WAVEFRONT INTERPRETATION OF SEM RESONANCES, TURN-ON TIMES, AND ENTIRE FUNCTIONS

E. Heyman
Department of Electrical Engineering, Tel Aviv University, Israel

L. B. Felsen
Department of Electrical Engineering and Computer Science/Microwave Research Institute
Polytechnic Institute of New York, Farmingdale, NY 11735 USA

ABSTRACT

By the Singularity Expansion Method (SEM), transient scattering is analyzed in terms of the damped oscillations corresponding to the complex resonant frequencies of the scatterer. Since the resonances describe global wave fields that encompass the scattering object as a whole, the SEM series representation encounters convergence difficulties at early observation times when portions of the object are as yet unexcited. Deficiencies in this representation must then be repaired by inclusion of an entire function in the complex frequency domain. The choice of the entire function is related intimately to the excitation coefficients, called coupling coefficients, of individual resonances and also to the "turn-on" and "switch-on" times of the SEM series. By using a traveling wave formulation in terms of progressing incident, reflected and diffracted wavefronts, these constructs in the SEM can be given a cogent physical interpretation. The wavefront analysis clearly identifies those portions of the entire function that are essential (intrinsic) and those that are removable. By combining wavefronts and resonances self-consistently, one may construct a hybrid field that avoids the difficulties at early times in the SEM formulation. These concepts are illustrated for two-dimensional scattering by a circular cylinder and a flat strip.
I. INTRODUCTION

Progressing waves (wavefronts) and oscillatory waves (resonances) may be employed as alternative building blocks to synthesize the transient fields scattered by an object. In a progressing wave formulation, one tracks a causal wavefront from the source to the scatterer, and thereafter observes contributions corresponding to multiple wavefront passes around the object and (or) multiple diffractions from scattering centers located on the object. This locally sensitive description becomes cumbersome at late observation times when many wavefronts have had time to reach the observer. Moreover, analytic tractability, by asymptotic considerations, usually is limited to moderate times after passage of a wavefront, with consequent difficulties when early arrivals are monitored at late times.

The oscillatory representation, formalized by the Singularity Expansion Method (SEM), expresses global phenomena due to the scatterer as a whole. These global responses, the resonances, may be shown to account for the cumulative effect of multiple wavefront arrivals. Therefore, this formulation is most convenient for late observation times whereas at early times, convergence problems may arise due to the many resonances needed to synthesize the abruptly changing local field near a wavefront or the causal zero field before the first wavefront has arrived. In the formal structure of the SEM, based on the solution of an integral equation formulation for the surface field, the SEM resonance series has had to be augmented by an entire function in the complex frequency plane to cope with these difficulties. The entire function, in turn, influences the excitation coefficients of the resonances, thereby introducing an arbitrariness which has, however, been clarified in recent studies. Concerning the phenomenology, the cumulative effect of the many high-frequency resonances required at early times may actually be shown to produce a wavefront field.

A recently developed hybrid representation avoids the difficulties associated with either of the above descriptions by incorporating the well-behaved portions of both - wavefronts at early times and resonances at later times - within a single self-consistent framework that is applicable and convenient for all times. The hybrid approach - illustrated in ref. 5 for two-dimensional smooth convex objects - formalizes the intimate relation between wavefronts and resonances as cumulative phenomena of the one in terms of the other, and thereby furnishes a cogent physical picture of the scattering process. The bilateral equivalence is established directly from an analysis based on the concepts of the Geometrical Theory of Diffraction (GTD) and avoids the use of integral equations entirely. The connection between wavefronts and resonances in terms of the physically motivated constructs of GTD furnishes an interpretation that has remained hidden within the integral equation format.