FACTA UNIVERSITATIS
Series: **Mechanics, Automatic Control and Robotics** Vol.3, N^o 15, 2003, pp. 1083 - 1088

Invited Paper

BROADBAND DESIGN OF MICROSTRIP ANTENNAS: RECENT TRENDS AND DEVELOPMENTS

UDC 621.396.67

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Abstract. *Thorough survey of open literature shows that the in recent years, the major fraction of research on microstrip and printed antennas is devoted to developing new design to improve antenna bandwidth along with other figures of merit. The recent trends are also some what different from those of last two decades. Some developments in allied branches like, MIC's and printed circuits, are now being investigated to antenna applications and those are discussed in a brief and comprehensive fashion in the limited scope of this article.*

INTRODUCTION

With the development of MIC and high frequency semiconductor devices, microstrip has drawn the maximum attention of the antenna community in recent years. In spite of its various attractive features like, light weight, low cost, easy fabrication, conformability on curved surface and so on, the microstrip element suffers from an inherent limitation of narrow impedance bandwidth. So, along with other developments, widening the bandwidth of microstrip elements, in general, has become a major branch of activities in the field of printed antennas. Three books [1-3] and three book chapters [4-6] have covered the developments occurred time to time during the last two decades. But the advancement in this area is so fast and volumous that a review at every considerable interval of time adds new techniques, structures and results.

In this paper, the author intends to present a comprehensive review of bandwidth enhancement techniques in general with a major emphasis on the recent trends and developments. The new investigations and their results show the maturity of this field of research and also indicate the lacunae along with the scope of future works.

Received April 20, 2003

BASIC PRINCIPLE OF BROADBAND DESIGN

The fundamental and basic principles of broadband design of microstrip and printed antennas are often discussed in the related papers and reports which are quite general and incomplete in true sense. References 1-6 cover this in a more detail. The basic principles are sometimes achieved using some other principles, which are in the phase of very rapid development. Thorough discussions are beyond the scope of this paper and hence the main points are highlighted. The basic principles and their corresponding antenna geometries can be listed as:

i. Low Q-factor of the magnetic wall cavity under the patch:	Low dielectric constant or larger thickness of the substrate
ii. Multiple resonances:	Parasitic patches in stacked or planar geometry, Reactive loading by shaped slot, notch, cuts, pin or post.
iii. Impedance matching of the feed:	Probe compensation using series capacitor, L-shape probe or any reactive loading
iv. Optimization of patch geometry:	Very irregular and unconventional patch shape optimized using Genetic Algorithm.
v. Suppression of Surface waves in a thick substrate:	Periodic patterns on the ground plane or on any substrate produces Photonic Band Gap (PBG) Structure on one face of which microstrip element or arrays are printed.
vi. Frequency dependent substrate or ground plane:	Multiple layers of Frequency Selective Surfaces (FSS) can reflect at respective frequency bands. For closely spaced frequency bands, the FSS combination act over a larger frequency range as pass band.

vii. Various combinations of (ii) and (iii)

RECENT TRENDS

The recent trends in improving the impedance bandwidth of microstrip antennas can be broadly divided into the following categories:

(i) Various geometries and perturbations to introduce multiple resonances as well as input impedance matching,
(ii) Genetic Algorithm (GA) based optimization of antenna geometries,
(iii) Photonic Band Gap (PBG) structures used as printed antenna substrates,
(iv) Frequency Selective Surfaces (FSS) used as multilayered substrate or ground Plane.

The first one is the leading of all four categories in numbers and varieties. A few recent reports are discussed here. A proximity-fed triangular patch in a circular slot is reported in [7] which shows more than 90% of SWR<2 bandwidth. A novel design of broad band stacked patch antenna has been proposed very recently by Ooi *et. al* [8] where they have used stacked patch with shaped slots and used probe compensation by metallic washer on the probe. They have obtained 44.9 % impedance bandwidth. Another new technique of impedance matching by capacitive loading of inverted microstrip has been recently proposed by the present author [9]. This simple design, shown in Fig. 1 offers more than 20% bandwidth with appreciable satisfactory radiation patterns. Stacked patch geometries with efficient feeding techniques are examined to achieve large bandwidth in [10, 11]. The structure proposed in [11] is comparatively simpler but provides broadband dual frequency operations as shown in Fig. 2.

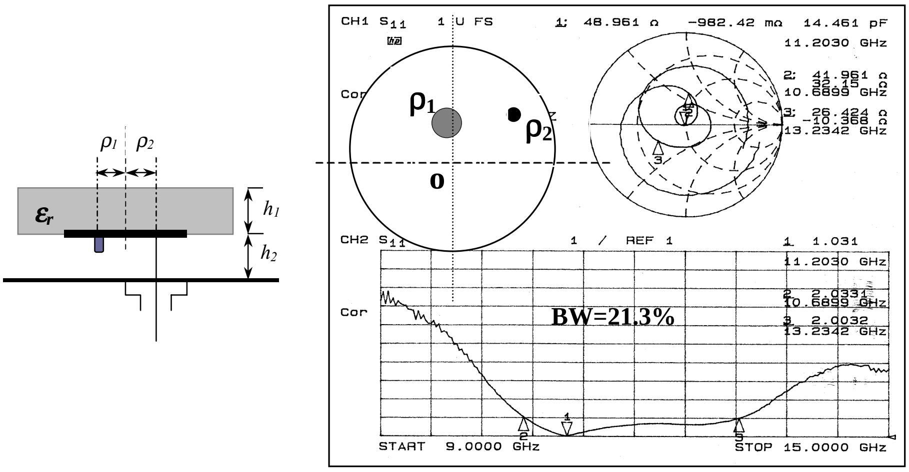


Fig. 1. Inverted microstrip patch loaded with a capacitive post. Radial distance of the post (dia 2mm, ht 0.6mm) ρ_1 = 2 mm, radial distance of the coax-feed ρ_2 = 3 mm.

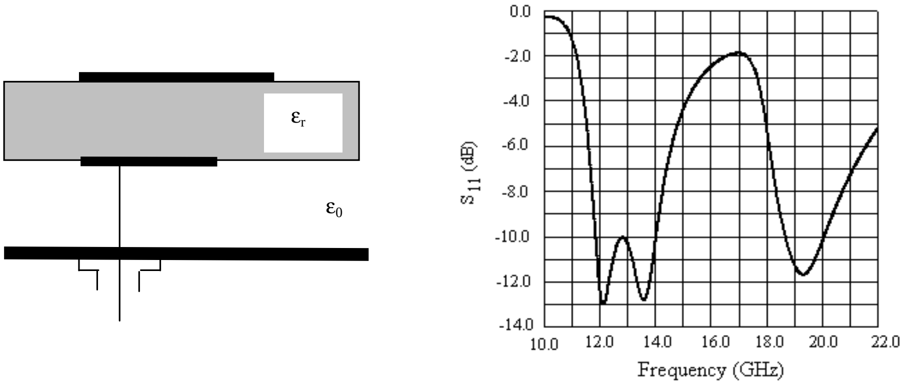


Fig. 2. Stacked inverted microstrip circular patches with asymmetric geometries

Optimization of patch geometry is an ideal technique to have single or more optimized figures of merit like, impedance bandwidth. The GA has been successfully applied by a number of researchers to improve the impedance bandwidth . The optimized shape, however is too much irregular and unconventional and as such this can only be fabricated using the pattern produced in true scale by the GA code. One example of shape optimization of a microstrip patch using the GA is shown in Fig. 3.

The principle of introducing low Q-factor of the cavity below the patch can be achieved by lowering the dielectric constant of the substrate or by increasing the substrate thickness. The latter one is more flexible for design purpose but restricted by the surface wave generation leading to low gain and low efficiency of the antenna. Use of the PBG structures as antenna substrates is one promising solution to this problem and thus it attracts a large fraction of antenna people to work with PBG. [12-15]. The PBG structure is basically a periodic metallic pattern printed on dielectric substrate for microwave and millimeterwave applications and this provides a stop band of electromagnetic waves propagating through it. The frequency range of the stop band depends on the pattern geometry and its dimensions. If the antenna operating frequency falls within this stop band, it is attenuated during propagating through the substrate. Thus the generation and propagation of surface wave is stopped. Horii and Tsutsumi [15] used a two-dimensional PBG pattern in the ground plane beneath the square patch. They used a $76\times76\ mm^2$ square patch on the glass-epoxy substrate with dimensions of $200\times250\times1.6\ mm^3$ having relative permittivity of $\varepsilon_r = 4.8$. 3×4 circles with diameter of 18mm were etched in the ground plane at the period of 38mm as shown in Fig. 4. This arrangement produces the required PBG structure having the stop band characteristic of the transmission parameter at more than −20 dB form 1760 to 2720 MHz.

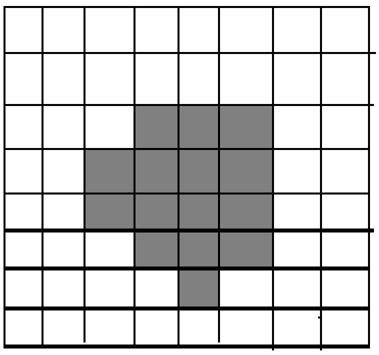


Fig. 3. A typical GA optimized patch geometry

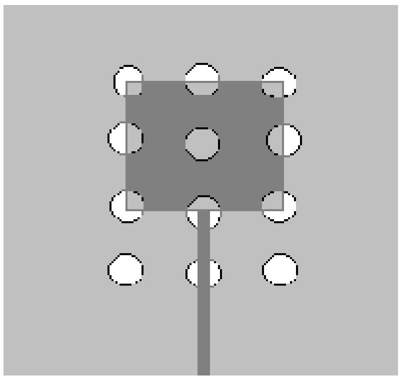
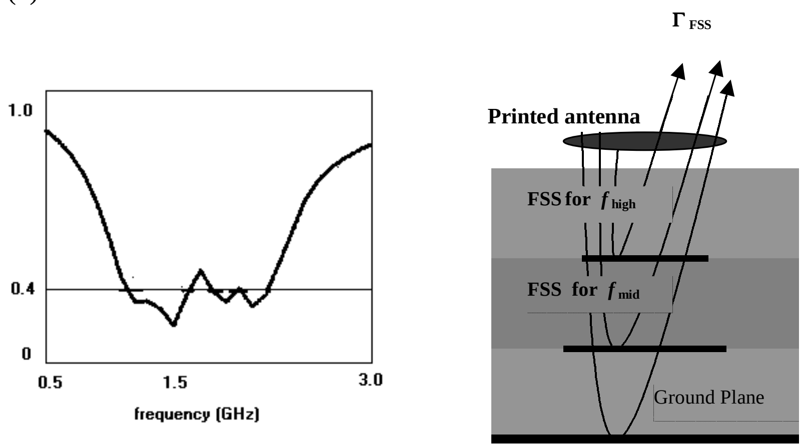


Fig. 4. Rectangular patch printed on a PBG Substrate [15]

Frequency selective surface (FSS) is another area of interest to antenna researchers. The FSS is also created by printing periodic patterns on microwave substrates to simulate equivalent L and C to an electromagnetic wave and thus its basic characteristic is to scatter or reflect certain frequencies of electromagnetic waves incident on it. Out of various studies with FSS in the context of microstrip and printed antennas, increase in pass band of printed antenna or antenna arrays find a significant importance [16-17]. A broadband design of printed antenna arrays with multilayer FSS, as shown in Fig. 5, is developed very recently by Erdemli *et al* [17]. The broadband characteristic is shown in Fig. 5 (b).



(a) (b)

Fig. 5. A printed antenna on multilayer FSS and its impedance bandwidth over a frequency range [17]

CONCLUSION

Enhancement of the impedance bandwidth of Microstrip elements is a challenge to the researchers. Various techniques have been developed during last two decades. Still a significant fraction of researchers is involved in this area resulting in new techniques which are almost in their infancy. The techniques employing GA optimization of patch, PBG structures as no-surface-wave-substrates, multiplayer FSS or FSS ground plane and various new geometries with feed compensation are discussed. The first three techniques are in their infancy and hence very few results are available in the literature. But the trend reveals their highly promising scope in antenna applications.

Acknowledgments. *The author thankfully acknowledge the assistance and help received from his students Mr. J. Y. Siddiqui, Mr. M. K. Mandal and Mr. M. G. Tiary in collecting the materials and preparing this article. Related research works of the author are supported by the Center of Advanced Study (CAS) in Radio Physics and Electronics, University of Calcutta.*

REFERENCES

1. J. F. Zürcher and F. E. Gardiol, Broadband microstrip antennas, Artech House, Boston.
2. Girish Kumar and KP Ray, Broadband patch antennas, Artech House, Boston.
3. K. L. Wong, Compact and broadband microstrip antennas, Wiley, NY,2002
4. D. M. Pozar, "A review of bandwidth enhancement techniques for microstrip antennas", *Ch.4* in Microstrip Antennas, ed. D. M. Pozar and D. H. Schaubert, IEEE Press, New York.
5. R. Garg *et. al.*, *Ch.9* in Microstrip Antenna Design Handbook, Artech House, Boston.
6. D. M. Pozar, " Microstrip patch antennas", *Ch.6* in Handbook of Antennas in Wireless Communications, ed. L. C. Godara, CRC Press, New York.

7. Y. W. Jang, " Characteristics of a large bandwidth rectangular microstrip-fed inserted triangular patch in a circular slot antenna", *Microwave Journal*, vol.45, no.5, pp.288-298, May, 2002.
8. B. L. Ooi, S. Qin and M. S. Leong, "Novel design of broad-band stacked patch antenna," IEEE Trans. Antennas Propagat, No. 10, Vol. 50, pp. 1391-1395, Oct. 2002.
9. D. Guha and J. Y. Siddiqui," Simple design of a novel broadband antenna: Inverted microstrip patch loaded with a capacitive post," *dig. 2002 IEEE AP-S Int. Symp.* held in San Antonio, Texas, June 16-21, 2002. pp.534-537.
10. K. Ghorbani, and R. B. Waterhouse, "Ultrabroadband printed (UBP) antenna," IEEE Trans. Antennas Propagat, No. 12, Vol. 50, pp. 1697-1705, Dec. 2002.
11. S. S. Iqbal, J. Y. Siddiqui, and D. Guha, "Simple design of a compact broadband microstrip antenna for mobile communication," to be published in the *2003 IEEE Int. Symp. on Antennas and propagation and USNC/CNC/URSI North American Radio Science Meeting*, to be held at Columbus, OH, during June 22-27, 2003.
12. H.Y.D. Yang, N.G. Alexopoulos, and E. Yablonovitch, "Photonic band gap materials for high gain printed circuit antennas," *IEEE Trans. Antennas Propagat.*,vol. 45, pp. 185-187, Jan. 1997.
13. V. Radisic, Y.X. Qian, R. coccioli, and T. itoh, "Novel 2-D photonic band gap structure for microstrip lines," *IEEE Microwave Guided Wave Lett*. , vol. 8, pp. 69-71, Jan.1998.
14. C. Cheype, C. Serier, M. Thevenot, T. Monediere, A. Reinix, and B. Jecko, "An electromagnetic bandgap resonator antenna," *IEEE Trans. Antennas Propagat.*, Vol. 50, No. 9, pp. 1285-1290, Sep. 2002.
15. Y. Horii, and M. Tsutsumi, "Harmonic control by photonic bandgap on microstrip patch antennas," *IEEE Microwave and Guided Wave Lett.* , vol. 9, No.1, pp. 13-15, Jan.1999.
16. R. Mittra, C.H. Chan, T. Cwik, " Techniques for analyzing Frequency Selective Surfaces- A Review," *Proc. IEEE*, Vol. 76, PP.1593-1615, 1988.
17. Y. E. Erdemli, K. Sertel, R. A. Gilbert, D. E. Wright, and J. L. Volakis, "Frequency selective surface to enhance performance of broad-band reconfigurable arrays," *IEEE Trans. Antennas Propagat.*, Vol. 50, No. 12, PP.1716-1724, December 2002.

PROJEKTOVANJE ŠIROKOPOJASNIH MIKROSTRIP ANTENA: SAVREMENI TREND I RAZVOJ

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Detaljan uvid u savremenu literaturu ukazuje na znatne napore da se ostvare što bolje širokopojasne karakteristike mikrostrip i štampanih antena, a da pri tome ostale performanse antena ostanu sačuvane. Savremeni pristupi za rešavanje ovog problema se razlikuju od onih koji su korišćeni u poslednje dve decenije. Odredjeni novi pristupi zasnovani na zajedničkoj primeni MIC i štampanih kola biće prikazani u radu, uz diskusiju i poredjenje dobijenih sa postojećim rezultatima.