Simultaneous Synthesis of Arrays for Near Field Focusing and Far Field Constraints

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A scheme for the synthesis of antenna arrays accounting simultaneously for Near Field Focusing and Far Field specifications is proposed. The technique is based on the minimization of a proper cost function and the definition of a target Near Field distribution. This approach increases the flexibility of traditional focusing techniques to deal with different sets of specifications both in the near and far environments. Some illustrative examples will be presented.

Near Field Focusing (NFF) is a technique able to concentrate radiated field into a predefined position in the near environment of an antenna, the so-called focal spot. Among other applications, it is specially suitable for communication in close distances between devices with information about each other position, for example, for Wireless Power (and Information) Transfer, avoiding interferences from other elements that might be placed in the same environment. However, other interfering elements might be distorting the communication from other positions in the far field that are not accounted for, or energy might be wasted radiating in the far field region. In this contribution we propose a scheme for synthesis of NFF able to take into account constraints both in the near and the far field radiation patterns. This allows designing both radiating systems able to concentrate the information into a focal spot without interfering on other devices or wasting energy, or able to read from a device placed in the focal spot without interference from other sources.

The proposed technique is based on the minimization of a cost function able to account for both the NF and FF conditions at the same time. A target NF distribution is specified defining a vector $\mathbf{e}_{target}$ with null values except in the position corresponding to the desired focal point, where a value 1 is set. In this technique notation will be used, so that

$$\mathbf{e}_{NF} = \mathbf{S}_{NF} \cdot \mathbf{w} \tag{1}$$

where $\mathbf{e}_{NF} = [E_{NF}(\vec{r_1}), E_{NF}(\vec{r_2}) \ldots E_{NF}(\vec{r_M})]^T$ is a column vector containing the values of the field radiated at the M considered positions of the near environment, $\mathbf{w} = [w_1, w_2, \ldots, w_N]^T$ is a vector with the weights applied to each element of the array, and $\mathbf{S}_{NF}$ is a matrix with elements $S_{n,m} = \frac{e^{-jk|\vec{r_m} - \vec{r_n'}|}}{|\vec{r_m} - \vec{r_n'}|}$. Similarly, FF vector and matrix $\mathbf{e}_{FF}$ and $\mathbf{S}_{FF}$ can also be defined.

A general cost function J to be minimized is then proposed as

$$J = \{||\mathbf{e}_{target} - \mathbf{S}_{NF} \cdot \mathbf{w}|| + \gamma\, f_{FF}(\mathbf{w})\} \tag{2}$$

where $||.||$ is the $l2$-norm, and $f_{FF}(\mathbf{w})$ is a generic function of the weights applied to the array, that should be defined according to the FF constraints for a specific application. The first term guarantees that the NF radiation is close to the desired pattern, with a maximum at the focal point and minimal values at any other position. The second term accounts for the specifications in the FF radiation pattern. The tradeoff parameter γ is used to determine the importance of each term in the cost function and hence in the obtained solution.

For example, let us consider the case aiming to guarantee a required field level at the focal spot and reducing the overall radiated power. For this problem, the proposed FF-specifications function might be defined according to:

$$f_{FF}(\mathbf{w}) = var\{\mathbf{S}_{FF} \cdot \mathbf{w}\} \tag{3}$$

where var stands for the variance. The second term minimizes the variance of the FF radiation, leading to a radiation pattern as omnidirectional as possible and with minimum power at the same time.

Other cases and definitions of the function $f_{FF}(\mathbf{w})$ will be presented, along with illustrative examples showing the flexibility of the proposed method.

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