

Electric Field in the Presence of Humans

Miroslav J. Veljovic, *Student member, IEEE*, Dragan I. Olcan, *Member, IEEE*, and Branko M. Kolundzija, *Fellow, IEEE*

Abstract— In this report, results for simulations of electromagnetic field propagation at 900 MHz in the presence of groups of people are presented. The starting geometry of humans is modeled using combination of programs MakeHuman and Blender. It is then imported into 3-D electromagnetic numerical solver based on surface integral-equation formulation, higher-order basis functions and Galerkin testing (WIPL-D). The goal of these simulations is to estimate the attenuation of electromagnetic field propagating through human crowds. The initial experimental verification is done and the results are presented.

Index Terms— Human crows, Electromagnetic propagation, 3-D EM simulation, higher order basis functions, method of moments.

I. INTRODUCTION

AT the stages of design, planning and deployment of radio systems that are intended to work in the presence of large human crowds (mobile communications, peer-to-peer radio links, etc.) it is of interest to know the attenuation of electromagnetic (EM) field. In the work presented here we concentrate estimating the attenuation at open area.

The scenarios of radio links needed in the presence of human crowd in open area can be large sports or arts events [1], peaceful rallies, or a consequence of natural disasters, etc.

II. ELECTROMAGNETIC MODELING OF HUMANS

The initial quadrilateral mesh for 3-D models of humans is obtained with open-source MakeHuman software [2]. Human poses were varied using the software Blender [3]. Additionally, body cavities were manually closed to obtain an enclosed 3D model and some details were also removed. The final quadrilateral (surface) mesh is imported into 3-D EM numerical solver based on surface integral-equation formulation, method of moments (MoM) with higher-order basis functions, and Galerkin testing WIPL-D [4], [5].

The human body is approximated as a homogeneous dielectric for the electromagnetic simulation [6]. The complex dielectric permittivity is frequency dependent. At 900 MHz, the relative dielectric permittivity is $\epsilon_r = 38.63$, and the specific conductivity is $\sigma = 0.83$ [7].

Alternatively, the surface of human body is modeled as a conductive layer with distributed loadings [8]. The surface

impedance of those loadings is carefully calculated to match the more complex model with homogeneous dielectric. This approach yields reduction of the total number of unknowns of about 50%, with the electric field around the human body within the 10% margin. When such discrepancy is tolerated, it is possible to simulate larger groups of humans, using the same resources. If the high accuracy is needed, the dielectric model should be used.

III. MODELS OF HUMAN ECHELONS

Using the homogeneous dielectric human model, we created groups of people organized in various echelons, i.e., formations with well-defined structure.

The groups are illuminated with a linearly polarized (both vertically and horizontally) transversal plane EM wave from the direction parallel to the human columns. The intensity of electric field is 1 V/m, i.e., 120 dB μ V/m. The operating frequency is 900 MHz.

The electric field was calculated in a set of point uniformly distributed over a flat rectangle placed behind the last human row, as shown in Fig. 1. The average (mean) value of electric field intensity is calculated by post-processing of results.

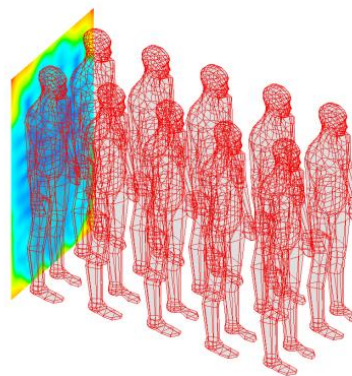


Fig. 1. Electric field behind a human echelon.

We created models with one to four parallel columns of humans, with up to 10 humans per column. The distance between humans in a column was 0.5 m. The average intensity of electric field as a function of number of humans in a line, N , for various number of columns, is shown in Fig. 2. The results show that the attenuation of electric field is larger for the case of vertical polarization, i.e., in the case when vector of electric field is parallel to the humans, then in the case of horizontal polarization.

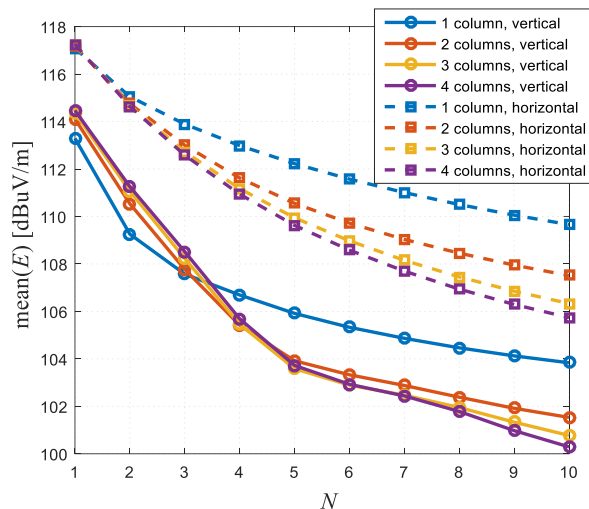


Fig. 2. Average electric field behind the last row at 0.9 GHz.

IV. EXPERIMENTAL VERIFICATION

In order to verify the results and the presented approach we performed experimental verification. A series of measurements were done in a semi anechoic chamber using log-periodic antenna for excitation and NARDA SRM-3006 for electric field measurement.

Up to four persons, were positioned in a line, about 10 wavelengths away from the antenna. The distance between people was approximately 0.5 m. The electric field was measured behind the last person, in 33 positions over three parallel lines. The probe distance from the person's back was in the range from 5 to 15 cm in all cases.

As a reference, electric field was measured in each position without the presence of persons. Attenuation is afterwards calculated relative to this result. The polarization was vertical or horizontal, and the operating frequency was 900 MHz.

We created a number of models of up to four humans in a line, so that the model geometry resembled actual humans from the laboratory procedure. The analysis performed was similar to the one described in the previous section. The electric field was calculated in a set of 33 points, which correspond to the ones in measurements.

The electric field was averaged for both measurements and simulations, and shown in Fig. 3, for two polarizations, as a function of number of humans in a line, N . In order to better correlate the simulation results with the measurements, the electric field was additionally calculated along several parallel planes, from 6 to 20 cm from the back of the last person.

The measured results show an increase in attenuation with the increase of the number of humans per column, in a similar manner as in the simulations. However, simulated attenuation is several dB higher, and further model calibration is necessary.

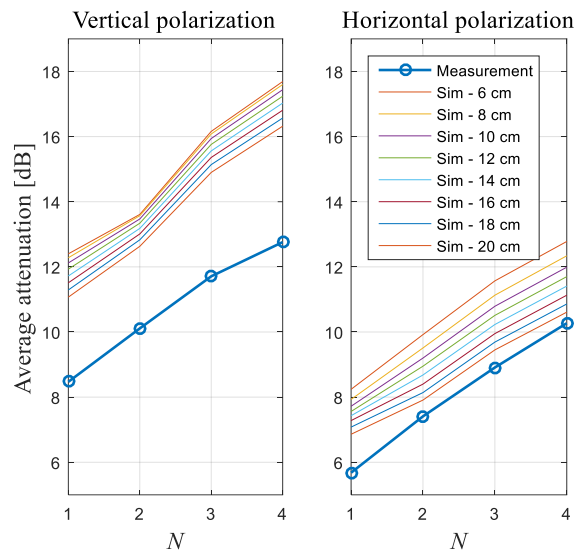


Fig. 3. Comparison of measured and simulated attenuation.

V. CONCLUSIONS

In this report we present a process of modeling and simulation of groups of people, in order to investigate their effect on EM wave propagation for the frequency of 900 MHz. Alternate ways of describing the human body are presented. Simulations were performed with defined formations of humans, and the results for the average electric field are shown. In the end, a series of measurements are performed and the measurements and simulations results are compared.

STATEMENT

The IEEE MTT-S Pre-Graduate Scholarship has been one of the turning points in my education. Thanks to this opportunity, amongst other, I decided to continue with the research in microwave domain, as a PhD student at Swiss Federal Institute of Technology in Lausanne (EPFL). This scholarship has also allowed me to travel to COMCAS 2015, where I had my first paper presentation at an international conference and a chance to attend several interesting lectures on antennas and microwaves.

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