Bit-Error-Rate Over-The-Air Testing of Weighted-Polarization BAN Antenna Using an Arm-Swinging Dynamic Phantom

Kazuhiro HONDA1, Keisuke MURATA1, Kun LI1, Koichi OGAWA1, Yoshio KOYANAGI2, Hiroshi SATO2, Ritsu MIURA2
1Graduate School of Engineering, Toyama University
2AVC Networks Company, Panasonic Co., Ltd.

Abstract: In healthcare data radio system, it is essential to avoid the communication disconnection when the transmission signal bit error rate (BER) exceeds a specific value. When the BAN antenna is attached at wrist, the polarization characteristics will be varied significantly according to the antenna rotation angle caused by the arm-swing motion. In this paper, the BER characteristic of a weighted-polarization BAN antenna considering human walking motion is measured while the validity of the proposed antenna is verified. At first, a method of BER Over-The-Air (OTA) Testing is proposed, where a fading emulator is utilized for realizing the actual propagation environment. Then, the BER measurement is carried out in considerations of the arm-swing motion using a human phantom. Compared with the conventional antenna, less SNR is required when the weighted-polarization BAN antenna is used to obtain the desired BER, indicating the effectiveness of proposed weighted-polarization antenna for BAN wireless applications.

Keywords: Weighted-Polarization BAN Antenna, BER-OTA Testing, Arm-Swinging Dynamic Phantom, Walking Motion

1. Introduction

In previous study [1], we have reported a weighted-polarization antenna that can be controlled to obtain the optimum signal according to the propagation environment and antenna inclination angle. This paper presents a measurement method on the Bit-Error-Rate (BER) Over-The-Air (OTA) Testing of frequency shift keying (FSK) signals for wrist-attached Body Area Network (BAN) antennas using a fading emulator with a dynamic phantom.

2. Weighted-Polarization BAN Antenna

Figure 1 shows the configuration of a 3-axis weighted-polarization BAN antenna [1]. The proposed antenna is comprised of three orthogonal dipole antennas (Ax, Ay, Az). When the antenna is rotated by an operator, two of the three dipole antennas are selected using two switches (SW1, SW2). The received signals (sV, sH) are multiplied by the weight functions (WV', WH'). Thus, the signal at the output port (a) of the proposed antenna is expressed by Eqs. (1) - (5).

\[
\begin{align*}
a &= W'_v s_v + W'_h s_h e^{i\frac{\pi}{2}} \\
W'_v &= W_v \cos \alpha + W_v \sin \alpha \\
W'_h &= W_v \sin \alpha + W_h \cos \alpha \\
W_v &= \frac{XPR}{\sqrt{1 + XPR}} \\
W_h &= \frac{1}{1 + XPR}
\end{align*}
\]

Figure 1 3-Axis Weighted-Polarization BAN Antenna.

3. BER-OTA Testing Method

Figure 2 shows the configuration of the developed fading emulator for BAN-OTA testing. The arm-swinging dynamic phantom is located at the center of the fading emulator. The diameter of the fading emulator is 240 cm, and the height of each surrounding dipole antenna measured from the floor is 90 cm.

A vector signal generator (SG) and a commercial FSK module [2] are used for BER measurement. The pseudo random noise RF signal with FSK modulation at 926 MHz is created, which is divided into the fading emulator comprised of power divider and phase shifter. The signals radiated from the seven scatterers are summed around the phantom, and the desired Rayleigh fading propagation environment can be generated. Based on this OTA apparatus, the instantaneous BER characteristic can be measured.

Figure 3 shows a photograph of the spatial fading emulator with an arm-swinging dynamic phantom. The arm-swinging dynamic phantom with salt water inside is close to the electrical property of the human body [3]. The weighted-polarization BAN antenna is attached at left wrist of human phantom. The received signal from DUT antenna is input into SG while the BER
measurement is carried out. The fading signals in each snapshot is stopped from several seconds. At this interval, the measurement of instantaneous BER, is started while the number of total BER data is set to 200,000 as an exit condition. When the measurement of BER, is finished, the phase shifters are controlled to move to the next snapshot of fading profile with a separation of \( \Delta d = \lambda / 100 \). Then, BER, is measured while the process is repeated until the antenna has covered the prescribed moving distance. In this paper, the arm-swing angular range is set from +40 to −10 degrees in order to simulate the realistic human walking motion. The stride is 70 cm (2.16m). Since the number of snapshots is set to be 100 samples per wavelength, each step covers 216 snapshots. Thus, there are 6 intervals from +40 to −10 degrees, resulting in 36 snapshots per section (10 degrees of arm-swing angle region).

In order to measure the instantaneous BER, according to the arm-swing angle \( \alpha \), the weight function is controlled base on the arm-swing angle of human phantom in each 36 snapshots intervals. The weight function is realized by using the power divider and attenuators, where the power loss caused by the attenuators needs to be considered [4]. In the experiment, the CNR needs to be fixed at a specific situation. Thus, the output signal \( P_{\text{out}} \) from SG is varied according to the power loss from attenuators.

4. Measurement Results

Figure 4 shows the results of instantaneous received signal power in one period of arm-swing motion (2 steps). The frequency of measurement is 926 MHz. The XPR is set to be 50 dB while the CNR is 15 dB. In Fig. 4, the black curve shows the result of weighted-polarization BAN antenna while the red curve indicates that of horizontal dipole antenna.

As shown in Fig. 5, the horizontal dipole antenna shows a high instantaneous bit error rate BER, in the entire moving distance. On the contrary, the proposed weighted-polarization BAN antenna shows a degraded profile of instantaneous BER,. The average bit error rate BERave of weighted-polarization BAN antenna is lower compared with the horizontal dipole, corresponding to a 10 dB degradation of CNR. This feature indicates the validity of proposed weighted-polarization BAN antenna, which can be used for the wearable BAN wireless applications.

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**Reference**