Microstrip and Printed Antennas: Recent Trends and Developments

Debatosh Guha

Abstract: **In this paper, a very brief and comprehensive survey of recent trends and developments in microstrip antenna research is presented. Comparatively newer fields with potential scope of developments are discussed in more detail. Some advanced topics of microstrip antennas still find enormous scope of improvements and are covered in the limited scope of this article.**

I. Introduction

With the development of MIC and HF semiconductor devices, microstrip and printed circuits have 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 disadvantage of narrow impedance bandwidth and low gain.

Many aspects of significant contributions and developments in these fields were discussed in some books and book chapters [1]-[7]. The book [8] is the latest one that has covered the developments and advances occurred up to 1996. Since then, within the last six years some of them have further advanced, some have attained saturation and also many new areas have come up with potential scopes.

In this paper, the author intends to discuss those recent trends and developments in microstrip and printed antennas reflected from the survey of open literature. These may be broadly categorized as: (i) Wideband and multiband antennas, (ii) Compact reduced size antennas, (iii) Application of Genetic Algorithm (GA), (iv) Circular Polarization with wide impedance bandwidth and multifunction antennas, (v) Microstrip and Printed antennas on Photonic Band Gap (PBG) structures, (vi) Application of Frequency Selective Surfaces (FSS), (vii) Active Integrated Antennas, (viii) New approaches of Design and analysis, (ix) Antennas for wireless communications and handsets. Some areas of this above list are quite advanced and matured and some of these are at the stage of infancy. The recent trends thus can be divided into two categories:

(1) comparatively newer areas of research and
(2) those which are well cultivated but still with potential scope of research.

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II. New Areas of Research

In microstrip antenna research a new trend is found where the researcher try to improve antenna characteristics by introducing different structures within the antenna geometry. Those are described in this section. With the development of computational electromagnetics new approaches of analysis has become another branch of activity. Some recent reports are also presented.

IIA. Photonic Band Gap (PBG) Antenna

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 while propagating through the substrate. Thus the generation and propagation of surface wave is stopped. A microstrip line printed on conventional substrate (Fig. 1(a)) and on a PBG material (Fig.1(b)) show different transmission characteristics as revealed from Fig. 2.Unlike conventional microstrip line, the microstrip on PBG substrate shows a stop band over 5.5 to 10.5 GHz in their transmission characteristics. Restricting the propagation/generation of surface waves in a mictostrip, the PBG attributes new features in a microstrip structure. Those are applied to improve antenna characteristics.

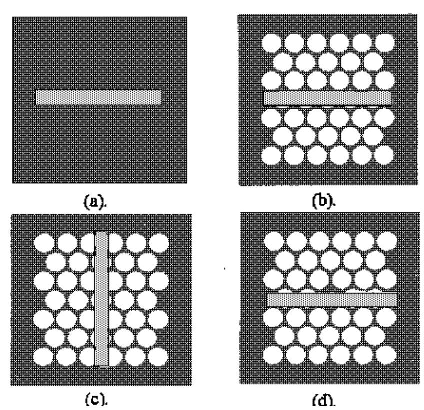

Fig.1 (a) microstrip line on a conventional substrate. (b) microstrip line on a PBG substrate. (c)and (d) microstrip line on a PBG substrate with a defect. (From [9] © 2003 IEEE. Reprinted with permission.)

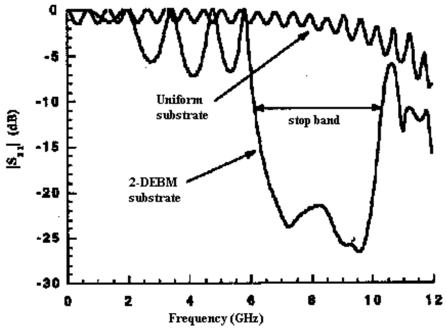

Fig.2. Measured S_{21} of a microstrip line on a uniform substrate and PBG substrate. (From [9] ©2003 IEEE. Reprinted with permission.)

Microstrip patch is inherently a narrow bandwidth structure. One fundamental way to improve the bandwidth is to increase the substrate thickness. This is 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 attracted a large fraction of antenna people to work with PBG [10]-[13].

Yang *et.al.*[14 first proposed that high gain antennas could be obtained by printing an element on a 2-D PBG material. If the operating frequencies of the substrate modes fall within the stop-band, those will exponentially decay. Suppression or reduction of surface waves reduces side lobe levels, improves antenna efficiency and thus improves antenna gain. Dielectric slab with planar square gratings (square air implants) was examined with a printed dipole on it in [14]. The improvement in directivity of the printed dipole is shown in Fig. 3.

Oscillator type active antenna using MESFET or Gunn diode suffers from another problem of spurious radiation near its operating frequency. Itoh [15],[16] first introduced PBG substrate to tackle this problem. Horii and Tsutsumi [13] used a two-dimensional PBG pattern in the ground plane beneath the square patch as shown in Fig. 4.

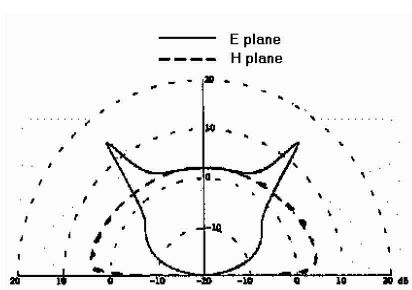

Fig.3 Radiation pattern of an elementary dipole on a square-lattice PBG substrate. ε_r =10. (From [14] © 2003 IEEE. Reprinted with permission.)

This arrangement produces the required PBG structure having the stop band characteristic over 1760 to 2720 MHz to eliminate the higher harmonic radiation as shown in Fig. 5.

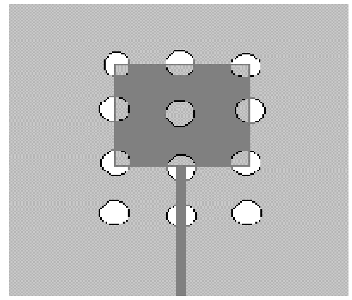

Fig. 4. Rectangular patch printed on a PBG Substrate [13]

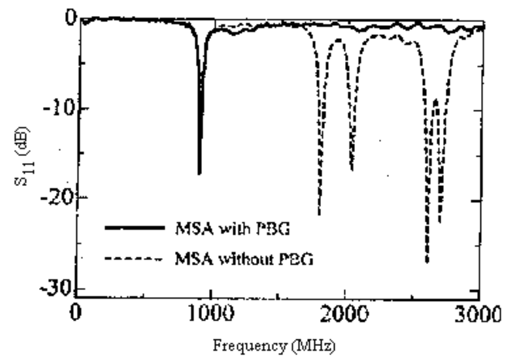

Fig.5 Measured return loss of a PBG antenna (rigid line) and the conventional antenna (broken line) (From [13] . © 2003 IEEE. Reprinted with permission.)

IIB. Application of Frequency Selective Surfaces (FSS)

Frequency Selective Surface (FSS) is a low-cost printed electromagnetic material used to control surface currents on it. This is usually formed by a two dimensional array of metallic patterns to form printed inductors and capacitors.

Various application of FSS in electromagnetics are reported of which some are focused to improve the gain [17] and the pass-band of operation [18] of a printed antenna. The gain and bandwidth depend on the reflection co-efficient (amplitude and phase) from the partially reflected surface like FSS. Typically they exhibit total reflection (Patches) or transmission (Aperture) at the resonance frequency and they are partially reflecting at the frequencies near resonance.

This can be achieved by using multiple layers of FSS [19] as part of the substrate as shown in Fig. 6. Each screen is resonant at a given frequency and is placed at a distance λ /4 from the element. The antenna structure and its impedance bandwidth are shown Fig.6 [19].

IIC. Antennas for wireless communications and handsets

This new branch deals with printed antennas suitable for mobile communication equipment and handsets. These applications demand some features like, compactness, wideband/multiple band operation, high gain, diversity reception, uniform radiation pattern, reduced radiation hazards etc. The radiation hazard is an important

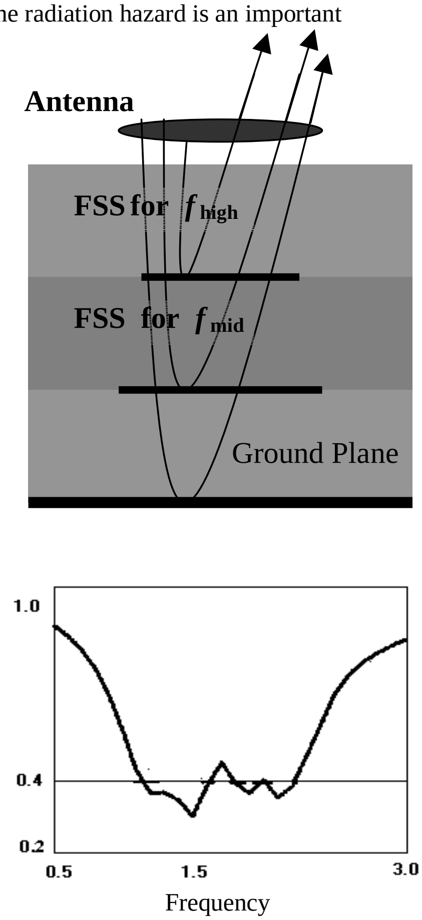

Fig. 6. A printed antenna on multilayer FSS and its reflection coefficient [19]

issue from the point of view of user's health. Two circular microstrip patches placed back to back and resonating at TM_{11} and TM_{02} modes [20] have been tested for handset applications. Mridula et al [21] used TM_{11} and TM_{21} modes in identical configuration with nearly 35% size reduction. This configuration exhibits minimum radiation in one quadrant and sufficiently good radiation over other three quadrants.

Planar inverted-F antenna (PIFA) is highly suitable for mobile communication due to its light weight, small size and ability to receive/radiate both vertically and horizontally polarized field. Virga and Rahmat-Samii [22] used PIFA as handset antenna and recently, Ng et al. [23] developed a PIFA for laptop computer. A compact broadband design of PIFA has been reported very recently by Wong and Yang [24]. Kuo and Wong [25],[26] have developed compact planar inverted-L antennas with coax-fed geometry. Their designs are made for mobile phone handsets.

IID. New Approaches of Analysis and Design

Many researchers dealing with computational electromagnetics are engaged with various numerical techniques for microstrips and printed circuits. The Finite Difference Time Domain [FDTD] technique[8] is one suitable example. Some researches are still trying to improve this method by improving its absorbing boundary conditions [27], minimizing its computational time[28] and extending its versatility to diversified geometries[29]. Apart from these, some people are engaged with analytical or semi-analytical analysis to develop CAD formulas for new or some kinds of variants of microstrip antennas like, circular patch antenna with and without air-gap[30], inverted microstrip circular patch antenna [31], circular patch antenna covered with dielectric superstrate[32], triangular patch antenna with and without air-gap[33], rectangular patch with thick substrate[34].

III. ADVANCED AREAS OF RESEARCH

Many wings of printed circuit antennas are quite matured, but still they find enormous scopes of developments even in the recent years. Those topics are briefly discussed in this section.

IIIA. Wideband and Multiband Antennas

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

(i) New geometries/perturbations to obtain multiple resonances as well as feed compensation
(ii) Genetic Algorithm(GA) based optimization ,
(iii) Photonic Band Gap (PBG) antennas,
(iv) Application of Frequency Selective Surfaces (FSS)

The first one is the most popular and investigated of all techniques and as such is very difficult to discuss in detail. Some recent reports are mentioned here. A proximity-fed triangular patch in a circular slot is reported in [35] 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* [36] 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 [37]. This simple design, shown in Fig. 7 offers more than 20% bandwidth with appreciable satisfactory radiation patterns. Stacked patch geometries with efficient feeding techniques are examined to achieve large bandwidth in [38],[39]. The structure proposed in [39] is comparatively simpler but provides broadband dual frequency operations as shown in Fig. 8.

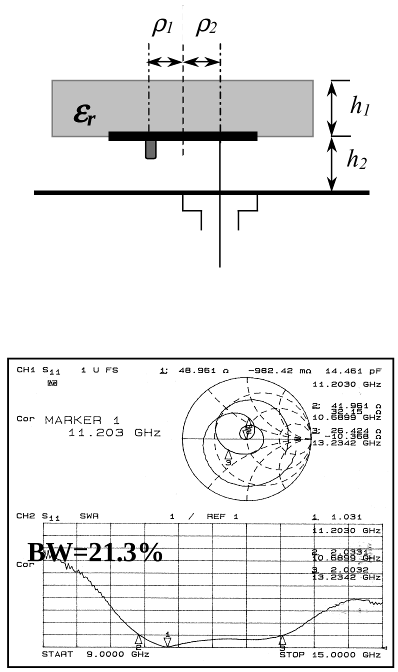

Fig 7. Inverted microstrip patch loaded with a capacitive post. Radial distance of the post (dia 2mm, ht 0.6mm) ρ_1 = 2 mm, radial distance of the coax-feed ρ_2 = 3 mm. [37]

Optimization of patch geometry is an ideal technique to have single or more optimized figures of merit like, impedance bandwidth, efficiency and gain. The GA has been successfully applied by a number of researchers to improve the impedance bandwidth as discussed in Section III. Similarly, the applications of PBG and FSS structures have already been discussed in the previous section.

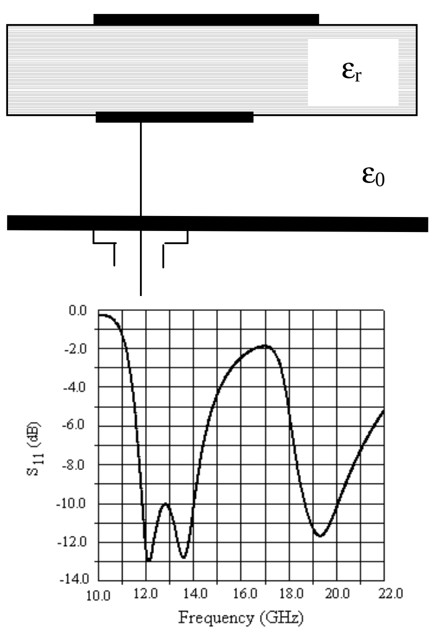

Fig. 8. Stacked inverted microstrip circular patches with asymmetric geometries [39]

IIIB. Compact Reduced Size Antennas

Compact reduced size printed antennas are mainly required for mobile communication equipment to meet its miniaturization requirement along with light weight. Recent developments in this area is thoroughly covered in [7]. Numerous geometries have been investigated so far to develop compact microstrip antenna with (i)wide bandwidth, (ii)dual frequency dual polarization, (iii)Enhanced gain and (iv)Circular polarization.

The basic technique to achieve all these is to introduce shorting pin[40], strip[41] or wall [25] or their combination with different shaped slots [42],[43], slits[44] or spur line [45] cut on the patch element. The meandered path of surface currents on the patch effectively increases the patch dimension which in turn results in lower operating frequency. Reduced size of patch is thus obtained. Feeding mechanism, particularly, feed location of coaxial probe in probe-fed geometry is also another aspect in obtaining desired polarization as investigated in [46]-[48].

IIIC. Circularly Polarized Antennas

Circular polarization (CP) in microstrip patches have been studied for a long time. In recent years it finds potential applications in mobile communication equipment and handset antennas [49] which further demand for compactness of antenna structure, wide polarization bandwidth, suitable radiation pattern with high gain. These aspects of CP antennas are discussed in section IIIB. One typical design of CP antenna by Wong and Lin [50] is shown in Fig. 9.

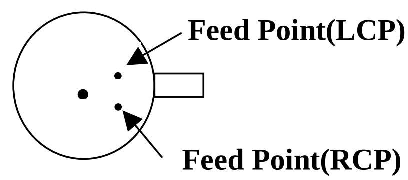

Fig. 9. Circular patch with a stub designed for circular polarization [50]

IIID. Integrated Antennas

Printed antennas may be placed close to the microwave source or transmitters fabricated on the same board. If the antenna element becomes a part of the oscillator or receiver, then it acts as an equivalent LC circuit as well as a radiating device. This is the basic concept of integrated antennas. Hybrid type integrated antennas were developed by Chang and his group [51], [52] where they proposed very simple design using inverted microstrip patch integrated with Gunn diode, varactor diode and FET. Its application as quasi optical power combiner was also studied by many researchers, e.g. [53], [54]. Improved broadband and polarization features of an integratable patch antenna has been reported very recently in [55].

IIIE. Application of Genetic Algorithm (GA)

Genetic Algorithm finds many applications in optimizing antenna parameters. One is shape optimization of microstrip patch as shown in Fig.10. The GA has been applied to continuously optimize the signal-to noise-plus-interference ratio of an adaptive antenna array [56]

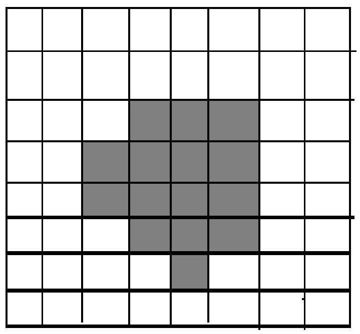

Fig. 10. A typical GA optimized patch geometry for broader impedance bandwidth

IV. CONCLUSION

The current trends in printed antenna researches are discussed with a special emphasis on the newly growing topics. Particularly, the scopes and developments of Photonic band gap materials, High frequency selective surfaces in antenna applications are covered in more detail. Antenna for mobile communication handsets is another potential field of current research. Some areas are already developed and is still fertile. Scopes of those fields are reflected from the current trends of research. A general overview of microstrip antenna research is thus present in present perspective within the limited scope of this article.

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