On The Radiations from Micromachined Patch Antennas

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Abstract

This paper reports a comparative study of regular and micromachined rectangular patch antenna at 3 GHz in L-band of microwave frequency range. Bandwidth, input impedance, total resistance and gain of these antennas have been computed for low and high dielectric substrate. The results are quite encouraging.

1. Introduction

With the advancement in wireless communication technologies, a number of requirements are imposed on antenna systems that are in use. From a technological point of view, wireless communication antenna should be relatively cheap and easy to construct. They should be light weighted and conformal in nature. From an environment point of view, the antenna should have a minimum impact. As such these antennas should have a low profile and should be as compact as possible. This of course also goes for handset antennas where the size of such devices is constantly shrinking. Obviously one type of antenna that fulfills these requirement very well is microstrip antenna. Currently the interest in these antennas has been growing steadily due to their potential applications in radiometry & missile, satellite & radar communication and mobile communication system. In fact these antennas are very practical for space application because they can be flush mounted on the surface of spacecraft or aircraft [1-3].

Micromachined antenna is relatively new concept in which certain radiation characteristics are achieved by using micromachining to eliminate a portion of the substrate material. Here a comparative study of regular and micromachined antenna is carried out.

2. Design of Micromachined Antenna

The geometry of micromachined antenna is shown in fig 1.

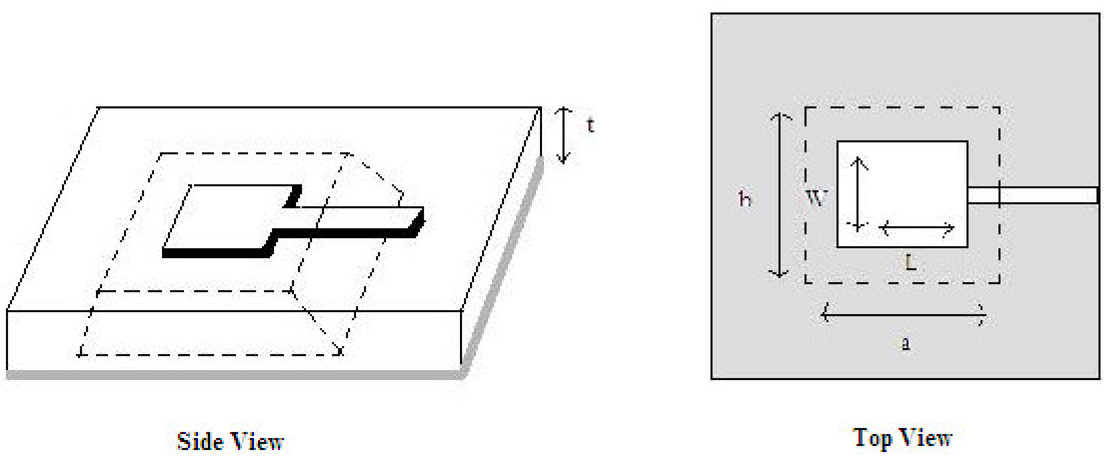

Fig: 1 geometry of micromachined patch antenna with mixed air-substrate region that has been laterally etched away.

This antenna configuration consists of rectangular patch centered over the cavity, sized according to the effective index of the cavity region and fed by a microstrip line. More specifically the antenna is printed on a cavity region that is comprised of the dielectric sections (1) air (2) high dielectric substrate. Using micromachined technique, substrate is laterally removed from a cavity region producing a substrate area that has thickness < 50% of the original substrate thickness and an air region that is created by the removal of the material. A cavity model is used to predict the effective dielectric constant of mixed air-substrate region for varying thickness ratios underneath the patch antenna. The effective dielectric constant ϵ_{reff} is given below [4-5].

$$\epsilon_{reff} = \epsilon_{cavity}\left[\frac{L + 2\Delta L\frac{\epsilon_{fringe}}{\epsilon_{cavity}}}{L + 2\Delta L}\right] \tag{1}$$

$$\frac{\epsilon_{fringe}}{\epsilon_{cavity}} = \frac{\epsilon_{air} + (\epsilon_{sub} - \epsilon_{air})\chi_{air}}{\epsilon_{air} + (\epsilon_{sub} - \epsilon_{air})\chi_{fringe}} \tag{2}$$

$$\epsilon_{cavity} = \frac{\epsilon_{air}\epsilon_{sub}}{\epsilon_{air} + (\epsilon_{sub} - \epsilon_{air})\chi_{air}} \tag{3}$$

Here the ϵ_{cavity} represents the relative dielectric constant of the mix substrate constant and ϵ_{fringe} represents the relative dielectric constant in the fringing field region respectively. Thus using these concept regular and micromachined antenna has been designed. The representations of these designs are as follow [6-7].

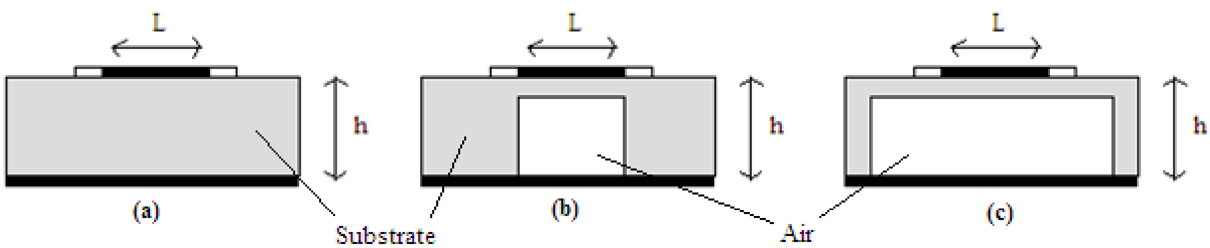

Fig: 2 Geometry for the (a) regular patch antenna-Type I, (b) micromachined patch antenna with radiating edges into the substrate-Type II, (c) radiating edges over the mixed air-substrate cavity-Type III.

3. Results and Discussions

The analysis and computation has been carried out for three types of antenna geometry as follow:

- The conventional regular patch antenna type I on low ($\epsilon_r = 2.33$) and high ($\epsilon_r = 10.8$) index material.
- Antenna of type II in which substrate is removing 80% just below the patch by using etching technique such that the radiating edges are into the substrate of low and high index.
- Antenna of type III printed on a mixed air-duroid cavity such that the radiating cavity is over the mixed air-duroid substrate cavity. The duroid substrate of low ($\epsilon_r = 2.33$) and high ($\epsilon_r = 10.8$) index constant (dielectric loss tangent tan δ=0.00066) with varying substrate thickness 'h' have been considered.

The important antenna radiation parameters for type 1, 2, and 3 have been estimated at 3 GHz. The comparisons of the results for bandwidth, input impedance, total resistance and gain are given in table 1 to 4 respectively.

Table: 1 Bandwidth on regular & micromachined patch antennas at 3 GHz

h (cm)	Bandwidth (%) of antenna at $\epsilon_r = 2.33$			Bandwidth (%) of antenna at $\epsilon_r = 10.8$		
	Type I	Type II	Type III	Type I	Type II	Type III
0.159	1.6	1.9	2.1	0.9	1.2	2.0
0.559	6.6	8.1	8.0	4.5	4.6	7.9
0.959	13.6	17.4	15.6	11.0	1.8	15.4
1.359	22.1	28.3	24.0	18.4	-	23.8

Table: 2 Input Impedance on regular & micromachined patch antennas at 3 GHz

h (cm)	Input Impedance (ohms) of antenna at $\epsilon_r = 2.33$			Input Impedance (ohms) of antenna at $\epsilon_r = 10.8$		
	Type I	Type II	Type III	Type I	Type II	Type III
0.159	171-j1.7	219.9-j2.6	152.5-j1.9	258.6-j1.4	469.1-j3.4	153.0-j1.9
0.559	153.5-j6.4	182.7-j9.1	154.3-j7.4	214.5-j5.8	269.7-j7.6	153.9-j7.4
0.959	146.7-j12.2	148.3-j15.8	152.1-j14.6	176.2-j11.9	1056.7-j11.8	150.1-j14.2
1.359	142.5-j19.3	134.2-j23.3	157.8-j23.3	181.4-j20.4	-	155.1-j22.6

Table: 3 Total Resistance on regular & micromachined patch antennas at 3 GHz

h (cm)	R_T (ohms) of antenna at $\epsilon_r = 2.33$			R_T (ohms) of antenna at $\epsilon_r = 10.8$		
	Type I	Type II	Type III	Type I	Type II	Type III
0.159	300.65	192.59	192.31	1064.95	202.96	200.68
0.559	299.88	191.76	191.74	1062.36	200.37	200.09
0.959	299.78	191.59	191.67	1062.11	204.16	200.02
1.359	299.75	191.63	191.65	1062.07	-	200.00

Table: 4 Gain on regular & micromachined patch antennas at 3 GHz

h (cm)	Gain (dB) of antenna at $\epsilon_r = 2.33$			Gain (dB) of antenna at $\epsilon_r = 10.8$		
	Type I	Type II	Type III	Type I	Type II	Type III
0.159	8.1817	8.1730	8.1794	8.1834	8.1307	8.1796
0.559	8.1929	8.1918	8.1922	8.1938	8.1864	8.1923
0.959	8.1943	8.1941	8.1939	8.1949	8.1051	8.1939
1.359	8.1949	8.1947	8.1944	8.1952	-	8.1944

4. Conclusions

A comparative study of regular and micromachined rectangular patch antenna have been performed and the results are presented for bandwidth, input impedance, total resistance and gain of antennas under investigations. It reveals from the results that due to micromachining a significant improvement in the bandwidth has been found. Thus the concept of micromachining may be useful for realizing broadband microstrip antenna which has its potential applications.

5. References

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