Modeling Radiated Emissions from Medical Equipment for EMC Environmental Management in Hospitals

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Abstract — This paper reports the development of a modeling method in order to evaluate electromagnetic radiated emissions originated from medical equipments in hospital environments. The models are based on *in situ* and Open Area Test Site (OATS) measurement techniques, and they are applied to numerical simulation using Transmission Line Matrix Method (TLM). This approach provides a useful tool in order to assess electromagnetic profiles established within the clinical area, and it allows implementing optimization process to develop an effective electromagnetic compatibility (EMC) management program.

I. INTRODUCTION

The remarkable growth of electro-electronic technologies in several fields of application, in addition with the increased use of electromedical devices within health care facilities, such as therapeutic, diagnostic or even life support equipment, can lead to the raising of electromagnetic energy presented in clinical environments. In such circumstances, when this electromagnetic energy reaches a considerable level in which electromedical equipment (EME) were not developed to operate, it can provide an environment favorable to the appearance of electromagnetic interference (EMI).

Considering that malfunctions in EME can degrade not only the functionality of an equipment piece, but possibly an entire range of treatment methods or diagnoses, it manifests a hazardous situation that may put patients at critical risk conditions. For this reason, the knowledge of electromagnetic characteristics shown by these environments, including EME radiated emission features, can represent an important tool in order to promote electromagnetic compatibility (EMC) and avoid the EMI appearance in medical equipments [1]-[2].

A number of research groups have been developing efforts in order to investigate different approaches to model the emitting sources. Most of them are basically related to the development of EMC projects, such as PCB and electronic circuits, where near-field patterns of radiation are used as reference [3]-[6]. The main goal is to approximate the radiation pattern using a model composed by different kinds of infinitesimal dipoles sets or equivalent sources [3]. This equivalence principle has been successfully used to address many practical EMC problems [4].

For the purposes of this work, the total environmental condition is the main goal. So, it is not necessary the computation of very complex near-field patterns. On the other hand, OATS and free-space conditions are defined as reference radiation patterns used to model EME, also because it presents a more accurate amplitude result.

II. THE ENVIRONMENT UNDER TEST

In this analysis the environment under test is a typical OR of approximately 30 m^2. The disposal of EME and objects within the room follows clinical staff directives to configure a usual setup for the HCF standard procedure (Fig. 1).

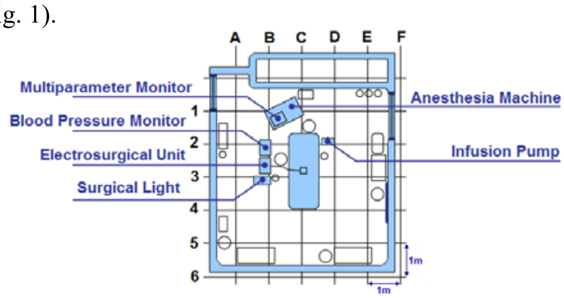

Fig. 1. Typical Environment Under Test: Operating Room (OR).

Concerning computational prediction, the environment under test was modeled by a 800 x 800 TLM mesh. Each node has an area of 1 cm^2, and it is characterized by the medium electric parameters ε_r and σ [1]. All mesh borders are modeled as open boundaries, simulated by a TLM "matched" (absorbing) boundary condition.

III. METHODOLOGY

The basic principle used in this research to model electromagnetic sources in clinical environments is developed in three stages: measurement tests (*in situ* and OATS), analytical calculation, and numerical simulation.

A. *Measurement Test I: Environmental Measurements*

During this stage is performed a number of *in situ* measurements concerning electrical fields established within the clinical environment under evaluation. The method used is based on IEEE Std.139 and IEEE Std. C95-3 and it is already described in [1]. The main internal and external sources are identified through spectral analysis, and all critical frequencies and amplitudes are evaluated according to EMI risk stated by IEC 60601-1-2 (EMC collateral standard for medical equipment).

B. *Measurement Test II: EME Measurements*

The EME are submitted to a typical OATS using a GTEM cell. This step allows us to quantify the electromagnetic contribution and the radiation pattern of each single source (i.e. EME) presented in the clinical environment during *in situ* measurements. The results of OATS measurements are computed to the EME model via analytical calculation as follows.

C. *Analytical Calculation*

The main objective of modeling is to obtain a set of equivalent sources that radiate the same field as the equipment under test (EUT) [6]. In this work, the multipole expansion is employed and it states that "*any radiation source of finite size may be replaced by an equivalent multipole expansion which gives the same radiation pattern outside a volume encompassing the source*".

Though an analogy between OATS and free-space propagation it is possible to compute the total radiated power of the EUT. This is done assuming that the radiated power is emitted by a set of short dipoles (replacing the EUT) according to (1):

$$P_T = \frac{E_{OATS}^2 \cdot 4\pi}{3\eta_0 \cdot g_m^2}, \qquad (1)$$

where g_m is the geometric factor of the OATS.

The expression (2) is applied in order to find the adequate electric field that can stimulate the TLM mesh at numerical simulation. In this way, is provided a numerical model which is able to simulate the environment under test in the same way as the EUT does in the clinical area.

$$E_{rms} = \sqrt{\frac{\eta_0 \cdot D \cdot P_T}{4\pi r^2}}. \qquad (2)$$

The modeling method can be illustrated as in Fig. 2.

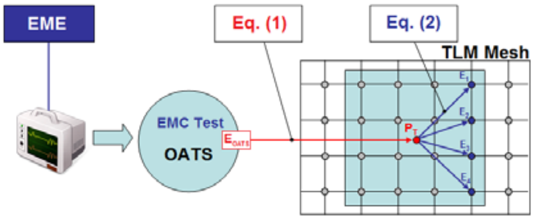

Fig. 2. Modeling Method for EME.

D. *Numerical Simulation (TLM Method)*

The TLM is a differential numerical technique based on light propagation principle stated by Huygens. In this method, the propagation medium is modeled by a network of interconnected transmission-lines (TLM mesh), and material properties are represented by the equivalent lumped circuit components. The analogy between Kirchhoff laws for shunt node circuit and wave Maxwell's equations in time domain can define the relation between voltage/current and electrical/magnetic field [1]-[2]:

$$E_z = \frac{V_z}{\Delta l} \qquad H_X = \frac{I_y}{\Delta l} \qquad H_Y = \frac{-Ix}{\Delta l} \qquad (3)$$

Likewise, it is also possible to establish the relations between TLM cells and medium parameters:

$$\mu = L_d \qquad \varepsilon = \left(2C_d + \frac{C_s}{2}\right) \qquad \sigma = G_s \qquad (4)$$

IV. PRELIMINARY RESULTS

Validation tests using free-space model are performed employing an "empty" mesh (ε_r = 1.0, σ = 0 S/m) in numerical simulation. It is possible to confirm that the amplitude values and radiation patterns for each EME model agree quite well with measurements tests. Then, EME models are inserted in its correspondent location in the clinical environment. Field scattering can be observed and optimization process can be developed in order to provide the best EMC condition for EME operation. Due to the limited space, in this digest the modeling results presented is focused only at critical frequency of 335,7 MHz for 4 equipment pieces as shows Fig. 3.

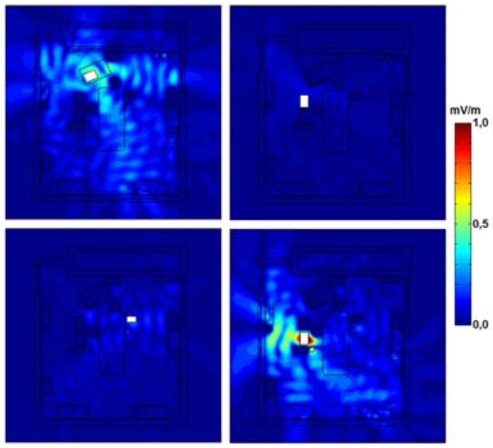

Fig. 3. Field Scattering Results at 335,7 MHz: a) Monitor Multiparameter; b)Blood Pressure Monitor; c) Infusion Pump; d) ESU.

V. FINAL CONSIDERATIONS

In the full paper, a better detailing is given to the treatment of this problem, allowing more discussion about the subject. The results of other important sources will be presented providing a complete analysis of the environment under test. Finally, an optimization process using genetic algorithms (GA) will be employed in order to promote EMC management in the clinical environment.

VI. REFERENCES

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