“1.5 - 40 GHz Meander Spiral Antenna Simulation and Design”

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Introduction

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- Design Methodology
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Application

- **Electronic Support Measurement (ESM)**
- **Radar Warning Receiver (RWR)**

![Antenna and Radome](image)

![ESM System](image)
Design Specification

- **UWB Frequency Operation** → $f_{\text{Max}} : f_{\text{min}}$
- **Accepted Field Polarization** → LHCP − PO − PV
- **Gain Flatness** → $G_{\text{dB}}(f) \pm \Delta G$
- **HPBW Stability** → $\text{HPBW}(f) = \text{HPBW}_0 \pm \Delta \theta$
- **Return Loss** → $|S_{11}(f)| < S_{\text{0dB}}$
- **Mechanical Constraints** → $L_{\text{Max}} \times H_{\text{Max}} \times W_{\text{Max}}$
- **Reproducibility** → **Industrialization**
- **System Requirement** → **Target Cost; ...**
Antenna Topology

Spiral Antennas are suitable for ESM/RWR System application

Typical Electrical Parameter

- \( S_0 \text{dB} < -10 \text{ dB} \)
- \( \text{HPBW}_0 \approx 80^\circ \)
- \( G_{\text{LHCP}} \approx 3 \text{ dBi} \)
- Low Profile \( W_{\text{Max}} < R_{\text{Max}} \)
- Cross-polarization < -20dB @ Boresight
**Numerical Approach**

**Mixed Potential Integral Equation (MPIE) Formulation of Maxwell Equation**

\[ \hat{n} \times (-j\omega \vec{A} - \nabla \phi) = \hat{n} \times Z_s \vec{J} \]

**MoM applied to MPIE (ANSOFT Planar EM)**

- Suitable for Planar Structure
- Tetrahedrical Mesh
Design Methodology

The Antenna Design is divided in two phases:

The three substructure Design

- Feeding Circuit
- Absorber material filled Cavity
- Radiating Circuit

Complete spiral antenna analysis and total radiating element performances evaluation
The feeding circuit must provide a transition from an unbalanced guiding structure to a balanced one (Balun).

In addition, it must provide an impedance transformation to match the radiating circuit input impedance over the whole frequency bandwidth.
Feeding Circuit Design (2/2)

Balun Material: ARLON® AD600 ($\varepsilon_r = 6$) with thickness $t = 0.508\text{mm}$

$S$-parameter Simulation

\[
| S_{11}(f) | \quad | S_{21}(f) |
\]

![Graph of Return Loss](image1)

![Graph of Insertion Loss](image2)
The Backside Cavity is filled with Honeycomb Absorber (HC) to suppress the back radiation.

The HC Absorber has been modeled with three different uniform lossy dielectric layers.
Radiating Circuit Design (1/3)

- **Equiangular Shape**
  \[ r = r_0 e^{a(\phi + \varphi)} \]
  - Self Complementary Structure
  - Lower Losses

- **Archimedean Shape**
  \[ r = r_0 (\phi + \phi_0) \]
  - Stability of phase centre
  - Improved Axial Ratio
  - Wider operating frequency BW with a given antenna diameter
Radiating Circuit Design (2/3)

- Combined Spiral Antenna

\[ \frac{r_{\text{Max}}}{r_{\text{Eq}}} \approx 1.5 \]
Radiating Circuit Design (3/3)

- Meander Combined Spiral Antenna

Ω = 2π/60
Technology Choice

- **Antenna Dielectric Substrate Analysis**
  - Current Density distribution (@2GHz) vs Dielectric **substrate permittivity** $\varepsilon_r$

  $$r_a \equiv \frac{\lambda_{\text{eff}}}{2\pi}$$
  $$r_a = \text{Radius of active region}$$

- **Current Density distribution (@2GHz) vs Dielectric **substrate Thickness** $H$

  | $H=0.2\text{mm}$ | $H=0.4\text{mm}$ | $H=0.8\text{mm}$ | $\varepsilon_r=1$ | $\varepsilon_r=3.5$ | $\varepsilon_r=10$ |
Size Reduction

**15% size reduction with**
**Meandering last spiral wings**
NF to FF Measurement (1/3)

- Near Field Measurements with STARLAB by SATIMO from 0.8 to 18 GHz Antenna
NF to FF Measurement (2/3)

Gain @ 4 GHz

Gain @ 5 GHz

Gain @ 8 GHz

Gain @ 10 GHz

Gain @ 13 GHz

Gain @ 18 GHz
NF to FF Measurement (3/3)

Gain

freq [GHz]

dBi

Gain_phi
Gain_teta
Gain_LCPH
Far Field Measurement (1/2)

- **Far Field Measurements 18-40 GHz** with Anechoic Chamber
Far Field Measurement (2/2)

**Gain @ 26 GHz**

![Graph showing gain at 26 GHz with different patterns]

**Gain @ 30 GHz**

![Graph showing gain at 30 GHz with different patterns]

**Gain @ 35 GHz**

![Graph showing gain at 35 GHz with different patterns]

**Gain @ 40 GHz**

![Graph showing gain at 40 GHz with different patterns]
Simulation Vs Measurement (1/3)

\[ |S_{11}(f)|_{\text{Meas}} \quad \text{Vs} \quad |S_{11}(f)|_{\text{Simu}} \]
Simulation Vs Measurement (2/3)

Broadband LHCP Gain @ Boresight

Gain

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<th>freq [GHz]</th>
<th>Measured</th>
<th>Simulated</th>
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dBi
Simulation Vs Measurement (3/3)

Gain @ 4 GHz

Gain @ 32 GHz

Gain @ 18 GHz

Gain @ 40 GHz
Conclusion

- The design of 1.5 - 40 GHz Meander Spiral Antenna has been performed using Planar EM by Ansoft

- The Antenna Design has been divided in **three substructure**:
  - Balun
  - The Absorber Filled Cavity
  - Circuit Layout

- Combining the **Equiangular** shape and the **Archimedean** shape we have avoided the drawbacks of each radiating structure.

- Meandering the last spiral turns we have obtained about **15% size Antenna reduction**

- The simulated results are in **good accordance** with the measurements in terms of **Return Loss, Gain and Pattern**
Acknowledgments

Design, Simulation and Measure of Broadband Cavity Backed Combined Spiral Antenna
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Optimization of a UWB Vivaldi Antenna Array and Measurements with a Near Fields STARLAB System and Farfield Anechoic Chamber
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