Antenna in Package

From an idea to volume production

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Antenna in Package
- The origins

AiP Concept
- Definition

AiP Advantages
- Why to use it

The Design Process
- From an idea to a product

AiP Products
- Smart Bluetooth, UWB, Cellular

Other Integrated Antennas
- Hearing Aids
- Watches

Conclusions

“From an Idea to Volume Production”
Insight SiP designed WiFi SiP modules for Nanoradio in 2005
Par Bergsten (CEO and founder of Nanoradio)
✓ “Why don’t you integrate the antenna into the module too?”
Insight SiP started R&D project on AiP with LEAT in 2005
OSEO provided support from 2006
Thesis by Mickaël Jeangeorges 2010
First AiP product In 2008 (Wireless USB)
First Smart Bluetooth AiP 2009
Volume production ISP130301 in 2014
**First Integration level uses packaged parts on PCB**
- SoCs in standard packages (BGA/QFN…)
- SMTs as discretes
- Flexible approach for initial prototypes and production

**RF SiP – first level of miniaturization**
- All the functionality in a single package (except antenna)
- Much smaller footprint
- Reduced RF complexity

**AiP – Ultimate level of miniaturization**
- Smallest footprint
- Further reduced RF complexity
Antenna in Package

An antenna integrated inside a SiP

- Ideally using SiP technology
- No need to add ceramic parts

Makes it easier to design systems

- "RF for Dummies"
**AiP Advantages**

**Design of complete system**
- AiP removes need for antenna expertise at system level
- AiP is smaller than SiP + antenna

**Radio Certification**
- Radio modules MUST have integrated antenna to be certified as modular transmitters (FCC).
- Eliminates radio certification at system level

**Time to Market**
- AiP module works “out of the box”
- Fewer design tweaks and spins
Miniaturization to fit in the package
✓ Size reduction of 2 to 3 times cf discrete antennas

Must use standard SiP technology
✓ LTCC or Organic substrates
✓ IPD (silicon or glass based passive devices)
✓ SMT components down to 01005

Performance Margins
✓ Multiple application platforms (ground plane size variations)
✓ Standard SiP production tolerances
  ▪ Dimensions
  ▪ Material properties

Technical Specifications
✓ Return Loss over operating band
✓ Radiation Efficiency over operating band
✓ Radiation Patterns and Gain
**AiP Design Process**

- **Starts from Knowledge Base**
  - Antenna experts

- **Batch EM sim**
  - Modeling

- **Final Antenna**
  - Fully EM simulated

**Diagram:**
- **Assess antenna topologies**
  - Topology 1
  - Topology 2
- **Mechanical Object 1**
- **Mechanical Object 2**
- **Batch EM Simulation**
- **Schematic Model 1**
- **Schematic Model 2**
- **Optimisation of parameters**
- **Fine tuning of best antenna With 3D EM tool**

**Equation:***

$$ S_{11} = f(W_1, W_2, X_1, X_2, X_3, Y) $$

**Additional Details:**
- **Knowledge Base**
- **Batch EM sim**
- **Final Antenna**
AiP for Smart Bluetooth

- Based on Insight SIP patent EP2348578 A1 / US20120293392
- Initial Implementation
  - ISP091201 Antenna size 8 x 6 mm
  - ISP130301 Antenna size 8 x 5 mm
- Optimized implementations
  - ISP1302 Antenna size 8 x 3.5 mm
  - ISP1507 Antenna size 8 x 3.5 mm
  - 3rd party module 6 x 3.5 mm
- Reduced size obtained with virtually no loss in radiation efficiency or matched band

AiP for Ultra Wide Band

- Based on patent WO2015018745 A1
- Implementation 8 x 8 x 1.6 mm
- Implementation UWB module ISP1510
**ISP130301 Module**

- Radiation efficiency > 60%
- 6dB Bandwidth > 250 MHz
- Radiation Pattern
- Range at 1m from ground > 70m with 0dBm output power

![Smart Bluetooth AiP Performance](image)
**UWB AiP**

- 8 x 8 x 1.6 mm
- Radiation efficiency > 60%
- 6dB Bandwidth 6.5 – 8.5 GHz
- Operates over ground plane
- “Patch like”
Custom Integrated Antennas

- Based on AiP designs
- Integrated specifically for custom use case
- Examples
  - Metal Watch
  - Hearing Aid
**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

**All Metal**
**Custom Antenna Design**

1. **Obtain Data**
2. **Create 3D Idealized Model**
3. **Determine space for Antenna**
4. **Evaluate Antenna Topologies**
   - N
   - Best?
   - Y
5. **Build and Test Prototypes**
6. **Verify Link Budget**
   - N
   - OK?
   - Y
7. **Solution Validated**
8. **Mechanical and Materials Data**
   - PIFA, IFA, Monopole,... Meanders 2D 3D
Constraints
✓ Near watch back (2mm)
✓ Small size (<30mm²)
✓ Near watch side walls

Best Structure
✓ PIFA 3D type

Performance
✓ -9dBi gain
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
✓ λ  Wavelength – 122cm
✓ R Range

\[
\frac{Pr}{Pt} = GrGt(1 - S11^2)(1 - S22^2)\left(\frac{\lambda}{4\pi R}\right)^2
\]
Despite relatively low gain
Free space range > 40 m
Close to ground range > 20 m
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

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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>
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<td>14.3</td>
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**Head Model**
- Octagonal Prism
- Filled with dielectric
- Small Air Cavity = Ear

**Return Loss > 6dB in band**

**Total Gain > -16 dBi in band**

![Head Model](image)

![Ear Cavity](image)

![Graph](image)
Hearing Aid Performance

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

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<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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<td>-16</td>
<td>25</td>
<td>15</td>
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Conclusions

- AiP allows for smallest in class solutions
- AiP reduces dependency on RF expertise
- AiP accelerates time to market
- Custom antennas use AiP miniaturization techniques to resolve difficult system issues
- Insight SiP has volume production for its AiP products today
Thank you

ANY questions?