Consider the Design and Analysis of Antennas for a modern Smartwatch

By Tracey Vincent
Smart watch design

1. Overview of a modern smart watch.
2. Challenges posed for the antenna design engineer.
3. An example design.
4. Discuss some approaches in relation to:
   - Electromagnetic design and analysis
   - Mechanical design and co-design
   - Meeting regulatory standards

Examples developed in collaboration between CST, Magus and SIMULIA
A modern smart watch

- Casing and strap
A modern smart watch

- Casing and strap
  - Must be practical size
A modern smart watch

- Casing and strap
  - Must be practical size
  - Aesthetics and materials
A modern smart watch

- **Casing and strap**
  - Must be practical size
  - *Aesthetics and materials*

- **Touchscreen**
A modern smart watch

- Casing and strap
  - Must be practical size
  - Aesthetics and materials

- Touchscreen
- Battery and charging
A modern smart watch

- Casing and strap
  - Must be practical size
  - Materials and aesthetics

- Touchscreen
- Battery and charging
- Electronics
A modern smart watch

- Casing and strap
  - Must be practical size
  - Aesthetics and materials

- Touchscreen
- Battery and charging
- Electronics
- Flexibility and functionality
Concept design

- Modular strap.
- Connected to watch body.
- Interchangeable modules.
- User customization.

- Large screen.
- Differentiate touch and tap.

- Bluetooth, Wi-Fi, GPS and GSM capable

- Wireless charging required.
Concept design

- Standard mating connectors between modules / to watch body.
- Continuous ground plane, data and power lines

- Maximize data transfer rates achievable between strap modules (>1 Gb/s)
- Minimize interference risk
- Adhere to exposure standards
- Optimise for mechanical reliability and manufacture methods

- Aluminium/polycarbonate casing
- Polycarbonate strap/module housing
Design process

Antenna Design

Sub-system design (touchscreen, charging, etc.)

Mechanical design (touchscreen, connectors, etc.)

EM Simulation

Mechanical analysis
Concept design - Connectivity

- WiFi (2.401 - 2.495 GHz)
- Bluetooth (2.4 - 2.485 GHz)
- GPS (1.563 - 1.587 GHz)
- GSM/Cellular (e.g. 880 - 960 MHz)
- S11 < -10 dB
- Best possible radiation efficiency
Antenna requirements

- Fit within the space available
- Efficient and well matched antennas (power use)
- Work alongside other electronics/systems
- Cater for different usage scenarios and environments
- Adhere to safety standards
Antenna challenges: Space
Antenna challenges: Space

- WiFi (2.401 - 2.495 GHz)
- Bluetooth (2.4 - 2.485 GHz)
- GPS (1.563 - 1.587 GHz)
- GSM (880 - 960 MHz)

Freespace wavelength/2

~70 mm
Antenna challenges: Space

- Metal casing (Aluminum)
- Strap module and electronics
- Touchscreen with conductive sensing grid
- Watch PCB
- Battery
- Metal/polycarbonate underside
- Wireless charging coil and circuitry
WiFi and Bluetooth antennas

Published papers

Design of a Compact UWB Diversity Antenna for WBAN Wrist-Watch Applications
*Seungmin Woo, Jisoo Baek, Hyungsang Park, Dongtak Kim and #Jaehoon Choi
Department of Electronics and Computer Engineering, Hanyang University 17 Haengdang-Dong, Seongdong-Gu, Seoul, 133-791, Korea

Conformal Bluetooth Antenna for the Watch-Type Wireless Communication Device Application
Chih-Hsien Wu* (1), Kin-Lu Wong (1), Yuan-Chih Lin (1), and Saou-Wen Su (2)
(1) Department of Electrical Engineering
National Sun Yat-Sen University, Kaohsiung 804, Taiwan
(2) Technology Research and Development Center
Lite-On Technology Corp., Taipei 114, Taiwan

Published papers
WiFi / Bluetooth antenna - option 1
WiFi / Bluetooth antenna - option 1
Choose application
Choose application
Choose application
Choose antenna
Choose antenna
Automatic design

Dual-band planar inverted-F (PIFA) with parasitic element

Specification
WLAN 2.4 (802.11b/g/n) 1

Prototype Designs and Tweaks
- WLAN 2.4 (802.11b/g/n) 1

Design Info:
- Frequency Band 1
  - f_L = 2.45 GHz
- Frequency Band 2
  - f_H = 4.9 GHz

Dimensions:
- X: 17.21 mm
- Y: 17.21 mm

Performance:
- Impedance vs frequency
- Radiation pattern (θ = 0°)
- Radiation pattern (θ = 90°)
- Radiation pattern 2D (first)
- WLAN 2.4 (802.11b/g/n) 1
  - [2.450 GHz]
- Radiation pattern 3D (oct)
- WLAN 2.4 (802.11b/g/n) 1
  - [4.807 GHz]
Adjust specification
Learn about the antenna limitations
WiFi / Bluetooth antenna - option 1
WiFi / Bluetooth antenna - option 2

Conformal Bluetooth Antenna for the Watch-Type Wireless Communication Device Application

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National Sun Yat-Sen University, Kaohsiung 804, Taiwan
(2) Technology Research and Development Center
Lite-On Technology Corp., Taipei 114, Taiwan
WiFi / Bluetooth antenna - option 2
WiFi / Bluetooth antenna - position

Polycarbonate
‘Windows’
WiFi / Bluetooth antenna - option 2
WiFi / Bluetooth antenna - option 2
WiFi / Bluetooth antenna - option 2
WiFi and Bluetooth antennas
WiFi and Bluetooth antennas
WiFi and Bluetooth antenna

WiFi/Bluetooth

S-Parameters [Magnitude in dB]

- Frequency / GHz
- Magnitude / dB
WiFi and Bluetooth antennas

Watch on arm
WiFi and Bluetooth antennas

Watch off arm
WiFi and Bluetooth antennas

- WiFi and Bluetooth antennas designs are shown with red crosses indicating incorrect designs.
- Green check marks indicate correct designs.

Detailed diagrams showing dimensions and specifications are present, but the exact values are not readable from the image.
WiFi and Bluetooth antennas
GPS antennas

- GPS signals are Circularly Polarised
- Traditionally patch antennas or helix variants are used for GPS applications
- Literature and Antenna Magus designs show that these antennas are too large
GPS antennas

- Inverted-F type antenna designed for GPS housed in the watch body
- The GPS antenna is poorly matched and realised circularly polarised gain is poor
- Performance varies on or off the wrist
We would like improved axial ratio and efficiency.

A high-performance GPS strap module could be used.

Largely immune to usage scenario.
GPS antennas

GPS on-board

GPS Module

<table>
<thead>
<tr>
<th>Type</th>
<th>Farfield</th>
</tr>
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<tbody>
<tr>
<td>Approximation</td>
<td>enabled (kR &gt;&gt; 1)</td>
</tr>
<tr>
<td>Monitor</td>
<td>farfield (f=1.5) [1]</td>
</tr>
<tr>
<td>Component</td>
<td>Ludwig 3 Right</td>
</tr>
<tr>
<td>Output</td>
<td>Gain</td>
</tr>
</tbody>
</table>
What about GSM?

At lower frequencies (e.g. GSM 900) more space than is available in the casing is needed

Published papers

**Antenna Designs of Smart Watch for Cellular Communications by using Metal Belt**

Kun Zhao\(^1\), Zhinong Ying\(^2\), Sailing He\(^1\)

\(^1\) Department of Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden
\(^2\) Corporate Technology Office, Sony Mobile Communication AB, Lund, Sweden
What about GSM?

- Use the strap like a dipole
- Investigate and design by simulation with simplified ‘canonical’ models
- Will it work with the modular strap?
- How will electronics be influenced?
What about GSM?
What about GSM?

For GSM850/900 only 5 of the 6 strap modules should be connected to form the antenna.
Modelling the environment
Modelling the environment
Antenna challenges: Exposure

- European standard for limbs:
  - SAR (Specific absorption rate) should be less than 4 W/kg averaged over 10 g

Transmitter:
- 2W peak power
- Active for 1/8th of every second
- 0.25W RMS input power
Concept design

- Maximize data transfer rates achievable between strap modules (>1 Gb/s)
- Minimize interference risk
- Large screen.
- Differentiate touch and tap.
- Bluetooth, Wi-Fi, GPS and GSM capable
- Wireless charging required.
- Optimise mechanical reliability
Analysis - mechanical reliability

- Many studies and optimizations possible
  - Reliability of strap module connectors
  - Material choices and manufacture methods
  - Drop test simulation
  - Etc.
Analysis - Touch Screen

Movement of finger

Capacitance Values

C_y_6, GND

C / pF vs. offset_x / mm

4.7 4.75 4.8 4.85 4.9 4.95 5 5.05

0 2 4 6 8 10 12 14 16 18
Analysis - Touch Screen

Considering deformation due to finger pressure on glass

Capacitance

Undeformed

2.304e-012

Deformed

2.05785e-012

Electric field lines

Mechanical and EM co-simulation
Analysis - Wireless charging
Analysis - Wireless charging

Magnetic Field @ 6.78MHz
Analysis - Modular electronics

“Bus”
Analysis - Modular electronics

“Daisy chain”
Analysis - Modular electronics
Analysis - Signal Integrity

Eye Diagram - 1.5Gb/s

<table>
<thead>
<tr>
<th>“Daisy-chain”</th>
<th>Achieved</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer Rate</td>
<td>1.5Gb/s</td>
<td>1Gb/s</td>
</tr>
<tr>
<td>Eye Opening</td>
<td>0.3mV</td>
<td>0.2mV</td>
</tr>
</tbody>
</table>
Analysis - Signal Integrity
Designing in a system

- Each antenna and subsystem design requires assumptions about other system components
- An understanding of the interaction between sub-systems and the shared impact of design choices takes time to evolve
- Each component design needs to be refined, leveraging understanding of this interaction
- An integrated, multi-disciplinary toolset is critical in this process
First antenna concepts

GSM antenna using the strap and casing body

IFA-type antennas for Wifi/Bluetooth and GPS

High-performance GPS module
A first design concept
Thank you