Information Sciences

Receive Mode Analysis and Design of Microstrip Reflectarrays

A new method developed for the design of microstrip reflectarrays is extremely efficient.

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Traditionally microstrip or printed reflectarrays are designed using the "transmit mode" technique. In this method, the size of each printed element is chosen so as to provide the required value of the reflection phase such that a collimated beam results along a given direction. The reflection phase of each printed element is approximated using an infinite array model. The infinite array model is an excellent engineering approximation for a large microstrip array since the size or orientation of elements exhibits a slow spatial variation.

In this model, the reflection phase from a given printed element is approximated by that of an infinite array of elements of the same size and orientation when illuminated by a local plane wave. Thus the reflection phase is a function of the size (or orientation) of the element, the elevation and azimuth angles of incidence of a local plane wave, and polarization. Typically, one computes the reflection phase of the infinite array as a function of several parameters such as size/orientation, elevation and azimuth angles of incidence, and in some cases for vertical and horizontal polarization. The design requires the selection of the size/orientation of the printed element to realize the required phase by interpolating or curve fitting all the computed data. This is a substantially complicated problem, especially in applications requiring a computationally intensive commercial code to determine the reflection phase. In dual polarization applications requiring rectangular patches, one needs to determine the reflection phase as a function of five parameters (dimensions of the rectangular patch, elevation and azimuth angles of incidence, and polarization). This is an extremely complex problem.

The new method employs the reciprocity principle and reaction concept, two well-known concepts in electromagnetics to derive the receive mode analysis and design techniques. In the "receive mode design" technique, the reflection phase is computed for a plane wave incident on the reflectarray from the direction of the beam peak. In antenna applications with a single collimated beam, this method is extremely simple since all printed elements see the same angles of incidence. Thus the number of parameters is reduced by two when compared to the transmit mode design. The reflection phase computation as a function of five parameters in the rectangular patch array discussed previously is reduced to a computational problem with three parameters in the receive mode. Furthermore, if the beam peak is in the broadside direction, the receive mode design is polarization independent and the reflection phase computation is a function of two parameters only. For a square patch array, it is a function of the size, one parameter only, thus making it extremely simple.

The present method is substantially less intensive computationally. Since most practical antenna arrays require the design of a broadside beam or a single collimated beam, the receive mode design is expected to be substantially simpler than the traditional transmit mode design. In addition, when a designer needs to generate the reflection phase data using a computer intensive commercial software such as Ansoft HFSS, the reduction of computational effort in the receive mode will result in a substantial saving in design turnaround time. Similarly the receive mode analysis technique has potential to save computer time for large reflectarrays.

Microstrip reflectarrays have desirable features such as ease of design, manufacture, and deployment for application in many space-based radar and remote sensing systems. They are being investigated for many JPL systems such as SWOT (Surface Water Ocean Topography). The receive mode design and analysis technique is expected to find many future applications in NASA.

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Chance-Constrained Guidance With Non-Convex Constraints

This solution can be used for non-convex guidance problems in small-body rendezvous, formation flight, and uninhabited aerial vehicle applications.

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Missions to small bodies, such as comets or asteroids, require autonomous guidance for descent to these small bodies. Such guidance is made challenging by uncertainty in the position and velocity of the spacecraft, as well as the uncertainty in the gravitational field around the small body. In addition, the requirement to avoid collision with the asteroid represents a non-convex constraint that means finding the optimal guidance trajectory, in general, is intractable.

In this innovation, a new approach is proposed for chance-constrained optimal guidance with non-convex constraints. Chance-constrained guidance takes into account uncertainty so that the probability of collision is below a specified threshold. In this approach, a new bounding method has been developed to obtain a set of decomposed chance constraints that is a sufficient condition of the original chance constraint. The decomposition of the chance constraint enables its efficient evaluation, as well as the application of the branch and bound method. Branch and bound enables non-convex problems to be solved efficiently to global optimality.

Considering the problem of finite-horizon robust optimal control of dynamic systems under Gaussian-distributed stochastic uncertainty, with state and control constraints, a discrete-time, continuous-state linear dynamics model is assumed. Gaussian-distributed stochastic uncertainty is a more natural model for exogenous disturbances such as wind gusts and turbulence than the previously studied set-bounded models. However, with stochastic uncertainty, it is often impossible to guarantee that state constraints are satisfied, because there is typically a non-zero probability of having a disturbance that is large enough to push the state out of the feasible region.

An effective framework to address robustness with stochastic uncertainty is optimization with chance constraints. These require that the probability of violating the state constraints (i.e., the probability of failure) is below a user-specified bound known as the risk bound. An example problem is to drive a car to a destination as fast as possible while limiting the probability of an accident to 10^{-7}. This framework allows users to trade conservatism against performance by choosing the risk bound. The more risk the user accepts, the better performance they can expect.

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