Bandwidth Improvement of the Rectangular Microstrip Antenna by Using Single Dipole Stub

Yazdan Khan, Ashish Kumar, Aakash Dhiman

Abstract: In the most recent days microstrip antennas are mostly used in the wireless communication due to the salient features like low cost, less weight, small size. But these antennas are having some drawbacks like narrow bandwidth, low gain etc. In this paper a microstrip antenna with wide bandwidth is presented. For this purpose we took two different radiating elements which are connected together through a matched section and these elements are embedded on a single layer structure. This new introduced structure offers a dual-band microstrip antenna. By controlling the resonant frequency of these two elements, means by keeping constant value of resonant frequency of one element and varying the resonant frequency of other element, then a much more improved bandwidth approximately 21 % has been obtained. Representation, calculation and measurement for this new antenna has been done with the help of software MATLAB and also from EM-TALK online antenna calculator.

Keywords: Bandwidth Improvement; Microstrip Antenna; Radiating elements; Resonant Frequency.

I. INTRODUCTION

These days, there is a very large demand of microstrip antenna for use in wireless applications due to their light weight, smaller size and lesser volume. Also the fabrication process of such kind of antennas is very simple and their production is also easy. But the field of application of these microstrip antennas is limited because they are having a number of disadvantages as compared to the conventional antennas. Some of the disadvantages are its low bandwidth, low gain and also low efficiency [1,2]. There are number of ways by which we can improve the bandwidth of these antennas. Some of the techniques for improving bandwidth of these antennas are: by using thick substrate,[3] by cutting slots in the metallic patch, by using aperture coupled stacked patch antennas etc. But the thick substrate will support surface wave modes that will increase mutual coupling in antenna arrays. Due to this mutual coupling give results to the impedance mismatch, large radiation loss, polarization distortion and scan blindness in phased array antennas.[4,5] Also the other two methods which are stated above i.e. by cutting slots in the metallic patch and by using aperture coupled stacked patch antennas gives result to the increase in complexity to the system and also affect the gain of antenna.[6] The main target of this paper is to present a new antenna configuration with dual-element offering dual-band frequency with a controllable frequency ratio of the two elements.

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Once the frequency response of the dual-element can be controlled, we can get a wide bandwidth antenna configuration by overlapping the two-element frequency response. Finally, the wide-band antenna performance has been improved by using parasitic elements with one of the two elements. Two most commonly used microstrip radiating geometries are rectangular and circular. We used rectangular type of geometry in for the enhancement in bandwidth due to reason that the rectangular shape is the simplest configuration used in fabrication of microstrip antennas.

II. RMPA BASIC DESIGN

A microstrip antenna consists of a metallic pattern on one side of a dielectric substrate and ground plane on the other side of the substrate. In this project I have focused on making a microstrip patch antenna. The antenna patch can have different shapes, but is most likely rectangular. In order to make performance predictions the rectangular patch antenna has the following parameters, where λ0 is the wavelength in vacuum also called the free-space wavelength.

Length(L) : $0.3333\lambda 0 < L < 0.5\lambda 0$
Height(h) : $0.003\lambda 0 \le h \le 0.05\lambda 0$
Thickness(t) : $t << \lambda 0$
Dielectric constant (εr) : $2.2 \le \varepsilon r \le 12$

In electromagnetic radiation λ is often given instead of λ0 as the speed of light in vacuum is very close to the speed of light in air.

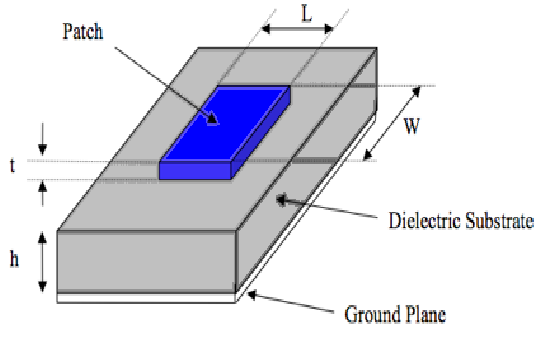

Figure 1: Structure of a microstrip patch antenna.

Dielectric Constant: The dielectric constant [7] (also called "Ɛr", "DK" or "relative static permittivity") is the ratio between the stored amount of electrical energy in a material and to that stored by a vacuum. It is also a measure of the degree to which an electromagnetic wave is slowed down as it travels through the insulating material. Dielectrics are i.e. used in capacitors to store more electrical charge than vacuum. The lower the dielectric constant is, the better the material works as an insulator. The better an insulator, the better it resists electrons from being absorbed in the dielectric material, creating less loss.We have choosen the material PTFE (teflone) whose dielectric constant is 2.22

Thickness: The thinner the substrate is, the less loss, but the less power you can send through it, because the transmission line has to be thinner to keep the same impedance. The thickness also depends on your application. For instance: a designer wants to design a thin mobile phone because that attracts certain customers. This means that there is use for a thinner substrate and you therefore have to cater to it. Thickness for this antenna is taken 1.5875 mm.

III. DUAL-BAND RMPA DESIGN

In this section, a novel dual-band MPA is described where two different radiating elements connected together through a matched section and is embedded on a single layer structure as shown in Figure 2. The first element is a rectangular MPA with frequency f_1 controlled by patch dimensions L_{mpa}, and W_{mpa} and the second element is a printed dipole with frequency f_2 controlled by the dipole dimensions L_{dipole}, and W_{dipole}. The structure is fed by a coaxial probe through the dipole element which is direct coupled to the MPA by a quarter wave length matched section with width $W_{m.s.}$, and length $L_{m.s.}$ [2]. The graph between the resonant frequency and length has been developed with the help of the software MATLAB. Structure parameters given in Table 1 for a resonant frequency f_1 of the rectangular MPA at 5.74 GHz [1]. The calculated results are given in Table 2 which shows that as the dipole length L_{dipole} increases, its resonant frequency f_2 get closer to the RMPA resonant frequency f_1 with slightly decrease in the later resonant frequency.

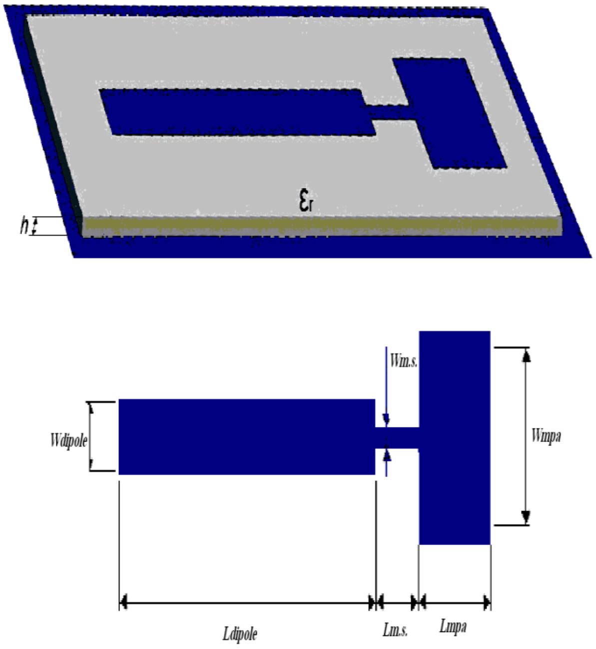

Figure 2: Configuration of the dual band RMPA.

IV. OPTIMIZING THE DUAL-BAND ANTENNA FOR A WIDE BANDWIDTH

It is clear from Table 1 that we can get a wide bandwidth antenna by controlling the length L_{dipole} of the dipole element to get the resonant frequency.

L_{dipole} = 17 mm, and the other parameters which are given in Table 1, has been fabricated on a Duriod substrate with permittivity ε_r = 2.22, and thickness h = 1.587 mm with copper cladding of thickness = 0.017 mm.

Table 1. Designed structure parameters:

Rectangular MPA	L_{mpa} (mm)	W_{mpa} (mm)
	17.00	10.00
Dipole element	L_{dipole} (mm)	W_{dipole} (mm)
	17-21	4.8618
Matching section	$L_{m.s.}$ (mm)	$W_{m.s.}$ (mm)
	5.3405	1.4232

Calculation of Resonant Frequency:

For Microstrip Patch Antenna:

$$f_r = \frac{c}{2L\sqrt{\varepsilon r}}$$

where

c = speed of light

fr = resonant frequency

L = length of RMPA

εr = dielectric constant of the substrate

For Dipole Patch Antenna: $f_r = \frac{1}{2}k\frac{c}{l}$

where

k [8] is an adjustment factor. The adjustment factor compensates for propagation speed being somewhat less than the speed of light. The dipole elements will have distributed inductance and capacitance. The value of *k* is typically 0.95

c = speed of light.

fr = resonant frequency

L = length of dipole antenna

Calculation of Bandwidth

$$B.W. = \frac{Fmax. - Fmin.}{Fceneral} * 100$$

where Fmax. = highest or maximum frequency (frequency of dipole antenna)

Fmin. = lowest or minimum frequency (frequency of dipole antenna)

Fcenteral = mean frequency

Table 2. Calculated results*:*

L_{mpa} (mm)	f_1 of mpa (GHz)	L_{dipole} (mm)	f_2 of dipole (GHz)	$f_2 - f_1$ (GHz)	f_2/f_1
17	5.74	17	8.38	2.64	1.45:1
17	5.74	18	7.91	2.17	1.37:1
17	5.74	19	7.50	1.76	1.30:1
17	5.74	20	7.12	1.38	1.24:1
17	5.74	21	6.78	1.04	1.18:1

As it is cleared from the table which is given above that with the increase in the length of dipole, the resonant frequency of the dipole antenna is decreasing continuously.

Also as the length of RMPA is constant therefore there is no variation in its resonant frequency also. One stage comes when the resonant frequency of both of these elements becomes equal or closer. Then if we calculate the bandwidth of the dipole antenna by the formula which is given above then we come to know that there is a increase of bandwidth, which was our goal.

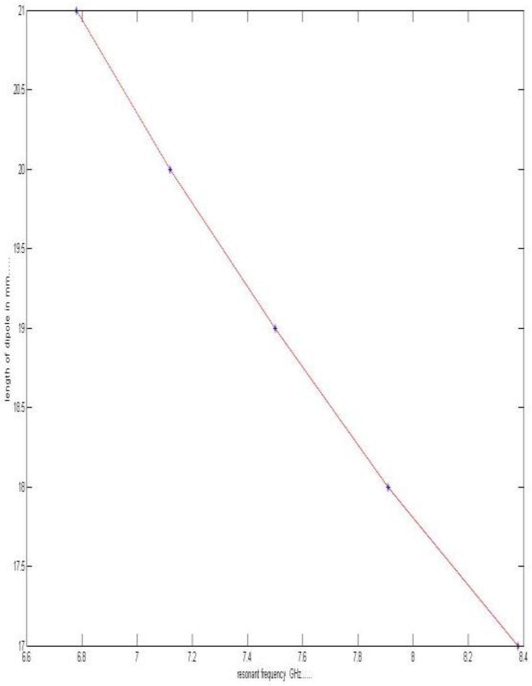

Figure 3: Graph between length of dipole Vs resonant frequency.

V. CONCLUSION

If we consider the bandwidth ratio of resonant frequency in case of dipole antenna. It is improving better and better with the increase in length of dipole. Calculation and measurements on the new proposed antenna configuration have provided a useful design for a wide bandwidth MPA of 21%, or with a controllable frequency separation of the two frequencies of the dual-element with $f_2/f_1 = 1.45 : 1$ for the given construction.

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