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Design of Slotted Circular Microstrip Patch Antenna Array for 5G Millimeter-Wave Applications

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Abstract: *Fifth generation (5G) is a reliable and advanced high-speed network compared to fourth generation (4G). This paper proposes a circular microstrip patch antenna (CMPA) array with slots for 5G technology. This paper presents the design of a 1x4 CMPA array at a resonating frequency of 30 GHz which is used for 5G applications. The antenna uses Rogers' R04350B substrate having the thickness of 0.76mm, a dielectric constant of 3.48 and Loss tangent of 0.0037. Further, the elements of the antenna considered for the array are spaced at a distance of 5mm in order to avoid mutual coupling. The major aim of this antenna configuration is to achieve more gain and high radiation efficiency. The uniqueness of this design is that Rogers R04350B substrate is used for the circular patch antenna array with a compact size and 3/4th fed quarter wave transmission line. The dimensions of antenna are calculated and then simulated using a HFSS 18. The array antenna resonates at three different frequencies namely 34 GHz, 36.2GHz and 40 GHz. A gain of 13.2dB, return loss of -13.19 dB is achieved at 34 GHz and radiation efficiency at 40GHz is 86.6%. After the design and analysis of this antenna, it has been found that the design is highly reliable and effective for 5G application.*

Keywords: **Circular Patch Antenna Array, 5G, Rogers' R04350B, 1x4 Array, Gain, Millimeter-wave frequency;**

1. Introduction

With a growth of Internet of Things (IoT), data traffic in wireless communication is increasing because of a greater number of smart phone users [1]. The 4G technology is used in applications like machine to machine (M2M) communication, video call data and remote monitoring [2]. Even though, 4G has many benefits, it is not able to overcome the problem of poor interconnectivity, bad quality, overcrowded channels and high consumption of energy [3]. Therefore, 5G system is developed to meet the smart phone user's requirements at millimetre wave (mmw) and it provides low latency, security and high-speed data [4]. The mmw aims to improve the data bandwidth. The bands used in a frequency range of 20 GHz to 60 GHz is known as mmw band [5]. 5G technology utilize mmw and it has a data rate higher than 100Mbps when the mobility is full and 1Gbps when the mobility is low [6]. It will aid in the industry, transportation, economic growth, power grid, and education etc. 5G communication will interlink all digital and electronic appliances such as maintenance of temperature, refrigerator and printer etc [8]. Spectrum allocation is the major anxiety of 5G technology. The frequency suggested for 5G are: 27.5 to 29.5 GHz, 33.4 to 36 GHz, 37 to 40.5GHz, 42 to 45 GHz, 47 to 50.2GHz, 50.4 to 52.6 GHz and 59.3 to 71 GHz respectively. But for mobile communication, the frequency range of 28 to 38 GHz with BW 500 MHz and 1 GHz are considered as beneficial, however operating at high frequency develops complexity in design of antenna [9] [10].

Microstrip patch antennas (MPA) have drawn a huge attention because of their directional radiation and data rate for wireless applications. The utilization of MPA become diverse due to their size and weight. For practical applications, the antenna size and bandwidth (BW) are the main

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Research Article

Enhancement of Radiation characteristics in a planar Microstrip patch Antenna using Defected Ground Structure

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Abstract: A circular Defected Ground Structure is proposed to improve the radiation properties of a Rectangular Microstrip Patch Antenna with Quarter Wave Transformer feed (QWTRMPA). By crack down cross-polarization (XP) levels, higher isolation between co-polarization to cross-polarization radiation is achieved without disturbing the co-polarized radiation. In this design a circular slot etched on the ground plane as a Defected Ground Structure (DGS) results in a suppression of XP in H-plane. The conventional configuration resonates at 5.24 GHz, having a co-polarization peak gain of 4.5 dB and total isolation of 27 db. The proposed MPA shows compactness of 420 MHz by resonating at 4.82 GHz with total isolation of 44 db. The XP levels fall below 17 dB in H-plane when compared to the conventional configuration. The fabrications of proposed and conventional prototypes are done using the substrate FR4 epoxy whose dielectric constant is 4.4 and thickness of 1.6 mm. The simulation results go hand in hand with the experimental data.

Keywords: Antenna radiation patterns, Cross-polarization, HFSS, Defected Ground Structure, Isolation and Microwave Integrated Circuits

1. Introduction

Microstrip patch antenna (MPA) has been widely used for most of the wireless applications due to their attractive features like low cost, lightweight, compatibility to MMIC, easy fabrication and broadside radiations. The MPA concept is presented for the first time in 1953 [1], but the first work was patented in 1970 [2] and became dominant in all wireless communication applications from 1970 onwards. The MPAs have some drawbacks such as less gain, narrow bandwidth and more XP radiation. In Probe-fed microstrip patches usually, high cross-polarized radiation pattern gets distorted due to unwanted probe radiation [3]. Its significance is more in H-plane than that of E-plane. It is not desirable in wireless applications [4-5].

Several research groups have taken an interest to suppress cross-polarized radiation from the last two decades. Recently, the DGS technique is proposed to reduce the XP radiation by Guha *et al.* achieved 5-8 dB suppression [6]. A Circular Microstrip Patch Antenna (CMPA) with single and double arc DGS investigated using different dielectric substrates. The single and double arc DGS with RT/Duriod 5870 substrate achieved 10.08 dB and 11.13 dB XP suppression is achieved. But for FR4 epoxy 11.93 dB and 14.34 dB XP suppression is achieved. In both attempts observed a small reduction in peak gain [7]. Guha and the team further carried out the work using DGS technique [8-13]. The arc-shaped DGS provides 30 dB isolation in H-plane [8]. A CMPA with two new geometries of DGS push down XP to 5 - 7 dB compared to the normal ground plane [9]. The dot-shaped DGS was used for suppression of orthogonal fields [10]. The CMPA with annular and circular shaped DGS provides10 dB to 12 dB XP suppression [11]. The rectangular and folded rectangular DGS reduces the XP levels to -32 dB, but smaller angular coverage [12]. The control of the third harmonic of the fundamental resonance and XP suppression of 12 dB is achieved by using compact DGS-integrated feed [13]. The XP suppression of about 15 dB is achieved by circular-shaped DGS [14]. A shorted non-radiating edge rectangular microstrip antenna with modified cavity model (MCM) using different substrates achieved XP suppression of 16 dB with a total isolation of 34 dB [15]. A patch antenna with two rectangular grooves in a ground plane gives H-plane XP less than 25 dB with -90^0 to -90^0 directions and improves XP radiation around 28 dB near 50^0 broadside directions [16]. Linear full wavelength R-DGS gives H-plane XP fields less than −30 dB [17]. Symmetric DGS integrated RMPA has improved the XP and gives almost 17 dB principal radiation planes and achieved XP suppression [18].

Asymmetric geometry of DGS of a rectangular MPA gives more than 28 dB isolation [19]. Dumbbell-shaped defect in Rectangular patch improve polarization purity more than 30 dB [20]. Dumbbell-shaped defected patch surface investigated for different W/L suppress the cross-polarization of 27 dB [21]. A small circularly polarized (CP) patch suppresses cross-polarization in the sideways from −14.2 to −26.1 dB [22]. Defected ground structure (DGS) with 2 × 2 DGS integrated microstrip array, etched 50% of the ground plane designed in X-band show 12 dB improvements [23].

Development of Remote Instrumentation and Control for Laboratory Experiments using Handheld Devices

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Abstract—The unprecedented growth in Internet technologies has created revolutionary changes in the use of collaborative learning tools with remote experimentation. These tools enhance the experiential learning aspects of engineering education. Laboratory experiments are integral part of science and engineering education. Automation is changing the nature of these laboratories, and the focus of the system designer is on the availability of various interfacing tools to access the laboratory hardware remotely with the integration of computer supported learning environment.

Work on laboratory experiments and project works requires access to expensive hardware equipments. The high cost of these instruments along with time consuming development process of experimentation in the educational process creates a significant bottleneck. There is a need for the development of remote laboratory using which the users can access the laboratory instruments and the programmable devices remotely on their smart phones/tablets to perform the laboratory experiments. This implementation avails laboratory facility for complete twenty four hours a day and will increase the productivity of the laboratory hardware and measuring instruments.

This paper presents the detailed architecture and the implementation details of remote laboratory by which user can perform laboratory experiments remotely. Develop mobile based remote laboratory where user can access remote laboratory on his smart phone or tablet to perform the experiments. Software application is developed on Android platform for the implementation.

Keywords—Remote Laboratory, Virtual Instrumentation, Remote Access, Android studio.

1 Introduction

With the advent of wireless technology, mobile phones are being used for many other applications other than communication. Mobile applications are being developed for aiding students, teachers and universities in academics. Apps are developed for research application which consolidates the journals across the

A New Method to Estimate Skew Angle in Printed and Historical Document Images

Banumathi K L, Jagadeesh Chandra A P

Abstract: ***In this paper, a new approach to assess the skew angle for scanned/printed documents and historical document images has been proposed. This is substantial for an automatic document processing system (as text and image segmentation) to avert errors in auxiliary stages. The proposed tactic is based on the statistical analysis of the slope of the connected lines in the document. The proposed technique detects skew and corrects it by initial letter (X1, Y1+200) from left margin of the resized (800X800) image and (X1+200, Y1) from top margin. Final letter (X2, Y2-200) and (X2-200, Y2) were chosen from right and bottom margins of the same image. The skew angle estimation is done for standard skewed dataset and effective correction of the same is performed with minimum errors.***

Index Terms: ***Printed text, Multiple Skew, Skew Detection and Correction.***

I. INTRODUCTION

Deskewing is a procedure to align the image properly, before further processing the data in the image. There are many existing approaches for deskewing the image such as mathematical morphology, principal of connected components, projection profile technique, Fourier transform, Hough transform, Radon transform and KL Transform. These methods for deskewing have their own constraints with respect to font style, font size and are not rotation invariant [1-4].

A number of skew estimation and deskewing techniques of document images is proposed in the literature. It has been bracketed into two types, they are, spatial and frequency domain approaches. The following are the frequency domain procedures for skew estimation and correction.

Bo Yuan proposed an approach to deskewing based on Hough Transform. Skew estimation method was based on the presence of noises like the straight lines; edges exist in the images and not textual content present in that image. This model works if the input image has well-defined edges from the black bars around the pages, the graphical inserts, and the separators of tables, columns or paragraph [2]. Jonathan Fabrizio presented an algorithm for skew estimation for binary images in the frequency domain. In this methodology first preprocessing of the image using KNN clustering method is to be done and then Fourier transform should be applied to the image to the outlines of the convex hulls of the

clustered regions. But preprocessing an image using KNN clustering requires parameter (K) number of nearest neighbours and also computation cost is very high [3]. Nandini N et al proposed a model algorithm based on connected component analysis and Hough transform. There are two approaches namely word centroid approach and dilate & thin approach. In this approach, an only printed document containing text are taken into consideration. But the method restricts for images containing pictures [5].

M. Sarfraz et al proposed an algorithm for deskewing of the image by using Haar wavelet transform and principal component Analysis. Initially, the image was decomposed into detailed sub images into various levels with the help of Haar wavelet transform. PCA was used to estimate the orientation of the principal axis in horizontal, vertical direction in each level. Output was accurate for the input image of Arabic font which is connected and English Font which is isolated in nature [6]. Mandip Kaur et al proposed an algorithm based on Fast Fourier Transform and Discrete Cosine Transform. The main purpose of using FFT is to find the skew angle. Initially, the DCT compression technique was applied on the image to reduce timing computation. Fourier spectrum is obtained for the compressed image. The obtained spectrum is divided into four quadrants and the skew angle of each quadrant is obtained. At last input image is rotated using the bilinear interpolation method. Here skew angle of 45 degree to -45 degree was taken into consideration [7]. Sargur N. Srihari et al used the Hough transform method for deskewing of the image. Here various problem faced in the Hough transform like Aliasing and Quantization Problem were discussed as well as the solution to those problems was mentioned. The output image in some case was found to be upside-down or right side-up [8]. Xiaoyan Zhu presented an approach where the image with textual and non-textual content is taken into consideration. Initially, document image was divided into blocks of equal size using Fourier Transform and Support Vector Machines were applied to determine whether each block is textual or non-textual. They determined the skew for only textual blocks by taking standard deviation of the projection profile of various angles [9]. The following are the spatial domain approaches for skew estimation and correction. Nguyen D.T et al came up with a mathematical morphology operation which can be used for deskewing of the image.

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Research paper

Moment method approach to analyze waveguide array radiator with crossed dipole as a near field sensor

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Abstract

Moment method approach is used to estimate the error encountered by the sensor in the near field and probe measures co-pole and cross-pole voltages at the same time. Conversely, due to several reflections between the waveguide and dipole sensor, near field values are changed. Calculations are done to analyze the absolute sampled co-pole voltage pattern and relative sampled electric field (without probe) pattern in the scan plane, and inaccuracy induced by the sensor is determined. The waveguide reflection coefficient, radiation admittance and susceptance with measuring sensor are reformed with respect to the equivalent values in the absence of the sensor in the near field.

***Keywords**: Admittance; Moment Method; Reflection Coefficient; Susceptance; Waveguide.*

1. Introduction

The problem of modeling the error induced by the near-field sensor and the impedance seen by the open-ended waveguide is extremely important in order to estimate the electromagnetic susceptibility of the waveguide. Thin, finite length, perfectly conducting crossed dipole alone measures in the near field values, this introduces error due to the multiple reflection between the radiator and dipole, scattering properties of the dipole and mutual coupling effects of the poles of the dipole. As far field measurement is not practicable in most of the cases, these near field values are transformed into a far field pattern. Also for enhancing the accuracy of the theoretically predicted result, it is necessary to evaluate the field at the radiating aperture instead of assuming those fields, which was done by many researchers [1], [2]. Therefore, it is necessary to determine the radiated field at any point in the free space accurately.

The crossed-dipole is an important probe, since it measures both co-pole and cross-pole components simultaneously. The earlier researchers [3], [4] neglected effects of multiple reflections between the radiator and probe. However, the mutual coupling effect between poles of the dipole must be determined, since the cross-polarized components are generated in the near-fields. This paper has made an effort to fill in these gaps in the existing state of knowledge.

The situation addressed above requires an analysis for an open ended waveguide radiator aperture in the transmitting mode. The algorithm once developed can be used for finding out those for different broadband and narrow-band configurations of sensors and will make the sensor calibration possible without going into the rigour and expense of experimentation.

The rectangular opening in an unbounded ground plane fed by a waveguide being considered as a transmitter is excited in the dominant TE_{10} mode. The waveguide opening electric field and the induced current on dipole is described by weighted sinusoidal global basis functions and Dirac delta functions respectively. The boundary conditions at the waveguide opening and on the axis of sensors are enforced by taking the properties of reciprocal connection and multiple reflections between transmitter and probe. The waveguide radiator reflection coefficient and probe voltage across 50 ohms terminating impedance are determined using the known coefficients of the entire domain and pulse basis functions respectively. Because of the multiple reflections between the radiator and probe, radiator reflection coefficient and near-field values are changed.

Many authors used different approaches such as a transverse operator method, variational, correlation matrix and integral equation method [5] - [7], while others [8] - [10] have used moment method technique to explain the waveguide problems. An electromagnetic wave in an open space incident on a thin, finite, perfectly conducting wire was analyzed by [9]. Moment method analysis of waveguide radiator with dipole and crossed dipole as the near field sensor are given by the authors [9] and [10].

2. Theoretical formulation

The crossed dipole in the near field of an open ended two waveguide radiator array of opening width and breadth of $2a\times2b$ in an unbounded base plane is displayed as in Figure 1.

Error Estimation of Three Dipoles used as near Field sensors

Suma M, Goutham M A, Paramesha

***Abstract:** Three sensors coupled in a crossed configuration are used as near field calculating unit of a transmitter in an unbounded ground plane. The Method of Moments is applied to calculate approximately the inaccuracy produced by the measuring unit in the near field. The Probe measures both co-pole, cross- pole and z-directed dipole components simultaneously. However, due to multiple reflections between the radiator and dipoles, near field values are changed. Computation was carried out for the calibration of the probe and to test the co-pole voltage and field (with no probe) in x-y plane at 10GHz to compare the relative tested co-pole voltage pattern with the relative tested field pattern (with no measuring unit). Since the relative tested co-pole voltage and field are analyzed, no inaccuracy is forced at the midpoint of the plane.*

***Keywords** – Basis Functions; Co-pole; Cross pole; EM wave; MoM; Waveguides.*

I. INTRODUCTION

The opening of waveguide in an unbounded ground plane supplied by a waveguide being taken as a transmiter is considered as energized in the TE10 condition. The three dipoles i.e. along y-axis (co-pole), along x-axis (cross-pole) and dipole in z-axis are connected in crossed structure are considered as a near-field estimating unit. These sensors are delicate to electric field slanting alongside the axis of the y-axis, x-axis and z-directed dipole of the sensor. The scattering charecteristics of the elements are polarization oriented. The method of moments approach is applied to resolve boundary value problems. The waveguide opening field is designated by the weighted sinusoidal global basis functions, and currents over co-pole, crossed pole and z-axis directed dipole are designated by pulse basis functions. The boundary conditions at the opening is forced at the same time on the plane of a waveguide opening and on the axis of co-pole, cross pole and z-axis directed dipole by considring multiple reflections and mutual coupling automatically.

Estimation has been done for the calibration of the measuring unit and to test the relative co-pole voltage pattern to the relative electric field (without probe) pattern, and inaccuracy produced by the sensors is evaluated.

Several researchers used many methodologies such as the variational, correlation matrix, and integral equation methods [1], [2]. The number of approaches has been evolved for the calculation of the mutual and self-admittance between radiating elements [2], [3]. Various authors used the method of moment procedure to work out the waveguide [3], [4], [5]. MoM investigation of waveguide transmitter and dipole, crossed dipole as the near field measuring unit is given by writer [8], [9].

II. PROBLEM FORMULATION

The three dipoles i.e. along y-axis (co-pole), along x-axis (cross-pole) and along z-axis in the near field of waveguide transmitter opening is illustrated in Figure 1.

The magnetic field at the opening is given by:

$$H_x^{inc} = -Y_0 \cos\left(\frac{\pi x}{2a}\right) e^{-j\beta z} \quad [1]$$

The current on the y-axis dipole is designated by [8]:

$$I = \hat{u}_y \sum_{p=1}^{M} I_{yp}\, i_{yp} \quad [2]$$

Where i_{yp}(p=1, 2, 3., M) is described by [9]:

$$i_{yp} = \begin{cases} 1 & y_{p-1} \le y \le y_p \\ 0 & elsewhere \end{cases} \quad [3]$$

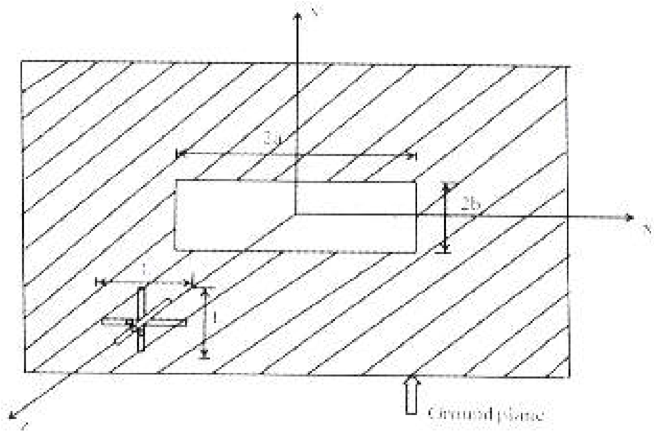

Figure 1 Measuring units in the near-field of the trasmitter

Similarly current on the cross-pole (along x-axis) is designated by [9]:

$$I = \hat{u}_x \sum_{p=1}^{M} I_{xp}\, i_{xp} \quad [4]$$

$$\text{Where } i_{xp} = \begin{cases} 1 & x_{p-1} \le x \le x_p \\ 0 & elsewhere \end{cases} \quad [5]$$

Similarly current on the z-axis directed dipole of the near-field probe is designated by:

$$I = \hat{u}_z \sum_{p=1}^{M} I_{zp}\, i_{zp} \quad [6]$$

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Gain Enhancement of Microstrip Patch Antenna Using Metamaterial Superstrate

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Abstract — In this work, a gain enhancement of conventional microstrip patch antenna has been treated for WLAN applications. About 1.3dB gain enhancement, compared to a conventional patch, has been achieved by loading the microstrip patch with a metamaterial superstrate composed of 2x3 array of Square Split Ring Resonator. Simulations have been carried out using Ansys HFSS. Measured results have been taken to validate the simulation result.

Index Terms — Metamaterials, microstrip patch antenna.

I. INTRODUCTION

Modern wireless communication system requires high data rate that depends on the gain of the antenna. Towards this, metamaterial starts playing a very important role in the design of an antenna [1]-[3]. In [4], gain enhancement of microstrip patch antenna (MPA) is achieved by using graded index dielectric superstrate. In [5], a planar two-layer superstrate over a printed patch antenna to enhance the broadside gain is considered. The problem of enhancing the directivity of an aperture coupled microstrip patch antenna using one dimensional electromagnetic bandgap (EBG) structure is treated in [6]. It was found that the directivity level, beamwidth as well as reflection coefficient and gain could be enhanced by using superstrate with two layers. In [7], study of performance parameters of patch antennas with different feeding methods is presented and compared with that of patch antennas without dielectric superstrate. It was found that the directivity level, beam width as well as reflection coefficient and VSWR could be further enhanced by using superstrate with two layers rather than one, regardless of the feeding method. In [8], a meandered line-double split ring resonator (DSRR) superstrate loaded high gain circular patch antenna is presented for X-band and showed that the superstrate loading has minor effect on the return loss characteristics but a major effect on the gain characteristics of the circular patch. Scope for miniaturization and compactness of an antenna leads to the design of novel antenna structure loaded with metamaterial. Hence, in the proposed work, a metamaterial superstrate loaded microstrip patch antenna is designed on low cost, FR4 epoxy substrate for WLAN application.

II. ANTENNA DESIGN

A. Microstrip patch antenna without superstrate

The microstrip patch antenna with co-axial feeding is designed using ANSYS HFSS on a less expensive, widely available FR4 epoxy substrate with relative permittivity of 4.4 and dielectric loss tangent of 0.02 for 5.5 GHz WLAN application. Figure 1 shows simulated top view of MPA. The dimension of the patch and the substrate is 12mm x 16mm x 0.1mm and 26mm x 30mm x 1.6mm respectively. The equations to calculate the dimension of patch antenna are given in [9].

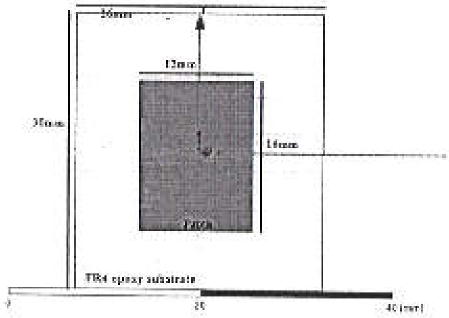

Fig. 1. Simulated top view of rectangular MPA.

B. Proposed MPA with metamaterial superstrate

The proposed design consists of metamaterial superstrate loaded microstrip patch antenna. Figure 2 (a) shows the geometry of square split ring resonator metamaterial. The dimension of the ring is 6mm x 6mm. The gap width is 1.5mm. Figure 2 (b) shows the simulated

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COMPARATIVE ERROR ANALYSIS OF DIFFERENT NEAR FIELD PROBE ARRANGEMENTS IN THE PLANE OF OPEN ENDED WAVEGUIDE RADIATOR

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ABSTRACT

The Moment Method is used to evaluate the inaccuracy caused by different dipole probe arrangements in the plane of the open-ended waveguide aperture. The radiated magnetic field and internally scattered wave at the plane of the opening is estimated by the plane wave spectrum and modal expansion approach respectively. The fields dispersed due to induced current on the dipoles have also been calculated by means of the theory of vector potentials. The boundary conditions are all together forcedon the plane of the radiator opening and on the axis of the sensors by seeing numerous reflections between the radiator and sensors. The boundary condition on the plane of the radiator opening is the tangential component of the magnetic field, both within and outside the radiator should be identical. Calculation has been accomplished to equate the relative sampled sensor voltage pattern to the relative sampled electric field (without probe) pattern in the scan plane with different arrangement of the dipole and error induced by the dipoles are compared.

Keywords: Basis Functions, Co-pole, Cross pole, Infinite flange, Moment Method, Mutual coupling, Multiple Reflection, Waveguides.

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