International Journal of Engineering Research & Technology (IJERT)
NCACCT`14 Conference Proceedings
ISSN: 2278-0181

Design and Analysis of a Circular Aperture Patch Antenna with a Common Mode Noise Rejection Filter Based on Defected Ground Structure for Narrow Band .

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***Abstract*—A balanced system composed of a circular aperture patch antenna (CAPA) and a common-mode (CM) noise rejection filter is proposed. The antenna is fed by microstrip coupled transmission lines. In order to eliminate CM noise, a common mode noise rejection filter is designed on a suitable substrate. The size and feed positions are determined through theoretical design and ADS (Advanced Design System) software simulation. The purpose of this antenna is to prove the noise rejection capability of the antenna and to reduce radiation emitted by the antenna. Radiation patterns in E and H planes for different frequencies are obtained. Finally, measurements of antenna with filter are compared against one without it.**

***Keywords*- Patch antennas, ADS, microwave filters, noise measurements.**

I. INTRODUCTION

Among the diversity of microwave devices, differential systems have been target of great interest. Their advantages include the ability to reject the effect of cross-talk coupling , high gain and the capability of the signals to travel longer distances. However, they can also guide Common-mode (CM) currents which will contribute to the electromagnetic noise even more than the Differential Mode (DM) currents. In digital applications efforts have been made in order to eliminate CM Currents.

If large antenna arrays are used to receive signals in a specific range where every single element operates at the same frequency. Thus, each element can also radiate undesirable power within the operational bandwidth which can couple in the form of CM noise to adjacent antennas. Hence a component of CM currents is inherently induced as noise, so a noise rejection filter is necessary to cancel the noise. The balanced currents properly feed the antennas by two coaxial cables. An array of several elements is needed to observe the effect of CM radiation noise. In a system made by a microstrip antennas a multilayer configuration is needed.

In this paper, a balanced system (filter-antenna) with CM noise rejection filter is presented suitable for narrowband applications. The system was made entirely from two components, namely: a circular aperture patch antenna (CAPA) and a novel common mode (CM) noise rejection filter. An original form to prove the efficiency of an antenna with CM noise rejection is proposed, where the in-phase currents are attenuated by a filter which leads to reduction of radiation emitted by the antenna in a transversal plane.

The paper is organised as follows. section II is about theory of CM noise. Section III describes the design procedure of patch antenna. Its principal characteristics and layout of antenna is presented. Simulated results of the reflection coefficient and radiation patterns are obtained. In Section IV the CM filter is presented with its simulated results. Section V is about attachment of antenna-filter system. Simulated radiation patterns in E and H planes are presented. Finally conclusions are given.

II. COMMON -MODE NOISE RADIATION IN DIFFERENTIALLY- FED ANTENNA

The ubiquity of CM noise makes it difficult to design electronic circuits. If we consider two radiating wires the CM currents produce electric fields in a direction where transmission lines are placed. Half - wave dipole theory states that if two wire conductors are placed close to each other, the total electric field is the product of superimposing the field of each metallization. The total electric field (E) is the sum of individual one

$$E_T=E_1+E_2 \quad (1)$$

Equations for the magnitude of maximum emissions for DM and CM currents are given by

$$|E_{Dmax}| = 1.316\times10^{-14} \frac{|I_D| f^2 L_s}{d} \quad (2)$$

$$|E_{Cmax}| = 1.257\times10^{-6} \frac{|Ic| f L}{d} \quad (3)$$

Where I_d and I_c are differential and common mode currents, f is frequency in Hz, L is the length of conductors, d is the distance where the field is measured.

The common-mode electric field increases linearly to the frequency. It does not depend on the separation of the conductors. The first term of the right side in (3) is larger than

ISSN: 2278-0181

that of the differential field in (2), which indicates that the total E is dominated by CM current rather than DM current.CM radiation covers an omni directional region whereas DM has a maximum within the place of conductors, which otherwise would be zero. Thus, CM currents must be avoided in systems when used in vicinity of other electric conductors or when implemented in arrays of a balanced antenna. So, it is necessary to find the amount of radiation that CM current can produce it.

III. CIRCULAR APERTURE PATCH ANTENNA (CAPA)

Patch antennas are used in application that requires a narrow operational bandwidth. In this work a novel CAPA is implemented. In order to maintain narrow beam in the E plane, two quarters of circles (**A** and **B**) with different radii are used to build the aperture. The rectangle labelled with **C** is used to fill the space due to due to difference in radii. To obtain differential current between ports $\mathbf{P_1}$ and $\mathbf{P_2}$, the width and separation of the microstrip coupled lines (rectangle **E**) is calculated to obtain 50Ω for odd-mode propagation. In order to achieve optimization a rectangle **D** is required on each line. The ground plane is modified to curved profile with a radius of 8.9 mm on each side denoted by letter **G.** All the optimizations are done using Advanced Design System (ADS) momentum simulator. The design is shown in fig.1 and the detailed description of the antenna is in fig.2 and dimensions is tabulated in table I. The relative permittivity is 3.55 and thickness is of 0.8 mm.

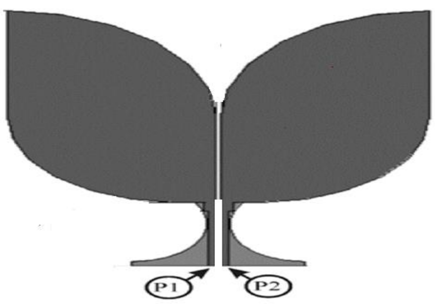

Fig .1. Diagram of a circular Aperture Patch Antenna.

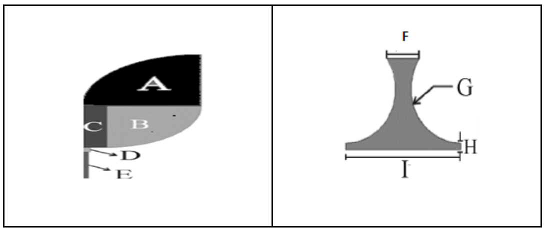

Fig. 2.Detailed description of top metallization (left) and ground plane (right).

In order to obtain the reflection coefficient ($\mathbf{S_{11dd}}$) for DM is given as

$$S_{11dd} = \frac{1}{2}(S_{11}-S_{12}-S_{21}+S_{22}) \qquad (4)$$

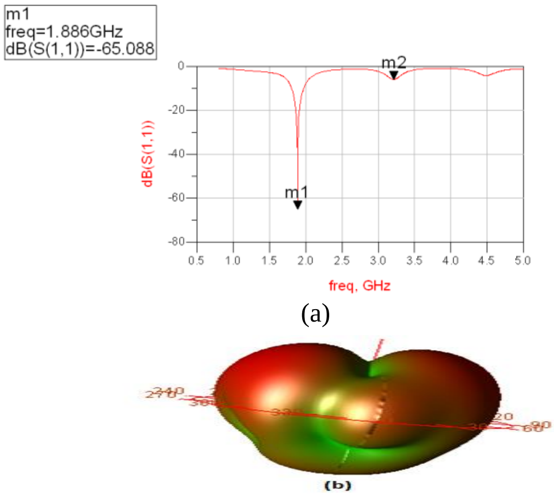

Fig.4. Simulated results of CAPA (a) Reflection coefficient (b) Radiation pattern

Where the S-parameters are extracted of the two port network obtained from ports **P1** and **P2**.simulated results are presented. There is a peak above the limit 1.8 GHz. This antenna can be used for Long Term Evolution (LTE) and finds a wide application for 4G communication. In radiation pattern there is a high level of symmetry along maximum radiation (90°).E plane has a narrow beamwidth whereas H plane is wider.

IV. FILTER DESIGN

The balanced filter concept is implemented. In a microstrip coupler DM signal is propagated by the odd mode whereas the CM signal is related to the even mode. The structure of the filter is hourglass form and the central slot is curved. These gaps are built by the approaching of two ellipses close together and using Boolean difference function. These curved slots increases the smoothness of the change in capacitance. The greatest advantage of this filter is that it's shape is not periodic. The dimension and spaces between the slots were optimized using ADS simulator.

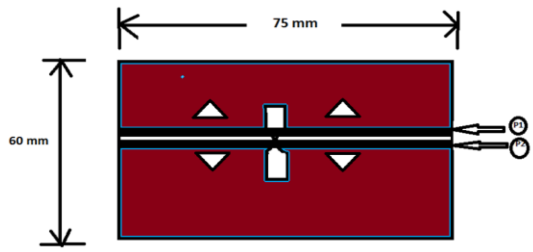

Fig.5. Filter With Dimensions.

ISSN: 2278-0181

Implementation of the filter is made in the substrate same as simulated CAPA . The central defected ground slot is of height 35 mm whereas side triangular DGS is of 6.5 mm .The substrate material used is FR4. The permittivity of the material is 4.7. Hence common mode noise rejection filter can be attractive to be use for noise suppression of antennas. It provides low adjacent radiation. Brick red colour denotes the conducting material which is selected as copper since copper provides better conductivity. The central curved slot acts as noise suppression filters.

V. ATTACHMENT OF CM-REJECT FILTER AND CAPA

Implementation of the antenna with the filter and antenna without filter were made in the same substrate. The filter is attached to the antenna with no other modifications but the elimination of feeds marked as $\mathbf{P_3}$ and $\mathbf{P_4}$ so that the antenna can be connected at that terminations. since the dimensions of the patch antenna is different from that of dimensions of the filter, a combination of step tapered microstrip line can be used to achieve proper matching between them.

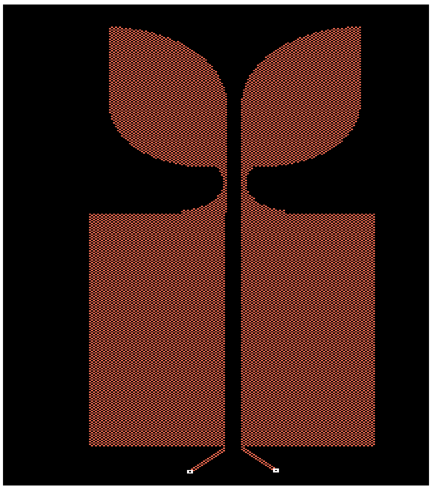

Fig.6.Circular Aperture patch antenna without filter.

Implementation of the antenna with the filter and antenna without filter were made in the same substrate. The filter is attached to the antenna with no other modifications but the elimination of feeds marked as $\mathbf{P_3}$ and $\mathbf{P_4}$ so that the antenna can be connected at that terminations. since the dimensions of the patch antenna is different from that of dimensions of the filter, a combination of step tapered microstrip line can be used to achieve proper matching between them. The simulated results of reflection coefficients and the radiation patterns of the antenna with filter and without filter is presented. A common mode filter is employed specifically to remove egress of noise for electromagnetic compatibility purposes. It avoids antenna operating at unwanted frequencies and operates within user band of interest at 2.4 GHz .Thus, common mode filter also reduces spurious amount of radiation from an antenna and also provides better radiation pattern.

TABLE I

DIMENSIONS OF DETAILED FIGURES

LETTER	BRIEF DESCRIPTION	DIMENSION (mm)
A	Radius of Major Quarter	25
B	Radius of Minor Quarter	20
C	Rectangle C	20×5
D	Rectangle D	2×1.5
E	Rectangle E	13×1
F	Minor base of ground plane	5.7
G	Radius of curve in groundplane	8.9
H	Height Of Curve In ground Plane	1.1
I	Major Base Of ground Plane	20.5

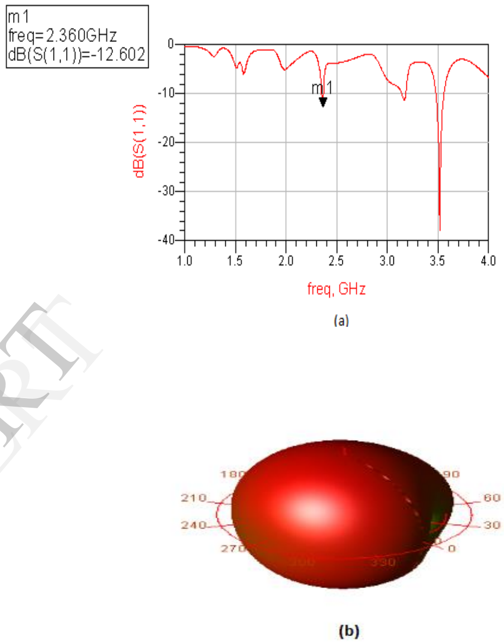

Fig.7. simulated results of Patch antenna without filter. (a)Reflection coefficient (b) Radiation pattern.

Simulated results of patch antenna without filter implies that the antenna is operating for six different range of frequencies namely 1.3 GHz, 1.6 GHz, 1.8 GHz , 2 GHz, 3.5 GHz, 3.9 GHz .The measured radiation pattern in E and H planes of an antenna without filter is shown .The amount of power radiated from an antenna tends to be larger in an antenna without a filter . Hence a common mode noise rejection filter designed to operate at 2.4 GHz. for WLAN and Wi-Fi applications. Attachment of Circular Aperture patch antenna with a common mode noise rejection filter is implemented as

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Fig.8. Circular Aperture Patch Antenna With a Common –mode noise Rejection Filter.

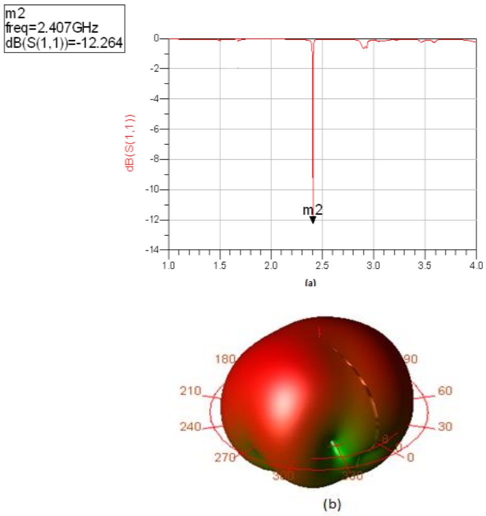

Fig.9. Simulated results of patch antenna with filter (a) Reflection coefficient (b) Radiation Pattern.

Table II

Performance Comparison

PARAMETERS	ANTENNA WITHOUT FILTER	ANTENNA WITH FILTER
VSWR	1.024	1.008
GAIN(DB)	1.2	4.7
DIRECTIVITY (DB)	5.6	14.65
BANDWIDTH(%)	2.5	1.1

The measured radiation patterns with filter is shown. The bandwidth obtained is almost narrow. It is clear that the filter removes egress of noise at different frequencies. It operates only at 2.4 GHz frequency range within the band of interest for Wireless LAN and Wireless Fidelity applications. The transversal radiation is highly suppressed by addition of filter. Hence, in-phase currents are attenuated by the filter which leads to reduction of radiation emitted by the antenna.Finally measurements of an antenna with filter is compared against one without it and parameters are indicated in table.

VI. CONCLUSION

A new CAPA with CM noise rejection filter is implemented in this paper. The system includes a CAPA and a novel filter based on 2D technology. simulated results of the antenna were obtained with accuracy. several radiation patterns for E and H planes were taken. Finally, an antenna with filter removes egress of noise at different frequency range and operates only at desired frequency range of 2.4 GHz. The radiation pattern due to CM currents were obtained by an innovative measurements for the system with filter. This element can be attractive to be use in dense array of antennas and provides its low adjacent radiation.

ACKNOWLEDGMENT

The authors like to express their thanks to the management of Sri SaiRam Engineering College and the department of Electronics and Communication for their encouragement and support during this work. Special thanks to A.R. Rajini, HOD of ECE department and V.S.Sundaramurthy, Professor for their continuous help in pursuing our work.

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ISSN: 2278-0181

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