VARIABLE RADIATION PATTERN FROM CO-AXIAL PROBE FED RECTANGULAR PATCH ANTENNA USING METAMATERIALS

Saleem Akram[1], T. Venkata Ramana[2]

[1]*Research scholar, Dept of ECE, GITAM University, Vishakapatnam, India*
[2]*Associate Professor, Dept of ECE, GITAM University, Vishakapatnam, India*

Abstract

The idea of obtaining variable radiation patterns from the same antenna is important aspect in achieving the adaptive antenna systems. In the EM signal processing the change of radiation signifies the information to be transmitted, its rate of transmission, the geographical changes and direction to transmit etc. i.e. each time when the requirement arises to change the radiation pattern it has to be done to satisfy the conditions. Electronically steerable antennas were used where the antenna radiation will be altered by varying the feed and similar case is applied for shaped patterns from array antenna where the feed to be given will be calculated and given accordingly. In the present concept the metamaterials are used to obtain different radiation patterns occurred at different operating frequencies using the same antenna without changing the antenna physically are varying its feed.

Key Words: *Inductance, capacitance, operating frequency, variable radiation, enhancement, radiation cancellation.*

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1. INTRODUCTION

In the past few decades the research carried out on metamaterials proved to be useful in creating new kinds of artificial magnetic conductors which exhibits unique properties when used in EM applications. Originally the metamaterials are invented to reduce the surface wave propagation in the antennas and stop speckle interference [1-3]. Later it is seen that these metamaterials will vary the radiation coming from the radiating element either in a constructive way i.e. enhancement, or in a destructive way i.e. radiation cancellation [4]. When the metamaterials are used as ground plane or the reflector in antenna applications, when antenna is radiating its energy generally has amplitude and the phase likewise the metamaterial exhibits its own EM waves consisting amplitude and the phase. If the phase of the radiating element energy in particular direction and place is similar to EM wave coming from metamaterial ground or reflector these vectors will be added together this will leads to the enhancement in radiation similarly if they are same and having opposite sign they will cancel each other results radiation cancellation [5]. With these qualities this metamaterials used to obtain the directional beams to enhance the radiation of antenna into particular area [6].

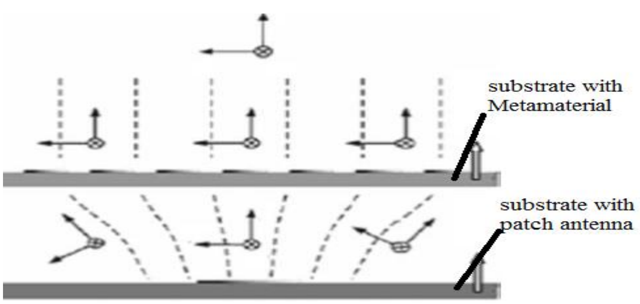

Figure [1] Radiation principle of patch antenna tuned with Met material structure

The gain of an antenna refers to the ratio of its radiation energy in a specific direction to its power in all directions [7].Patch antenna with metamaterial cover plays a vital role in controlling the EM wave propagation direction. In the far-field view, the radiation coming from the sides will be reduced and the forward radiation will be enhanced in the radiation pattern. As results the gain will increase and a more directional antenna will be obtained [8-9].

2. DESIGN OF METAMATERIAL AND PROPOSED ANTENNA

The metamaterial used in this work is general one, a square shaped metal sheet is used and it is supported by a cylindrical shape metal pin and are placed in a periodic manner on a common metal ground. 4×4 array periodic structure is used and the metal used for the design in cooper which has relative permittivity 1F/m and relative permeability 0.999991H/m. the proposed metamaterial structure is designed using the Anasoft HFSS 15 and the model is as shown in the figure [2]. The dielectric substrate filled in the gapes will also affect the working of these artificial magnetic conductors and proper care is needed when filling these substrates when the working antenna is a patch antenna because the patch antenna also has dielectric substrate below the radiating element in this work the gap is left unfilled.

The antenna used is coaxial probe fed rectangular patch antenna designed to work at 10GHz frequency. The patch size is 1.19cm×0.9cm, ground dimension is 3cm×3cm and substrate dimension is 3cm×3cm×62mil the substrate used is Rogers Rt/duroid 5880(tm) which has relative permittivity 2.2F/m and relative permeability 1H/m. the feed is given to the antenna by coaxial probe with pec material carrier inside having a radius of 0.025cm and the wave port resistance is set to default 50ohm.the antenna model is shown in the figure [3].

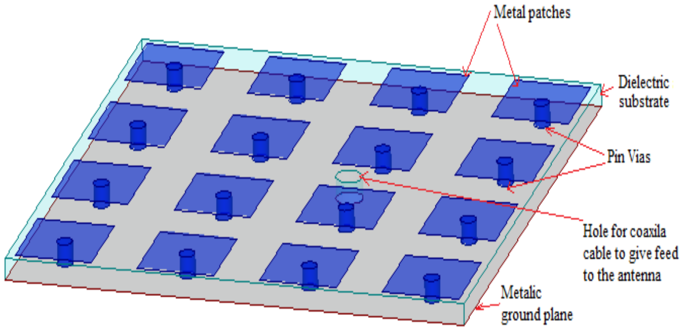

Figure [2] Designed metamaterial structure

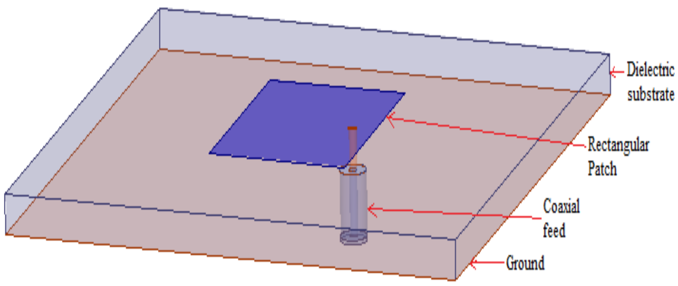

Figure [3] Co-axial probe fed rectangular patch antenna (10GHz)

Now the tuning is made by varying the metallic plate and pin dimensions of the metamaterial and the variations in pin length LP are 0.1,0.15,0.2,0.25 and 3cm and the variations in metallic plate dimensions PS are 0.6,0.55 and 0.5cm this tuning of metallic plate size changes the gap between plates G to 0.2, 0.25 and 0.3cm respectively. And this tuning is explained in the below figure [4].

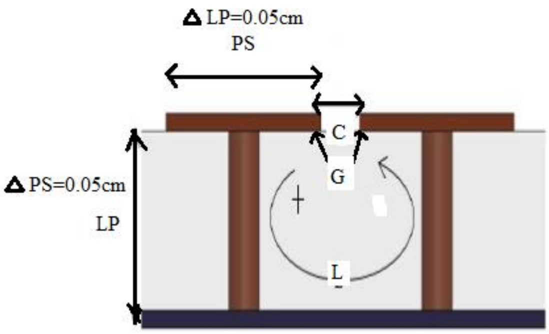

Figure [4] Tuning of metamaterial structure

In the above figure when ΔPS and ΔLP are changed the change in PS is the change in gap i.e. it varies the capacitance C in the tuning circuit the change LP changes the induced current in pin via i.e. changes the inductance L in the circuit this will affect the overall impedance of the metamaterial structure.

The L and C are determined by the equation 1 and 2.

$$L = \mu_o LP \quad \ldots 1$$

$$C = PS\varepsilon_o(1+\varepsilon_r)\cosh^{-1}\left(\frac{2PS+G}{G}\right)/\pi \quad \ldots 2$$

Where μ_o is the permeability of free space,
ε_o is the permittivity of free space,
PS is patching size,
G is gap between patches,
LP pin length or thickness of dielectric substrate filled in metamaterial,
And ε_r is dielectric Constant.

3. RESULTS

3.1. Working Of Designed Antenna

The designed rectangular patch antenna is simulated and its return loss curve is illustrated in the figure [5].

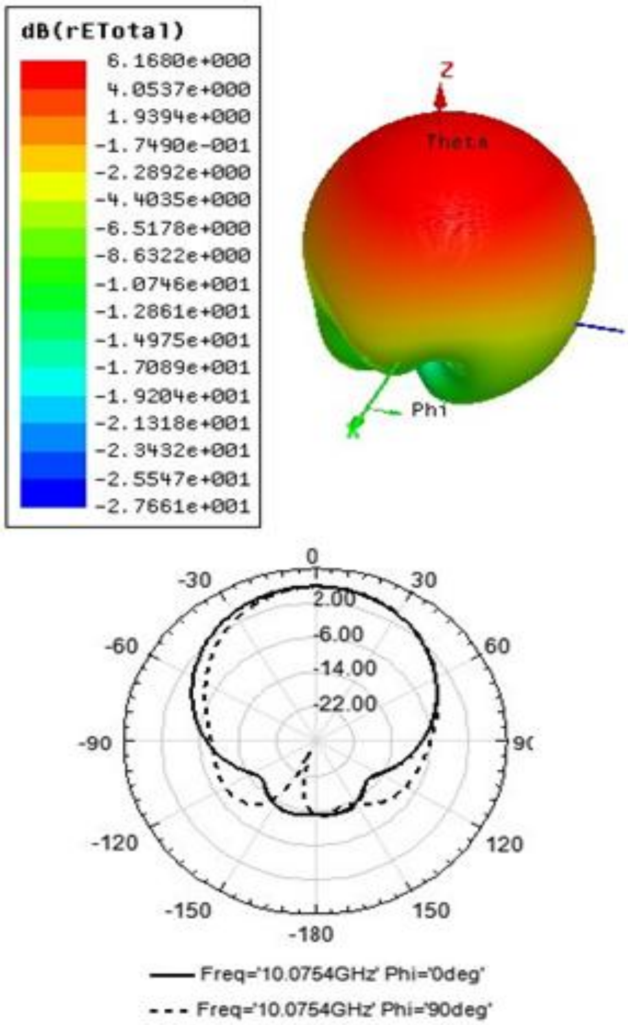

Figure [5] a), Radiation pattern of co-axial fed rectangular patch antenna at operating frequency of 10.0754GHz for phi=0° & 90° and b) 3D radiation energy

In the above figure [5] the conventional antenna works at 10.0754GHz frequency and radiation pattern is described.

3.2. Antenna Gain Enhancement and Variable Radiation Pattern Using Metamaterial Structure of Different Dimensions.

Now the ground plane of designed antenna will be replaced by the periodic metamaterial structure and the change in operating frequency and return loss are illustrated in figures [6] to [10]. Each time when ΔLP occurs ΔPS occurs 3 times. The tuning of dimensions is illustrated in the following Table 1.

Table - 1: Change in dimensions for Tuning

Length of pin LP(ΔLP= 0.05cm)	Patch size PS (ΔPS=0.05cm), Gap G					
0.1	PS=0.6cm	G=0.2cm	PS=0.55cm	G=0.25cm	PS=0.5cm	G=0.2cm
0.15	0.6	0.2	0.55	0.25	0.5	0.2
0.2	0.6	0.2	0.55	0.25	0.5	0.2
0.25	0.6	0.2	0.55	0.25	0.5	0.2
0.3	0.6	0.2	0.55	0.25	0.5	0.2

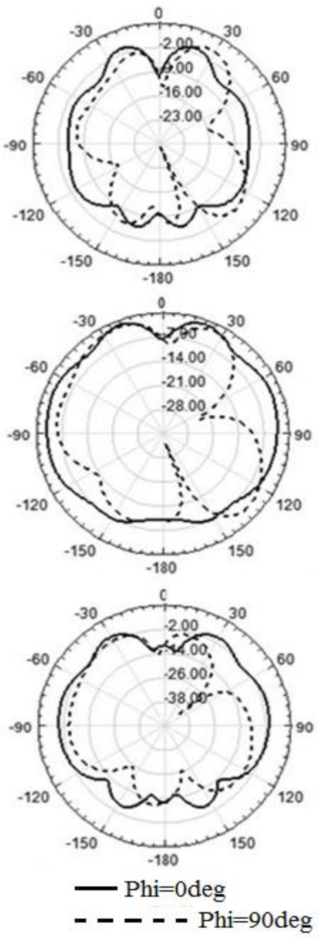

Figure [6.a] Radiation pattern of co-axial fed rectangular patch antenna a) LP=0.1cm, PS=0.6cm operating at 17.8141GHz, b) LP=0.1cm, PS=0.55cm operating at 18.7487GHz & c) LP=0.1cm, PS=0.5cm operating at 19.809GHz

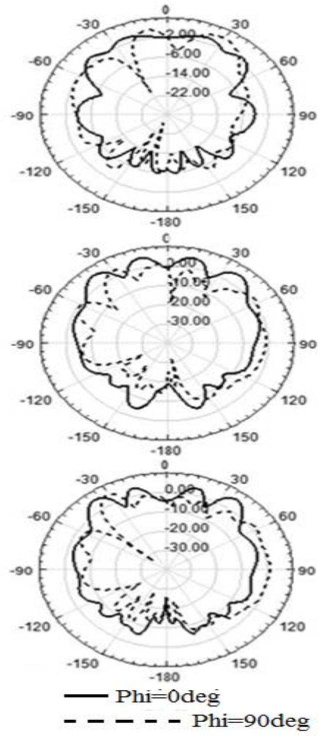

Figure [7] Radiation pattern of co-axial fed rectangular patch antenna a) LP=0.15cm, PS=0.6cm operating at 32.6382GHz, b) LP=0.15cm, PS=0.55cm operating at 45.4975GHz & c) LP=0.15cm, PS=0.5cm operating at 46.0201GHz

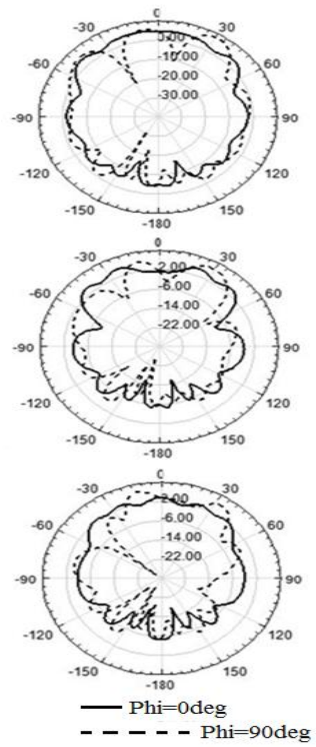

Figure [8] Radiation pattern of co-axial fed rectangular patch antenna a) LP=0.2cm, PS=0.6cm operating at 31.3618GHz, b) LP=0.2cm, PS=0.55cm operating at 33.1759GHz & c) LP=0.2cm, PS=0.5cm operating at 34.8643GHz

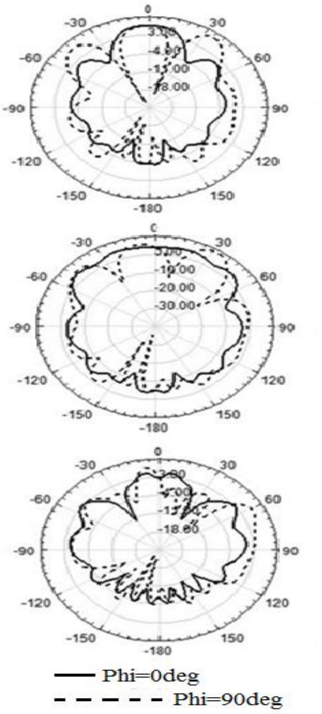

Figure [9] Radiation pattern of co-axial fed rectangular patch antenna a) LP=0.25cm, PS=0.6cm operating at 29.9397GHz, b) LP=0.25cm, PS=0.55cm operating at 31.5276GHz & c) LP=0.25cm, PS=0.5cm operating at 40.2111GHz

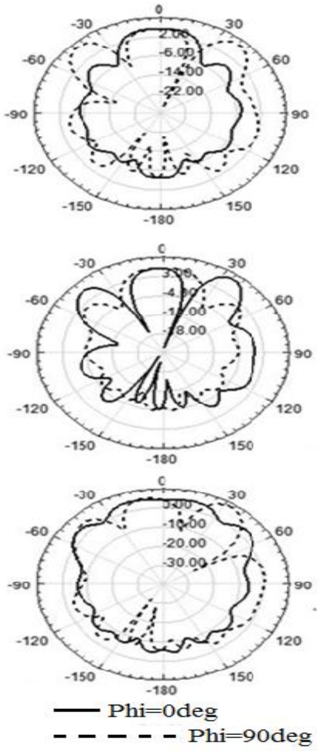

Figure [10] Radiation pattern of co-axial fed rectangular patch antenna a) LP=0.3cm, PS=0.6cm operating at 28.5327GHz, b) LP=0.3cm, PS=0.55cm operating at 29.799GHz & c) LP=0.3cm, PS=0.5cm operating at 30.9296GHz

In the above radiation pattern curves one can observe that whenever the distance between the metallic plates increases the radiation at +90^o to -90^o area leakages increase and the distribution of energy and its operating frequency changes every time according to the tuning of metamaterial structure.

Table – 2: Effect of metamaterial tuning on antenna parameters

Dimensions	Max U (W/sr)	Peak Directivity	Peak Gain	Radiation Efficiency	Front to Back Ratio
Conventional	0.00548824	7.02935	6.9856	0.993776	121.234
0.1LP0.2G	0.00283858	3.80819	3.76407	0.988413	2.12879
0.1LP0.25G	0.00320195	4.15929	4.09748	0.985139	2.43905
0.1LP0.3G	0.00415483	5.354	5.27623	5.27596	5.36602
0.15LP0.2G	0.00615336	7.87296	7.98108	1.01373	749.107
0.15LP0.25G	0.00847116	10.6148	10.8145	1.01881	44.5095
0.15LP0.3G	0.00728993	9.10142	9.27382	1.01894	81.1061
0.2LP0.2G	0.00925343	11.5971	11.7563	1.01373	174.033
0.2LP0.25G	0.00723529	9.10326	9.20486	1.01116	132.288
0.2LP0.3G	0.00660228	8.53494	8.6673	1.01551	31.1793
0.25LP0.2G	0.00881602	11.0712	11.2365	1.01493	20.9867
0.25LP0.25G	0.0101733	13.0118	13.1656	1.01182	75.1659
0.25LP0.3G	0.00647478	8.39098	8.6877	1.03536	25.8414
0.3LP0.2G	0.00851799	10.861	10.9949	1.01233	6.81477
0.3LP0.25G	0.00887289	11.7004	11.8648	1.01405	21.863
0.3LP0.3G	0.00936258	12.846	13.0223	1.01373	65.4667

In the above table 2 the conventional antenna gives peak gain of 6.9856 where it is reduced in case of 0.1cm LP size that explains the radiation cancelation or loss. In all other cases the gain in enhanced due to the enhancement of radiation in forward direction. For 0.25cm LP&0.25cm G it gives highest peak gain of 13.1656, peak directivity of 13.0118 and radiation intensity of 0.0101733(W/sr). For 0.25cm LP & 0.3cm G the proposed antenna gives best radiation efficiency and best front to back ratio at 0.15cm LP & 0.2cm G.

4. CONCLUSION

The proposed antenna is analyzed by changing the metamaterial ground to different dimension and each time the antenna produced various radiation patterns generated at different frequencies. And metamaterials also enhanced the antenna parameters like gain, directivity, radiation intensity, front to back ratio and radiation enhancement etc. so according to the design of metamaterial the antenna operating frequency and its parameters can be enhanced or reduced.

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BIOGRAPHIES

Saleem Akram was born in India, A.P in 1984. He received M.Tech (Communication Engg) from VIT University, Vellore, India. He is a research scholar of GITAM University, Visakhapatnam. In the field of Antennas. Presently working as Assistant Professor, in Dept of ECE, KLU, Vaddeswaram, A.P, INDIA

Dr. T. Venkata Ramana currently working as Associate Professor in ECE Dept. in GITAM University, Visakhapatnam, A.P, India. His research area is Satellite Communications. His research topics are published in several National & International Journals.