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A New Type of Loop Antenna for EMC Measurement

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Abstract

A newly developed EMC (Electromagnetic Compatibility) antenna is proposed in this paper which can simulate highly directive standard EM (Electromagnetic) waves. The proposed antenna can be made by placing a one-sixth of conducting loop-wire (H-Loop) in front of a 60^0 degree corner reflector. The mathematical model of such a quasi-shield probe called H-loop is developed. The characteristics of this antenna have been compared with those of the existing quarter loop antenna and a complete loop antenna.

Introduction

Scientists and engineers in the field of Electromagnetic Compatibility (EMC) are always interested in designing electronic systems which are invulnerable to hostile or interfering electromagnetic environments and at the same time electromagnetically harmless to their neighbouring devices. The simplest way of reducing ingress or emission of Electromagnetic Interference (EMI) is by enclosing electrical and electronic equipment using conducting materials. Again, the level of shielding of the enclosure against EMI is usually determined by the measurement of Shielding Effectiveness (SE) of the material used for the enclosure[1].

Standard field simulation is the starting point of any SE measurement technique. Thus it is necessary for an antenna which could simulate standard EM waves. Recently, a Quarter loop antenna in front of 90° reflector was designed for near magnetic field SE measurement of the plannar sheet[2].

In this paper a H-Loop antenna has been proposed to simulate standard EM wave for magnetic field shielding effectiveness measurement of the plannar sheet.

The paper is organised as follows. At first the mathematical model and antenna parameters of the H-Loop antenna are presented. Comparison of developed H-Loop antenna parameters with that of a quarter loop as well as a complete loop antenna are presented in the next section. Finally, concluding remarks are presented.

Mathematical Model

The mathematical model of the H-loop antenna has been developed by using image

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theory and the theory of pattern multiplication[3]. The field due to the are (one sixth of the loop) is to be calculated first and then applying image theory for determining the images of the are. The effect of these images on the field of the original H-loop are then superimposed by a method similar to pattern multiplication.

One sixth of a loop in front of a 60° corner reflector produces five image loops of the original one (fig.1). Thus the H-Loop antenna can be considered an array of coplanar three pairs of dipoles shown in Fig. 2.

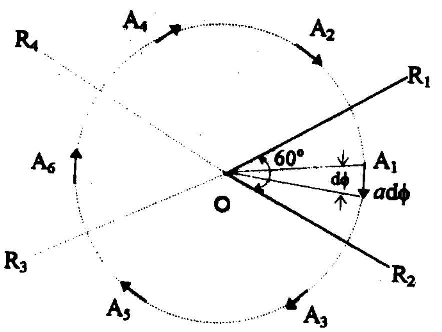

Fig. 1 : Image produces by an infinitesimal dipole of one sixth of loop in front of a 60° corner reflector.

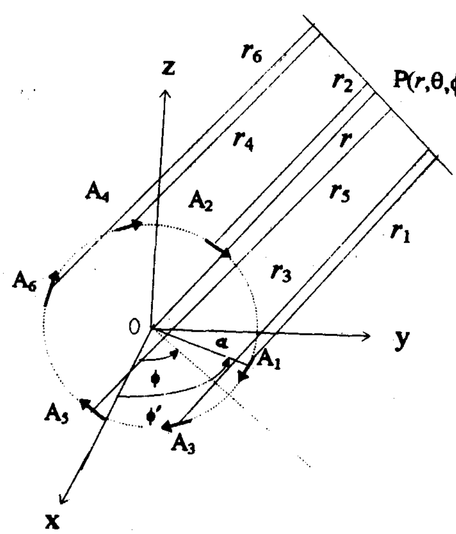

Fig. 2 : Far field of three pair of dipoles.

Each pair of dipole are parallel to each other carrying equal and out of phase current. Let the current through the arc is in ϕ direction only, so the vector potential at any point in space will be ϕ directed only. The far field is computed from vector potential of coplanar hexad dipoles and the vector potential of the one sixth of loop element.

To compute the vector potential of the one sixth of loop and coplannar hexad dipoles the differential length $ad\phi$ of the arc is considered at point A_1, shown in fig. 3. The distance (r_1) between the observation point $P(r,\theta,\phi)$ and the point A_1 can be computed as[4]

$$r_1 = r\left[1 - \frac{2a}{r}\sin\theta\cos(\phi' - \phi)\right]^{1/2} \qquad (1)$$

where a is the loop radius.

It is assumed that $a \ll r$, thus, for distance consideration only first term of the expression is taken. The eqn. 1 then becomes as

$$r_1 \cong r \qquad (2)$$

and for phase consideration first two term of the expression are taken and eqn. 1 then becomes as

$$r_1 \cong r - a\sin\theta\cos(\phi - \phi') \qquad (3)$$

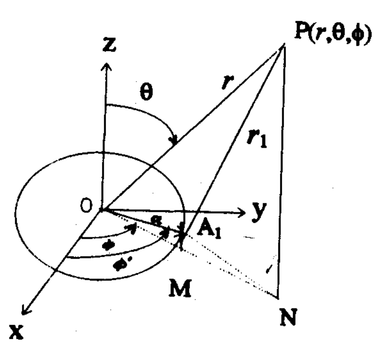

Fig. 3 : Geometry of one sixth of loop for determining the vector potential of the H-Loop arc.

The vector potential (A_{arc}) at point P(r,θ,φ) in free space due to the current in the one sixth of loop can be written as[5]

$$\vec{A}_{arc} = \frac{\mu[I]a}{4\pi r}\int_0^{\pi/3} e^{j\beta a \sin\theta \cos(\phi - \phi')} d\phi' \quad (4)$$

where $[I] = I_o e^{j(\omega t - \beta r)}$

For simplicity of the definite integral of eqn. 4, it is assumed that $\lambda >> a$ and $\beta a << 1$. Thus the solution of definite integral of eqn. 4 will be $\pi/3$ [4] and

$$\vec{A}_{arc} = \frac{\mu[I]a}{4\pi r}\cdot\frac{\pi}{3}\vec{\phi} \quad (5)$$

The same analysis can then extended to compute the vector potentioal due to original arc and its five similar images. The resultant vector magnetic potential due to the three pairs of dipoles at the far field point P(r,θ,φ) will be[4]

$$\vec{A} = \hat{\phi} 3 j\beta a \sin\theta \times \vec{A}_{arc} \quad (6)$$

where, φ is the unit vectors along φ direction and $3j\beta a \sin\theta$ is known as the array factor.

Field Computation

The expression for far electric and magnetic field produced by the arc alone can be written as[4]

$$E_{\phi arc} = j\omega\frac{\mu[I]a}{4\pi r}\frac{\pi}{3} \quad (7)$$

$$H_{\theta\, arc} = -j\beta\frac{[I]a}{4\pi r}\frac{\pi}{3}$$

The net field of the H-Loop antenna can be obtained (choosing the co-ordinate axes of the loop is in the x-y plane and the reflectors OR_1 and OR_2 are parallel to plane of z, fig. 1), as

$$E_\phi = \text{Array factor} \times E_{\phi arc}$$

$$= \frac{\mu\omega[I]a}{4r}\beta a \sin\theta \quad \text{for } 0\leq\phi\leq\pi/3 \text{ and } 0\leq\theta\leq\pi$$

$$= 0 \quad \text{elsewhere} \quad (8)$$

$$H_\theta = \text{Array factor} \times H_{\theta arc}$$

$$= \beta\frac{[I]a}{4r}\beta a \sin\theta \quad \text{for } 0\leq\phi\leq\pi/3 \text{ and } 0\leq\theta\leq\pi$$

$$= 0 \quad \text{elsewhere} \quad (9)$$

The theoretical prediction of the radiated electric field (Eφ) according to eqn. 8 are shown in fig. 4.

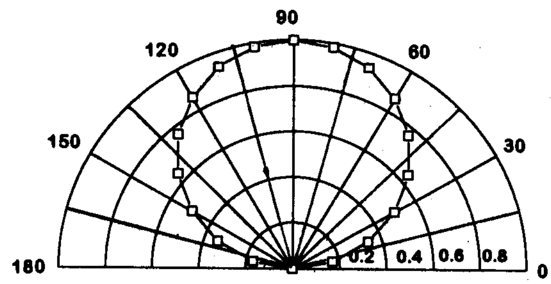

Fig. 4 (a) : Normalized radiated electric field (Eφ) of the H-Loop antenna at φ=90° plane with θ varying from 0 to 360°.

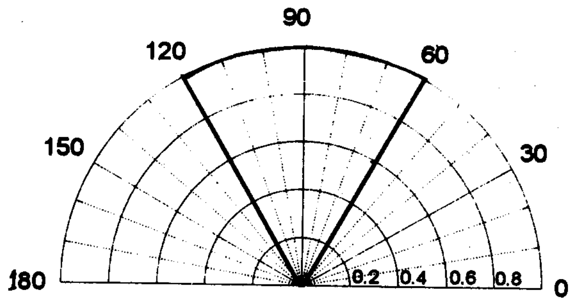

Fig. 4(b) : Normalized radiated electric field (Eφ) of the H-Loop antenna at θ=90° plane with φ varying from 0 to 360°.

Antenna parameters

To calculate the important antenna parameters (such as directivity gain and radiation efficiency) it has been assumed that the antenna radiates only in front of the the reflectors i.e. θ varies from 0 to π and φ from 0 π/3 and $a<<\lambda$.

The diectivity of an antenna is the ratio of maximum to average radiation intensity. Again, these intensities are related to the total power radiated by the antenna. For H-Loop antenna total radiated power will be[4]

$$P_r = \frac{5\pi^2 \beta^4 a^4 I_0^2}{3} \qquad (10)$$

The maximum and average radiation intensities are[4]

$$U_m = \frac{9}{4\pi} P_r, \text{ and } U_{av} = \frac{P_r}{4\pi} \qquad (11)$$

Hence, the directivity of H-Loop antenna D_H will be 9.

The gain of H-Loop antenna,

$$G_H = \eta_H D_H \qquad (12)$$

where the radiation efficiency η_H is

$$\eta_H = \frac{R_r}{R_r + R_{ohmic} + R_{ref}} \qquad (13)$$

Here, R_r is the radiation resistance, R_{ohmic} is the ohmic resistance and R_{ref} is the reflector resistance.

Results and comparison

The H-Loop antenna parameters have been computed by considering the following design data:

loop radius (a) = 15cm.

wire radius (r_w) 8mm.

reflector size = 60cmx60cmx2mm

The above designed data are also to be considered to find the antenna parameters of the quarter loop and the complete loop antenna.

Predicted gain of the proposed H-Loop antenna has been compared with those of the quarter loop antenna and a complete loop antenna. This is shown in fig. 5. The plot shows that gain of the proposed antenna is higher than that of quarter loop and a complete loop. Predicted radiation efficiency of the H-Loop antenna has been compared with the complete loop antenna which is shown in fig. 6. From fig. 6 it is evident that the H-Loop has the same radiation eficiency as that of the complete loop. This is due to the consideration of all five images in the case of H-Loop. The directivity of the H-Loop has also been compared with that of quarter loop and a complete loop. The comparison is shown in table-1. It is evident from the table that the directivity of H-Loop antenna is 1.5 times of quarter loop and 6 times of complete loop antenna.

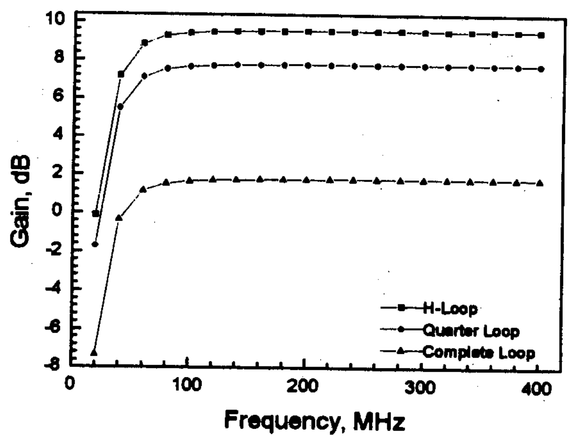

Fig. 5 : Comparison of gain vs frequency curve of H-Loop, Quarter Loop & Complete Loop Antenna.

Conclusion

This paper shows that, newly developed H-Loop antenna is a highly directive antenna with high gain. It is found that both the gain and radiation efficiency remains constant at all frequencies above 100MHz. Thus the developed antenna may be referred to as frequency independent antenna above 100MHz. It can also noted here that complete loop antenna radiates over a solid angular surface in 360° whereas the H-Loop radiates in only 60° which is one-sixth of such a surface.

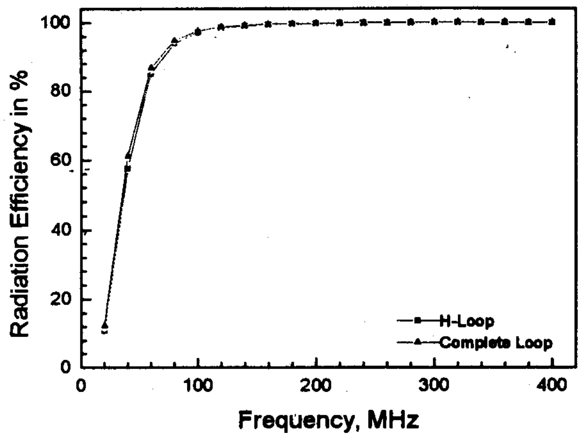

Fig. 6 : Comparison of radiation effeciency vs frequency curve of H-Loop & Complete Loop Antenna.

Table : 1

Antenna	Complete loop[3]	Quarter loop[2]	H-loop[4]
Directivity	1.5	6	9

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