EuCAP 2019

On the Size Reduction of Slotted Finite Ground Plane of a Circularly Polarized MicrostripPatch Antenna Using Substructure Characteristic Modes

Arka Bhattacharyya, Bhaskar Gupta

Department of Electronics and Telecommunication Engineering
Jadavpur University,
Kolkata, India

3rd April, 2019
Krakow, Poland

arkabhattacharyya47@gmail.com

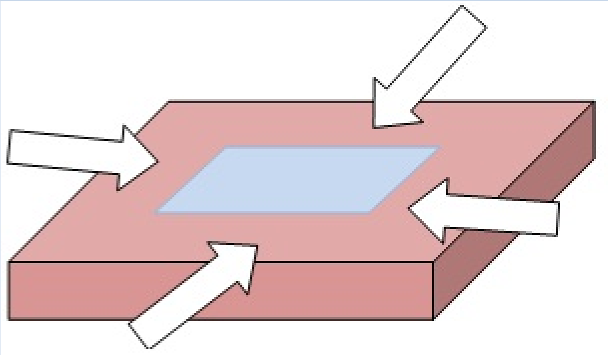
Paper id : 1570499018

Outline of the Presentation

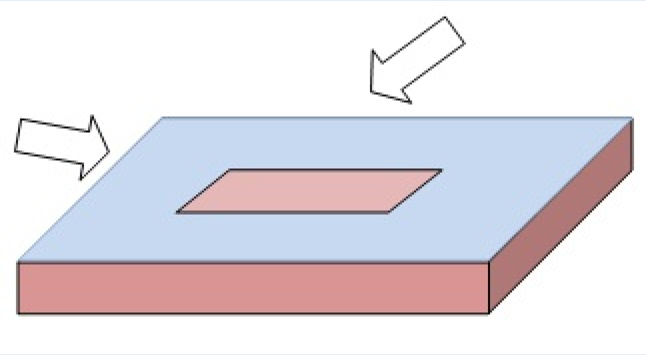
- Introduction
- The Problem in Hand
- Solution Technique
- Antenna Design
- CM Analysis
- Simulation Results
- Discussions
- Future Works

Introduction

- Slotted ground/ defected ground helps decreasing the resonant frequency of a microstrip antenna
- Also miniaturization of the patch can be achieved by inserting slots on the ground
- Size reduction of the ground plane can be a challenge



Patch



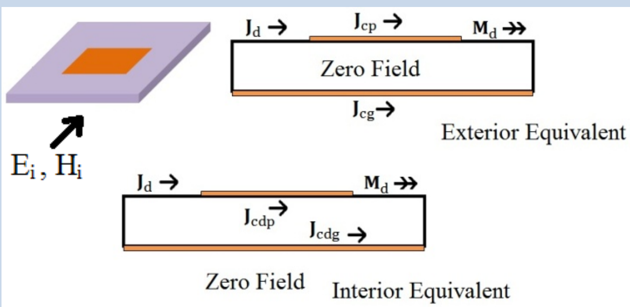
Slotted ground

The Problem in Hand

- Our question : How to reduce the ground plane (slotted) size at a particular frequency ?
- Aim is to reduce the overall size of the antenna
- Interest: To what extent we can reduce the overall antenna size keeping the frequency of operation same as well as achieving circular polarization.
- We investigate this using substructure based TCM
- The proposed technique can compute the modes of each object separately in a whole system

Solution Technique: Substructure TCM of Substrate Based Patch Antenna

- Substructure based TCM [1] is required to accurately characterize the CMs of the metallic parts of the antenna in dielectric environment
- It gives CMs of metallic patch and ground plane separately



$$\begin{bmatrix} Z_{d,d} & Z_{d,cdp} & Z_{d,cdg} & Y_{d,d} & Z_{d,cp} & Z_{d,cg} \\ Z_{cdp,d} & Z_{cdp,cdp} & Z_{cdp,cdg} & Y_{cdp,d} & 0 & 0 \\ Z_{cdg,d} & Z_{cdg,cdp} & Z_{cdg,cdg} & Y_{cdg,d} & 0 & 0 \\ Y_{d,d} & Y_{d,cdp} & Y_{d,cdg} & Z_{d,d} & Y_{d,cp} & Y_{d,cg} \\ Z_{cp,d} & 0 & 0 & Y_{cp,d} & Z_{cp,cp} & Z_{cp,cg} \\ Z_{cg,d} & 0 & 0 & Y_{cg,d} & Z_{cg,cp} & Z_{cg,cg} \end{bmatrix} \begin{bmatrix} I_d \\ I_{cdp} \\ I_{cdg} \\ m_d \\ I_{cp} \\ I_{cg} \end{bmatrix} = \begin{bmatrix} v_a \\ v_b \\ v_c \\ i \\ v_e \\ v_f \end{bmatrix} \quad \ldots(1)$$

Replacing other variables for Icp and Icg taking the right hand side zero

For the patch $[Z_p][I_{cp}] = [V_p] \quad \ldots(2)$

For the ground $[Z_g][I_{cg}] = [V_g] \quad \ldots(3)$

where, $[Z_p] = [R_p] + j[X_p]$

$[Z_g] = [R_g] + j[X_g]$

[1] J. L. T. Ethier and D. A. Mcnamara, "Sub-structure characteristic mode concept for antenna shape synthesis," in *Electronics Letters*, vol. 48, no. 9, pp. 471-472, 26 April 2012.

[2] A. Kishk and L. Shafai, "Different formulations for numerical solution of single or multibodies of revolution with mixed boundary conditions," in *IEEE Transactions on Antennas and Propagation*, vol. 34, no. 5, pp. 666-673, May 1986.

Solution Technique

The Generalized eigenvalue problem is constructed as follows

For the patch $[\mathrm{X_p}][\mathrm{I_n^{cp}}] = \lambda_n^c[\mathrm{R_p}][\mathrm{I_n^{cp}}]$ …(4)

For the ground $[\mathrm{X_g}][\mathrm{I_n^{cg}}] = \lambda_n^g[\mathrm{R_g}][\mathrm{I_n^{cg}}]$ …(5)

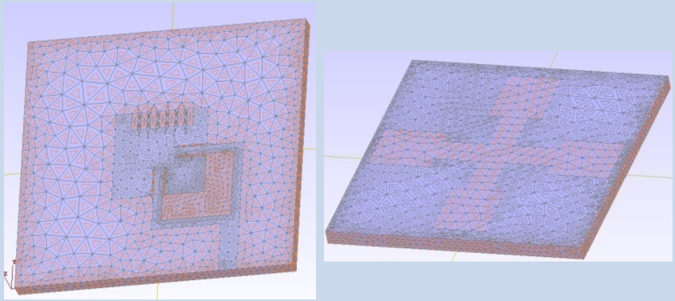
The CM currents on the patch and the ground plane in (6) and (7) respectively

$$\mathbf{J}_n^{cp} = \sum_m \mathbf{f}_m^p \mathrm{I}_{n,m}^{cp} \quad \ldots(6)$$

$$\mathbf{J}_n^{cg} = \sum_m \mathbf{f}_m^g \mathrm{I}_{n,m}^{cg} \quad \ldots(7)$$

Antenna Design

- The substructure technique is used here to address the present problem
- Substructure modes helps in obtaining this loading effect separately in a strong mutual coupling environment
- In order to study, Microstrip patch antenna with cross slot loaded ground plane is simulated in EMCoS Antenna VLab using plane wave excitation
- EMCoS uses a special Greens' function and gives only conductor currents for finite substrate operation
- Slot on ground plane loads the patch and helps miniaturizing it
- Cross slot controls both modal currents to obtain CP
- The patch also loads the ground plane to reduce resonant frequency

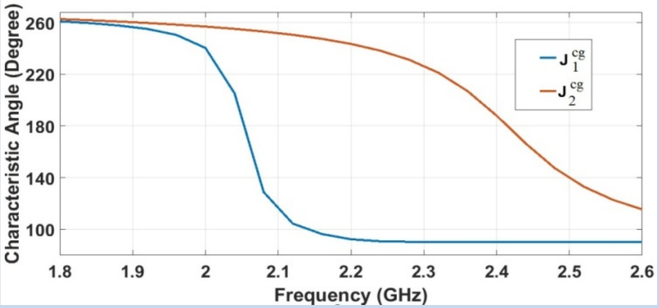


Meshed structure in EMCoS

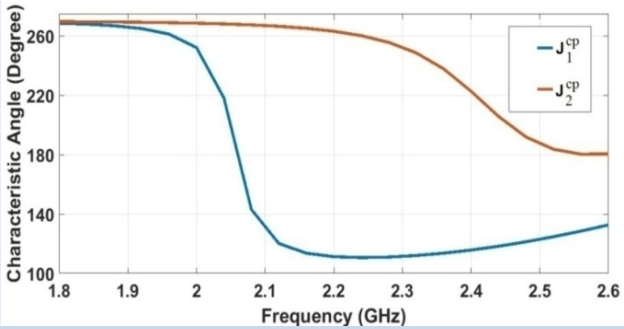
- The meshed structure is shown here, by varying iteratively (experiment) the size of the ground plane, ground slot and the patch, we obtain desired operation
- Loading effect between patch and ground plane needs to be studied in order to reduce overall size

CM Analysis

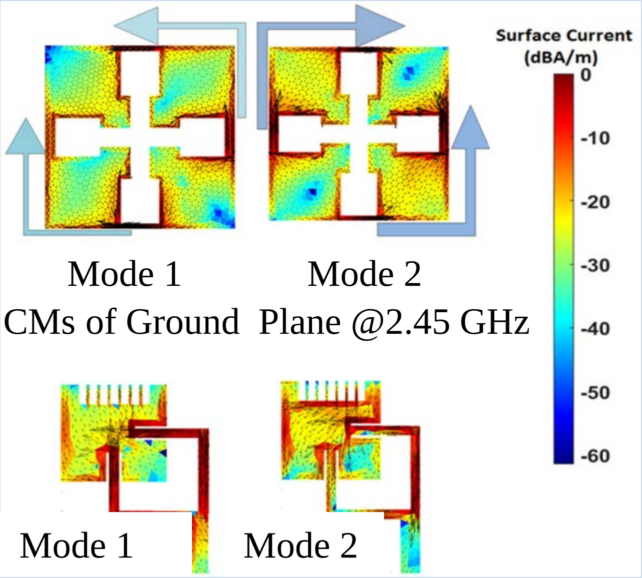
- ➢MoM matrix is extracted from EMCoS
- ➢In-house MATLAB code is developed to evaluate eigenvalues and eigencurrents of the patch and ground plane separately
- ➢Eigencurrent tracking method is used to track the modes over the whole frequency range of interest



CA plot of the ground plane



CA plot of the patch

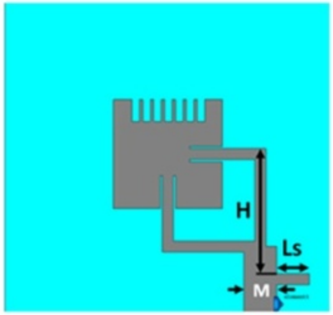


CMs of Ground Plane @2.45 GHz

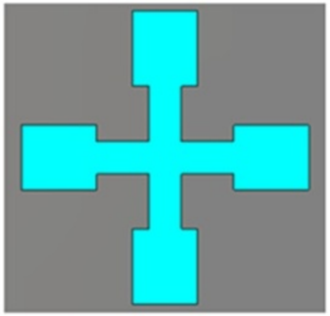
CMs of Patch @2.45 GHz

- ➢The teeth on the top edge of the patch are introduced to adjust the eigenvalue curve so that the desired CP operation of the antenna is obtained

Simulation Results

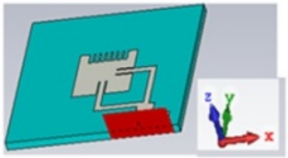


Top view

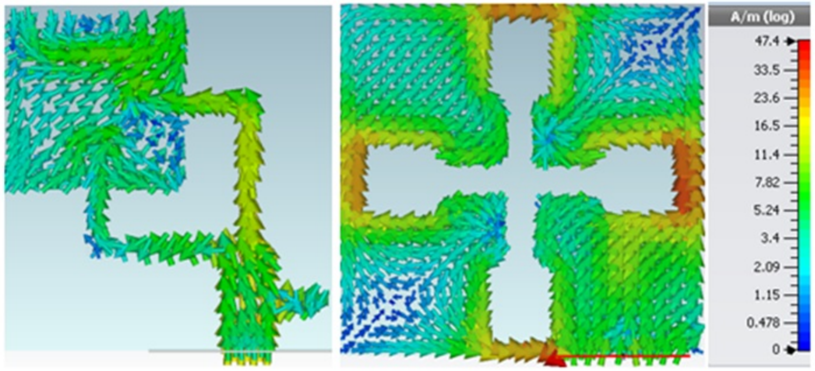


Bottom view

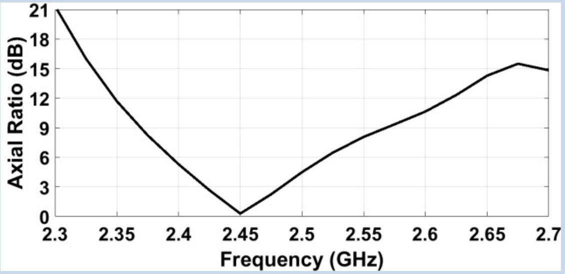
Side view



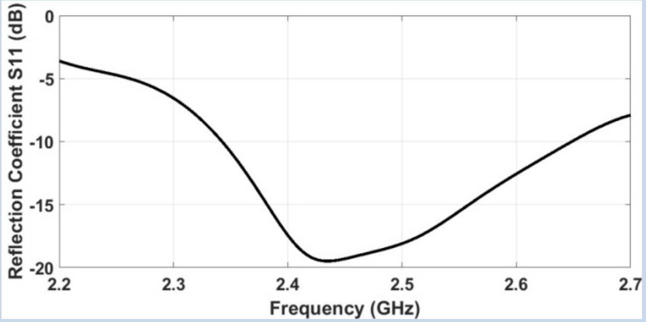
Perspective view



Simulated current distribution at 2.45 GHz on the patch and the ground plane

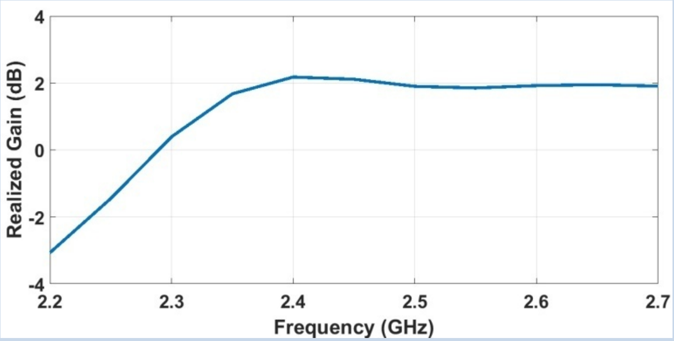


Axial ratio plot

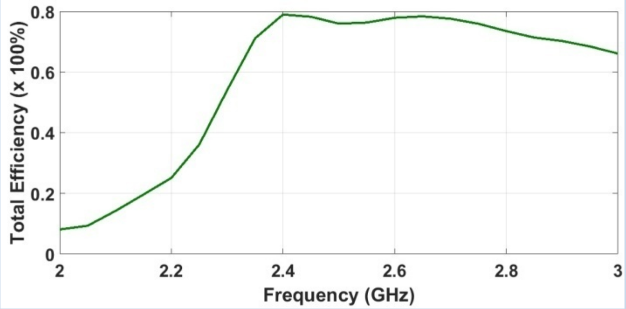


S11 plot

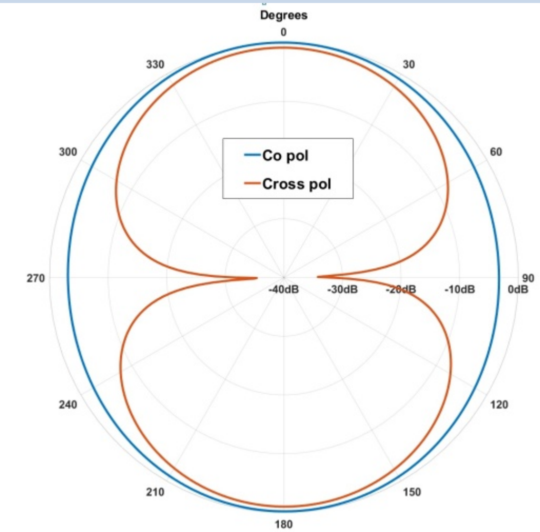
Simulation Results



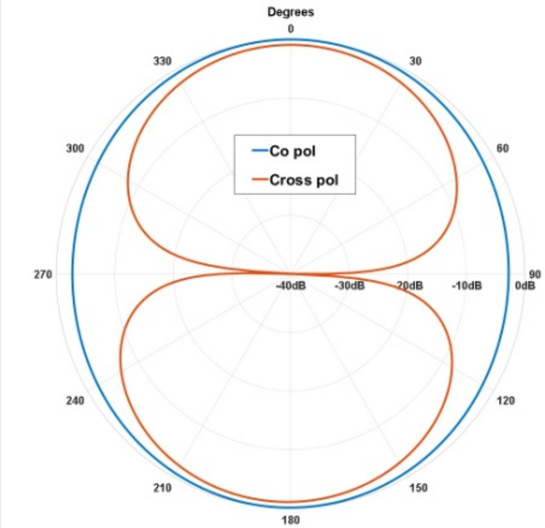
Realized gain plot



Total efficiency plot



Normalized pattern at 2.45 GHz on x-z plane (phi=0 degree)



Normalized pattern at 2.45 GHz on y-z plane (phi=90 degree)

Discussions

- The overall antenna size is $0.246\lambda_o$ x $0.237\lambda_o$. The area of the ground plane is reduced by 56% as compared to half wave patch at the same frequency. The size of the patch is reduced by 94%
- 7542 RWG bases with an average execution time of 1minute for each frequency point (intel Xeon @3.30GHz, 32 GB memory size) but using special Greens' function it takes only 3 seconds for each point
- A low profile miniaturized antenna is obtained by using this technique
- The patch is used to miniaturize the ground plane size further
- The radiation pattern becomes bidirectional as the ground plane is having a cross slot on it
- It can be used as a repeater antenna in cars

Future Works

- ➢ The antenna can be mounted on a suitable platform to get unidirectional radiation pattern
- ➢ The theory of substructure modes is applicable to ---
  - Multilayer antennas
  - Antennas on complex platform
  - Antenna in devices

Acknowledgement

- I would like to thank **CSIR (Council of Scientific & Industrial Research), Government of India** (Ack no.-143139/2K15/1, File no.- 09/096(0882)/2017-EMR-I, dated 31st March, 2017) for their financial support.

- I would also like to thank my colleague Mr. Kaushik Patra, Ph.D. scholar, Jadavpur University, Kolkata, India, for valuable discussions on this work.

THANK YOU