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Transient Transfer Coupled Response - Spherical Harmonics Expansion

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Extended Abstract

Signal transfer between antennas either in a transmit/receive scenario (e.g., for communication or remote sensing applications) or between antennas in close proximity (e.g., antenna elements in an array) can be modeled, in the time domain (TD) for transient/short-pulsed excitations, by the *transfer coupled response*. In case where a time harmonic excitation is involved, the transfer coupled response can be associated with a mutual impedance/coupling between the antennas. In a recent presentation [1] the TD transfer coupled response was formulated using the reciprocity theorem of convolution type (and similarly of the correlation type) to be given by a spatial temporal integration of a symmetric scalar product of the currents of the involved antennas with the dyadic Green function propagator of the medium. This integration may be calculated by several alternative approaches that depend on the convenient representation of the Green function. One approach is to apply the plane wave spectrum (PWS) representation of the Green function, as was demonstrated in [1]. The PWS formulation leads to an expression that is composed of delayed contributions that are structured upon a skeleton of all signal paths along and between the antennas. This format of presentation emphasizes the physical structure of the antennas involved. The PWS-based formulation is convenient in near field applications where there is a variance in the length of the propagation paths, however it becomes inefficient when the distance between the antennas increases (intermediate and far zones). An alternative approach follows the TD spherical harmonics (SH) expansion of the Green function. In the TD SH expansion the individual structure of the antennas and the signal paths between/along the antennas are not directly transparent but weighted into the time-dependent spherical harmonics expansion coefficients. Furthermore, the characteristics of the spherical harmonic expansion make it a convenient tool in an analysis of the dynamic energy/power transfer between antennas (see, e.g., [2]) in the near, intermediate and far radiation zones.

Following this brief introduction, the presentation, first, concerns the formulation of the transient transfer coupled response between two antennas based on the TD SH expansion of the Green function, followed by its application to the analysis of the time-dependent power/energy transfer between the antennas. To that end, a convenient SH type of expansion can be obtained, for example, by using the TD addition theorem of the Green function with the integral expression of the transfer coupled response. A possible alternative approach follows the TD SH expansion of the far-field representation of the transfer coupled response (given as a convolution product of the effective heights of the antennas and weighted inversely by their separation distance [3]) and its "tracing back" to finite distances. Once the SH-based expansion of the couple response is available, the energy/power transfer is formulated as a summation of power- and cross power-type spherical harmonics contributions. Moreover, this TD SH energy/power expansion can be used for further identification of TD power transfer contributions (between antennas and their loads) and to reactive type contributions [2]. Thus, a complete time-dependent dynamic description of the energy/power transfer mechanism between the antennas is obtained that can be used for further study of the system/network characteristics for antennas in different distances. These issues and more will be elaborated in the presentation.

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References

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