Harmonic Chipless Sensor
Exploiting Wireless Autonomous Communication and Energy Transfer

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May 8-9, 2014 – Ramada Plaza Jeju Hotel, Jeju, Korea
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• Harmonic Tag Concept
• Design
• Proposed Application
• Proposed Circuit
• Results
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Ubiquitous Electronics

- Energetic Atonoumy
- Green Technologies
- Wearable Electronics
- Internet of Things (IoT)
- Wide Area Networks (WANs)
Green Electronics (GE)

- Recyclable, biodegradable
  - Passives
    - Recyclable, biodegradable materials
  - Actives
    - Organic Devices
- Energetically autonomous
  - Low power
  - Wireless Power Transfer (WPT) and Energy Harvesting (EH)

CHIPLESS SOLUTIONS
being low power, green, ...
**Harmonic Tag Concept**

- **Features:**
  - Chipless
  - Passive
  - Analog

- **Working Principle:**
  - Interrogated by a reader at $f_0$
  - Responds at a harmonic frequency $n f_0$ generated by a non-linearity embedded in the circuit
  - The tag responds only when there is a variation in the measured parameter
The reader can be composed by a transmitter at $f_0$ and two vectorial radio receivers at $2f_0$, able to sense both horizontal and vertical polarization.
• Goal:
  • Monitoring passively and wirelessly a certain parameter (temperature - t - for instance)

• How:
  • Use of an impedance-based sensible element just interrogated periodically by the reader

• Example:
  • Temperature wireless, chipless, autonomous sensor

Situation A:
\[ \Delta t = 0 \Rightarrow dR = 0 \ \Omega \]
There is no signal at \( 2f_0 \)

Situation B:
\[ \Delta t \neq 0 \Rightarrow dR = 0 \ \Omega \]
There is signal at \( 2f_0 \)
Proposed Circuit

- Block diagram of the tag able to sense the temperature variation
Simulated Schematic in ADS
• Maximum output power values of the harmonic, obtained by varying the input power, $\Delta R$ and the $R_{\text{fix}}$:

<table>
<thead>
<tr>
<th>$P_{\text{in-fund}}$</th>
<th>$P_{\text{out-harm}}$</th>
<th>$R_{\text{fix}}$</th>
<th>$P_{\text{out-harm}}$</th>
<th>$R_{\text{fix}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 dBm</td>
<td>-57.3 dBm</td>
<td>40 $\Omega$</td>
<td>-45.4 dBm</td>
<td>33 $\Omega$</td>
</tr>
<tr>
<td>-5 dBm</td>
<td>-69 dBm</td>
<td>57 $\Omega$</td>
<td>-57 dBm</td>
<td>51 $\Omega$</td>
</tr>
<tr>
<td>-10 dBm</td>
<td>-84 dBm</td>
<td>73 $\Omega$</td>
<td>-72 dBm</td>
<td>66 $\Omega$</td>
</tr>
</tbody>
</table>

In this case the output power is in the range of -57 dBm and -69 dBm, both of them detectable by a common reader with a sensitivity of at least -95 dBm.
• Simulated Power of the $2^\circ$ harmonic versus Rfix: each curve refers to a different dR

• This analysis serves to figure out the trade off between Rfix and dR and set Rfix of the impedance bridge $\rightarrow$ Rfix-optim = 50 Ohm for dR of 20 Ohm
Technology: Adhesive Copper Laminate Etching

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w )</td>
<td>377 ( \mu m )</td>
</tr>
<tr>
<td>( h )</td>
<td>250 ( \mu m )</td>
</tr>
<tr>
<td>( t_a )</td>
<td>40 ( \mu m )</td>
</tr>
<tr>
<td>( t_m )</td>
<td>50 ( \mu m )</td>
</tr>
<tr>
<td>( \varepsilon_r )</td>
<td>3.2</td>
</tr>
<tr>
<td>( \tan \delta )</td>
<td>0.08</td>
</tr>
<tr>
<td>( \varepsilon_{r,a} )</td>
<td>1.3</td>
</tr>
<tr>
<td>( \sigma_m )</td>
<td>58 MS/m</td>
</tr>
</tbody>
</table>
• Proposed layout of the impedance bridge connected to the antennas at f0 and 2f0

• Technology adopted → adhesive copper laminate, described in the previous slide

• Antenna geometry → crossed dipoles at f0=1.2 GHz and 2f0=2.4 GHz
CST Simulation Results: Return Loss

- **Simulation setup:**
  - **Paper characteristics:**
    - $\varepsilon_r = 2.9$
    - $H = 230\text{um}$
    - $\tan\delta = 0.08$
  - **Adhesive characteristics**
    - $T = 30\text{um}$
    - $\varepsilon_r = 1.3$
  - **Metal**
    - $t = m = 35\text{um}$
    - $\text{Sigma} = 5.8 \times 10^7 \text{S/m}$

![Graph showing return loss vs. frequency (GHz)]
Simulation setup:
  - Paper characteristics:
    - $\varepsilon_r = 2.9$
    - $H = 230\,\mu m$
    - $\tan\delta = 0.08$
  - Adhesive characteristics
    - $T = 30\,\mu m$
    - $\varepsilon_r = 1.3$
  - Metal
    - $t = m = 35\,\mu m$
    - $\sigma = 5.8 \times 10^7 \, S/m$
Conclusion

• Feasability study of a harmonic chipless tag sensor that monitors the change of a parameter by means of an impedance based sensitive element.

• The architecture uses all the energy wirelessly transferred by the reader to the tag without empowering any electronic circuit for modulation.

• A variation of 5 Ohm in a sensing thermistor with a quiescent resistance of 50 Ohm generates a second harmonic of -69 dBm, detectable at 50 cm, considering a receiver sensitivity of -95 dBm and a reader antenna gain of 5 dBi.

• The SiPoP, chipless implementation is also eco-freindly, flexible, low cost and energetically autonomous.
Thank you!

Questions?