Electrically Small Antennas

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**Electrically Small Antennas**

- The wavelength of these frequencies lies between 15cm and 35cm.
- Small portable devices are not 15cm-35cm long. We see the need of small antennas.
- On portable devices the antennas are small, usually between a fifth and a tenth of a wavelength ($\lambda/5 - \lambda/10$).

<table>
<thead>
<tr>
<th>System</th>
<th>Frequency [MHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM (2G)</td>
<td>900 / 1800 / 1900</td>
</tr>
<tr>
<td>UMTS (3G)</td>
<td>1955 / 2155</td>
</tr>
<tr>
<td>DECT</td>
<td>1890</td>
</tr>
<tr>
<td>PHS</td>
<td>1900</td>
</tr>
<tr>
<td>CT 2</td>
<td>866</td>
</tr>
<tr>
<td>GPS</td>
<td>1575</td>
</tr>
<tr>
<td>Satellite link</td>
<td>1620 (up) / 2490 (down)</td>
</tr>
<tr>
<td>Pager</td>
<td>&lt; 900</td>
</tr>
</tbody>
</table>

- Why do we need ESA?
Why do we need ESA?

Apple iPhone - back

Antenna location on the back of iPhone
GSM 850 - EGSM 900 - DCS 1800 - PCS 1900
AT&T Cingular typically sends PCS 1900
so place the Universal Adapter right above that location
What is an Electrically Small Antenna?

- An antenna small compared to the wavelength it generates.
- A small antenna is defined by the value $ka$
- Where $k$ is the wave number $\frac{2\pi}{\lambda}$ and $a$ is the radius of an imaginary sphere circumscribing the maximum dimension of the antenna.
- In general for an ESA $ka < 0.5$
Building the Antenna

- Copper ground plane
- Dielectric
- Copper Conductor
- SMA Feed Pin
- Plastic Dielectric Tubing
- 22 AWG Copper Wire
  ~30 Coils per arm
Old vs. New

Design Goals:
• Wider Arms, More Coils – Increases the electrical length of the antenna. Increase wavelength, decrease frequency. The new antenna will operate at a lower frequency.

\[ \lambda = \frac{v}{f} \]

\[ Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \]

• Larger Conductor – More capacitance between ground plane and conductor, decreases the impedance of the antenna. Attempting to match a 50 ohm system.
Measurements

Old

New

<table>
<thead>
<tr>
<th></th>
<th>(f_0) (GHz)</th>
<th>(k\alpha)</th>
<th>(BW_{HP})</th>
<th>(Q)</th>
<th>(\eta)</th>
<th>(\frac{Q}{Q_{ch}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.04</td>
<td>0.52</td>
<td>9.5%</td>
<td>21.1</td>
<td>88%</td>
<td>2.7</td>
</tr>
<tr>
<td>2</td>
<td>0.541</td>
<td>0.29</td>
<td>2.1%</td>
<td>95.7</td>
<td>71%</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**TABLE II**

**ELECTRICAL CHARACTERISTICS OF THE ANTENNAS**

Efficiency Measurements performed with several Wheeler Caps:

\[ \eta = \frac{R_r}{R_r + R_i} = \frac{P_r}{P_r + P_i} \]
Work Stations

- Milling Machine
- Spectrum Analyzer
What’s Next

• Make adjustments to current model to tune its frequency, wavelength, and radiation loss

• Other types of spherically shaped antennas
  – Each with a unique but important design in order for them to perform in certain ways
Conclusion

• What we learned about:
  – Milling
  – Network analyzer
  – Calibration
  – Antennas

• Thank You Jake
• Thank You PURE
QUESTIONS???

• About anything we did or our experience with PURE as a whole