Compact Antenna for Medical Wireless Communications Applications

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Topics Outline

- Basics Antenna & needs
- Antenna Frequency ranges and types antennas
- Compact ceramic antenna introduction
- Overview of wireless frequency bands
  - Short range
  - Long range
- Vishay Compact Ceramic antenna
  - Suited for UHF band MICS, MEDS, MMN, WMTS
  - Compact Ceramic antenna advantages
- Tuning capability of the Compact Ceramic antenna
- Ground plane optimization
- Summary
Basic wireless transmission:
Lower the frequency longer the wavelength, larger antenna is needed

<table>
<thead>
<tr>
<th>Frequency in Megahertz (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High Frequency</td>
</tr>
<tr>
<td>Ultra high Frequency</td>
</tr>
<tr>
<td>100 200 300 400 500 600 700 800 900 1000 1200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wave length in meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 1.5 1.0 0.75 0.6 0.5 0.43 0.375 0.333</td>
</tr>
</tbody>
</table>

C (Speed of light) = L Wavelength X Frequency

Basic Antenna & Needs

- Antenna like air-core inductor
- The antenna size and construction is based upon operating frequency. Higher the frequency shorter the wavelength. Example: 2.4GHz, quarter wavelength size = 3cm
- Resonance occurs at fractions/multiples of the fundamental frequency. Antennas can be made smaller because they can operate OK at fractions or multiples of the frequency
- The frequency corresponds to the wavelength $\lambda = c/f$
- Detuning/Fading of the RF signal when placed close to another object…due to low bandwidth
- Antennas constructed with ceramic(dielectrics), can have major advantages over traditional metal (conductive) antennas
Basic Antenna types

- Antennas common to Medical devices:
  - Monopole
  - Dipole

- Types:
  - Metal Telescopic
  - Loop, whip
  - Flat Wire or helix
  - Printed PCB
  - Ceramic/Chip
  - Patch

Antennas rule the air space!
Inside a medical device: challenging high density circuitry

Key Medical Grade Components for Implantable Medical Devices:
- Multi-layer Ceramic Chip Capacitors
- Solid Tantalum Chip Capacitors
- Non-Polarised Chip Capacitors
- Resistors
- Traps and Transformers
- Single and Dual MOSFETs
- ICs
- Thick and Thin Films Chip Resistors
- High Energy Charge capacitors
Ceramic Antenna introduction

- Effective wavelength of a radio wave is shorter in a ceramic dielectric material than in free space.
- Therefore Antennas constructed with Ceramic dielectrics can be made smaller than conventional metal antennas.
- Many medical devices made with high density circuits require very small size antennas, good efficiency.
- New low loss Ceramics can be used to construct an antenna with some nice advantages:
  - Antenna size can be reduced by 10 to 20 times.
  - Multi-tuning capability.
  - Surface mountable.
  - Radiates efficiently since the size is comparable with the half-wavelength dipole antenna.

Ceramic Antenna construction

- Antennas construction problem.. the size is a fraction of the wavelength effecting the bandwidth (lowering).
- However Antenna size can be decreased by increasing the dielectric or magnetic constant $\varepsilon$ around the antenna.
- An Antenna dimension should be $\sim \lambda/4\sqrt{\varepsilon}$, where $\lambda$ is the wave length and $\varepsilon$ the Dielectric Constant of the media.
- Example, For Frequency= 300 MHz, $\lambda = 1$ meter.
  In Air, $\varepsilon = 1$, so the equivalent antenna should measure a large electrical length of 250mm.
Ceramic Antenna at Medical Freq.

- Example: Antenna operating at Medical Freq.
  - 403MHz in air
  - Requires a wavelength of this frequency of ~750mm
  - Therefore a ½ wave dipole antenna would need to be a large electrical length of about 375mm or >1 foot in length!
  - Not practical for most medical devices

- Using Ceramic Antenna the electrical length (size) can be decreased by use of a low permittivity ceramic dielectric around the antenna
  - Why is Ceramic antenna smaller?
    - Using ceramic dielectric material greatly impacts the effective length of the antenna by a factor of $\sqrt{\varepsilon}$.
      - So for example, if the dielectric $\varepsilon$ is $= 400$, $\sqrt{400} = 20$. Therefore the antenna length can be reduced by up to 20X fitting is a smaller space inside the device.

  - Higher the dielectric constant results in higher electrical losses. Dielectric material used in Vishay Compact Ceramic antenna is a compromise between Dielectric constant and losses.
Benefits: Patient centered wireless medical device communication

- Smaller Devices using a ceramic antenna can facilitate remote monitoring of patients vital signs or download patient history for the clinician
- Wireless Neurostimulator devices with small antenna not only monitor but can program devices to move artificial limbs
- Wireless capability provides fast data access which can reduce health care cost and provide better treatment actions
- **FINDINGS:** People accessing their charts took better care of themselves… California HealthCare Foundation (CHCF), April 2010

Device benefits

- Small Wireless medical devices can be worn on the body or implanted with embedded antenna
- Antenna in wireless medical devices allow:
  - 2-way communication system between device and external control unit or directly to nurse station
  - Capability for close-range and long-range data exchange so the clinician can respond quickly and efficient
  - Most implantable devices provide short range communicate to bedside receivers which in turn are connected to the internet for longer range communication
### Wireless communication implantable devices

#### Medical devices

- **Freq.**
- **Medical devices**
- **Short distance applications**

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth, Wi-Fi, and Zigbee</td>
<td>900MHz, 2.4GHz, 5.8GHz</td>
<td>60 meters</td>
</tr>
<tr>
<td>Medical Body Networks or PAN-Personal Area</td>
<td>2.4GHz</td>
<td>1 meter</td>
</tr>
<tr>
<td>Ultra-Wideband</td>
<td>&gt;500MHz</td>
<td>1 meter &amp; &gt;</td>
</tr>
<tr>
<td><strong>MMN</strong> Medical Micropower Networks</td>
<td>413-457MHz</td>
<td>1 meter</td>
</tr>
<tr>
<td><strong>MICS</strong> Medical Implant Communications Systems</td>
<td>401-406MHz</td>
<td>2-4 meters</td>
</tr>
<tr>
<td><strong>Inductive</strong> Implants</td>
<td>&lt;200KHz</td>
<td>&lt;&lt;1 meter</td>
</tr>
</tbody>
</table>
Freq. Medical devices
Long distance applications

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>WiMax</td>
<td>2.5GHz</td>
<td>&gt;1000 meters</td>
</tr>
<tr>
<td>WMTS</td>
<td>600MHz to 1.4GHz</td>
<td>60 meters</td>
</tr>
<tr>
<td>Wireless Medical Telemetry Systems</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Implantable** devices; operate in MICS, MEDS and MMN band
- **Non-implanted devices**: For example Robots operate in WMTS (Wireless Medical Telemetry Service) band or IEEE standard 802.15.4
Telemetry systems for Medical devices

Some medical devices use multiple frequencies:

- Robots used in hospitals use:
  - Antenna Frequency (400, 868, 915MHz) per IEEE standard 802.15.4
- Implant devices use MICS band 401-406 MHz combined with multiple higher frequency ISM bands (Industrial, Scientific and Medical) 2.4-2.5 GHz +.
- Multiple frequencies can better meet power budgets

- Multiple-frequency band telemetry have different carrier frequencies for the power and data signals.

MICS Channel spacing

The maximum transmit power for MICS is very low $EIRP=25\text{milliwatts}$
Example: Compact Ceramic antenna bandwidth advantage

Medical Implant Communication Service
- MICS 402–405 MHz, setup by FCC
- MICS provides up to 10 channels with bandwidth of 3MHz
- Vishay Antenna in monitor Solves Detuning
- Vishay antenna covers a 100MHz bandwidth!

MICS solutions:
- Use a radio-frequency (RF) link to achieve high data rates 800/400/200 Kb/sec
- range of ~ 2-4 meters

Example: Vishay antenna tuned to a center frequency of 400-MHz
Ceramic Chip Antenna features

- Tunable across the UHF band
- Small outline SMD
  - 10 x 15 x 1mm
  - 35 x 5 x 1.2mm
- Omni directional, linear polarization
- Optimized with tuning circuit & ground plane
  - 50 Ohm unbalanced interface
- Operating Temperature Range:
  - -40°C to +85°C
  - RoHS compliant
- High Dielectric Constant Ceramic
- Vishay Proprietary ceramic formulation
  - Low Loss Factor
- Ideal for medical devices MICS, MMN and WMTS bands

Vishay Antenna can transmit & receive signals in the UHF band (400MHz - 860MHz) and up to 1.1GHz

Wide Band Tuning with Vishay Compact Ceramic antenna

- Easy to tune using only two Digital Control lines
- No Software Overloading
- Covers the entire UHF Band (470 MHz to 860 MHz)
- Can be adapted to cover other frequencies
Digital Tuning circuit concept:
Switch reactance to generate the appropriate tuning impedance.

<table>
<thead>
<tr>
<th>D0</th>
<th>D1</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Z1+Z2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Z1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Z2</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

50Ohm

Tuning circuit application: use low cost PIN diodes as switches.

<table>
<thead>
<tr>
<th>Digital In1</th>
<th>Digital In2</th>
<th>PIN 0</th>
<th>PIN 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>High Z</td>
<td>High Z</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>High Z</td>
<td>2Ω</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>2Ω</td>
<td>High Z</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2Ω</td>
<td>2Ω</td>
</tr>
</tbody>
</table>
How Tuning Works

470 MHz 860 MHz Frequency

Antenna
How Tuning Works

Antenna

470 MHz 860 MHz Frequency

How Tuning Works

Antenna

470 MHz 860 MHz Frequency
Single Channel Tuning

- The Compact ceramic antenna can be tuned to any single frequency of active range (460 MHz to ~ 1.1 GHz)
- Simple LC tuning circuit
- No need for Digital Control

Example:
- To tune the antenna @ 725 MHz, L1 = 47nH, C1 = 3.9pF

Design in support: Vishay Antenna Evaluation board and ground plane

Complete info can be found at:
http://www.vishay.com/chip-antenna/
Summary - Compact Antenna for Medical Wireless Applications

- Medical Devices with wireless capability will increase even more because of the Patient / Physician benefits
- Remote monitoring for wireless control of therapeutic medical devices is a reliable, robust method and can be implemented at multiple frequencies
- MICS and newly announced MMN frequency bands are safe, and effective for medical implantable devices
- Antenna efficiency should be considered especially where space is constrained for the ground plane.
- Vishay Compact Ceramic antenna offer significant advantages over conductive metal antennas