Application Sheet

FEKO

Comprehensive Electromagnetic Solutions

Microstrip Antennas and Circuits

Introduction

Explosive growth in commercial and military applications for microstrip antennas has resulted in a highly active field for microstrip antenna research and development. The low cost, low weight, small dimensions and volume, as well as general ease of bulk fabrication, often make these antennas the preferred choice over conventional antenna types. Applications for microstrip antennas and circuits include mobile satellite communications, direct broadcast (DBS) system, global positioning system (GPS), biomedical to military applications such as aircraft, missiles, radar, to name but a few.

Theoretical Formulation

FEKO uses full-wave formulations to model currents on metallic surfaces. It enables accurate simulations of coupling, near fields, far fields, radiation patterns, current distributions, impedances, S-parameters and many more. While the hybridised method of moments (MoM) and finite element method (FEM) method is ideally suited to dielectric structures, different formulations can be used for cross-validation purposes. For example:

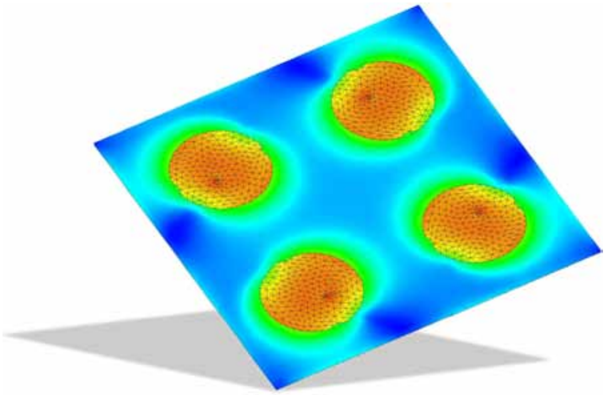
- The planar layered Green's function, where a substrate is considered infinite in two dimensions, is simulated with low computational cost.
- The surface equivalence principle (SEP) or volume equivalence principle (VEP) accurately models finite substrate effects.
- The FEM / MoM hybrid method simulates large finite arrays and complex feed structures efficiently.
- Periodic boundary conditions (PBC) compute the solution for an infinitely large array and estimate the performance for large, finite arrays.
- The large finite array solver simulates large finite arrays of metallic elements efficiently.

Microstrip Antennas

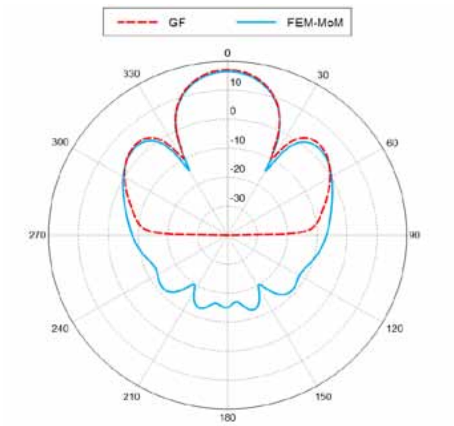
Planar microstrip antennas can be used in a variety of configurations, for example:

- Single element antennas with a pin feed, microstrip feed or proximity coupled feed.
- Array antennas with complex corporate feed networks to excite the arrays with a single source.
- Array antennas where the elements are fed individually to control the voltage and phase of each feed.

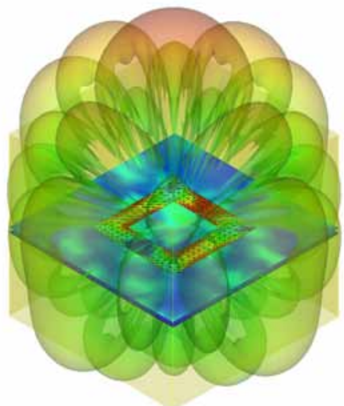
For the simulation of microstrip antennas, the planar layered Green's function method is an efficient tool, considering an infinitely large substrate of arbitrary thickness and containing any number of dielectric layers. The method solves the effect of the dielectric layers analytically. As such, only the metallic elements need to be meshed. This results in an



Currents at 1.5 GHz on a 2 x 2 microstrip patch antenna array



Gain of a four-by-four microstrip patch antenna calculated with planar layered Green's function (GF) and FEM / MoM



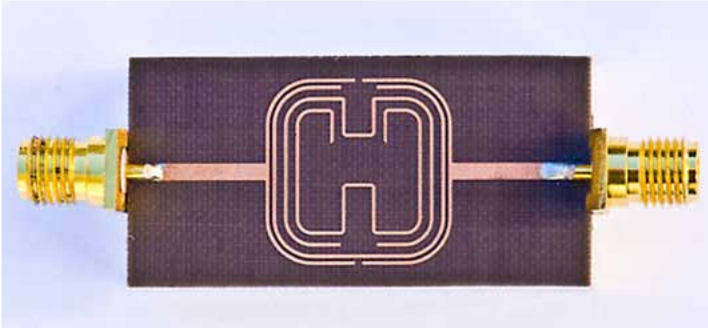
PBC calculation of the 3D far field gain for an eight-by-eight array of square ring microstrip antenna elements effective solution method which require little computational resources.

The planar layered Green's function approach yields excellent simulation performance and results for situations where the finite substrate effects may be ignored. When the effects of the finite substrate are of interest, the SEP simulation method should be used. The SEP discretises dielectric boundaries in a planar structure, accurately modelling the equivalent currents on the boundaries. This current-based solution accounts for the electrical effects of the finite substrate. It follows that these effects will be reflected in derived quantities, for example input impedance, near fields, far fields and axial ratio.

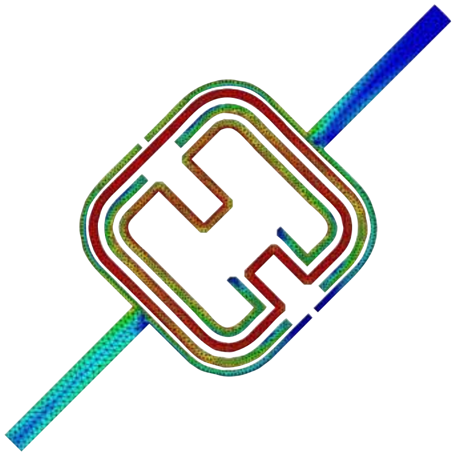
When simulating large objects, the scaling of resource requirements for the MoM results in both the planar layered Green's function and SEP methods to saturate the available resources. These structures can be solved with the FEM / MoM hybrid method, which is more efficient for large finite antenna arrays than pure MoM methods.

The simulation of extremely large planar array antennas or reflective surfaces with periodic geometry requires the special PBC method. The PBC method simulates a single array element (called the unit cell) as if it was part of an infinite array. Mutual coupling is taken into account as if the element is in the centre of a much larger array. All elements are excited with a fixed inter-element phase shift. Field values for a finite-sized array (for example, 32 x 32 elements) can then be calculated by repeatedly integrating the surface currents of the PBC unit cell over all cells. For large finite-sized arrays, the biggest effect on the field computations are due to the contribution of the centre elements. As a result, the effect of the edge elements can be largely ignored.

Large finite arrays can also be solved with the finite array solver. Based on the domain Green's function method (DGFM), it makes use of the MoM to solve a single element of the array. The method couples the solution to all elements of the array, while feeding each element individually. This method requires computational resources in the order of the solution of a single array element. It allows for a large saving in computational resources versus other solution methods for large and finite arrays.



Triple split-ring resonator microstrip filter simulated with the planar layered Green's function

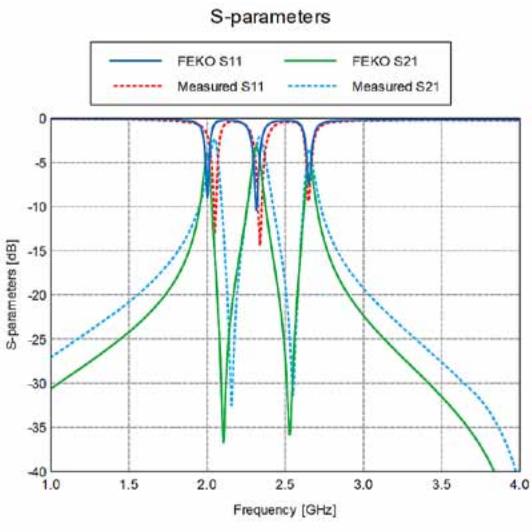


Currents on a Triple Split-Ring Resonator at 2 GHz

Microwave Circuits

Planar layered Green's function and SEP solution methods are both well suited to the analysis of printed microwave circuits. The planar layered Green's function is the optimal solution method in instances where modelling infinite substrates is acceptable. SEP is the ideal solution to use when having to account for finite substrate effects. Both methods use integral equations which are inherently phase stable, yielding accurate results for phase computations.

Split-ring resonator (SRR) filters [1] are a typical example of how FEKO may be applied to cutting-edge microstrip designs. Such filters are extremely sensitive to small manufacturing tolerances and are difficult to manufacture. The graph on the right, comparing simulated and measured results, confirms that FEKO's planar layered Green's function method provides accurate simulation results. This method is an ideal tool for evaluating electromagnetically coupled microstrip designs. Using the planar layered Green's function method can reduce the number of prototype iterations before producing costly prototypes for measurement.



Measured S_{11} and S_{21} versus simulation for a split-ring resonator microstrip filter

References

[1] R.H. Geschke, B. Jokanovic, P. Meyer, "Compact Triple-Band Resonators Using Multiple Split-Ring Resonators," Proceedings of the European Microwave Week 2009, Sept. 2009, Rome, Italy.

Altair

32 Techno Ave, Technopark, Stellenbosch, South Africa
Phone: 0027 21 831 1500 • Fax: 0027 21 880 1936
www.altair.com • info@altair.com