New Techniques for Realizing Desired Raiation Patterns of Antennas and Arrays Mounted on Complex Platforms

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Abstract **- A new approach for realizing the radiation patterns of antenna systems located on a complex platform is proposed in this paper. The proposed technique is based on the use of Characteristic Basis Functions (CBFs). The CBFs are generated by exciting a number of antenna elements, typically specified by the user, and placed at "allowable" locations on the platform. The Characteristic Basis Function Patterns (CBFPs) are derived from the CBFs, and are used as the basis functions in the pattern space to realize the desired pattern. An novel eigenvalue problem, which is numerical considerably more efficient to solve, is developed to find the best-fit solution that maximizes the energy radiated in the desired angular range, while minimizing the undesired radiation outside of this range.**

Index Terms—*Characteristic Mode (CM), Characteristic basis Functions (CBFs), reconfigurable antennas, MIMO, pattern synthesis, antennas on complex platforms.*

1. Introduction

Realizing desired radiation patterns of antennas or arrays mounted on complex platforms, such as mobile phones, automobiles, military vehicles, topsides of ships, etc., is a very desirable goal and techniques for determining the placement and excitation coefficients of the antenna elements is a dauntingly challenging task indeed. Techniques for controlling the radiation pattern of an antenna system--such that it not only radiates along the desired direction but also suppresses the interfering signal--is a desired goal in some applications, as is the lowering of back- and side-lobes of the radiation pattern. Lowering the Q of a small antenna, and thus widening its bandwidth, is yet another goal that is highly sought after. A brute-force approach to accomplishing the task at hand is to use an optimization method, such as the GA or the Particle Swarm algorithm. However, such techniques can be highly time-consuming to apply, especially when the platform is complex and, hence, requires a very large number of DoFs (degrees of freedom) .Consequently, a more systematic and computationally efficient approach to realizing the goal of pattern synthesis as stated above is much needed, and is presently being vigorously pursued by a number of researchers around the world.

One such approach, which has recently caught the attention of many researchers, is the Characteristic Mode (CM) method [1-3], which has been used to design and synthesize patterns of multiple antennas located on platforms such as automobiles and mobile terminals [4-5]. The first step in the CM approach is to solve an eigenvalue problem. The eigenvectors can be interpreted as being associated with "modal" current distributions on the platforms *in the absence of any excitation*. The next step is to utilize these characteristic modes to solve the problem at hand, namely to realize the specified radiation pattern, which entails the determination of the location of the antenna exciters on the platform, as well as their weight coefficients. However, there is no clear-cut way to find the locations and the weight coefficients of the excitations in order to realize the modal current distribution that produces the specified pattern. In fact, simply placing an excitation source--which is typically specified by the user to satisfy the requirements of frequency coverage and bandwidth--at the location of the 'maximum' of the modal current distribution on the platform corresponding to the CM of interest, often fails to reproduce the desired pattern associated with the CM. Furthermore, the problem is exacerbated if we need to excite a plurality of CMs to realize the desired radiation pattern.

Although various strategies for addressing this important problem have been proposed [4-6], none of them are as systematic or direct as we would desire, and this is what motivates us to develop a new technique for accomplishing this goal. The proposed scheme takes a cue from the Characteristic Basis Function (CBF) method for the analysis of antennas mounted on complex platforms, and then tailors it to the problem of exciting multiple antennas on these platforms in a manner such that a specified radiation patterns is realized--at least within a realistic approximation--under the given constraint of permissible locations of the antennas on the platform specified by the user.

2. Proposed method

The application of the proposed approach is illustrated by considering several practical examples, including the antenna placement problem for the mobile handset and shipboard topside environment (see Figs. 1 and 2). In addition, the paper describes how the proposed scheme can be readily and conveniently adapted for the design of MIMO and reconfigurable antenna systems operating in a complex environment. The topic of interference suppression is also included in the discussion (Fig.3).

We begin by briefly reviewing the basics of the Characteristic Mode (CM) approach, as well as those of the CBF method, underscoring the fact that the CMs are source-free solutions while the CBFs are excitation- dependent. The paper shows that this is an important distinction between the two, and plays an important role when it comes to systematically realizing the desired current distribution on the platform. Illustrative examples are provided in the paper to further explain and support the assertion that, in contrast to the CM-based method, the CBF-based approach is both more direct and systematic. Furthermore, the proposed CBF-based algorithm is especially suited for large and complex platforms because it does not require the solution of eigenvalue problems associated with large matrices, as for instance those typically associated with shipboard antenna problems, which often require upward of 10^6 unknowns for the representation of induced currents on such platforms, and which render the eigenvalue problem somewhat intractable, especially when platforms with dielectric or complex media are involved, because of ill-conditioned nature of the matrices.

A new approach is also presented in the paper for the problem of pattern synthesis in general. Rather than relying on optimization methods to determine the weight coefficients of the excitations, we set up an eigenvalue equation, with a relatively small-size matrix, say M, whose rank is only 3 or 4 for most practical problems, even though the rank of the original MoM matrix associated with the complex platform may be very large—upward of tens of thousands or even millions. We show how the eigenvectors associated with the *largest* eigenvalue of the small-size matrix M directly yield the excitation coefficients, without the need for iterative or optimization algorithms that are often used for the same purpose. The paper will provide an illustrative example to walk through and explain the procedure based on the proposed algorithm. Incidentally, it is worthwhile mentioning here that the algorithm is also useful for a general class of pattern synthesis problems, for instance the synthesis of radiation patterns of thinned phased arrays, with little compromise of gain and sidelobe levels.

3. Conclusion

The proposed algorithm can be extended to pattern synthesis problems that not only require radiation along desired directions, but selective suppression of interference signals incident from certain angles. An example of such a case is a GPS antenna cluster, which needs to be reconfigured to mitigate the untoward interference problem arising from the presence of undesirable signals that compromise the performance of the GPS system in terms of its accuracy.

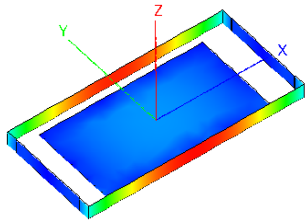

Fig.1.Mobile Phone Chassis.

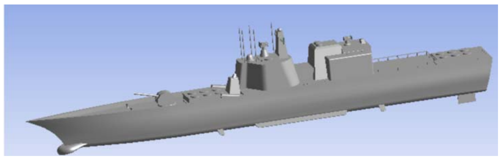

Fig.2. Shipboard Antenna

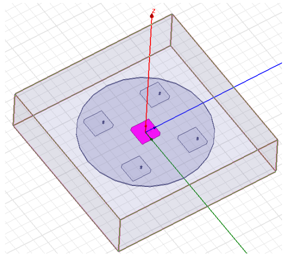

Fig.3. Microstrip patch Antenna

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