THE MUTUAL IMPEDANCE OF TWO CROSSED LOOP ANTENNAS

by
Kamal H. Awadalla & Said M. A. El-Halafawy
The Faculty of Electronic Engineering
Menoufia University , Menouf , Egypt

Abstract- The mutual impedance of two identical crossed loop antennas has been determined using the moment method for different angles between their planes. This has been done for several values of perimeter to wavelength ratio. It has been proved that the expected cosinusoidal variation of the mutual impedance with the variation of the angle between the two crossed loops only holds for those of infinitesimal dimensios.

I. INTRODUCTION

Crossed loops has a high potential to be used in diversity reception techniques especially when the dimensions of the area on which the antennas are to be erected is of the order of a wavelength or less as in mobile communications. Therefore there is a great need to investigate and understand the characteristics and behaviour of such antenna system.

The impedance of loop antennas has been treated several times in the literature [1] ,[2],[3]. Also parallel loops has been analysed [4],[5], but the authors are not aware of any published work dealing with crossed loop system. However, there is a common belief that the mutual impedance between such loops will vary cosinusoidally with the angle between them. In fact, it is the purpose of this paper to correct this belief and show that it is true only in case of infinitesimal loops .

II. ANALYSIS OF THE CROSSED LOOPS

It is very easy to show that for infinitesimal loops (or loops of uniform current distribution along their perimeter), the mutual impedance for two identical crossed loops, as shown in Fig.1, is given by

$$Z_m = \pm Z_s \cos \theta \qquad (1)$$

where Z_s is the self impedance of any of the two identical crossed loops, and θ is the angle between the planes of the two loops.

For loops of dimensions comparable to the wavelength the mutual impedance has been computed exactly using the moment method [6],[7]. The system of crossed loops was analysed by expanding the current on each loop in subsectional triangular functions with the weighting functions were triangular as well. The impedance matrix was then formed and the current distribution on both antennas is then worked out with the assumption that a source of unit voltage is applied at the center of one of the primary loop sides, which is selected for symmetry to be on one of the sides that cross the plane of the other loop. The point of feed will be in this case at the crossing point.

The second loop is identical with the first one with its feed point is assumed to be congruent with that of the first loop when the angle between them is zero. In the computations, the terminals of the second loop were assumed to be short circuited therefore the mutual impedance is given by

$$Z_m = -\ (I_2 / I_1)\ Z_{2s} \qquad (2)$$

where I_2 is the short circuit current at the feed point of the second loop, I_1 is the current fed to the primary loop, and Z_{2s} is the self impedance of the secondary loop (equal to that of the first loop due to the identity). It is clear that this is the same as the ratio of the open circuit voltage across the terminals of the second loop to the feed current of the first loop.

In the extreme case of zero angle between the planes of the two loops i.e. when the two loops are coincident, the mutual impedance between the two loops becomes equal to the self impedance of any of them because of their identity. This is used to extend the curves of the mutual impedance to the zero axis as shown in Fig.2.

III. THE RESULTS

The two loops are assumed to be made of a wire of radius 0.00318 meters. The side length of each loop is taken to be 0.1 m with the loops having square configuration, therefore the perimeter length equals 0.4 m. Four frequencies were selected for computing the variation of the mutual impedance with the variation of the angle between the loops. These are 120, 300, 480 and 600 MHz, which correspond to perimeter to wavelength ratios of 0.16, 0.4, 0.64 and 0.8 . These ratios are chosen to cover the range of small loops to relatively large loops.

In Fig.2 the mutual impedances for the mentioned cases are given, with the curve of the 0.64 ratio being compared to an assumed one with cosinusoidal variation. It is clear from the figure that neither of the curves follows a cosinusoidal or even close to a cosinusoidal variation. The magnitude of the mutual impedance drops relatively fast at first (near the zero angle) and approaches the zero level at 90 degrees in a slower rate than the cosinusoidal variation. This indicates that the rate of variation of the actual mutual impedance is opposite in behaviour to the case of cosinusoidal variation. It is also noted from Fig.2 that the rate of variation at a certain angle vary with the variation of the perimeter to wavelength ratio (P/λ), and its ratio relative to the value at zero angle is not the same. This indicates that the variation of the mutual impedance with angle is not a function of the θ angle only but also it is a function of the ratio (P/λ) of the loop, i.e. it can be expressed as

$$Z_m / Z_{mo} = \text{fun}\ (\theta\ ,\ P/\lambda) \qquad (3)$$

where Z_{mo} is the mutual impedance at zero θ angle.

IV. CONCLUSIONS

The mutual impedance of two identical crossed loop antennas has been investigated using the moment method. From the given results it can be concluded that the variation of the magnitude of the mutual impedance with the variation of the angle between the two loops is not a cosinusoidal variation as it has been commonly accepted. It becomes clear that the mutual impedance variation is a function of the angle θ between the two loops in addition to the dimensions of the loops in terms of wavelength.

REFERENCES

1- R.W.P.King & C.W.Harrison; Antennas and Waves: A Modern Approach, The M.I.T.Press, Cambridge, Massachusetts, 1969.

2- G.S.Smith, "A Note on the Imperfectly Conducting Circular Loop Antenna,"Radio Science, Vol. 9, No. 1, Jan. 1974, P.35.

3- K.H.Awadalla & A.A.Sharshar,"A Simple Method to Determine the Impedance of a Loop Antenna,"IEEE Trans. Ant.&Prop., Vol. AP-32, No. 11, Nov. 1984.

4- A.Abul-Kassem & D.C.Chang,"On Two Parallel Loop Antennas," IEEE Trans. Ant.&Prop., Vol. AP-28, No. 4, July 1980,P.491.

5- R.W.King; Fundamental Electromagnetic Theory, 2nd Ed., Dover, N.Y. 1963.

6- R.F.Harrington,"Matrix Methods for Field Problems," Proc. IEEE, Vol. 55, No. 2, Feb. 1967, P. 136.

7- R.F.Harrington; Field Computation by Moment Methods, The Macmillan Co., N.Y., 1968.

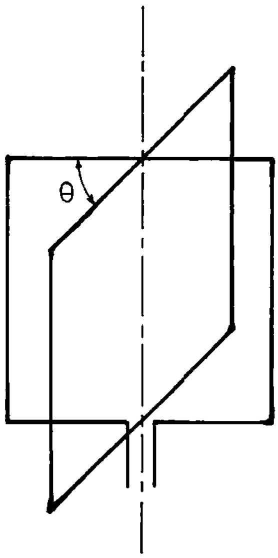

Fig. 1 - Crossed loop antennas.

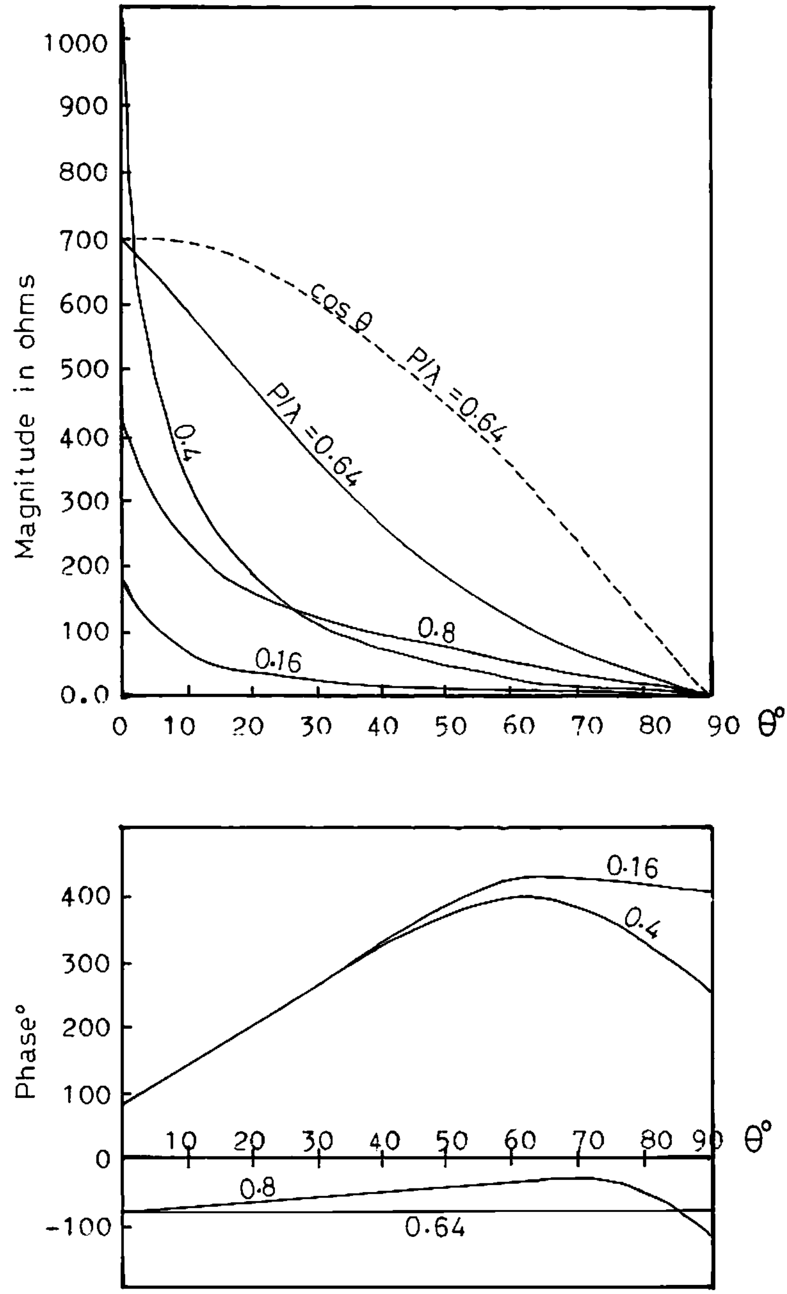

Fig. 2 - The magnitude of the crossed loops mutual impedance in ohms and its phase in degrees.