Accurate Time-Domain Modelling of MEMS Antennas for Wireless Telemetry Systems

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***Abstract*— A singularity-expansion-method-based technique for the accurate time-domain modelling of reconfigurable *MEMS* antennas for wireless telemetry applications is presented. Closed-form expressions of the radiated electromagnetic field in time domain are derived in terms of the newly introduced incomplete spherical Bessel functions depending on the complex frequencies of the natural resonant processes occurring in the antenna.**

I. INTRODUCTION

Recently, *MEMS* antenna devices have drawn attention as the near future communication tool [1]-[7], including implanted antenna systems [8]-[10]. The dimensions in radiating implanted applications are very important. Arrays of micro implanted antennas can study the monitoring of the physiological parameters such as temperature, blood pressure, etc. which require implantation of a wireless data telemetry unit in the interstitial fluid under the skin. Antennas have major role in implantable systems since they provide communication of the implant with the external equipment. However, implantable antenna design is quite challenging due to antenna size, impedance matching, low-power requirements, and biocompatibility with the body's physiology. In addition, the host environment (biological tissue) adds significant complexity to the problem due to high losses. For these reasons an accurate design tool is necessary.

According to theory [11] a wire antenna, whose length l is $\lambda/5 < l < \lambda/10$, behaves as infinitesimal dipole (small dipole). In view of this, emphasis in this paper is put on the electromagnetic characterization of small dipole-like antennas operating in the *GHz*-to-*THz* frequency range. To this end, a semi-analytical *SEM*-based methodology for accurate modelling of transient electromagnetic radiation processes is adopted. Using the proposed procedure, the radiated field is presented directly in the time domain as the superposition of outgoing propagating non-uniform spherical waves related to the complex resonant processes occurring in the structure under analysis. Any time-domain integral-equation or finite-difference technique can be adopted to carry out the full-wave analysis within a volume surrounding the antenna, and to determine on-the-fly in step with the numerical simulation a spherical harmonic expansion of the equivalent electric and magnetic currents excited on a suitable Huygens surface enclosing the radiating structure. Then, a pole/residue representation of the currents is derived by a dedicated time-domain vector fitting procedure [12]. In this way, closed-form expressions of the antenna parameters in time-domain can be obtained in terms of a newly introduced class of incomplete spherical Bessel functions, so generalizing and expanding the methodology in [12]. The suggested approach allows for a significant reduction of the computational resources (both in terms of time and memory).

II. TIME-DOMAIN MODELLING TECHNIQUE

Let us consider an antenna operating in free-space and driven through a transmission line by a matched voltage generator $v_g(t)$ having internal resistance R_g (see Fig. 1).

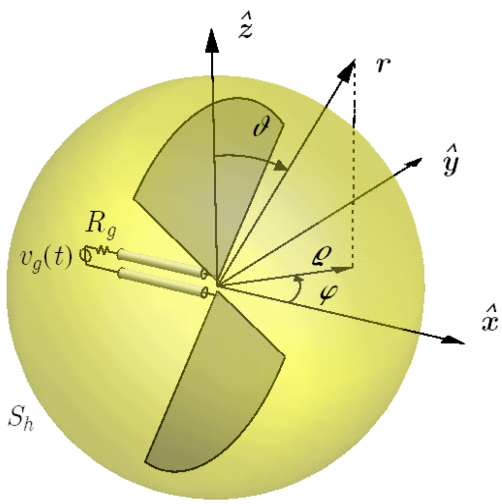

Fig. 1. Antenna enclosed by a spherical Huygens surface S_h . The radiating structure is assumed to be connected to a uniform transmission line excited by a real voltage generator $v_g(t)$ with internal resistance R_g . The reference system adopted to express the field quantities is also shown.

Denoting by S_h a spherical surface of radius R_h enclosing the structure, the relevant time-domain electromagnetic field radiated in the Fraunhofer region can be readily obtained as the vector slant-stack transform (*SST*) of the equivalent electric and magnetic current densities $\mathbf{I}_S(\vartheta,\varphi,t) = [\mathbf{J}_S(\vartheta,\varphi,t)\ \mathbf{M}_S(\vartheta,\varphi,t)]$ excited along S_h [1]. At any time, $\mathbf{I}_S(\vartheta,\varphi,t)$ can be conveniently approximated as a finite superposition of spherical harmonics: