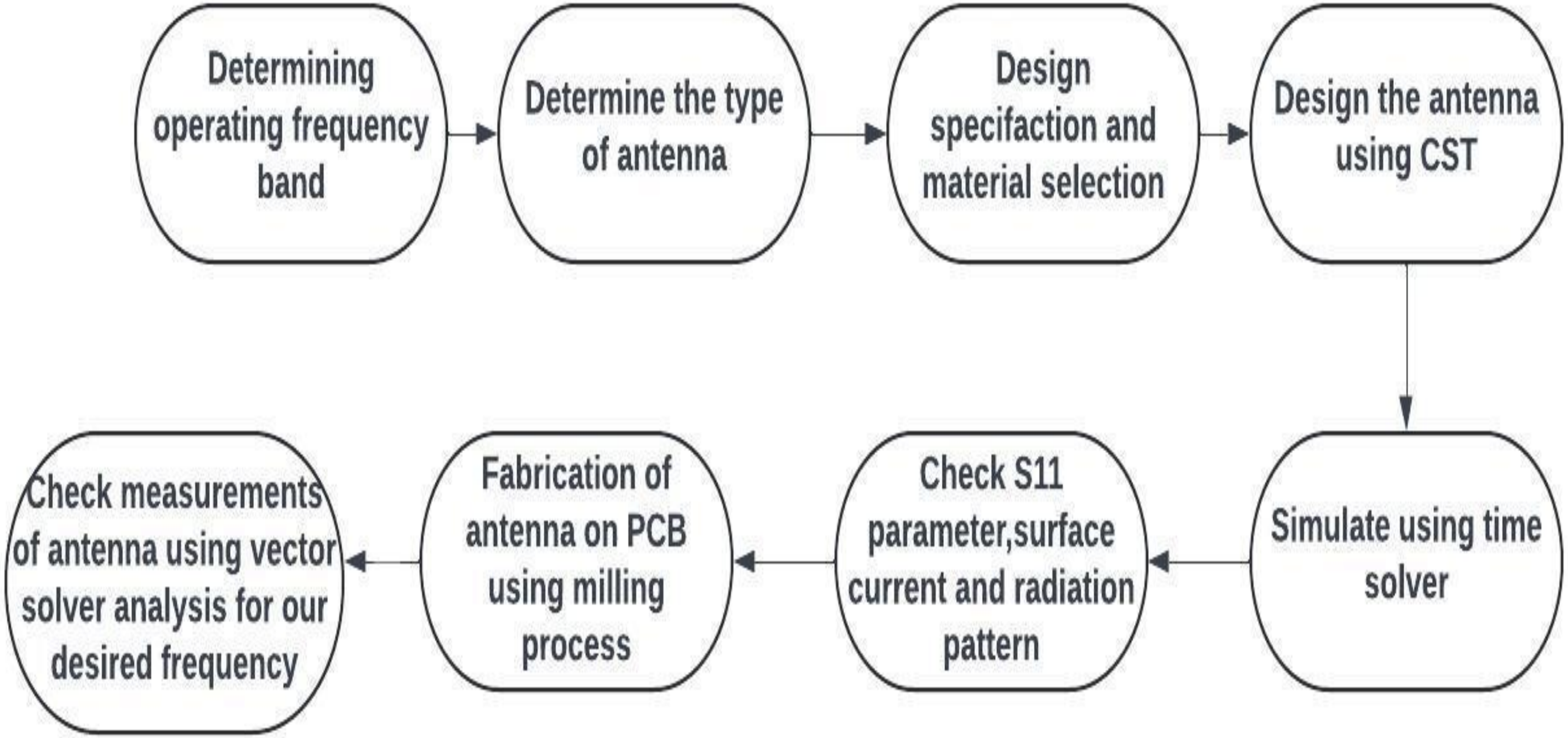
ABSTRACT

❖ This presentation showcases the design and development of a 2.4 GHz microstrip sensor for material characterization which is used for identifying unknown materials using its dielectric constant. Addressing the escalating demand for accurate material identification, this innovative sensor enables non-invasive and efficient analysis of dielectric materials, driving progress in material selection, design refinement, and quality assurance.

❖ To achieve optimal performance at 2.4 GHz, the proposed antenna is meticulously optimized using advanced simulation tools, leveraging substrate selection, impedance matching, and other design refinement techniques. This microstrip sensor design is well-suited for accurate material characterization at 2.4 GHz, offering enhanced insight into dielectric properties and enabling advanced material selection and design optimization for various wireless applications.

FLOWCHART



Determining operating frequency band
Determine the type of antenna
Design specifaction and material selection
Design the antenna using CST
Simulate using time solver
Check S11 parameter,surface current and radiation pattern
Fabrication of antenna on PCB using milling process
Check measurements of antenna using vector solver analysis for our desired frequency

SOFTWARE DESCRIPTION

- CST Studio Suite is a powerful electromagnetic simulation software, widely adopted in industries like electronics, telecommunications, and defense. Its comprehensive toolset enables users to design, analyze, and optimize electromagnetic components and systems, with a focus on antenna design for communication, radar, and satellite applications.
- Key simulation capabilities include:
  - 3D electromagnetic field analysis
  - Far-field radiation pattern simulation
  - Gain, directivity, and bandwidth analysis
- By utilizing CST Studio Suite, engineers can optimize antenna performance, reduce design iterations, and accelerate product development.

INTRODUCTION TO DESIGN OF ANTENNA

- ❖ The concept and development of microstrip sensor for material characterization with a resonant frequency of 2.4GHz
- ❖ The dimensions are 30x37 (in mm) made up of material called perfect electric conductor(PEC) with thickness of the ground layer is 0.035 (mm), substrate(FR-lossy) is 1.6 (mm), patch is 0.035 (mm). The total thickness of the sensor is 1.67(mm).
- ❖ The design of the antenna is based up on the surface current to get the desired frequency
- ❖ This antenna is used for identifying the material with the dielectric constant
- ❖ The antenna is designed and fabricated with a good condition. The impedance and radiation of the antenna are in good relation with the simulation results

APPLICATION

1. Dielectric Property Measurement

Dielectric materials are often characterized using 2.4 GHz signals to determine how they interact with electromagnetic waves. This helps in selecting materials for antennas, waveguides, and other RF components.

2. Antenna Radome Design

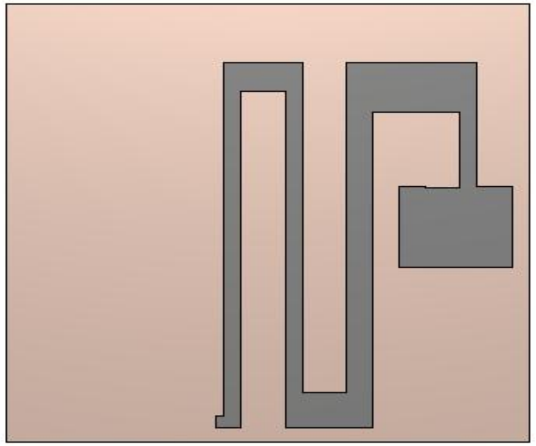
material characterization helps in selecting radome materials that have minimal impact on the signal, with low dielectric loss and high transparency at 2.4 GHz.

3.**Metamaterials for Antenna Design**

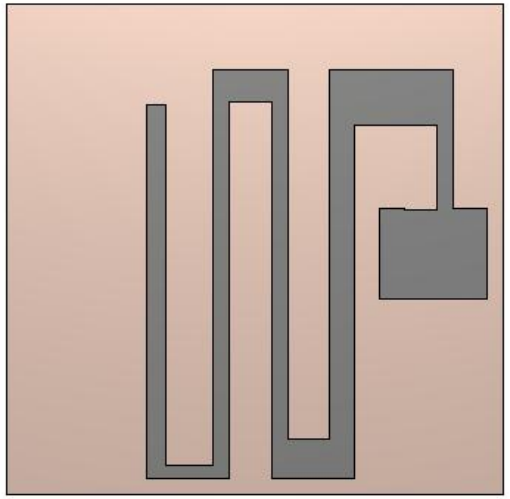
•Metamaterials are artificially engineered materials with unique electromagnetic properties. At 2.4 GHz, they can be used to manipulate electromagnetic waves in novel ways, improving antenna performance.

•Metamaterials can be characterized for their electromagnetic response and used to design compact, high-gain, or frequency-selective antennas.

EVOLUTION OF PROPOSED ANTENNA DESIGN

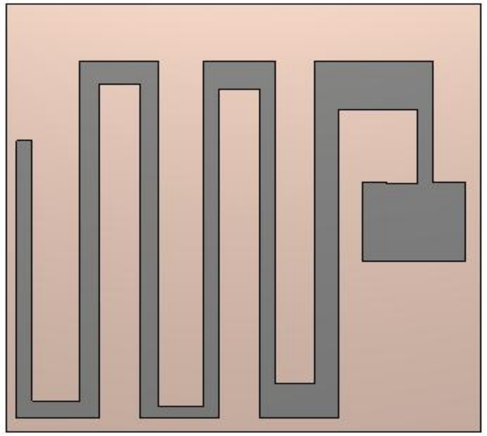


- Create a basic microstrip patch design to get our desired frequency. The patch design is in a rectangular shape. This design gives the resonant frequency of 2.8GHz and the gain of the frequency does not go below -10db to operate efficiently.



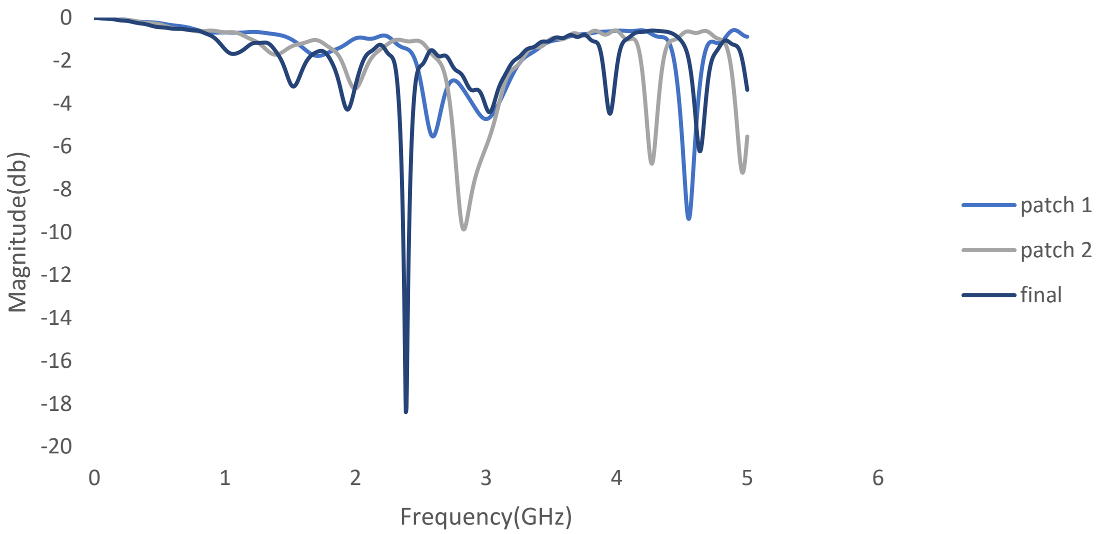
- In the previous design we did not get the desired frequency and gain, so we added some patch to the previous design based on the surface current flow on the antenna to prevent the overflow of the surface current. By extending the length of the antenna we got gain below -10db but the frequency shifted only to 2.565 ghz.

- In both steps we did not get the desired frequency, so we again extended the length of the patch which gives the desired frequency of 2.4GHz with the gain of -13db. This design works efficiently than the other two designs.

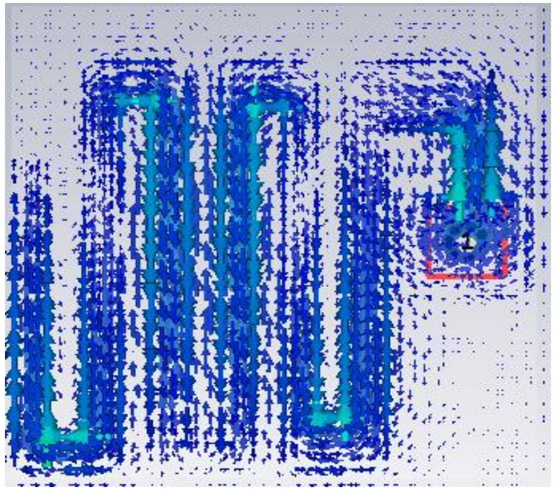


S11 Parameter Graph:

The combination of S-parameter obtained by these designs shown above



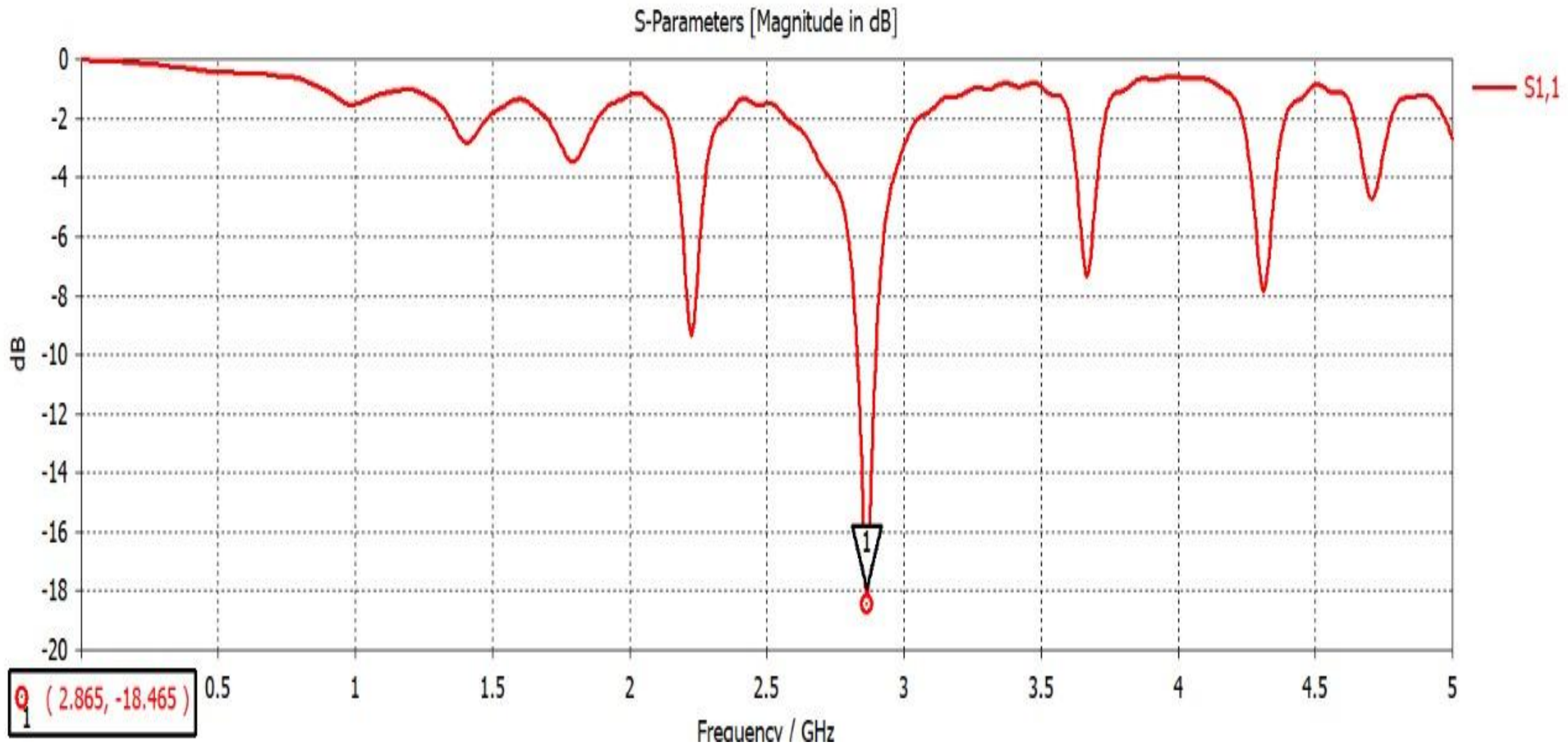
SURFACE CURRENT



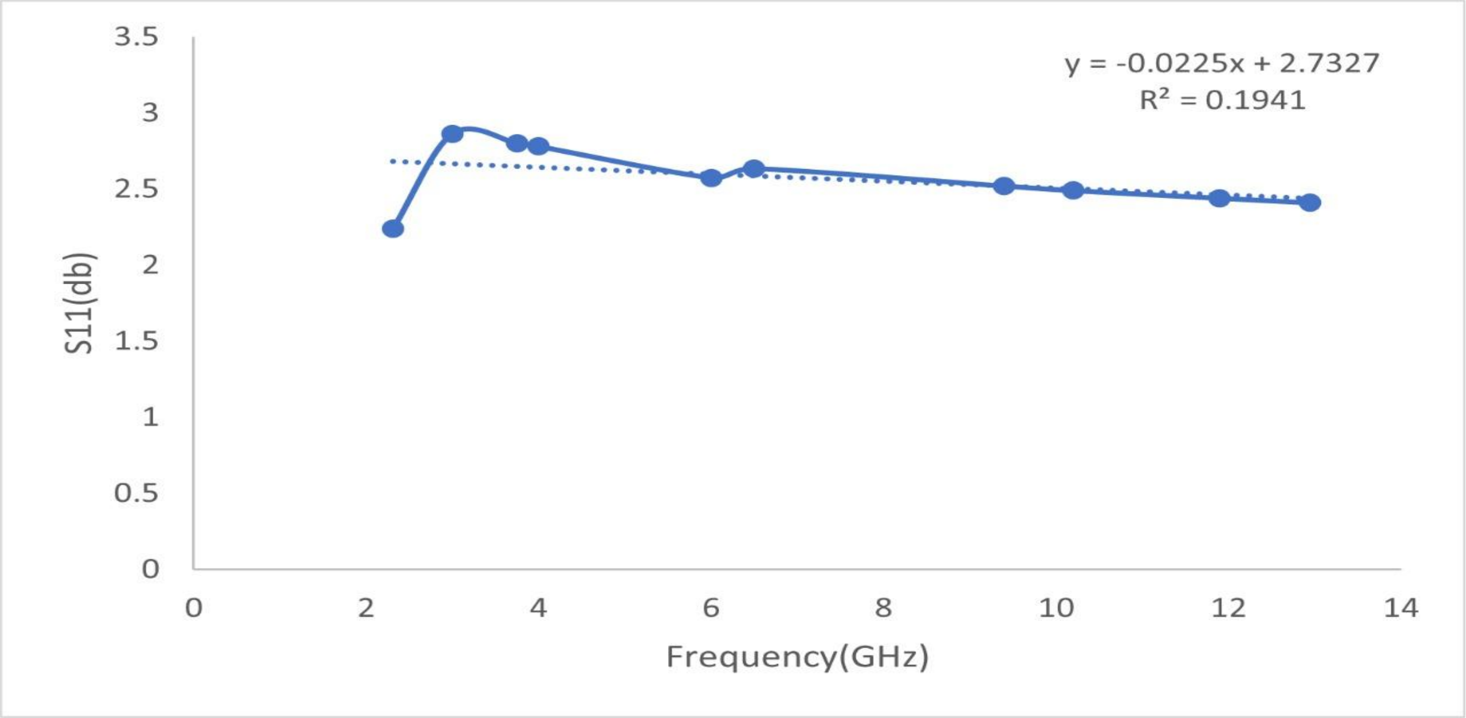
This surface current diagram shows the current flows on the surface of the material which is useful to adjust the frequency of the microstrip sensor. This surface current map illustrates how currents flow on a microstrip sensor, which is being used for material characterization. The variations in current intensity and direction can help in determining material properties.

RESULT

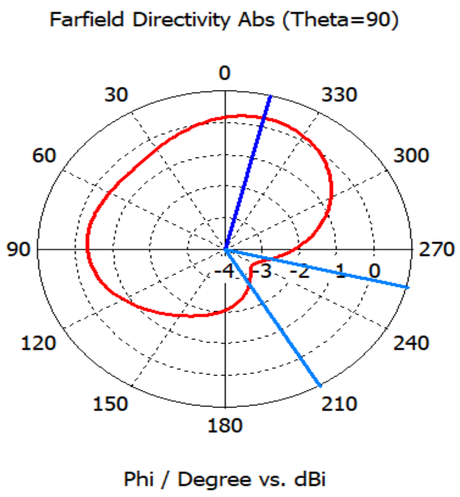
S11 parameter of the designed antenna:



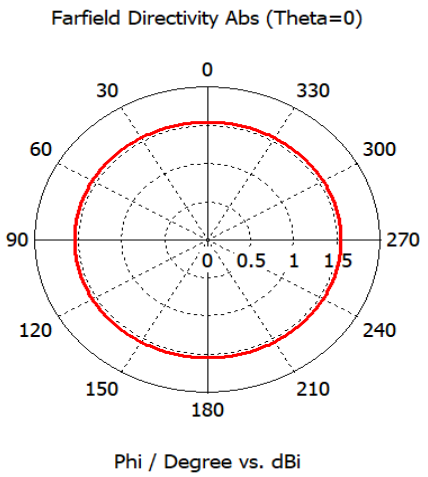
Obtained graph with materials on the antenna:



RADIATION PATTERN



Frequency = 2.4 GHz
Main lobe magnitude = 0.266 dBi
Main lobe direction = 346.0 deg.
Angular width (3 dB) = 314.1 deg.



Frequency = 2.4 GHz
Main lobe magnitude = 1.54 dBi

Fig Radiation pattern of antenna at f=2.4GHz in E-plane

Fig Radiation pattern of antenna at f=2.4 GHz in H-plane

MILLING PROCESS

- ❖ Secure and Align the PCB: Place the copper-clad PCB, with the selected substrate, on the milling machine bed, ensuring precise alignment for accurate fabrication.
- ❖ Load and Verify Design Files: Import the Gerber file into the CNC milling software, double-checking design orientation and layout to prevent errors.
- ❖ Configure Milling Parameters: Set the milling depth to selectively remove the copper layer, preserving the substrate. Adjust settings to achieve optimal material removal.
- ❖ Mill the Antenna Pattern: Initiate the milling process, where the machine precisely removes excess copper, following the design paths to create the radiating structure.

SUBSTRATE:

The green area depicted in Fig. represents the substrate, composed of FR4-Lossy material. This substrate serves as the foundation for the copper traces and plays a crucial role in determining the antenna's dielectric properties, which significantly influence its bandwidth, Efficiency and Overall performance

Fig

Copper Traces:

The copper pattern seen on the PCB forms the radiating element of the antenna. The intricate geometry of the trace is designed to resonate at specific frequencies, allowing the antenna to transmit and receive signals effectively

Connector:

At the bottom of the board, there is connector (an SMA connector) used to connect the antenna to an RF system, such as a vector network analyzer (VNA)

VECTOR NETWORK ANALYZER

The measurement of the fabricated antenna's performance using a Vector Network Analyzer (VNA).

Frequency(GHz)	S11(db)
2.4GHz	-13.786db