INVESTIGATION OF CHANNEL SPATIAL DIVERSITY FOR DUAL-LINK COOPERATIVE COMMUNICATIONS IN WBAN

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Introduction: In the last few years, the interest of Wireless Body Area Networks (WBANs) has increased considerably. WBANs are based on compact wireless devices around the body that generally transmit their measures to a common sink in real-time [1]. Radio channels in WBANs undergo strong scattering effects from the human body, which leads to high path loss within short propagation distances, as well as deep fading under certain body movements [2]. Consequently, the signal-to-noise ratio (SNR) in practical WBAN communications varies significantly despite the short inter-node distance. Therefore, cooperative multi-link technology appears to be one of the possible solutions to improve the reliability of body communications, e.g. by exploiting the channel spatial diversity and hence mitigate the channel fading [3]. However, the performance of such cooperative schemes depends on the channel allocations, the body postures, and the off-body environment.

In this paper, we analyze the channel spatial diversity for WBAN communications in indoor environments. A dual link topology is considered to investigate the time-variant channel properties over different scenarios. Based on the channel measurements, we compare the simulated bit error rate (BER) and the gain from a dual-link cooperative scheme with respect to a single-link. The experimental results support the assumption that the channel spatial diversity in WBANs can effectively improve the communication quality and BER.

Experimental framework: The measurements were conducted at 2.45GHz in a typical indoor environment on a female volunteer as shown in Fig. 1. Three small-sized SMT-3TO10M-A SkyCross antennas were selected to form two on-body radio links sharing one transmitter and having their receivers distributed in different locations as shown in Fig. 2. The time-variant on-body channels were measured by the S-parameters (S₂₁ for channel 1 and S₃₁ for channel 2) between the antennas via a vector network analyzer (VNA). All the scenarios were measured with three different movements of the body: lying on the bed without movements, stand/sit/stand movement, and walking.

Figure 1: Measurement environment

Figure 2: Different dual-link scenarios on the human body

In order to characterize the measured channels, their amplitude distribution is estimated. Moreover, with the help of recorded S-parameters, the corresponding single- and dual-link power mean and standard deviation have been computed for different on-body scenarios. For BER analysis, Quadric Phase Shift Keying (QPSK) modulation has been considered, assuming that the BER is a Q-function of the SNR [4-5], where experimentally each SNR corresponds to the channel power for dual link, using maximal ratio combining (MRC), and both single links. The BER can be written as

\[
\text{BER}(\text{SNR}_\text{TX}) = \sum_{n=1}^{K} \frac{\text{Q}(2^{-a^2 \text{SNR}_\text{TX}})}{K},
\]
where $s$ is the fading amplitude, and $K$ is the number of samples of the S-parameter.

We assume an equal power allocation cooperation scheme for the dual-link communication [7]. The final paper will include evaluation over more cooperation schemes.

**Measurement results:** One example of measured channel and the corresponding simulation results is presented here for walking movements, specifically for the scenario shown in Fig. 2(c), where both channels are measured around the waist.

In Fig. 3, the temporal variation of all channels is clearly observed as a result of the motions taking place during the walk. Moreover, it shows the typical on-body channel fading with body dynamics. It can be seen that the dual-link channel clearly benefits from cooperative diversity, which should result in a lower BER performance for the dual-link scheme.

![Figure 3: Channel values (in dB) for the walking case](image)

In Table 1, the highest standard deviation (STD) is observed for channel 1, while the dual-link (MRC) channel presents the lowest standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>STD channel 1</th>
<th>STD channel 2</th>
<th>STD dual-link</th>
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<tbody>
<tr>
<td>channel 1</td>
<td>4.5 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>channel 2</td>
<td>3.2 dB</td>
<td></td>
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<tr>
<td>combined</td>
<td>2.3 dB</td>
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</tbody>
</table>

Table 1: Channel STD for walking case

The simulated BERs of dual-link, single-link, and additive white Gaussian noise (AWGN) channels are compared on the basis of the channel measurements in Fig. 4.

![Figure 4: BER curve for walking case](image)

It can be observed that the MRC dual-link offers a significant BER improvement with respect each individual link as explained above.

**Conclusion:** Through the analysis over the measurements, it is concluded that the spatial diversity is a key factor for WBAN networks to mitigate on-body channel fading. Cooperative schemes are shown to improve the WBAN communication reliability, which is critical in biomedical data transmission.

**REFERENCES**


