Novel Miniaturized Sinuous Antenna for UWB Applications

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Summary

- Introduction to the Sinuous Antenna

- Sinuous Antenna Design
  - Standard Sinuous Antenna
  - Non-Conventional Cavity Backed Sinuous Antenna

- Analysis and Simulation Results
  - Performance

- Conclusions
Introduction to the Sinuous Antenna

The operation principle of the Sinuous Antenna is described in the following picture:

- Multiple folded dipoles
- Self-complementary structure → frequency independent performance
- The UWB behavior is realized by means of dipoles that resonate at adjacent frequencies
Introduction to the Sinuous Antenna

The electromagnetic sensor should have the following capabilities:

- UWB Functionality
- Controlled HPBW
- S45 Polarization
- Light Weight
- Small Dimensions
- Direction Finding Application

\[ x = t \cos ( -1p \alpha \sin \left( \pi \left( \frac{t}{R_p} \right) \right) ) \pm \delta \]

\[ y = t \sin ( -1p \alpha \sin \left( \pi \left( \frac{t}{R_p} \right) \right) ) \pm \delta \]

Parameters:
- \( R_s \) minimum radius
- \( R_p \) maximum radius
- \( \tau_p \) expansion factor
- \( \delta \) arm thickness
- \( \alpha \) arm angular width
Introduction to the Sinuous Antenna

4-Arm Sinuous Antenna Properties:
- 2-18 GHz
- Controlled HPBW
- S45 Polarization
- 6 cm Diameter

The goal is to lower the minimum frequency operation maintaining the same diameter considering:
- $S11 < -5 \text{ dB}$
- $\text{Gain} > -5 \text{ dBi}$
- $\text{HPBW} < 120^\circ$

Parameters:
- $R_s < t < R_p$
- $R_s$ minimum radius
- $R_p$ maximum radius
- $\tau_p$ expansion factor
- $\delta$ arm thickness
- $\alpha$ arm angular width
Free Space Sinuous Antenna – Substrate Investigation

The best choice is Rogers RT5880LZ

\[ \Delta \phi = \pi \]
Free Space Sinuous Antenna – Meandering

Classical Sinuous Antenna

Meandered Sinuous Antenna

The meandering increases the electrical length of the arms introducing a cross-polarization contribution.
Free Space Sinuous Antenna – Meandering

Meandered Sinuous Antenna

Parameter:

- $R_s < t < R_p$
- $R_s$ minimum radius
- $R_p$ maximum radius
- $\tau_p$ expansion factor
- $\delta$ arm thickness
- $\alpha$ arm angular width
- $x_p$ meander amplitude
- $\xi$ meander number

\[
x = \begin{cases} 
    \tau \cos \left( -1^{\alpha} \sin \left( \pi \left( \frac{\tau}{R_p} \right) \right) \pm \delta \right) & R_s < t < R_d \\
    \tau \cos \left( -1^{\alpha} \sin \left( \pi \left( \frac{\tau}{R_p} \right) \right) \pm \delta \right) \left( 1 + x_p \cos \left( \xi \left( -1^{\alpha} \sin \left( \pi \left( \frac{\tau}{R_p} \right) \right) \pm \delta \right) \right) & R_d < t < R_p 
\end{cases}
\]

\[
y = \begin{cases} 
    \tau \sin \left( -1^{\alpha} \sin \left( \pi \left( \frac{\tau}{R_p} \right) \right) \pm \delta \right) & R_s < t < R_d \\
    \tau \sin \left( -1^{\alpha} \sin \left( \pi \left( \frac{\tau}{R_p} \right) \right) \pm \delta \right) \left( 1 + x_p \cos \left( \xi \left( -1^{\alpha} \sin \left( \pi \left( \frac{\tau}{R_p} \right) \right) \pm \delta \right) \right) & R_d < t < R_p 
\end{cases}
\]
Free Space Sinuous Antenna – Meandering

HPBW on the Azimuth Plane

Classical Sinuous Antenna

Parameter:
- \( R_p \) maximum radius = 60 mm
- \( \tau_p \) expansion factor = 0.79
- \( \delta \) arm thickness = \( \pi/10 \)
- \( \alpha \) arm angular width = \( \pi/10 \)
- \( x_p \) meander amplitude = 0
- \( \zeta \) meander number = 0

Meandered Sinuous Antenna

Parameter:
- \( R_p \) maximum radius = 60 mm
- \( \tau_p \) expansion factor = 0.79
- \( \delta \) arm thickness = \( \pi/10 \)
- \( \alpha \) arm angular width = \( \pi/10 \)
- \( x_p \) meander amplitude = 0.05
- \( \zeta \) meander number = 40
Free Space Sinuous Antenna – Sharp ends

Optimized sharp ends

reduction of the sharp ends $t_R$ [mm]
Free Space Sinuous Antenna – Sharp ends

Optimized sharp ends

For $t_R > 10$ mm the increases the gain at low frequency and the flatness in band

reduction of the sharp ends
Free Space Sinuous Antenna – Substrate

Dielectric Cylinder Loading

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<th>εr</th>
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<tr>
<td>d₈  = 2</td>
<td>εr₈  = 6</td>
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</tbody>
</table>
Free Space Sinuous Antenna – Substrate Loading

Parameter:

- $R_p$ maximum radius = 60 mm
- $\tau_p$ expansion factor = 0.79
- $\delta$ arm thickness = $\pi/10$
- $\alpha$ arm angular width = $\pi/10$
- $x_p$ meander amplitude = 0.05
- $\xi$ meander number = 40

Meandered Sinuous Antenna

Meandered Sinuous Antenna with dielectric loading
Free Space Sinuous Antenna – Substrate Loading

Reduction of the minimum working frequency from 2.9 to 1.5 GHz
Optimized Cavity Backed Sinuous Antenna

- Polyethylene (FOAM)
- Meandered Sinuous Antenna Circuit
- Dielectric Cylinder Loads
- Polypropylene-based magnetic absorber (PP1000)
- Dielectric RG5880 2mm
- PEC
Optimized Cavity Backed Sinuous Antenna

Boresight Realized Gain

Squint

HPBW

Elevation = 0°
Conclusions

✓ Introduction to the Sinuous Antenna

✓ Design
  o Substrate Investigation
  o Meandered Shape
  o Dielectric loads
  o Cavity Backed Sinuous Antenna

✓ Simulation Results
  o HPBW on the Azimuth Plane
  o S45 Boresight Realized Gain
  o Squint
Thank you for the attention!

Any questions?
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