Channel Characterization for RF Localization Inside Human Body

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Overview of CWINS Program on BAN

- **Current Project:** RF Propagation Measurement and Modeling for Wireless Body Area Networks – *Sponsored by NIST*

- **Staff and Students at the CWINS Lab:**
  - Kaveh Pahlavan
  - Allan H. Levesque (research scientist)
  - Kaveh Ghaboosi (Post Doc)
  - Reza Zekavat (visiting professor)
  - Ning Yang (affiliated research scientist)
  - Yunxing Ye, Fardad Askarzadeh (PhD)
  - Umair Khan, Ruijun Fu, Shen Li, Pranay Swary (MS)
  - Monir Islam (UG)

- **Staff and Student at the Antenna Lab:**
  - Sergey Makarov
  - Gregory M. Noetscher, Yang Xu (MS)
  - Ishrak Khair (UG)
Innovations starts with science fictions and a technical challenge!

How can we localize the capsule using RF signal?
Performance evaluation needs channel models

Internet Channel for in-body localization

Channel Models for
- RSS-based systems [4]
- TOA-based systems [NA]

Current research topics at CWINS

– What are the bounds on ranging error for RSS-based localization?
– What is the effect of non-homogeneity of human body on TOA ranging?
– What are the effects of body motions?
– How can we measure inside human body?

RSS-Based Localization for Capsule Endoscopy

<table>
<thead>
<tr>
<th>Implant to Body Surface</th>
<th>$L_{p}(d_0)$</th>
<th>$\alpha$</th>
<th>$\sigma_{dB}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep Tissue</td>
<td>47.14</td>
<td>4.26</td>
<td>7.85</td>
</tr>
<tr>
<td>Near Surface</td>
<td>49.81</td>
<td>4.22</td>
<td>6.81</td>
</tr>
</tbody>
</table>

$$L_{p}(d) = L_{p}(d_0) + 10\alpha \log(d/d_0) + S(d > d_0)$$

Performance for capsule endoscopy

Localization performance as a function of number of receiver sensors in different organs:
- Stomach
- Small intestine
- Large intestine

Localization performance as a function of number of pills in each organ:
- Stomach
- Small intestine
- Large intestine

Effects of non-homogeneity

\[ d = \hat{d} = (\sum_{i=1}^{n} \frac{d_i}{\varepsilon_i}) = \left( \frac{d_1}{c/\sqrt{\varepsilon_1}} + \frac{d_2}{c/\sqrt{\varepsilon_2}} + \ldots + \frac{d_n}{c/\sqrt{\varepsilon_n}} \right) \frac{c}{\varepsilon} \]

Illustration of the calculation scenario (a cross section of human torso)

500 random point experiment

\[ \varepsilon = 52.95 \]
\[ \text{std(dme)} = 6.03 \text{mm} \]

Effects of human motions

• (a) No motion
• (b) Stand Still
• (c) Walk
• (d) Jog

[8] Ruijun Fu, Yunxing Ye, Kaveh Pahlavan and Ning Yang, "Doppler Spread Analysis of Human Motions for Body Area Network Applications" 22nd Annual IEEE international symposium on personal, indoor and mobile radio communications PIMRC 2011, 11-14 September, Toronto, Canada.
Measurement program

Hollow Phantom in the Chamber

Phantom Phil with Bones and Organs

Using human subject
Challenges in computer simulations
