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# A Comparative Study of Gain Enhancement Techniques for Microstrip Patch Antenna

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*Abstract— In the recent era of wireless communication, Microstrip antenna (MSA) is hot research topic attracting attentions of many researchers .MSA are low profile, lightweight and have a compatibility with integrated circuit technology. The major limitations of MSAs are their narrow impedance, axial ratio(AR), bandwidth, small gain and lower power handling capacity. Here the overview of air fed high gain patch antenna is presented. Various gain enhancement methods like microstrip antenna array, superstrate structure, change in dielectric material and partial removal of substrate will be studied and the review is presented. Air is used as dielectric medium between feed patch and ground plane.*

*Index Terms— Array method, gain enhancement, hybridization. Microstrip patch antenna.*

## I. INTRODUCTION

Microstrip antenna technology has been the most rapidly developing topic in the antenna field in the last fifteen years, receiving the creative attentions of academic, industrial, and government engineers and researchers throughout the world. During this period there have been over 1500 published journal articles, many books and innumerable symposia sessions and short courses devoted to the subject of microstrip antenna and arrays. As a result microstrip antennas have quickly evolved from academic novelty to commercial reality, with applications in a wide variety of microwave systems [1]. The conventional microstrip antennas (MSAs) made up of single conducting patch on grounded dielectric substrate fed by microstrip line or coaxial probe. MSAs have number of advantages over the other antennas such as low profile, light weight, low cost and it is very easy to integrate with accompanying electronics. MSAs show inherent resonant performance because of this they have efficient narrow BW operation. Its typical BW is to 1 to 4% [1].

In recent years, microstrip ultra wideband antennas have attracted more attention owing to their advantages such as simple structure, low profile, high data rate, easy integration with monolithic microwave integrated circuits (MMICs), and ease of fabrication. When compared to traditional antenna elements such as reflectors, horns, slots, or wire antennas. However, the electrical performance of the basic microstrip antenna or array suffers from a number of serious drawback including very narrow bandwidth high feed network losses, poor cross polarization, and low power handling capacity. The purposes of this paper is review different techniques for enhancing the gain of antenna

## II. DEVELOPMENT HISTORY

The microstrip antenna concept dates back about 26 years 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. Additional studies were undertaken in the late 1960's by Kaloj, who studied basic rectangular and square configurations. However, other than the original Deschamps 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 described by Byron. This half wavelength wide and several wavelength long strip was fed by coaxial connections at periodic intervals along both radiating edges, and was used as an array for Project Camel. Shortly thereafter, a microstrip element was patented by Munson and data on basic rectangular and circular microstrip patches were published by Howell. Weinschel developed several microstrip geometries for use with cylindrical S band arrays on rockets. Sanford showed that the microstrip element could be used in conformal array designs for L band communication from KC-135 aircraft to the ATS6 satellite. Additional work on basic microstrip patch elements was reported in 1975 by Garvin et al, Howell, Weinschel and Janes and Wilson. The early work by Munson on the development of microstrip antennas for use as low profile wall mounted antennas on rockets and missiles showed that this was a practical concept for use in many antenna system problems and thereby gave birth to the new antenna industry [1].

### III. RECTANGULAR MICROSTRIP ANTENNA STRUCTURE

The microstrip device in its simplest form consists of a sandwich of two parallel conducting layers separated by a single thin dielectric substrate. The lower conductor functions as a ground plane and the upper conductor may be a simple resonant rectangular patch, and the associated feed network. The feed network employed may be a microstrip transmission line or coaxial fed connector. Figure 1 shows a microstrip line fed rectangular microstrip antenna and coaxial fed rectangular microstrip antenna respectively.

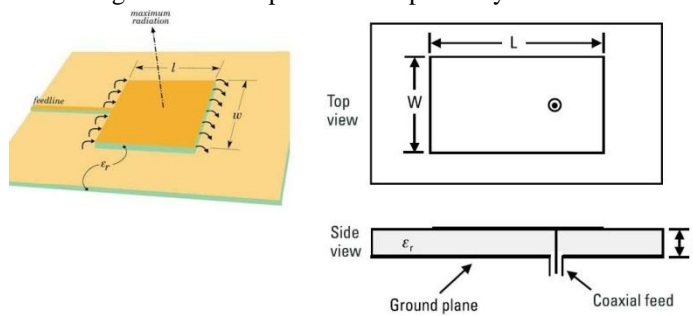


Fig. 1 Basic Microstrip antenna

#### A. Antenna Geometry and Design

A low profile microstrip patch antenna is proposed as shown in Figure 1. Practical microstrip antennas have been developed for use from 400 MHz to 38 GHz, and it can be expected that the technology will soon extend to 60 GHz and beyond.

#### B. Material for printed rectangular microstrip antenna

The propagation constant for a wave in the microstrip substrate must be accurately known in order to predict the resonant frequency, resonant resistance, and the other antenna quantities. Antenna designers have found that the most sensitive parameter in microstrip antenna performance estimation is the dielectric constant of the substrate material, and the manufacturer's tolerance on  $\epsilon_r$  is sometimes inadequate. The dielectric substrate materials used in microstrip antennas are broadly classified in to relative dielectric constant range of 1 to 2 (low dielectric constant), 2 to 4 (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 is required to enhance the bandwidth of the antenna. The substrate material is coated with required conducting material of antenna pattern backed by conducting ground plane. For testing purpose, commonly available FR4 substrate. ( $\epsilon_r$  of 4.4 and loss tangent 0.02) is generally employed. This material comes in standard thickness of 1.59 to 1.6 mm and in various sheet sizes.

#### C. Feeding methods

There are generally three common types of feeding mechanisms in microstrip patch antenna. Microstrip line fed, coaxial connector feed, and aperture feed method. The microstrip line fed method incorporates feed structure on the surface of substrate itself, facilitating us to integrate in microwave integrated circuits. The drawbacks of this feed are cross polar radiations and complex design of matching element. In coaxial feed method, a coaxial connector is directly soldered to patch element and impedance matching is achieved by variable locations of feed, the drawback here is that, it is needed to drill the hole in the substrate material through which the connector protrudes to the patch. In aperture feed method, the patch is indirectly excited by source. The structure becomes complex in this method, but on the other hand it provides more number of variable for optimizing the structure and hence better control of radiation pattern can be achieved.

#### D. Theoretical approaches of analysis

The microstrip antennas (MSA) generally have a two-dimensional radiating patch on a thin dielectric substrate and therefore may be categorized as a two-dimensional planar component for analysis purposes. The analysis methods for MSAs can be broadly divided into two groups. In the first group, the methods are based on equivalent magnetic current distribution around the patch edges (similar to slot antennas). There are three popular analytical techniques:

- The transmission line model;
- The cavity model;



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- The MOM.

In the second group, the methods are based on the electric current distribution on the patch conductor and the ground plane (similar to dipole antennas, used in conjunction with full wave simulation/numerical analysis methods). Some of the numerical methods for analyzing MSAs are listed as follows:

- The method of moments (MoM);
- The finite element method (FEM);
- The spectral domain technique (SDT);
- The finite difference time domain (FDTD) method.

Although the transmission line model is easy to use, all types of configurations cannot be analyzed using this model. Since it does not take care of variation of field in the orthogonal direction to the direction of propagation. In the cavity model, the region between the patch and the ground plane is treated as a cavity that is surrounded by magnetic walls around the periphery and by electric walls from the top and bottom sides. Since thin substrates are used, the field inside the cavity is uniform along the thickness of the substrate. The fields underneath the patch for regular shapes such as rectangular, circular, triangular, and sectoral shapes can be expressed as a summation of the various resonant modes of the two-dimensional resonator. The fringing fields and the radiated power are not included inside the cavity but are localized at the edges of the cavity. However, the solution for the far field, with admittance walls is difficult to evaluate. In multi port network model, the patch structure is divided into 'n' number of ports and field configuration evaluated through each port is finally summed to get total field over the surface. The numerical methods of analysis are more accurate in calculation of dimensions of the patch, but they provide relatively less inside significance compared to analytical methods. On the other hand the analytical methods described above are simple to understand and provides greater details inside significance.

**E. Element Width**

For an efficient radiator, width is given by,

$$W = \frac{C}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \dots\dots\dots(1)$$

Where W represent width of antenna, f0 represent the resonant frequency, C represented velocity of light, ε<sub>r</sub> relative dielectric constant of substrate

**F. Element Length**

To choose the resonant length would also mean choosing the frequency of resonance since the resonant frequency of the patch is determined by the patch length. The length of the patch should be slightly less than half the dielectric wavelength since the actual patch is 'longer' due to the fringing fields. The length of the patch is given as,

$$L_{eff} = \frac{C}{2f_0 \sqrt{\epsilon_{eff}}} \dots\dots\dots(2)$$

Where L<sub>eff</sub> represented effective length of antenna, f0 represent the resonant frequency, C represented velocity of light, ε<sub>eff</sub> effective dielectric constant and ΔL represent the line extension at the ends given by Hammerstad as

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left( \frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left( \frac{W}{h} + 0.8 \right)} \dots\dots\dots(3)$$

Where W is the width of the feed patch and h is the height of the feed patch from the ground plane. The effective dielectric constant ε<sub>eff</sub> may be static or frequency dependent value which is given as follow. The effective dielectric constant ε<sub>eff</sub> may be static or frequency dependent value where,

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( 1 + 12 \frac{h}{W} \right)^{-\frac{1}{2}} \dots\dots\dots(4)$$

Where ε<sub>r</sub> represented relative dielectric constant of material Therefore length of the feed patch can be calculated as



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$$L = L_{\text{eff}} - \Delta L \dots \dots \dots (5)$$

#### IV. COMPARITIVE STUDY

Before two and half decades Deschamps from USA and also Gutton and Bassinot from France delivered the concept of Microstrip antenna (MSA). Later Munson developed microstrip antenna which use as low profile flush mounted antenna on rocket and missiles proved that microstrip antenna was practical concept for use in many antenna system problems and from his valuable invention new era of antenna industry come into birth [1]. Researchers studied the MSAs considering different parameters such as gain, BW, radiation pattern etc. They also consider methods to improve these parameters such as change in shape of patch antenna, change in dielectric substrate, using superstrate, removal of substrate, and combination of different methods.

For enhancement of gain of MSAs array method is effectively used by H. Wang et.al designed 2 x 2 MSA line feed U-slot rectangular array these antenna gave gain of 11.5 dBi and 18% BW [2]. Chao Sun, Jiu-sheng Li proposed planar microstrip antenna for WLAN application at 5GHz WLAN band without any modification as observed in [2] this structure gave gain of 19.72 dBi [3]. M.T.Ali et. al developed 2 x 2 MPA with air substrate at 5.8 GHz operating frequency and they found enhancement of gain up to 38.21% [4]. Horng-Dean Chen, Chow-Yen-Desmond Sim, Jun-Yi Wu, and Tsung-Wen Chiu modified MSA by developing two novel array antenna i.e 3 x 2 and 3 x 3 array antennas for WiMAX application and these antenna structure gave gain of 17 dBi and cover up to 3.3 GHz to 3.8 GHz WiMAX band operating frequency [5]. Tommy Reynalda et al designed 4 x 4 array antenna using dielectric constant of 2.5. This structure is inspired by [4] having difference in number of array and dielectric substrate. Later it compare with single patch antenna having dielectric constant of 2.5. Researcher observed that modified structure has gain 16.02 dB and 150 MHz BW, while single patch antenna has gain 6.10 dB and 50 MHz BW [6]. This proved that array structure enhances the gain of the MSAs. Halim Boutayeb et al proposed new design of MSA introducing cylindrical EBG structure which enhanced the gain of 2.9 dB as compare to conventional MSAs [7]. Shi – Wei Qu et al in the same year designed Y shaped stub proximity coupled V-slot MPA (Microstrip Patch Antenna) and observed 21% BW enhancement and 9 dBi gain feeding technique of this antenna is different than that of researchers [7] [8]. Jung-han Kim et al used very new structure for designing MSA known as SAP i.e. Short Annular Patch structure it improves a gain by 3.12 dBi and 300 MHz BW compare to reference simple rectangular patch antenna [9]. Bahadir Yildirim et.al projected antenna in which a rectangular loop shaped parasitic radiator placed at different distance away from the patch antenna at 1.6 GHz operating frequency gain increases up to 3.3 dB [10]. Change in feed patch structure i.e modification of patch leads to enhance the gain this showed by the authors. Modifications in shape of antenna tends to increase gain of MSAs was scrutinize by these researchers. Furthermore change in dielectric substrate also influences the gain of the MSA. Sudhipta chattopadyay et.al devises rectangular MPA with part of dielectric substrate as PTFE and rest is air and enhanced gain of the MSA [11]. Dongying Li et al considered structure in which low meta-material used as substrate at 9.45 GHz frequency range and observed 80% gain enhancement [12].

Using superstrate in MSAs also contributes in gain enhancement Avinash R. Vaidya et.al deliberate the superstrate height on MSA. They observed that high gain is achieved by placing superstrate layer at above integral multiple of half wavelength above the ground plane [13]. Siew bee yeap and Zhi Ning Chen improved gain of MSA by partial removing the substrate and observed that gain enhanced up to 2.4 dB to 2.7 dB by this method [14]. Different gain enhancement method is studied by the many researchers some authors also combine two methods like

V. Priyashman et.al analyzed the performance of elliptical shaped antenna by using superstrate with random slots at 5.8GHz frequency they also showed that gain and BW influenced by the superstrate structure [15]. In this author combine change in shape along with the superstrate cover. Kaushik Mandal and Partha Prtim Sarkar designed U-shaped patch antenna with two equal arms using PTFE (poly tetra fluoro ethylene) substrate. Just under the U shaped patch introduced inverted U-shaped slot on circular shaped ground plane. They achieved 4.1 dBi gain and BW enhancement of 86.76%. Structural modification in MSAs effect the gain of the MSAs these proved by the researches [16]. Author achieved high gain by combining two gain enhancing method that are change in feed patch shape and change in dielectric material. This stated that hybridizing gain enhancement methods help to improve the gain of MSAs.



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It is summarized that different methods have been attempted for enhancing gain of MSAs. This study reveals that there is further scope to improve gain of MSAs by attempting the hybridization of existing method.

## V. CONCLUSION

Table I: Method comparison table

Sr. no	Method used for enhancing gain	Gain in dB
1	Array Method	17
2	Change of Dielectric	10
3	Partial Removal of Substrate	9.4
4	Change of Dielectric	10

Various methods were examined by the researcher 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 methods individually enhance the gain of MSA is being proved by researches. But still there is scope for improving gain of the antenna by hybridization techniques.

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