Frequency Reconfigurable Microstrip Patch Antenna

by

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A comprehensive project report has been submitted in partial fulfillment of the requirements for the degree of

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in
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Under the supervision of

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CERTIFICATE OF APPROVAL

This is to certify that the project titled "**Frequency Reconfigurable Microstrip Patch Antenna**" carried out by

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for the partial fulfillment of the requirements for B.Tech degree in **Electronics and Communication Engineering** from **Maulana Abul Kalam Azad University of Technology, West Bengal** is absolutely based on his own work under the supervision of Mrs**. Pampa Debnath**. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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DECLARATION

"We Do hereby declare that this submission is our own work conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute and that, to the best of our knowledge and belief, it contains no material previously written by another neither person nor material (data, theoretical analysis, figures, and text) which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text."

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CERTIFICATE of ACCEPTANCE

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ABSTRACT

In Satellite and airborne communication, and ECM system, there has always been a continuous demand for smaller size, lighter weight antenna systems that has properties to achieve selectivity in frequency, bandwidth, polarization and gain.

So, in particular, planar designs enjoy all of these features including smaller size, lower RCS, lower manufacturing cost and surface conformability.

In this project, we'll be working in the frequency range of (0-2.4) GHz which includes it's application in cell phone working in frequency 0.8GHz, wireless applications working in frequency 2.4GHz(not Wi-Max which works in 5.8GHz).

Reconfigurable antenna is capable of operating at more than one frequency band thereby the number of antennas.

CONTENTS

1. Introduction to Frequency Reconfigurable Patch Antenna

2. Theory Of Patch Antenna

3. Microstrip Line

4. Antenna Design with HFSS

LIST OF SYMBOLS & Abbreviations

EMI- Electromagnetic Interference

PIFA- Printed Inverted F Antenna

PIL -Printed Inverted L Antenna

FDTD- Finite Difference Time Domain

MPA- Microstrip Patch Antenna

AR -Axial Ratio

TM -Transverse Magnetic

RF -Radio Frequency

RL -Return Loss

EDM- Electrical Discharge Machine

ε_{eff} -Effective permittivity

ε_r-Relative permittivity

ε''- Imaginary part of the complex permittivity

ε'- Real part of complex permittivity

μr- Relative permeability

A -Ampere

dB- decibel

E -Electric field vector

H -Magnetic field vector

EM- Electromagnetic

fr -Resonant frequency

GHz- Giga Hertz

K- Co- efficient of thermal conductivity

Q -Quality Factor

Z0 -Characteristic impedance

$\lambda 0$ -Free space wavelength

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Chapter 1

Introduction to Frequency Reconfigurable Antenna

1.1. Introduction

Patch antennas are widely used today. They are used for satellite communications and various military purposes such as GPS, mobile, missile systems, etc., due to their light weight, simple structure and easy implementation. The main advantages of patch antennas are as follows:

(1) Low cost to fabricate.
(2) Easy to manufacture.
(3) Efficient radiation.
(4) Support both linear and circular polarization.
(5) Light weight.
(6) Integrate easily with microwave integration circuits.

The increasing demand for modern mobile, satellite and wireless communication systems have driven many researchers to work on improving performance and enhancing applications of patch antennas. Reconfigurable antennas have drawn much attention for future wireless communication systems due to their ability to modify their geometry to adapt to changes in environmental conditions or system requirements such as enhanced bandwidths, operating frequencies, polarizations, radiation patterns, etc
Microstrip antenna is one of the most popular choices in designing the reconfigurable antenna because of their advantages we introduced above.

A reconfigurable radiation pattern antenna reduces the effects of noisy environments by changing the null positions, and it saves energy by adjusting the main beam signal towards the intended user to improve the overall system performance.

Polarization reconfigurable antennas have drawn increasing attention because they have some desirable advantages for modern wireless communications, such as avoiding fading loss caused by multipath effects in wireless local area networks, providing a powerful modulation scheme in active read/write microwave tagging systems, realizing frequency reuse to expand the capability in satellite communication systems, and being a suitable candidate in multiple-input-multiple-output (MIMO) systems.

There is a developmental trend in wireless communication systems that requires the use of antennas capable of accessing services in various frequency bands, sometimes with the use of a single antenna. So far, most of the reported pattern reconfigurable antennas can only switch the beam in a limited range. And there are few antenna designs concerned with both radiation pattern and dual-frequency. A pattern reconfigurable antenna that has multiband characteristics improves the whole system performance.

1.2. Objectives

The objective of this thesis is designing and testing of frequency reconfigurable microstrip patch antenna with resonating frequency of 2.4GHz.

The antenna can be used for applications operating in the frequency range of (0-2.4)GHz like for cell phones and other wireless devices operating in the mentioned frequency range.

1.3. Reconfigurable antenna classification

A **reconfigurable antenna** is an antenna capable of modifying dynamically its frequency and radiation properties in a controlled and reversible manner. In order to provide a switches, varactors, mechanical actuators or tunable materials) that enable the intentional redistribution of the RF currents over the antenna surface and produce reversible modifications over its properties. Reconfigurable antennas differ from smart antennas because the reconfiguration mechanism lies inside the antenna rather than in an external beamforming network. The reconfiguration capability of reconfigurable antennas is used to maximize the antenna performance in a changing scenario or to satisfy changing operating requirements.

Frequency Reconfiguration

Frequency reconfigurable antennas can adjust dynamically their frequency of operation. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna. Frequency reconfiguration is generally achieved by modifying physically or electrically the antenna dimensions using RF-switches, impedance loading or tunable materials.

Radiation Pattern Reconfiguration

Radiation pattern reconfigurability is based on the intentional modification of the spherical distribution of radiation pattern. Beam steering is the most extended application and consists in steering the direction of maximum radiation to maximize the antenna gain in a link with mobile devices. Pattern reconfigurable antennas are usually designed using movable/rotatable structures or including switchable and reactively-loaded parasitic elements. In last 10 years, metamaterial-based reconfigurable antennas have gained attention due their small form factor, wide beam steering range and wireless applications.

Polarization Reconfiguration

Polarization reconfigurable antennas are capable of switching between different polarization modes. The capability of switching between horizontal, vertical and circular polarizations can be used to reduce polarization mismatch losses in portable devices. Polarization reconfigurability can be provided by changing the balance between the different modes of a multimode structure.

Compound Reconfiguration

Compound reconfiguration is the capability of simultaneously tuning several antenna parameters, for instance frequency and radiation pattern. The most common application of compound reconfiguration is the combination of frequency agility and beam-scanning to provide improved spectral efficiencies. Compound reconfigurability is achieved by combining in the same structure different single-parameter reconfiguration techniques[15][16] or by reshaping dynamically a pixel surface

1.4. Applications

Reconfigurable antennas find applications in many areas especially when multiple radiation properties are required from a single element. These areas are stated below:

- Cognitive radio
- Plug and play reconfigurable satellites
- Multiple Input Multiple Output (MIMO) communication systems
- Cellular and personal communication systems
- Military applications

As examples to these applications, the antennas in can be used for GSM, DCS, PCS, UMTS, Bluetooth, and wireless local-area network (LAN). The antenna in can reconfigure its radiation patterns by altering its structure, while the resonant frequency and polarization remain unchanged. A lot of the previously stated applications require different radiation pattern changes without affecting the frequency and polarization response.

Chapter 2

Theory of Patch Antenna

2.1. Introduction

A **patch antenna** (also known as a rectangular microstrip **antenna**) is a type of radio **antenna** with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "**patch**" of metal, mounted over a larger sheet of metal called a ground plane.

Low profile antennas have drawn much attention because they are suitable for high performance aircraft, spacecraft and satellite and missile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are significant constraints. For today's rapidly-developing mobile or personal communication devices, there exists same need for compact and low profile antennas. Microstrip antennas (also referred to as patch antennas or microstrip patch antennas) can be used in a wide range of applications from commercial communication systems to satellites, and even biomedical applications [27]. Chapter 14 of Antenna Theory: Analysis and Design contributes greatly to the fundamentals of patch antenna addressed in this chapter of the thesis.

2.2. Basic Characteristics

The history of patch antenna can be traced back to 1953, when G.A. Deschamps first proposed this kind of antenna. However, patch antennas didn't become practical until the 1970s. In that time, it was developed further by researchers such as Robert E. Munson and others by using low-loss soft substrate materials that were just becoming available during that time.

Based on that, a microstrip antenna (Patch antenna), as shown in Figure 2.1, normally consists of a very thin ($t<<\lambda 0$ where $\lambda 0$ is the free-space wavelength) metallic patch placed a small fraction of a wavelength ($h<<\lambda 0$, usually $0.003\lambda 0 \leq h \leq 0.05\lambda 0$) above a ground plane. The distance between the patch and the ground plane – the substrate or dielectric height h – determines the bandwidth of antenna. A relatively thicker substrate can increase the gain, but it may result in some undesired effects such as surface wave excitation. Surface waves can decrease efficiency and perturb the radiation pattern. The patch antenna is designed so its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. In general, modes are designated as TMnmp. The ‘p’ value is mostly omitted because the electric field variation is considered negligible in the z-axis since only a phase variation exists in the z axis. So, TMnm represents the field variations in the x and y directions. The field variation in the y direction (impedance width direction) is negligible and so m is considered 0. The field has one minimum-to-maximum variation in the x direction (resonance length direction and a half-wave long), thus n is 1 in this case, and we say that this patch operates in the TM10 mode.

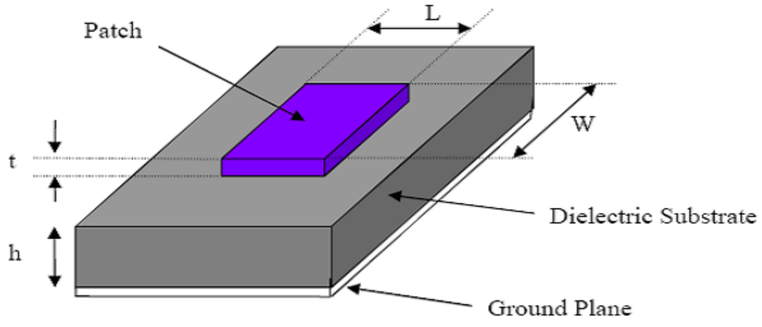


Figure 2.1: Microstrip Antenna

For a rectangular patch, the length L of the element is usually

$(\lambda o/3) < h < (\lambda o/2)$.

The patch and the ground are separated by a dielectric sheet (usually referred to as the substrate), also
as shown in Figure 2.1.
There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants, εr , are usually in the range of $2.2 \le \varepsilon r \le 12$ .The most desirable ones for antenna performance are thick substrates with dielectric constants at the lower end of the range because they provide better efficiency, larger bandwidth, and loosely bound fields for radiation into space, but at the cost of large element size. Thin substrate with higher dielectric constants are suitable for microwave circuity because they require tightly bound fields to minimize undesired radiation and coupling, and result in smaller element size. However, they are less efficient and have a relatively smaller bandwidth because of their great losses. Since microstrip antennas are often integrated with other microwave circuits, a compromise has to be made between good antenna performance and circuit design.

Basically, microstrip antennas are also referred to as patch antenna. Usually, the radiating elements and feed lines of micorstrip antennas are photoetched on the dielectric substrate. The radiating patch is generally made of conducting material such as copper or gold and can be any possible shape, such as rectangular, thin strip (dipole), circular, elliptical, triangular, etc. These and others are illustrated in Figure 2.2. Among the possible shapes, the square, rectangular, dipole, and circular are the most common because they are easy to analyze and fabricate. As well, they have other attractive characteristics, especially low cross-polarization radiation. Microstrip dipoles are attractive because they inherently possess a larger bandwidth and occupy less space, which makes them very suitable for arrays. Linear and circular polarization patch antennas can be obtained
with either single elements or arrays of microstrip antennas. An array of microstrip elements, with single or multiple feeds, can also be used to introduce scanning capabilities and achieve greater directivities.

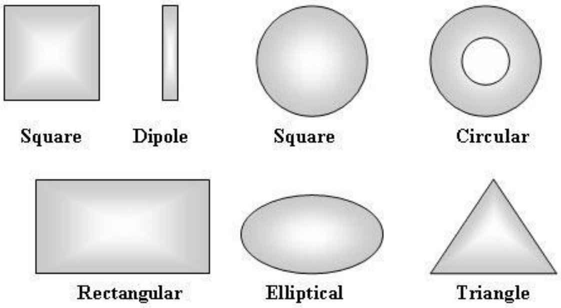


Fig. 2.2 :Different shapes of Patch Antenna

2.3. Radiation Pattern

A patch antenna radiates energy in certain directions and we say that the antenna has directivity (usually expressed in dBi). So far, the directivity usually has been defined relative to an isotropic radiator. An isotropic radiator emits an equal amount of power in all directions and it has no directivity. If the antenna has a 100% radiation efficiency (meaning the energy delivered to the antenna can be 100% radiated from antenna), all directivity would be converted to gain. The typical rectangular patch excited in its fundamental mode has a maximum directivity in the direction perpendicular to the patch (z-axis). The directivity decreases when moving away from zenith direction towards lower elevations. Figure 2.3 shows a typical radiation pattern for half-wave square patch antenna

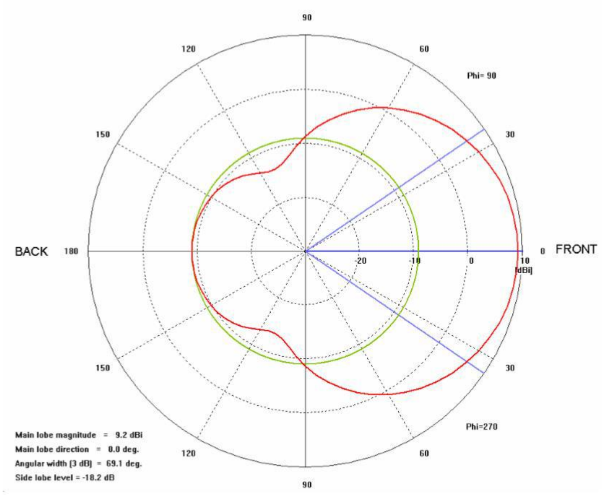


Figure 2.3 Radiation pattern for half-wave square patch antenna

2.4. Polarization

The plane in which the electric field varies is also known as the polarization plane. The basic patch antenna is linearly polarized since the electric field varies in only one direction. However, a large number of applications such as satellite communications, do not work well with linear polarization because, due to the moving antenna platform, the relative orientation of the antenna is unknown. In these applications, circular polarization is useful since it is not sensitive to antenna orientation. Basic antennas do not generate circular polarization; hence some changes have to be made to the patch antenna to enable it to generate circular polarization. For a circularly polarized patch antenna, the electric field varies in two orthogonal planes (x and y directions) with the same magnitude but a 90° phase difference, as shown in Figure 2.4. Necessary to generate circular polarization for a patch antenna is the simultaneous excitation of two modes, i.e. the TM10 mode (x direction) and the TM01 mode (y direction). One of the modes is excited with a 90° phase delay to the other mode. A circularly polarized antenna can either be right-hand circular polarized (RHCP) or left-hand circular polarized (LHCP). The antenna is RHCP when the phases are 0° and -90° for the antenna in Figure 2.4, and the signal radiates towards the reader. It is LHCP when the phases are 0° and +90°, and the signal radiates away

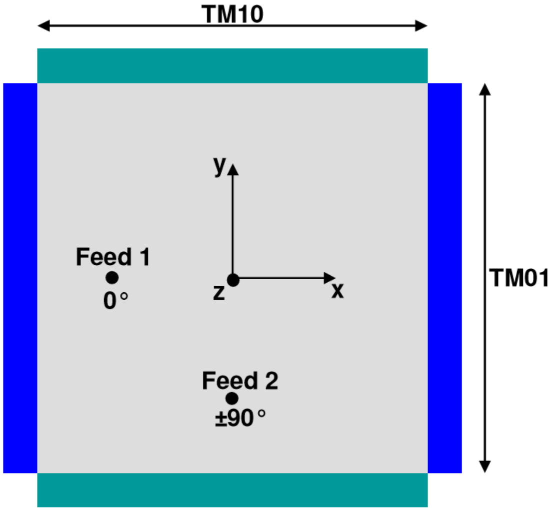


Figure 2.4 The nearly square antenna for circular polarization

2.5. Bandwidth

The impedance bandwidth depends on a large number of parameters related to the patch antenna element itself like quality factor, Q, and the type of feed technology used. Usually, the impedance bandwidth of a square, half-wave patch antenna is typically limited to 1 to 3%, which is a major disadvantage of this type of patch antenna.

Chapter 3

Microstrip Line

3.1. Introduction

Microstrip technology is quite mature,offering asuperior blend of performance characteristics to the designer of the microwave integrated circuit.Nearly 50 references at the end of this article attest to the number of investigators who have published design formulasfor microstrip.So today,the problem is not the circuit designer lacks information concerning this transmission medium,but that to much information available,scattered throughout many journals.What followesis an attempt to review the most useful formulas and conclusions, and arrange them in a logical,easy-to-follow oder.

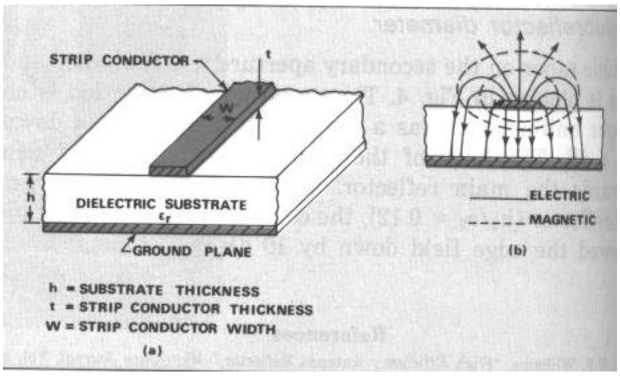
But first,understand the difference between microstrip and other forms of MCI transmission that are often erroneously refers to as "microstrip." By defination ,a microstrip transmission line consist of strip conductor and a ground plain seperated by a dielectric medium.The dielectric material serves as a structural substraite upon which a thin-flim metal conductors are deposited .Conductors are ususlly gold or copper.

3.2. Microstrip

Sincefield lines between the strip and the ground plain are not contained entirely in the substraite ,thepropagiting mode along the strip is not puerly transverse electromagnetic(TEM) but quasi-TEM. Assuming thequasi-TEM mode of propagation, the phase vilocity in microstrip is given by

$$V_{p=}\ c/\mathrm{sqrt}(E_{eff})$$

Where c is the vilocity of light ,and E_{eff} is the effecitive dielectric constant of the substraite material .The effictive dielectric constant is lower then the relative dielectric constant, E_r, of the substraite, andtake in to account external fields.



the wavelength , λ_g, in microstrip line is given by

$$\lambda_g = V_p/f$$

Where V_p isgiven by Eq.1 and f is frequency.

The characteristics impedance of the transmission line is given by

$$Z_o = 1/V_pC$$

Where C is the capacitance per unit length of the line.

The analysis for the evaluation of E_{eff} and C based on quasi-TEM mode is fearly accurate at lower microwave frequencies. At higher frequencies , the radio of longtudinal-to-tranverse electric field components becomes significent and the propageting mode can no longer be considered quasi-TEM .

Closed-form expression are vitle

Early attempt to charactercize the performance of microstrip line where on based on the quasi-TEM model . various electrostatic approximation such as conformal mapping ,relaxation methods ,variation techniques ,the mothod of green function and the moment method aer geberlly used . Closed form expression are absolutely necessary for optimization and computer aided design of a micro strip circuit.

The closed form expression for Z_o and E_{eff} have been reported by Wheeler , Schneider and Hammerstad . Wheeler and Hammerstad have also given an expression for W/h in termsof Z_0 and E_r. For a practical range of microstrip line ($0.05<=W/h<=20$ and $E_r<=16$) Hammerstad reported that his expression are more accurate then earlier work ,and fall within +1 and -1 per sent of wheeler's numerical results . His expression, which are based on work of Wheeler and Schneider ,includes useful relationships defing both characteristic impedance and effective dielectric constant:

For W/h<=1,

$Z_0= 60 \ln(8 h/W +0.25 W/h)/\mathrm{sqrt}(E_{eff})$ (4)

where

$E_{eff}=((E_r+1)/2) +((E_r-1)/2)*[(1+12 h/W)^{-1/2} +0.04(1-W/h)^2]$ (5)

For W/h>=1

$Z_0=(120 \pi/\mathrm{sqrt}(E_{eff}))/(W/h +1.393+0.667 \ln(W/h +1.444))$ (6)

where:

$E_{eff} =((E_r+1)/2) +((E_r-1)/2)*[(1+12 h/W)^{-1/2}]$ (7)

Hammerstad notes that the maximum relative error in E_{eff} and $Z_0$is less then +-0.5

per cent and 0.8 per sent,respectively, for $0.05<=W/h<=20$ and $E_r<=16$.His expression for W/h in terms of Z_0 and E_r

are:

for W/h<=2

$W/h= 8 \exp(A)/\exp(2A)-2$

for W/h>=2

$W/h =2/\pi [B-1-\ln(2B-1)+ (E_r-1)/E_r2)\{\ln(B-1) +0.39 -0.61/E_r\}]$

where

$A=Z_0/60(sqrt(E_r+1)/2))+ (E_r-1)/(E_r+1)(0.23+0.11/E_r)$

$B= 377 \ \pi/2 \ Z_0$

These expression provided the same accuracy as Eqs 4,5,6 and 7.

The results discussed above assumed a two dimentional strip conductor.However,when $t/h<=0.005,2<=E_r<=10$ and $0.1<=W/h<=5$,the agreement between experimantal and theoritical($t/h=0$)result is excellent .

Expression for W_e are:

For $W/h>=1/2 \pi$

$$W_e/h=W/h \ +t/\pi h \ (1+\ln(2h/t) \qquad (10)$$

For $W/h>=1/2 \pi$

$$W_e/h=W/h \ +t/\pi h \ (1+\ln(4\pi W/t) \qquad (11)$$

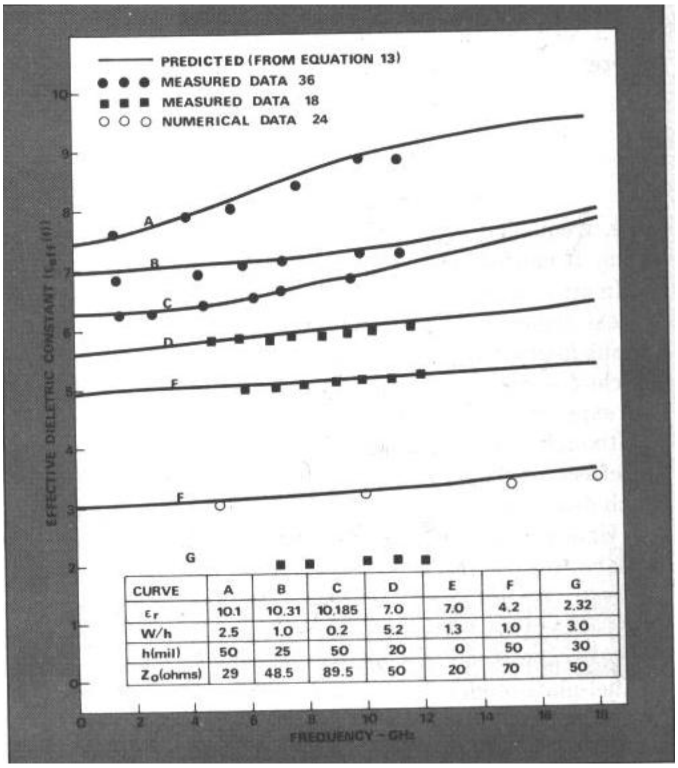
Additional rectrications for applying Eqs 10,11 are $t<=h$ and $t<W/2$. typical strip thickness varies from 0.0002 to 0.0005 inch for matalised alumina substrate ,and from 0.001 to 0.003 inch for low dielectric substrates.

most micro wave intregrated circuit application require a matilic enclosure for hermetic sealing ,strength,electromagnetic shilding and easeof handling.But whene the ratio of the distant between the lower and upper to substrate thickness is larger then five.

3.3. Dispersive effects

Consider dispersion at higher frequencies

The formulas for characteristic impedance and effictive dielectri constant presented thus far have have been based on a quasi-TEM mode 0f propagation ,At lower frequencies ,this is a good static approximation of a dynamic structure.This dispersive characteristic is due to propagation of hybrid modes.



CURVE	A	B	C	D	E	F	G
ϵ_r	10.1	10.31	10.185	7.0	7.0	4.2	2.32
W/h	2.5	1.0	0.2	5.2	1.3	1.0	3.0
h(mil)	50	25	50	20	0	50	30
Z_o(ohms)	29	48.5	89.5	50	20	70	50

Dispersive effects raise the effective dielectric constant slightly as frequency is increased.

The numerical analysis for dispersion in shilded as well as open microstrip transmission has been treated extensively .The numerical approach is not convenient for microstrip circuit design and therefore ,not discuss in the paper.

Both experimental and empirical attempts to describe microstrip dispersion have alsobeen reported .Analytical formulas for dispersion which agree closely with experimental and numerical results have appered just recently.

These analytical expression ,by Getsinger and Carlin ,are very similar ,but result given by Getsinger are closer to experimental as well as numerical results.The dispersion in E_{eff} is given by

$$E_{eff}(f) = E_r - (E_r - E_{eff})/1+G(f/f_p)^2 \qquad (13)$$

where:

$$f_p = Z_0/(8 \pi h)$$

$$G = 0.6 + 0.009 Z_0$$

Here frequency ,f ,is in GHz and substrate thickness ,h,in cm .High -impedance lines on thin substrates are less dispersive .There is a close agreement between the calculated values and experimental values.

Although many researchers have attempted to describe the effect on dispersion on

E_{eff},there are fewer analyses which deal with frequency dependent behaviour of Z_0.The agreement between the results given bythese two analysis is resonably good .

Recently ,closed -form expression for $Z_o(f)$ based on a parallel-plate model of microstrip line have been reported .These expression are:

$Z_0(f)= 377h/((W_{eff}(f)(sqrt(E_{eff})(f))$ (14)

The effictive width ,$W_{eff}(f)$,is given by

$W_{eff}(f)= W +((W_{eff}(0) -W)/(1- (f/f_p)^2))$ (15)

Where $W_{eff}(0)$ is obtained from Eq 14 when f=0.

The variation in characteristic impedence with frequency .The solid curve is arrivedat using Eqs 14 and 15,while the dotted curve is the one reported by Knorr and Tufekcioglu.The incresede in $Z_0(f)$is only 4 persent from DC to 10 GHzwhich is quite small.This change cannot be confirmed experimentally since,at 10GHz, transisation pose a considerable problem in accurate measurement.Therefore ,the effect of dispersion on Z_0 can be generaiiy neglacted.

3.4. Characteristic Impedance

Two mechanisms contribute to loss

Attenuation constant, 'a', is one of the most important characterstics of any transmission line.There are two source of dissipative losses in microstrip circuit :conductor loss and substrate dielectric loss. The conductor loss may be approximated as:

a_e=8.68 R_s /(Z_oW) dB/cm (16)

where R_s is surface resistivity.

It should be noted that this simple expression for conductor loss is valid only for very wide strip.however Eq 16 can be brought closer to reality by considering nonuniform current distribution .

For W/h <= 1/2 π ,

$a_e=(8.86 R_s/2 \pi Z_0h)*P*[1+ (h/W_e) +(h/\pi W_e) (\ln (4\pi W/t)+(t/W))]$ (17a)

For 1/2π<W/h <=2,

$a_e =(8.86 R_s/2 \pi Z_0h)*P*Q$ (17b)

For $W/h >= 2$,

$a_e = (8.86\ R_s/Z_0 h)*Q*\ [W_e/h\ + (2/\pi)\ \ln\{\ 2\pi e(W_e/2h\ + 0.94\}]^{-2}\ [W_e/h\ + W_e/\pi h/(W_e/2h\ + 0.94]$ (17c)

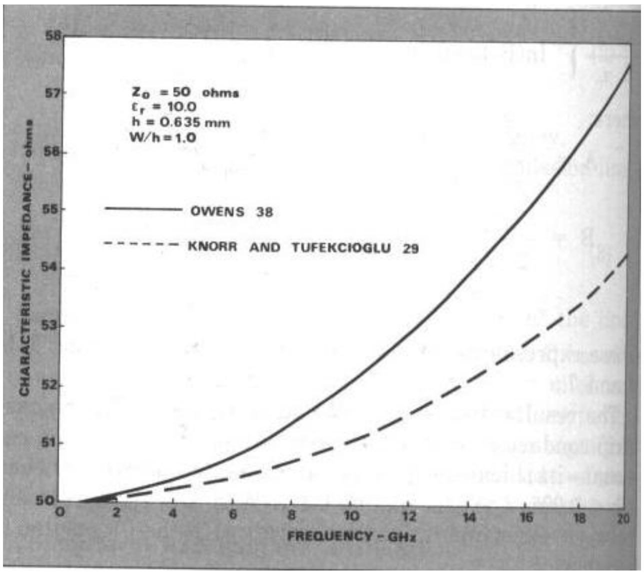
where:

$P = 1 - (w_e/4h)^2$

$Q = 1 + h/W_e\ \ + h/\pi W_e\ (\ln 2h/t - t/h)$

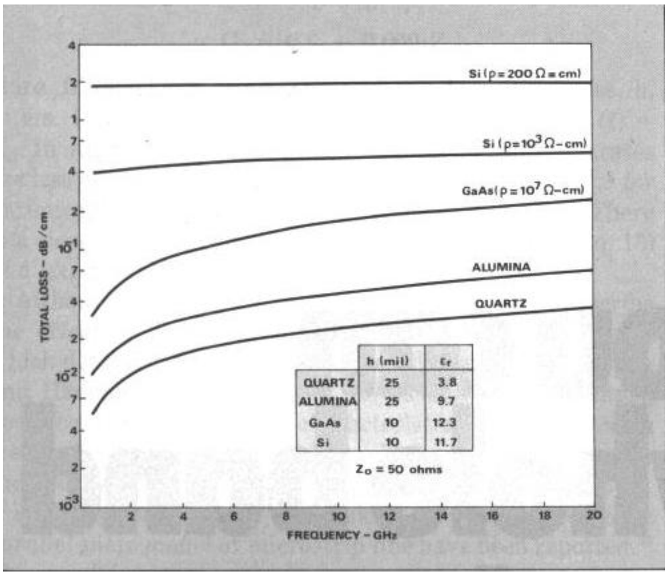
The dielectric loss in microstrip line is an important parameter when microwave circuits requireing small attenuation are considered.Dielectric losses are very small compared with conductor losses for dielectric substrate . Dielectric losses in silicon substrates ,however are ususlly same order as ,or larger then conductor losses .Higher resistivity can be maintained in GaAs, and hence the lossses are less for this material.

Figure 4 compares the total loss for 50 -ohm microstrip lines on silicon ,GaAs,alumina and quartz substrate .It is obvious from the figure that silicon MICsare more lossy.Lines on quartz have the least loss.



Characteristic impedance increases somewhat with frequency. But note that it is only a 4% change from DC to 10GHz.

3.5. Losses in Semiconductor substrates



Losses in semiconductor substrate are substantially higher than those in ceramic or quartz material. Silicon introduces high losses due to the difficulty of growing high resistivity of material.’

Quality factor depends on substrate

The quality factor ,Q, of a microstrip line can be related to the total losses in the line by

$Q_T=B/2a_T$ (19)

Where Q_T is atotal resonator Q, a_T is the total loss in the resonator and $B = 2\pi\ \lambda_g$.

When the losses in a resonant are considered another loss factor ,a_T, due to radiation at the discontinuities must also be considered .The correspondingradition Q-factor is given by

$Q_r= Z_0/(480\pi(h/\lambda_0)^2F$ (20)

where

$F=(E_{eff}(f) +1)/E_{eff}(f) \quad -((E_{eff}(f) +1)^2/2(E_{eff}(f))^{2/3} \ * \ln (sqrt(E_{eff}(f)))+1/(sqrt(E_{eff}(f))) -1$

The total Q 0f the resonator can be expresed by

$1/Q_T=1/Q_c + 1/Q_d + 1/Q_r$ (21)

Here Q_c ,Q_d and Q_r are the quality factor corresponding to conductor ,dielectric and radiation loss ,respectively.Finally ,the circuit quality factor ,Q_0, can be define as

$1/Q_0 = 1/Q_c + 1/Q_d = \lambda_0(a_c + a_d)/(\pi \mathrm{sqrt}(E_{eff}))$ (22)

The variation of Q_0,Q_r and Q_T with frequency for a quater-wave resonator GaAs,alumina quartz substrates .A quater -wave ,50-ohm resonator on 25-mil-thick alumina substrate has a Q_0 of about 240 at 2 GHz and 550 at 10GHz, whereas Q_T is 230 at 2GHz and nearly 160 at 10GHz.A quarter wave ,50 ohm resonator on 10 mil GaAs substrate has Q_0 of about 82 at 2GHz and 160 at 10GHz,whereas Q_T is 82 at2GHz and nearly at 145 at 10GHz .Thus commonly accepted rule for high Q microstrip circuit using thick substrate does not apply due to hi radiation losses incurred under this condition .

Moding limits high frequency operation

Maximum frequency of operation in microstrip line is limited by the excitation spurious modes in the form of surface waves and transverse resonances.surface wave are TE and TM modes which propagate across a dielectric substrate with ground plane . The frequency at which significant coupling occurs between the quasi-TEM mode and the lowest order surface wave mode is given by

$f_T = c/2\pi h \ \mathrm{sqrt}(2/(E_r - 1)) * \tan^{-1}(E_r)$ (23)

For $E_r > 10$, Eq reduce to

$f_T(\mathrm{GHz}) = 10.6/h(\mathrm{sqrt}(E_r))$ (h in cm) (24)

Cut off frequency,f_T,decreases when either the substrate thickness or dielectric constant is incresed.

Thus three limitation maximum substrate thickness ,minimum Q and surface wave excitation - defines a region of useful microstrip line operation .

For $E_r = 9.7$, this range is:

$0.23 <= h <= 1.8$ cm @ 2GHz

$0.01 < h <= 0.36$ cm @ 10GHz

$0.01 < h <= 0.17$ cm @ 20GHz

In addition to the conductor and dielectric losses,the maximum Q of microstrip is also limited by radition losses from dis continuities.When radiation losses are taken in to account for calculation of maximum Q ,the plot in Fig.6 are slightly modified.But ,if packaging and circuit disign techniques are employed to reduce radiation losses ,the curves in Fig.6 will remain valid.

Chapter 4

Antenna Design with HFSS

4.1. Introduction

Here is a simplified Microstrip antenna design with Ansys HFSS.

There are few basic things that must be known before designing an antenna in general such as:

The frequency range in which the antenna is planed to be be propagating, the size of the antenna, the material, the gain of the antenna and the structure of the antenna.

4.2 Microstrip Antenna design with HFSS

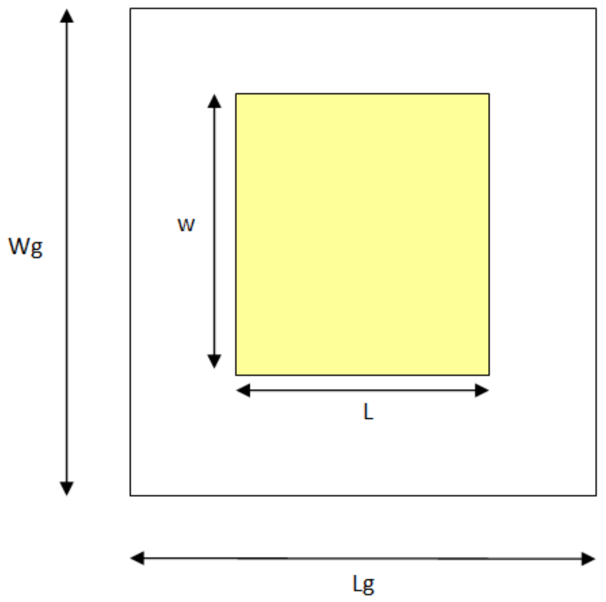
We will attempt to design a frequency reconfigurable microstrip patch antenna with the following characteristic:

Resonant frequency:- 2.4GHz.

Transmission line impedance: 50 Ohm.

The dielectric constant of the substrate: $\xi_r = 2.3$ *(Rogers RT/duroid 5880)*
Thickness of dielectric substrate (h) : 0.787 mm

Relative Permittivity :-2.2 and Relative Permeability: 1



Top view

Wg: Height of the ground plane

W: Height of the path

L: Width of the patch

Lg: Width of the groupn plane

The following step will be the derivation of other dimensions using the characteristic of the antenna

Microstrip Antenna design with Ansys HFSS

Height of a dielectric constant

$$w = \frac{c}{2f_0\sqrt{\frac{(\xi_r + 1)}{2}}}$$

$$c = 3.10^8 \, m/s$$

$$w = 30mm$$

Effective dielectric constant ξef

$$\xi_{eff} = \frac{\xi_r + 1}{2} + \frac{\xi_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

$$\xi_{eff} = 10.70$$

Effective length

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

$$L_{eff} = 23.27mm$$

Length extension

$$\Delta L = 0.412h\frac{(\xi_{eff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\xi_{eff} - 0.258)\left(\frac{w}{h} + 0.8\right)}$$

$$\Delta L = 0.67mm$$

Actual length of the path

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

$$L = 22mm$$

Ground plane dimensions

$$L_g = 6h + L$$

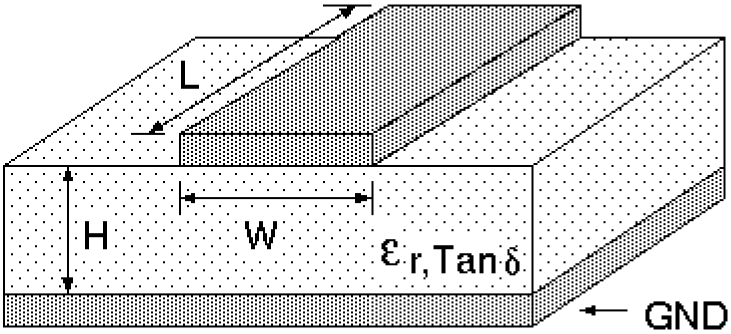
$$W_g = 6h + w$$

$$L_g = 31.6mm$$

$$W_g = 39.6mm$$

Now that we have all dimensions of the antenna, We need to design a transmission line to feed the antenna.

4.3. Design Of Microstrip Transmission line



The characteristic impedance Zo is a function of the ratio W/H and

When $\frac{W}{H} \geq 1$

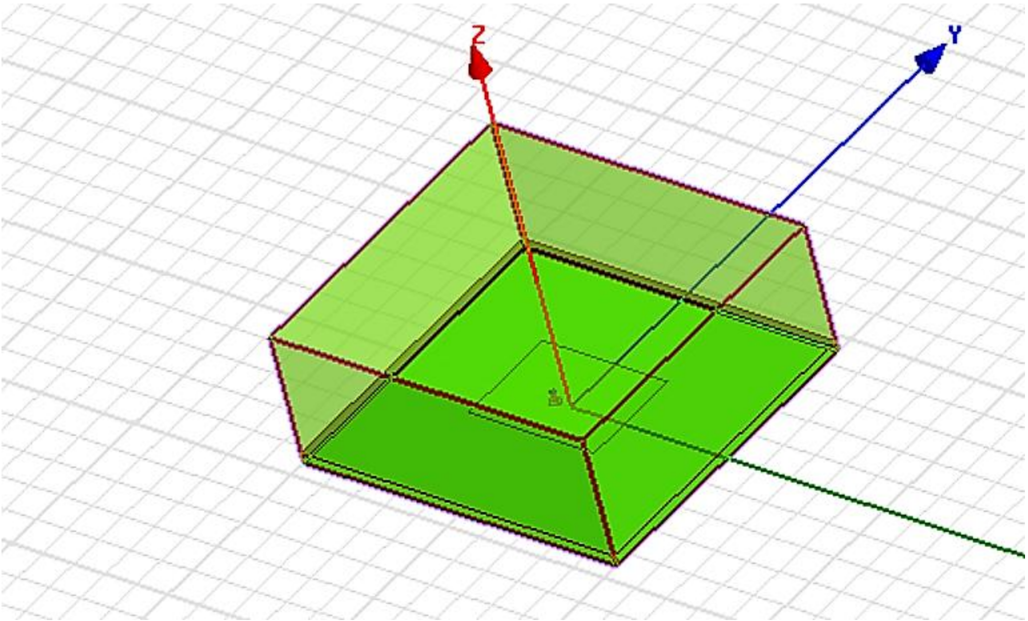
$$Z_0 = \frac{120\pi}{\sqrt{\xi_{eff}} \times \left[\frac{W}{H} + 1.393 + \frac{2}{3}\ln\left(\frac{W}{H} + 1.444\right)\right]} (ohms)$$

Since the value of the Zo is proportional to the W/H, we can alternatively change W and H and keep the value of Zo more or less constant. This is made for the sake of finding a value that will allow the transmission line to match our others dimensions.

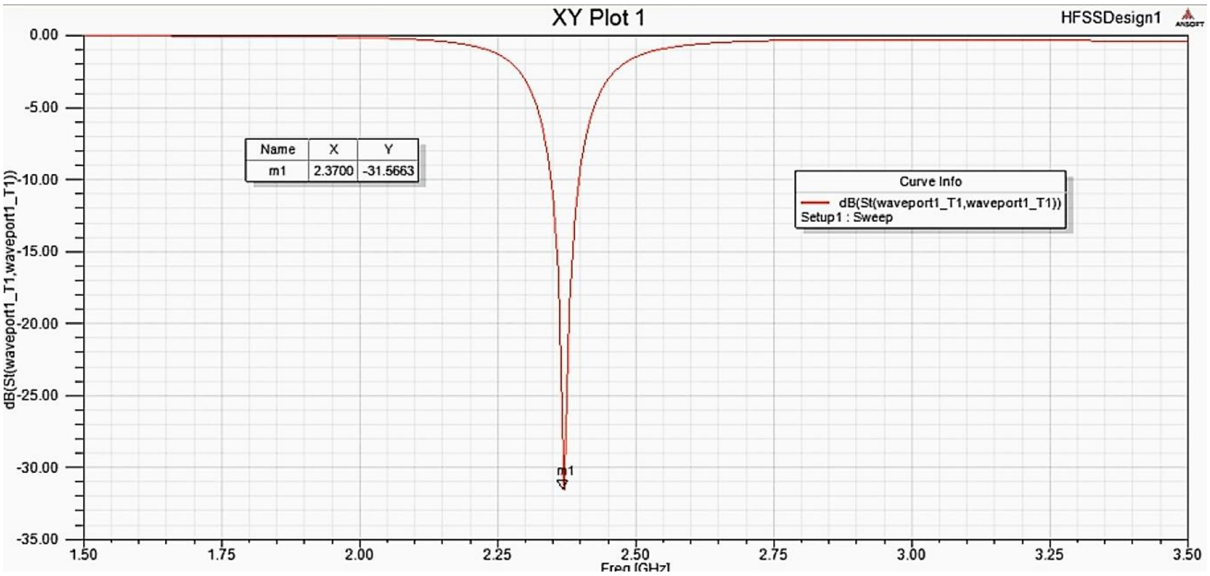
Using the following table, we observe that we have a choice between several W and H while keeping the Zo almost constant.

Our concern here was to reduce the height as much as possible to help the whole (transmission line + radiating element) fit nicely on the ground plane.

We will then choose the last value for the antenna design: H=6 mm, W=2.8 mm

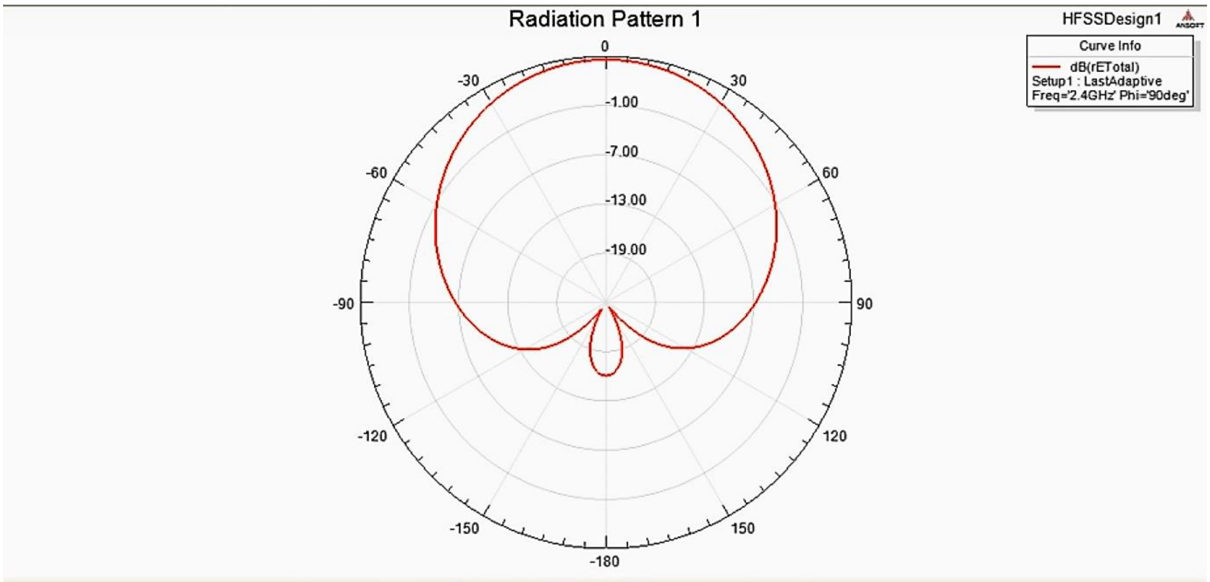


We now need to simulate the microstrip transmission line and make sure the return loss is ok.



The plot above shows a return loss way under -31.3 dB for our chosen dimensions which confirms the design of a 50 ohms microstrip transmission line.

Radiation Pattern is:



Conclusion:

In this work three major reconfigurable antenna's research characteristics are addressed. The first aspect is the design of reconfigurable antennas. These antennas are reviewed, classified and grouped. They are categorized into different groups based on their reconfiguration techniques and they are classified based on their reconfigurability properties. Previous reconfigurable antenna designs, their reconfiguration techniques and their applications are reviewed.

Frequency reconfigurable microstrip patch antenna was designed to cater wireless applications in operating in the frequency range of (0-2.4) GHz.

The plot shows a return loss way under -35.0 dB for our chosen dimensions which confirms the design of a 50 ohms microstrip transmission line.

Reconfigurable antenna designers need to answer a very important question: will they be able to achieve their design objectives in the most efficient and less expensive way. This work tries to answer this question knowing that a designer has to always compromise between improved performance of an antenna and an increased complexity in its structure.

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