Circular Focal Plane Array for Astronomic Applications

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Outline

- **Introduction**
  - Rectangular Arrays Vs Circular Arrays.

- **ASM in Circular Arrays**
  - ASM – MoM gives the exact solution for the circular array.

- **Design of 3D Vivaldi Single Antenna**
  - Return loss and Radiation pattern.

- **Analysis of Wideband arrays of 3D Vivaldi antennas**
  - Return loss and Radiation pattern.

- **Future Works**

- **Conclusion**
Rectangular Arrays Vs Circular Arrays

- Less truncation effect at the border of the array.
- Advantage of the rotation similarity of the radiation pattern.
- Polarimetric advantage using different polarizations.
- Rotational symmetry: pattern calibration is made easier.
ASM-MoM applied to Circular Array
The current on a given point can be regarded as progressive waves launched by the excited element and reflected by the ends of the array.

Array Scanning Method

\[ I(m) = \frac{1}{2\pi} \int_{0}^{2\pi} I^\infty(\psi) e^{-jm\psi} \, d\psi \]

Current at ant. \( m \) for ant. 0 excited

Infinite-array solution for phase shift \( \psi \) between elements

\[ I(m) \simeq \frac{1}{N} \sum_{p=0}^{N-1} I^\infty(\psi_p) e^{-jm\psi_p} \]

Aliasing:
Repetition of the source every \( N \) elements

\[ \psi_p = 2\pi p/N \]

(B. Munk et al., 1979)
Array Scanning Method

If Array Scanning Method is implemented with the help of finite summation, the source is repeated. (see figure auxiliary peaks)
ASM applied to Circular Array

- Repeated source every N elements, i.e. always on the same element in N-element circular array: with the aliased source, the exact solution is obtained!
ASM applied to Circular Arrays

Method of Moments
(N*M)x(N*M) system of equations

\[
I(m) \approx \frac{1}{N} \sum_{p=0}^{N-1} I^\infty(\psi_p) e^{-jm\psi_p}
\]

\[
\psi_p = p \frac{2\pi}{N} \quad \text{with} \quad (0 < p < N - 1)
\]

N Reduced systems of (MxM).

ASM approximation

\[
[Z_c]\left[I^\infty(\psi_p)\right] = [V(\psi_p)]
\]

\[
Z_c = Z \left[ C_1 \, C_2 \, \cdots C_{N-1} \, C_N \right]^T
\]

\[
C_p = U(N)^* e^{jm\psi_p}
\]

Equivalent to DFT approaches to solving block circulant matrix:
R. Vescovo: “Inversion of Block-Circulant Matrices and Circular Array Approach”,
Design of 3D Vivaldi Antenna
Design of 3D Vivaldi Antenna

- Width $a = 24 \text{ cm.}$
- Height $b = 20\text{ cm.}$
- Circular cavity of diameter $d = 2.4 \text{ cm.}$
- Thickness of 2cm.

- Discretization of the 3D Vivaldi antenna.

Coaxial cable will arrive here from inside the 3D structure.

No transitions required.
Manufacturing

Mazak Variaxis 200 5-axis machine
At the department of mechanical engineering at UCL

Design characteristics:
- Manufacturing precision
- Aluminum used for light weight
- Almost no soldering is required
- Fed via SMA connector on the back

Inside view
Perspective view
The feed
The coaxial feeding
Coupe view
This antenna enhance a 4:1 bandwidth

- Good matching between MoM, CST and Measurements.
Patterns

E-plane (xOz)

H-plane (yOz)

1GHz

3GHz

4GHz

MoM

CST

1GHz 3GHz 4GHz
Circular Array of Wideband Tapered-slot Antennas
Circular Array Design

Sector of the array without the connection

Array structure

Sector of the array with the connections

This arrays is in manufacturing process
Connected elements
⇒ No sharp reflection at ends of slots
⇒ Smoother frequency response
Radiation patterns and connecting BF

At 1GHz

E-Plane
(xOz)

H-Plane
(yOz)

At 2GHz

At 3GHz

With connecting basis functions in red
Dense circular array for focal plane arrays
Dense Hexagonal Array

Periodic element of the array

Dense Hexagonal Array
Bi-concentric Circular Array

Periodic element of the array

Bi-concentric Circular Array
Outer

E-plane (xOz)

1GHz

H-plane (yOz)

2GHz

3GHz
Inner

E-plane (xOz)

H-plane (yOz)

2GHz

3GHz

4GHz

"to be fixed"
Further studies
Circular structures

Concentric Circular Array ?

Dense Hexagonal Cells Array ?
Conclusion

- Link between ASM and Block circulant matrix solution.
- Novel design of 3D Vivaldi antenna
  - Light weight of the antenna.
  - Precise fabrication technology.
  - Suitable to host LNA.
- Effect of the connecting functions: smoother frequency response
- Study of different circular array structures
  - Dense and Concentric Hexagonal arrays.
  - Easier Calibration: Radiation pattern can be compensated.
- Proposed further studies.
Thank You