Analysis of the Body Proximity Cross-Polarization Power Ratio in a Human Walking Motion

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***Abstract*- This paper presents a preliminary investigation on the body proximity cross-polarization properties considering the human walking motions for BAN on-body wireless communication systems. A novel concept of the BP-XPR (Body Proximity Cross-Polarization Power Ratio) in on-body channel is defined, which has been quantified based on relative antenna locations and radiation gain of test antennas. The analytical results show that the estimated value of Cross-Polarization Power Ratio (XPR), given by the proposed BP-XPR, can represent the cross-polarization properties using the radiation gain of test antenna instead of the practical measurement.**

Keywords— Body Proximity Cross-Polarization Power Ratio, On-Body channel, Dynamic human model, Walking motion

I. INTRODUCTION

In BAN (Body Area Network) on-body system, due to the polarization mismatch caused by the dynamic characteristics such as walking, significant signal variation between two on-body terminals is an indispensable subject.

This paper presents a preliminary investigation on the body proximity cross-polarization properties considering the human walking motions for on-body communication systems. A novel concept of the BP-XPR (Body Proximity Cross-Polarization Power Ratio) in on-body channel is defined, which was quantified based on antenna locations and radiation gain of test antennas. The results show that the estimated value of Cross-Polarization Power Ratio (XPR), given by the proposed BP-XPR, can represent the cross-polarization properties using the radiation gain of test antennas instead of the practical measurement.

II. DEFINITION OF BP-XPR IN DYNAMIC ON-BODY CHANNEL

In previous study [1], a simple two-dimensional dynamic on-body channel model is proposed, where a uniformly distributed plane wave from the sensor to the access point is assumed, which is decomposed into vertical and horizontal polarization allocated in z-axis and x-axis. Thus, the XPR in the on-body situation (LOS) at receiving point is defined as follows.

$$XPR = \left(\frac{V}{H}\right)^2 = \tan^2\theta \tag{1}$$

where θ denotes the value of the angle between z-axis and the direction of the incident wave in zx-plane.

However, in the actual measurement, the signal level of vertical and horizontal polarization at the receiving point need to be measured, respectively, using the test antenna such as dipoles. Therefore, the measured value of XPR is simultaneously affected by the human effects and the different types of test antennas.

Fig. 1 shows the variation of XPR in on-body channel. ΔXPR_1 and ΔXPR_2 indicate the variation caused by the test antennas and human effects. Thus, we define the BP-XPR (Body Proximity Cross-Polarization Power Ratio) of the incident wave as follows.

$$BP\_XPR = XPR \cdot \Delta XPR_1 \cdot \Delta XPR_2 = \frac{P_{V_h}}{P_{H_h}} \tag{2}$$

where P_{Vh} and P_{Hh} indicate the received power of the vertical and horizontal dipoles in on-body situation. Since the uniformly distributed incident wave with θ-polarization component in the two-dimensional channel [1] was assumed, the value of BP-XPR in Eq. (2) can be estimated as follows.

$$BP\_XPR = \frac{P_{V_h}}{P_{H_h}} = \frac{G_\theta^{(V_h)}}{G_\theta^{(H_h)}} \tag{3}$$

where $G_\theta^{(V_h)}$, $G_\theta^{(H_h)}$ indicate the radiation gain of vertical and horizontal dipole antenna towards the incident wave angle (θ).

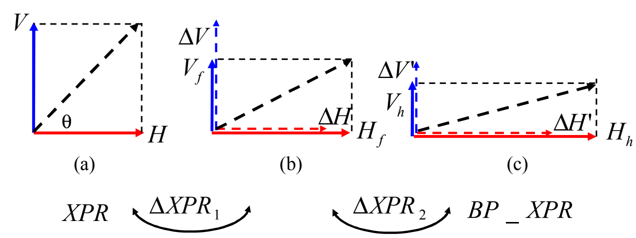

Figure 1. Variation of XPR in on-body channel.

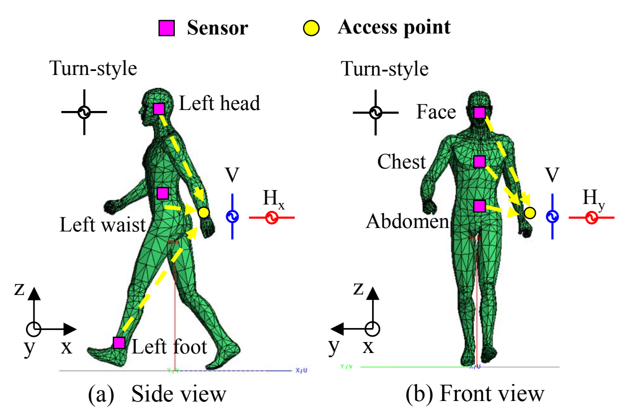

Figure 2. Simulation model with human walking motion

III. Simulation and Discussions

Based on Eqs. (1), (2) and (3), a simulation using the actual human phantom has been carried out, as shown in Fig. 2. Fig 2 (a) and (b) indicate the side and front view, respectively. The arm-swing postures are separated from –20° to 50° at 10° intervals [2]. The human phantom shown in Fig. 2, is derived from an animation software, POSER [3]. The phantom is a male with a height of 170 cm, which is homogeneous made of the dielectric properties of average muscle tissue, i.e., relative dielectric constant ε_r = 54.2 and σ_s = 1.51 S/m at 2 GHz. The simulation is carried out by a commercial EM solver FEKO [4].

In Fig. 2 (a), the sensor (turn-style antenna) is mounted at left head, left waist and left foot while in Fig. 2 (b), it is located at face, chest and abdomen, respectively. In the access point antenna at wrist, the vertical and horizontal antennas are used for measuring the received signal power P_{Vh} and P_{Hh} while the radiation gain $G_\theta^{(V_h)}$, $G_\theta^{(H_h)}$ are also analyzed, simultaneously. The feed point of vertical and horizontal dipoles to the surface of the human phantom is set with a separation of 4 cm.

Fig. 3 shows the VSWR of the test dipole antenna V, H_x and H_y in the simulation of BP-XPR, which are arranged along with z, x and y-axis, respectively, as shown in Fig. 2. In Fig. 3, it can be seen that the motion of the arm does not have a serious impact on the impedance characteristics because the dipoles with relatively wideband characteristics are used. Also, the VSWR of the sensor antenna has little variation at different on-body locations.

Fig. 4 shows the analytical results of the BP-XPR as a function of the arm-swing angle from –20° to 50°. Fig. 4 (a) (b) and (c) indicate the on-body channels from the side view, while Fig. 4 (d) (e) and (f) indicates those from the front view, corresponding to situation shown in Fig. 2 (a) and (b), respectively.

As shown in Fig. 4 (a), (b) and (c), in the on-body channels shown in Fig. 2 (a), the calculated value of XPR using Eq. (1) has not a large difference compare with the other two curves. However, in Fig. 4 (d), (e) and (f), the obvious variations occur. The reason is that in the case of side view, the dynamic phenomenon caused by the arm-swing motion is significant. However, in the on-body channels from front view, the dynamic phenomenon is not obvious, which means that the incident wave angle θ has a stable value regardless of sensor antenna locations and arm-swing motion, resulting in a steady profile of the XPR.

Further, in the entire arm-swing regions with different on-body channels in Fig. 4, the estimated values of BP-XPR calculated by Eq. (3) using the radiation gain agree well with those calculated by Eq. (2) using the received signal power, indicating that in any sensor antenna location and arm-swing angle, the proposed method using radiation gain can represent the accurate value of cross-polarization properties in human proximate situation, instead of the practical link measurement.

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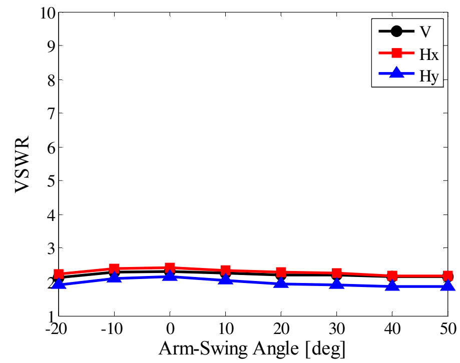

Figure 3. VSWR of test dipole antenna vs. arm-swing angle

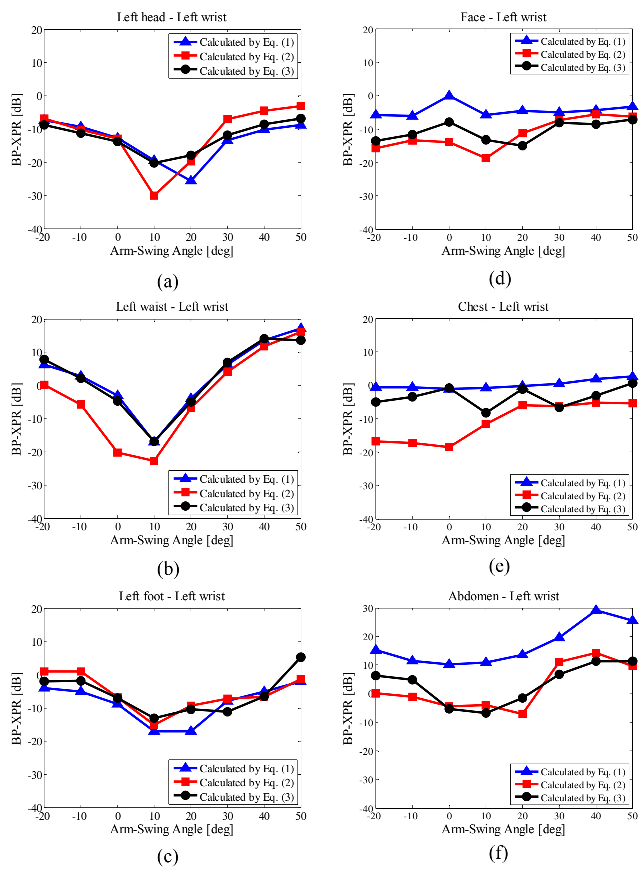

Figure 4. Analytical results of BP-XPR in different on-body channels.

References

[1] K. Li, K. Honda, and K. Ogawa, "On-body Polarization-controlled Active Antenna to Enhance Signal Power in Human Dynamic Channel," ISAP2014, Kaohsiung, Taiwan, Dec. 2014.

[2] K. Omote, K. Honda, and K. Ogawa: "Motion Capture Modeling of a Human Walking for Wearable MIMO Antennas," AWAP2014, Kanazawa, Japan, pp.99-100, May 2014.

[3] [Online]. Available: http://poser.smithmicro.com/

[4] FEKO https://www.feko.info/