Planar Sleeve Dipole array Antenna with Directional Radiation

Valipireddy Venkatesh, Nirmala Yerpula

Abstract—**Nowadays microstrip print circuit board (PCB) antenna is widely used for communication systems. Microstrip antenna array is widely used due to its several advantages, such as low profile, light weight, and low cost, etc.. Microstrip antenna array antennas are the solution of choice for many radar and access point applications in space and on earth. However, microstrip antenna suffers from low gain, low efficiency, and low power handling capability. Various broadband techniques have been reported using multilayer or stacking the patches. High- gain antenna is usually realized by using either line-fed antenna arrays or reflect arrays. In this case, we proposed a 1 × 5 coplanar back-to-back sleeve dipole antenna with a microstrip line to balanced transmission line feeding and tuning pad. In addition, a reflector is put behind the dipole array antenna in order to obtain directional radiation and high gain. The proposed antenna was analyzed, fabricated, and successfully optimized for the improved performance. Details of the printed dipole array antenna design and the simulated and measured results are presented. A novel planar sleeve dipole array antenna with directional radiation has been proposed, and a prototype has been implemented and measured.**

Index Terms— **Dipole array antenna, Microstrip, radiation efficiency, radiation pattern, antenna gain.**

I. Introduction

Wireless communications are developed wide and quickly within the modern times. Users ar encircled by differing kinds of communication technology like mobile phones, wireless native space networks (WLAN), world system for mobile communications (GSM), digital cellular service (DCS), personal communication services (PCS) and different personal communication systems. These days microstrip print printed circuit (PCB) antenna is wide used for communication systems. Microstrip antenna array is wide used because of its many blessings, like low profile, light-weight weight, and low price, etc.. Those array antennas are the answer of alternative for several microwave radar and access purpose applications in house and on an earth. However, microstrip antenna suffers from low gain, low potency, and low power handling capability. Numerous broadband techniques are according victimisation multilayer or stacking the patches . High-gain antenna is typically completed by victimisation either line-fed antenna arrays[2][7] or reflect arrays.

In this case, we have a tendency to projected 1 × 5 planar succeeding sleeve transmitting aerial with a microstrip[1] line to balanced line feeding and calibration pad . Additionally, a reflector is place behind the dipole array antenna so as to get directional radiation and high gain. This case is simply made by being written on each side of a nonconductor substrate (shown in Fig. 1) . The projected antenna was analyzed, fabricated, and with success optimized for the improved performance. Details of the written dipole array[3]-[7] antenna style and therefore the simulated and measured results are conferred.

An associate degreetenna is a device that converts electrical power into radio waves, and the other way around. Generally associate degree antenna consists of a meeting of aluminiferous conductors, electrically connected to the receiver or transmitter. Associate degree periodic current of electrons forced through the associate degreetenna by a transmitter can produce a periodic magnetic flux round the antenna components, whereas the charge of the electrons conjointly creates associate degree periodic field of force on the weather. These time-varying fields radiate removed from the antenna into house as a moving crosswise magnetic attraction field wave. Conversely, throughout reception, the periodic electrical associate degreed magnetic fields of an incoming electromagnetic wave exert force on the electrons within the antenna components, inflicting them to maneuver back and forth, making periodic currents within the antenna. they're employed in systems like radio broadcasting, broadcast tv, two-way radio, communications receivers, radar, cell phones, and satellite communications, still as different devices like garage door openers, wireless microphones, blue tooth

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enabled devices, wireless laptop networks, baby monitors, and RFID tags on merchandise.

In telecommunication, there area unit many varieties of microstrip antennas (also called written antennas) the foremost common of that is that the microstrip patch antenna or antenna. A microstrip or patch antenna could be a low profile antenna that incorporates a range of benefits over alternative antennas .It is light-weight, cheap, and simple to integrate with related to natural philosophy. a bonus inherent to patch antennas is that the ability to possess polarization diversity. A microstrip patch antenna [9] (MPA) consists of a conducting patch of any two-dimensional or non-planar pure mathematics on one facet of a nonconductor substrate with a ground plane on alternative facet. it's a well-liked written resonant antenna for narrow-band microwave wireless links that need semi-hemispherical coverage. Patch antennas will simply be designed to possess vertical, horizontal, hand circular (RHCP) or left circular (LHCP) polarizations, mistreatment multiple feed points, or one feed purpose with uneven patch structures. This distinctive property permits patch antennas to be utilized in many sorts of communications links that will have varied needs.

Common microstrip antenna shapes area unit sq., rectangular, circular and elliptical, however any continuous form is feasible. as a result of such antennas have a awfully low profile, area unit automatically rugged and might be formed to adapt to the flexuous skin of a vehicle, they're usually mounted on the outside of craft and artificial satellite, or area unit incorporated into mobile radio communications devices. Microstrip antennas have become more and more helpful as a result of they will written directly onto circuit card. they're turning into widespread among the itinerant market. Patch antennas area unit low value, have an occasional profile and simply fancied. These patch antennas area unit used for the best and difficult applications. Rectangular geometries area unit severable in nature and their analysis is easy.

The disadvantages of microstrip antennas embrace low power handling capability and slim information measure. Recent studies and experiments are attempting to beat these drawbacks. a range of approaches are taken, as well as modification of the patch form, experimentation with substrate parameters.

II. Literature Survey

The first antennas were in-built 1888 by German scientist Heinrich Hertz in his pioneering experiments to prove the existence of magnetic attraction waves foreseen by the speculation of James Clerk Maxwell. Hertz placed dipole antennas at the focus of parabolic reflectors for each transmission and receiving. The origin of the word antenna relative to wireless equipment is attributed to Italian radio pioneer Guglielmo Marconi. In 1895, whereas testing early radio equipment within the Swiss Alps at Salvan, Schweiz within the mountain peak region, electrical engineer experimented with long wire "aerials". He used a 2.5 meter vertical pole, with a wire hooked up to the highest running right down to the transmitter, as a diverging and receiving aerial part.

Compact and Broadband Quasi-Yagi Antenna for X- to Ku-band Applications as well as balun and electrical device for electric resistance matching. In several of the reported style approaches, there have been no express pointers steered for activity electric resistance matching between the cycle line and therefore the input microstrip transmission lines. additionally, within the style of most typically used MS-to-CPS balun structures for the quasi-Yagi antenna steered one hundred eighty degree part distinction on the cycle lines was warranted just for slim information measure close to the middle frequency; i.e., the odd-mode conversion with the part delayed leg was expected to figure just for slim frequency information measure. Also, most of the broadband quasi-Yagi antenna styles were in the main supported come back loss performances. Broad electric resistance information measure, of course, could be a necessary demand for the broadband antennas, however might not be a spare criterion permanently radiation characteristics for whole waveband. a quick history of antenna evolution is as follows

- Yagi-Uda antennas 1920s
- Horn antennas 1939
- Antenna arrays 1940s
- Parabolic reflectors late 1940s and early 1950s
- Patch antennas 1970s
- PIFA 1980s

III. Theoretical Analysis

The theoretical analysis of basic rectangular patch antenna structure, theoretical formulas and calculations required in designing E-shape microstrip patch antenna.

A. Microstrip Patch Antenna Structure

A microstrip patch antenna (MPA) consists of a conducting patch of any non-planar or planate pure mathematics on one facet of a nonconductor substrate and a ground plane on different facet. it's a written resonant antenna for narrow-band microwave wireless links requiring semi-hemispherical coverage. Attributable to its planate configuration and simple integration with microstrip technology, the microstrip patch antenna has been wide used. The oblong and circular patches ar the essential and most typically used microstrip antennas.

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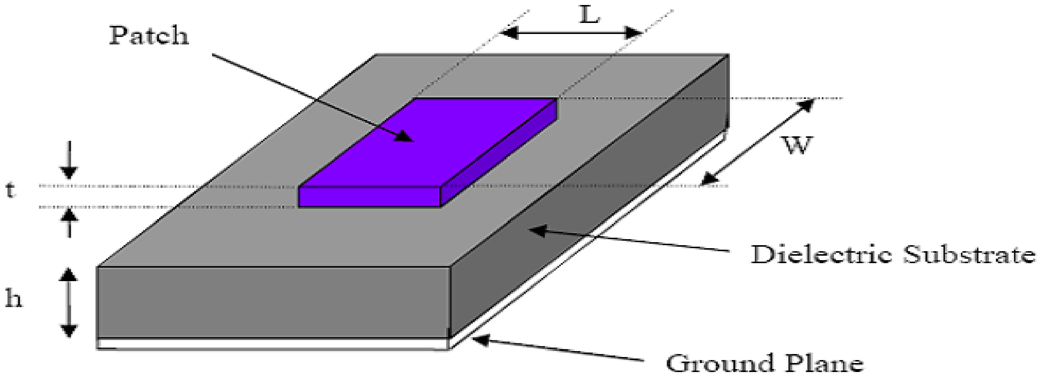

Fig. 3.1: Microstrip Patch Antenna Configuration

The above figure shows a microstrip patch antenna with a nonconductor substrate mounted on a ground plane. The nonconductor substrate is of thickness (h). The patch is mounted on the nonconductor substrate with nonconductor constant or permittivity (∈_r). The patch is of length (l), dimension (w) and thickness (t).

In our design we tend to use microstrip printing operation. The microstrip patch with microstrip feed a is as follows

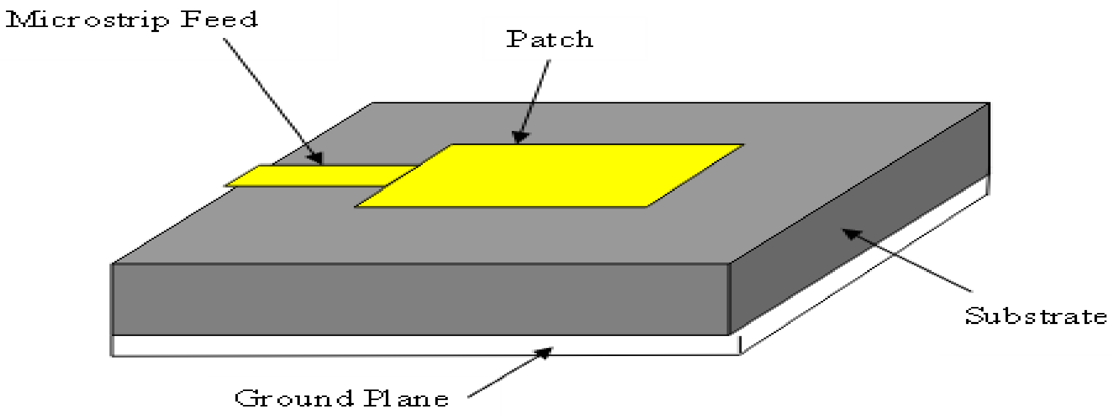

Fig. 3.2: Microstrip Antenna With Microstrip Feed

In the above figure, a conducting strip is connected on to the sting of the microstrip patch. thus it's a microstrip feed. The normally used substrates are FR-4 substrate and RT DUROID 5880 substrates.

The frequency of operation of the patch antenna of Figure 3.1 is determined by the length L. The center frequency will be approximately given by:

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

The above equation equation shows that the microstrip antenna ought to have a length adequate to one half a wavelength at intervals the nonconductor (substrate) medium. The dimension W of the microstrip antenna controls the input ohmic resistance. Larger widths can also increase the information measure. For a sq. patch antenna fed within the manner higher than, the input ohmic resistance are going to be on the order of three hundred Ohms. By increasing the dimension, the ohmic resistance will be reduced. However, to decrease the input ohmic resistance to fifty Ohms typically needs a really wide patch antenna, that takes up plenty of valuable house. The dimension any controls the radiation diagram. The fields of the microstrip antenna ar planned in Figure3.3 for W=L=0.5λ.

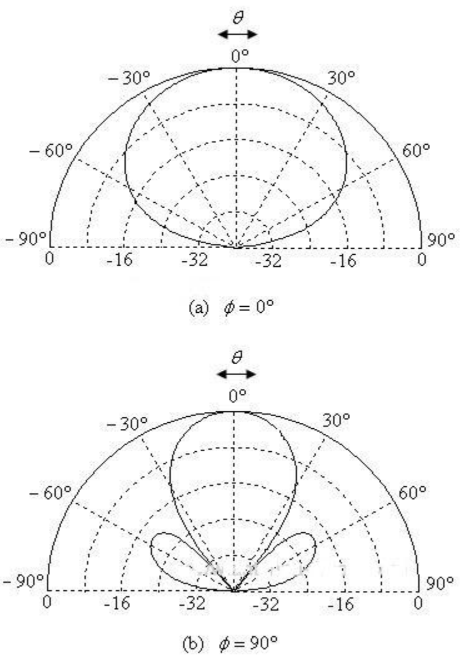

Figure 3.3: Normalized Radiation Pattern for Microstrip (Patch) Antenna

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B. Theoretical Values And Calculations

To calculate the dimensions of E-shape microstrip patch antenna, the following theoretical values and formulas are required

1) The width of the patch element (W) is given by

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$$

Where W is the width of patch element

c is the velocity of light= $3x10^8$ m/s

fo is the optimum frequency = 5 GHz

Substituting c = $3x10^8$ m/s, ε r = 2.2, and fo = 5 GHz, then

W =2.3717cm or 933.74 mile.

2) The effective of the dielectric constant (εreff) depending on the same geometry (W, h) but is surrounded by a homogeneous dielectric of effective permittivity εreff, whose value is determined by evaluating the capacitance of the fringing field.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{W}]^{0.5}$$

Substituting εr = 2.2, W =2.3717cm, and h =0.1575cm, then εreff = 2.1074cm or 829.69mile

3) The effective length (L eff) is given by

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Substituting, c = $3x10^8$ m/s. εreff = 2.0475cm, and fo = 5GHz, then

Leff = 2.0665cm or 813.6 mile

4) The length extension (ΔL) is given by:

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

Substituting εreff = 2.1074cm, W =2.3717cm, and h =0.0787cm, then ΔL= 0.041469cm or 16.3266mile.

5) The actual length (L) of patch is obtained by

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

The design of E-shape microstrip antenna is as follows

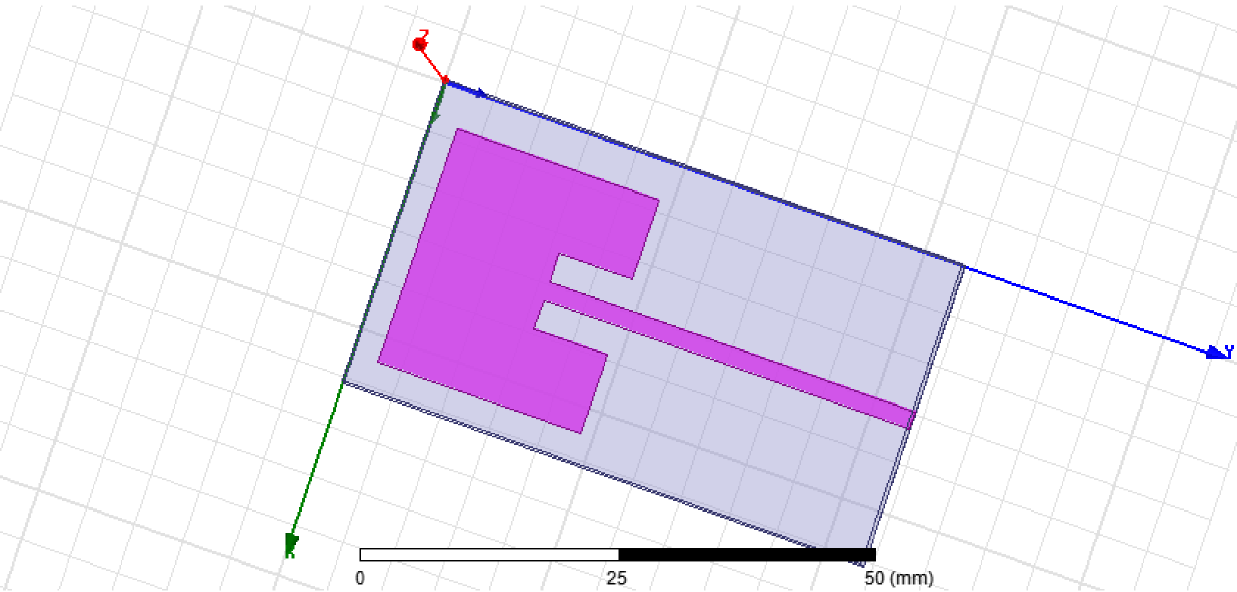

Figure 3.4: Design of E-Shape Microstrip Patch Antenna

In the above design, we use RT-DUROID 5880 substrate as dielectric. In this theme, every node with message searches for potential path nodes to repeat its message. Hence, potential path nodes of a node ar thought of. Using NSS, every node having message selects its path nodes to produce a adequate level of end-to-end latency whereas examining its transmission effort. Here, it derives the CSS live to allow CR-Networks nodes to choose that authorised channels ought to be used. The aim of CSS is to maximise spectrum utilization with minimum interference to primary system. Assume that there are M authorised channels with completely different information measure values and y denotes the information measure of channel c. every CR-Networks node is additionally assumed to sporadically sense a collection of M authorised channels. Mi denotes the set together with Ids of authorised channels that ar

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sporadically detected by node i. suppose that channel c is sporadically detected by node i in every slot and channel c is idle throughout the quantity x known as channel idle length. Here, it use the merchandise of channel information measure y and also the channel idle length x, tc = xy, as a metric to look at the channel idleness. Moreover, failures within the sensing of primary users ar assumed to cause the collisions among the transmissions of primary users and CR-Networks nodes.

IV. Design Analysis

The design of the structure is based on the theoretical calculations discussed in the previous chapter. The design is done in two simulation softwares namely CST (COMPUTER SIMULATION TECHNOLOGY) and HFSS (HIGH FREQUENCY STRUCTURE SIMULATOR). CST and HFSS are electromagnetic simulators used in the design and analysis of high frequency (HF) devices such as antennas, filters, couplers, planar and multi-layer structures and SI and EMC effects.

A. Design Simulator –CST Studio Suite

CST - Computer Simulation Technology AG (CST) is a German computer code company with headquarters in Darmstadt. The most product of CST is CST STUDIO SUITE, that includes varied modules dedicated to specific application areas. There square measure modules for microwave & RF applications, summarized in CST MICORWAVE STUDIO, low frequency (CST EM STUDIO), PCBs and packages (CST PCB STUDIO), cable harnesses (CST CABLE STUDIO), temperature and mechanical stress (CST MPHYSICS STUDIO) and for the simulation of the interaction of charged particles and magnetism fields (CST PARTICLE STUDIO). All modules square measure integrated with a system AND gate machine (CST style STUDIO).

In our style we tend to use CST MICROWAVE STUDIO (CST MWS). CST MICROWAVE STUDIO® (CST MWS) could be a specialist tool for the 3D EM simulation of high frequency parts. CST MWS' unique performance makes it 1st selection in technology leading R&D departments. CST MWS allows the quick and correct analysis of high frequency (HF) devices like antennas, filters, couplers, placoid and multi-layer structures and SI and EMC effects. Exceptionally user friendly, CST MWS quickly offers associate insight into the EM behavior of high frequency styles.

B. Design Process in CST

For designing the required shape in CST MICROWAVE STUDIO (CST MWS).the following steps are followed.

- ➔ Open CST STUDIO SUITE and then click on CST MICROWAVE STUDIO (CST MWS).
- ➔ As the required design is planar, select planar shape from the basic shapes given.
- ➔ Select brick shape and assign X, Y and Z co-ordinates to it as required per the design. This is the Ground plane. X & Y co-ordinates denote the length and width of the ground plane respectively. Z denotes the thickness. Select the material as PEC (Perfect electric).
- ➔ Then select solid 2 and assign X1,Y1 co-ordinates to it same as that of the ground plane. Z2 is varied .This is the di-electric substrate RT DUROID 5880.The thickness(Z2) of di-electric substrate is varied in our design and simulation results are carried out .
- ➔ Then select solid 3 and co-ordinates to it .This the patch.
- ➔ Select solid and assign X4, Y4 co-ordinates to it. These are the cut width and cut depth of the antenna. Subtract it from solid 3.We get a cut-shape piece (Boolean subtract).
- ➔ Select another solid and assign X5, Y5 co-ordinates. These are the strip patch length and strip patch width respectively. Add it to solid 3 (Boolean add).
- ➔ This completes the design of the structure. Then go to quick start guide and assign frequencies, boundary conditions, wave guide ports etc required as per the design.
- ➔ Start the transient solver and see the simulation results.
- ➔ Return loss (S11) and VSWR are calculated for different substrate thickness (Z2) and simulation results are noted down.

C. Design Simulator –HFSS

HFSS is a commercial finite element method solver for electromagnetic structures from Analysis. The acronym originally stood for high frequency structural simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University.

HFSS is the industry-standard simulation tool for 3D full-wave electromagnetic field simulation. HFSS provides E- and H-fields, currents, S-parameters and near and far radiated field results. Intrinsic to the success of HFSS as an engineering design tool is its automated solution process where users are only required to specify geometry, material properties and the desired output. From here HFSS will automatically generate an appropriate, efficient and accurate mesh for solving the problem.

D. Design Process in HFSS

1) Open HFSS software.

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2) Select insert HFSS design and draw rectangle1 .This is ground plane. All x,y and z dimensions are kept in mil.
3) Then draw box1 which is dielectric with thickness .Assign x,y and z co-ordinates.
4) Then draw rectangle2 which is patch. Assign x,y and z co-ordinates.
5) Then draw rectangle3 with different centre and subtract it from rectangle 2. Assign x,y and z co-ordinates.
6) Draw rectangle4 and assign x,y and z co-ordinates. This gives the strip path length and strip path width.
7) Then draw box2 which is the radiation box. Select wave guide port and give excitation.
8) Start the solver and see the simulation results. The substrate thickness is varied and simulations are carried out for different substrate thickness

V. RESULTS

5.1 Structure in CST/HFSS:

The Figure 5.1 shows the structure in CST/HFSS,

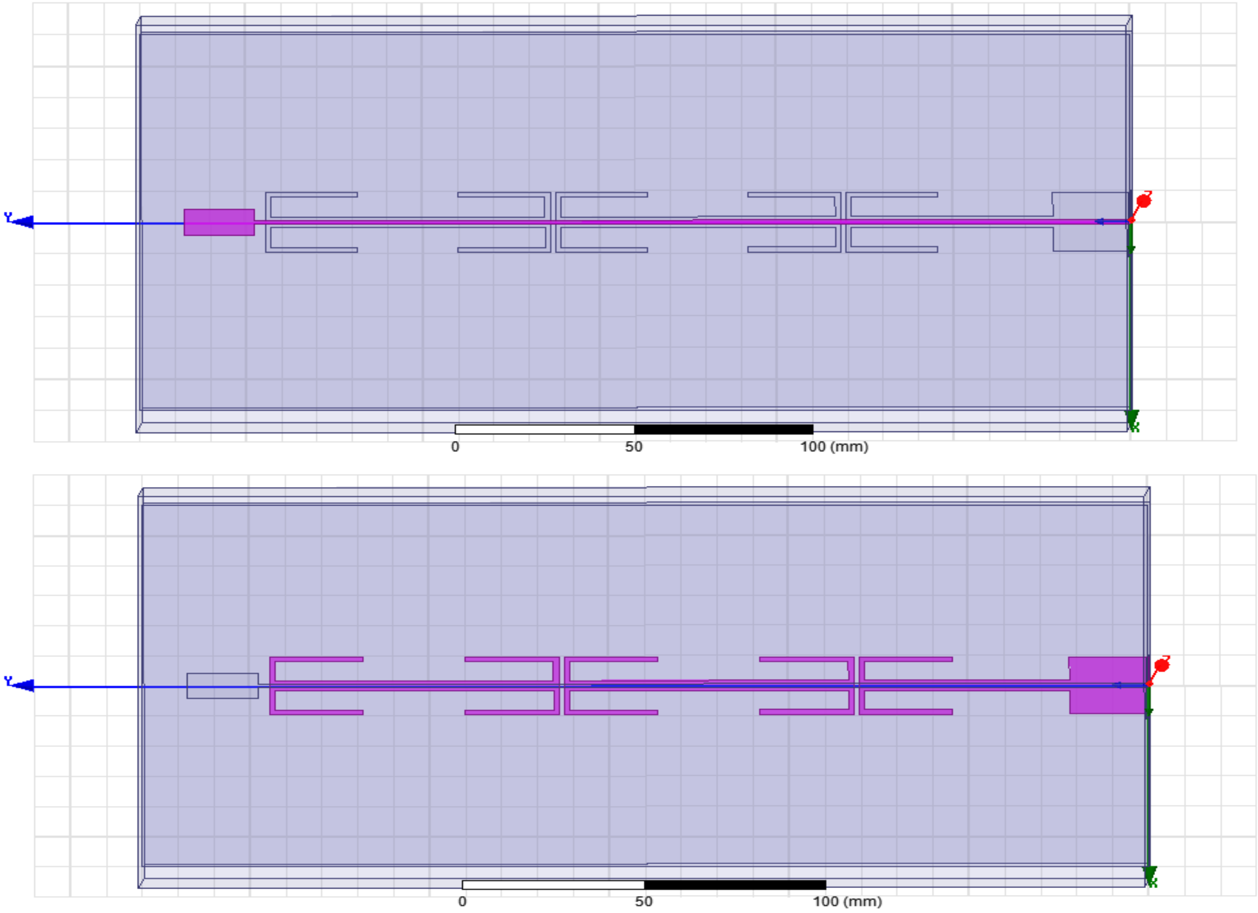

Fig 5.1 Structure in CST/HFSS

5.2 Results in CST/HFSS

The results in CST/HFSS shown in the Figure 5.2, S11 parameters shown in the Figure 5.2 (a) radiation pattern . shown in the Figure 4.2 (b), gain shown in the Figure 4.2(c),

5.2.1 S-Parameters:

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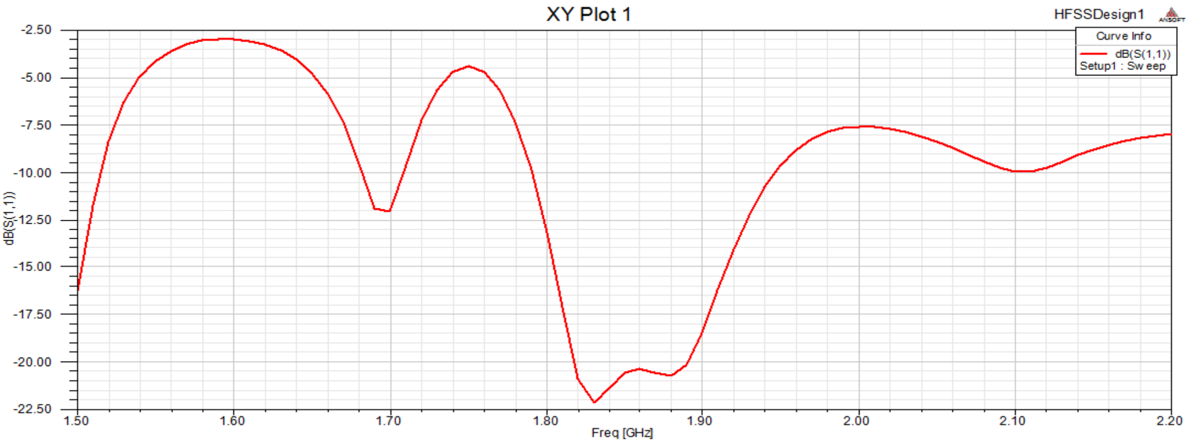

Fig 5.2(a)S-Parameters

5.2.2 Radiation Pattern :

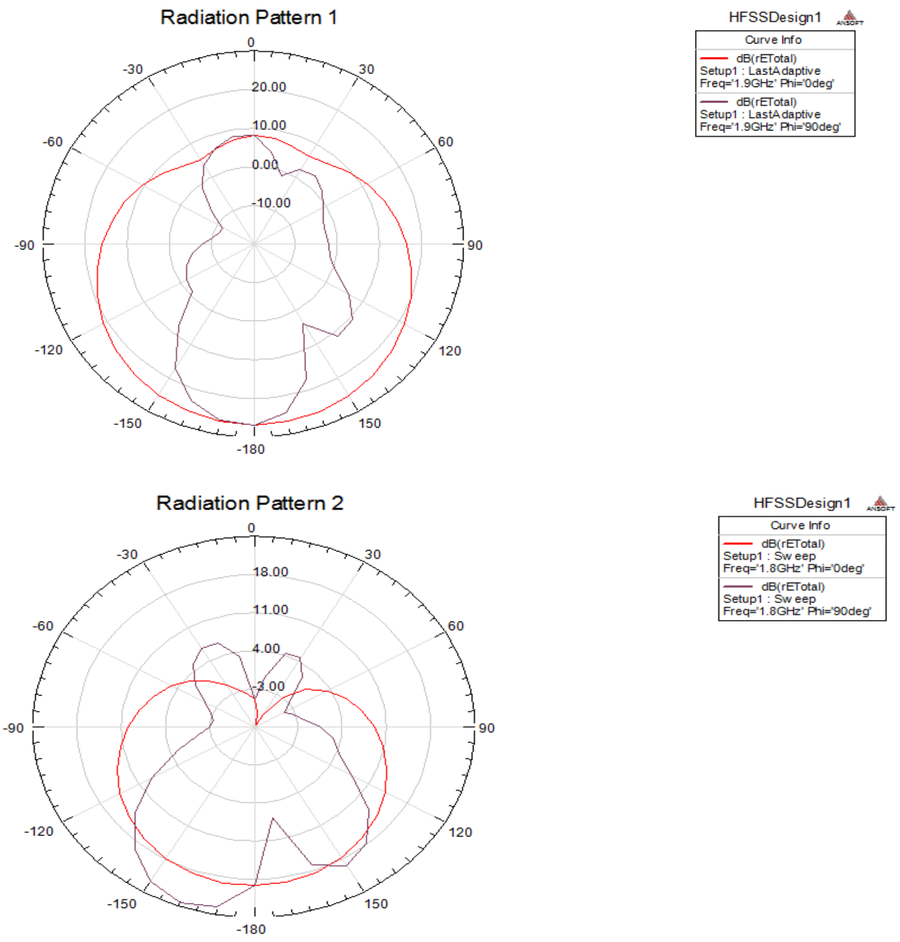

Fig 5.2(b) Radiation Pattern

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5.2.3 Gain :

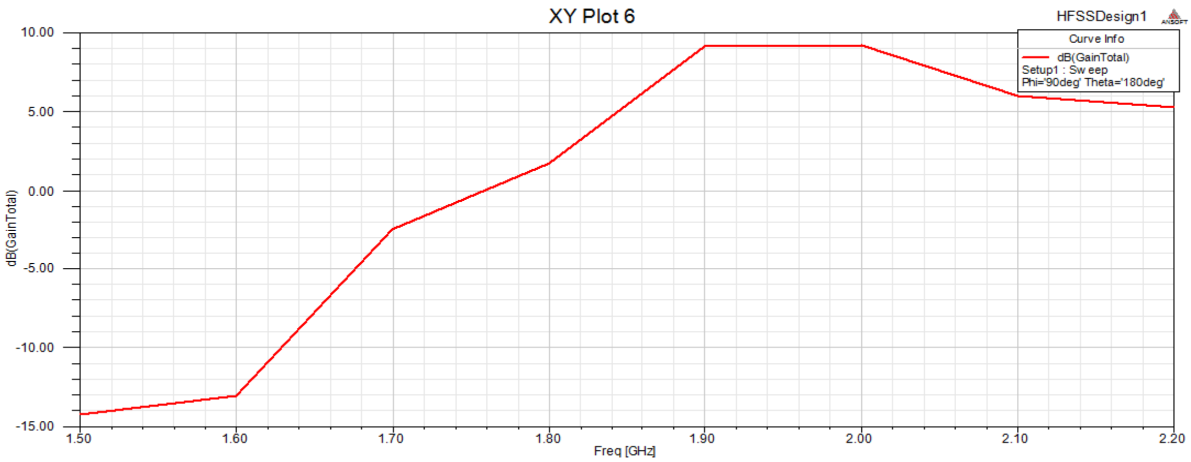

Fig 5.2.3Gain

6 Conclusion

A novel planar sleeve dipole array antenna with directional adiation has been proposed, and a prototype has been implemented and measured. The measured −10 dB $S11$ impedance bandwidth is around 13.2% (1690–1930 MHz).The radiation patterns of the proposed antenna at 1800/1900 MHz are also measured. The *x-z* cut (*E*-plane) 3 dB beamwidth is $15^{\circ}/14^{\circ}$; the first side-lobe on the right hand side is −18.1/−17.6 dB; and the front to back ratio is 36.5/37.2 dB. In practice, the antenna gain is in the range of 7.2–9.1 dBi, and the measured radiation efficiency varies from 47%–63%. In applications, it can be applied to the PCS 1800 communications and the DECT system. Both simulated and measured results agree with the verified frequency responses and radiation characteristics.

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