Enabling The Cloud of Things

BLUETOOTH SMART® SOLUTIONS FOR TINY METAL OBJECTS
TECHNICAL TRADE OFF AND SOLUTIONS

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AGENDA

- Introduction
- Metal Case Connected Watch
  - Metal Case Description
  - Design process
  - Design Example
  - Performance
  - Link Budget
- In-ear Hearing Aid
  - Design Example
  - Performance
  - Link Budget
- Conclusions
Introduction

- Bluetooth Smart
  - Dominant Standard for short range communication
    - Reduced power consumption of individual functions <10mA radio

Mostly Off
Introducción 2

- Bluetooth Smart
  - Block Diagram

- uProc
- Radio Rx/Tx
- Sensors I/F Man m/c
- Real Time Clock
- Small electronic module

Small is beautiful
BUT
Will it Work?
Metal Case Connected Watch

- Stylised Metal Watch Case
  - 28 to 35 mm diameter
  - Height 10mm
    - Reduced power consumption of individual functions <10mA radio
    - Electronics under movement
    - Antenna close to Electronics
    - Antenna near back plate
Design Process

Obtain Data

Create 3D Idealized Model

Determine space for Antenna

Evaluate Antenna Topologies

Best?

Build and Test Prototypes

Verify Link Budget

OK?

Solution Validated

Mechanical and Materials Data

PIFA, IFA, Monopole, … Meanders 2D 3D
Design Example

- **Constraints**
  - Near watch back (2mm)
  - Small size (<30mm²)
  - Near watch side walls

- **Best Structure**
  - PIFA 3D type
**Optimum Performance**

- Measured Prototype
  - Needs small re-centering
  - Gain ca. \(-9\) dBi
  - Return loss > 6 dB
Link Budget

\[
\frac{Pr}{Pt} = GrGt(1 - S11^2)(1 - S22^2)\left(\frac{\lambda}{4\pi R}\right)^2
\]

- Parameters
  - \(Pt\) – Transmit Power \(0dBm\)
  - \(Pr\) – Received signal at sensitivity level \(-85dBm\)
  - \(Gt\) – Transmit Antenna Gain \(0dBi\)
  - \(Gr\) – Receive Antenna Gain \(-9dBi\) (from measurements)
  - S11 and S22 – 6dB Return Loss
  - \(\lambda\) – Wavelength – 122cm
  - R – Range
Link Budget as Function of $Gr$

- **Link Budget**
  - Bluetooth Smart
  - Cell Phone $G_t$ 0 dBi
  - Tx power 0 dBm
  - Rx sensitivity $-85$ dBm
  - Slave antenna Gain $Gr$
  - $Gr=9$ dBi
  - $\Rightarrow$ Range 60 m
  - $Gr=-20$ dBi
  - $\Rightarrow$ Range = 18 m
In-Ear Hearing Aid

- In-Ear Hearing Aid
  - Tiny Form Factor
    - Battery
    - Microphone
    - Loud Speaker
    - Electronics
  - Bluetooth Smart
    - Add Antenna
    - It is inside the head
    - Must be very small
Major Challenges

- Antenna space is tiny
- Antenna is surrounded by absorbing soft tissue

<table>
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<th>Freq (MHz)</th>
<th>$\varepsilon'_r$</th>
<th>$\varepsilon''_r$</th>
<th>$\sigma$ (S/m)</th>
<th>$\varepsilon_r$</th>
<th>$\tan \delta$</th>
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<td>2450</td>
<td>52.7</td>
<td>14.3</td>
<td>1.9</td>
<td>54</td>
<td>0.27</td>
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Simplified Human Head Model

- Head Model
  - Octagonal Prism
  - Filled with dielectric
  - Small Air Cavity = Ear
Optimum Performance

- Return Loss > 6dB in band
- Total Gain > -16 dBi in band
Radiation Patterns

- Gain $-16$ dBi towards outside
- Gain $-35$ dBi in worst case position “through the head”

<table>
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<tr>
<th>Max. gain (dBi)</th>
<th>Max. free space range $R_{\text{max}}$ (m)</th>
<th>Multipath error correction $\alpha = 0.6 , R_{\text{max}}$ (m)</th>
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<tbody>
<tr>
<td>-16</td>
<td>25</td>
<td>15</td>
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Conclusions

- Design of Small Smart Bluetooth Antennas proven
- Take into account all material and size constraints
- Accept Link Budget compromise/tradeoff
- Connected metal watch range $>> 10m$
- Hearing Aid range $> 1.5m$ worst case