Analytical Review on Different Gain Improvement Techniques in Microstrip Patch Antenna

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Abstract— This paper presents the different techniques of gain improvement in Microstrip Patch Antennas (MPAs). MPAs are characterized by their parameters. The different parameters required are radiation pattern, Voltage Standing Wave Ratio, Reflection Coefficients etc. Among all the parameters Gain and Bandwidth plays an important role in the efficiency of MSAs. In this work comprehensive analytic review is done on improving the gain of an antenna.

Index Terms—. Microstrip Patch Antenna, Gain, Bandwidth etc

1 INTRODUCTION

Recent development in the field of wireless communication systems to realize high speed data transfer between PCs, laptops, cell phones etc, lead to antenna with improved gain and bandwidth. WLAN and Wi-MAX evolved as two commercial communication standards to provide high speed connectivity. The microstrip antenna is the backbone for these applications[1,2] .One of the major need for modern communication devices is the operation on the wider band so that the antenna can support high speed operations , multimedia communication and many other broad band services[3]. Microstrip antenna full fills most of the wireless requirements. Microstrip patch antenna offer a specific solution to compact and low-cost design of many wireless application system such as ATM Wireless Access(AWA) and millimetre – wave automobile sensor .For easy integration with RF front-end, patch antennas , on a substrate with high dielectric constant (Si, GaAs, etc) are preferred. From this it results in very narrow bandwidth and decrease in radiation efficiency and gain.

The Microstrip Patch Antenna is widely used because of its low profile .The antenna has attracted more attention owing to their advantages such as simple structure, high data rate, easy integration with monolithic microwave integrated circuit (MMIC)and fabrication [4].These are light weight ,small in size ,simple to manufacture, cost effective, reliable and have a varied range of configuration. Due to these advantages of antenna there are wide range of applications in space technology, aircraft, missiles, mobile communications, GPS system and broadcasting. However, the electrical performance of basic microstrip antenna and array has some serious drawbacks i.e. very narrow bandwidth high feed network losses, poor cross polarization, lower power handling capacity and low gain if the gain is less There are various methods in this paper to improve bandwidth and gain such as using various impedance matching, feeding techniques, utilization of thick substrate with low dielectric constant, etching slot in the radiating patch.

Over the years, several substitutes have been made to overcome the gain limitation, usually at the expense of decreasing the impedance bandwidth. Electromagnetic band gap [EBG] or photonic band gap [PBG] surfaces are two of the most popular alternatives because of their ability to suppress the propagation of electromagnetic waves in a frequency band [5].The suppression of electromagnetic waves leads to a significant enhancement of the maximum gain when a microstrip patch antenna is placed above one of these surfaces [6,7].

In now a days there are various implantable antenna used in medical applications have been reported [8-10] .These antennas have been studied with the great interest as communication tools to transfer data to external receivers recording the status of patient .The antennas are embedded under the human skin to improve the condition of patients suffering from diseases such as diabetes cardiac arrhythmia and retinitis pimentos', blood pressure, temperature etc. In most cases, the antenna should have a high gain to guarantee communication between human body and external devices but the body absorbs microwaves and hence significantly reduce the gain. Antenna gain enhancement methods for free space applications have been included using metametrials at millimetre [11] waves or using a square aperture superstrate [12].The performance of an implanted antenna was enhanced by up to 10db using a parasitic monopole and a matching printed grid surface placed on the skin of the patient .This is a simple way to improve the antenna gain using a parasitic ring and glass hemispherical lens placed on the skin [13].

2 Development History of Microstrip Patch Antenna.

The microstrip antenna concept dates back about 26 year to work in the U.S.A. by Deschamps and in France by Gutton and Baissinot. Shortly thereafter, Lewin investigated radiation from strip line discontinuities.[4] Some more studies were undertaken in the late 1960 by Kaloi, who studied basic rectangle and square configuration .However , other than the original Des champs report , work was not reported in the literature until the early 1970's, when a conducting strip radiator separated from a ground plane by a dielectric substrate was introduced by Byron. This half wavelength wide and several wavelength long strip was fed by coaxial connection at periodic intervals with both radiating edges, and also was used as an array for project camel. Shortly thereafter, a microstrip element was invented by Munson on the basis of rectangular and circular microstrip patches. These patches were published by Howell. Weinschel developed several microstrip geometries for use with other shapes such as cylinder.

3 Antenna Geometry And Design

A low profile antenna is design as it use from 400 MHZ to 38GHz practically, and it can be expected that the technology will soon extend to 60 GHZ and beyond which is very easy to design and is cost effective. In designing of antenna the propagation constant for a wave in the microstrip substrate must be properly known in order to predict the various parameters such as resonant frequency , resonant resistance etc. Antenna designers have found that the most sensitive parameter in microstrip antenna performance estimation is dielectric constant of a substrate material, and the manufacturers tolerance on εr is sometimes inadequate. The dielectric substrate material used in microstrip antenna are broadly classified in to relative dielectric constant range of 1 to 2(low dielectric constant), 2to4 (medium dielectric constant), and 4 to 10(high dielectric constant). Usually a low dielectric constant material with low loss tangent such as air, foam etc is cost effective .The thick and low dielectric constant substrate material are required to enhance the bandwidth of the antenna. The substrate material is covered with required conducting material of antenna pattern which is backed by conducting ground plane

3.1 Antenna Feeding To Improve the Gain

In microstrip patch antenna there are generally two common type of feeding methods i.e. microstrip line feed and coaxial probe feed method .Since there are many other new feeding techniques have been developed to increase the gain ,bandwidth, VSWR, return loss and many other parameters . The other new feeding techniques are coaxial feed technique, proximity coupled microstrip feed, aperture feed microstrip and coplanar waveguide feed. Aperture –Coupled feeding is the best feeding to increase the gain. To increase the gain the coupling is supplied by adding another slot in the ground plane as shown in fig1. The coupling is controlled by varying the distance between the slots [14].

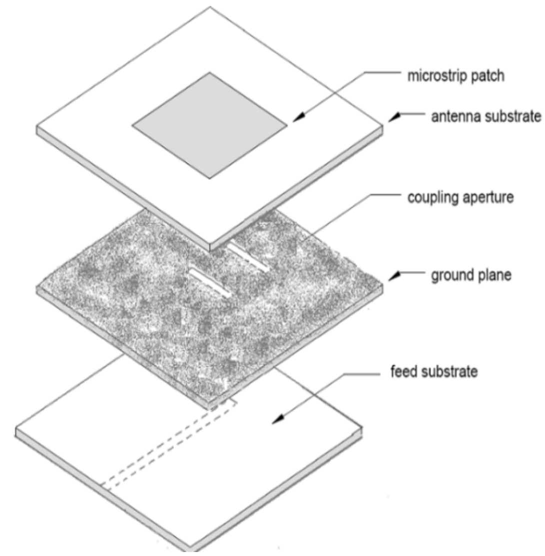


Fig1-Aperture Couplng Antenna

4. Antenna Gain Enhancement Techniques

One of the usually used methods to enhance the gain of microstrip patch antenna is by using the concept of gap coupled parasitic elements .In most of the reported gap coupled parasitic patch antenna ,either probe feed or corporate feed is employed to excite the patch. Many researchers have reported electromagnetically feed gap coupled patch antennas for wireless applications. A capacitive coupled micro strip patch antenna for single band operation is reported where the radiating patch is feed only on one side of the micro strip line [14]. Antenna having a pair of square radiating patches coupled in close proximity to a microstrip line with a coupling arrow shaped slot on the other side of the antenna is shown. [15]. another method was presented for gain enhance in [16] where a high gain slot antenna with parasitic patches and windowed metallic superstrate is used. In this case, compete size of the antenna is large, which is undesired in several other applications. In most common form of microstrip patch antennas metal patch is on the top of the grounded dielectric substrate and when antenna is energized it radiates EM waves in every directions and the EM waves that goes into the substrate that is known as surface waves and loss due to these surface wave is known as surface wave losses , this is main loss related with microstrip patch antennas that reduce the gain of microstrip patch antennas .Other losses such as conductor on dielectric losses can be reduced using good quality conducting material and substrate .Many other methods are introduce to overcome the surface wave losses such as EBG and PBG[17]-[19] structures that allow the emission and propagation of EM waves in a certain frequency band. The other methods of gain enhancement in microstrip patch antennas are array of antennas [20] and by using superstrates [21] ,hybrid substrates [22], surface mounted horn [23]etc. But main problem associated with these methods is complexity of construction surface waves, travel in the substrate and don't contribute to the main radiation .Over the years, many alternatives have been proposed to overcome the gain limitation, usually at the expense of decreasing the impedance bandwidth. Electromagnetic band gap or Photonic band gap surfaces are most popular options to enhance the gain.

4.1 Surface Wave

Surface waves are excited on microstrip patch antenna whenever the substrate ϵ_r>1.Due to surface wave coupling between various element of an array take place. The characters tics of the surface wave are shown in the fig 1 .Surface waves are entered into the substrate at the elevation angle $\boldsymbol{\theta}$ lying between $\frac{\pi}{2}$ and $\sin^{-1} 1/\sqrt{\epsilon}$.These waves incident on the ground plane at this angle as shown, get reflected and then meet the dielectric air interference, which also reflect them. Following this zigzag path, they finally reach the boundaries of the microstrip antenna, but these waves are reflected and detracted by the edges and produce end fire radiation. While reaching the boundary, if there is any other antenna, the surface waves can be coupled to it. Couplings also reduce it from the point of excitation

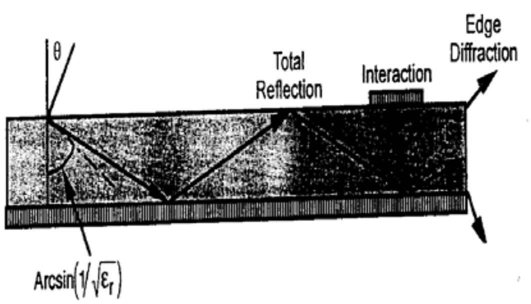


Fig2- Surface Wave propagation in the substrate of a patch antenna leading to coupling between different circuit or antenna element and diffraction at the edge

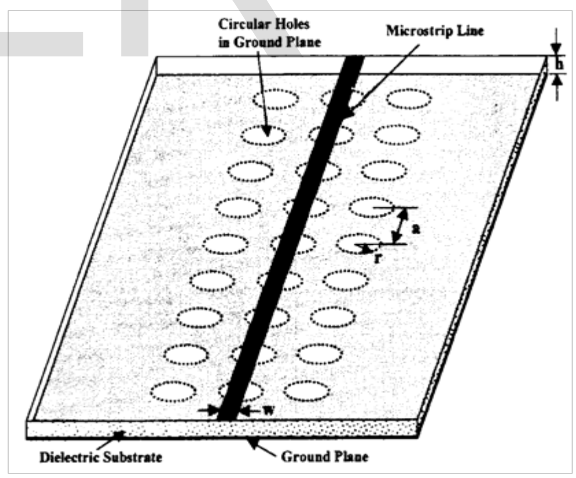
Surface wave propagation is the main problem in micro strip antenna .Surface wave decrease the efficiency and gain limit, bandwidth, but increase end fire radiation , cross polarization levels and limits the applicable frequency range of micro strip antenna [24].

Solution to Surface Wave Problem

Two solutions to surface wave problems are available now. One approach is based on the micro matching technology in which the part of the substrate under the radiating element is removed to realize low effective dielectric constant for the antenna. In this case the power loss through surface wave excitation is decreased and coupling of power is increase .The second technique is based on Photonic band gap PBG engineering [25]-26] in this case the substrate is periodically loaded so that the surface wave dispersion diagram present the forbidden frequency range about the antenna operating frequency [27] because these waves cant propagate along the substrate and increased amount of radiated power couples to the waves space.

4.2 Photonic band gap structures

Photonic band gap material are new class of periodic dielectrics, which are the photonic parallel of semiconductors .Electromagnetic waves behave in photonic substrate as electron behave in semiconductor. Various other types of periodic loading have been studied to realize the PBG nature of the substrate [25-28]. Early attempts involved drilling a periodic pattern of holes in the substrate [29] or etching a periodic pattern of circles in on the ground plane as shown in fig 2(a).Next a periodic pattern of metallic pads was shorted to ground planes shown in fig 2 (b). New loading pattern has been studied as sown in fig 3 (c).



(a)

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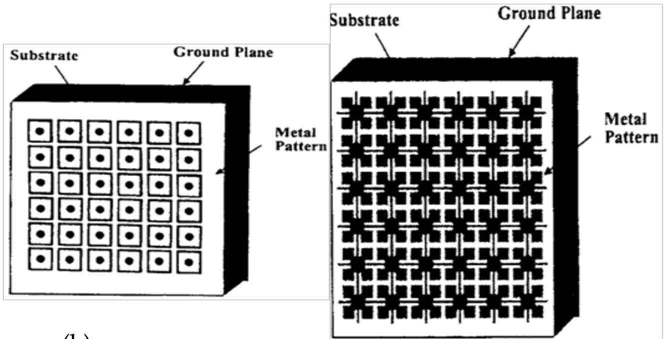

(b) (c)

Fig3-: Three types of perodic loading of ground substrate to obtain photonic bandgap characterstic (a) square lattice of etched circle (b) square lattice of small metal pad with gronding vias (c) uniplanar conpact PBG substrate

The other gain enhancement techniques are explained by Anil Kumar and Suryakanth [30].

A. Gain enhancement of a Microstrip patch antenna using partial substrate in multilayer dielectric substrate.

The gain enhancement using partial substrate removal in a multilayer dielectric by suppression of surface wave by taking low dielectric (air) voids. In this way improvement in gain is achieved by fractional removal of substrate.

B. Gain Enhancement of a Microstrip Patch Antenna Using a Reflecting Layer

A low profile, unidirectional, dual layer, and narrow bandwidth are some characteristic of microstrip patch antenna. This type of antenna is suitable for specific applications , such as security and military system ,which require narrow bandwidth and small antenna size .This work is mainly focused on maximizing the gain as well as reducing the size of unidirectional antenna has a higher gain and higher front to back ratio (F/B) than the bidirectional one. This is achieved by using a second retardant layer (FR-4), coated with copper of 0.035 mm at both sides, with an air gap 0.040 as a reflector. Using this layer substrate which is coated with copper, reduce (f/b) ratio and enhance gain as well as maximize he directivity. Moreover this type of antenna shows flexibility during optimization techniques. [31]

C. Gain Enhancement of Proximity Coupled Microstrip Antenna Using Parasitic Patch

One of the most used methods to enhance gain of microstrip patch antenna is by using the concept of coupled parasitic elements [3]. The microstrip patch antenna should have two-layer substrate. The radiating microstrip patch element is etched on top of the first layer substrate, while on the second layer substrate microstrip feed line is etched. The thickness and dielectric constant of these two substrates may thus be chosen independently to optimize the distinct electrical function of radiation and circuitry.

Thus proximity coupled microstrip antenna is influenced by many parameters such as microstrip feed line, patch length etc.. In most of the gap coupled parasitic patch antenna , either probe feed or corporate feed is employed to excite the patch [32-35].The other method were introduced in [36] where a high gain slot antenna with parasitic patches and windowed metallic superstrates is used. In this case the overall size of the antenna is large, which is undesired in several compact applications. The parasitic patch is used for gain enhancement along with dual band operation.

D. Enhance Gain of Patch Antenna Using EBG

In paper [37] , author proposed a rectangular microstrip patch antenna with substrates and compare the performance of the proposed antenna with a conventional patch antenna with the same physical dimension. Due to the presence of the EBG structure in the dielectric substrate , the electromagnetic band gap is created that reduces the surface waves. As a result, the performance of the new antenna is improved comparing the conventional existing microstrip patch antenna. When the surface wave is reduce the gain enhancement in the antenna

E. Gain Enhancement in Compact Microstrip Patch Antenna

In paper [38], a new compact of microstrip patch antenna has been proposed in stacked configuration. The features of the antenna are obtained in term of return loss, gain, and bandwidth and are compared with conventional microstrip patch antenna. It is observed that the new proposed configuration reduces the patch area by 66.34% and also enhance the gain with superstrate loading.

F. Gain Enhancement by Replacing Conventional (FR4 and Rogger) Substrate with Air Substrate

Microstrip patch Antenna designed with IE3D/HFSS simulation software .In paper [39] simply modified the shape of the patch , such as circular, rectangular ,triangular patches, along with each patches they have used different substrates material and observed the gain and then compare with each other as shown in the Table 1. All these patches geometries were investigated theoretically and reasonable values of resonant frequent return loss and gain were compared. Numerical calculation to predict the circular and triangular geometry and the resultant increase in gain from this geometry when the conventional substrate is replaced with the air substrate was analysed theoretically.

Table 1 Gain result for different patches

Patch -Design	Substrate ad Gain(db)			
	FR4	Air	Roger	Air
Rectangular	5.62	9.5	6.07	9.60
Triangular	5.5	9.0	5.84	8.89
Circular	5.59	9.18	5.97	9.73

The further more gain enhancement method using parasitic ring and glass hemispherical lens placed on the skin is explained by Almari & Alamoudi [40]

G. Gain Enhancement Using Lens.

To improve the implanted antenna functioning, an external hemispherical glass lens was designed and investigated using CST software, which is to be placed on the skin over the antennas. The hemispherical lens material was used Pyrex glass of permittivity 4.82. The simulation results showed that there was a significant gain enhancement when the hemispherical lens.

H. Gain Enhancement Using Parasitic Ring

To improve the implanted antenna gain and efficiency by coupling the existing EM wave to an external parasitic ring .It was found that by placing the parasitic ring over the skin increased the gain compared the antenna without parasitic ring.

I. Gain Enhancement Using Ring & Lens

The lens and parasitic ring were combined together .The simulation indicated that there should be a significant gain enhancement compared with implanted antenna.

5. Conclusion

Microstrip patch antenna is widely used because of its many useful advantages but at the same time it is having many other drawbacks such as lower gain .In this paper we have studied the various gain enhancement techniques and we have explain the way to decrease the various parameters to increase the gain. .Proximity coupled Microstrip Antenna is the best way to increase the gain.

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