

# Impact of Mutual Coupling between Antenna Elements on BER Performance of Dual Diversity Adaptive Array

**J. Rajeshwar Goud<sup>1</sup>**  
Asst. Prof., ECE Dept.,  
St. Martin's Engineering  
College,  
Hyderabad, T.S., India.

**Dr. N. V. Koteswara Rao<sup>2</sup>**  
Professor, ECE Dept., Chaitanya  
Bharathi Institute of  
Technology,  
Hyderabad, T.S., India.

**Dr. A. Mallikarjuna Prasad<sup>3</sup>**  
Professor, ECE Dept.,  
University College of  
Engineering, JNTUK, Kakinada,  
A.P., India.

**Abstract**— The impact of mutual coupling between antenna elements on the Bit Error Rate (BER) performance of a novel dual diversity adaptive antenna system employing Triple-COLD array is investigated. This adaptive array can provide up to six degrees of freedom in polarization domain and thereby increase the capacity of wireless communication system. Design description and the implementation of COLD array using EM simulation tool CAD FEKO is presented.

**Index Terms**—BER, Adaptive Array, CAD-FEKO, Mutual coupling, COLD.

## I INTRODUCTION

In recent times, demand for mobile wireless services continues to explode. This high demand for wireless communications services requires increased system capacities. In this way the effective utilization of accessible frequencies is vital [1].

Utilization of antenna arrays has been proposed as of late for versatile mobile communications systems to conquer the issue of restricted channel transmission capacity, in this manner fulfilling a consistently developing interest for a substantial number of mobiles on interchanges channels [2]. An increase in capacity is possible by reusing frequencies with space division multiple access using adaptive antenna arrays. In our earlier work [6], [7], we proposed a novel polarization diversity scheme, in which each user is assigned a different set of polarization angles. And the adaptive array, employing polarization sensitive elements such as, triple-COLD, can separate the signals arriving from the same or very close directions, based on their

polarization angles thereby supporting more users in spatial diversity scenario. The weights of the adaptive array are adjusted to maximize the response of the array for desired user signal polarization and cancel the interference user signal arriving from the same direction but with different polarization. However, in our earlier investigations presented, it has been expected that the antenna elements are isolated from each other. Practically speaking, elements of an antenna array have mutual coupling, which thusly influence the performance of the system. The reradiated fields collaborate with alternate components making the receiving antenna elements be commonly coupled. Gupta and Ksienski [8] broke down the impacts of mutual coupling on a measurable versatile adaptive algorithm. Numerous creators have utilized this plan to examine and kill the impacts of mutual coupling on direction of arrival (DOA) estimation algorithms [9], [10].

In this paper, we discuss the design description and implement co centered orthogonal loop and dipole (COLD) array using EM simulation tool CAD FEKO. We compute the normalized impedance matrix and using this impedance matrix, we demonstrate the mutual coupling effects on the BER performance of dual diversity adaptive array system.

## II MUTUAL COUPLING EFFECTS

The formulations for the adaptive array using Triple-COLD, its steering vector, bit error rate (BER) given by equations (2), (3) in [7], are modified for incorporating the mutual coupling effects. The real accepted voltage signal  $x(k)$  at the adaptive array output given in [5]-[7], is without taking the mutual coupling effects into account. Taking into account the

mutual coupling, the real accepted voltage vector is given by [8]

$$\begin{aligned} x(k) &= \bar{x}(k) + n(k) \\ &= Z^{-1}x_o(k) + n(k) \\ &= Z^{-1}Pb(k) + n(k) \end{aligned} \quad (1)$$

where,  $Z$  is a nonsingular normalized impedance matrix. It ought to be noticed that the matrix  $Z$  is a normalized impedance matrix, normalized to the load impedance. It acts like a transformation matrix, changing the open circuit component voltages to the terminal voltages. If the element spacing is sufficiently extensive so that the mutual coupling impact between the elements is little and hence the impedance matrix  $Z$  becomes diagonal. The array performance will be the same as discovered utilizing the open circuit voltages as the input signals to an adaptive processor.

According to the MMSE approach, the adaptive weight, taking the mutual coupling into account, can be written as [8]

$$w_{MMSE} = (Z^{-1}PP^H(Z^{-1}PP^H + \sigma^2 I_L)^{-1})^{-1} p_1 \quad (2)$$

The problem of mutual coupling effect can be analyzed as follows. First step is to find the impedance matrix by EM simulation tool. Second step is to discover the weight vector by incorporating the  $Z$  matrix in the weight vector expression as given in equation (2).

#### A. Computation of Impedance Matrix $Z_c$

The impedance of an antenna at a point is described as the extent of the electric to the alluring fields by at that point; then again, at a couple of terminals it is portrayed as the extent of the voltage to the current over those terminals. There are numerous techniques that can be used to find the impedance of an antenna. Generally, these can be ordered into three classifications [8]; The boundary-value technique, The transmission – line technique, the Poynting vector technique. The impedance of an antenna can likewise be discovered using an integral equation with a numerical technique solution, which is generally alluded to as the Integral Equation Method of Moments. In MoM, each antenna array element is represented as a wire of finite thickness divided up into segments. At the core of the MoM is the computation of a system impedance matrix giving the coupling between segment and in the antenna array model where is the aggregate number of wire segments in the model.

To simplify the analysis, it is assumed that the antenna system consists of two elements. The system can be represented by a two-port (four-terminal) network, as shown in Fig.1

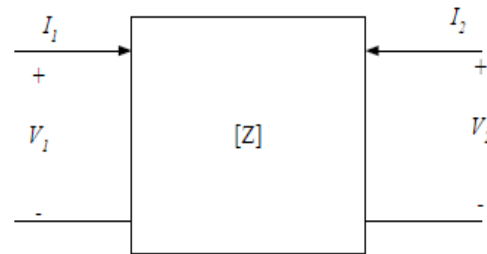


Fig. 1. Two – Port Network

The impedances  $Z_{11}$  and  $Z_{22}$  are the input impedances of antennas 1 and 2, respectively, when each is radiating in an unbounded medium. The excitation depends upon the spacing between the elements, antenna type and the type of feed. It is, therefore that the mutual impedance plays an important role in the performance of an antenna and should be investigated.

To achieve this require an extensive definition, PC programming, and as a rule a computerized PC. There are many computer codes available for EM simulation, such as Numerical Electromagnetic Code (NEC) and CAD-FEKO etc.

#### B. Mutual Coupling Effect on BER Performance of COLD Array

We implemented COLD array in CAD-FEKO. Our main focus here is to find the coupling impedance matrix  $Z_c$  and find weight vector, BER with mutual coupling taken into account. We designed a half wave length dipole at 950 MHz The length of the dipole is found to be 152mm and the diameter is set to 2mm. Whereas, the diameter of the loop is taken as  $2\pi r = \lambda$ , which is found to be 55mm. The thickness or the diameter of the wire is taken as 2mm. The element spacing is chosen to be one wavelength. The screen shot of implementation of COLD array in CAD-FEKO is illustrated in Fig. 1. The return losses and coupling between the elements are recorded. The scattering matrix is finding from impedance matrix using equation (3)

$$S = [Z - I][Z + I]^{-1} = [I - 2[I][Z + I]^{-1}] \quad (3)$$

where  $I$  is identical matrix and  $Z$  impedance matrix.

The scattering matrix in dB is given in matrix form in Eqn. (4). The coupling between the two dipoles is found to be about -18dB, and it is found to be -91dB between the dipole and loop. The coupling between loop and dipole is found to be about -107dB and between loop and loop it is found to be about -31dB. It is understood that the coupling between the two loops is also less, and they are well isolated. Only the considerable coupling in between the two

co polarized dipoles. The s-parameters versus frequencies is plotted in Fig. 3 and 4.

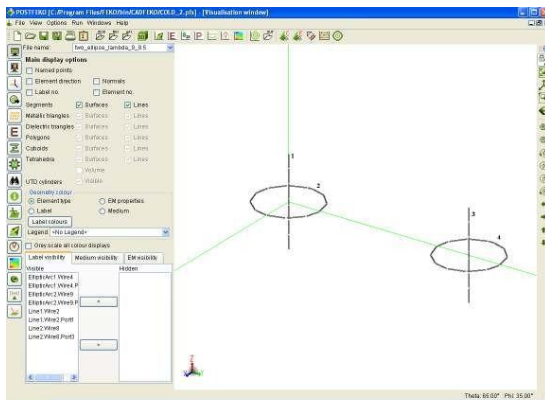


Fig. 2. Screenshot of COLD Implementation in FEKO

TABLE I. COLD array impedance matrix

Z11	1.3949 - 0.1121i	Z31	0.1144 + 0.3276i
Z12	-0.0000 - 0.0000i	Z32	-0.0001 - 0.0001i
Z13	0.1144 +0.3276i	Z33	1.3949 - 0.1121i
Z14	0.0000 + 0.0001i	Z34	0.0000 + 0.0000i
Z21	0.0000 +0.0000i	Z41	-0.0001 - 0.0001i
Z22	2.7606 - 0.3174i	Z42	-0.1935 - 0.0246i
Z23	0.0001 +0.0001i	Z43	0.0000 - 0.0000i
Z24	-0.1944 - 0.0239i	Z44	2.7609 - 0.3176i

$$S - COLD_{(dB)} = \begin{bmatrix} -14.52 & -107.72 & -18.51 & -91.22 \\ -109.98 & -6.50 & -93.12 & -31.22 \\ -18.51 & -91.19 & -14.52 & -107.12 \\ -93.16 & -31.19 & -108.77 & -6.50 \end{bmatrix} \quad (4)$$

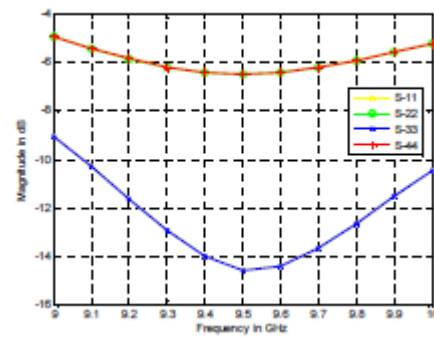


Fig. 3. Return Loss for Various Element in COLD Array

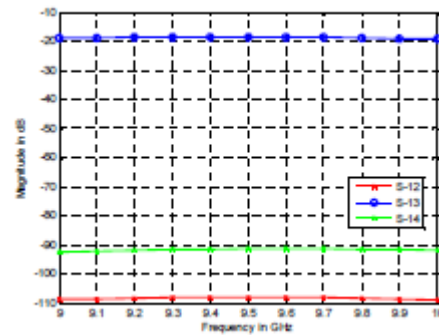


Fig. 4. Coupling between Various Element in COLD Array

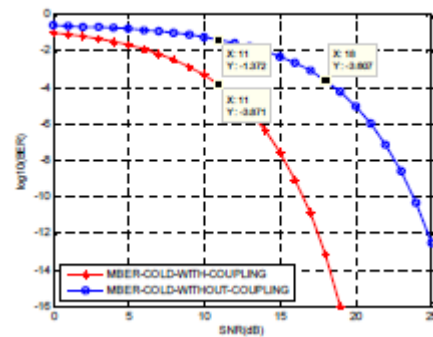


Fig. 5. Impact of mutual coupling on the BER performance of Adaptive array with COLD

The effect of mutual coupling on the BER performance of COLD array is illustrated in Fig.5. It is found that the BER without mutual coupling is  $10^{-3.871}$  at SNR=11dB and the same BER is achieved at SNR=18dB with mutual coupling. BER is found to be  $10^{-1.372}$  at input SNR=11dB with mutual coupling.

### III CONCLUSION

In this paper, the polarization sensitive COLD array implementation in CAD-FEKO EM simulation tool is presented. Its frequency response, s-parameters are computed. Coupling impedance matrix is also computed. It was also shown the impact of mutual coupling on the BER performance of dual diversity adaptive antenna system employing COLD array. It is also demonstrated that the coupling is very less between the orthogonal elements even though are co-centered. The main contribution for the reduction in BER is the return loss or the self impedance, and the coupling between the elements which are oriented along the same axis and placed at a distance of one wavelength.

### REFERENCES

- [1] Joseph C. Liberti, Jr., Theodore S. Rappaport, Smart Antennas for wireless Communications: IS-95 and Third Generation CDMA Applications. Prentice Hall PTR, 2000.
- [2] Joseph C. Liberti, Jr., Theodore S. Rappaport, Smart Antennas for wireless Communications: IS-95 and Third Generation CDMA Applications. Prentice Hall PTR, 2000.
- [3] R.T. Compton Jr., Adaptive Arrays- Concepts and Performance, Englewood, NJ: Prentice Hall, 1998.
- [4] S.Chen, N.N. Ahmad and L.Hanzo, "Adaptive minimum bit error rate beam forming" IEEE Trans. on Wireless Commun., Vol.4, pp. 341-348, March 2005.
- [5] Li. Jian. , Petre Stoica, Dunmin Zheng, "Efficient direction and polarization estimation with COLD array" IEEE Trans. Antennas Propagat., vol.44, no. 04, pp.539-547, April 1996.
- [6] Y. Ravinder, V. M. Pandharipande, "Polarization Diversity Triple-COLD adaptive antenna with Minimum Bit Error Rate approach". 3<sup>rd</sup> International conference on Microwaves, Antennas, propagation, Remote sensing(ICMARS), December, 2006 at ICRS Jodhpur.
- [7] Y. Ravinder, V. M. Pandharipande, V.M "Polarization Diversity Smart Antenna with Triple-COLD Array

Using Genetic Algorithm" International Symposium on Antennas and Propagation (ISAP'07), Aug., 2007, Niigata, Japan.

- [8] Inder J Gupta, Aharon A Ksienski, "Effect of Mutual Coupling on the Performance of Adaptive Arrays" IEEE Trans. Antennas Propagat., vol. AP-31, no.5, pp.785-791, Sept. 1993.
- [9] Kapil R. Dandekar, "Experimental Study of Mutual Coupling Compensation in Smart Antenna Applications" IEEE Trans. Wireless Commun., vol. 1, no. 3, pp.480-487, July 2000.
- [10] Bin Wang, Yongyu Chang, Yang Sun, "Performance of the Large-Scale Adaptive Array Antennas in the Presence of Mutual Coupling" IEEE Trans. Wireless Commun., vol. 64, no.6, pp.2236-2245, April. 2016

### AUTHORS DETAILS

1. **J. Rajeshwar Goud** working as an Assistant Professor in the Department of Electronics and Communication Engineering, St. Martin's Engineering College, Hyderabad, Telangana, India. He awarded UGC-NET Lectureship in 2013. He is currently working toward the Ph.D degree in the Department of Electronics and Communication Engineering, JNTUK, Kakinada, Andhra Pradesh, India. His current research interest in Planar antennas.
2. **Dr N. V. Koteswara Rao** is Professor and HOD, Department of ECE, CBIT, Hyderabad. He is also Chairman, Board studies of ECE under Autonomous and also Coordinator for TEQIP-II. He is best teacher awardees' and best paper awardees' in an international conference. Presently he is working on a project from DRDO and one in-house project on reconfigurable Microstrip antennas. He is guiding Ph.D. Research Scholars. He is associated with Center for Excellence in Microwave Engineering of Osmania University, Hyderabad.
3. **Dr A. Mallikarjuna Prasad** is Professor and VICE PRINCIPAL, UCEK, JNTUK, Kakinada. He obtained his Ph.D from Andhra University. He worked as HOD, Department of ECE, UCEK, JNTUK. He worked as Controller of Examinations in JNTUK. His research interests include Wireless Communications, Biomedical Instrumentation and Microwave antennas.