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Design and Implementation of Decoupling Network for Phased Array Antennas

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Abstract

Secure communications are highly demanded by many wireless sensor network (WSN) applications. The random key pre-distribution (RKP) scheme has become well accepted to achieve secure communications in WSNs. However, due to its randomness in key distribution and strong constraint in key path construction, the (RKP) scheme can only be applied in highly dense networks, which are not always feasible in practice. In this paper, we propose a methodology called network decoupling to solve this problem. With this methodology, a wireless sensor network is decoupled into a logical key-sharing network and physical neighborhood network, which significantly releases the constraint in key path construction of scheme. We design a secure neighbor establishment protocol (called RKP-DE) as well as a set of link and path dependency elimination rules in decoupled wireless sensor networks. Our analytical and simulation data demonstrate the performance enhancement ofour solution and its applicability in non-highly dense wireless sensor networks.

I. INTRODUCTION

Why we are going for the decoupling network? Means this is reciprocal and lossless. The input ports of decoupling network can be matched and decoupled independently with each other with self-matching network. This the decoupling network that can be used to save some hardware equipments. If both the input ports are matched means that can be done independently and individually. If there is any loss in the network means there we can use the genetic algorithm based on decoupling methods. There are two main approaches to deal with the problem. The first one is based on reducing the mutual coupling using preliminary measures and calculations, leading to compensation for the mutual coupling.

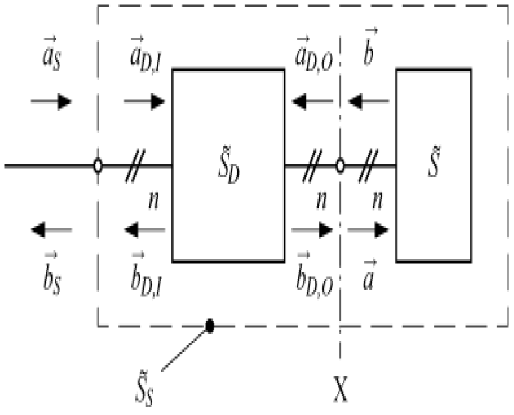


Figure1. Wave quantities at a decoupling network

Application based on the decoupling network which is done as a reference point of view:

1.Eigen analysis network
2.Multiport coupling network
3.Mutual coupling coefficients method

II. Eigen analysis network:

To improve the power matching, a lossless decoupling and matched networks on 180 degrees directional coupler upto 8 radiators. Spacing between radiators is reduced to half in mobile terminals, a mutual coupling effects and decrease antenna gain. Based on the power considerations at antenna array ports, the concept of eigen modes 2-port antenna can be designed, because the ports are decoupled and radiation pattern are orthogonal.

Main aim to design this network is to transform set of decoupled antenna array ports into a set of ports that are decoupled. The power can be stored in Eigen mode analysis. The decoupling network input can be taken from the different eigen modes of antenna which is called eigen mode excitation network. From this the reflection coefficients will appear due to input that distributes power to output with no power matching.

The decoupled antenna array can be obtained as the input ports can be matched independently and if single port matched means it is to improve the efficiencies. This the decoupling network is better than the reflection coefficients predicted from eigen-analysis of antenna.

Due to this we can have some losses in the network, power matching occur and power dissipation can be seen. For this we are using the prototype like DMN having 1GHz frequency. This the DMN(decoupling and matched network) can increase the efficiency of the antenna, power can be saved and net gain can be saved.

1 Multiport coupling network:

The main algorithm used here is lossless multiport matching network.

Features:

1. Bandwidth
2. Pattern constraints like directivity and side lobe levels
3. Multiwinding transformers which are impractical at microwave frequencies

This the multiport feeding network that can be used to calculate the array performance.

2 Mutual coupling coefficients method:

This can be done according to matrix multiplication method which produces signals by restored isolated elements when there is no mutual coupling and digital beam forming which is having no requirements of reciprocal array elements.

Error:

I. Noise floor

II. Due to having high quality patterns and low side lobes or deterministic pattern nulls. Signal processing arrays

This method can be determined from fourier decomposition and coupling measurements between array ports. This method can be helpful for the small arrays. This method is difficult to realize in analog form, but it is easy to implement in a digital beam forming antenna system. Mathematically this the matrix multiplication can be done and appeared as a compensation on received signal vector.

3 Implementation of decoupling network A wider bandwidth alternative to the software implementation is hardware implementation of the decoupling network in the RF layer. The implementation of the decoupling network for an N-port array is based on the solution for a 2-port array, in which a 180 directional coupler is connected in tandem with a transmission line with electrical length [2]. This can be described by the scattering matrix

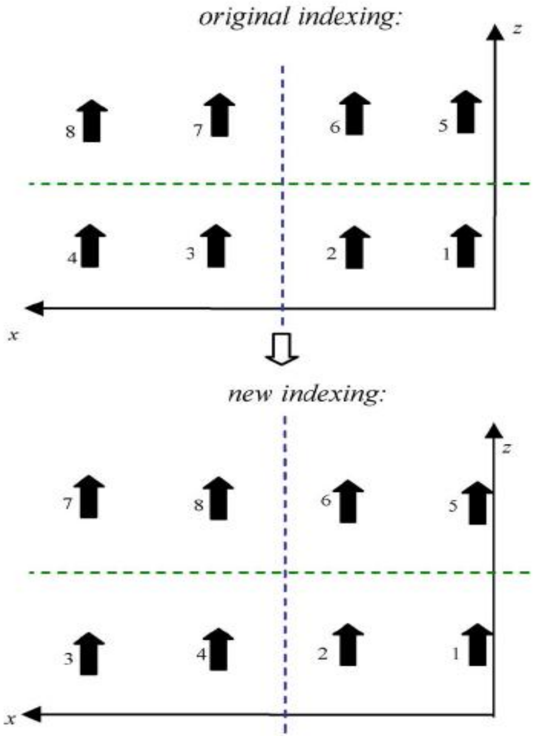
$$[S_{\text{coupler}}] = e^{-j\theta} \times \begin{pmatrix} 0 & 0 & k & e^{-j\varphi}\sqrt{1-k^2} \\ 0 & 0 & \sqrt{1-k^2} & ke^{-j(\varphi+\pi)} \\ k & \sqrt{1-k^2} & 0 & 0 \\ e^{-j\varphi}\sqrt{1-k^2} & ke^{-j(\varphi+\pi)} & 0 & 0 \end{pmatrix}.$$

The directional coupler and the transmission line are schematically represented by Fig. 3. Such a directional coupler is able to decouple a 2-port array by choosing proper values for k ,x , and tA general method to decouple an arbitrary N-port array was developed by Geren *et al.* and is described in [3]. It is based on diagonalizing the imaginary part of compensating it at each port with a serial imaginary impedance, followed by the diagonalization of its real part and matching it. Each of these diagonal zing matrices is real, and therefore can be factored into sub matrices, using Givens rotations [3].

Each one of these simple sub matrices can be represented by the scattering matrix of a directional coupler, the parameters of whichcan be derived from the comparison between each of the matrices and the general matrixshown in (6). In our case , using this method would result in two sub networks of cascaded couplers, compensating both the real and imaginary parts of . This procedure results in 56 couplers for the whole decoupling.network. As one can observe, this implementation is very complicated and inapplicable for large arrays.

In the present work, a different approach is adopted [5]. It involves a combination of the method mentioned above and the method described in [2]. The suggested method uses the symmetry planes in the array to divide the array elements in symmetrical groups, resulting in decoupling between these groups. In our case, a symmetric rearrangement of the elements (which is realized by renumbering them) leads to a new indexing as shown in Fig. 4.

The horizontal symmetry plane divides the array into two groups so that the element is symmetric to the element in terms of the same scattering parameters. Every symmetrical pair of elements needs to be connected by a 3-dB 180 coupler [the scattering matrix of which is derived by substituting k, x, and t in (6)]. As a result of the connection of these four hybrids (which constitutes the first layer of the decoupling network), there will be no coupling between the elements 1–4 and 5–8.dipoles above a large ground plane. Due to its simplicity, the matrix of such an array can be easily calculated with no need of using advanced numerical methods. The suggested array geometry is shown in Fig. 1. Such an array has a full 8 8 (and) matrix, where all of its elements can be calculated using the reciprocity theorem and the analytical expressions of the near field of a dipole [4]. Mathematically, the main goal is to transform the full (or) matrix to a diagonal (or) matrix through an additional network connected to the antenna array.



One can observe that, without the decoupling network, the reflection coefficient varies significantly at each port, producing

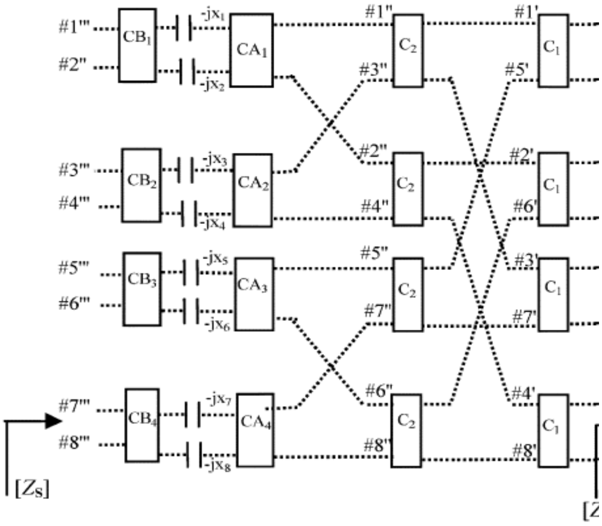
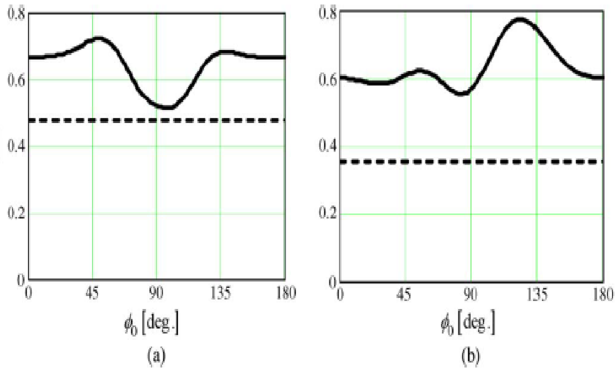


Figure:2 Decoupling network with 8*8 array planes different return losses as a function of the scanning angle. A similar dependence occurs for other current distributions as well.



Accordingly, the new coupler scattering matrix is

$$[S_{\text{coupler}}] = e^{-j\theta}$$

$$\times \begin{pmatrix} S_{11} & D & k & e^{-j\varphi}\sqrt{1-k^2} \\ D & S_{11} & \sqrt{1-k^2} & ke^{-j(\varphi+\pi)} \\ k & \sqrt{1-k^2} & S_{11} & D \\ e^{-j\varphi}\sqrt{1-k^2} & ke^{-j(\varphi+\pi)} & D & S_{11} \end{pmatrix}$$

Consequently, the new structure of the decoupling network described in (2) transforms to

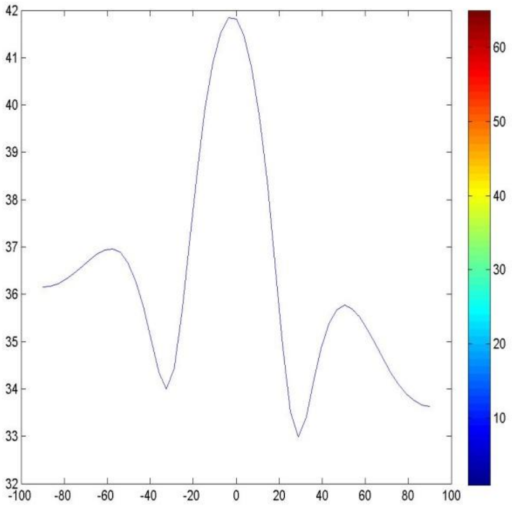
$$[S_D] = \begin{pmatrix} [S_{D,11}][S_{D,21}]^T \\ [S_{D,21}][S_{D,22}] \end{pmatrix}$$

and the total system scattering matrix given in (3) changes to

$$[S_S] = [S_{D,11}] + [S_{D,21}]^T [S]\left([U] - [S_{D,22}][S]\right)^{-1} [S_{D,21}].$$

III. Simulation Results:

As previously mentioned, the first advantage this method does not require the removal of antenna elements such that the scattering effect from all antenna elements is taken into consideration in the calculation when we calculate/measure *Vk*. Preliminary results in [15] have first demonstrated that better accuracies can be obtained for DOA estimations using the RMI determined based on method 3 as compared to method 2.More importantly, as the element separation of the antenna elements becomes smaller, the scattering effect from other elements becomes significant and RMI determined using method 2 may fail to compensate the mutual coupling effect.Software used here is Matlab 12.0.



IV. Conclusion:

Hence we conclude that to avoid the mutual coupling problem in the practical use we are using one genetic algorithm based on the some decoupling methods. Then this can be taken from the receiving mutual impedance method based on the impedance matrix. The decoupled voltages can be appeared from the matrix based on the impedance matrix. These voltages with linear or phased array equations can be applied to the antenna to get the matrix form. Hence we can avoid the mutual coupling problem in the experimental issueby this design and implementation with phased array antennas.

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