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Multilayer Slit Loaded Gap coupled Orthogonal Shorting Post Microstrip Antenna for L- Band Pervasive Wireless Communication

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ABSTRACT

In this paper, a three layer Small single feed multiband microstrip antenna loaded with slit and two perpendicular shorting posts, is presented. Wide band frequency of operation demonstrated by single geometry, for broadening the bandwidth gap-coupled multi-resonator loaded on the patch, the simulation of proposed design antenna has done by MOM IE3D^{TM} Simulator. The geometry of a single probe fed rectangular microstrip antenna has textured by slit loading and two orthogonal shorting pin on the top layer patch. We have also textured the size of the antenna. This proposed antenna is used for GSM, satellite and wireless communication in, L Band. Achieved 63% reduction of geometrical area of the antenna for L –Band, achieved 57% -10dB impedance bandwidth of L Band.

I. Introduction

An explosive growth of the wireless radio communication systems is currently observed in the microwave band. In the short range communications or contactless identification systems, antennas are key components, which must be small, low profile, and with minimal processing costs [1-4]. The main limitations of the microstrip antennas are low efficiency and narrow impedance bandwidth. The bandwidth of the microstrip antenna can be increased using various techniques such as by loading a patch, by using a thicker substrate, by reducing the dielectric constant, by using a gap-coupled multi-resonator etc. [3-5]. However, using a thicker substrate causes generation of spurious radiation and there are some practical problems in decreasing the dielectric constant. The spurious radiation degrades the antenna parameters. Among various antenna bandwidth enhancement configurations, the two gaps-coupled Circular microstrip patch antenna is the most elegant one. So, gap-coupling is the suitable method for enhancing the impedance bandwidth of the antennas [6, 7]. In the con-figuration of gap-coupled microstrip antennas method, two patches are placed close to each other. The gap-coupled microstrip antennas generate two resonant frequencies and the bandwidth of the microstrip antennas can be increased [6]. There exists a wide range of basic microstrip antenna shapes such as rectangular, circular and triangular patch shapes which are commonly used patches. For these patches, operating at their Fundamental mode resonant frequency, are of the dimension of the patch is about a half wavelength in dielectric. At lower frequencies the size of the microstrip antennas becomes large. In modern communication systems the compact microstrip patch antennas are desirable. There are various techniques to reduce the size of the microstrip antennas. A common technique to reduce the overall size of a micro-strip patch antenna is to terminate one of the radiating edges with a short circuit. The short circuit can be in the form of a metal clamp or a series of shorting posts [1]. It was shown that by changing the number of shorting posts and the relative position of these posts, the resonance frequency of the short-circuited microstrip patch can be adjusted [2]. In fact, by reducing the number of shorting posts the resonance frequency of the modified patch can be reduced. Thus for as set resonance Frequencies, a significantly smaller element can be achieved using this technique compared to conventional micro-strip patches. Further decrease in size can be obtained by loading the basic shapes by shorting post or slots [1, 8, and 9]. In [10, 11], rectangular microstrip patch antenna with multiband frequency operation is designed with multi slits loaded on the patch and the results are compared with the conventional rectangular microstrip antenna (without a shorting post) which Shows that the size of the rectangular microstrip antenna can be reduced to the same frequency application. It is also observed that the resonant frequency of the rectangular microstrip antenna with shorting post can be varied by varying its location. In [12, 13], the technique of shorting post is used for multiband frequency. The impedance frequency bandwidth of a microstrip antenna depends primarily on both the thickness and the dielectric permittivity of the substrate. A thick substrate with a low dielectric permittivity can increase the bandwidth of the printed patch. Both these selections could be a solution of the problem of bandwidth enhancement if the thickness of substrate did not

- Pose difficulties in integration of antenna with other microwave circuits
- Cause some other problems such as the surface wave propagation and the large inductive image part of the input impedance of the antenna, which makes its resonance unfeasible. Thus, a reasonable thickness should be considered in the selection of substrate and the bandwidth would be enhanced using additional techniques. The most common and effective of them are:

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- The loading of the surface of the printed element with slots of appropriate shape
- The Texturing of narrow or wide slits at the boundary of the micro-step patch.
- Stacked, shorted
- Extra microstrip resonators

The technique of stacked patches is based on the fact that bandwidth is in general proportional to the antenna volume measured in wavelengths but at the same time a relatively large volume is a disadvantage for many applications. The utilization of additional parasitic patches of different patches of different size directly –or- gap coupled to the main patch is an effective method but results in an increased antenna size which would also be undesired. Superior to these methods is the techniques of slot loading or Texturing the patches by slits because they ensure the small size and the low profile of the antennas.

II. Proposed Design Analysis

- ***Proposed design included***
- Patch dimension is 700 x 800mil^2
- 17 slits loaded on patch, L_1= 60mil, L_2=20mil, and W_1= 760 mil
- The air gap between layers Δ = 3 mil
- Whole geometry consist by the layer (FR-4 – air- FR-4), Total height = 121 mil
- Bottom ground plan is 1400 x 1600 mil^2
- The proposed design model shown in fig 1 and fig 2.

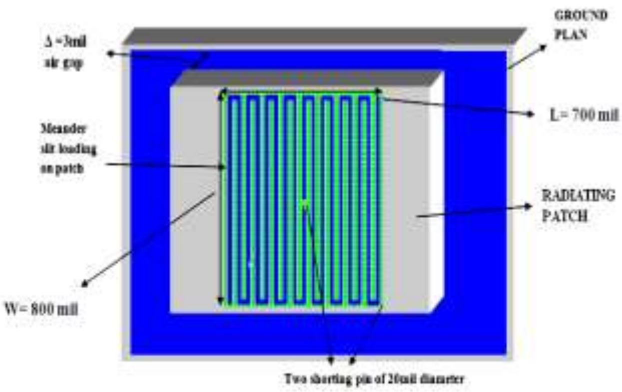

Fig. 1. Proposed Design

- Top view of Proposed Design

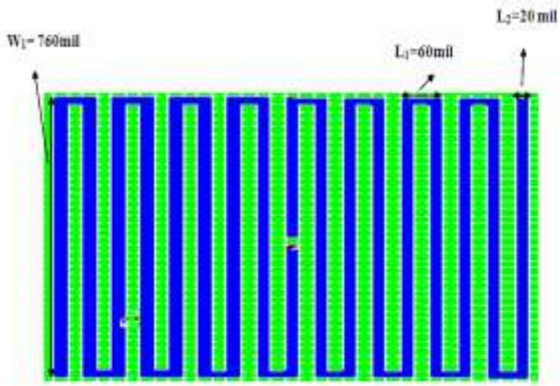

Fig. 2 . Inner structure of Proposed Design

- **Equivalent transmission line model of proposed design**

They are exactly the above features of the propagating waves that permit us to approach the electromagnetic behavior of the EBG surface using an equivalent parallel resonant circuit which can be tuned to exhibit high impedance over a pre-specified frequency band. From the physical side of view this equivalence can be explained as follows: as the EBG interacts with electromagnetic waves, currents are induced in the top metal plates. A voltage applied parallel to the top surface causes charges to concentrate around and on the ends of the plates which can be considered as a capacitance. As the charges move back and forth, they flow around a long path through the vias and the bottom plate fig3. Associated with these currents are a magnetic field and thus, an inductance.

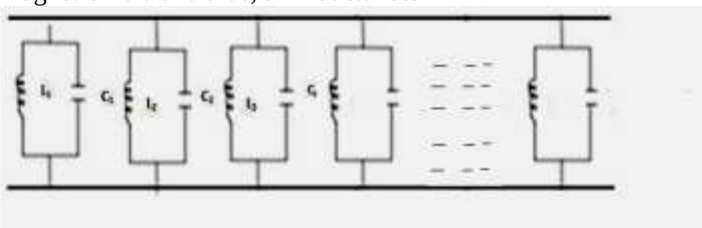

Figure. 3. Equivalent ckt of proposed design

By this circuit model, the surface impedance, assigned to the sheet, corresponds to the impedance of a parallel resonant circuit, consisting of the sheet capacitance and the sheet inductance

$$Z = \frac{j\omega L}{1-\omega^2 LC} \quad (1)$$

The surface is inductive at low frequencies, capacitive at high frequencies and the impedance is very high near the resonance frequency ωo, $\omega_o = \frac{1}{\sqrt{LC}}$ this high impethe forbidden frequency band forbidden frequency band. In the 2D geometry of the lattice of the EBG patches the capacitors are formed by fringing electric fields between adjacent metal patches and the inductance is fixed by the thickness of the structure. An approximate expression of the capacity [79],

$$C_{fringe} = \frac{W(\varepsilon_1 + \varepsilon_2)}{\pi} \cosh^{-1}\left(\frac{\alpha}{g}\right) \quad (2)$$

In the above expression g is the gap between the plates, **W** is the width of the plates, α is the lattice constant namely α = g+w, and ε_{r1} and ε_{r2} are, respectively , the dielectric constants of the substrate of the EBG and the material surrounding the surface which may be free space. Equation (16), although approximate, is adequate for first order designs. The inductance of a high- impedance surface is determined entirely by its thickness. This can be understood by considering a solenoid of current that includes two rows of plates and their associated vias. Current flows up one row of vias across the capacitors and down the next set of vias to return through the ground plane. The length and width of the solenoid are canceled to obtain the sheet inductance, L

$$L = \mu H \quad (3)$$

From the investigation of proposed design we have concluded that the Equivalent ckt included 17 closely near by resonance mode due to 17 slit loading in patch (capacitive in nature) , two orthogonal shorting pin (inductive in nature) and feeding inductance (inductive in nature) shown in fig 3. The wideband performance of the slit loaded patch is based similar to the method of slot loading, on the excitation of more than one adjacent resonant mode. Moreover the presence of the slits in the vicinity of the feeding probe could add a capacitive load at the input impedance of the patch. This capacitive load could effectively contribute to the resonance of the patch because can counteract the inductive part of the probe input impedance. It is noticed that this inductive part would inevitably be argue if a thick substrate is chosen for wideband operation so the insertion of slits enhances by two ways the width of the operating band, and it has been reported greater bandwidth. The width of the frequency band of the antenna can be controlled by slits' length and width and the slits' position. The slits divided the in more parts and each one corresponding an equivalent circuit of resonance.

III. Result And Discussion

The proposed Antenna consists of seventeen capacitive arms due to slit (periodically EBG Structure) on the patch and seventeen inductive arms, which are connected to a patch. All are etched on the top of the substrate model shown in Fig. 1 and top view shown in Fig.2. The rectangular slot and air gap between layers corresponds to a capacitance and two orthogonal shorting posts; feeding point corresponds to an inductance. The bottom surface is etched by the ground plan of dimension 1400 x 1600 mil2. Bottom surface and a top surface separated by an air gap. The air gap is easily available dielectric material so that fabrication is easy and less costly and provide enhancement in bandwidth. Texture in size of the antenna is easily done due periodically EBG structure. This proposed design is investigated to tune at low frequency band L-Band due to two orthogonal shorting posts and multiple slits are used in the patch. Proposed design has textured, firstly by 17 slit loading on the patch so that seventeen resonance mode forms, after that patch has textured by two orthogonal shorting posts. The resonance modes modify due to the inductance of shoring post and all resonance modes redefine for lower frequency. The orthogonal position of shorting posts reduces circular polarization and mismatching losses. To decrease the resonant frequency of an antenna for a given surface area, the current path must be maximized within that area by the shorted patch concept. The design of this proposed microstrip antenna is based on the philosophy of maximizing the current path for a given surface area to decrease the resonant frequency of shorting post and use three-layer substrate material to reduce the radiation losses by surface waves to improve the efficiency.

This leading position can ensure maximum reduction in the resonant frequency of the microstrip antenna that is maximum patch size reduction for the antenna can be obtained at a fixed frequency. The impedance matching (open circuit and short circuit stub) associated with this class of antennas are also simpler compared to other methods. Due to short circuit post overall inductance of resonance circuit is increased so that significant reduction in resonance frequency. It is important to note that at a fixed frequency, the patch size can be increased or decreased, depending on the distance of the shorting post from the feed.

In proposing antenna configuration, we have considered the concept of shorting post and three-dielectric layer substrate material to increase the bandwidth and efficiency for miniaturized dimension. It is clearly seen that, for the short-circuited patch antenna, the input impedance become very sensitive to the feed position and strongly depends on the distance between the shorting pin and the feed position. We achieved a 63% reduction of geometrical area for L –Band. The equivalent dielectric constant is calculated from giving formula

$$\varepsilon_{eq1} \cong \frac{\varepsilon r_1 \varepsilon r_2 \times (h2 + \Delta)}{(\varepsilon r_1 \varepsilon r_2 \ \Delta + \ (h2 + \Delta))} \quad (4)$$

(1)

$$\varepsilon_{eq2} \cong \frac{\varepsilon r_3 \varepsilon_{eq1} \times (h1 + h2 + \Delta)}{(\varepsilon r_3 \varepsilon_{eq1} (\Delta + h1) + (h1 + h2 + \Delta)\ )} \quad (5)$$

$\varepsilon_{r1}=1$, $\varepsilon_{r2}=4.3$, $\varepsilon_{r3}=4.3$

• **Fabricated Hardware of Proposed Design**

Figure 4 Top view of proposed antenna

Figure 5 Bottom side of proposed antenna

For fabrication of antenna, FR-4, air and SMA Connector are used. Top view and bottom side view are shown in figure 4 and figure 5. Fabricated proposed antenna is validated by the Agilent scalar network analyzer, Agilent source and received hardware validation and simulation validation results are same.

Hardware Validation and Simulation Results of Proposed Design

A. Return Loss vs. Frequency

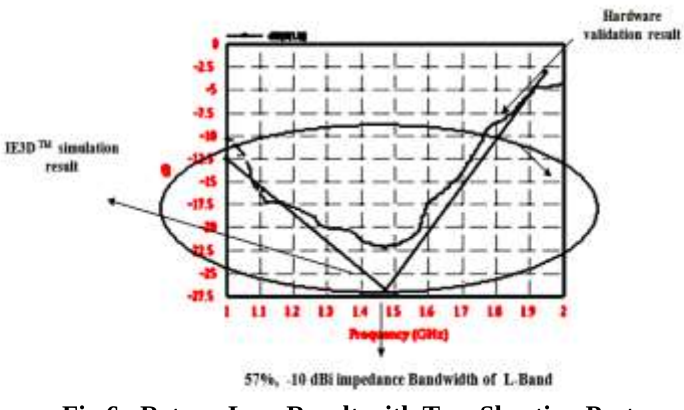

Fig 6: **Return Loss Result with Two Shorting Post**

Hardware validation and simulation Results of Return Loss shown in Table-1 and , fig 6. From this result discussion, we have been concluded that multilayer slit loaded gap coupled orthogonal shorting post microstrip antenna shown in figure 1, has shown bandwidth Enhancement of about 57% of L Band, minimum return loss up to -27.5dBi at 1.47 GHz and hardware validation and simulation results are matched.

B. VSWR vs. Frequency

The measured VSWR versus frequency has shown in figure 6 , showing VSWR cannot greater than 6 over a band 1GHz-2GHz.

Table -1 Return loss vs. Frequency

Frequency (GHz)	Simulation results of Proposed design	Hardware validation results of Proposed design
1	-12.5	-10
1.05	-13.8	-13.5
1.1	-15.3	-15.5
1.15	-16.8	-17.5
1.2	-18.5	-17.6
1.25	-20	-18.5
1.3	-21.5	-20
1.35	-23.5	-20.1
1.4	-24.8	-21.5
1.45	-26.5	-21.5
1.47	-27.5	-22.5
1.5	-25	-22.2
1.55	-23	-21
1.6	-20	-17.5
1.65	-17	-15.8
1.7	-15	-13.2
1.75	14	11
1.8	10	8

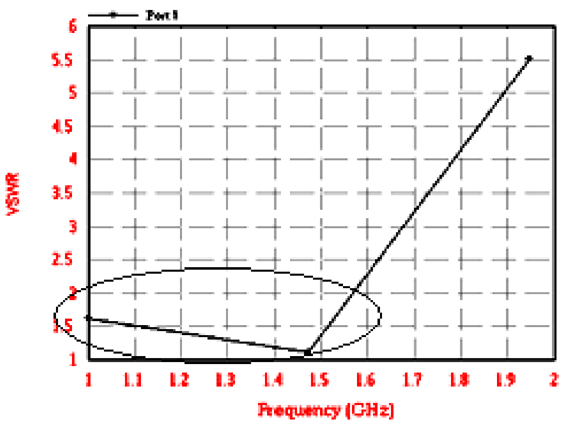

Fig .6 . VSWR vs Frequency for Proposed Design

IV. Conclusions

In this paper Texturing of micostrip antenna has been presented. A multilayer slit loaded gap coupled orthogonal shorting post microstrip antenna have fabricated and validated, achieved 57% -10dB impedance bandwidth of L Band and 63% reduction of geometrical area for L –Band, This proposed antenna is used for GSM, satellite and wireless communication at, L Band..

V. References

[1] R. Porath, "Theory of miniaturized shorting-post micro-strip antennas, "IEEE Transactions, Antennas and Propagation, Vol. 48, No. 1, pp. 41-47, 2000.

[2] M. Sanad, "Effect of the shorting posts on short circuit microstrip antennas, "Proceedings, IEEE Antennas and Propagation Society International Symposium, pp. 794-797, 1994.

[3] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, "Micro-strip antenna design handbook," Artech House: London, 2001.

[4] D. M. Pozar, "Microstrip antennas," Proceedings of IEEE, Vol. 80, No 1, pp. 79-91, January 1992.

[5] T. Chakravarty, S. Biswas, A. Majumdar, and A. Die,"Computation of the resonant frequency of annular-ring-loaded circular patch," Microwave and Optical Technology Letters, Vol. 48, No. 3, pp. 622-626, 2006.

[6] P. Kumar, G. Singh, and S. Bhooshan, "Gap-coupled microstrip antennas," Proceedings of International Conference on Computational Intelligence and Multimedia Applications, pp. 434-437, 2007.

[7] K. P Ray, S. Ghosh, and K. Nirmala, "Compact broadband gap-coupled microstrip antennas," Proceedings of IEEE Antennas and Propagation Society International Symposium, pp. 3719-3722, July 2006.

[8] R. B. Waterhouse, S. D. Targonski, and D. M. Kokoto, "Design and performance of small printed antennas," IEEE Transactions, Antennas and Propagation, Vol. 46, pp. 1629-1633, 1998.

[9] T. K. Lo, C.-O. Ho, Y. Hwang, E. K. W. Lam, and B. Lee, "Miniature aperture-coupled microstrip antenna of Engineering, 2009, 1, 1-54 very high permittivity," Electronics Letters, Vol. 33, pp. 9-10, 1997

[10] C. L. Tang, H. T. Chen, and K. L. Wong, "Small circular microstrip antenna with dual frequency operation," Electronics Letters, Vol. 33, No. 73, pp. 1112-1113, 1997.

[11] K. L. Wong and W. S. Chen, "Compact microstrip antenna with dual-frequency operation," Electronics Letters, Vol. 33, No. 8, pp. 646-647, 1997.

[12] T. Chakravarty and A. De, "Investigation of modes tunable circular patch radiator with arbitrarily located shorting posts," IETE Technical Review, Vol. 16, No.1, pp. 109-111, 1999.

[13] T. Chakravarty and A. De, "Design of tunable modes anddual-band circular patch antenna using shorting posts,"IEE Proceedings on Microwave, Antennas and Propaga-tion, Vol. 146, No. 3, pp. 224-228, 1999.

[14] A. Vallecchi, G. B. Gentile, and M. Calamia, "Dual-band dual polarization microstrip antenna," Proceedings, IEEE International Symposium, pp. 134-137, 2003.

[15] R. Waterhouse, "Small microstrip patch antenna," Electronics Letters, Vol. 31, pp. 604-605, 1995.

[16] S. Dey and R. Mitra, "Compact microstrip patch antennas," Microwave and Optical Technology Letters, Vol.13, pp. 12-14, 1996.

[17] H. K. Kan and R. Waterhouse, "Size reduction technique for shorted patches," Electronics Letters, Vol. 35, pp. 948-949, 1999.

[18] E. Lee, P. S. Hall, and P. Gardner, "Compact dual-band dual-polarization microstrip patch antennas," Electronics Letters, Vol. 35, pp. 1034-1036, 1999.

[19] N. Engheta R.W. Ziolkowski, Matamaterials –physics and Engineering Extrapolations, IEEE Press and John Wiley &Sons, 2006.

[20] E. Raja-lglesias , O. Quevedo-Teruel and L. Inclan-Sanchez, 'Mutual coupling reduction in patch antenna

[21] Design of broadband dual-layer Micro-strip antenna Li Xuzhe; Su Hua; Zhang Huaiwu; Zhong Zhiyong; Mechanic Automation and Control Engineering (MACE), 2011 Second International Conference on Digital Object Identifier Publication Year: 2011 , Page (s): 6422 - 6425

[22] Bilayer miniature broadband Microstrip patch antenna with Minkowski Fractal Guan long Huang; Shu Lin; Xueying Zhang; Runnan CAI; Wenbin Zhang; Caitian Yang; Jinxiang Wang; Microwave Conference Proceedings (CJMW), 2011 China-Japan Joint Publication Year: 2011 , Page

[23] Gain and efficiency enhancement of compact miniaturized Microstrip antennas using multi-layered laminated conductors Latif, S.I.; Shafai, L.; Shafai, C.; Dept. Of Electr. & Comput. Eng., Univ. Of Manitoba, Winnipeg, MB, Canada This paper appears in: Microwaves, Antennas & Propagation, IET Issue Date: March21, 2011 Volume 5, Issue:4 On page (s): 402-411 ISSN: 1751-8725