Bandwidth Enhancement of Microstrip Patch Antennas for Wireless Applications

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Abstract - *The paper proposes optimization of E-shape antenna for bandwidth enhancement. The antenna is designed to wide bandwidth. Mixed potential integral equations (MPIE) in conjunction with Rao, Wilton and Glisson triangular discretization (RWG basis function) are utilized. The antenna characteristics are analyzed by MOM method. Considering the fact that smaller area is preferable, the technique of modifying the topology of patches is adopted. The basic idea is to modify the structure and see the effects. It has the advantage of wide bandwidth and ease of integration. Height (h) of substrate is 5.8mm. The return loss is below -10db and (VSWR<2) is achieved. The antenna polarization is linear. The antenna finds its application in mobile networks, base antennas, IEEE 802.1a and j standards.*

Key Words: VSWR, Return Loss, MOM, Modified E-Shape, Ultra wide band, IE3D

1. INTRODUCTION

Rapid developments in wireless technology have led to design of many antennas that operate in S and C band. The designed antenna supports IEEE 802.11 a and j standard that can be used for mobile network communication. The increase in demand for wireless communication system has attracted significant interest in antenna design. Many novel designs are being proposed for UWB (ultra wideband) antenna. Microstrip antenna is obvious choice due to their inherent advantages such as low profile, low cost and ease of integration with other microwave solid state devices. Although microstrip antenna suffers from small impedance bandwidth, the bandwidth can be improved by 1) increasing substrate thickness.2) using substrate that has low 3) introducing parasitic patches.4) cutting slots strategically in the metal patch [1] as has been done. In this paper E- shaped patch is modified to enhance the bandwidth. The antenna is fed with coaxial probe. In order to attain better impedance bandwidth E-shaped patch antenna with slots is discussed. By properly choosing the suitable slot shape, selecting the feed and tuning, a large bandwidth is obtained.

1.1 MOM AND THE RWG BASIS FUNCTION

This section describes the use of the RWG basis functions and the MPIE to resolve the method of moments. The RWG basis functions are developed in [2] and used here as both basis and testing functions. Details on the properties of those functions and their derivatives can be found in [2] and will not be repeated here. The mixed potential integral equation(MPIE) formulation is chosen in the present analysis because it provides a less singular kernel as compared with electric field integral equation (EFIE) [3]For a given excitation, the surface current distribution on the antenna structure can be obtained by solving the MPIE through the MOM. The MPIE relates the electric field incident upon the upper conductor to the vector and the scalar potentials generated by the unknown surface current and charge densities [3].

The microstrip antenna structure is assumed to be of 5.8mm thickness. The induced current on the antenna can be obtained for the MOM solutions of the pertinent MPIE. The calculation of the impedance matrix is very complex. It is the principal cause of the heaviness of the moment's method.

1.2 ANTENNA LAYOUT

The configuration of modified E-shape patch antenna is shown in fig-1 and fig-2.

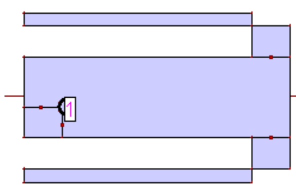

Fig-1: Antenna 1

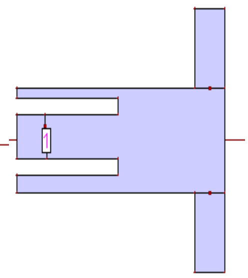

Fig-2: Antenna 2

In the antenna-1 the upper and lower arm is rectangle which will not perturb the surface current and thus there is no introduction of a local inductive effect which is responsible for second resonant mode, and thus we get a wide band. In the antenna-2 the centre arm width has been increased and the upper and lower arms are eliminated to conserve the substrate area and also incorporation of slots has been done. A probe which is an extension of the inner conductor of a coaxial feed line, feeds both the patches. Meshing of both the antennas were done at 7GHz, and the mesh was refined close to probe feed.

2. ANTENNA DESIGN

First a rectangular patch antenna is designed using the following design equations,

$$W = \frac{c}{2f0\frac{\sqrt{\varepsilon r+1}}{2}} \quad (1)$$

$$\varepsilon e = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1 + \frac{10h}{W}]^{\wedge}(-0.5) \quad (2)$$

$$f0 = \frac{c}{2\sqrt{\varepsilon r}}[(\frac{m}{L})^2 + (\frac{n}{W})^2]^{\wedge}0.5 \quad (3)$$

$$Le = L + 2\Delta L = \frac{\lambda}{2\sqrt{\varepsilon e}} \quad (4)$$

$$We = W + 2\Delta W \quad (5)$$

$$\Delta L = \frac{h}{\sqrt{\varepsilon e}} \quad (6)$$

Where,
W=width of the patch
εe = effective dielectric constant
fo= resonant frequency
Le= effective length
We= effective width

The calculation of patch dimensions is based on the transmission line model. A substrate dielectric constant of 4.4 is selected to obtain a compact radiating structure that meets the demanding bandwidth specification. The above antennas shown, is first optimized into basic E-shape design and then the upper and the lower strips of the E-shape are changed into two rectangles to enhance the bandwidth. This method is adopted which results in antenna-1 shown in fig-1. To obtain the antenna-2 configuration the two rectangles were removed and incorporating of slots resulted in fig-2. The antenna geometry was modified twice to obtain a compact structure.

2.1 SUMMARY TABLE OF ANTENNA PATAMETERS

Table-1: Antenna Parameters

Parameters	Antenna1	Antenna2
Length of patch((L)	17.5mm	17.5mm
Width of patch(W)	10.6mm	6.5mm
Length of slot(ls1)	15mm	15mm
Width of slot(ws1)	2mm	5mm
Substrate height	15.8mm	15.8mm
Dielectric constant(εr)	4.4	4.4
Length of slot(ls2)	-	8.5mm
Width of slot(ws2)	-	1mm

In this section two antennas are illustrated. The geometries are designed and optimized using high electromagnetic field simulation software (IE3D). The length and slot parameters (ls), (ws), are adjusted using the simulation software to obtain the desired results to meet the design requirements. A very good bandwidth of about 1610 MHz for antenna -1 and 1808 MHz for antenna-2 is achieved.

2.2 GENERAL ASPECTS

In general, antenna is a resonant device and its input varies greatly with frequency. If the antenna input impedance can be matched to its feeding structure across a certain frequency range then that frequency range will define the antenna bandwidth (BW). The bandwidth can be specified in terms of the return loss or the voltage standing wave ratio (VSWR). The typical values for microstrip antennas are VSWR<2 or return loss (S11 in db) < -10db. Furthermore, the BW is inversely proportional to the quality factor (Q) and given by [4]

$$BW = \frac{VSWR-1}{Q\sqrt{VSWR}} \quad (7)$$

The technique to increase the bandwidth and to decrease the antenna dimensions generally employs, in combined way or otherwise, high dielectric constant substrates, modification of patch shapes of the antennas. Also to reduce the area of the E shape antenna a technique of shorted pin between the patch and the ground plane can be applied in position where the higher frequency has major reduction in value. As the bandwidth for wideband operation is due to interaction between close resonant frequencies, the first basic step is to vary feed positions.

3. SIMULATION RESULTS

Table-2: Performance comparison

Parameters	Antenna1	Antenna2
Bandwidth(MHz)	1610	1808
Return loss(db)	-17.88	-37.27
VSWR	1.13	1.2
Frequency range(MHz)	4.55-6.16	4.5-6.3

3.1 VSWR, RETURN LOSS, DIRECTIVITY

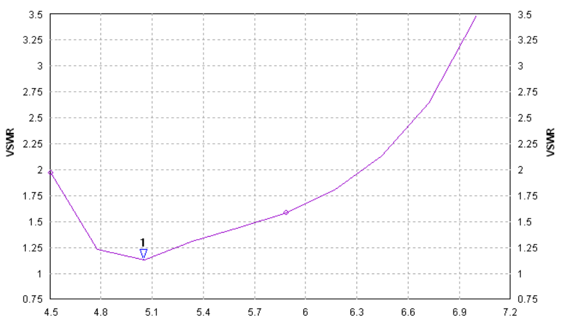

Fig-3: VSWR for antenna-1

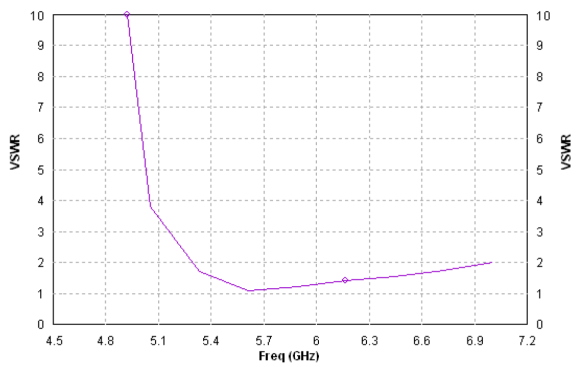

Fig-4: VSWR for antenna-2

The simulation results of the proposed antennas are shown in this section. The return loss gives the understanding that by adding slots symmetrically, the basic radiation characteristics of the rectangular patch do not change. The structure of antenna-1 is evolved from E-SHAPE antenna and further antenna-1 is modified to antenna-2 structure which gives the advantage of reduced area on the patch without affecting the advantage of other characteristics. This is achieved by trial and error method of simulation. In telecommunication, standing wave ratio is the ratio of the amplitude of a partial standing wave at antinodes (maximum) to the amplitude at an adjacent node (minimum).SWR is used as an efficiency measure for the transmission line. It also expresses the degree of match. In fig-4 and fig-5 we can observe that both antennas are well within the VSWR limit. The return loss against frequency for the realised antennas is shown in fig-6 and fig-7. The return loss for antenna-1 is -17.88 db and for antenna-2 it is -37.27 db which is good.

Directivity is a fundamental antenna parameter. It is a measure of how 'directional' an antenna's radiation pattern is. An antenna's normalized radiation pattern can be written as a function in spherical coordinates as

$$F(\theta, \emptyset) \tag{8}$$

Mathematically, the formula for directivity (D) is written as

$$D = \frac{1}{4\pi \int_0^{2\pi} \int_0^{\pi} |F(\theta,\emptyset)|^2 \sin\theta \, d\theta \, d\emptyset} \tag{9}$$

The equation (9) for directivity might look complicated, but the numerator is the maximum value of F, and the denominator just represents the “average power radiated over all directions”. This equation then is just a measure of the peak value of radiated power divided by the average, which gives the directivity of the antenna. Directivity of the two modified E-shape antennas are shown below in fig-7, and fig-8.

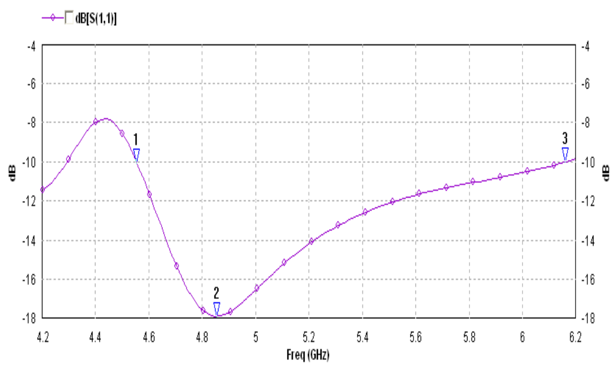

Fig-5: Return loss for antenna-1

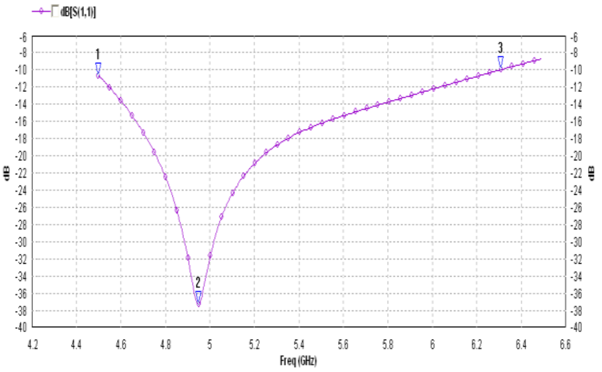

Fig-6: Return loss for antenna-2

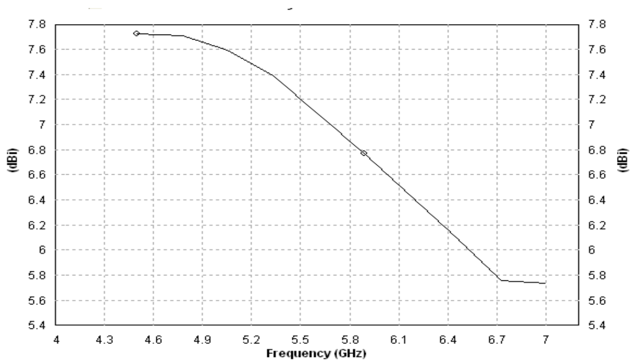

Fig-7: Directivity of antenna-1

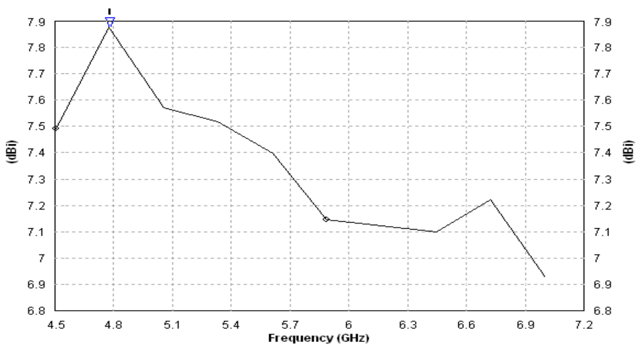

Fig-8: Directivity of antenna-2

After comparing the return loss, polarization and directivity of the two antennas it is found that the resonant frequency of antenna-2 is greater that antenna1 and return loss for antenna-2 is better than antenna-1. Both the antennas are linearly polarized with VSWR well below 2. The directivity of the antenna-1 and antenna-2 are close by each other. Hence the antenna-2 parameters are not more deviated from the antenna-1 parameters and at the same time antenna-2 is occupying less area than antenna-1.

4. CONCLUSIONS

Two wide band modified E-shape microstrip patch antenna has been designed for wireless communication system. The bandwidth of antenna-1 is 1610MHz (from 4.55-6.16 GHz) while the antenna-1 also maintains a thin thickness of 0.1λ at the centre frequency f= 4.85GHz, and for antenna-2 the bandwidth is 1808MHz (from 4.5-6.3 GHz) with centre frequency f=4.94GHz.

Both the antennas are thin and compact with a dielectric constant of 4.4 substrate material. It should be noted that the performances of the proposed antennas are not further optimized using schemes like Powell or fasta optimization. By tuning the arms of the basic E-Shape antenna a wideband antenna has been obtained.

Further enhancement on the antenna parameters can be done by implementing aperture coupling.

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