Computing the Scattering Matrix of Multiport Systems

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A new computation method has recently been introduced, that is capable of extracting the multi-dimensional scattering matrix of even very large-scale, multiport microwave systems, by simulating measurements performed with a multiport, Vector Network Analyzer (VANA) system. The new method may be applied by using any appropriate frequency-domain, 2D or 3D Maxwell-field solver, provided the solver used computes complex field-values, everywhere within a given bounded domain.

The new computation method, simulates the functions performed by a multiport, Vector Network Analyzer (VANA) system, by first computing the real and imaginary components of the complex electromagnetic field, within the internal regions of a set of virtual measurement-lines. Each line is assumed to be connected to one of the ports of the large-scale, multiport microwave system that is to be characterized.

As a representative example of such large-scale, multiport system, we may consider a planar, cylindrical, or spherical Near-Field Antenna-Testing facility, where field-data are being acquired by scanning, to obtain the radiation-pattern of a large, high-directivity, electronically-steered phased array.

All the virtual measurement-lines, that are connected, in the simulation, to the various ports of the given multiport microwave system, may be of different physical form, possibly including at the same time a number of coaxial lines, a number of waveguides of different cross-sections, and even a number of printed-circuit strip-line and/or coplanar lines.

The multidimensional scattering matrix of the multiport system extracted by the new computation method, is automatically normalized, at each system-port, to the wave-impedance of the specific virtual measurement-line, that is connected to that system-port.

All the virtual measurement-lines connected to the given multiport microwave system, are assumed to be lossless and uniform, but may be considered to be dispersive, with frequency-dependent wave-impedances and phase-velocities. All the virtual measurement-lines must however extend a number of wavelengths, from the line-end connected to a system-port, towards the line-end connected to the signal-source used to perform the scattering-parameter measurements.

The new computation method extracts the complex parameters of the forward and backward waves, along each virtual measurement-line from the complex standing-wave field-pattern solution, computed along the internal regions of each measurement-line. Indeed, the complex field-patterns, computed by the solver, provide instantaneous snap-shots of the standing-wave fields, along the axial length of each virtual measurement-line, from its connection to a system-port, to its interface to the signal-source used to perform the measurements.

This new method of computer-simulation of multiport scattering-parameter measurements is based on a rigorous mathematical analysis of the simultaneous propagation of the forward and backward waves, that respectively flow from the measurement signal-source towards a system-port, and from a system-port back towards the measurement signal-source. The new analysis exploits the remarkable, mutual-correlation between the imaginary and real components of the standing-wave field-pattern, along the length of each virtual measurement-line, a correlation only evidenced by using a Maxwell-field solver that computes complex field-solutions. The newly performed rigorous mathematical analysis of the simultaneous propagation of the forward and backward waves has shown that the mutual correlation of the imaginary and real components of the standing-wave field, along the length of each virtual measurement-line, can be rigorously represented by the implicit equation of a tilted, perfect-ellipse, drawn in a 2D, planar Cartesian reference-frame. The new computation method can therefore exploit that a-priori knowledge, to enhance the accuracy of the simulated scattering-parameter measurements, by performing a least-squares fitting of the field-pattern data, computed by the Maxwell-field solver, using the rigorous equation of a tilted perfect-ellipse.
Conclusions.

This paper has given a short description of a computational method that provides the capability of performing numerical simulations of calibrated, complex, multi-port and multi-mode scattering parameters. The method described here does not require the simulation of a full physical, multi-port, automated vector network analyzer. Indeed, the only enabling requirement, for performing the simulation of multi-port, multi-mode scattering parameter measurements, is the addition of the inner volume of short lengths of *virtual* measurement transmission lines (*or waveguides*) to the domain of the (*necessarily complex*) electromagnetic field solution being computed. The *virtual* measurement transmission lines are assumed to be uniform, and lossless, but not-necessarily non-dispersive. The simulated virtual lines are connected to the system under test, exactly as physical measurement lines would be connected, in an experimental vector network analyzer set-up. At every step of a simulated measurement cycle, a stepped-frequency sine wave signal is assumed to be fed towards one of the ports of the system under test. During the full measurement cycle the stepped frequency sine wave excitation signal is switched towards a different port of the system under test, being fed through a different *virtual* measurement transmission line. Uncalibrated values of the scattering parameters are obtained by extracting the values of the real and imaginary components of the standing-wave field along each of the *virtual* measurement lines, obtained from a *complex* electromagnetic-field solver.

REFERENCES.


Figure 1 - Analytic Geometry of the Slanted Ellipse.
Figure 2 - The Tilted-Ellipse Representation of a Standing-Wave Pattern.

Forward-Wave Vectors Shown in Blue
Backward-Wave Vectors Shown in Red