ABSTRACT
OF THE THESIS ENTITLED

Improvement on Different Characteristics of Microstrip Antenna and Its Applications in Various Fields

Thesis Submitted for the Degree of
DOCTOR OF PHILOSOPHY (ENGINEERING)
UNDER THE FACULTY OF ENGINEERING, TECHNOLOGY & MANAGEMENT

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UNIVERSITY OF KALYANI
KALYANI
NADIA, WEST BENGAL
INDIA
2016
A microstrip antenna generally consists of a dielectric substrate sandwiched between a radiating patch on the top and a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. For simplicity of analysis, the patch may be of different shapes like square, rectangular, circular, triangular, elliptical etc.

For a rectangular patch, the length $L$ of the patch is usually in the range of $0.3333 \lambda_0 < L < 0.5 \lambda_0$, where $\lambda_0$ is the free space wavelength. The patch is selected to be very thin such that $t << \lambda_0$ (where $t$ is the patch thickness). The height of the substrate is usually $0.003 \lambda_0 \leq h \leq 0.05 \lambda_0$. The dielectric constant of the substrate $\varepsilon_r$ is typically in the range $2.2 \leq \varepsilon_r \leq 12$ [1-3].

Microstrip antennas are used as embedded antennas in handheld wireless devices such as cellular phones and also employed in Satellite communications. Some of their advantages are

- Light weight, low fabrication cost.
- Supports both linear as well as circular polarization.
- Can be easily integrated with microwave integrated circuits.
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from some drawbacks also as compared to conventional antennas. Some of their major disadvantages are

- Narrow bandwidth.
- Low efficiency and Gain.
- Low power handling capacity.
The objective of the thesis are
To design better performed antennas which provide
- compactness
- broad bandwidth
- high gain
- multi-frequency operation
- application in various fields

In the current research work we proposed the designs of few Microstrip antennas that have been studied for their compactness, broadband, high gain and multi-frequency operations and also for the application of the designed antenna in medical field and satellite communication. The antennas designed during the research work are mentioned here.

A compact, coaxially feed microstrip patch antenna has been designed and fabricated. The fabricated antenna has been experimentally studied which shows 97% compactness.

Fig. 2: Layout of the Designed Antenna

Fig. 2 shows the geometry of the proposed antenna. A rectangular patch of size 30mm×40mm is fed at the centre w.r.to the ground plane of the antenna. A crossed slot is embedded in the ground plane at the centre position. The crossed slot has unequal lateral lengths, \( L_1 = 100\text{mm} \) and \( L_2 = 80\text{mm} \), with a slot width \( W = 2\text{mm} \). Glass-PTFE substrate with dielectric constant 2.5 is used as dielectric material. Simulated and Practical Reflection Coefficient Vs Frequency Plot of the Slotted Antenna is shown in Fig. 3.
Another investigation is done by inserting a "T" shaped slot in the radiating patch and three asymmetrical slots in the ground plane. 92% size reduction has been achieved of this designed antenna which is shown in Fig.4. Simulated Reflection Coefficient Vs Frequency plot for slotted antenna has been shown in Fig.5.

The design of a proposed monopole antenna has been shown in Fig.6. The proposed antenna is designed using cost effective glass epoxy (FR4) dielectric substrate material having thickness \( h = 1.6 \text{mm} \), permittivity \( \varepsilon_r = 4.4 \). The designed antenna contains two U shaped radiating patches on the slotted rectangular ground plane. The length and width of the patch has been chosen 20mm×25mm. The two radiating patches are placed in that position with respect to ground plane of the antenna. The layout of the antenna is drawn in Ansoft designer software. Simulations have been carried out using Ansoft Designer Software.

The fabrication of the designed antenna is done using an FR-4 substrate.
This antenna has dual resonant frequencies with first one is 3.38GHz & other one is 6.24GHz. The minimum Reflection Coefficients at the resonant frequencies are -25.41dB and -50.4dB. The -10 db bandwidth is 4 GHz. The percentage impedance bandwidth is 80%. The gain of this antenna is high which is around 6dBi shown in Fig.7. The simulated and measured radiation patterns of the antenna are good.

Another design for the achievement of broadband is monopole antenna which has been shown in Fig.8. This antenna has been designed using cost effective glass epoxy (FR4) dielectric substrate material having thickness (h) = 1.6mm, permittivity $\varepsilon_r = 4.4$. The proposed antenna consists of circular ring shaped radiating patch on the hexagonal ground plane. The optimized dimensions are taken after a several number of simulations with different dimensions.

![Fig.8: Design of the proposed antenna](image)

![Fig.9: Simulated and Practical Reflection Coefficient Vs Frequency Plot](image)

The optimized dimensions are a=24mm, b=20mm, c=24mm and d=14mm

This antenna has simulated and practical operating band from 1.94GHz to 13.84GHz and 1.82GHz to 14.07GHz respectively as shown in Fig.9. From this figure it has been shown that the simulated and practical -10 dB bandwidth is 11.9GHz and 12.25GHz which is sufficiently broad enough. The simulated and practical percentage impedance bandwidth is 151% and 154% respectively. There is a little difference between the simulated and practical results which may be due to the fabrication tolerance and measurement process. The gain with maximum value of 8dBi is achieved experimentally. However throughout the whole band lowest value of gain measured is 2.34dBi. The simulated and measured curves of the Radiation pattern in two principle planes (E plane and H plane) with co and cross polarization are also good.

High gain microstrip antennas have been designed using array structure and multi-resonators. Fig 10 shows the designed array structure. The designed antenna contains four...
circular shaped radiating patches on a square shaped ground plane. Each circular patch has radius of 5mm. The dimension of the square ground plane is 50mm×50mm. The array antenna is fabricated on an FR4_epoxy dielectric substrate with a thickness \((h)\) of 1.6 mm, relative permittivity \(\varepsilon_r = 4.4\). The antenna is excited by coaxial probe feed.

The simulated and measured gain of this designed array antenna has been shown in Fig.11. The gain is more than 8dBi in the frequency range of 9GHz to 13GHz and around 11dBi at 13.8GHz frequency. The measured bandwidth at -10dB is 8.15GHz (from 11GHz to 19.15GHz). Simulated and Practical H plane and E plane Co, Cross Radiation patterns are also good. So, the antenna operates at Ku frequency band which is applicable for satellite communication.

Gain of the microstrip antenna is also enhanced using multi-resonator structure which has been shown in Fig.12. The basic antenna structure contains three unequal sized U shaped patch, a feed line and a slotted ground plane. The patch has a width of 2mm. The patch is excited through a feed line of width 3mm and length 22mm as shown in Fig.12. The position of the feeding point is chosen to obtain the best impedance matching. A conducting slot loaded ground plane of width 22mm and length 32mm is placed on the dielectric substrate. The gaps between U parasitic elements are 2mm and the distance between T slots in the ground plane is 7mm. The position of the T slots has been shown in the Fig.12. The upper most and lower most sides of the T slots are placed at a distance of 5mm from the upper and lower boundaries of the ground plane, which is aligned in the X axis and 5.5mm right side from the left side boundary of the ground plane.
layout of the antenna is drawn in the Ansoft designer software. The designed antenna is fabricated on FR4-epoxy dielectric substrate with dielectric constant $\varepsilon_r= 4.4$, loss tangent of 0.02 and thickness ($h$) 1.6mm.

![Design of the Proposed Antenna](image)

Fig.12: Design of the Proposed Antenna

Dimension of the designed antenna are $H=12\text{mm}$, $L=7\text{mm}$, $W=2\text{mm}$, $H_1=7\text{mm}$, $H_2=14\text{mm}$, $H_3=21\text{mm}$, $L_1=8\text{mm}$, $L_2=11\text{mm}$, $L_3=14\text{mm}$, $W_1=1\text{mm}$, $W_2=2\text{mm}$ and $W_3=3\text{mm}$

High gain and dual broad band characteristics have been obtained from this circularly polarized antenna which is applicable for long distance communication systems. From the practical result it is noticed that the antenna shows two broadband ranging from 2.46GHz to 4.82GHz and 6.24GHz to 12.4GHz resulting in percentage bandwidth of 64.8% & 66.09%. A maximum gain of 14dBi (measured) and 12dBi (simulated) have been achieved using this simple proposed antenna. The measured result of the fabricated antenna shows good agreement with the simulated data. The axial ratio of the antenna is less than 2. So, it is circularly polarized. The practical radiation patterns also follow the simulated patterns which are shown in Fig.13. This achievement is done using a simple monopole microstrip antenna with slotted ground plane.

In modern wireless communication systems, devices use many communication channels. A compact, high gain antenna providing multi-frequency operation has been studied. Fig.14 shows the structure of the designed compact linearly polarized antenna. The layout of the
antenna has been drawn in Ansoft designer software. A circular patch size of 15mm is circulated by four concentric circular ring patches of unequal width. The outer radius of outer ring is 38mm. The circular ring patch is excited through a coaxial feed. The position of the feeding point is chosen for the best impedance matching. For best matching of input impedance, the radiating patch is placed at the centre position with respect to ground plane of the antenna. Four rectangular unequal slots are inserted in the ground plane. The lengths of the slots are \( L_1 = 70\text{mm}, L_2 = 64\text{mm}, L_3 = 64\text{mm} \) and \( L_4 = 64\text{mm} \), slot width \( W = 2\text{mm} \). These patches are fabricated on FR4-epoxy dielectric substrate of permittivity \( \varepsilon = 4.4 \) and thickness 1.6 mm. The radius of the circular ground plane of the circular ring antenna operating at the frequency of 3.19GHz is 48mm.

Fig. 14: Design of the Slotted Antenna

Microwave engineers and researchers are exercising their best effort to achieve size reduction, multi-frequency operation and gain enhancement. Different papers are published regarding any one of the above three achievements. In few journals some research works are reported showing achievements of any two properties among them. It has been tried to design an antenna which will exhibit enhancement of more than two properties in a single antenna. The lowest resonant frequency of the designed antenna contributes size reduction of 94\%. Highest gain of 6dBi is also achieved. Using this design seven different antennas can be substituted by one antenna as it resonates at seven frequencies. Reflection Coefficient Vs Frequency plot with Simulated and Practical value for the slotted antenna has been shown in Fig.15.
It is clear that radiation patterns at different resonating frequencies are good and stable. So no doubt this achievement of three properties in a single antenna will be of great importance in the field of microwave communication.

Another investigation also has been done using Ansoft designer software. The configuration of the compact triple-band antenna is shown in Fig. 16. The antenna consists of an E shaped microstrip patch, supported on a slitted rectangular ground plane. The patch antenna is printed on a Glass-PTFE substrate with a relative permittivity of 2.4 and thickness of 1.6 mm and is fed by coaxial probe feed method.

![Fig. 16: Design of the Antenna](image)

The feeding point is positioned to obtain better impedance matching. The dimension of the patch is 15mm×25mm. Each arm of the E shaped patch has equal dimension i.e. 10mm×5mm. A cross shaped slit is embedded on the rectangular ground plane of 45mm×75mm dimension. The patch is embedded at centre position with respect to the ground plane.

The proposed antenna is resonating at three different frequencies. The proposed design also results in size reduction of about 94%. A gain of 6.7dBi has also been achieved. The radiation pattern of the antenna is acceptable for use with practical communication designs. Simulated VSWR Vs frequency plot has been shown in Fig.17. Here, the designed antenna may be used in compact wireless communication like compact handheld mobile phone, MRI Instrument etc.

![Fig.17: Simulated VSWR Vs frequency plot](image)
The designed broadband monopole antenna (shown in Fig.8) is applicable to differentiate the defected breast tissue from the normal tissue. At microwave frequencies the dielectric constant of normal and defected tissues are different due to their dissimilar water containing capacity. So the amount of reflected powers from the normal tissue and defected tissue are different. Specific Absorption Ratios of the two cases are also different at microwave frequencies. So, defected tissues are detected among the normal tissues by using microstrip antenna.

To fulfill the requirements of the satellite communication an array antenna has been designed with four circular patches on a square ground plane. The designed antenna (shown in Fig.10) operates in the frequency band of 12GHz to 18GHz. Also gain of this antenna for the range of 9GHz to 13GHz is near about 10dBi and at 13.8GHz is 11dBi. It is observed that the characteristics of this antenna are within the requirements of the satellite operating in Ku band. Hence this antenna may be used in satellite communication in Ku band.

References


Author’s List of Publications

Peer Reviewed Journals


Conference Presentation

