FDTD-based Antenna De-embedding in WBAN on-body Channel Modeling

Jun-ichi Naganawa*[1], Minseok Kim[1], Takahiro Aoyagi[2], and Jun-ichi Takada[1]

[1]Graduate School of Science and Engineering, Tokyo Institute of Technology
P.O. Box S6-4, 2-12-1, Ookayama, Meguro-ku, Tokyo, 152-8552, Japan
naga@ap.ide.titech.ac.jp, {mskim, takada}@ide.titech.ac.jp

[2] Graduate School of Decision Science and Technology, Tokyo Institute of Technology
P.O. Box W9-110, 2-12-1, Ookayama, Meguro-ku, Tokyo, 152-8552, Japan
aoyagi@cradle.titech.ac.jp

Abstract

For designing reliable and low-power wireless body area network (WBAN) systems, channel modeling plays an important role. However, coupling between antennas and a human body hinders from separately modeling their individual contributions. Therefore, this paper proposes an antenna de-embedding scheme that is based on the channel modeling by means of spherical wave functions (SWFs). A preliminary validation is also presented.

1. Proposed Approach

The channel modeling by spherical wave functions (SWFs) is an attractive alternative expression to the double-directional channel modeling [1]. The proposed scheme is the extension of the authors' previous work [2] that is the application of the SWF channel modeling to achieve the antenna de-embedding in FDTD-based propagation prediction. The antenna transmission property is modeled by a field excitation coefficient $\boldsymbol{T} \in C^{J\times 1}$ where J is the truncation number, which describes the linear relationship between the input signal v and the radiated spherical wave coefficient $\boldsymbol{b} \in C^{J\times 1}$. To obtain $\boldsymbol{T}$, antenna current distribution is simulated on the human body. The E-field caused by this current distribution is then calculated in free space. Finally, expanding this E-field by SWF provides $\boldsymbol{b}$ and $\boldsymbol{T} = \boldsymbol{b}/v$. The antenna reception property is modeled by a receiver coefficient $\boldsymbol{R} \in C^{J\times 1}$ defined by $w = \boldsymbol{R}^{\mathrm{T}}\boldsymbol{a}$ where $\boldsymbol{a} \in C^{J\times 1}$ is the incoming spherical wave coefficient and w is the received signal. $\boldsymbol{R}$ can be obtained by applying reciprocity to $\boldsymbol{T}$.

The propagation characteristic is expressed by a mode-to-mode mapping matrix $\boldsymbol{M} \in C^{J\times J}$ which describes the relationship between the radiated and incoming spherical waves by $\boldsymbol{a} = \boldsymbol{M}\boldsymbol{b}'$ where prime indicate the source. To obtain $\boldsymbol{M}$, a spherical wave source of j_{t} mode is placed at the position of the transmit antenna. This yields j_{t}th column vector of $\boldsymbol{M}$ by $\boldsymbol{m}_{j_{\mathrm{t}}} = \boldsymbol{a}/b_{j_{\mathrm{t}}}$. $\boldsymbol{a}$ can be obtained by applying the spherical wave expansion to the E-field at observation points that are hemi-spherically placed at the position of the receive antenna. The channel response is synthesized by $h = \boldsymbol{R}^{\mathrm{T}}\boldsymbol{M}\boldsymbol{T}$.

2. Numerical Example

As a preliminary study, the proposed approach is validated for a simple case. The frequency is 2.45 GHz. Two tangential half-wave length dipoles are operating 1.2 cm above the body surface. The distance between the antennas is 73.2 cm (6λ). The human body is modeled as an infinite plane of lossy dielectric, the dielectric constant and the conductivity of which are 2/3 of the average muscle. The FDTD cell size is 2 mm ($\lambda/61$) in order to simulate the small gap between the antennas and the body. The channel response by the proposed approach $\tilde{h}$ and the reference approach h were obtained. The reference approach is the direct FDTD method, in which antennas and the body are embedded. The obtained path gains are $|\tilde{h}| = -60.8$ dB and $|h| = -61.8$ dB, respectively. The phases are $\angle\tilde{h} = 145.9$ deg and $\angle h = 144.3$ deg, respectively. Good agreement is observed and the proposed approach was validated.

3. Conclusion

This paper proposed an antenna de-embedding scheme in WBAN on-body channel modeling. The proposed approach is based on the SWF channel modeling and its FDTD implementation. For future work, validation with more variety of antennas and the realistic human body are necessary.

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References

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