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A Survey and Review on Gain Enhancement Methods of Microstrip Patch Antenna

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ABSTRACT: Microstrip Patch antenna (MPA) is widely used in a number of antenna systems because of their low profile, light weight, low cost, compactness etc. Patch antenna is also used with Microwave IC's and Monolithic Microwave IC's because of its compatibility. But one of the major drawbacks of MPA is its lower gain and Bandwidth. Various methods were used by the researchers for the purpose of gain enrichment such as in microstrip antenna array, superstrate structure, change of dielectric material and partial removal of substrate. All these mechanisms individually increases the gain of MSA are being proved by researches. But however there is scope for improving gain of the antenna by hybridization techniques. In this paper we have made a survey and review on some of the different Gain and bandwidth enhancing techniques.

Index terms: MPA (Micro strip Patch Antenna), Gain, Bandwidth.

I. INTRODUCTION

Microstrip antenna technology has been now recognized as emerging trend in the antenna field in the last fifteen years. Throughout this period there have been over 1500 published journal objects, many books and countless symposia sessions and short courses devoted to the subject of microstrip antenna and arrays.

As we know that the Microstrip Patch Antenna is widely used because of its low profile but simultaneously it is having some disadvantages such as Lower Bandwidth and Lower Gain. We presented here a survey of various methods used in increasing the bandwidth (BW) and Gain.

II DIFFERENT GAIN ENHANCING TECHNIQUES

A. Gain and Bandwidth Enhancement of a Microstrip Antenna Using Partial Substrate Removal in Multiple-layer Dielectric Substrate.

In this paper [1], authors presented a novel antenna design for simultaneous improvement of patch antenna gain and bandwidth using partial substrate removal in a multiple-layer dielectric by suppression of surface wave losses beneath the substrate surface by embedding a low-dielectric (air) void. In this way, improvement in gain is achieved by fractional removal of substrate. Bandwidth of the patch antenna is increased by using multiple layer dielectric substrates.

It is known that bandwidth of microstrip antenna is small and varies directly with the size of the patch. Increasing size of patch to improve bandwidth makes it large and bulky.Thus to overcome the bandwidth limitation without increasing size unacceptably, a patch on multiple-layer scheme has been designed to reduce the effective dielectric constant. This ensures that bandwidth increases greatly while size is nearly unaffected. Performance parameters like bandwidth and reflection loss have been evaluated and compared with that obtained from single layer dielectric substrates.

Results suggest considerable improvement in bandwidth using the proposed patch antenna design on multi-layered dielectric substrate. The designed patch has a size of 12× 8 mm^2 and gives a bandwidth and gain of 314MHz and gain 4.035 dB at 6.479 GHz.

Table 1 shows the dimensions and the simulation results of the tested microstrip antenna designs.The parametric description of the multiple-layer substrate is as follows: Glass substrate (ε_r= 4.6) of 1mm is sandwiched between two silicon layers (ε_r=11.9) of thickness 0.5mm each.

Table 1: Comparison of Simulation Results on Rectangular Patch Antenna Using Different Types of Substrates.

Dielectric	Dielectric constant	Thickness (mm)	BW (MHz)	Size Patch	G	D
Silicon Layer (Single layer)	11.9	2	72.7	8x6	2.490	4.728
Glass(Single Layer)	4.6	2	86.4	12x13	2.326	4.528
Silicon/Glass/Silicon(Multiple Layer)	11.9/4.6/11.9	0.5/1/0.5	314	8x12	4.035	6.646

The rectangular patch has size 12×8mm^2 and has been fed using microstrip feed. All of the designed microstrip antenna have 15×15mm^2 ground plane. Best bandwidth-size trade-off was observed using the proposed multiple-layer dielectric substrate (Si/Glass/Si) giving a bandwidth of 314MHz (reflection loss: -9.5014 dB) at patch size8X12mm^2 [1]. The proposed antenna design using multiple layer dielectrics with partial substrate removal hasbeen found to give a bandwidth of 314MHz with a gain of 4.035 dB at an operating frequency of 6.646 GHz. This is a note worthy improvement in bandwidth over that obtained using microstrip antenna over single-layer silicon or single-layer glass substrate [1].

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

A low profile, unidirectional, dual layer, and narrow bandwidth microstrip patch antenna is designed to resonate at 2.45GHz.The proposed antenna is suitable for specific applications, such as security and military systems, which require a narrow bandwidth and a small antenna size.This work is mainly focused on increasing the gain as well as reducing the size of the unidirectional patchantenna.

The proposed antenna is simulated and measured. According to the simulated and measured results, it is shown that theunidirectional antenna has a higher gain and a higher front to back ratio (F/B) than the bidirectional one. This is achieved by usinga second flame retardant layer (FR-4), coated with an annealed copper of 0.035mm at both sides, with an air gap of $0.04\lambda_0$ as areflector.

A gain of 5.2 dB with directivity of 7.6 dBi, F/B of 9.5 dB, and −18 dB return losses (S_{11}) are achieved through the use of adual substrate layer of FR-4 with a relative permittivity of 4.3 and a thickness of 1.6 mm. The proposed dual layer microstrip patchantenna has an impedance bandwidth of 2% and the designed antenna shows very low complexity during fabrication. A unidirectional and low profile microstrip patch antenna of $0.069\lambda_0$ has been introduced. Using a second layer of FR-4, which is coated with copper, reduced the back lobe and enhanced the gain up to 5.4 dB as well as increased the directivity up to 7.74 dBi with F/B ratio of 9.5 dB. Moreover, the proposed antenna shows flexibility during the optimization technique and the simulation results are evaluated by measurements [2].

Table 2: Comparison of the Antennas' Parameters.

Design	f_r (GHz)	S11 (dB)	G (dB)	D (dBi)	Size (L×W×H)
First Stage	2.423	-7.85	2.22	6.340	55×60×1.6
Second Stage	2.411	-25.028	3.30	5.938	55×60×1.6
Proposed design	2.45	-28.028	5.4	7.747	55×60×8.37
Conventional	2.344	-12.617	3.11	5.02	40×40×1.6

The proposed antenna is compatible for specific applications, such as security and military systems, due to considerable gain, small size, low profile, and unidirectional propagation. Furthermore, it is easily fabricated at low cost and low complexity. The proposed antenna outperforms both the conventional one in terms of the matching impedance and gain and the DB-CPWFA in terms of matching impedance and a significant size reduction of 67.4% with a comparable gain [2].

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

In this paper [11], a single element proximity coupledrectangular patch antenna is designed for future radarapplication, where high gain and wide bandwidth is required. A proximity coupled fed antenna is used to enhance the antenna's gain and bandwidth. The gain of the single patch antenna is 4.22dBi. By adding side parasitic patch, the bandwidth of the antennacan be improved up to 375%. The antenna works from 2.8 to 3.1GHz this band is used for air surveillance radar. Moreover thegain of the side parasitic patch antenna is 5.57 dBi. A single element proximity coupled rectangular patchantenna has been designed for future air surveillance radarapplication in Indonesia.

A proximity coupled feed with additional side parasitic patch is used to enhance theantenna's gain and bandwidth. The simulated S-parameter hasa fractional bandwidth of 10%. As for the absolute gain, it is5.57 dBi with only a single element. This preliminaryresearch satisfies the required bandwidth of air surveillanceradar, however to achieve the complex specificationrequirement for the antenna radar, more research has to beconducted.

Table 3: Performance Comparison of Several Feeding Techniques.

Performance	Feeding Techniques			
	Probe feed	Line feed	Aperture coupled	Proximity coupled
Frequency(GHz)	2.971-3.045	2.962-3.011	2.973-3.036	2.973-3.038
BW(MHz)	74	49	63	101
Directivity(dBi)	-	6.274	6.339	6.378
Gain(dB)	-	2.884	3.53	3.921

D. High Gain of C Shape Slotted Microstrip Patch Antenna for Wireless System

In this paper [3], a novel C-shape slotted microstrip patch antennawith enhanced gain is presented and discussed. The proposed design offers low profile, high gain and compact antenna element. The maximum gain is 7.31541 dBi at 2.31610 GHz, antenna and radiation efficiency are more than 95.5319% andbandwidth is 50% from 1GHz to 3GHz.

The proposed design is suitable particularly for wireless communication applicationsuch as Wi-Fi and WiMaxbeen proposed in this paper the return loss is -17.2610 can beachieved by using C shape slot on the patch the bandwidth ofthe antenna is 50% from 1GHz to 3GHz and gain is7.31541dBi.In comparison to simple microstriprectangular patch antenna the proposed antenna is betterbecause it gives maximum dual band return loss and very highgain at very low frequency. The new designed antenna is betterthan the simple microstrip rectangular patch antenna [3].

E. Enhanced Gain and Bandwidth of Patch Antenna Using EBG Substrates

In this paper [4], authors proposed a rectangular microstrip patch antenna with EBG substrates and compare the performance of the proposed antenna with a conventional patch antenna in the same physical dimension. Due to the presence of the EBG structure in the dielectric substrates, the electromagnetic band gap is created that reduces the surface waves considerably. As a result, the performance of the proposed antenna is better comparing the conventional existing microstrip patch antenna.

Table 4: Simulation Results.

S.No	Frequency	Return loss,S11	Directivity	Gain
1	1.28626	-7.58525	5.0607	4.23007
2	2.31610	-15.4347	7.51393	7.31541

The patch antenna mostly used in modern mobile communication. The goals of this paper are to design conventional patch antenna and the patch antenna on EBG substrates with same physical dimensions that can operate at 10GHz and study the performance of Microstrip antenna when EBG structure added on it. From the simulated results, it is seen that the performance is better of a patch antenna that is designed on EBG substrates than the conventional patch antenna.

Table 5: Geometrical Configuration of the Patch Antenna.

Antenna Part	Parameter	Value
Patch	Length	8.8mm
	width	11.4mm
Patch substrate (NelteeNx9245)(IM)(tm)	Dielectric constant	2.45
	Height	0.787mm
	Dielectric loss Tangent	0.01
EBG Substrate	Rectangle Width	$0.10\lambda_{12}$GHz
	Gap Width	$0.02\lambda_{12}$GHz
	Substrate thickness	$0.04\lambda_{12}$GHz
Operating frequency		10GHz

F. Gain and Bandwidth Enhancement in Compact Microstrip Antenna

In this paper [5], a new compact microstrip patch antenna has been proposed in stacked configuration. The characteristics of the antenna are obtained in terms of return loss, gain and bandwidth and are compared with theconventional microstrip patch. It is observed that the new proposed configuration reduces the patch area by 66.34% andat the same time enhances the gain and bandwidth significantly with superstrate loading. The Genetic Algorithm optimizer built in with IE3D Commercial simulator is used to obtain the optimized performance of the proposed antenna. A size reduction of 53% is obtained in the proposed configuration along with 4dBi gain and 91 MHz band width [5].

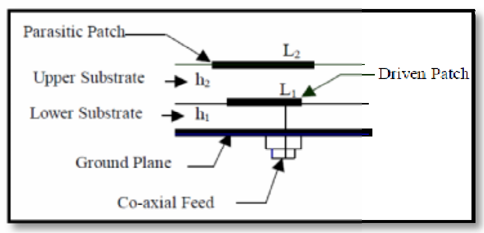

Fig. 1. Cross-sectional view of probe-fed stacked-patch geometry.

Table 6: Characteristics of Grooved Patch LP Patch Antenna In Stacked Configuration.

Fr (GHz)	Antenna type	Feed position f_p (mm)	VSWR BW(MHz)	Gain(dBi)
2.46	Conventional LP Square patch	6.65	85.33	3.46
2.46	Grooved patch antenna (LP)	2.6	50.14	0.497
2.44	Grooved patch antenna(LP) in stacked configuration	3.2	91.5	4.01

G. Design and Development of Dual E-Shaped Microstrip Patch Antenna for Bandwidth and Gain Enhancement

In this paper a dual E-shaped antenna is designed by cutting four notches in the rectangularshaped microstrip antenna. The designed antenna structure is further simulated using IE3D simulation software. The simulation result shows good enhancement in bandwidth and gainwhich also shows that the designed antenna structure can work in four different frequency bands.

The simulated result is further compared to the measured result of the antenna. The comparison shows that the result of the designed hardware of the antenna is in good agreement with the simulated result.

A dual E shaped antenna is designed and simulated over IE3D simulation software. The simulated result shows that the designed antenna structure is suitable to operate in threefrequency bands with bandwidth of 6.85%, 6.98% and 38.94%. The antenna structure alsoprovides a gain of 5.82dBi and the antenna efficiency of 85%. Further hardware of the antenna isimplemented and tested using network analyzer. The comparison of the tested and simulatedresult shows the result of the hardware implementation is comparable to that of the simulatedone [6].

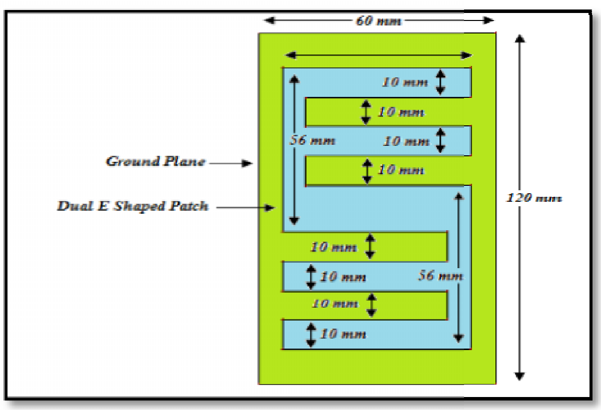

Fig. 2. Design of Dual E shaped Microstrip Patch Antenna.

H.Gain Enhancement in Microstrip Patch Antennas by Replacing Conventional (FR-4 and Rogers) Substrate with Air Substrate

In this paper [7], authors have designed Antenna using IE3D/HFSS simulation software. Here they have simply modified the shape of the patch, such as Rectangular, Circular and Triangular Patches. With respect to each patch they are used different substrate materials and observed Gain values and compared with each other as tabulated in Table 7.

The three patch geometries were investigated theoretically and reasonable values of resonant frequency, return loss and gain are examined and compared. Numerical computation to predict the equivalent circular and triangular patch geometry from a reference rectangular patch geometry and the resultant increase in gain from this geometry when the conventional substrate is replaced with air substrate was theoretical analyzed [7].

Table 7: Gain Results for Different Patches.

Patch Design	Substrate and Gain (dB)			
	FR-4	AIR	ROGERS	AIR
Rectangular Patch	5.62	9.5	6.07	9.60
Triangular Patch	5.5	9.0	5.89	8.89
Circular Patch	5.59	9.18	5.97	9.73

I. Gain Enhancement of V-Slotted Triangular Shape Microstrip Patch Antenna for WiMax Applications

A V-slotted triangular shape microstrip patch antenna is presented in this paper with enhanced gain for Wi-max applications. The microstrip patch antenna becomes very popular day by day because of its ease of analysis low cost, light weight, easy to feed and their attractive characteristics. The return loss is below −10dB from 3.54 GHz to 3.75 GHz with impedance bandwidth 210MHz.The antenna is thin and compact which makes it easily portable.

A maximum gain of 7.29dB achieved at 3.66GHz frequency. The VSWR parameter was found to be less than 2 within the operating frequency range. The antenna parameters of with v-slot and without v-slot of triangular shape patch are compared. The substrate material of RT-duriod-5880 with relative permittivity 2.2 and loss tangent of 0.009 is used in the proposed antenna. The total simulation has been done on Ansoft HFSS software [8].

J. Design and Enhancement of Gain & Bandwidth of Rectangular Patch Antenna Using Shifted Semi-Circular Slot Technique

Microstrip Antennas are strongly used in wireless communication applications. This paper proposed a rectangular patch antenna loaded with a semi-circular slot to operate at 5.25 GHz with moderate gain (about 8.53dBi),bandwidth (96.7 MHz) and a good matching (S11=24.13dB). This paper also describes the increment in Bandwidth andGain of Rectangular Microstrip Patch antenna with the Slot. Microstrip patch antenna is designed on a Duroid 5880 substrate with a dielectric constant of 2.2.

The results of both the designs with and without slots are compared and itwas found that an increase in the bandwidth by33.82% and gain by 28.25% are being achieved. The antenna isdesigned based on extensive HFSS simulation studies. In this paper we can enhance the gain value by changing the feed point position by using some mathematical analysis.

Table 8: Microstrip Patch Antenna Parameters.

Parameter	Dimension
Operating frequency	5 GHz
ε_r	2.2
Height of Sub(h)	0.787mm
Length(L)	19.84mm
Width(W)	23.71mm

The proposed antenna design operates at the frequency of 5.25GHz and has the bandwidth of 96.7MHz (5.2011GHz -5.2971GHz). It can be used in WLAN applications (IEEE 802.11ac standard).The IEEE 802.11ac is a standard under development which will provide high throughput in the 5 GHz band. The rectangular patch antenna with and without a shifted semi-circular slot are analyzed.

Both the feed probepositions and the slot positions are varied to achieve anoptimum bandwidth and gain. The Shifted slot increasedthe bandwidth by33.82% and more gain is obtained i.e.8.53dBi.The antenna model also provides good matchingwith return loss (S11= -24.13dB) [9].

K. Bandwidth and Gain Enhancement of Multiband Fractal Antenna Based on the Sierpinski Carpet Geometry

In this paper, authors have achieved a compact multiband fractal antenna based on Sierpinski carpet geometry. The simulation of the proposed antenna was done by CST Microwave Studio EM simulation software. The Sierpinski carpet fractal antenna proves that it is capable to create multiband frequencies. There are four resonant frequencies appeared at 0.85 GHz, 1.83 GHz, 2.13 GHz and 2.68 GHz. Simulated results indicates that the return loss is better than 15 dB, the VSWR is less than 1.3,the directivity is greater than 6dBi & the gain is more than 6dB in each band.

The simulated results show that return loss is more than -15 dB, VSWR is less than 1.3, directivity is more than 6 dBi, and gain is more than 6 dB. Multiband property is achieved with multiple iterations. Gain is enhanced with multiple iterations. Bandwidth enhancements for multiple iterations are compared. Antenna size is reduced by using fractal shapes with multiple iterations. So the designed antenna can be proposed for the fixed microwave & aviation applications [10].

Table 9: Comparison of Different Major Parameters for Multiple Iterations.

Parameters	0^{th} Iteration	1^{st} Iteration	2^{nd} Iteration	3^{rd} iteration
RL, S_{11}	-16.19	-15.5 -17.12 -13.14	-19.43 -11.6	-38.53 -17.47
VSWR	1.356	1.336 1.3 1.4	1.22 1.72	1.036 1.21
Directivity	6.043	9.602 5.956 9.440	9.262 3.961	9.359 4.491
Gain	1.550	9.393 5.629 9.019	7.524 0.570	7.417 1.252
Bandwidth	Nil	Yes(3)	Yes(2)	Yes(2)
Presence of multiband	0.1%	3.46% 1.69% 1.44%	1.96% 1.48%	2.09% 2.54%
Size reduction	-	33.3%	44.4%	52.1%

III. CONCLUSION

As we know that the Microstrip Patch Antenna is widely used because of its low profile and more advantages but simultaneously it is having some disadvantages also such as Lower Bandwidth and Lower Gain. In this paper, we have briefly discussed about design and comparative analysis of different techniques used for enhancing the Bandwidth and Gain of Microstrip Patch Antennas.

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