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Designing Patch Antennas for 2.4GHz Applications

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Abstract: Evolution of human begins is considered successful through his integrity of the group and communication, today communication and information plays a vital role for the human survival using the power of communication the man is able to understand the nature and share his experiences to the younger once. The optical communication devices utilized the light portion of the electromagnetic spectrum. It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of the humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource.

Keywords: Antenna; RF; Micro strip Patch Antenna

I. INTRODUCTION

An antenna is a device to transmit and receive electromagnetic waves. Electromagnetic waves are often referred to as radio waves. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the same frequency band as the radio system to which it is connected, otherwise reception and transmission will be impaired.

Antennas are a very important component of communication systems. By definition, an antenna is a device used to transform an RF signal, travelling on a conductor, into an electromagnetic wave in free space. Antennas demonstrate a property known as reciprocity, which means that an antenna will maintain the same characteristics regardless if it is transmitting or receiving. Most antennas are resonant devices, which operate efficiently over a relative narrow frequency band. An antenna must be tuned to the same frequency band of the radio system to which it is connected otherwise the reception and the transmission will be impaired. When a signal is fed into an antenna, the antenna will emit radiation distributed in space in a certain way.

A. Basis of Classification of Antennas

Antenna classification can be based on:

a) Frequency and Size

Antenna used for HF is different from the ones used for VHF, which in turn are different from antennas for microwave. The wavelength is different at different frequencies, so the antennas must be different is size to radiate signals at the correct wavelength. We are particularly interested in antennas working in the microwave range, especially in the 2.4GHz applications. At 2.4GHz, the wavelength is 12.5cm.

b) Directivity

Antennas can be omnidirectional, sectorial or directive. Omnidirectional antennas radiate the same pattern all around the antenna in a complete 360 degrees pattern. The most popular types of Omni directional antennas are the dipole-type and the ground plane. Sectorial antennas radiate primarily in a specific area. The beam can be as wide as 180 degrees, or narrow as 60 degrees. Directive antennas are antennas in which the beam width is much narrower than in sectorial antennas. They have the highest gain and are therefore used for long distance links. Types of directive are the Yagi, the biquad, the horn, the patch antenna and many others.

c) Physical construction

Antennas can be constructed in many different ways, ranging from simple wires to parabolic dishes, up to coffee cans. When considering antennas suitable for 2.4GHz WLAN use, another classification can be used.

d) Application

We identify two application categories which are Base station and Point-to-Point. Base stations are used for multipoint access. Two choices are Omni antennas which radiate equally in all directions, or sectorial antennas, which focus into a small area. In the point-to-point case, antennas are used to connect two locations together.

B. Types of Antennas

The fundamental antenna types are:

a) Wire Antennas

This classification includes antennas like Dipole antennas, short dipole antennas, half dipole antennas, loop antennas etc.

b) Travelling Wave Antennas

This includes Yagi-Uda antennas, helical antennas

c) Reflector Antennas

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Some examples are Parabolic reflectors (dish antennas),corner reflectors.

d) Microstrip Antennas

This classification includes Rectangular microstrip, Circular microstrip antennas etc.

e) Log-Periodic Antenna

Bow-Tie antennas, Log periodic antennas are some examples.

f) Aperture Antenna

Slot antennas, Horn Antennas, Telescopes etc.

g) Other Antennas

This classification includes NFC antennas, Fractal antennas, Wearable antennas.

C. ANTENNA GLOSSARY

a) Antenna

A metallic device used in the transmission and reception of electromagnetic waves. An antenna is a passive or an active device which permits transmission.

b) Beam Width

The angle of signal coverage provided by an antenna. Beam width usually decreases as antenna gain increases.

c) Gain

The increase in signal strength that is produced by an amplifier. The ratio between the amount of energy propagated from an antenna that is directional compared to the energy from the same antenna that would be propagated if the antenna were not directional. The gain of an antenna is the same regardless of if the antenna is used to transmit or receive.

d) Attenuation

The loss in power of electromagnetic signals between transmission and reception points.

e) Bandwidth

It refers to the range of frequencies over which the antenna operates correctly. BW=100x [(FH-FL)/FC] where, FH is the highest frequency in the band, FL is the lowest frequency in the band and FC is the centre frequency in the band.

f) Directivity

The theoretical characteristic of an antenna to concentrate power in only one direction, whether transmitting or receiving.

g) Efficiency

The ratio of useful output to input power, determined in antenna systems by losses in the system including losses in nearby objects.

h) Impedance

The Ohmic value of an antenna feed point, matching section or transmission line at a radio frequency. An impedance may contain a reactance as well as a resistance component.

i) Radiation Pattern

The graphical representation of the relative field strength radiated from an antenna in a given plane, plotted against the angular distance from a given reference.

j) Polarisation

The sense of the wave radiated by an antenna. This can be horizontal, vertical, elliptical or circular (left or right hand circularity) depending on the design and application.

k) VSWR

VSWR of the antenna is the ratio of the maximum to minimum values of voltage in the standing wave pattern appearing along a lossless 50 Ohms transmission line with an antenna as the load.

l) Return Loss

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fibre. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB).

D. Advantages And Disadvantages Of Microstrip Patch Antennas

Microstrip antennas have several advantages compared to conventional antennas and therefore many applications cover the broad frequency range from 100MHz to 100GHz.Some of the principle advantages of microstrip antennas compared to conventional antennas are:

a) Light weight, low volume, thin profile configuration.

b) Low fabrication cost, rely amenable to mass production.

c) Can be easily integrated with microwave integrated circuits.

d) No cavity backing is required.

e) Linear polarisation and circular polarisation can be made easily.

However, microstrip antennas also have some limitations compared to conventional antennas:

a) Narrow bandwidth and associated tolerance problems.

b) Large ohmic loss in the feed structure of arrays, low gain.

c) Complex feed structures required for high performance arrays.

d) Polarisation purity is difficult to achieve.

e) Low power handling capability(100W)

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II. LITERATURE SURVEY

The basic antenna shape is a circular patch and the substrate used is FR4 (Flame Resistant) epoxy with relative permittivity of 4.4.

To radiate electromagnetic waves, the microstrip antennas were first used in 1950s.Deschamps developed the oldest form pf antennas. By early 1970s, the researchers observed that more than half the power in microstrip radiator escapes as radiation. So, the microstrip radiation patch with considerable amount of loss was concluded as microstrip patch antenna later, it was proved that the discontinuities in the ends of transmission line was the main reason for radiation to occur.

At the time of its inception microstrip antennas were associated with many disadvantages, such as low efficiency, lower power, high Q, poor polarization purity, poor scan capability, and very narrow bandwidth. As the design technology has evolved, the microstrip patch antennas have improved impedance bandwidth, better polarization patterns, flexibility in terms of resonant frequency. The broadband microstrip patch antennas are finding increasing applications in satellite communications, WLAN and commercial usages especially as base station antennas, antennas for access point.

A. Reasons For Choosing Circular Shape Of The Patch

In this project, circular patch antenna is being designed, the reason being, that the circular patch requires less metalized area for the fabrication that the rectangular shape.(Out of all the shapes having same area, it proved that circular shape has the least perimeter.)Also, the circular patch antenna provides the required amount of circular polarization which is a must in the wireless communication field. Also, it is found that as the number of patches increase in rectangular and circular antenna, the rectangular patch antenna provides a high value of return loss which is not desirable. To fabricate, the rectangular patch antenna feed requires two parameters Length and Breadth, whereas the circular patch antenna requires only one parameter Radius for fabrication. This advantage becomes handy when we use a large antenna array with different shapes and areas.

B. Formulas Used For Designing The Antenna

The radius of the circular patch antenna can be calculated by a formula below the radius is dependent on the resonant frequency, height of the substrate used and the dielectric constant of the substrate. Chosen is a FR4 epoxy as a dielectric substrate with thickness h=1.6mm and dielectric constant=4.4. Radius of the circular patch is given by, The radius of the circular patch is found out to be 17mm. We have chosen the inter element spacing for the 2x1 and 4x1 Antenna arrays to be 62.5 mm. We also calculated the widths of each of these feedlines which are dependent on their impedance values for 2x1 and 4x1 Antenna arrays using the formula:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}},$$

$$Where\ F = \frac{8.791X10^9}{f_r\sqrt{\varepsilon}} \tag{1}$$

The radius of the circular patch is found out to be 17mm. We have chosen the inter element spacing for the 2x1 and 4x1 Antenna arrays to be 62.5 mm. We also calculated the widths of each of these feedlines which are dependent on their impedance values for 2x1 and 4x1 Antenna arrays using the formula:

$$Z_c = \begin{cases} \frac{60}{\sqrt{\varepsilon_{reff}}} ln\left[\frac{8h}{w_0} + \frac{w_0}{4h}\right], & \frac{w_0}{h} \le 1 \\ \frac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\frac{w_0}{h} + 1.393 + 0.667 ln\left(\frac{w_0}{h} + 1.444\right)\right]}, & \frac{w_0}{h} > 1 \end{cases}$$

(2)

Width of 100ohm feedline is 0.7mm and the Width of 50ohm feedline is 3mm.

C. Feeding Techniques

a) *Microstrip Line Feed:* In this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch. The conducting strip is smaller in width as compared to the patch. This kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. An inset cut can be incorporated into the patch in order to obtain good impedance matching without the need for any additional matching element. This is achieved by properly controlling the inset position. Hence this is an easy feeding technique, since it provides ease of fabrication and simplicity in modelling as well as impedance matching. However as the thickness of the dielectric substrate increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. This type of feeding technique results in undesirable cross polarization effects.

b) *Coaxial Feed:* The Coaxial feed or probe feed is one of the most common techniques used for feeding microstrip patch antennas. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired position inside the patch in order to obtain impedance matching. This feed method is easy to fabricate and has low spurious radiation effects. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled into the substrate. Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. By using a thick dielectric substrate to improve the bandwidth, the microstrip line feed and the coaxial feed suffer from

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numerous disadvantages such as spurious feed radiation and matching problem. The non-contacting feed techniques which have been discussed below, solve these problems.

c) *Aperture Coupled Feed:* The radiating microstrip patch element is etched on the top of the antenna substrate, and the microstrip feed line is etched on the bottom of the feed substrate in order to obtain aperture coupling. The thickness and dielectric constants of these two substrates may thus be chosen independently to optimize the distinct electrical functions of radiation and circuitry. The coupling aperture is usually centred under the patch, leading to lower crosspolarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. Also the effect of spurious radiation is very less as compared to other feed techniques. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness.

d) *Proximity Coupled Feed:* This type of feed technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth, due to increase in the electrical thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers that need proper alignment. Also, there is an increase in the overall thickness of the antenna.

III. DESIGN AND ANALYSIS

A. Single Patch Antenna

100ohm lines are connected to the patches. The equivalent at the junctions of each pair is 50ohm.Coaxial feeding technique is considered. The patch radius is 17mm.

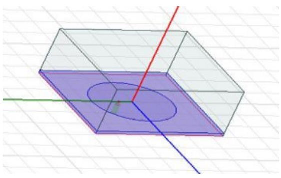

Fig 1. Single patch antenna

B. 1x2 Patch Antenna

100ohm lines are connected to the patches. The equivalent at the junctions of each pair is 50ohm.Edge feeding technique is considered.

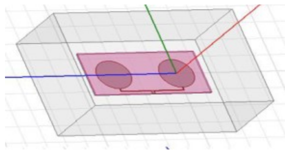

Fig 2. 1x2 patch antenna

C. 1x4 Patch Antenna

100ohm lines are connected to the patches. The equivalent at the junctions of each pair is 50ohm.A quarter wave transformers is used between a 50ohm equivalent point and 100ohm line to match the impedance between the two different impedances (50ohm and 100ohm)whose resultant impedance is calculated as 70.7ohm Finally two pairs of 100ohm lines from each side result in an equivalent of 50ohm where the edge feeding is considered.

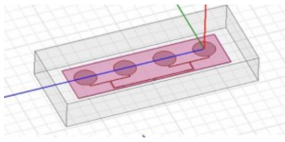

Fig 3. 1x4 patch antenna

D. 2x2 Patch Antenna

100ohm lines are connected to the patches. The equivalent at the junctions of each pair is 50ohm.A quarter wave transformers is used between a 50ohm equivalent point and 100ohm line to match the impedance between the two different impedances (50ohm and 100ohm)whose resultant impedance is calculated as 70.7ohm Finally two pairs of 100ohm lines from each side result in an equivalent of 50ohm where the coaxial feed is considered.

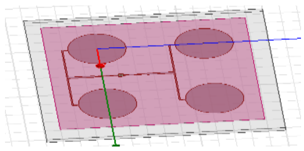

Fig 4. 2x2 patch antenna

E. 2x4 Patch Antenna

100ohm lines are connected to the patches. The equivalent at the junctions of each pair is 50ohm.A quarter wave transformers is used between a 50 equivalent point and 100ohm line to match the impedance between the two different impedances (50ohm and 100ohm) whose resultant impedance is calculated as 70.7ohm Finally two pairs of 100ohm lines from each side result in an equivalent of 50ohm where the coaxial feeding is considered.

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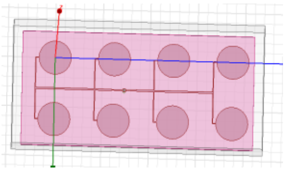

Fig 5. 2x4 patch antenna

F. Rectangular Patch

The dimension of the rectangular patch is 40mmX30mm. The dimension of the substrate and ground is 100mmX90mm. Co axial feeding is considered.

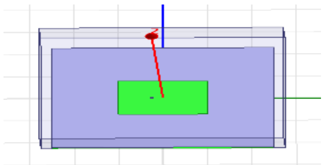

Fig 6. Rectangular patch

IV. 2.4GHz REAL TIME APPLICATIONS

Many cordless telephones and baby monitors in the United States and Canada use the 2.4 GHz frequency.

Bluetooth devices intended for use in short-range personal area networks operated from 2.4 to 2.4835 GHz. To reduce interference with other protocols that use the 2.45 GHz band, the Bluetooth protocol divides the band into 80 channels (numbered from 0 to 79, each 1 MHz wide) and changes channels up to 1600 times per second. Newer Bluetooth versions also feature Adaptive Frequency Hopping which attempts to detect existing signals in the ISM band, such as Wi-Fi channels, and avoid them by negotiating a channel map between the communicating Bluetooth devices.

Certain car manufacturers use the 2.4 GHz frequency for their car alarm internal movement sensors. These devices transmit on 2.45 GHz (between channels 8 and 9) at a strength of 500 mW. Because of channel overlap, this will cause problems for channels 6 and 11, which are commonly used default channels for Wi-Fi connections. Because the signal is transmitted as a continuous tone, it causes particular problems for Wi-Fi traffic.

The 2.4GHz is the frequency at which Wi-Fi standards 802.11b, 802.11g and 802.11n operate. In this project, circular patch antennas have been designed for this particular application

V. CONCLUSION

Microstrip patch antenna arrays of circular shaped radiating elements were successfully designed and implemented using FR4 Epoxy glass substrate. In this work edge feed technique used was used for simulation of 2x1 circular patch antenna array and 4x1 circular patch antenna arrays, whereas probe feed technique is used for single patch antenna, 2x2 and 2x4 circular patch antenna arrays. From proposed simulation design the maximum achieved gain was 8.56 dB for 2x4 array whereas 6.74 dB for 2x2 array and 8.21 dB for 1x4 array.

The disadvantage with the project implemented is, even though we get high values of gain with increasing size, the radiation efficiency decreases with increasing number of patches which is not desirable. To increase the radiation efficiency, we need to use materials of the patch and the substrate with better dielectric constants; doing so, may affect the values of some other parameters. Also, as number of patches increases, return loss tends to 0 and VSWR increases. Hence, the best suitable materials should be chosen to match the applications needs.

VI. SCOPE FOR FUTURE WORK

There is a lot of scope for upcoming work in the present study. It is envisioned in the future that a precise patch antenna will be designed for a precise frequency of practical applications like cellular phone antennas having centre frequency of 3GHz and to optimize full bandwidth. Future plan is also there for a systematic design and development of microstrip antenna with optimized values for practical, real time applications.

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