Consider the Design and Analysis of Antennas for a modern Smartwatch

By
Tracey Vincent

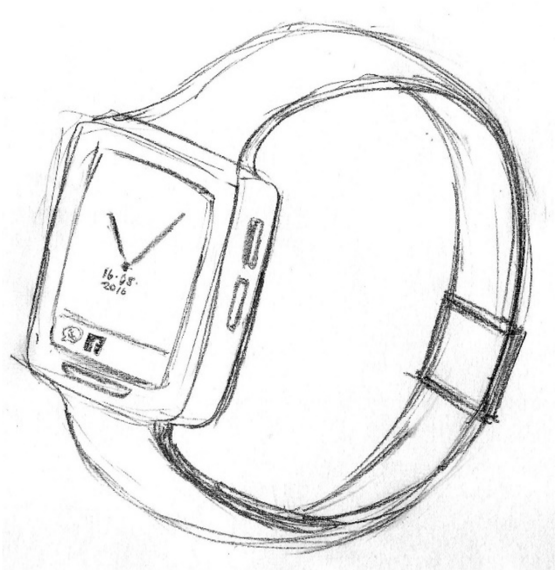
Smart watch design

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

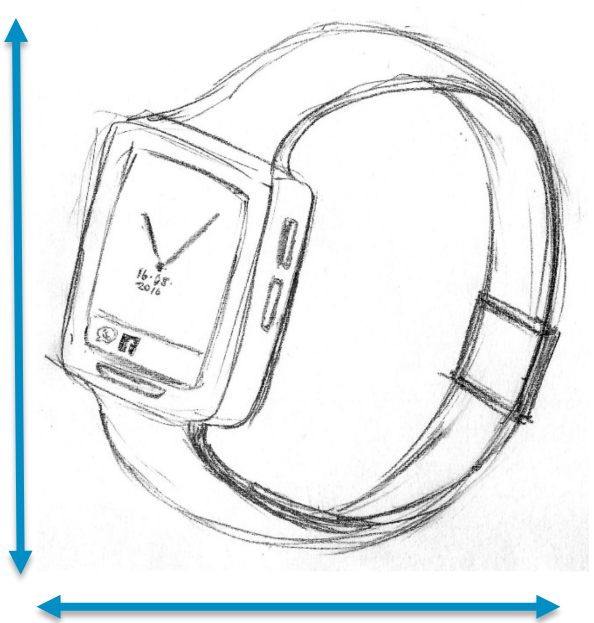
A modern smart watch

- Casing and strap



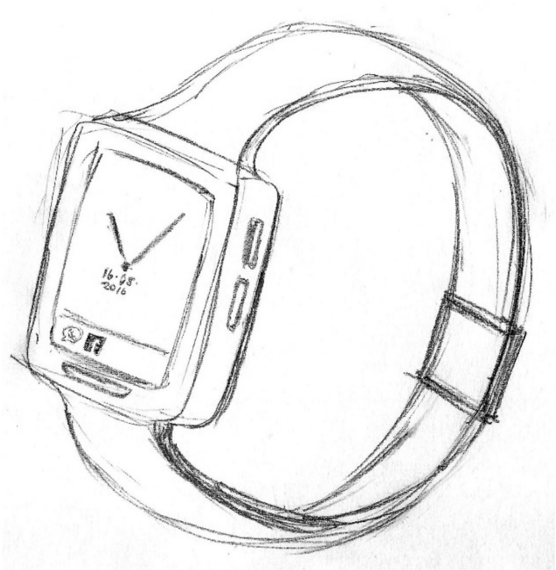
A modern smart watch

- Casing and strap
  - Must be practical size



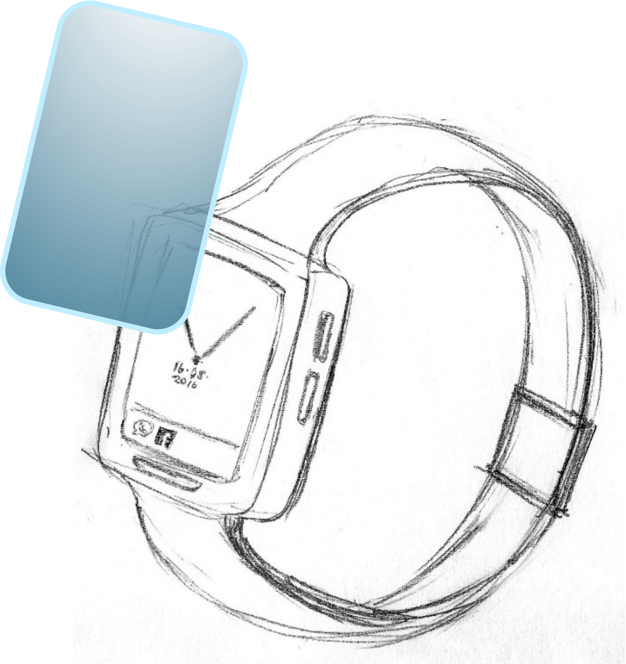
A modern smart watch

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



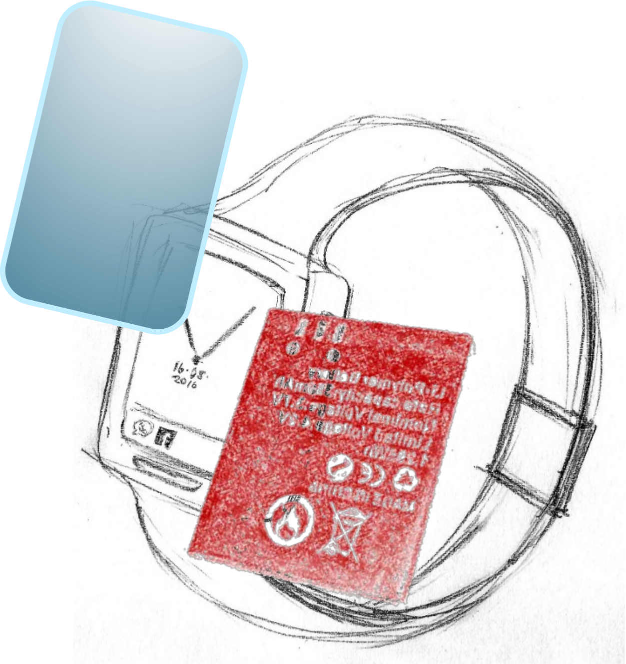
A modern smart watch

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



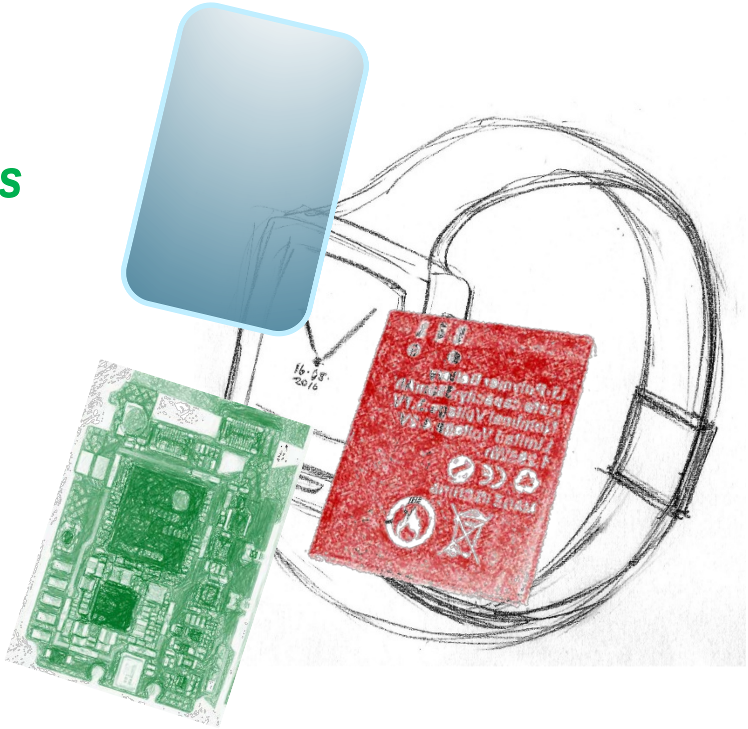
A modern smart watch

- Casing and strap
  - Must be practical size
  - ***Aesthetics and materials***
- Touchscreen
- Battery and charging



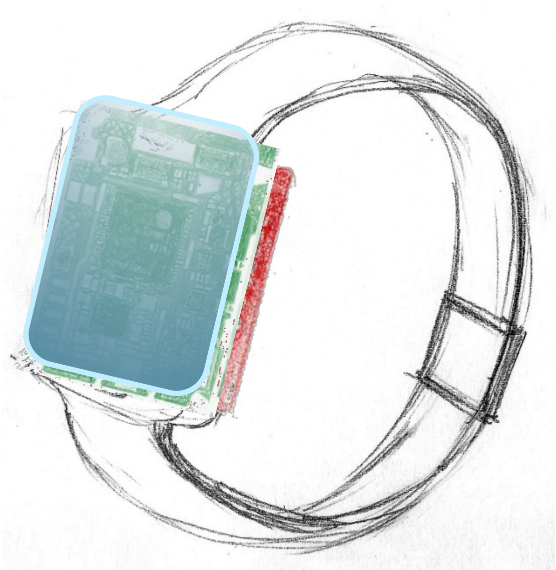
A modern smart watch

- 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.

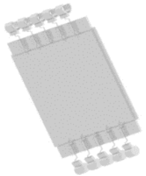
- Large screen.
- Differentiate touch and tap.

- 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

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Design process

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Concept and Mechanical design (connectors, touchscreen etc.)

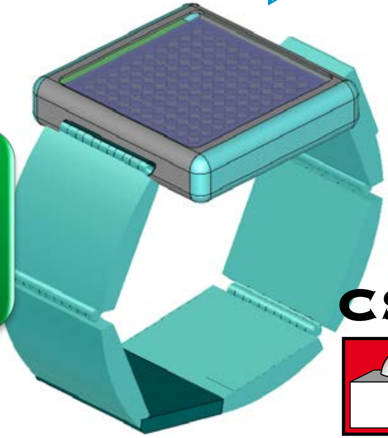
Mechanical Analysis

Antenna Design

AntennaMagus
Explore.Design.Deliver.

Sub-system EM and RF design (touchscreen, charging, etc.)

EM Simulation



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Design process

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Mechanical design (touchscreen, connectors, etc.)

Antenna Design

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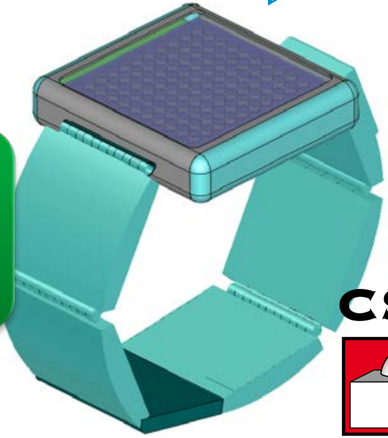


CST

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

Freespace wavelength/2

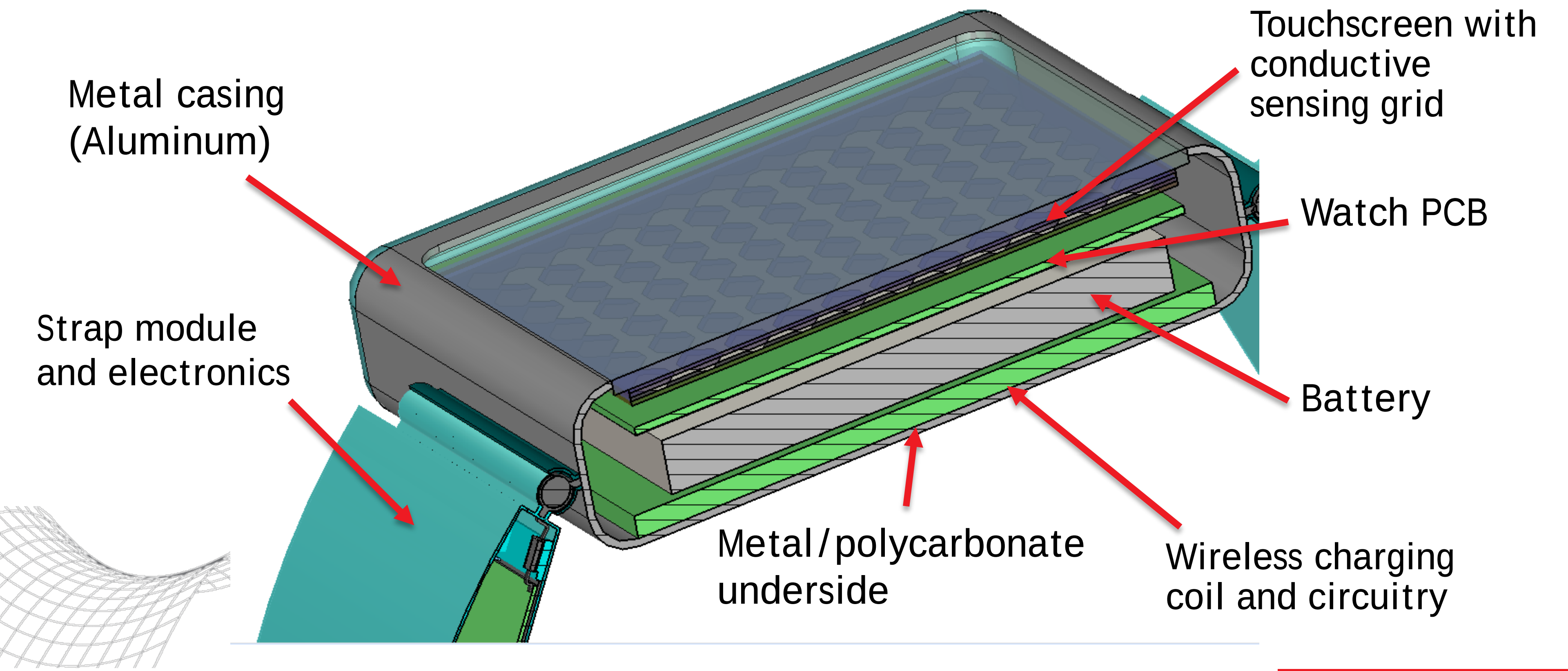
WiFi (2.401 – 2.495 GHz)

Bluetooth (2.4 – 2.485 GHz)

GPS (1.563 – 1.587 GHz)

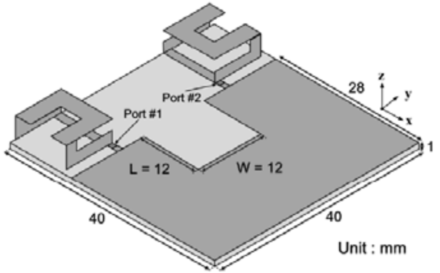
GSM (880 - 960 MHz)

Antenna challenges: Space



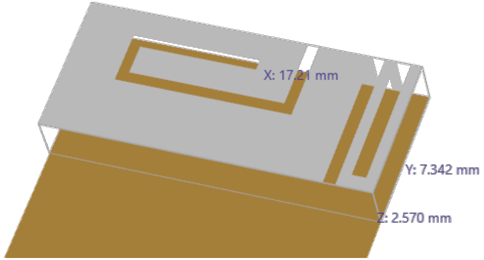
WiFi and Bluetooth antennas

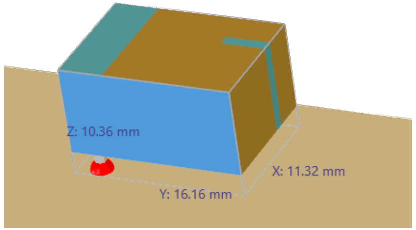
Published papers



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





AntennaMagus
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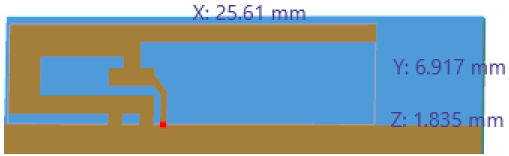
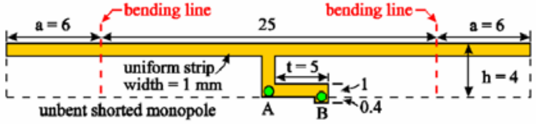
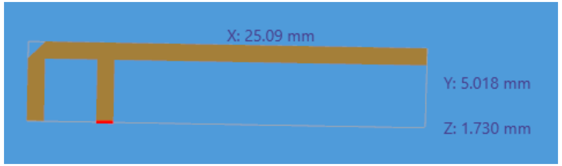


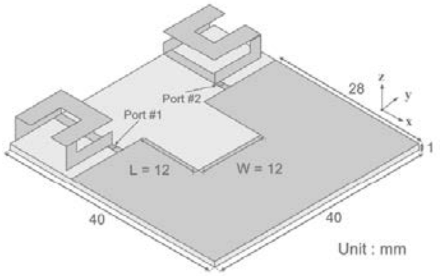


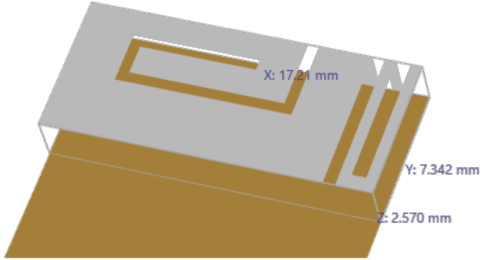
Conformal Bluetooth Antenna for the Watch-Type Wireless Communication Device Application

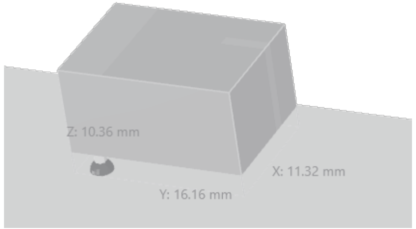
Chih-Hsien Wu*(1), Kin-Lu Wong(1), Yuan-Chih Lin (1), and Saou-Wen Su (2)
(1)Department of Electrical Engineering
National Sun Yat-Sen University, Kaohsiung 804, Taiwan
(2)Technology Research and Development Center
Lite-On Technology Corp., Taipei 114, Taiwan

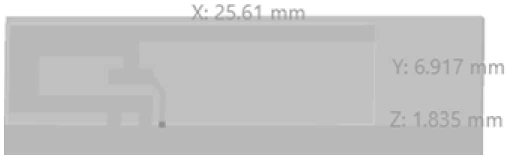


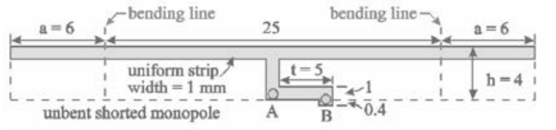
WiFi / Bluetooth antenna – option 1





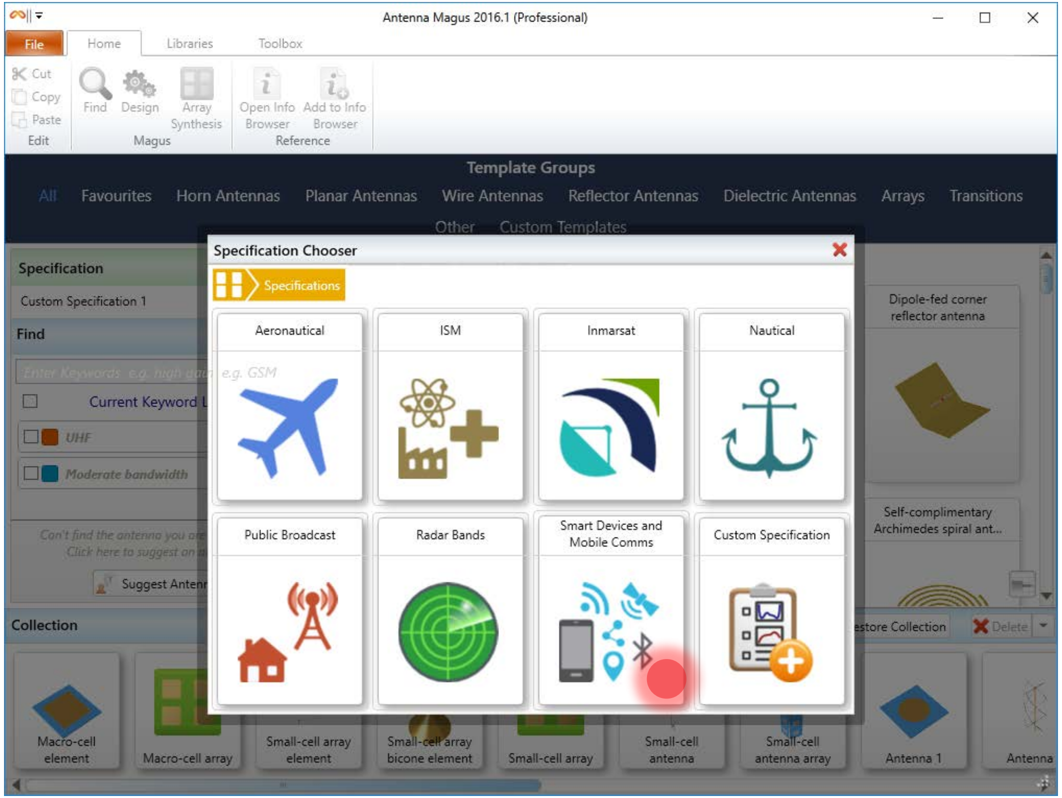




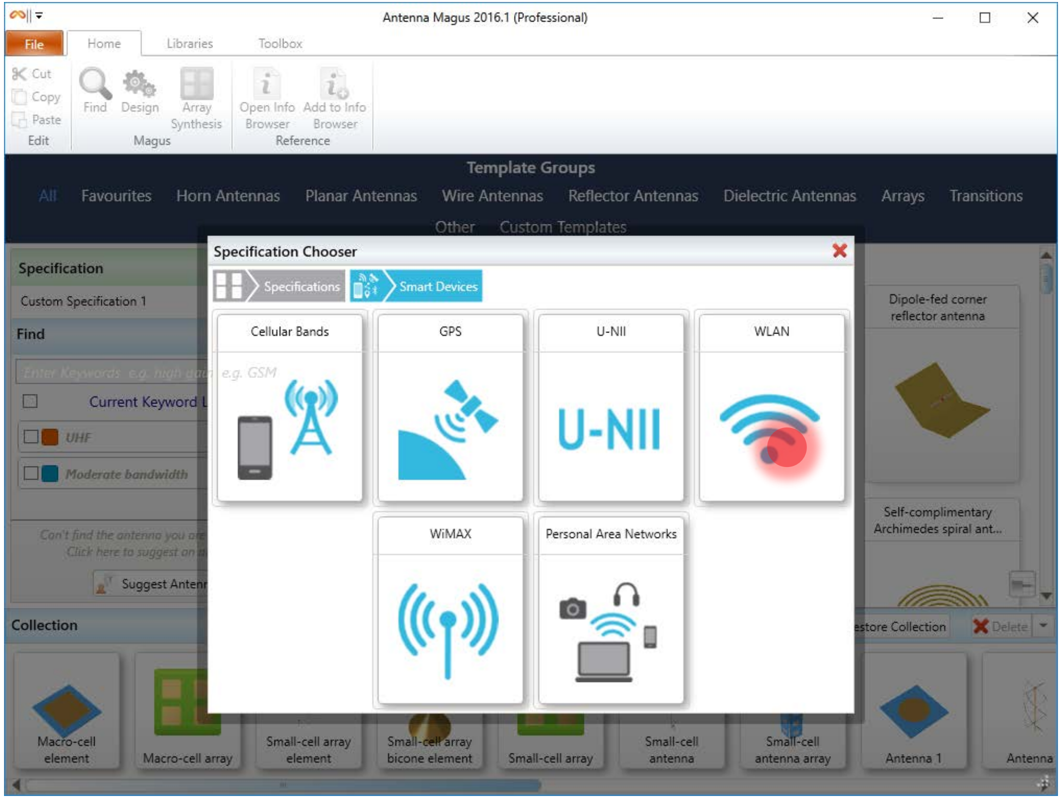


WiFi / Bluetooth antenna – option 1

Choose application



Choose application



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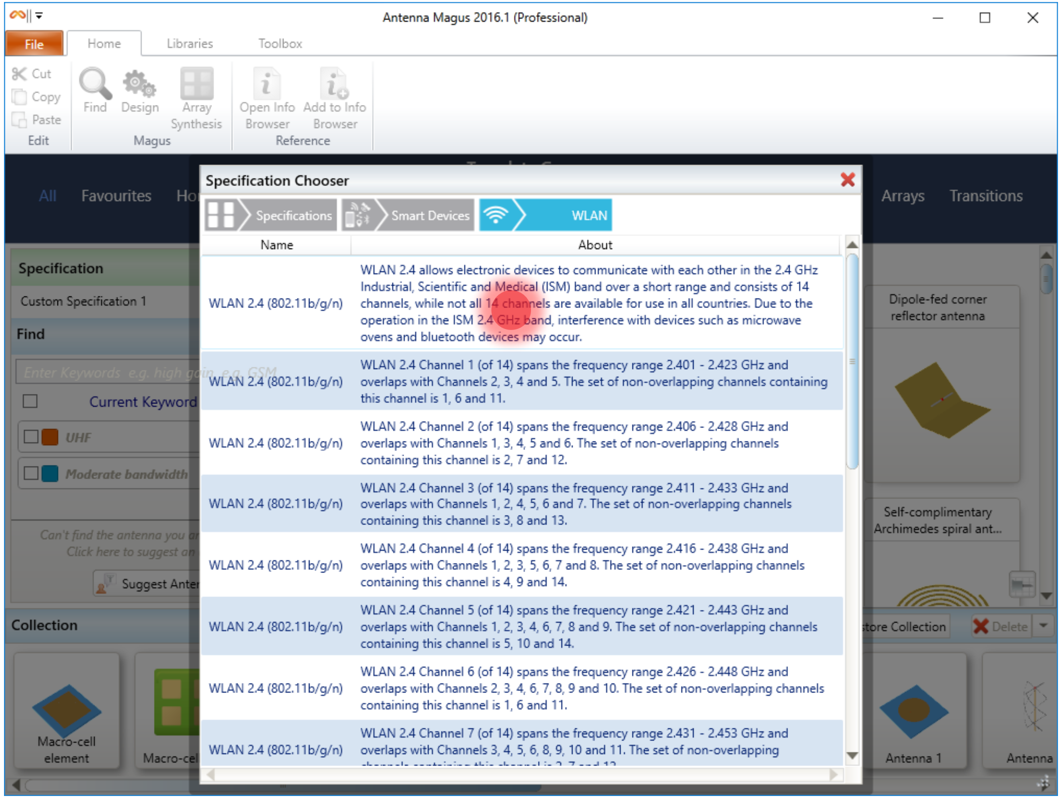
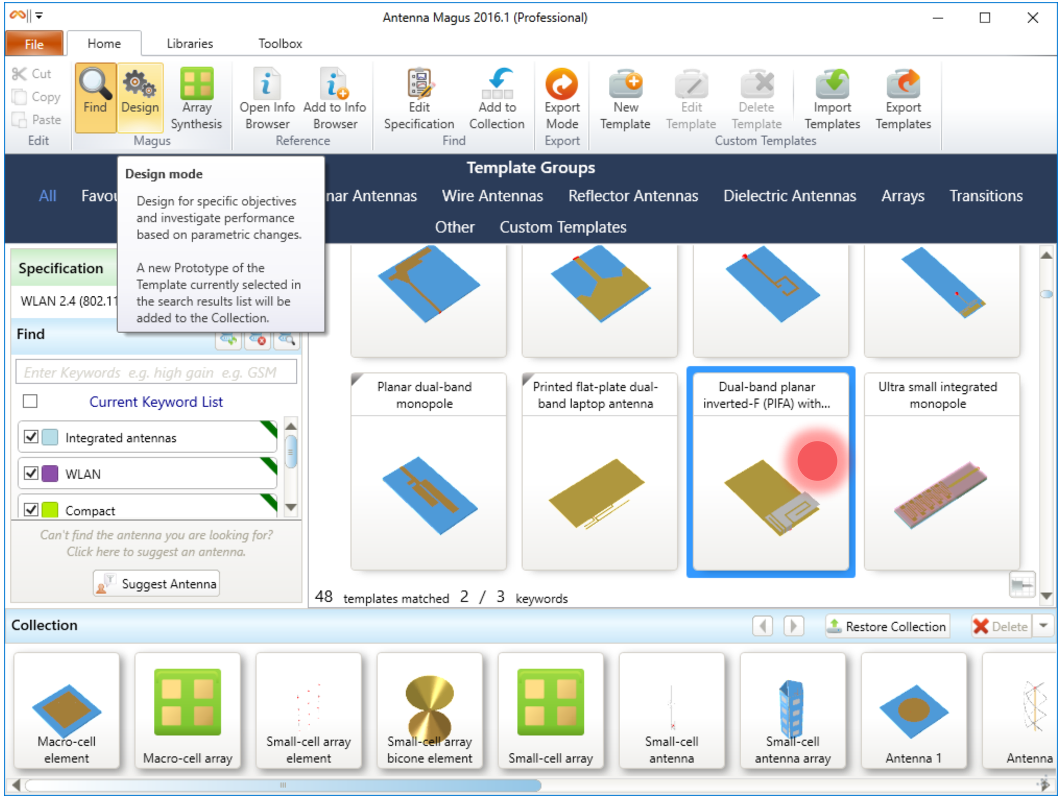
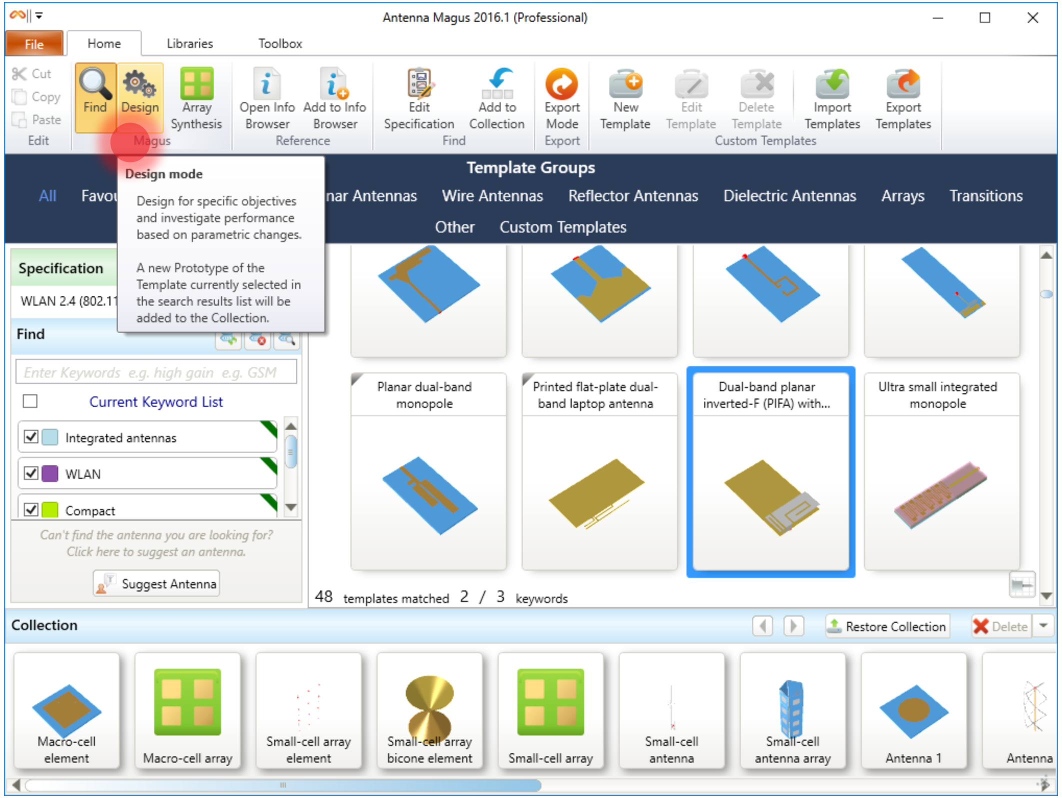


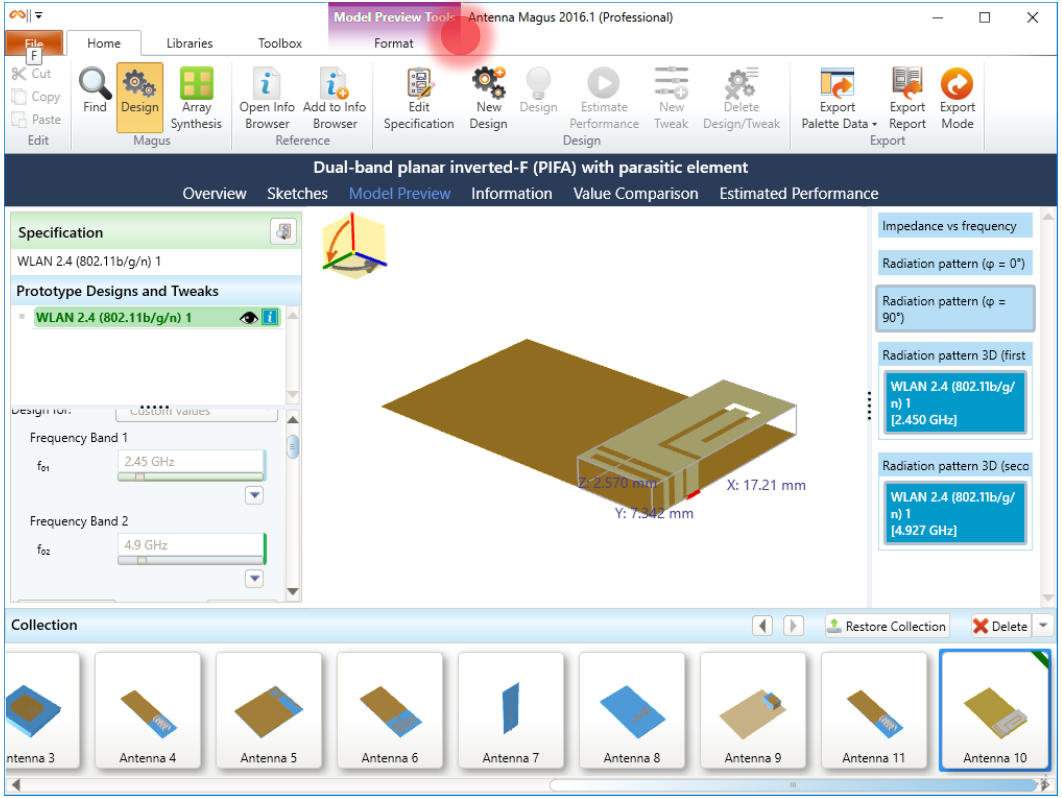
Choose antenna



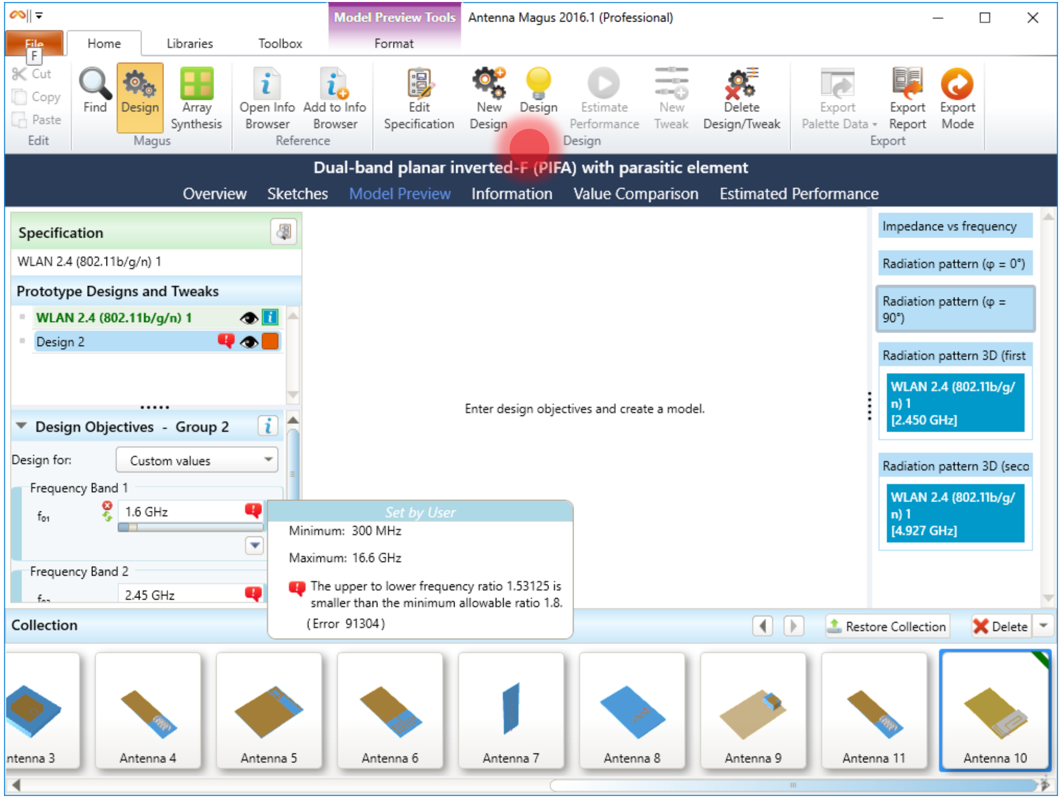
Choose antenna



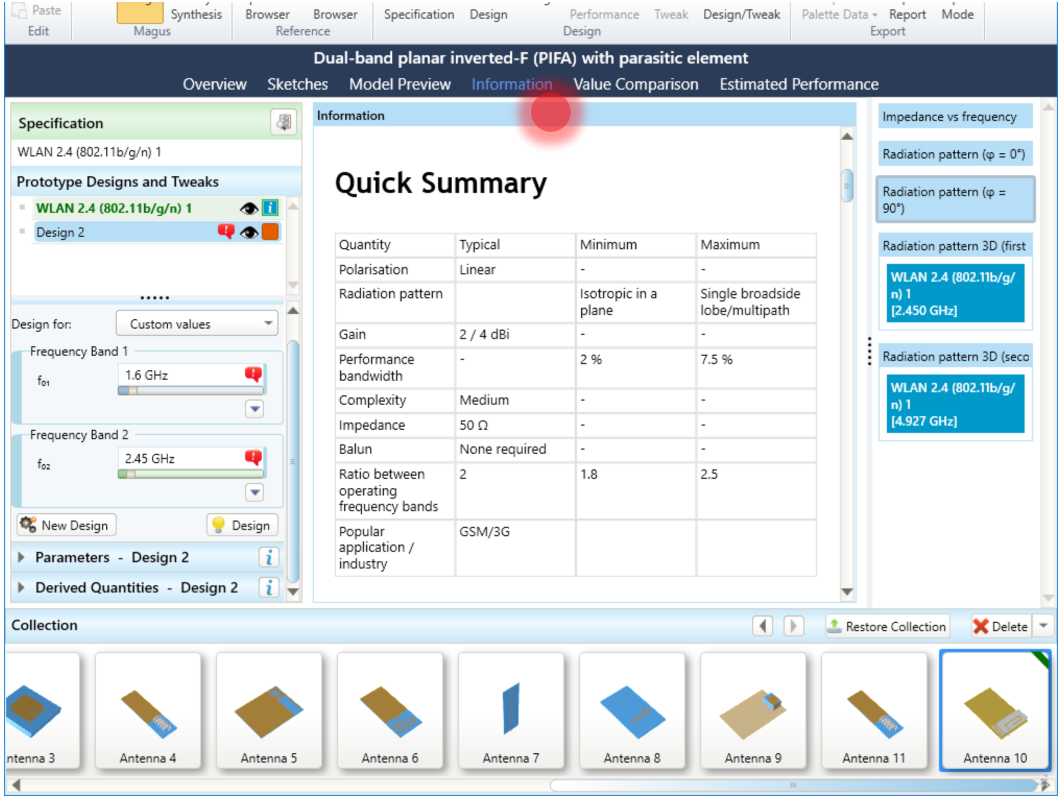
Automatic design



Adjust specification



Learn about the antenna limitations



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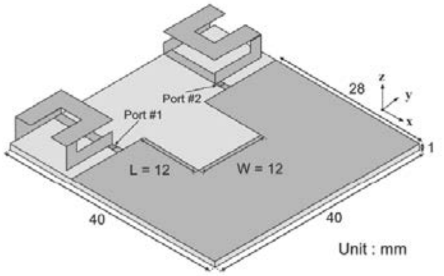
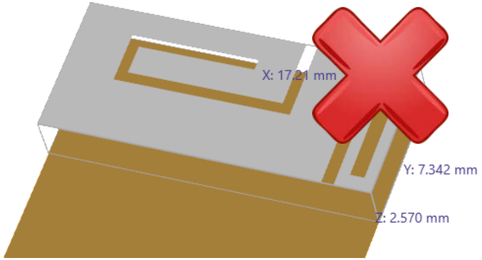
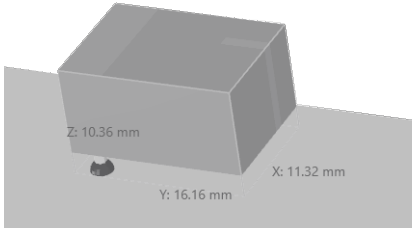
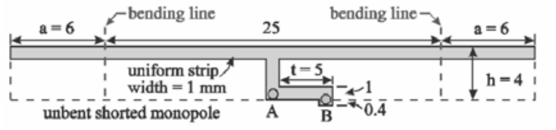
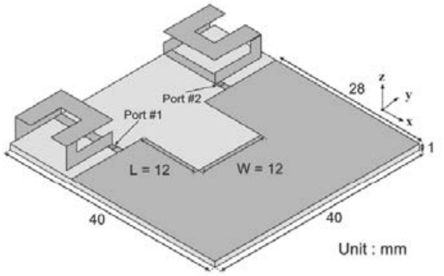


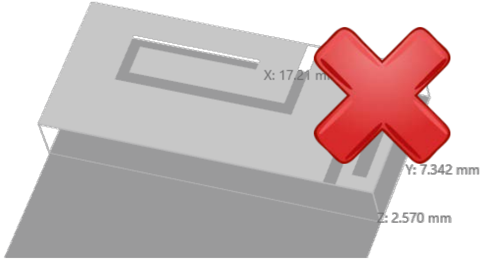


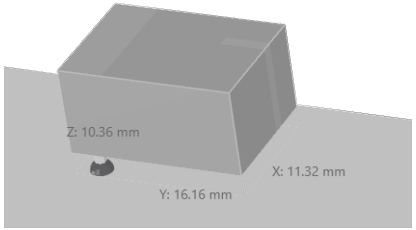


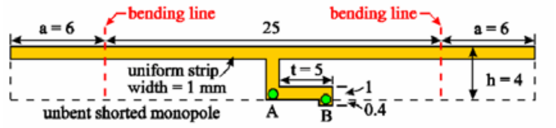


WiFi / Bluetooth antenna – option 2









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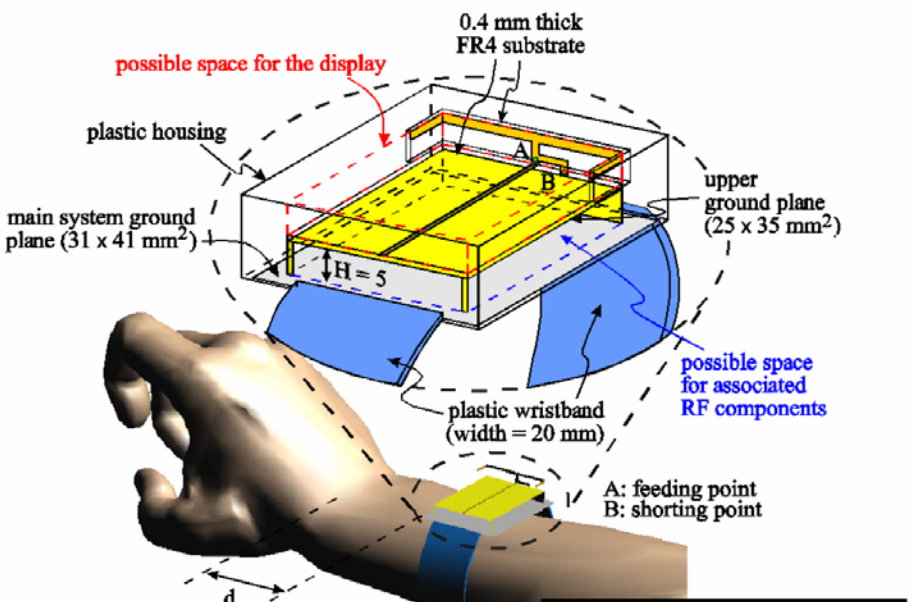
WiFi / Bluetooth antenna – option 2

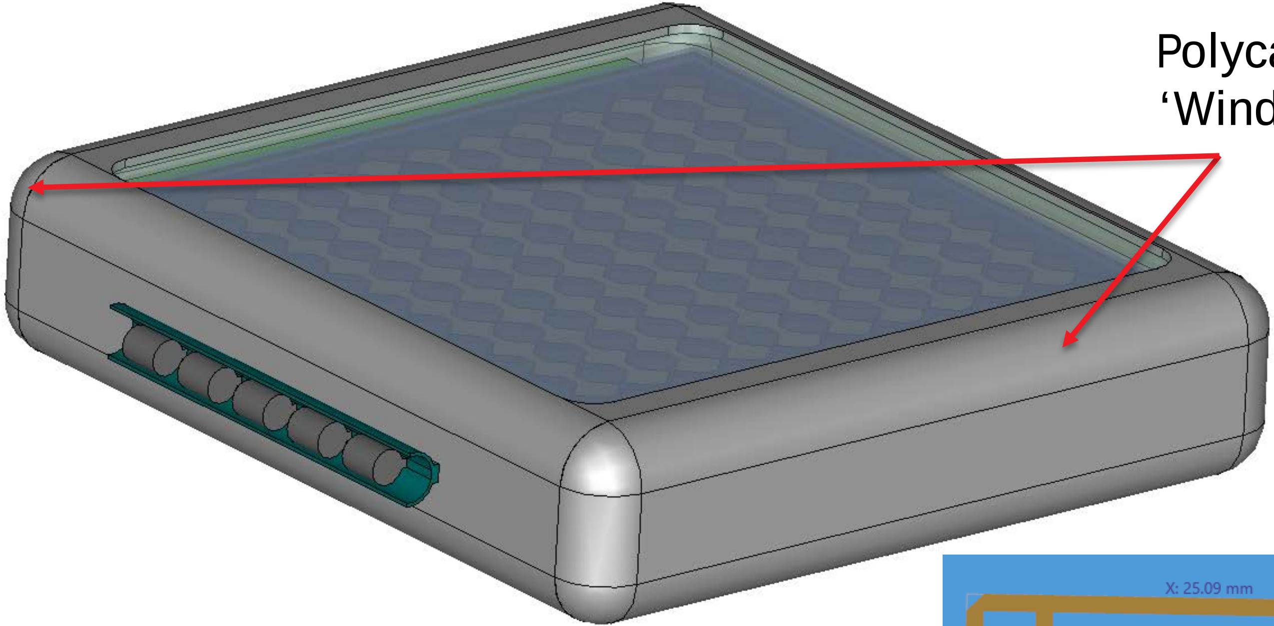


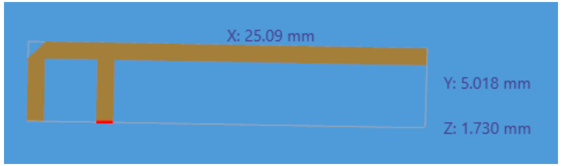
@2442 MHz	ε_r	σ (S/m)
Skin	38	1.46
Muscle	52.7	1.73
Bones	18.6	0.8

(a)

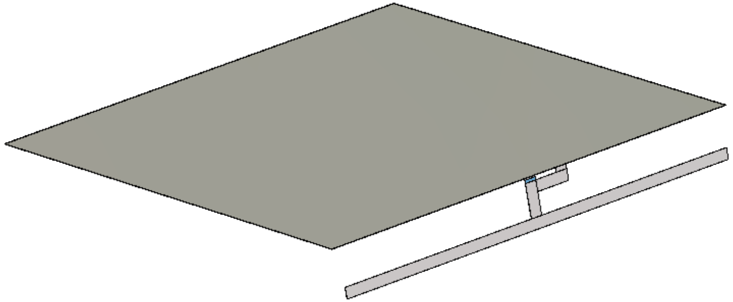
WiFi / Bluetooth antenna – position

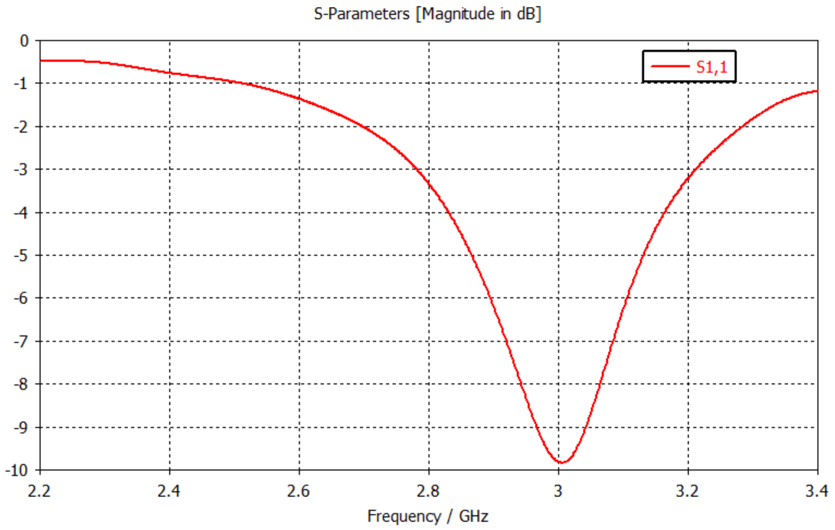
Polycarbonate ‘Windows’



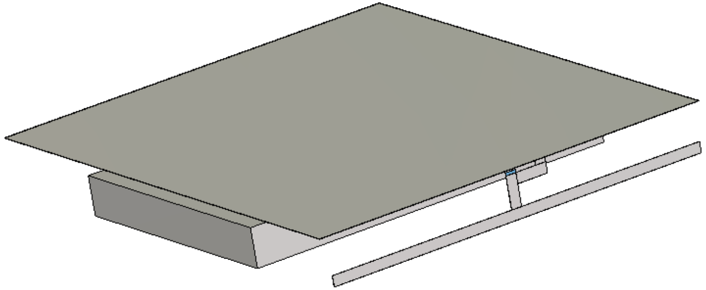


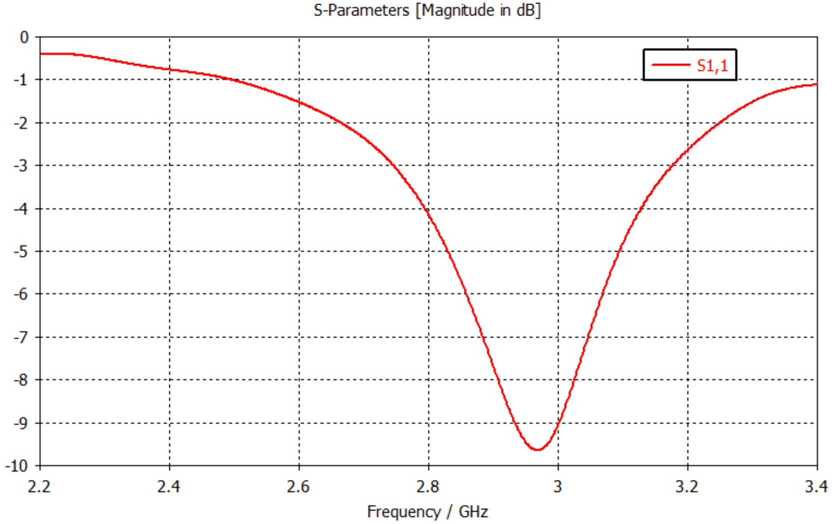
WiFi / Bluetooth antenna – option 2



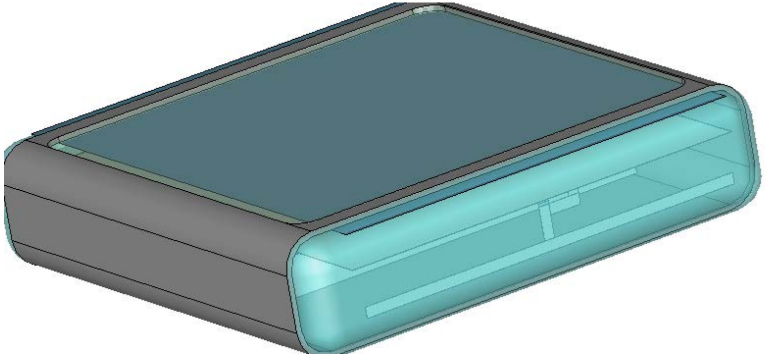


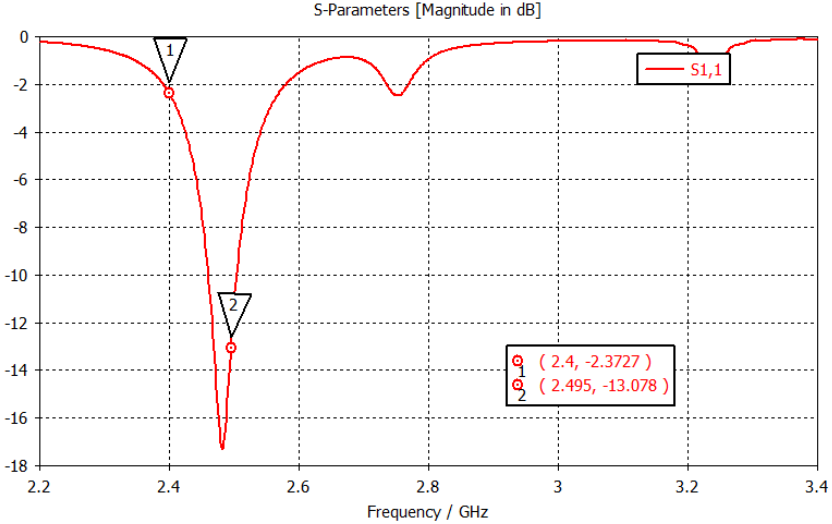
WiFi / Bluetooth antenna – option 2



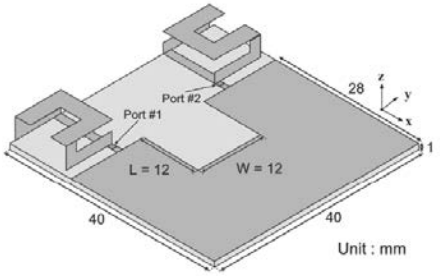


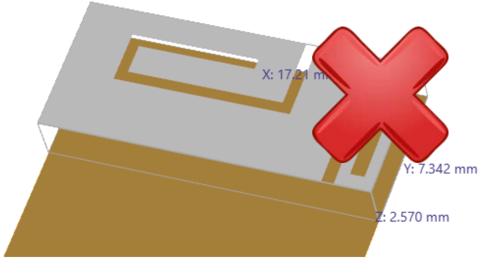
WiFi / Bluetooth antenna – option 2

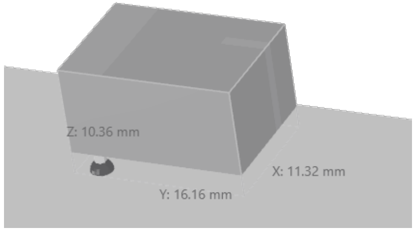


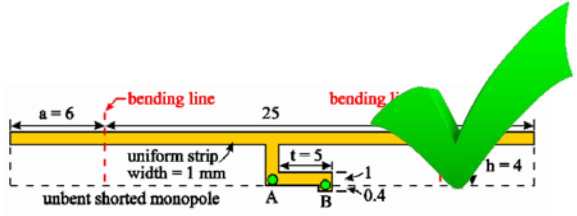


WiFi and Bluetooth antennas

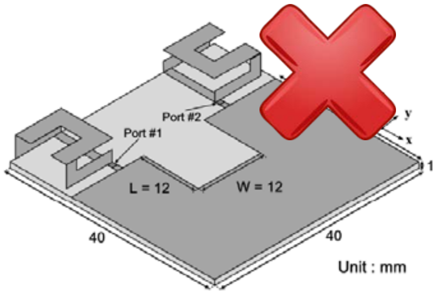


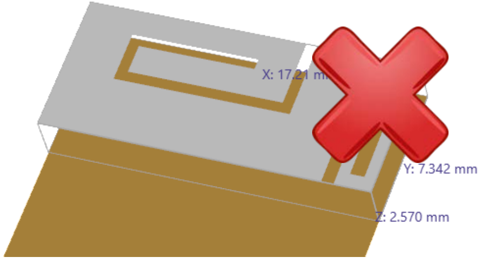


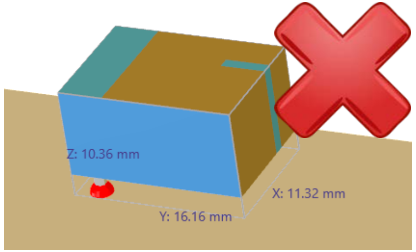


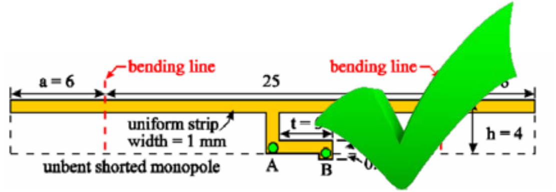


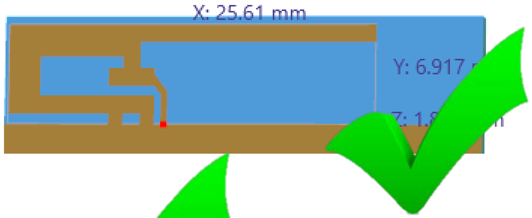
WiFi and Bluetooth antennas

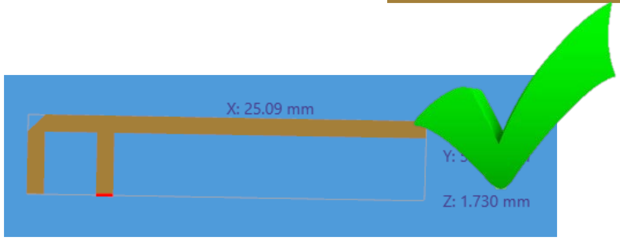




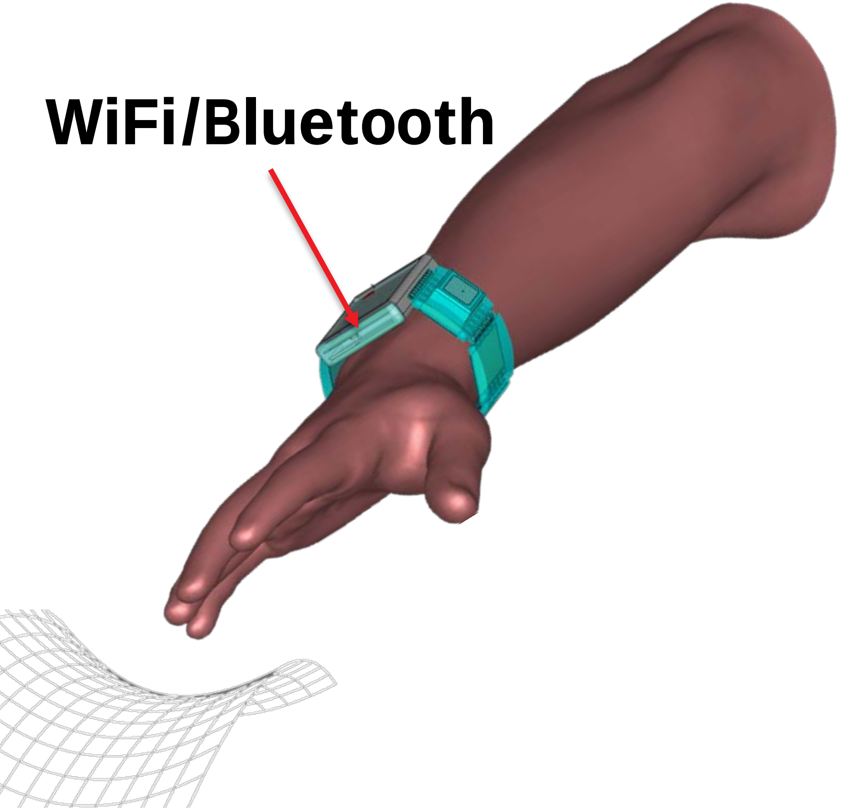


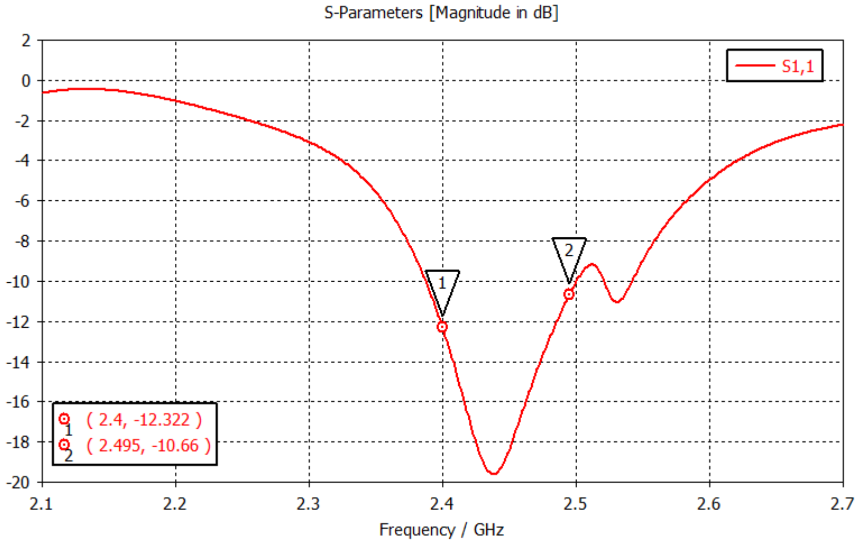






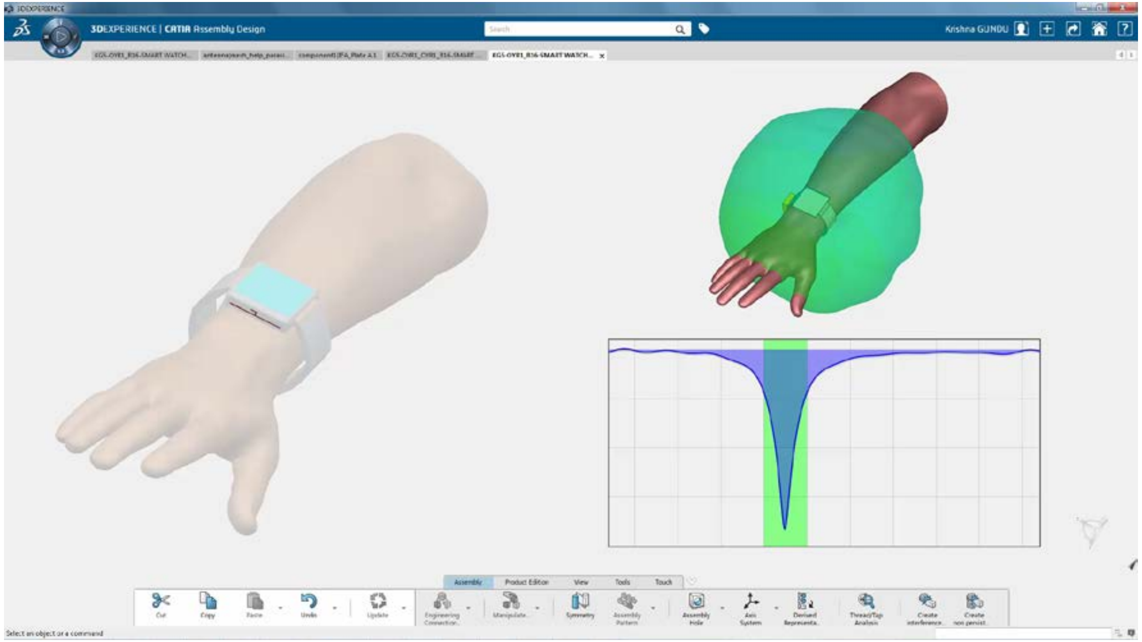
WiFi and Bluetooth antenna





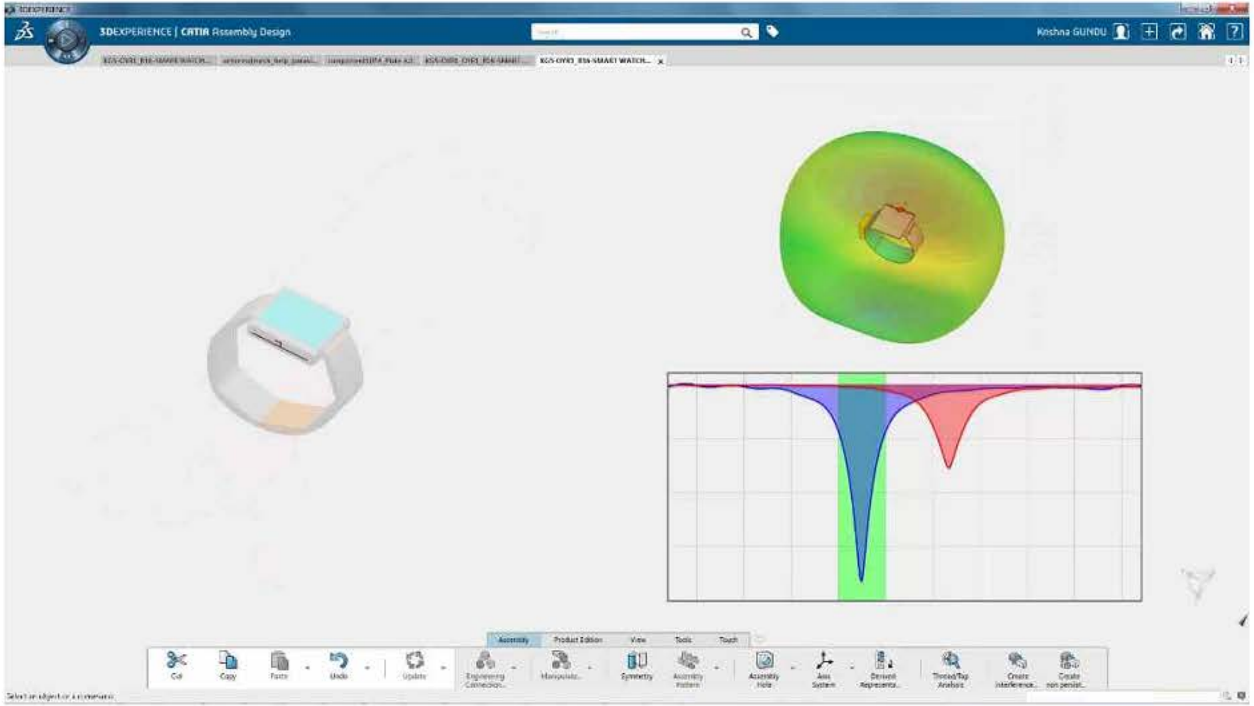
WiFi and Bluetooth antennas

Watch on arm

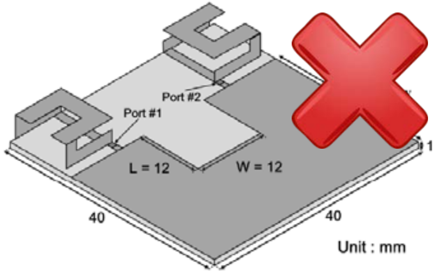


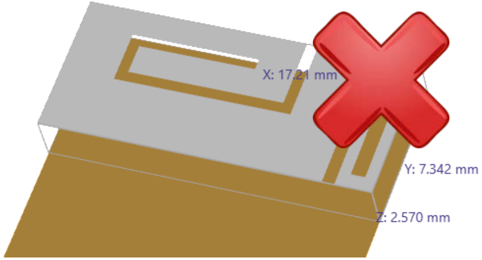
WiFi and Bluetooth antennas

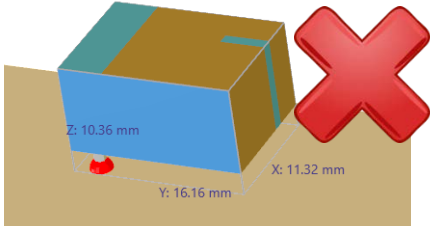
Watch off arm

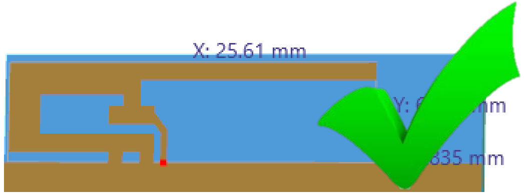


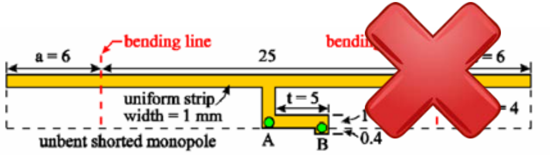
WiFi and Bluetooth antennas

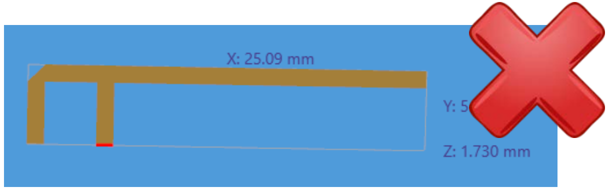




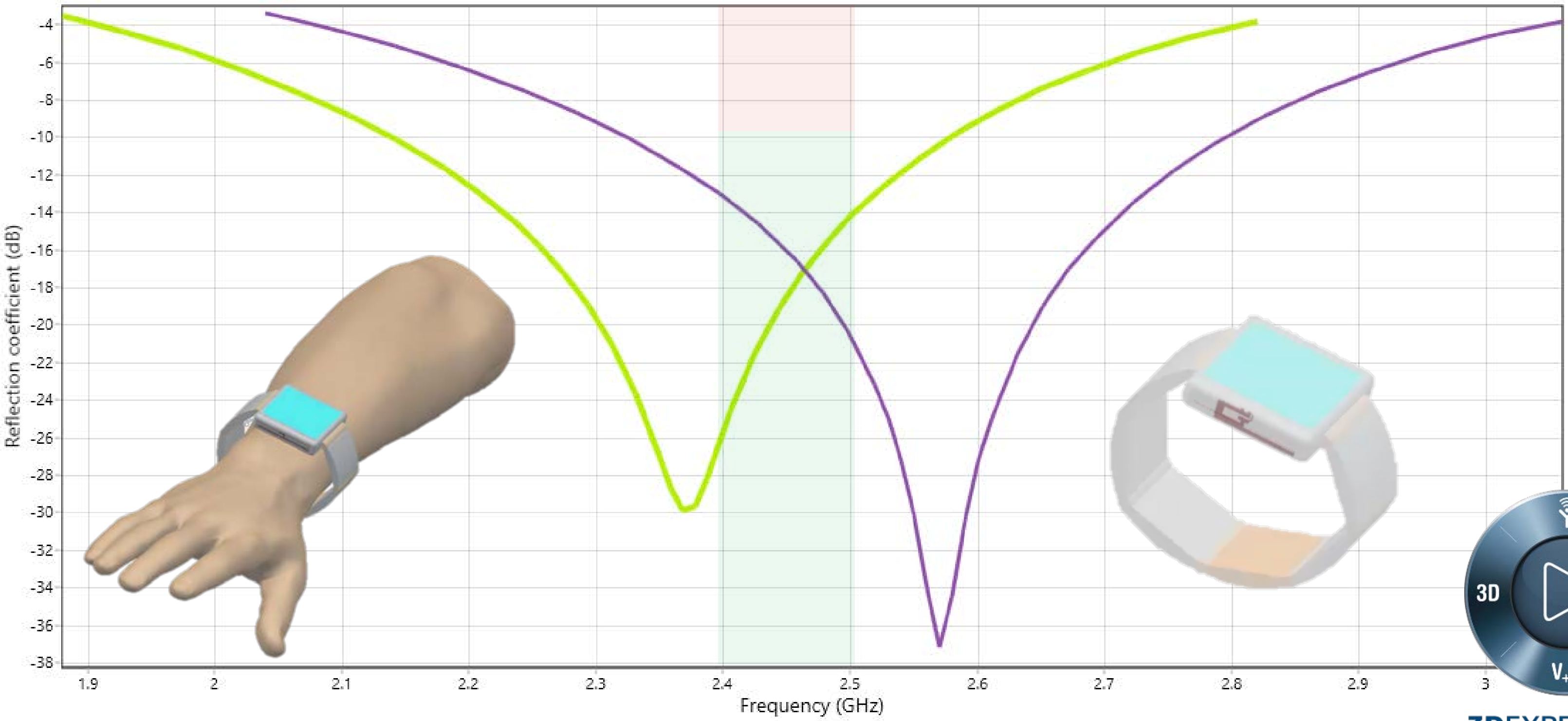








WiFi and Bluetooth antennas

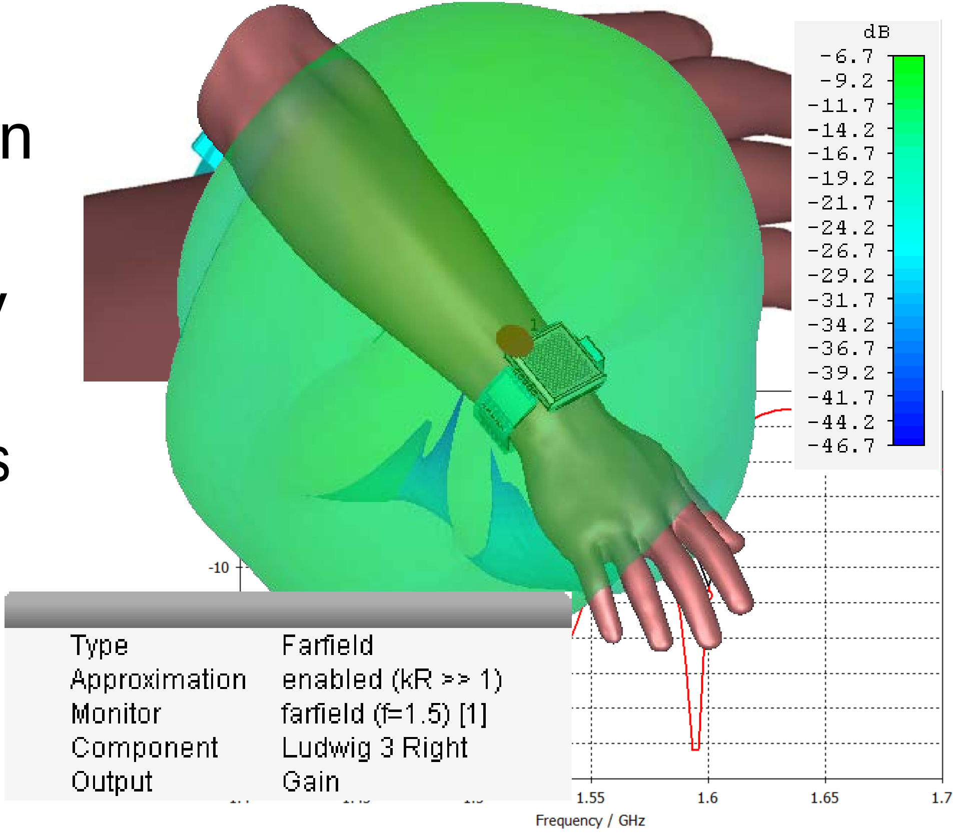


GPS antennas

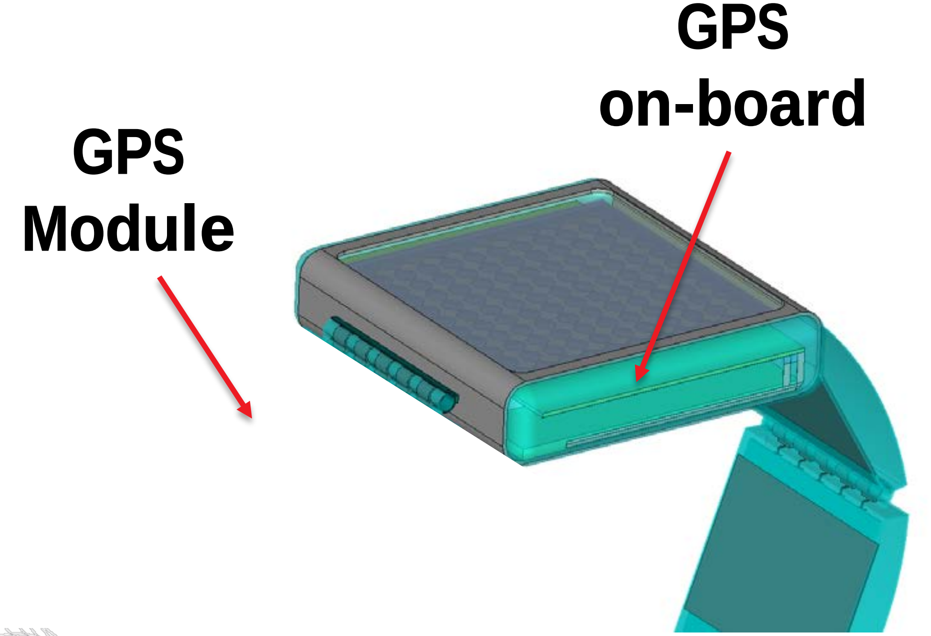
- GPS signals are Circularly Polarised
- Traditionally patch antennas or helix variants are used for GPS applications
- Literature and Antenna Magus designs show that these antennas are too large

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



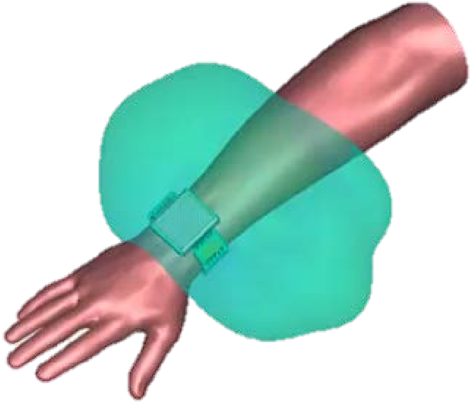
GPS antennas

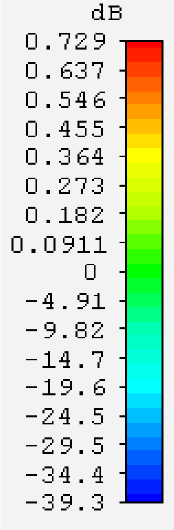


- We would like improved axial ratio and efficiency.
- A high-performance GPS strap module could be used
- Largely immune to usage scenario

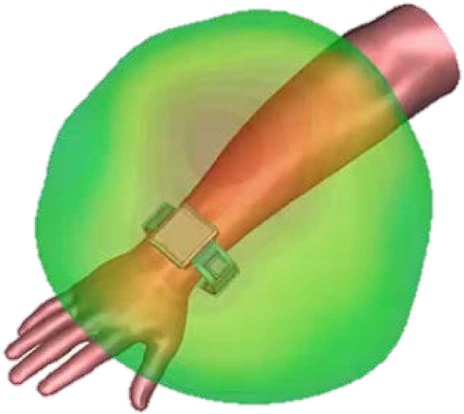
GPS antennas

GPS on-board





GPS Module



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=1.5) [1]
Component	Ludwig 3 Right
Output	Gain

What about GSM?

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

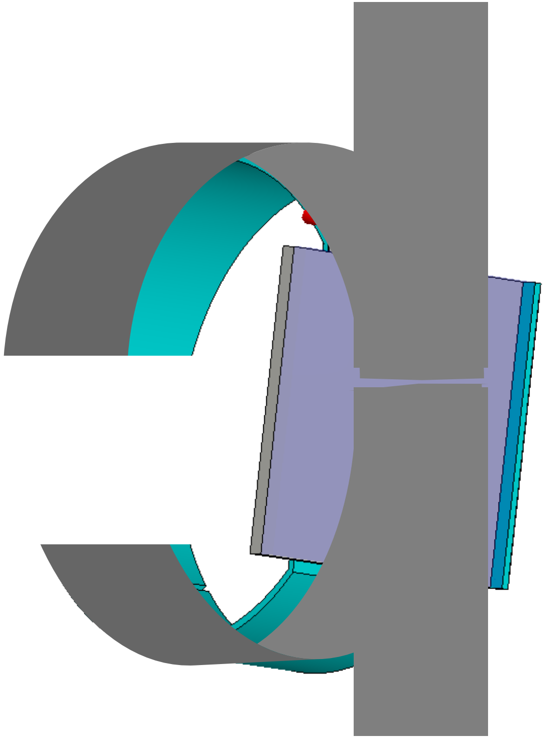
Published papers

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

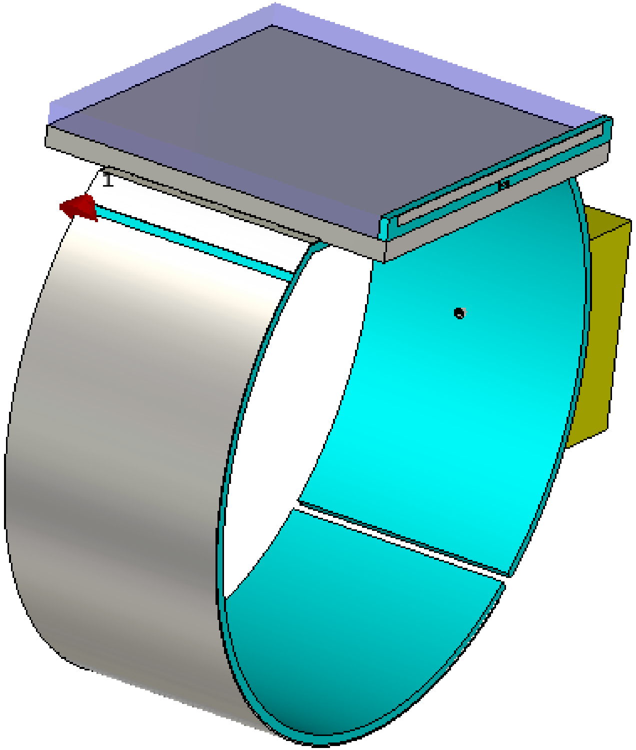
Kun Zhao[1,2], Zhinong Ying[2], Sailing He[1]
[1] Department of Electromagnetic Engineering, Royal Institute of Technology, Stockholm, Sweden
[2] Corporate Technology Office, Sony Mobile Communication AB, Lund, Sweden

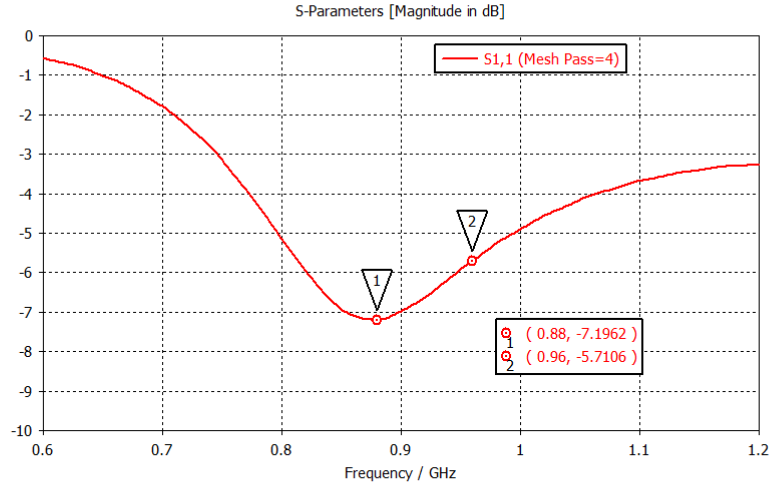
What about GSM?

- 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?

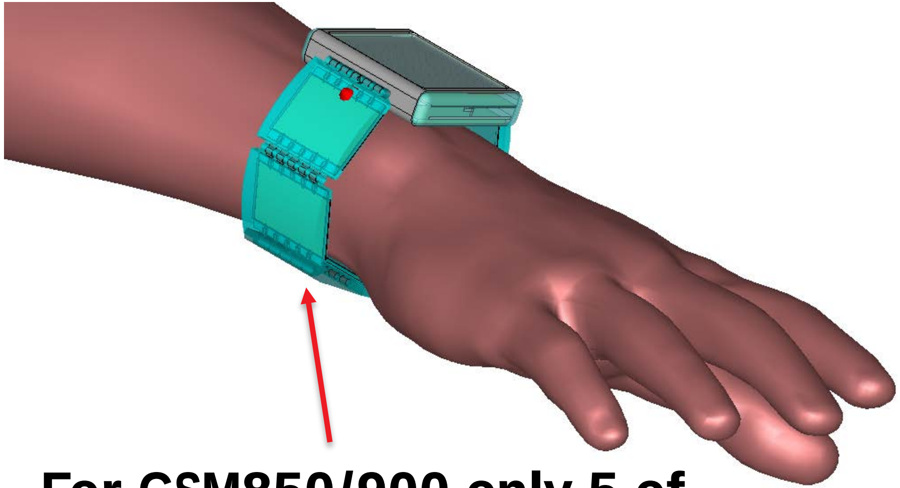


What about GSM?

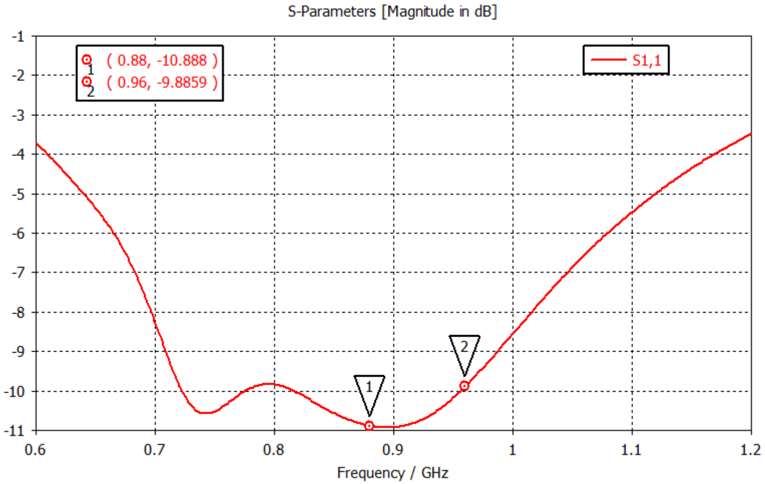




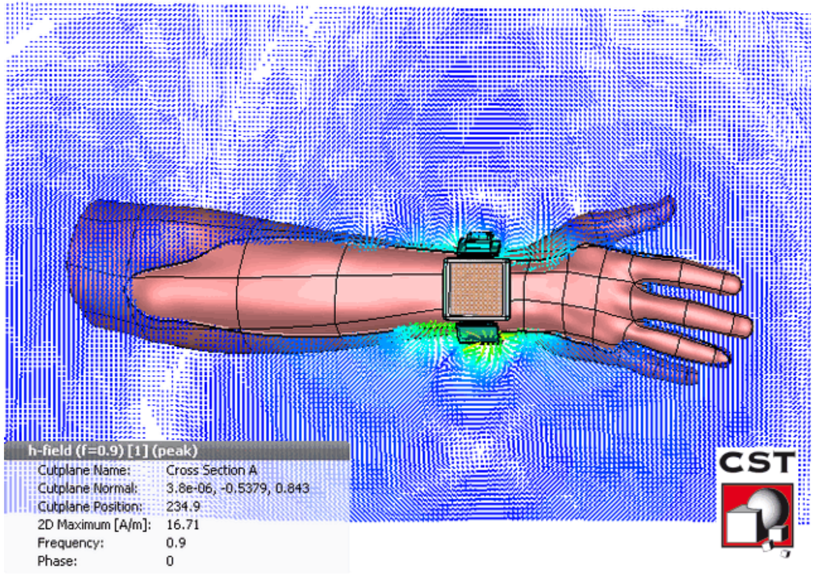
What about GSM?



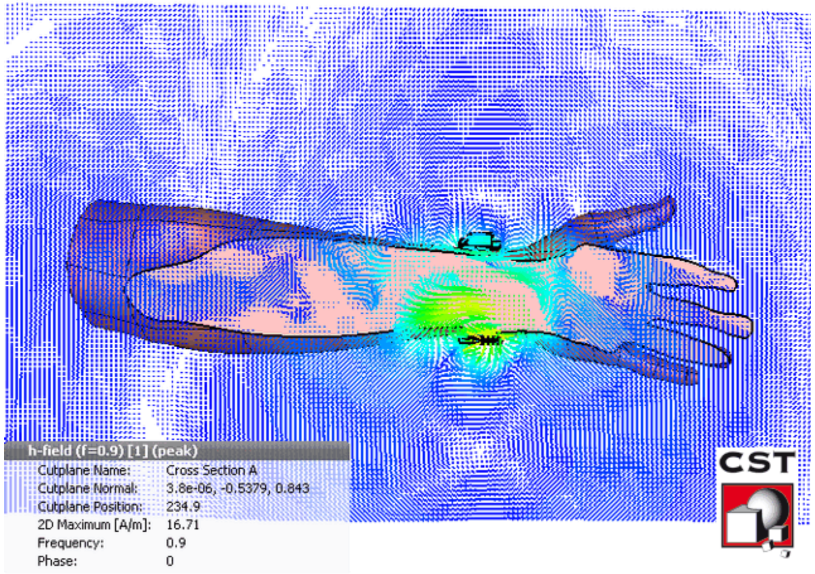
For GSM850/900 only 5 of the 6 strap modules should be connected to form the antenna



Modelling the environment



Modelling the environment

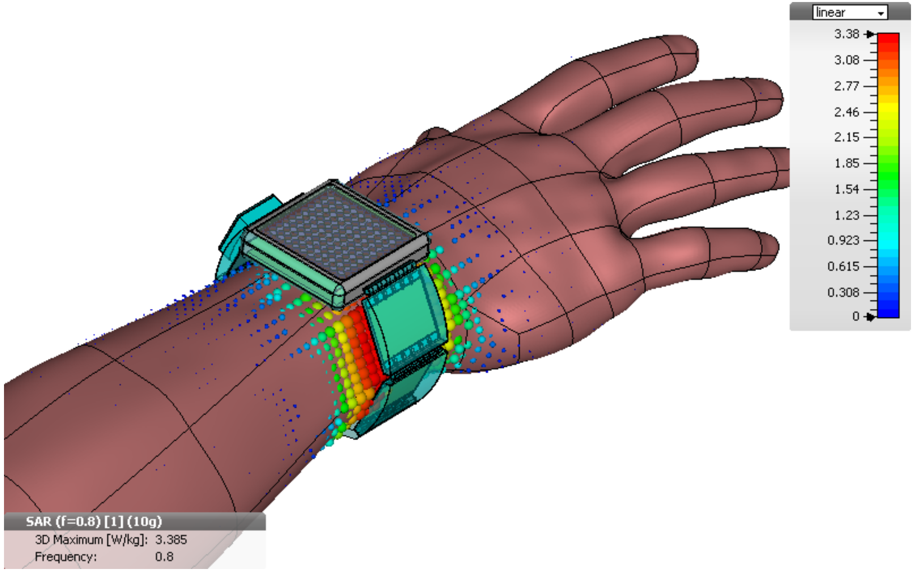


Antenna challenges: Exposure

- 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

- Large screen.
- Differentiate touch and tap.

- Maximize data transfer rates achievable between strap modules (>1 Gb/s)
- Minimize interference risk

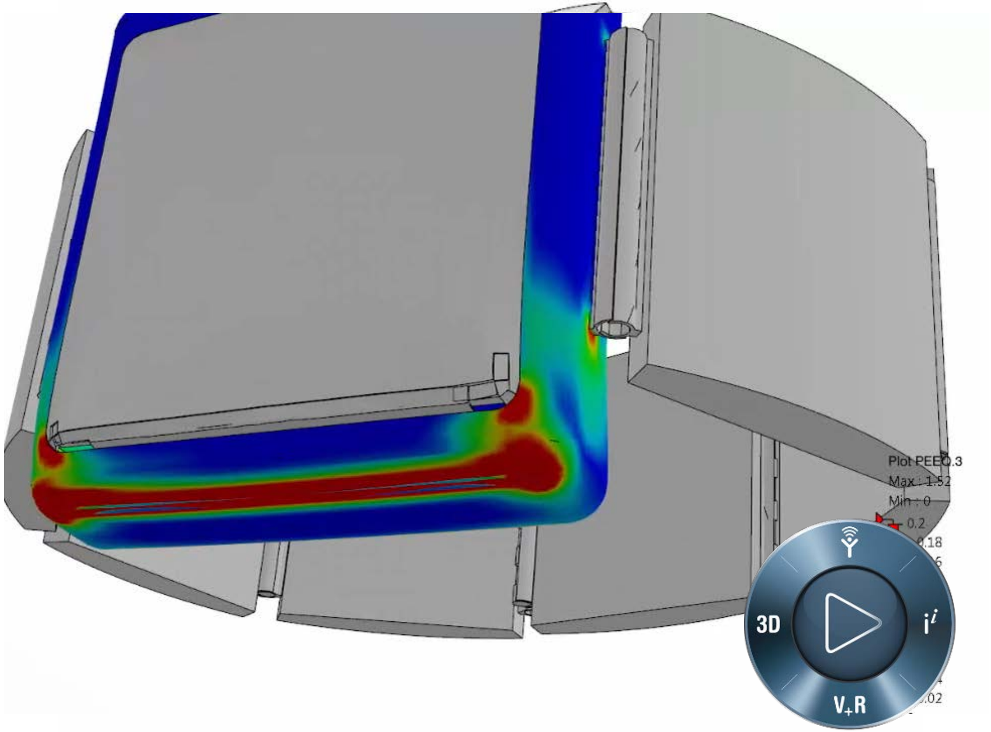
- Bluetooth, Wi-Fi, GPS and GSM capable

- 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.



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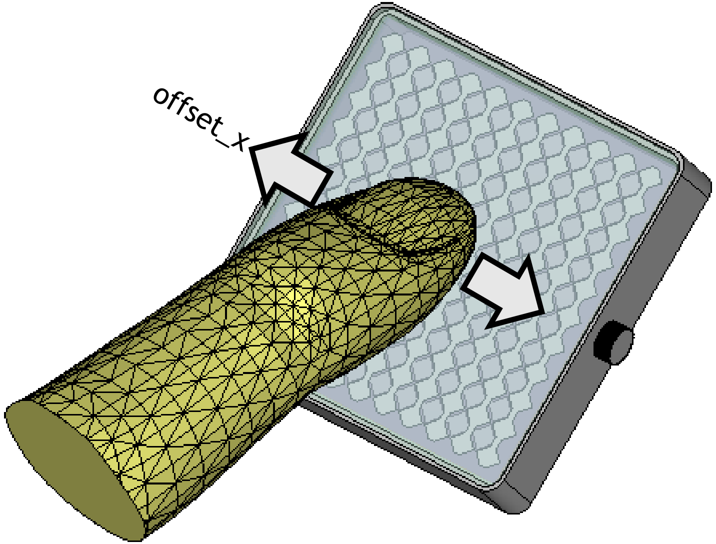
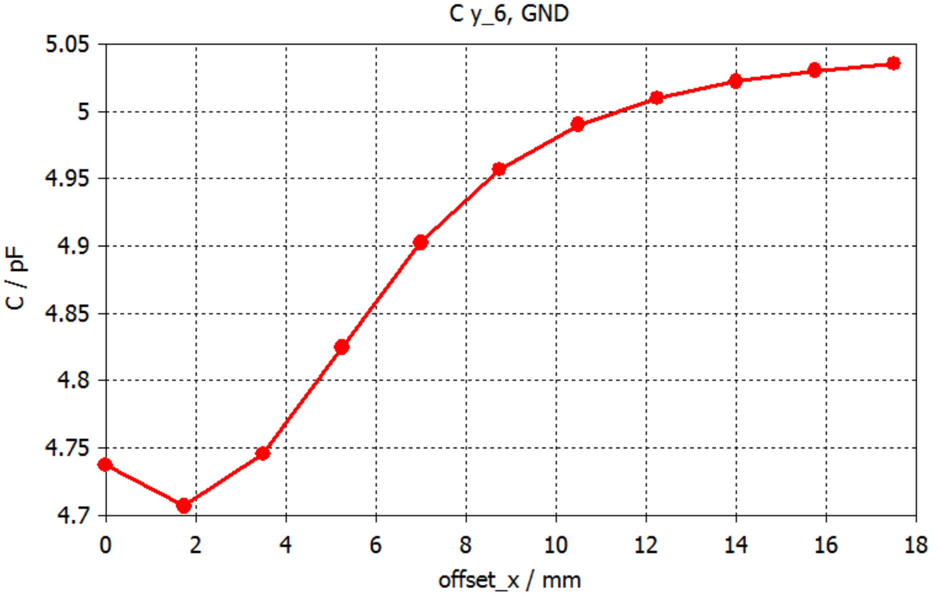
Analysis - Touch Screen

Movement of finger

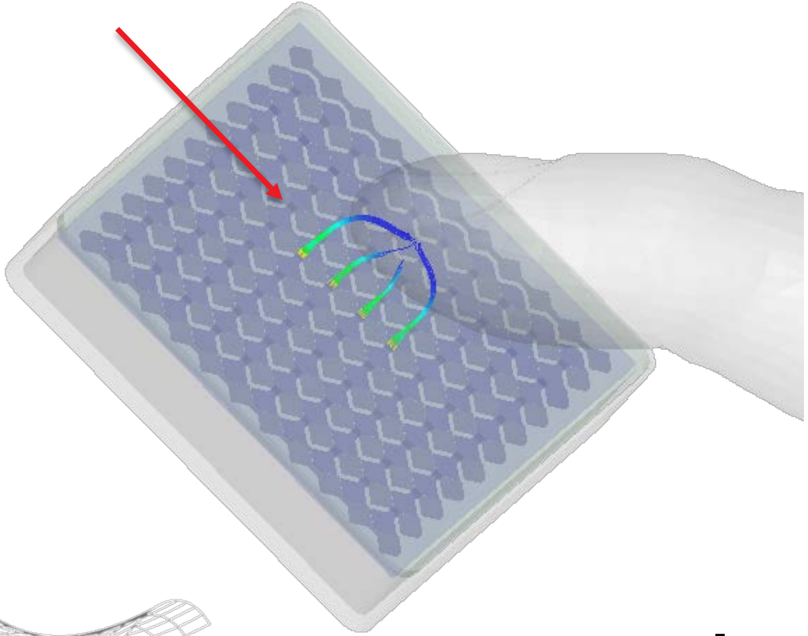


Capacitance Values



Analysis - Touch Screen

Electric field lines



Considering deformation due to finger pressure on glass

Capacitance Undeformed

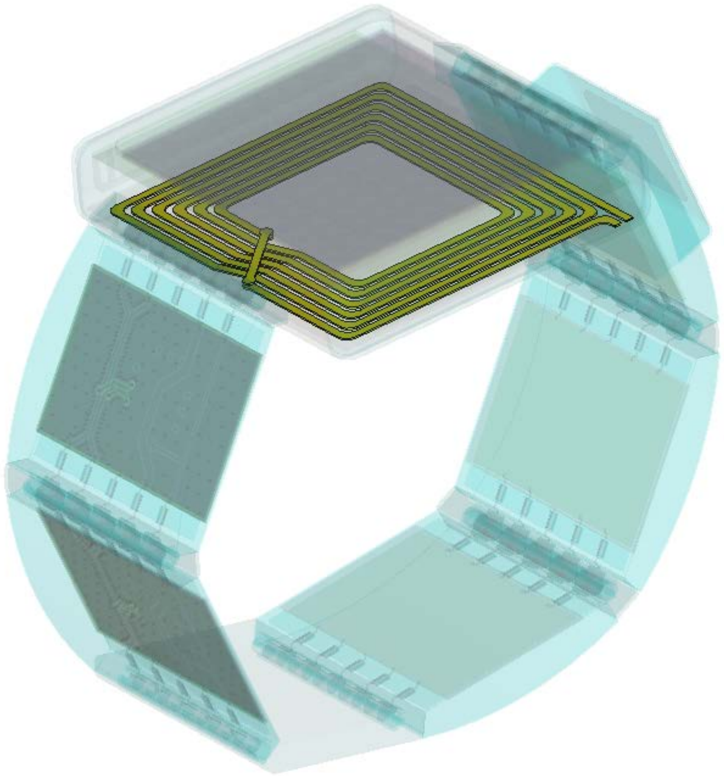
C x, y6
2.304e-012

Capacitance Deformed

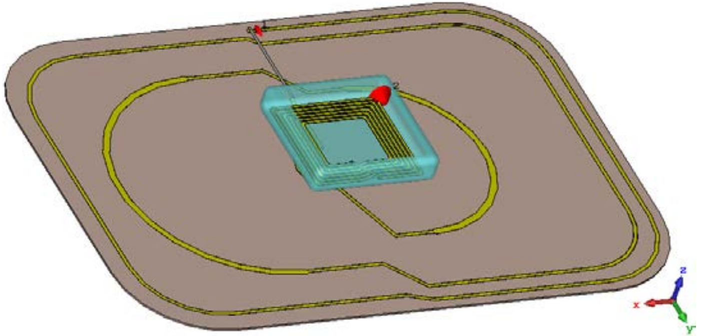
C x, y6
2.05785e-012

Mechanical and EM co-simulation

Analysis – Wireless charging



Analysis – Wireless charging

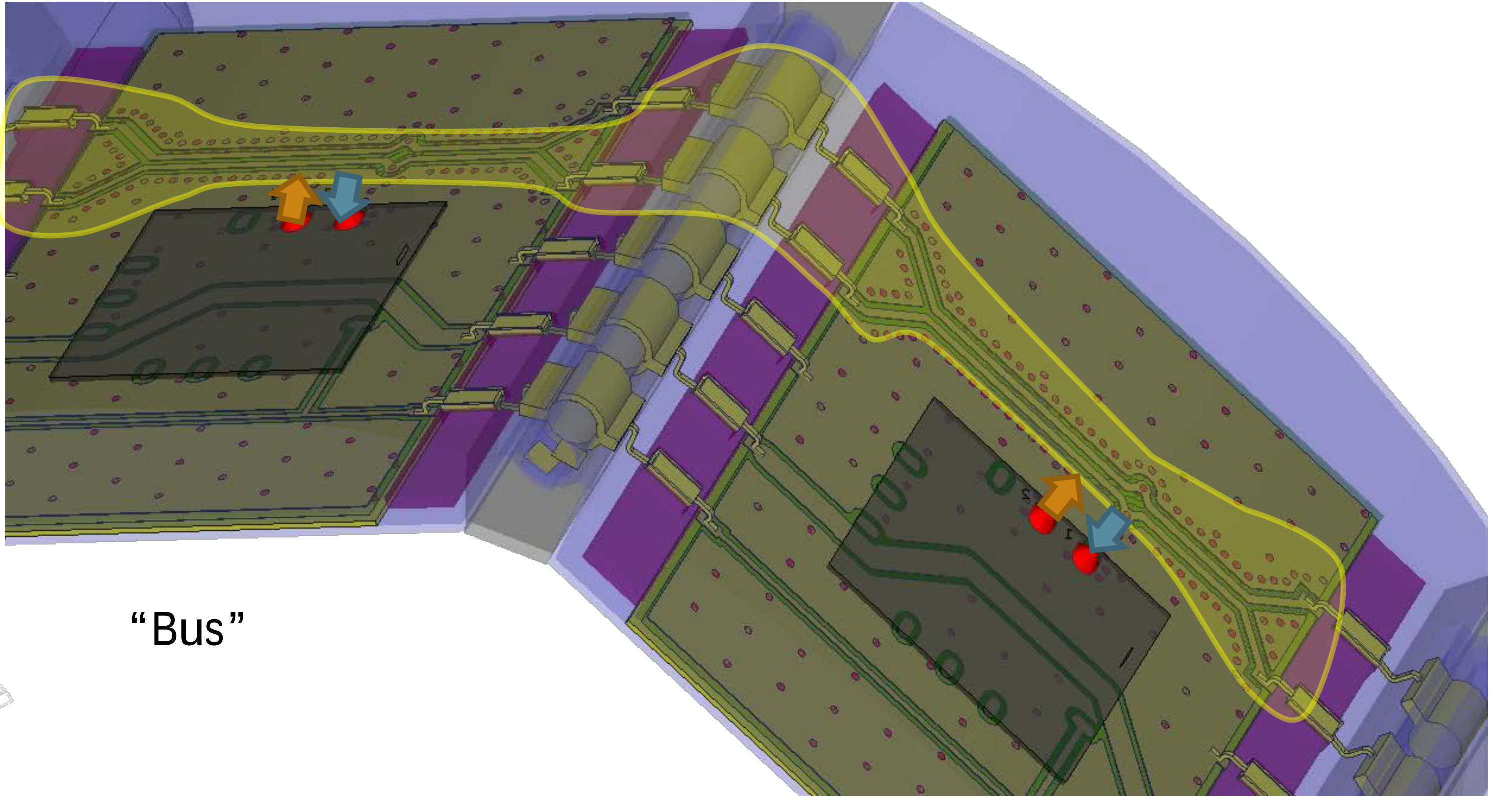


Magnetic Field @ 6.78MHz

YZ cut-plane

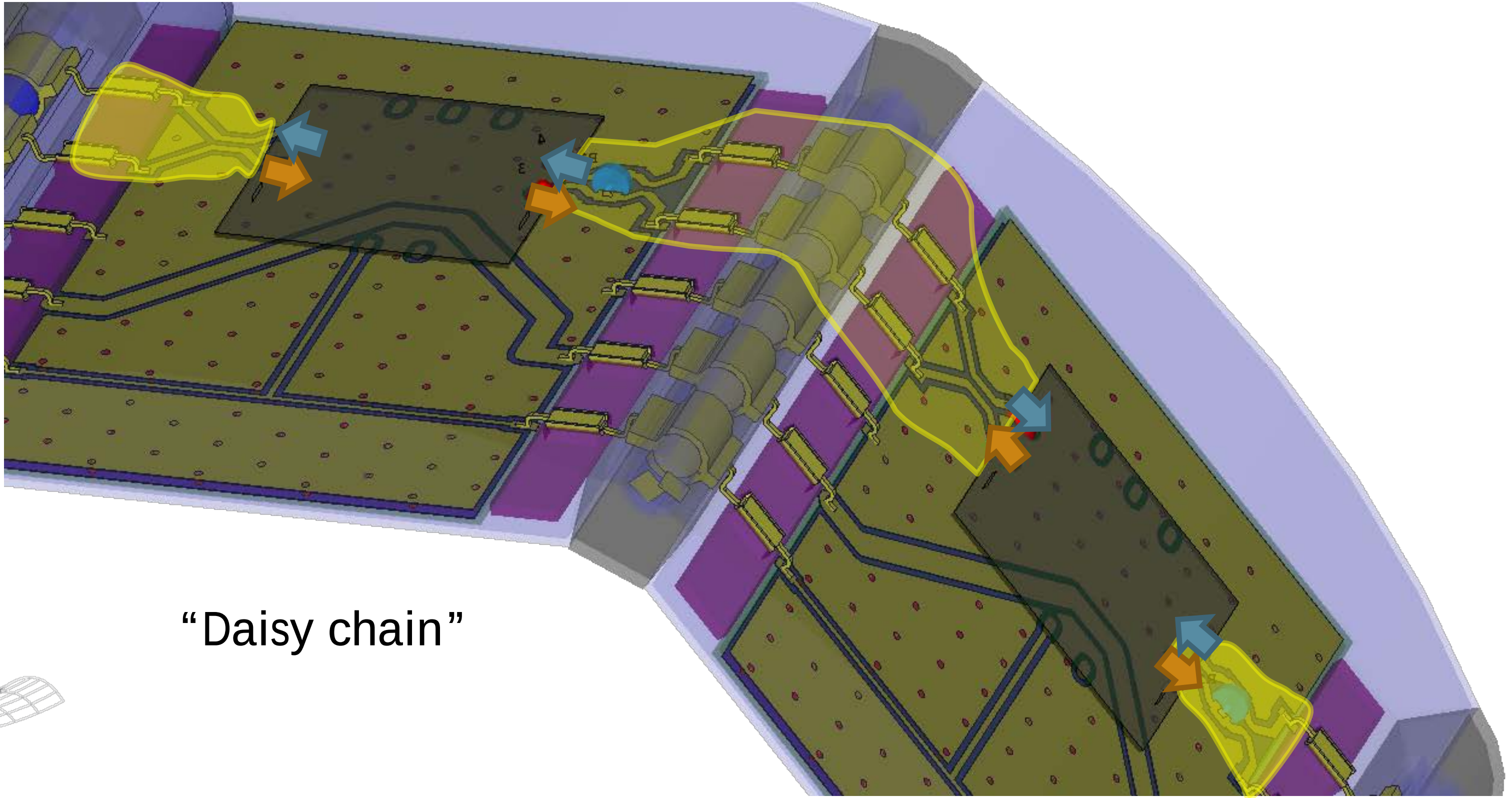
XZ cut-plane

Analysis - Modular electronics



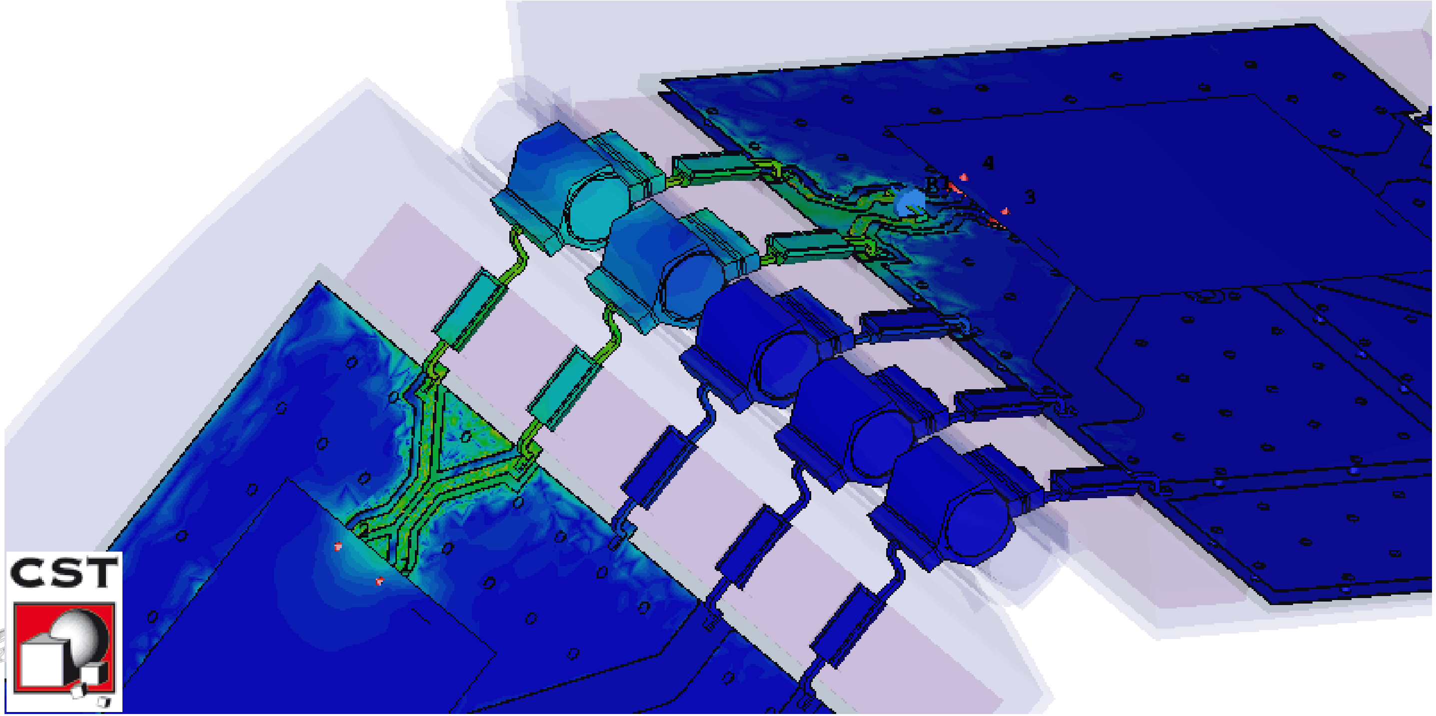
“Bus”

Analysis - Modular electronics

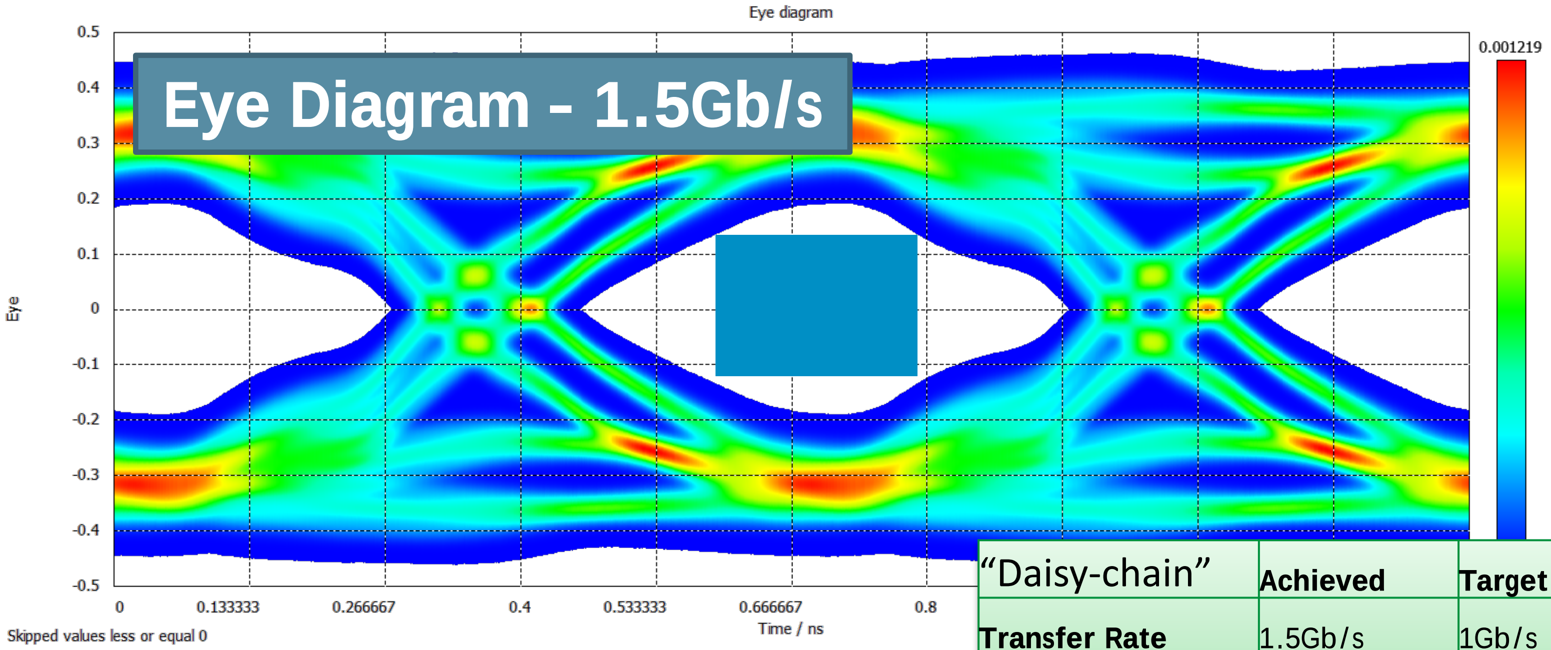


“Daisy chain”

Analysis - Modular electronics

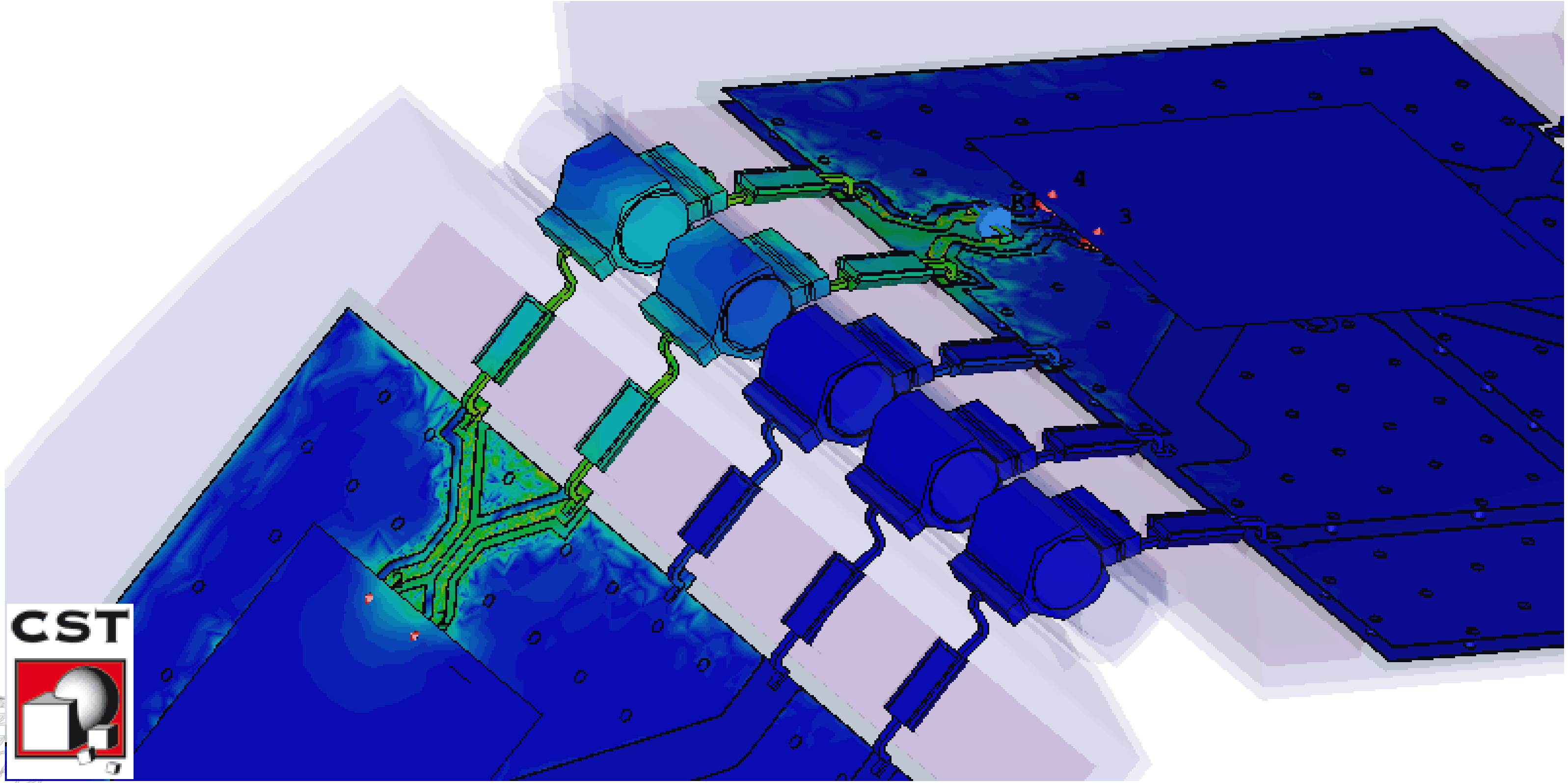


Analysis - Signal Integrity



“Daisy-chain”	**Achieved**	**Target**
Transfer Rate	1.5Gb/s	1Gb/s
Eye Opening	0.3mV	0.2mV

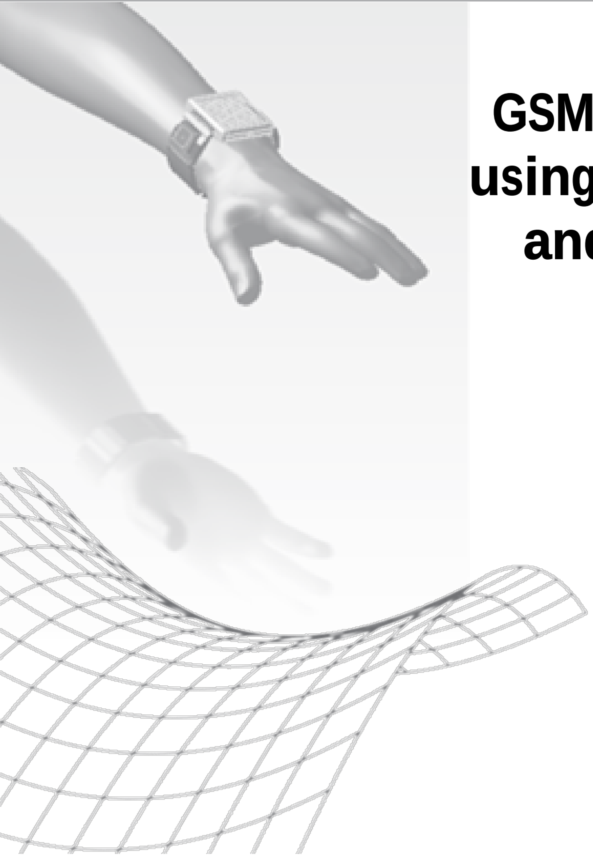
Analysis - Signal Integrity

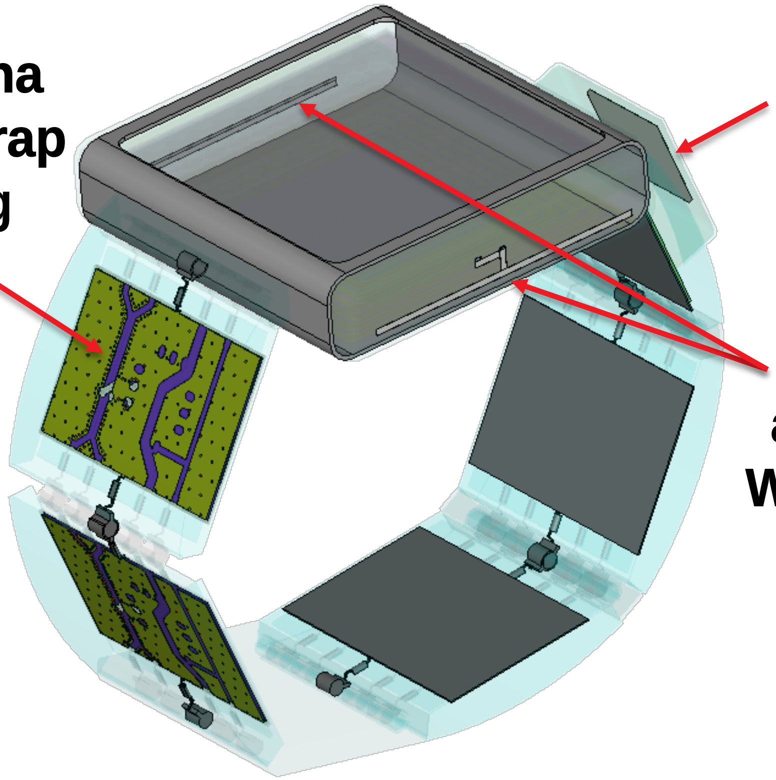


Designing in a system

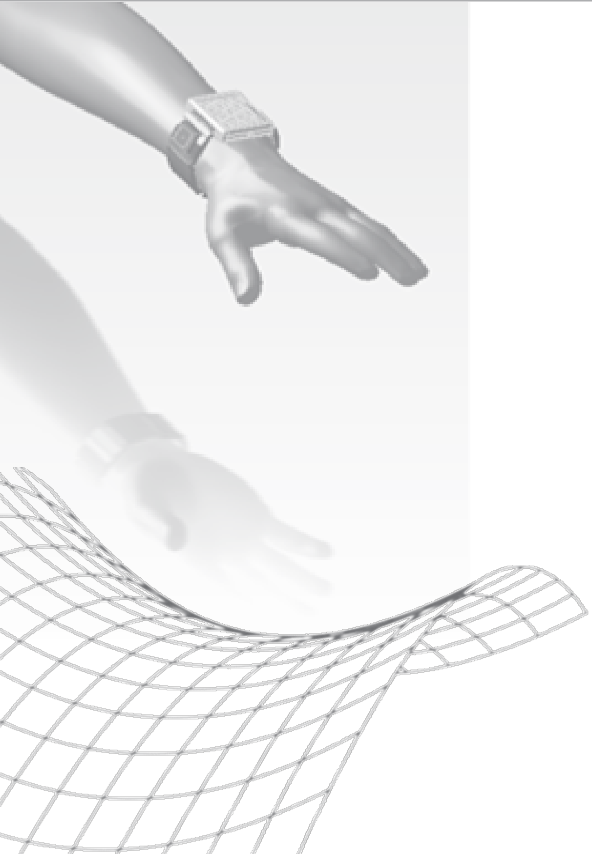
- Each antenna and subsystem design requires assumptions about other system components
- An understanding of the interaction between sub-systems and the shared impact of design choices takes time to evolve
- Each component design needs to be refined, leveraging understanding of this interaction
- An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

First antenna concepts





A first design concept



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Thank you


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