Scattering and absorption of short-time pulses by abruptly time-varying dielectric layer

Chen Firestein(1), Amir Shlivinski (1), and Yakir Hadad(2)
(1) Ben-Gurion University of the Negev, Beer Sheva, Israel, e-mail: amirshli@bgu.ac.il
(2) Tel-Aviv University, Tel Aviv, Israel; e-mail: hadady@eng.tau.ac.il

In this work we study the electromagnetic wave scattering and absorption of a short time pulse that impinges on a time-varying lossy dielectric layer that is sandwiched between half-space of vacuum and a perfect electric conductor. The electric characteristics of the dielectric layer, namely, the conductivity, permittivity, and permeability are assumed to *change abruptly in time*. To make the analysis as general as possible we study the equivalent transmission line problem of the actual electromagnetic system. Thus, we naturally take into account the effect of polarization and the effect of oblique incidence simply by introducing different transmission-line characteristics.
The short-time pulse impinges at $t = 0$ the dielectric layer with parameters $(\sigma_1, \epsilon_1, \mu_1)$, part of it is reflected back and part of it is transmitted into the layer. At $t = t_s > 0$ the electric parameters of the layer are switched in time into a new set of values $(\sigma_2, \epsilon_2, \mu_2)$. At the switching moment continuity of the magnetic flux and the electric charge is imposed, giving rise to the initial condition at $t = t_s^+$. Then, the wave inside the layer continues to propagate and bounce back and forth, some of it is absorbed by the lossy layer while some of it is transmitted back and creates additional scattering from the layer into the vacuum. Since we focus on short time pulses, we carry out the analysis largely in the time domain. After formulating the 1D transmission-line problem in the complex *temporal* frequency variable s, we apply the inverse Laplace transform to find the signals in time. We show that the spectral Green's function in the complex temporal frequency s plane possesses no branch point singularities but exhibits only simple pole singularities (analog to what is typically expected, on the complex k_x plane, for symmetric plane stratified media in a time-harmonic analysis), and we use this fact to substantially accelerate the application of the inverse Laplace transform.
The impinging pulse is taken as a Blackman filter, and thus can be used to expand a variety of short time pulses. The locations of the poles on the complex s plane shares certain features that enable to find them in a fast manner, with the aid of a Newton-Raphson algorithm. Therefore, the scattering and the absorption calculation is relatively quick and as such it is suitable for application as an engine solver in an optimization scheme, for example if we desire to find the transition $(\sigma_1, \epsilon_1, \mu_1)$ to $(\sigma_2, \epsilon_2, \mu_2)$ that maximizes absorption over a predefined bandwidth. Since the system is time-variant it is not limited by the Rozanov bound [1], and therefore, it may be possible to overcome the bound in a manner akin to our previous work on the Bode-Fano bound [2].
In the talk we will discuss this problem and possible applications.

References

[1] K. N. Rozanov, "Ultimate thickness to bandwidth ration of radar absorbers," *IEEE Trans. Ant. Prop.*, **48** (8) 1230-1234 (2000).

[2] A. Shlivinski, and Y. Hadad, "Beyond the Bode-Fano Bound: Wideband Impedance Matching for Short Pulses Using Temporal Switching of Transmission-Line Parameters,"*Phys. Rev. Lett.***,** 121, 204301 (2018).