Characteristics of Biconical Antennas Used for EMC Measurements

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Outline

• State-of-the-art of EMC Antennas
• Biconical Antenna
• Analytical Procedure
• Calculation of Antenna Factor
• Inclusion of a Balun
• Ground Effects
• Conclusion
EMC Antennas

- **Double Ridged Waveguide Horn Antenna**
  - Frequency Range: 200 MHz - 2.5 GHz
  - 6 dB Gain Improvement at 2 GHz
  - Maintains Single Lobe Radiation Pattern
  - Low VSWR over entire frequency band
  - Connector: N-type female

- **Shielded Active Loop Antenna**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>10 kHz - 30 MHz</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>85 dB @ 10 kHz</td>
</tr>
<tr>
<td></td>
<td>125 dB @ 1 MHz</td>
</tr>
<tr>
<td>Sensitivity (Typical)</td>
<td>-1 dB (uA/m) @ 10 kHz</td>
</tr>
<tr>
<td></td>
<td>-42 dB (uA/m) @ 1 MHz</td>
</tr>
<tr>
<td>1 dB Compression Point</td>
<td>5 V/m</td>
</tr>
<tr>
<td>Power Required</td>
<td>13.8 VDC</td>
</tr>
<tr>
<td>Impedance (Nominal)</td>
<td>50 ohms</td>
</tr>
<tr>
<td>Connector</td>
<td>BNC female</td>
</tr>
</tbody>
</table>
EMC Antennas

- **Conical Log Spiral Antenna**
  - Frequency Range: 200 MHz - 1 GHz
  - VSWR: 2.4:1
  - CW power: 100 Watt / peak power: 150 Watt
  - Impedance: 50 Ohm
  - Polarization: Circular
  - Connector: N-type female

- **Log-periodic Dipole Array Antenna**
  - Frequency Range: 80 MHz - 2 GHz
  - VSWR: 1.2:1
  - CW power: 1000 Watt
  - Impedance: 50 Ohm
  - Connector: N-type female

**EMC Antennas**

- **Mini-Bicon Antenna**
  - Frequency Range
  - VSWR: ~ 5:1
  - Maximum CW power
  - Impedance: 50 Ohm
  - Connector: N-type female
  - Cage Elements: 30 MHz - 1 GHz
  - Cone Elements: 30 MHz - 3 GHz

- **Biconical Antenna**
  - Frequency Range: 20 MHz - 300 MHz
  - VSWR: 2.8:1
  - CW power: 50 Watt / peak power: 100 Watt
  - Impedance: 50 Ohm
  - Connector: N-type female
  - Cage Elements: 200 Watt
  - Cone Elements: 50 Watt

**Source:** [http://www.ets-lindgren.com/EMCAntennas](http://www.ets-lindgren.com/EMCAntennas)
Biconical Antenna – Geometry and physical dimensions

Side View

End View

Cone separation $\delta = 87$ mm
Cone length $l = 603.5$ mm
Wire radius $a = 3$ mm.
Biconical Antenna – NEC simulation model

NEC model of the antenna showing tapered segmentation scheme

<table>
<thead>
<tr>
<th>Wire No.</th>
<th>Length mm</th>
<th>No. of segments</th>
<th>Segment lengths $/\lambda$ at 300 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>522.646</td>
<td>10</td>
<td>0.0523</td>
</tr>
<tr>
<td>2</td>
<td>301.750</td>
<td>5</td>
<td>0.0604</td>
</tr>
<tr>
<td>3</td>
<td>603.500</td>
<td>11</td>
<td>0.0549</td>
</tr>
<tr>
<td>4</td>
<td>87.000</td>
<td>3</td>
<td>0.0290</td>
</tr>
</tbody>
</table>

Total number of segments = 205

Initial segmentation scheme used for the Biconical antenna
Biconical Antenna – Input impedance

Measured and simulated impedance components of the antenna horizontally polarized at a height of 1.5 m above the ground.
Biconical Antenna – Dimensions’ Optimization

Measured impedance components of the Biconical antenna and predictions from a model with shortened cone lengths
### Segmentation schemes used for the Biconical antenna and their corresponding cone resonant frequencies

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Number of segments</th>
<th>Cone resonant frequency / MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wire 1</td>
<td>Wire 2</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>
Biconical Antenna – Input impedance

Measured drive-point impedance components of the Biconical antenna and predictions from the optimized NEC model.
Analytical Procedure – Various wire radii

Simulated input impedance of a half length antenna for various wire radii
(□ = 0.1, + = 0.25 mm, ◊ = 0.5 mm, ▲ = 1 mm, x = 2 mm, and ▼ = 3 mm).
Antenna Factors - Calculation

- Determination of the relationship between the voltage delivered by the antenna to its load impedance

\[ AF = \frac{E}{V_r} \]

\[ E: \text{incident field strength at the antenna} \]
\[ V_r: \text{voltage at the input of the measuring receiver} \]

\[ P_r = \frac{V_r^2}{R_r} \]
\[ P_r = A_e S_{av} \]
\[ P_r = \frac{MG_r(\theta, \phi) \lambda^2}{4\pi Z_o} \]
\[ A_e = \frac{MG_r(\theta, \phi) \lambda^2}{4\pi} \]
\[ S_{av} = \frac{E^2}{Z_o} \]
\[ M = 1 - \frac{P_{refl}}{P_{fwd}} = 1 - |\rho|^2 \leq 1 \]

\[ AF (dB \ m^{-1}) = 19.76 - 20 \log \lambda - G_r (dB) - M (dB) \]
Variation with frequency of the computed antenna factor (-), antenna gain $\theta=90$ and $\phi=0$ (+) and mismatch loss (◊) as well as the measured antenna factor (▲).
Inclusion of a Balun

- Use of jigs pair to mount N-type connectors in place of the cones of the antenna

Diagram showing how jigs were used to mount N-type connectors on the antenna support.
Inclusion of a Balun

- Balun can either increase or reduce its antenna factor according to the precise frequency of excitation.

**Predicted antenna factors for the Biconical antenna with and without its balun**
Ground Effects on the antenna factor

- Effect on the antenna factor

\[ Z_{IN} = Z_{11} + \frac{I_2}{I_1} Z_{12} \]

- \( Z_{11} \): antenna impedance in free space
- \( Z_{12} \): mutual impedance between the antenna and its image in the ground plane

Mutual impedance between the Biconical antenna and its image for both horizontal and vertical orientation. (\( R_{12} \), + \( X_{12} \))
Ground Effects on the antenna factor

- Antenna factor is virtually independent of height above 140 Mhz.
- There is noticeable height dependence in antenna factor below 120 MHz.
- The significant difference is with horizontal antenna at 20 MHz, whereas the vertical antenna shows variation less than 3dB in antenna factor for 1 to 4 m heights.

Computed antenna factors for horizontal and vertical orientation at various heights above the ground plane (- free space; + 1 m; ♦ 2 m; △ 3 m; × 4 m).
Ground Effects on the radiation pattern

- Comparing pattern of a dipole antenna above the ground to the Biconical antenna indicates any pattern differences caused by current asymmetry in the Biconical antenna.

![Graphs showing normalized pattern at 260 MHz for the antenna at 1 m (left) and 4 m (right) above the ground plane.](image)

Normalized pattern at 260 MHz for the antenna at 1 m (left) and 4 m (right) above the ground plane
Antenna Current distribution

- Significant pattern distortion can occur at some frequencies when a horizontal wire Biconical antenna is used close to the ground.

Magnitude and phase of the currents at the widest points of the antenna elements when 1 m above the ground plane.
Conclusion

• Antenna factor is dependent on both the antenna's polarization and height above the ground plane.

• Radiation pattern measurements above 200 MHz should be made due to the distortion occurrence.

• The antenna results will allow this broadband antenna to be used with confidence in applications where previously only resonant dipoles were specified.
References

Thank you for Your Attention

Questions