µWAVELAB

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MODELLISTICA, ELETTRONICA
E SISTEMISTICA
DIMES

Dual polarized reflectarray cell for 5G applications

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U.R.S.I.

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

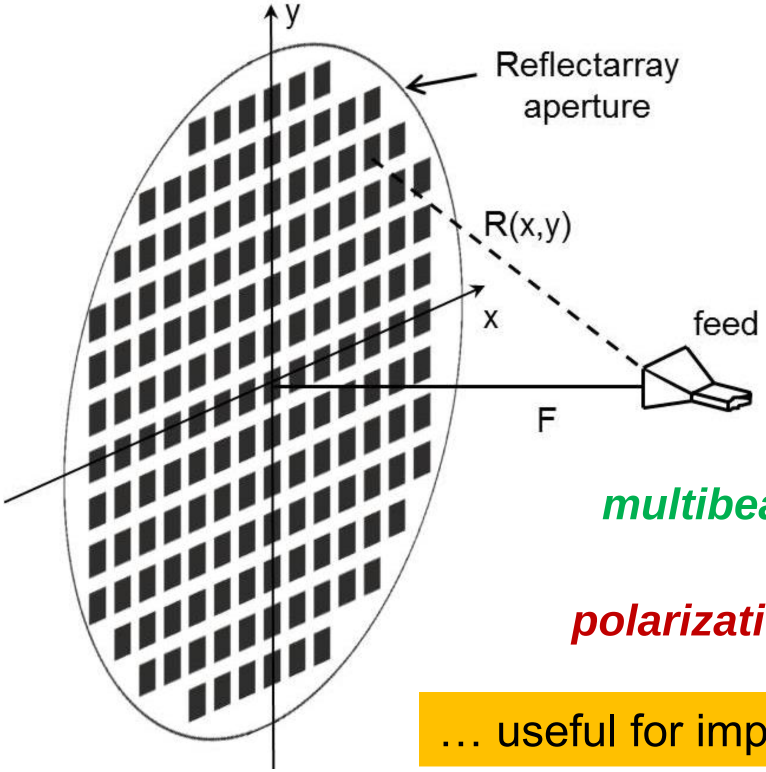
5G communication systems are expected to meet the growing demand for **higher data rates** (i.e. 1-10 Gbps), **lower latencies**, and **more connectivity**

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

Reflectarrays: an attractive solution for 5G antennas design

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

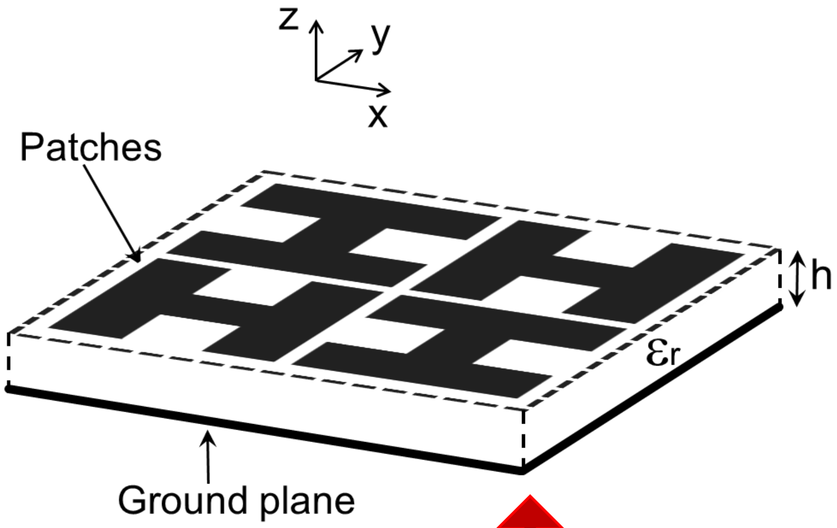
multiband operation modes

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)

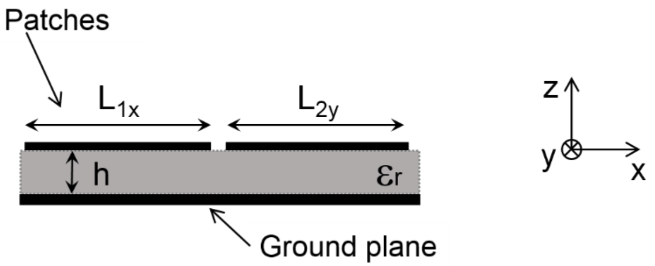
  is designed, by adopting **two pairs of miniaturized fractal patches**

- The proposed cell allows to achieve:
  - **an independent optimization of the phase at each polarization**
  - **negligible cross polarization effects**

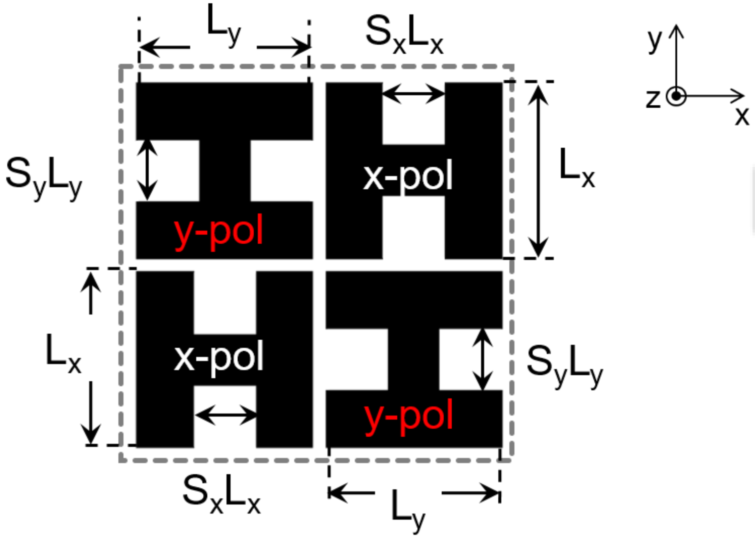
A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

Geometry and layout

The proposed reflectarray unit cell has a **single-layer structure** consisting of **two alternately arranged pairs of linearly polarized fractal patches**



Side view



Top view

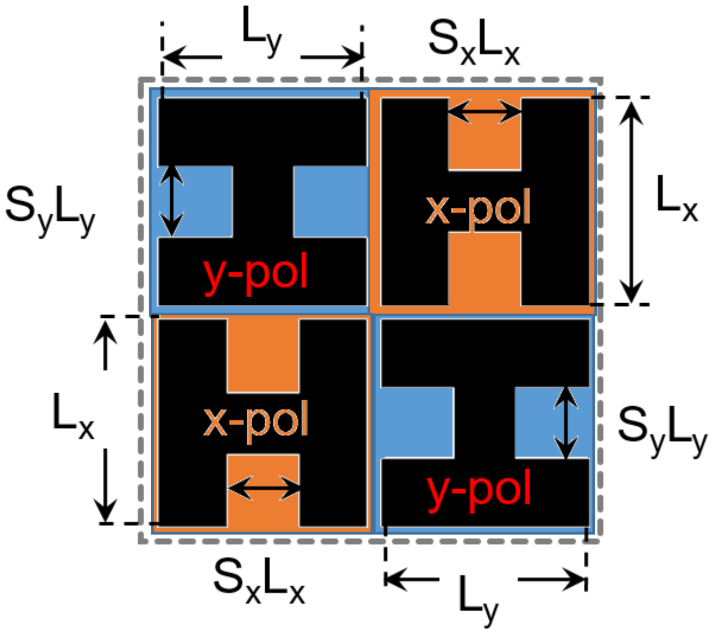
A Novel Dual-Band/Dual Polarized Reflectarray Cell for 5G

Geometry and layout

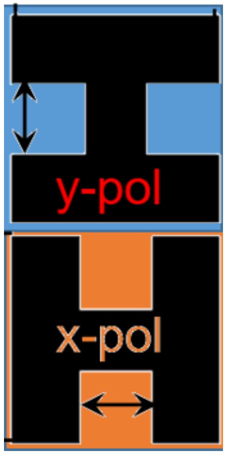
Each pair operates **at the same resonant frequency**

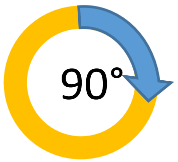
within the **Ka-band** (***f*=28GHz**) …which is under consideration for **5G systems**

Top view



The two pairs of patches are **rotated each other by 90°**



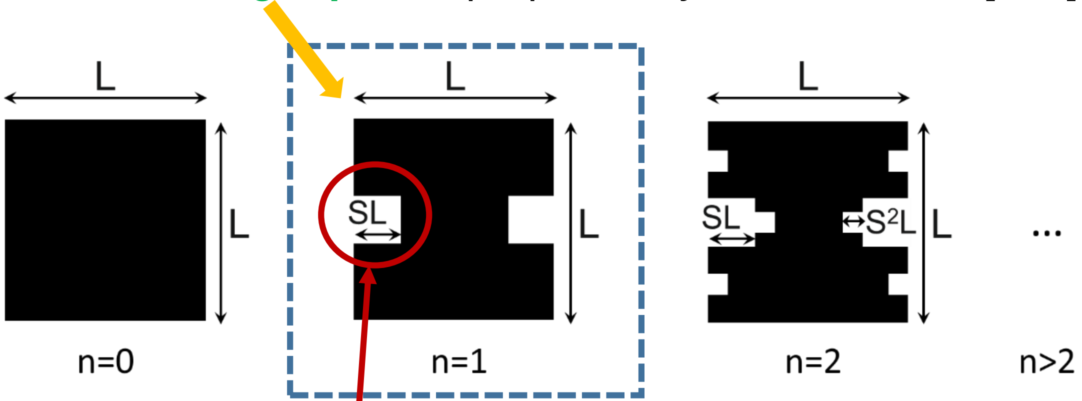


… in order to achieve **the desired dual-polarization mode**

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

Geometry and layout

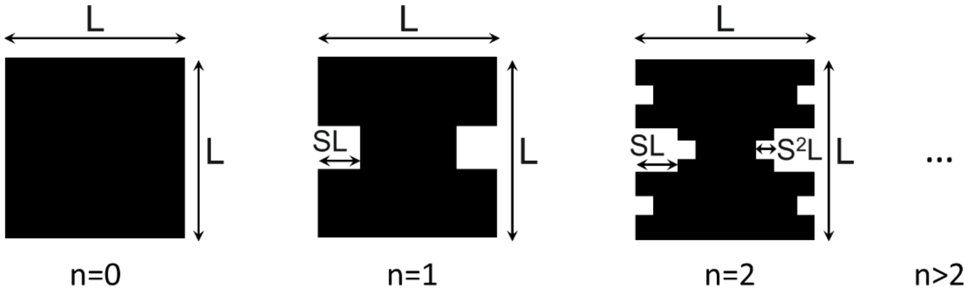
The layout of the single patch composing the cell is derived from the **1st iteration fixed-length patch**, proposed by the authors in [1, 2].



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

1. S. Costanzo, F. Venneri, and Giuseppe Di Massa, "Modified Minkowski Fractal Unit Cell for Reflectarrays with Low Sensitivity to Mutual Coupling Effects," *International Journal of Antennas and Propagation*, vol. 2019, Article ID 4890710, 11 pages, 2019
2. S. Costanzo, F. Venneri, "Miniaturized fractal reflectarray element using fixed-size patch," *IEEE Antennas and Wireless Propag. Letters*, vol.13, pp.1437-1440, 2014

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



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**

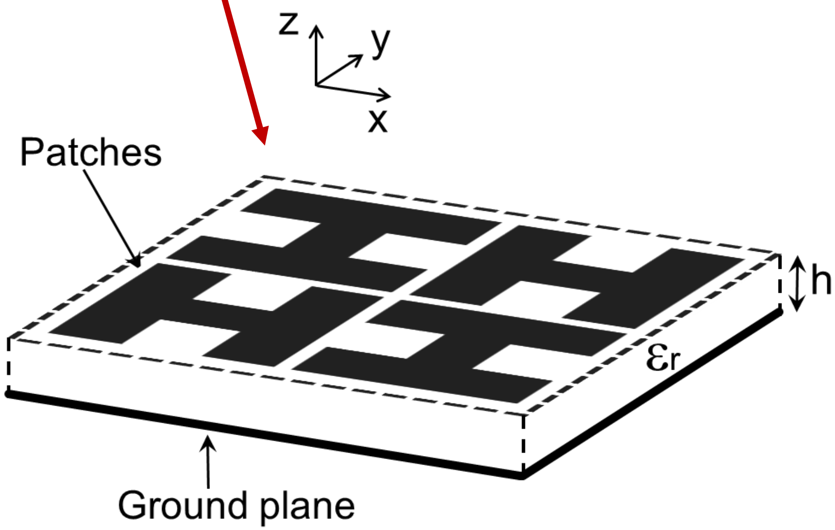
The **fractal antennas should be miniaturized** in order to obtain the resonance at the desired operating frequency

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

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** ($\cong$ **0.0237λ** @ 28 GHz) with respect to the most multilayer stacked configurations [3]
- **Smaller unit cell sizes** ($\cong$ **0.4λ** @ 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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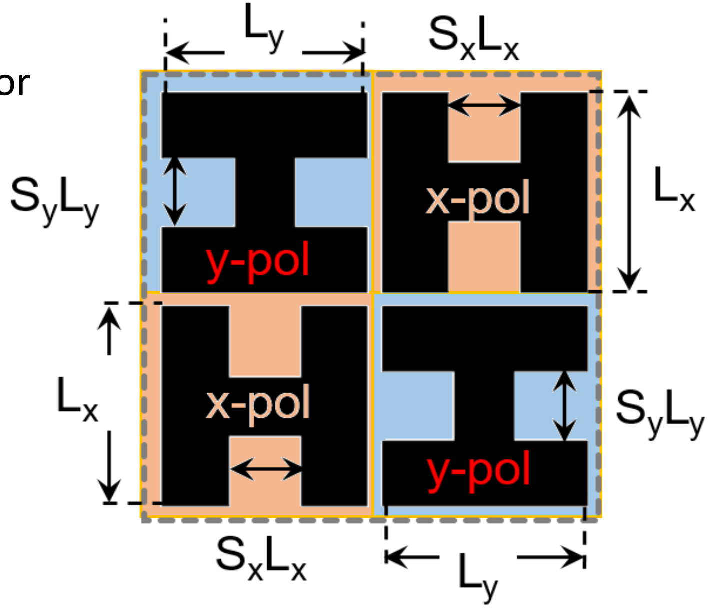
3. E. Martinez-de-Rioja, J. A. Encinar, M. Barba, R. Florencio, R. R. Boix, V. Losada, “Dual polarized reflectarray transmit antenna for operation in Ku- and Ka-bands with independent feeds,” IEEE Trans. Antennas Propag., 65, 2017, pp. 3241−3246.
4. Q. Wang, Z. Shao, P. K. Li, L. Li, Y.J. Cheng, “A dual polarization, broadband millimeter-wave reflectarray using modified cross loop element,” Microwave and Optical Technology Letters, 56, 2, 2014, pp. 287-293.

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 $\mathbf{L_p \times L_p}$ (p= x, y)

The phase shift **@f_1=28GHz** for
y-polarization
is controlled
by the inset size
S_yL_y



The phase shift **@f_2=28GHz** for
x-polarization
is controlled
by the inset size
S_xL_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

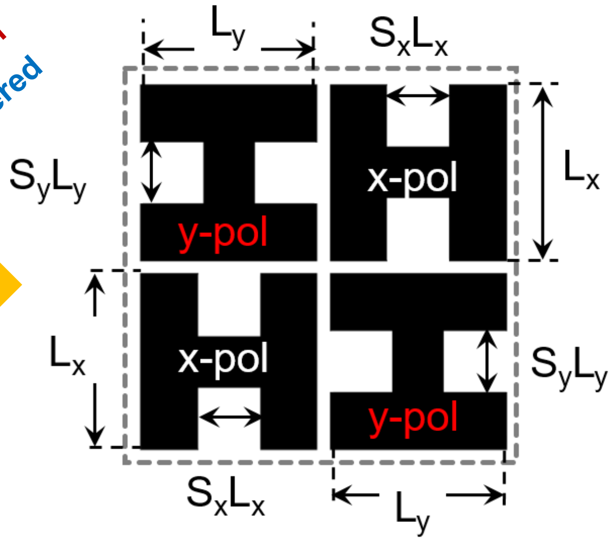
Operating frequency: *f*=28GHz

Substrate: Diclad880 (ε_r=2.24 - **h=0.254mm= *0.0237λ @ 28GHz***)

Unit cell size: Δx=Δy= 4.3 mm = 0.4λ @28 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

L_x= 2mm – S_x=0.357

L_y= 2mm – S_y=0.357

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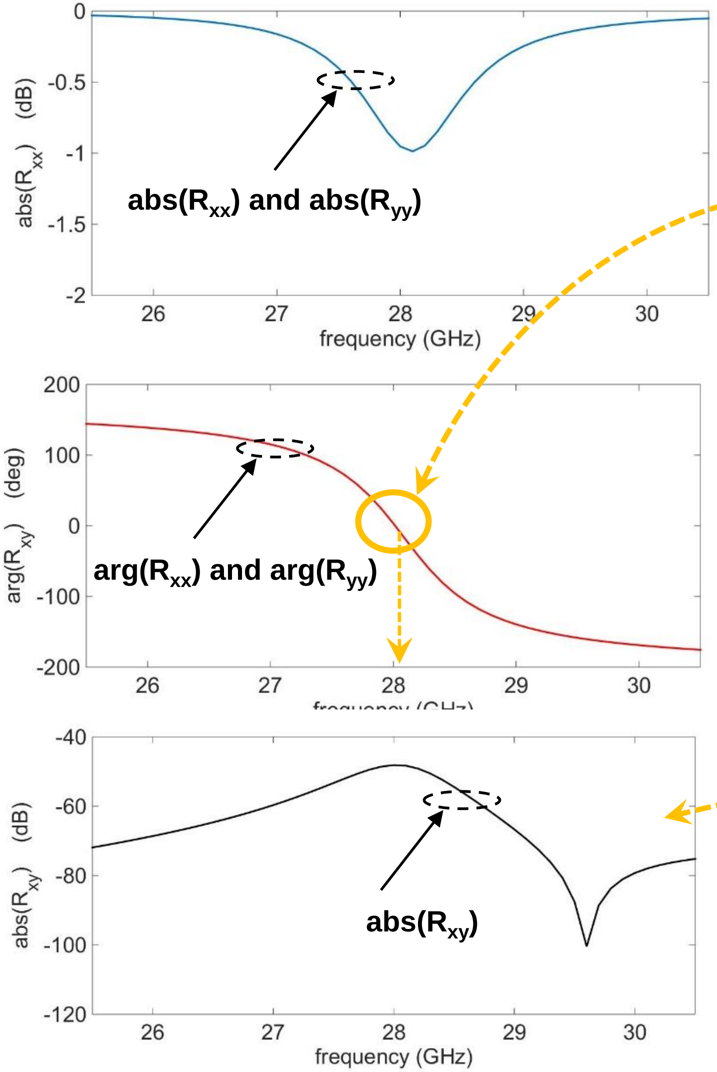
Reflection coefficient vs frequency



abs(R_{xx}) and abs(R_{yy})

arg(R_{xx}) and arg(R_{yy})

abs(R_{xy})

Numerical analysis

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

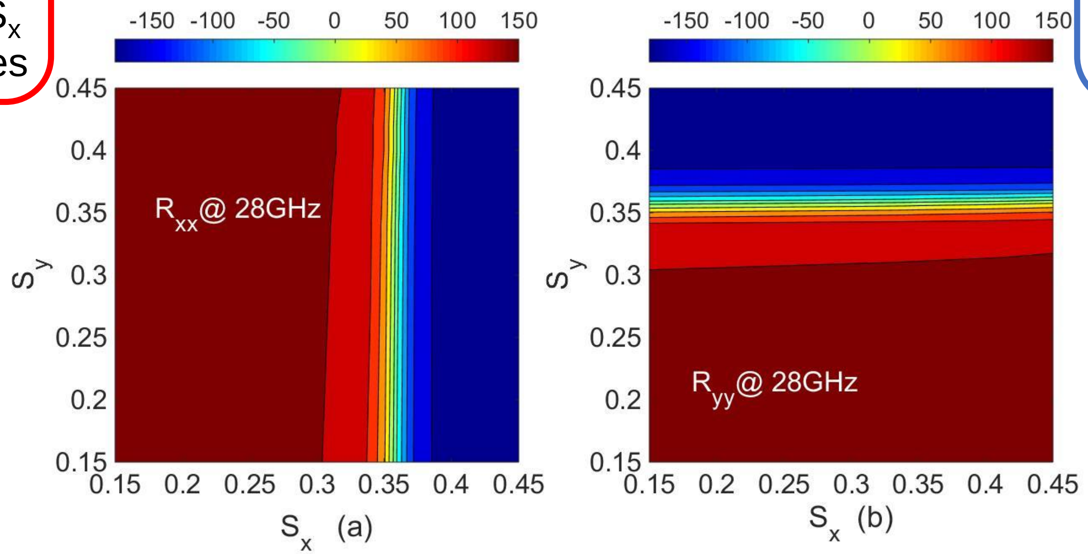
Very low cross-polarization levels (i.e. R_{xy}) are achieved

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

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

Phase variations of the reflection coefficient component R_{yy} *vs* S_y for different S_x-values



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