensor node. The optimisation of WSN modules in terms of their size, cost, and performance depends on the creation of effective antennas that are also incredibly small. For use in WSN nodes, microstrip patch antennas are frequently chosen [6, 7]. This is as a result of its low profile, light weight, ability to be produced at a low cost, and flexibility to connect with printed circuit boards. The substrate for microstrip antennas is often constructed of ceramic or FR-4, both of which are relatively inexpensive materials. As a result, it will be easy to etch the antenna element design onto the substrate using techniques used frequently in the manufacture of printed circuit boards (PCB) [8]. Since connectors are no longer required and there are less losses as a result of the integration, the efficiency of the system as a whole is increased when antennas and electronic components are combined into a single substrate board [9]. [10], can be used to form the feed network for the microstrip antenna in a flexible way. Additionally, by choosing the suitable patch element shapes, substrate dimensions, and feeding techniques, patch antennas' radiation properties, resonant frequency, and polarisation characteristics can be adjusted to meet the needs of the application [11].

Because it completely eliminates polarisation mismatch losses between transmitting and receiving antennas with any orientation, circular polarisation is frequently chosen for WSN antenna designs [12]. This increases the link's dependability between wireless networks. Asymmetric C-shaped antennas, hybrid coupler feeding, truncated corners, slot disruption, and circularly polarised microstrip antennas are all topics that have documentation [13–16]. These designs, however, employ a substantial number of layers or hybrid coupler circuits, both of which raise the thickness and fabrication costs. Compact modules with low overhead costs perform well with WSN topologies that are simple and have a single layer.

This study shows how a tiny circularly polarised microstrip patch antenna may be designed and built using industry-standard 0.18-micron CMOS technology. Because it doesn't require a licence and provides a reasonable balance between antenna size and propagation characteristics for a number of wireless applications, the popular 2.4 GHz ISM band is chosen as the operating frequency [17]. Additionally, this band is capable of supporting activities without external device interference. By first creating a rectangular patch with two slotted incisions, and then erasing that patch, circular polarisation can be created [18]. With this method, a single substrate layer can be used to create a straightforward and basic architecture.

Simulations can be used to enhance the design's impedance matching, axial ratio, gain, and radiation properties. The antenna is perfect for use in integration with wireless sensor nodes made using conventional semiconductor manufacturing processes because it is compatible with CMOS. The antenna is a great option because of this. The suggested design methodology provides a practical route to affordable and transportable wireless sensor modules, making it appropriate for cutting-edge WSN applications.

Design Methodology

The value of the input impedance depends on where the feed is located in relation to the patch length. The HFSS parametric sweeps for optimisation led to the selection of the following design parameters:

L = 6 mm
W = 5 mm
Substrate height h = 1.575 mm
Feed position xf = 2 mm
Slot length l = 2.8 mm
Slot width w = 0.5 mm
Slot separation d = 0.2 mm

The ground plane length is LG = 6 mm. The compact size ensures that the antenna can be integrated within the constrained area available for communication modules in wireless sensor nodes.

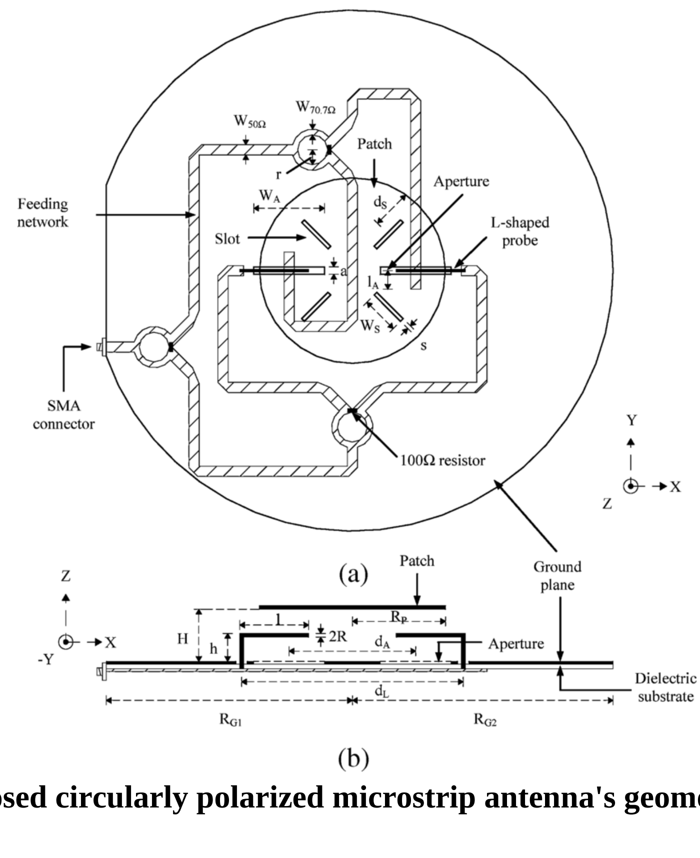

Fig. 1. Proposed circularly polarized microstrip antenna's geometrical design.

Simulation and Results

For the purpose of simulating the electromagnetic properties of the antenna, HFSS software, which is developed using the finite element method (FEM), is utilised. Figure 2 depicts the return loss map that was generated by the parametric optimisation of the antenna size. Within the range of frequencies where operations are carried out, a return loss of less than -10 decibels can be reached, indicating that the impedance matching properties are satisfactory.

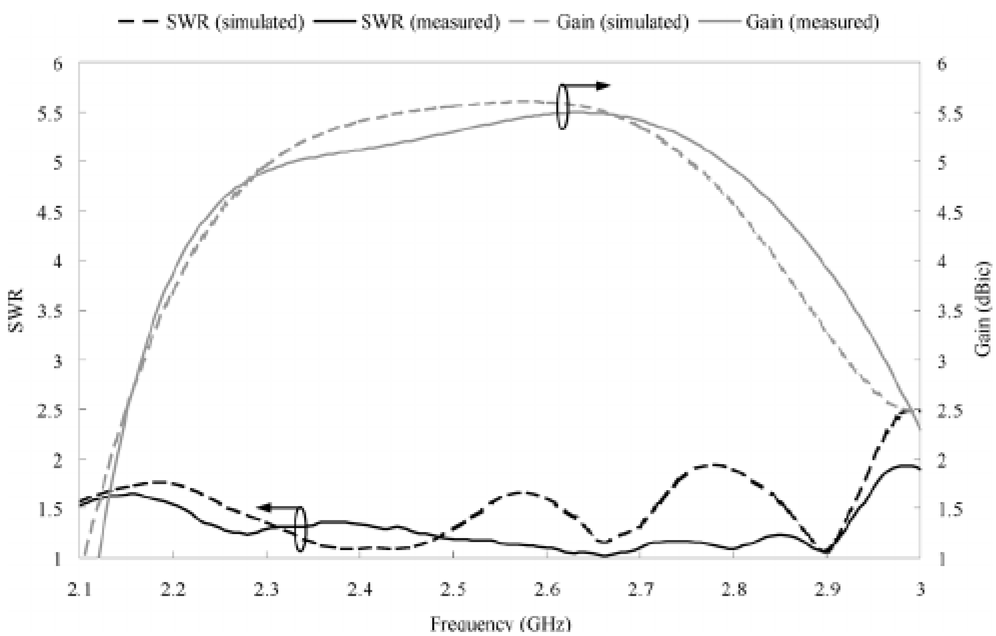

Fig. 2. Simulated return loss

The axial ratio presented in Fig. 3 indicates that circular polarization is attained with axial ratio < 3 dB from 2.38 GHz to 2.48 GHz.

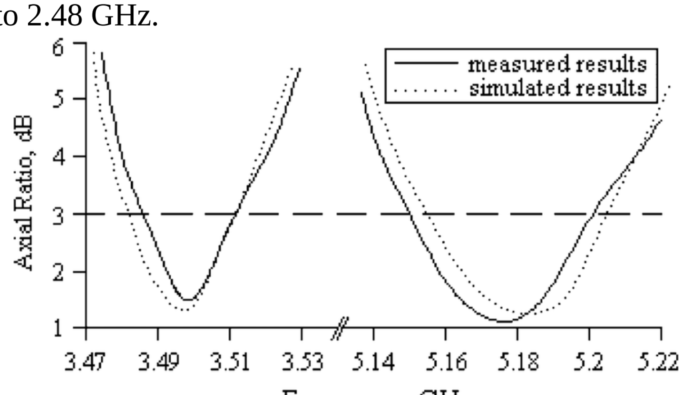

Fig. 3. Simulated axial ratio

The circular polarisation is a result of the slotted cuts' disruption of the resonant TM10 mode. It is feasible to generate orthogonal field components with a 90 degree phase difference as a result of this disturbance. Circular polarisation requires a phase delay between the two orthogonal modes, which is produced by the irregular slot lengths.

The Rogers 5880 is replaced with an industry-standard lossless silicon substrate with a dielectric constant of 11.9 and a height of 0.675 mm in order to assess the impact that a CMOS substrate has on antenna performance. CMOS integrated circuits are typically manufactured on silicon substrates. It is possible to see a modest reduction in impedance matching when the substrate is changed. On the other hand, by making only small changes to the feed location and slot size, a return loss of -10 dB, which is regarded reasonable, can be recovered. The silicon substrate's ideal dimensions are as follows:

These are the measurements: (L = 6 mm, W = 5 mm, h = 0.675 mm)

The dimensions of w are identical to 0.5 mm, d to 0.15 mm, xf to 1.8 mm, and l to 3 mm.

Figure 4 shows the predicted return loss and the axial ratio for the CMOS compatible antenna. Circular polarisation and impedance matching are advantageous features of the 2.4 GHz frequency spectrum, and the bandwidth of its 3-dB axial ratio is roughly 100 MHz.

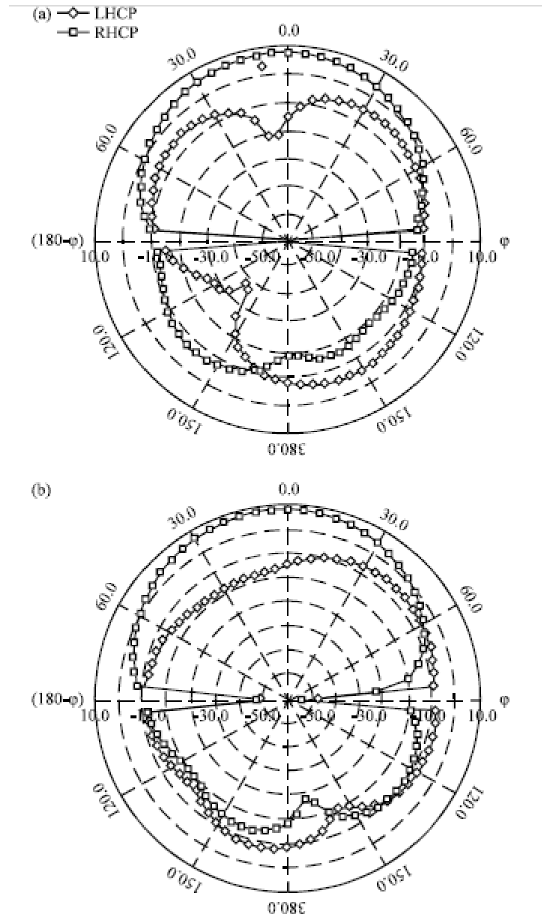

Fig. 4. The proposed antenna's 2.4 GHz radiation pattern for the (a) xz-plane and (b) yz-plane

The optimised CMOS compatible antenna's radiation characteristics are examined. The broadside changes more frequently. At 2.45 GHz, a peak gain of 1.8 dBi is noted.

In the H-plane, characteristics that are almost omnidirectional are noticed, whereas in the E-plane, a broad pattern is apparent. Right-hand circular polarisation (RHCP) of the antenna is present, as shown by the favourably tilted pattern in the RHCP plot. Left-hand circular polarisation (LHCP) is seen in the opposite axial direction as expected.

The suggested design's usefulness for wireless sensor network applications is supported by its consistent broadside radiation properties and good circular polarisation. The antenna can be integrated with sensor node electronics produced using conventional semiconductor methods thanks to CMOS compatibility.

Conclusion

It has been suggested to employ a small circularly polarised microstrip antenna for 2.4 GHz wireless sensor network applications. A rectangular patch and slot perturbation approach was used to attain the intended result, which was circular polarisation. In order for the antenna to operate in the ISM band at 2.4 GHz with impedance matching of better than -10 dB and at 100 MHz with an axial ratio bandwidth of 3 dB, electromagnetic calculations were used to construct it. Both of these requirements were satisfied. The CMOS compatible antenna's radiation characteristics included broadside patterns, a peak gain of 1.8 dBi, and good circular polarisation behaviour. The antenna was created with 6 mm by 5 mm dimensions so that it could be included into common wireless sensor modules. In new wireless sensor network applications, the proposed design offers a workable substitute for circularly polarised microstrip antennas that are compatible with CMOS. These antennas are compatible with these technologies and are also small and reasonably priced.

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