A Prototype Model Design of Wideband Standard Reference Rod-Dipole Antenna for 3-Axial EMC Measurement with Hybrid Balun for 0.9 to 3.2GHz Range.

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Abstract

Every electronics equipment must deal with EMC test. The testing laboratory of electronics equipment for radiation emission must have accurately calibrated antennas. The field strength of total radiated radio frequency is average of all incident signals at given point; this incident signal originates from various directions. To measure three components of all-electric field vectors, a tri-pole antenna is most beneficial over conventional antenna because of it responds to signal coming from multi-directions. This paper presents novel three axis wideband calculable rod-dipole antenna with the hybrid balun for the range of 900MHz to 3.2GHz frequencies, the proposed antenna is small in size and functional electrical characteristics. In this paper, antenna key parameters are measured and verified with designed values. In simulation results has observed the return loss (S11) less than -10dB within the frequency range 900MHz to 3.2GHz. The result of these articles is evident of efficient construction of antenna with low cost, lightweight. This module applicable for EMC pre-compliance test at the open field site.

1 Introduction

The uses of electronics and communications devices are increased everywhere, so demand of electronics equipment is increased form kitchen to satellite communication, because of that electromagnetic environment get polluted. The polluted electromagnetic environment directly affected on the performance of electronic and communications devices. So E-field measurement is essential in EMC for both near and far field primarily for handheld domestics Appliances.

Every electronics instrument or product should be facing compliance test at standard EMC test laboratory before the product launching for sale. But as per the data received from test laboratory 50% products are failing in the first attempt, so manufacturers need to redesign the product and again submit to compliance test, so it is the loss of time and increased the cost of manufacturing. To avoid this kind of problem, we have proposed low cost and highly accurate novel three axis EMC probe prototype model for the pre-Compliance test at open field site testing for manufacturing end.

To measure all three components of electric field vector, a tailor-made antenna type called "Tri-pole" is most beneficial over conventional antenna; different EM wave field was measuring antenna with the comparison is discussed in previous work [1].The simple structure symmetric balanced half-wave dipole used for various applications, it provides useful electrical characteristics but a narrow band, this problem is solved in [2].

Antenna designing is the hot topic for E-field probe, various kind of antenna have already developed for EMC/EMI applications, the half-wavelength dipole antenna is more attractive [3]-[6]. A half-wavelength calculable dipole antenna is designed for the frequency 30MHz to 2GHz by Alireza kazemipour et al. [7], this design covers entire frequency band by using two baluns. M J Salter et al. [8], was proposed open –field site EMC antenna design for 100MHz – 1000MHz range, for the broad bandwidth 3dB hybrid coupler is used.

Saou-Wen Su and Fa-Shian Chang proposed Wideband Rod-Dipole Antenna with a Modified Feed for DTV Signal Reception. Antenna for DTV reception is design with U-slit balun and described in [9], a proposed antenna designed with two symmetrical arms of diameter 3mm, length 120mm with modified feed. Feed is printed on board; the feed is etched on a single-layered 0.8mm FR-4 substrate to cover the frequency 470-530MHz. To provide wideband width, 1mm U-slit is used to increase additional resonance up to 860MHz. The antenna measured gain in the range of 1.0 to 3.2dBi and radiation efficiency exceeds above 70%.

Ki-Chai Kim et al.[10] proposed The Design of Calculable Standard Dipole Antennas in the Frequency Range of 1～3 GHz.Proposed antenna for the range of 1 to 3 GHz frequency band was designed with standard dipole with a 3dB hybrid balun, in this paper new formula is derived for Antenna factor(AF) using power mismatch loss concept. The dipole antenna designed with thin wire kernel with a segment length of 0.0125λ and radius is less than 0.007λ chosen, and characteristics impedance is 50Ώ.To achieve the full bandwidth characteristics, standard reference dipole designed at center frequency 1.3GHz, and dimensions for this L=10.8cm and r=0.75mm was selected. Two semi-rigid coaxial cables with length 100cm (>3λ) selected for matching the impedance. This design was having excellent performance, but the length of coaxial is too long, i.e., 100cm.

Ki-Chai Kim et al.[11] Proposed broadband calculable dipole reference antenna in the range 1GHz to the 3GHz frequency range.

In this paper, the theoretical background of three-axis antenna has described in section [2], part [3] the geometry and design of the proposed antenna discussed. In section [4] theoretical and simulated results are presented. Concluding remarks given in section 5.

2 Theoretical Background

Phillip h. Howerton et al.[12] Proposed Design of a Three-Axis Microwave E-Field Probe is described, field probe antenna designed for broadband ranging from 20MHz to 18GHz with field strength measuring ability is 60V/m to 1200V/m. This probe is intended explicitly for biomedical applications with best features include 1) an overall probe diameter of approximately 1.1 mm; 2) an extended resistive transmission line 15mm in length, and 3) a flexible transmission line. The small diameters were made possible by using a short (0.6 mm) dipole antenna. Each axis used separate diode detector, and the laminated resistive transmission line used in single axis field probe, The diode used in the probe is a Hewlett-Packard (HP 5082-2246) zero-bias Schottky barrier diode with its modified beam lead structure forming the dipole antenna.

Sang-il Kwak et al. [13] presented Design of the Electric field probe in the Personal Exposure Meter to find the radiated E-field near the human body, a-3-axis E-field probe application is to propose for personal exposure measurement meter. The proposed probe consists of three orthogonal dipoles antenna with diode detector and a transmission line for the range of frequency from 10MHz up to 6GHz; the diode used HSCH- 5330, readout device size is 60mm*30mm*90mm cover with metal.

J. Wayde Allen al.[14] suggest, A 3-Axis Antenna Array for Polarimetric Spectrum, the author describes construction details of an antenna to measure three axial components for a broadband range of directions, determine the total RF power at a given location regardless of polarization, and provide information about the polarization and arrival direction of signals. In this 3-axis antenna geometry described, simple design, easy to build antenna array will be work for spectrum survey work as well to test performance and characterization of three elements is well understood. It possible, when using a suitable three-channel receiver, to obtain complete real-time data. This antenna arrangement makes it possible to preserve the time and phase dependence of the signals in three-dimensional space elements is well understood and mounting these antennas coincident with each other in a crossed polar manner makes it possible.

B. Elnour et el.[15] present A novel co-located cross-polarized two-loop PCB antenna in the ISM 2.4 GHz band, for solving the problem of direction finding in radar. This antenna acts as an electromagnetic vector sensor (EMVS). In principle, an EMVS consists of three orthogonal dipoles and three orthogonal loops that are all co-located. The co-located cross-polarized loops antenna is constructed using two Kandoian loops. The design of a single Canadian loop is addressed –The electric loop is designed and built as a 2-layer PCB board, substrate material: Rogers 4003, ²r=3.38, Height=1.5 mm, board dimensions = 90 mm x 90 mm, Optimized radius of loop = 28.5 mm, 2 mm wide traces, bottom ground Patch = 15 mm x 15 mm, top ground Arms= 4 mm wide. Performance of electric loops is better than the electric dipoles, these two loops operate for the frequency range 2.3GHz to 3.5GHz, and bandwidth is only 200MHz. This antenna represents a step towards the realization of three orthogonal loops that are required to achieve the design of a theoretical EMVS.

Fredrik Rogberg et el.[16] implemented experimental setup of Three orthogonal polarized antennae for improving the capacity for wireless systems using uncorrelated propagation paths, a MIMO (Multiple Input Multiple Output) systems has been considered a better technology for enhancing the ability. In this experiment, triple orthogonal polarized with the radiation pattern equal to all for testing purpose. Construction of antenna is described in three parts: The cross dipole, Middle dipoles, and final structure. This antenna structures support for 2.5GHz to 2.7GHz frequency range with a small bandwidth of 200MHz.

W.D. Apel et al.[17] proposed LOPES-3D, an antenna array for full signal detection of air-shower radio emission describes, radio detection techniques of high-energy cosmic rays, emission of radio field form cosmic ray air showers detection is well suited in the LOPES-3D model. To measure all three components of electric field directly, a tailor-made type antenna developed called tri-poles. In LOPES 3D system used antenna type is triple which consists of three dipoles that are perpendicular to each other. Length of each dipole is 1.3m.frequency band of LOPES is 40MHz to 80MHz, Each dipoles couples to a coax cable via balun transformer. Impedance matching is selected 4:1 and characteristics impedance is 200Ώ.

3 Dipole antenna structure with Balun

Figure 1 shows the basic structure of the dipole antenna with coaxial cable, the total length of the dipole is defined by letter L and radius r. Wide-band calculable dipole antenna with Hybrid balun is shown in figure 1. The signal feed to antenna terminals using two coaxial cables with equal length by CL via hybrid balun as shown in figure 2. Coaxial cable inner conductor is connected to both the arm of balanced dipole and the outer conductor of both coaxial in electrically shorted to each other is displayed in figure 1.

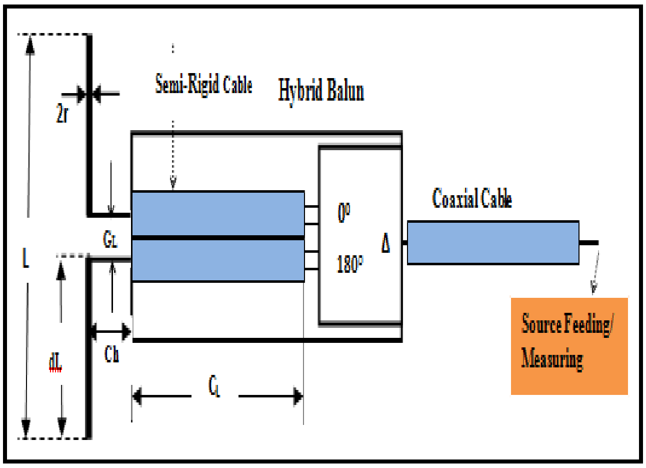

Figure 1: Proposed wideband Calculable dipole with Hybrid Balun

Two symmetrical dipole arms placed on Y-axis and gap between two dipoles is GL in millimetre, the length of the coaxial outer is CL, and the total length of the coaxial inner is CL+Ch, the Inner connector is soldered to dipole arm by length Ch above the outer conductor.

Accurate measurement of complex S-parameters, balun is must. Two semi-rigid coaxial cables with length CL for balun connected to balanced dipole arm, and a 50Ω load is connected to sum port, and a matched characteristics impedance measuring device connected to other port (Δ) via short length coaxial cable. Structure of both parallel coaxial is precisely symmetrical to each other, so similar potential is present in both cord, but phase shift is 180^0

The design value of dipole with balun is specified in table 1.

Table 1: Calculable reference dipole antenna design specifications

Sr. No	Antenna design parameters		
	Parameter Symbols	Description	Value
1	L	Total length of Dipole	10.3cm
2	dL	Single dipole rod length	4.8cm
3	r	Radius of dipole rod	9mm
4	GL	Gap between two symmetrical rod	7mm
5	Ch	Height of dipole from coaxial top end outer	1.2cm
6	CL	Length of coaxial cable	17cm

4 Three-Axis Antenna Structure

Three-axis antenna consists of three orthogonal dipole antenna oriented as shown in figure 2. Response of each dipole is more strongly to linear polarized signal that matches the antenna elements. Each element output of this array is proportional to the vector field components Ex, Ey and Ez.

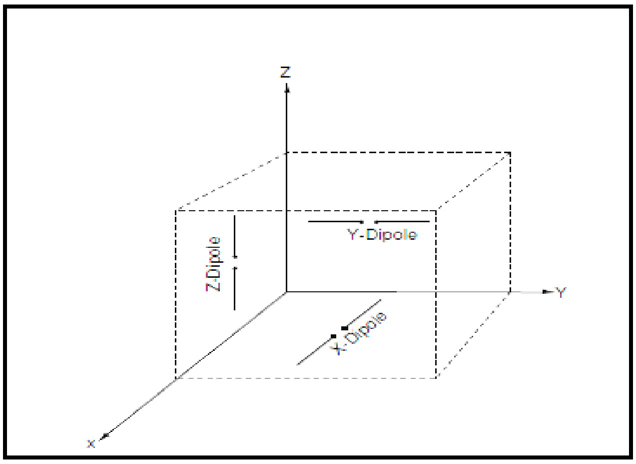

Figure 2: Three dipole elements orientation.

The antenna consists of an array of three orthogonally arranged dipole elements, each with its Feed line along with hybrid balun. As per the design explained in section III, the single dipole antenna is designed for reference frequency 1.3GHz to cover a range of frequencies from 900MHz to 3.2GHz. Unique antenna geometry along with coaxial cable with above-specified length placed orthogonally to each other, like one dipole on X-axis, second on y-Axis and third on Z-axis respectively. The result of this geometry explained in the following section.
See Figure 3 is three orthogonal dipole arrangements made in antenna design simulator HFSS V18.0

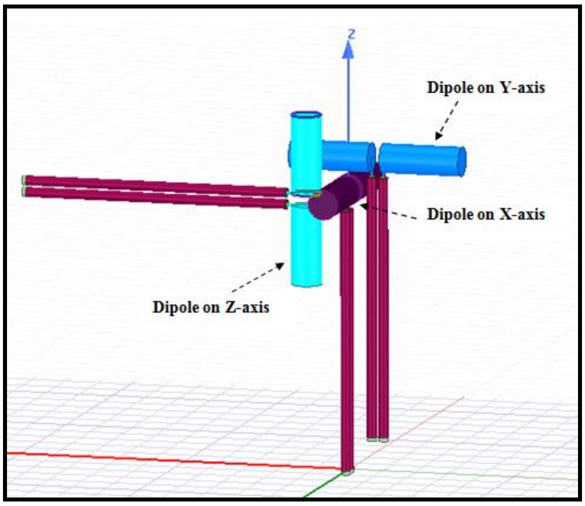

Figure 3: Proposed HFSS module of 3-Axis crossed dipole array.

5 Results

5.1 Single Dipole

5.1.1 Return Loss S11 of Single dipole

For the comprehensive band coverage from 700MHz to 3GHz, the reference frequency is set to 1.3GHz and accordingly dipole dimensions are calculated using a standard formula of the dipole. So dipole total length L is 10.3cm including a gap between two is GL =7mm. For this size, an antenna is simulated using HFSS.

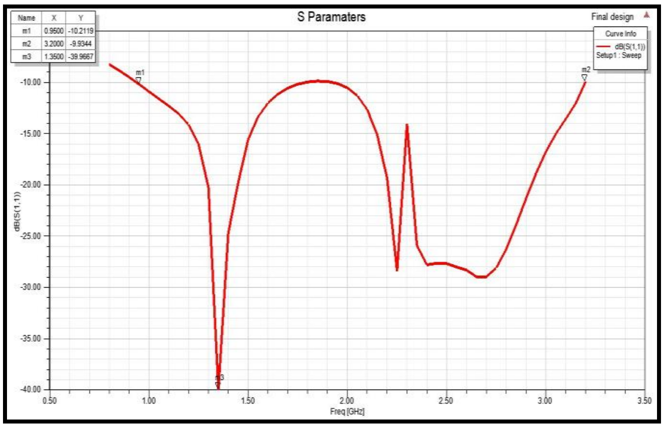

Figure 4: Simulated Return loss for dipole antenna.

Figure 4 shows the return loss of calculable reference antenna with a balun, As per above graph, marker-1 start from 900MHz and end at the 3.2GHz frequency and for this 0.9-3.2GHz frequency range return loss S11 value less than -10dB. The maximum peak detected at frequency 1.3GHz, and its value is -39.96dB.

5.2. Three axial Antenna Results.

5.2.1 Return Loss S11 of three orthogonal dipole

In electric field strength measuring case, for high accuracy, three crosses orthogonal dipole are arranged. Return loss s11 of XY plane shown in figure 5; it shows that return loss is below -10dB for the range of frequency approximately from 900MHz to 3GHz, similarly return loss S11 of xz and yz plane are shown in figure 6 and 7 respectively.

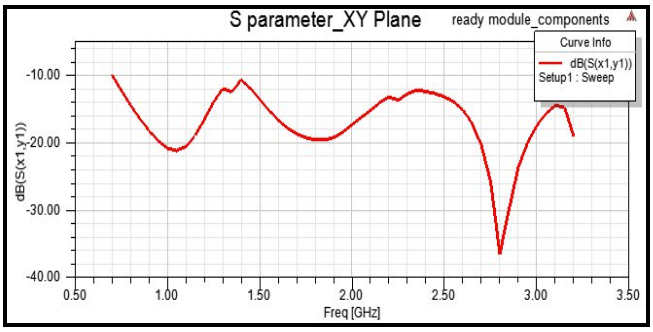

Figure 5: Simulated Return loss for dipole antenna.

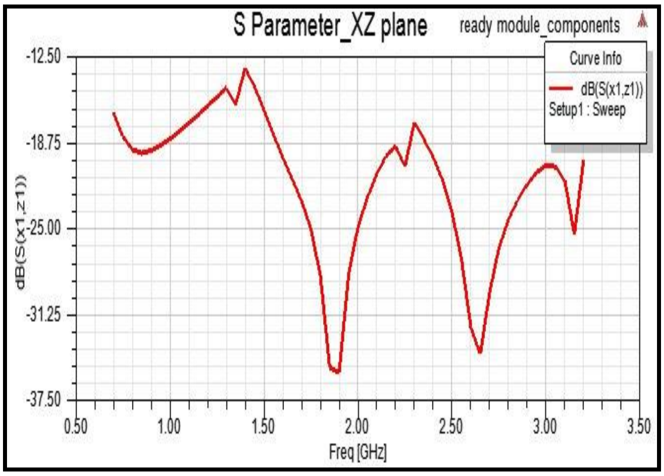

Figure 6: Proposed HFSS module of 3-Axis crossed dipole array.

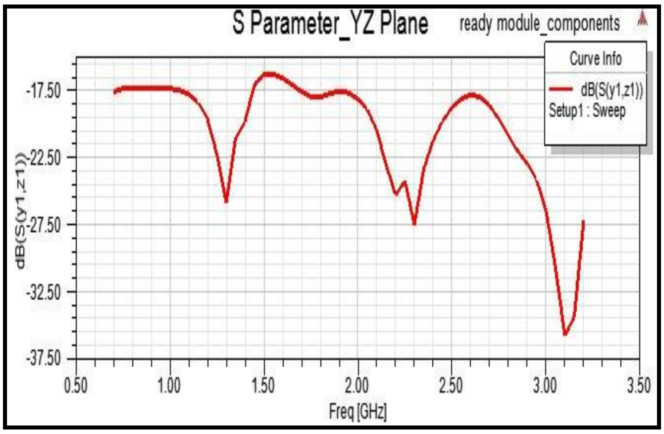

Figure 7: Proposed HFSS module of 3-Axis crossed dipole array.

5.2.2 Polar radiation pattern

Polar radiation pattern at frequency 2GHz shown in figure 8, an antenna provides a perfect pattern with maximum gain is 2.3 dB.

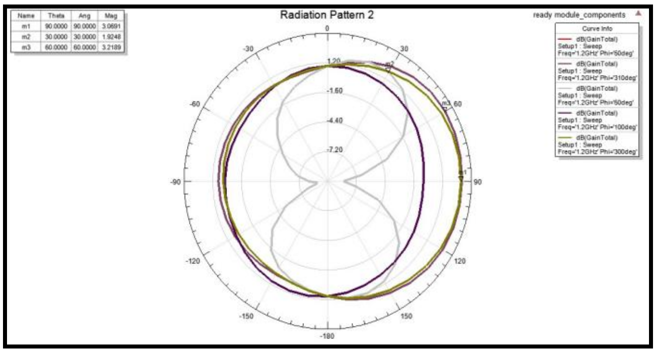

Figure 8: Polar Radiation Pattern of Antenna at 2GHz.

5.2.3 3D Radiation Pattern and Directivity.

3D radiation pattern and 3D directivity have shown in figure 9 and 10 respectively.

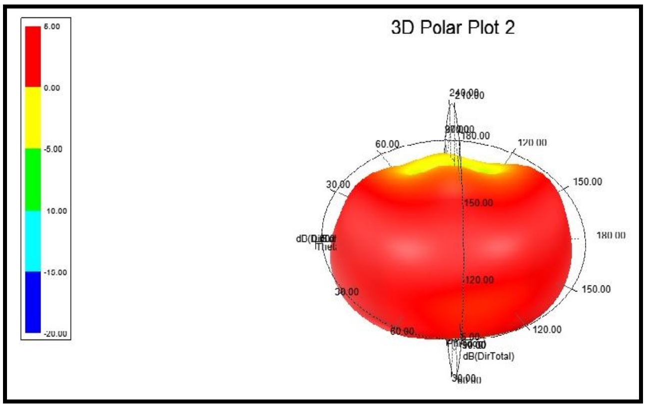

Figure 9: Polar radiation pattern of antenna at 2GHz.

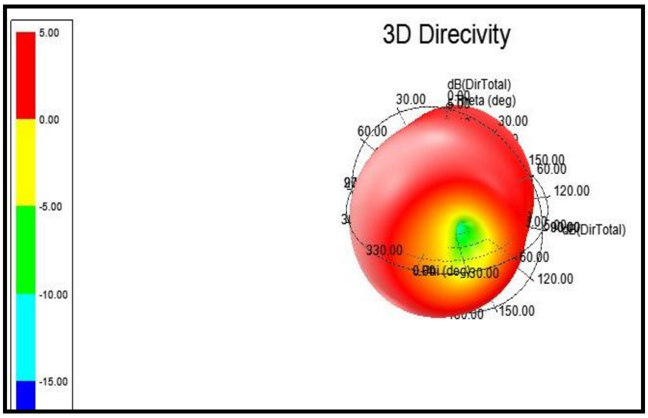

Figure 10: Polar radiation pattern of antenna at 2GHz.

5.2.4 Smith Chart

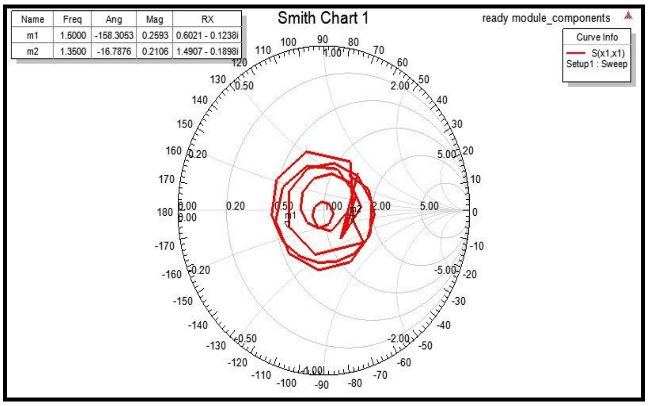

Figure 8: Polar radiation pattern of antenna at 2GHz.

Shown in figure 11, the Smith chart of the antenna, characteristics impedance is most crucial aspect in antenna designing, theoretically power and cable impedance was considered as 50**Ω**, a per the simulation results with Smith chart characteristics impedance is calculate, impedance value is approximately equal to theoretical consideration, as per the result characteristics impedance is 73.53 at 1.35 GHz frequency.

6 Conclusions

A single compact rod-type dipole antenna designed for reference frequency 1.3GHz, to improve the bandwidth and resonance for the frequency range 900 MHz to 3.2GHz by implementing the hybrid balun. This dipole assembly is mounted on each axis to make 3-Axis field probe for enhancing the performance of measuring field strength. The results show that the improvement in the bandwidth with the single compact dipole for the high-frequency range. In center dipole driven case, 17cm coaxial cable improves the performance of sensing antenna used in EMI/EMC applications.

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