Dual polarized reflectarray cell for 5G applications

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Outline

▶ mmWaves: a key enabling technology for emerging 5G systems

▶ Reflectarrays: an attractive solution for 5G antennas design

▶ A Novel Dual Polarized Reflectarray Cell for 5G:
  • geometry and layout
  • principle of operation
  • design and analysis

▶ Conclusions
mmWaves: a key enabling technology for emerging 5G systems

The development of new technologies for future fifth generation (5G) wireless communication networks is the main challenge in the telecommunications industry.

5G communication systems are expected to meet the growing demand for higher data rates (i.e. 1-10 Gbps), lower latencies, and more connectivity.

To address this demand, 5G systems will use millimeter wave (mmw) frequencies, which represent one of the key enabling technologies in the development and implementation of 5G communication networks.

However, the mmw frequencies are characterized by propagation limitations, such as higher path loss and shorter communication distances, mainly due to the atmospheric absorption of electromagnetic waves at higher frequencies.
Microstrip reflectarrays can represent an attractive solution in the development of mmw-antennas for 5G, being able to assure large gains/directivities, thanks to the adopted spatial feeding approach.

Furthermore…

reflectarrays can be properly designed to offer several reconfiguration capabilities, which are very appealing for 5G systems, such as:

- frequency agility
- beam-steering functions
- multibeam radiation patterns
- multiband operation modes
- polarization diversity

… useful for improving end-user throughput, capacity and coverage.
A novel dual-band/dual polarized reflectarray cell for 5G

- A single-layer dual-polarized reflectarray configuration is investigated for emerging 5G systems.

- A unit cell offering:
  - A dual-polarization operation mode within the Ka-band (28 GHz)
  - Is designed, by adopting two pairs of miniaturized fractal patches

- The proposed cell allows to achieve:
  - An independent optimization of the phase at each polarization
  - Negligible cross polarization effects
Geometry and layout

The proposed reflectarray unit cell has a single-layer structure consisting of two alternately arranged pairs of linearly polarized fractal patches.
A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

**Geometry and layout**

Each pair operates at the same resonant frequency within the **Ka-band** ($f=28$GHz) …which is under consideration for **5G systems**.

The two pairs of patches are rotated each other by 90° … in order to achieve the desired dual-polarization mode.
A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

**Geometry and layout**

The layout of the single patch composing the cell is derived from the 1\textsuperscript{st} iteration fixed-length patch, proposed by the authors in [1, 2].

Each patch is characterized by a **beginning square element of dimensions** $L \times L$ and a **smaller square of side** $SL$ is removed from the center of patch resonant sides.

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Main benefit of fractal geometries

more electrical length can be fitted into a smaller physical area

As a matter of the fact...

...the increased electrical length of fractal patches \( L_n = (1+2nS)L \)

... leads to lower resonant frequencies

The fractal antennas should be miniaturized in order to obtain the resonance at the desired operating frequency
The **miniaturization skills** of the adopted **fractal geometry** allow to obtain a **dual-polarization behavior**, by embedding **four miniaturized patches** within the same unit cell.
Unit Cell Benefits

Unlike existing dual polarized reflectarray cells

the **proposed reflectarray cell** allows to achieve the following **benefits**:

- **A simpler and thinner structure** \( \approx 0.0237\lambda \) @ 28 GHz) with respect to the most multilayer stacked configurations \[^3\]

- **Smaller unit cell sizes** \( \approx 0.4\lambda \) @ 28 GHz) with respect to other single-layer configurations \[^4\], preserving the capability to point the main beam at large scan angles

Furthermore…

... the above features make the proposed reflectarray configuration, a potential alternative also for space antennas in satellite systems working in transmit–receive (Tx–Rx) operation, with a dual-polarization mode

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A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

Principle of operation

The required phase shifts at both polarizations are obtained by independently varying the scaling factors $S_p$ leaving unchanged the patches sizes $L_p \times L_p \ (p= x, y)$.

The phase shift $\phi_1=28\text{GHz}$ for y-polarization is controlled by the inset size $S_y L_y$.

The phase shift $\phi_2=28\text{GHz}$ for x-polarization is controlled by the inset size $S_x L_x$.

Each scaling factor $S_p$ can vary from 0 up to 0.45.
A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

Design and Analysis

Operating frequency: \( f=28 \text{GHz} \)

Substrate: Diclad880 \( (\varepsilon_r=2.24) \) \( h=0.254 \text{mm} = 0.0237\lambda @ 28\text{GHz} \)

Unit cell size: \( \Delta x=\Delta y=4.3 \text{ mm} = 0.4\lambda @ 28 \text{ GHz} \)

A commercial full-wave code, based on the infinite array approach, is adopted as analysis tool.

A normal incident plane wave is considered.

Synthesized unit cell

\[
\begin{align*}
L_x &= 2 \text{mm} - S_x = 0.357 \\
L_y &= 2 \text{mm} - S_y = 0.357
\end{align*}
\]
A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

Numerical analysis

A resonant behavior can be observed @ 28GHz for both polarizations (i.e. $R_{xx}$ and $R_{yy}$)

Very low cross-polarization levels (i.e. $R_{xy}$) are achieved

Reflection coefficient vs frequency
Phase variations of the reflection coefficient component $R_{xx}$ vs $S_x$ for different $S_y$-values

Simulated reflection phase vs $S_x$ and $S_y$

- $R_{xx}$ @ 28 GHz
- $R_{yy}$ @ 28 GHz

A quite constant reflection phase can be observed @ 28 GHz by changing the scaling factor $S_x$ for a fixed $S_y$-value and viceversa

The proposed dual-polarized unit cell allows to achieve an independent phase tuning mechanism for each polarization.
Conclusion & Future developments

- A **single-layer dual-polarized reflectarray** cell has been designed for **5G applications**

- The proposed cell offers:
  - **a simpler and thinner structure** with respect to the most multilayer stacked configurations
  - **smaller unit cell sizes** with respect to other single-layer configurations

- A parametric analysis of the unit cell has been performed, demonstrating the independence between the two different polarizations

*As future developments* ... the proposed configuration will be further optimized for designing a dual-polarized mmw-reflectarray prototype.
Thanks for the attention