Broad Band Parasitically Coupled Concentric Semi Circular Elliptically Ring Antenna Surrounding an Elliptical Patch with Air Gap

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***Abstract*:- The paper presents the performance of a parasitically coupled semi circular elliptical ring antenna surrounding elliptical patch geometry having air gap between conducting patch and ground plane. With proposed modifications in the conventional circular patch geometry, the bandwidth of modified antenna with an air gap is around seven times higher than that of a simple circular patch antenna. The gain, directivity and efficiency of modified circular patch antenna with air gap is also improved to some extent but still these are less than desired values. The E and H plane radiation patterns presented by antenna in the frequency range where broadband performance is obtained are identical in shape and nature. Direction of maximum intensity retained by antenna at both frequencies is normal to patch geometry.**

I. INTRODUCTION

The major limitation of microstrip antennas is their capability to operate at a single frequency, narrow bandwidth (of the order 1-2%) and low gain. However for present day communication systems which require compact size antennas, microstrip antennas are highly suitable geometries. Extensive work started in recent past to achieve higher performance with microstrip antennas without losing their compact size. Several methods and geometries having improved bandwidth and gain were proposed in recent past [1-4]. Lee and Dahale [5] & Guha [6] proposed an easy way to improve the performance of patch antennas by introducing air gap between radiating patch and ground plane. This is an easy method for achieving higher bandwidth but at higher frequencies, where this metallic layers as patch and ground plane are required, structure with air gap no more remains stable. The uniform thickness between radiating patch and ground plane is difficult to achieve. In this paper, two identical dielectric layers separated by air gap are applied. Radiating element is etched on side of upper substrate and ground plane on back side of other material. Two sides of substrate layers facing each other are separated by a distance ‘d’ and do not have copper layer deposited on them. In this way structure having uniform air gap is more stable and air gap between the radiating element and ground plane may be varied through attached screws.

II. ANTENNA GEOMETRY AND SIMULATED RESULTS

(a) Circular patch antenna with air gap

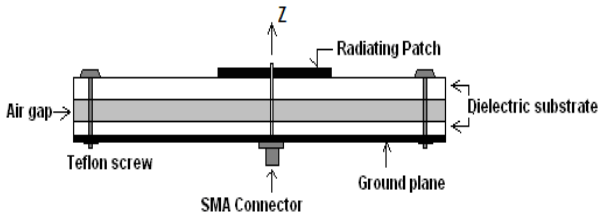

Figure (1): Side view of application of air gap in microstrip antenna patch geometry

A conventional circular patch antenna having physical radius 12 mm designed on glass epoxy FR-4 substrate (relative substrate permittivity ε_r = 4.4, substrate loss tangent 0.0148, substrate thickness ‘h’=1.58 mm) with no copper layer on its back side is shown in figure-1, through upper layer. The lower glass epoxy FR-4 substrate material has ground plane but no copper layer on its top side. Both these layers are arranged parallel to each other with separation ‘d through Teflon screws. Antenna is fed through inset feed arrangement by applying suitable SMA connector and 50 ohm coaxial cable.

With the present arrangement, the effective permittivity and loss tangent of the substrate reduces and the over all thickness of entire antenna geometry is less then 5mm. Guha [6] reported a relation to compute the equivalent dielectric constant of the substrate when radiating patch and ground plane are separated by single dielectric of thickness h_d and single air gap of thickness h_a. In the present case since we have two dielectric layers separated by an air gap in between radiating patch and ground plane, we therefore modified earlier reported relation [6] to obtain effective relative permittivity of the substrate under present arrangement as:

$$\varepsilon_{re} = \frac{\varepsilon_r \,(h_a + 2.h_d)}{(2.h_d + h_a\,\varepsilon_r)} \qquad (1)$$

The total height of substrate material will be $h = h_a + 2.h_d$. The present equivalent model reduces to the single layer structure having substrate thickness $2h_d$ when air gap width will be taken as $h_a = 0$. The

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resonant frequencies of conventional circular patch antenna having radius 'a' in z-independent TM_{mn} modes satisfying the perfect magnetic wall boundary condition are obtained following Wolff and Knoppik [7] as:

$$f_r = \frac{(K_{nm} a)c}{2\pi a_e \sqrt{\varepsilon_d}} \qquad (2)$$

where a_e is the effective radius of the patch and ε_d is the dynamic permittivity which is a function of dimensions of patch, equivalent permittivity of substrate material and field distribution under the patch for the mode under consideration. The computed resonance frequencies of circular patch microstrip antenna geometries with three air gap 'h_a' value are shown in table-1 for dominant TM_{11} mode of excitation following [7]. The antenna geometry is also simulated through IE3D simulation software [8] and its resonance frequencies are also arranged in this table. A fairly agreement between computed and simulated resonance frequency is recorded.

Table-1: Computed and simulated resonance frequency of CMPA geometry in TM_{11} mode with air gap. 'a'= 12mm, 'ε_r' =4.4

Air gap thickness	**Resonance frequency (GHz)**	
	Calulated	**Simulated**
h_a = 0 mm	3.494	3.2
h_a = 0.5 mm	4.224	4.5
h_a = 1 mm	4.705	4.7

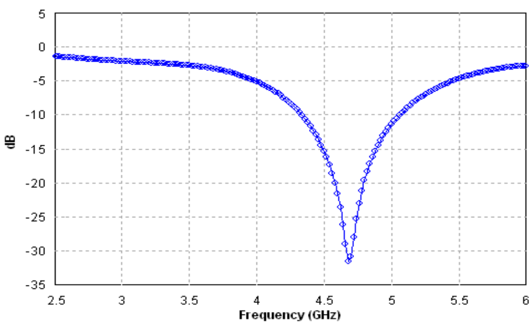

Fig. 2: Simulated return loss of a simple circular patch antenna with air gap h_a = 1mm

The simulated radiation return loss variation of antenna indicating its resonance frequency corresponding to dominant TM_{11} mode is shown in figure -2. On introduction of air gap of thickness h_a = 1.0 mm, the resonance frequency of this antenna now becomes 4.7 GHz which was 3.2GHz when no air gap was present i.e. h_a = 0. The band width of antenna is improved considerably up to 15.23 % which was 4.88 % in the absence of air gap. The E and H plane elevation pattern of antenna at frequency 4.7 GHz is shown in figure 3 which indicates that patterns are directed normal to the patch geometry with 3dB beam width nearly 87^o and 77^o in E and H planes respectively.

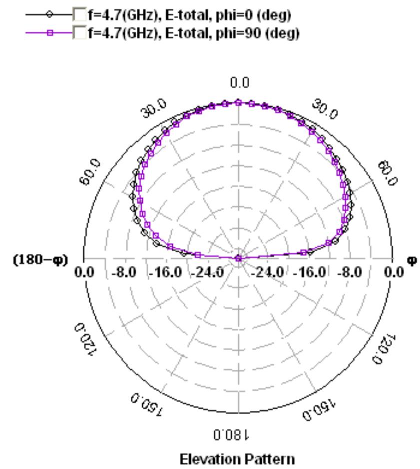

Fig. 4.6 (a): Simulated elevation patterns of a simple circular patch antenna with air gap h_a = 1mm

(b) Parasitically coupled semi circular elliptical ring antenna surrounding elliptical patch with air gap

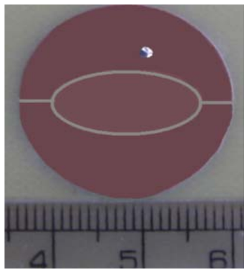

Fig.4: Parasitically coupled semi circular elliptical ring antenna surrounding elliptical patch geometry

A single layer parasitically coupled semi circular elliptical ring antenna surrounding elliptical patch antenna on glass epoxy FR-4 substrate is shown in figure – 4. With proposed modifications in conventional circular patch geometry, antenna now resonates at two frequencies 5.01GHz and 5.29GHz and presents impedance bandwidth up to 8.38% which is around three times higher than that of a conventional circular patch antenna under similar conditions.

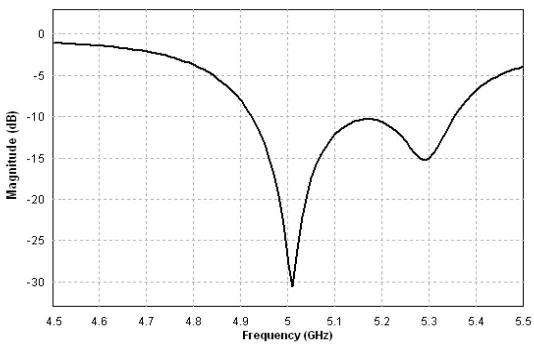

Fig. 5: Variation in return loss with frequency for proposed single layer antenna

An arrangement similar to that considered in previous case for applying an air gap of thickness h_a is again considered for the analysis of this modified circular patch antenna geometry with air gap.

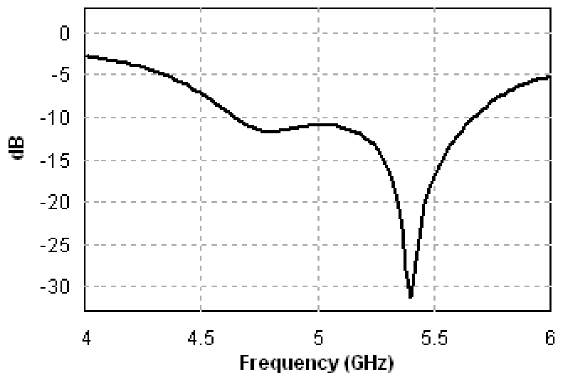

Fig.6: Measured return loss of modified circular patch antenna with air gap h_a = 1mm

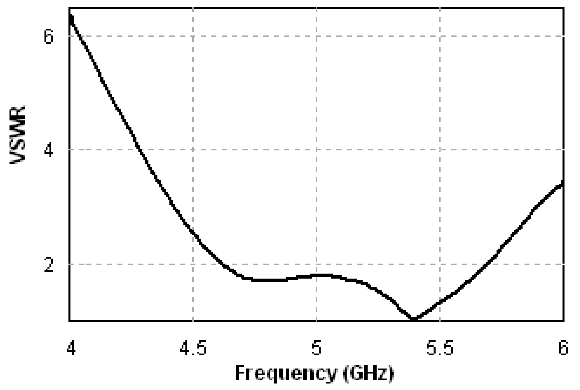

Fig. 7: Measured VSWR of modified circular patch antenna with air gap h_a = 1mm

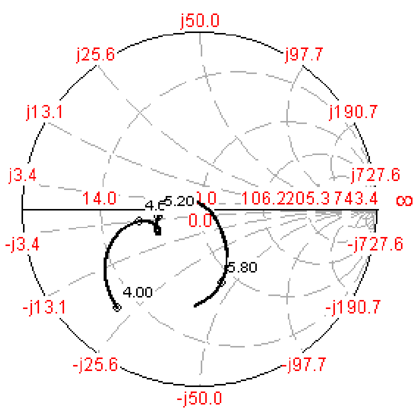

Fig. 8: Measured input impedance of modified circular patch antenna with air gap h_a = 1mm

The variation of return loss of antenna as a function of frequency is shown in figures-6. On introducing air gap, antenna is no more resonating at two closely spaced frequencies but rather these two frequencies are merged together at 5.4 GHz. An additional resonance frequency 4.8GHz comes into picture though with poor matching with feed network still its presence has improved the over all bandwidth of antenna to a great extent. The net result is that the bandwidth of antenna has jumped to 20.07% which is around seven times higher than that of a simple circular patch antenna and more than double in comparison to results shown in figure- 5. The variations of VSWR and input impedance of antenna with an air gap of 1mm are shown in figures-7 and figure-8 respectively. These results are presenting excellent matching between antenna geometry and feed network at one of the two frequencies (5.4 GHz).

The elevation plane simulated radiation patterns of this antenna with h_a = 1.0 mm are shown in figures 11a and 11b for two resonance frequencies. These patterns suggest that in both cases, direction of radiation intensity is maximum normal to the patch geometry and patterns are almost symmetric in nature. The E-plane patterns are marginally more directive than H-plane patterns.

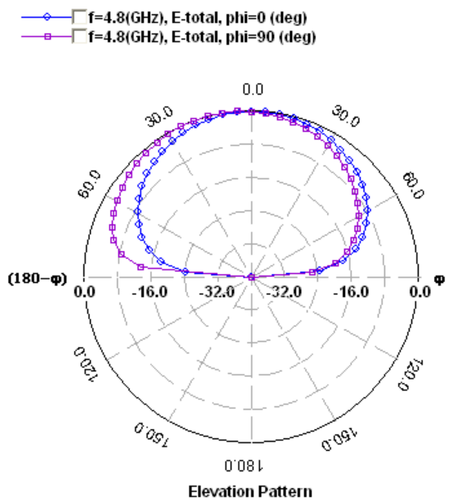

Fig.12a: Simulated elevation patterns of modified circular patch antenna with air gap h_a = 1mm

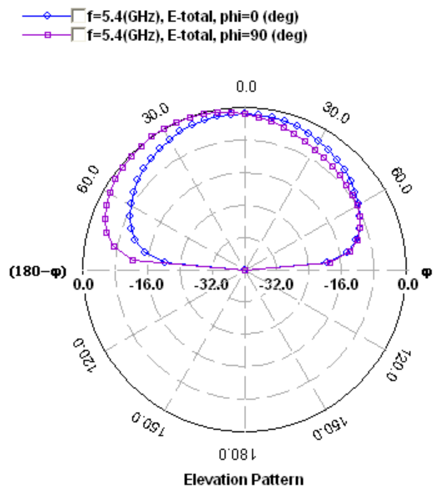

Fig. 12b: Simulated elevation patterns of modified circular patch antenna with air gap h_a = 1mm

A comparison between the performance of three antenna geometries viz. a single layer modified circular patch antenna, modified circular patch antenna with air gap h_a = 0.5mm and same antenna with h_a = 1mm is reported in table -2. The results suggest that gain, directivity and bandwidth of antenna under the presence of air gap of 1mm between the patch and the ground plane are improved considerable than that observed with a single layer antenna.

Table-2: Parasitically coupled semi circular elliptical ring antenna surrounding elliptical patch geometry under different conditions

Type of Antenna	Air Gap (mm)	Resonance Frequency (GHz)	Radiation Efficiency (%)	Directivity (dBi)	Gain (dBi)	Bandwidth (%)
Antenna No-1	Single dielectric layer	5.01	50.36	7.08	4.10	8.38
		5.29	28.93	6.75	1.23	
Antenna No-2	$h_a = 0.5$	4.73	41.09	8.14	3.98	18.86
		5.33	34.43	8.43	3.79	
Antenna No-3	$h_a = 1$	4.82	44.53	8.46	4.64	20.07
		5.43	43.97	8.40	4.83	

III DISCUSSION AND CONCLUSIONS

The simulation analysis of a parasitically coupled semi circular elliptical ring antenna surrounding elliptical patch geometry having air gap between conducting patch and ground planes is reported in this paper. With the introduction of thick substrate, effective radius of antenna decreases which in turn increases the resonance frequency of antenna. Since our aim was not to increase the resonance frequency to a large extent therefore we simultaneously introduced air gap between the two substrate materials. Due to this insertion, effective dielectric constant of the substrate material reduced and in turn the resonance frequency is decreased.

The obtained results suggest that the bandwidth of modified circular patch geometry with an air gap is around seven times higher than that of a simple circular patch antenna and direction of maximum radiations is normal to the patch geometry. The gain, directivity and radiation efficiency of proposed geometry are also improved to some extent but their obtained values are not up to desired target. The reason is obvious. We have applied substrate material having high loss tangent in antenna geometry. Though with application of air gap, effective dielectric constant and dielectric losses are marginally reduced but further better results are expected with substrate materials like foam material. The simulation results are encouraging and suggest that this antenna geometry with little more alterations, may be proved a useful structure for modern communication systems

ACKNOWLEDGEMENT

Authors express their sincere thanks to DST, New Delhi for supporting this work by sanctioning a research project.

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