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# Development of 60 GHz phased antenna array based on a Rotman lens

Michal Pokorný
Jussi Säily
Jouko Aurinsalo

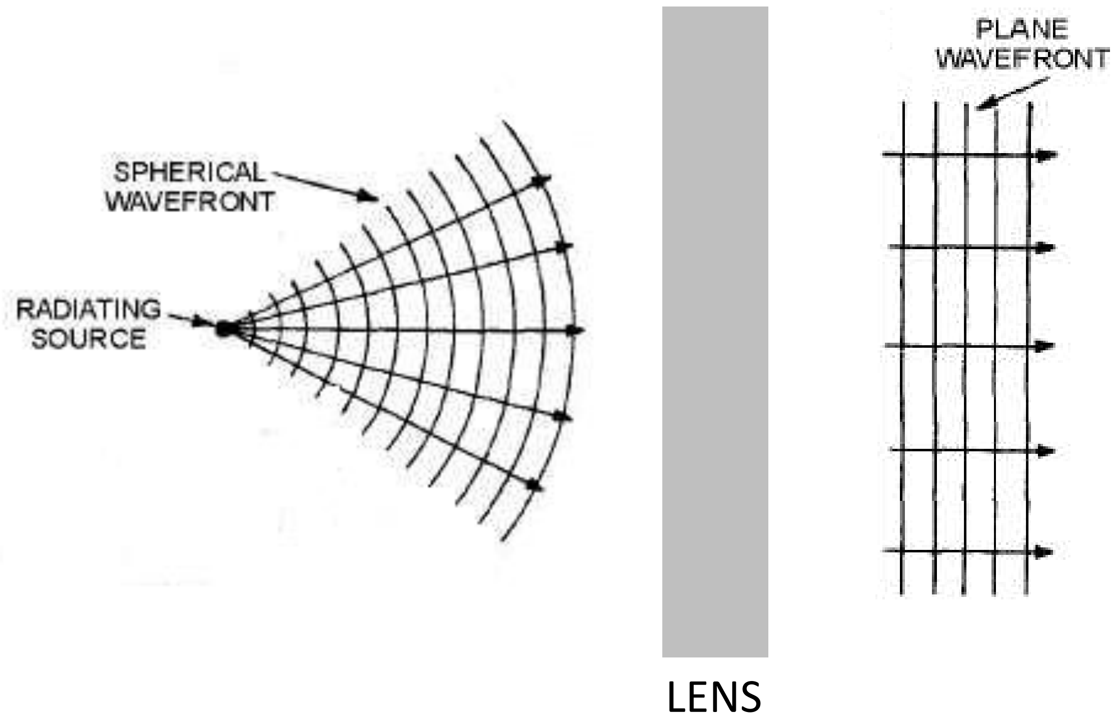
BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION
DREL DEPARTMENT OF RADIO ELECTRONICS
VTT

# Outline

- Rotman Lens Origin
- Interesting Properties of Rotman Lens
- Example RL Design at 50-70 GHz
- Difficulties in Practical Implementation

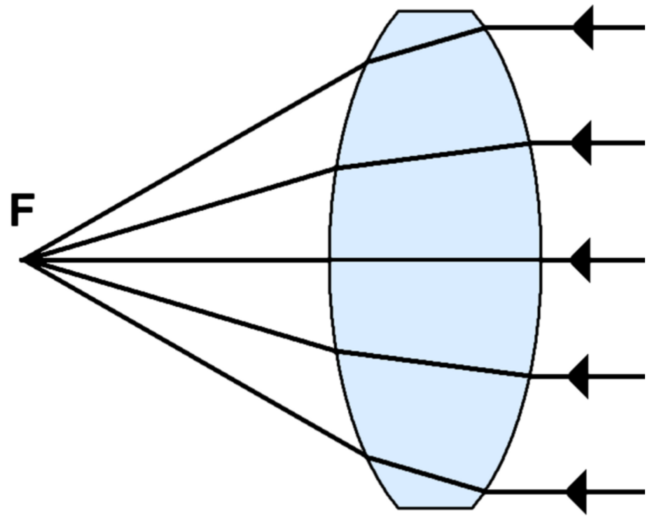
# Rotman Lens Origin

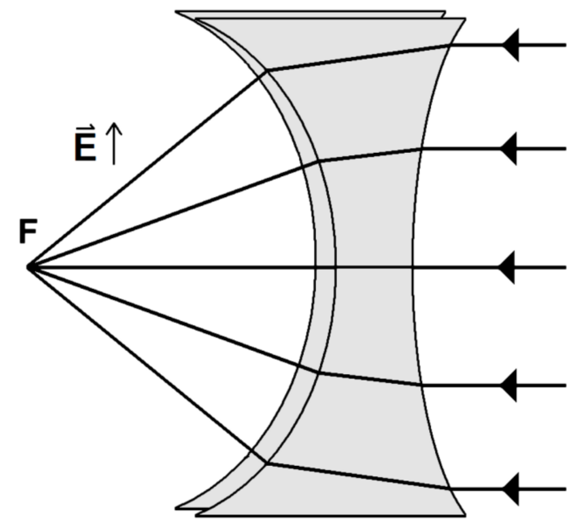
## Operation of Lens Antennas



# Rotman Lens Origin

## Typical Lens Antennas

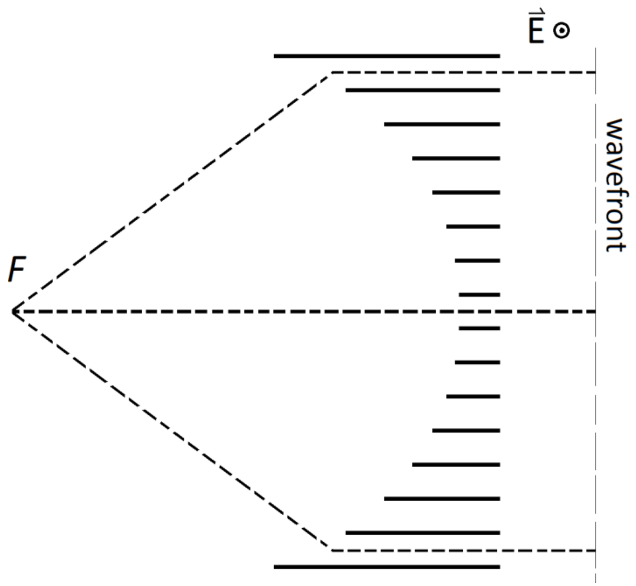


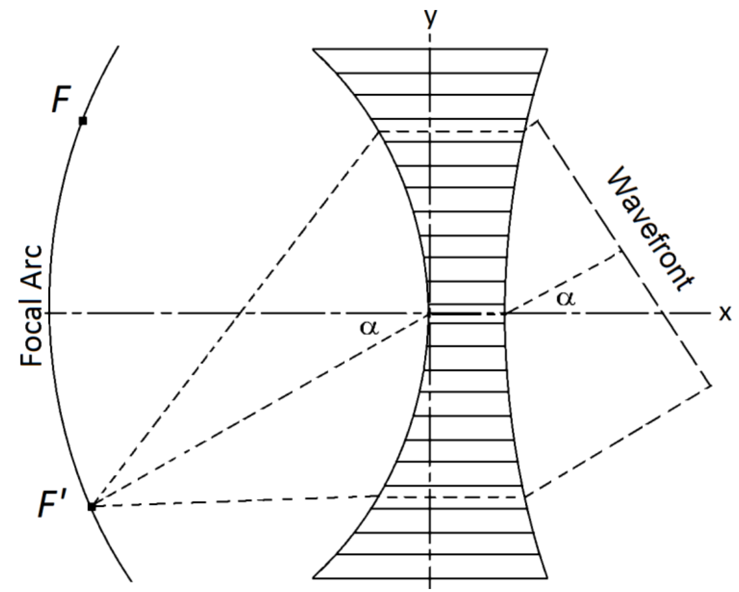

- **Dielectric lens**, using material with a **refractive index > 1**.
- **Metal Lens**, using metal plates to achieve a **refractive index < 1**

# Rotman Lens Origin

## Constrained Metal Lens



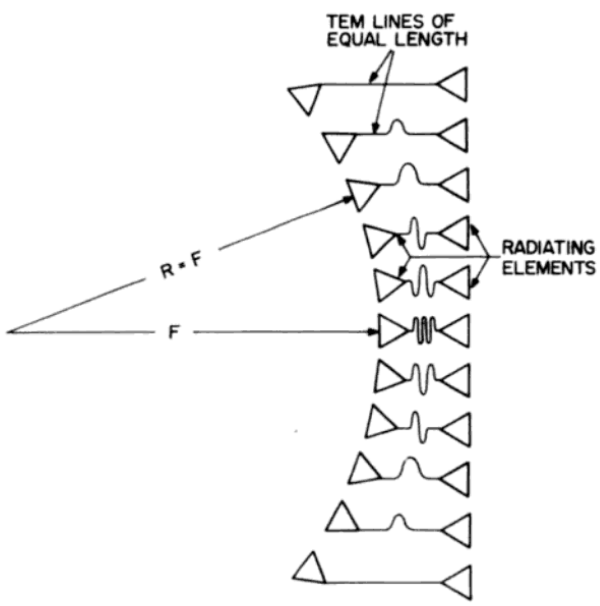

- Typical construction

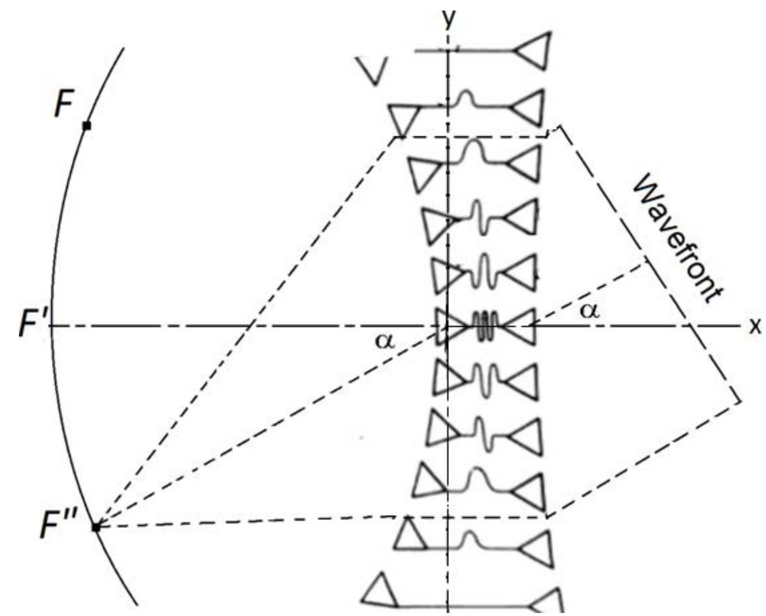



- Two focus points design (bifocal)

# Rotman Lens Origin

## Bootlace Lens

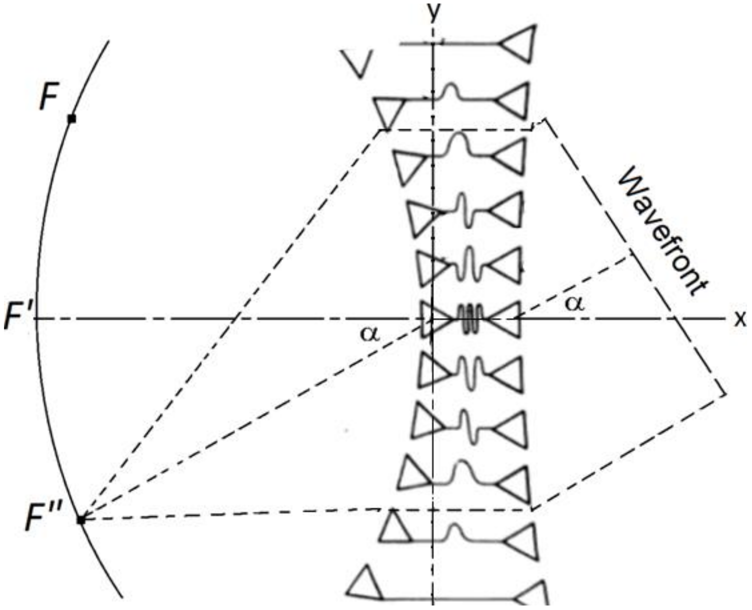


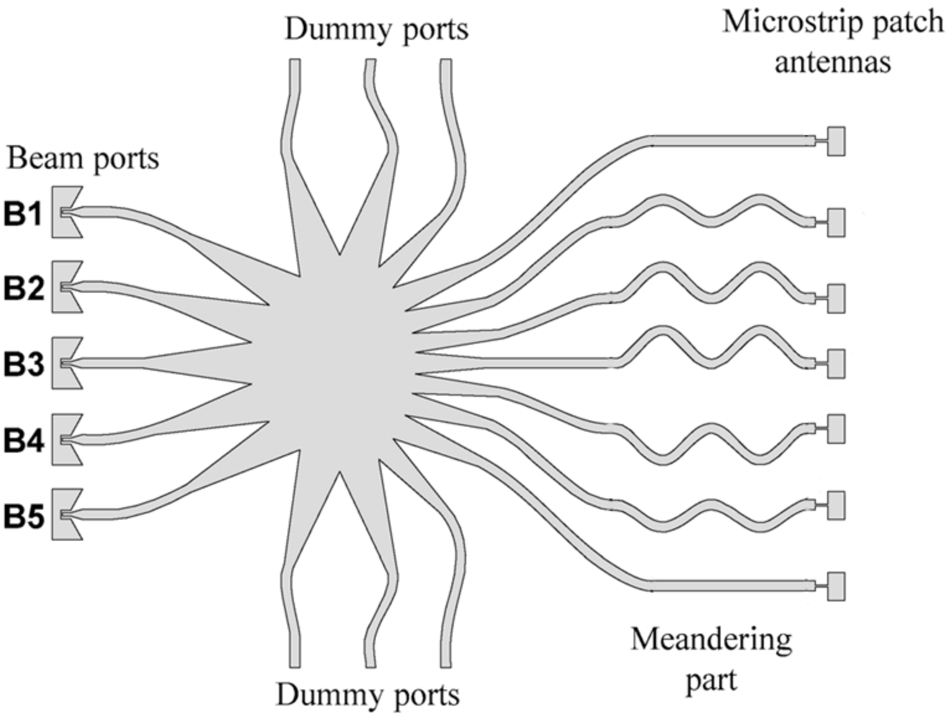




- Monofocal bootlace lens
- Trifocal bootlace lens = **Rotman lens**

# Rotman Lens Origin

## Typical realization of Rotman lens



# Interesting Properties of Rotman Lens

- Multiple beams without the need for phase shifters
- True time-delay device = broadband operation
- Wide scanning angle, typically ± 30°
- All beams can be used simultaneously or can be switched at high rate → pattern diversity (MIMO)
- Beam ports could be combined to create summative or differential diagrams.

# Example RL Design at 50-70 GHz

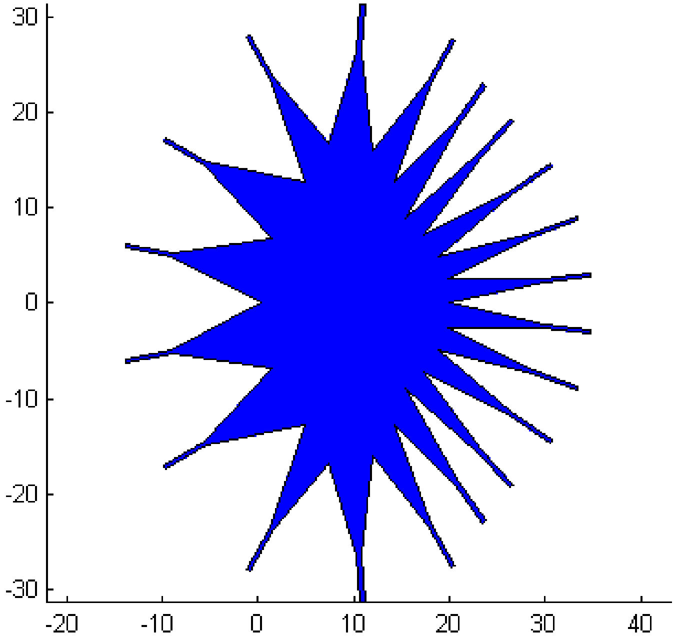
## Printed RL on LCP substrate; $\varepsilon_r$ = 2.9, th = 100 $\mu$m

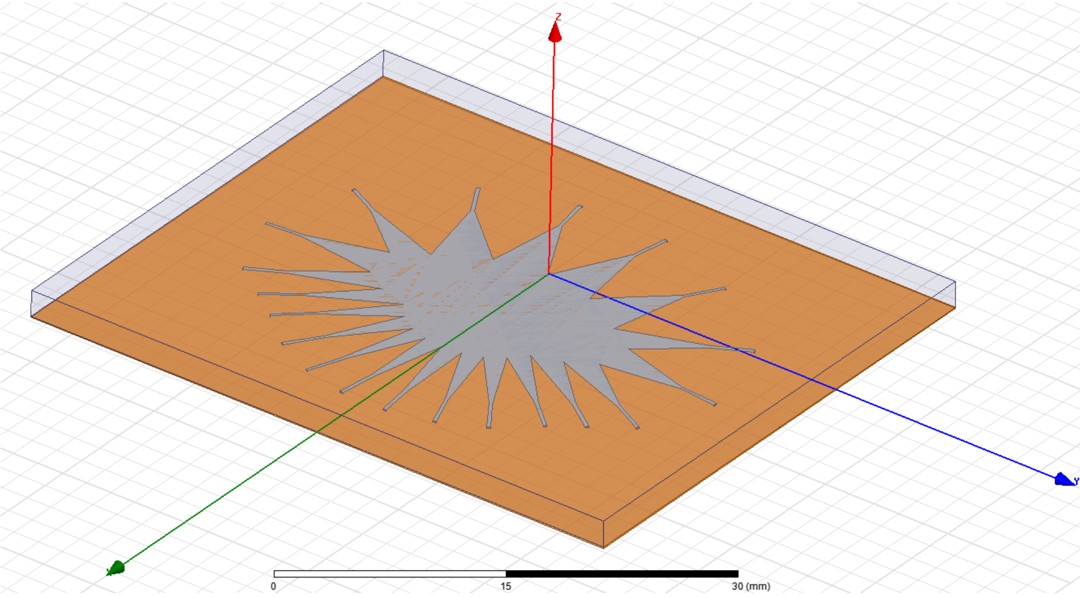
Important input design parameters:

- Central frequency 60 GHz
- Beam scanning angle $\theta = \pm 30°$
- Antenna element spacing $\lambda_0/2$
- Length of the parallel plate region $4\lambda_{\varepsilon_r}$
- 4 beam ports
- 8 array ports
- 8 dummy ports

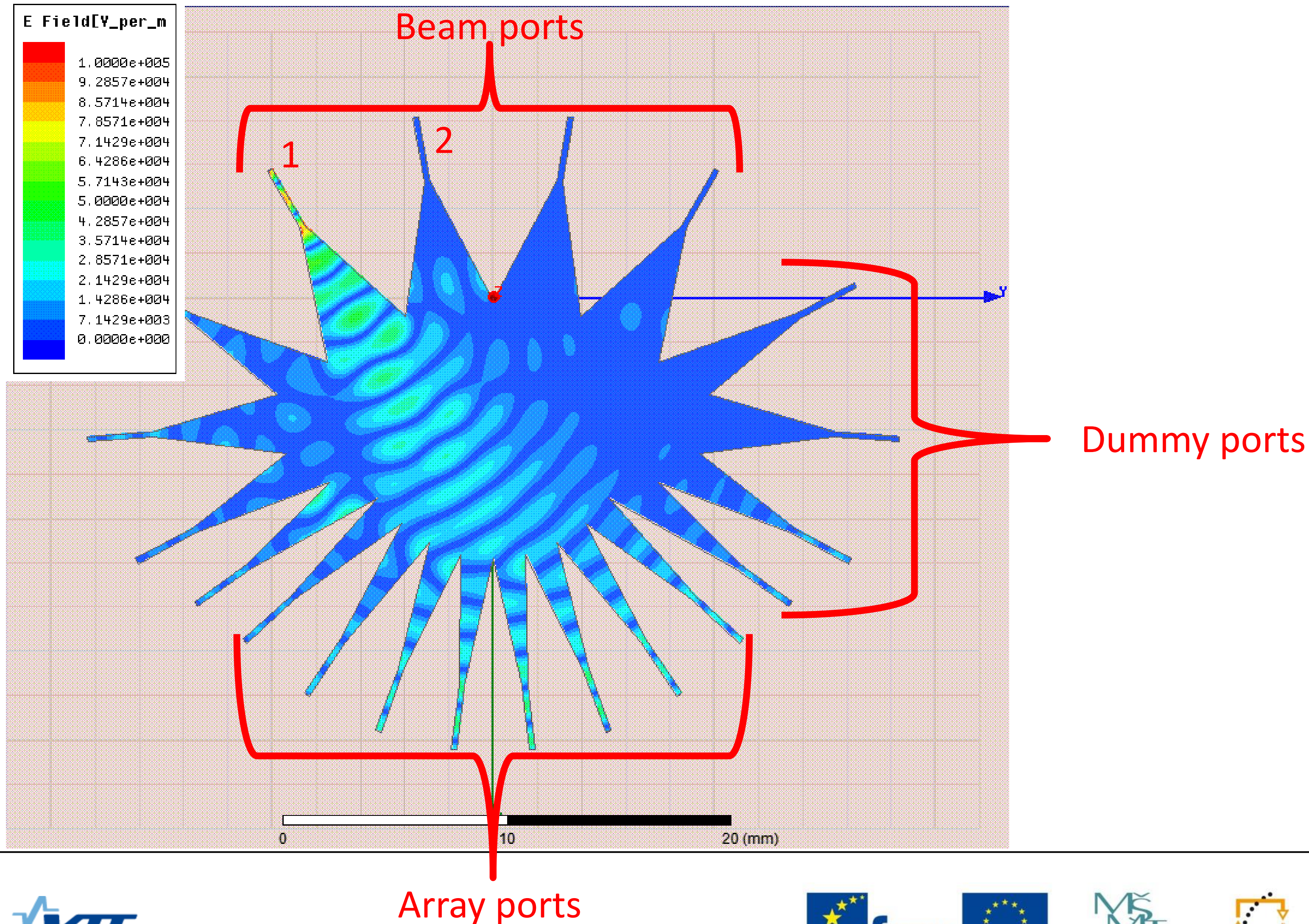
# Example RL Design at 50-70 GHz

MATLAB generated geometry and HFSS file



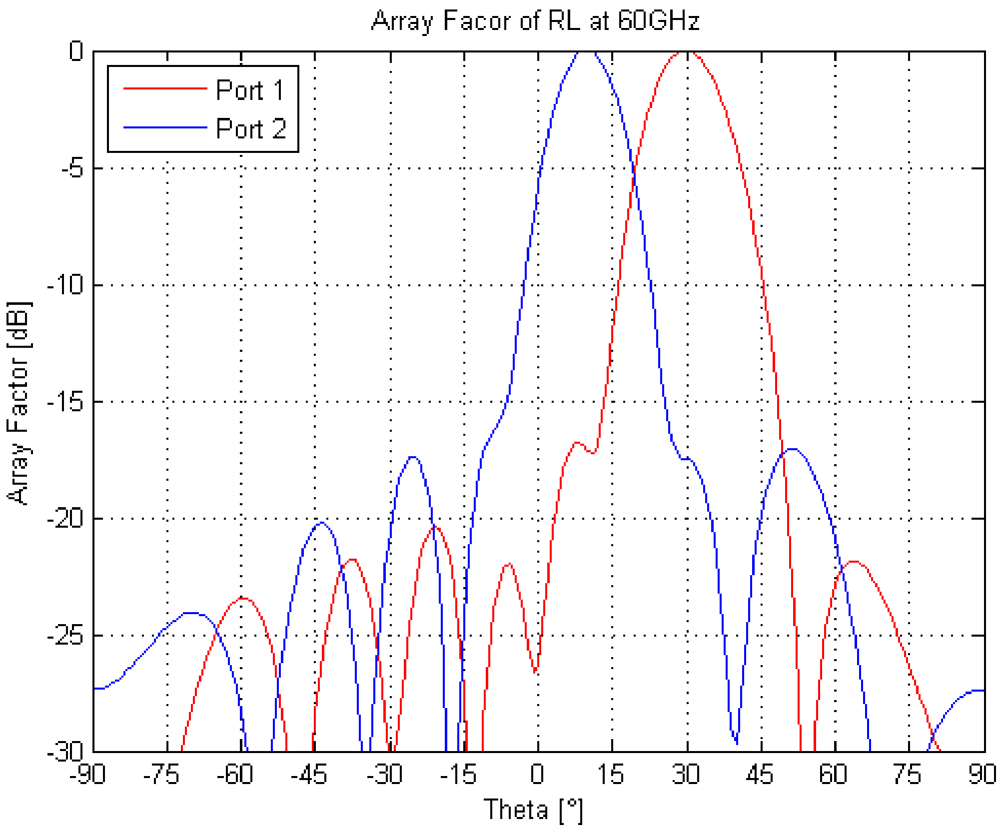



# Example RL Design at 50-70 GHz



# Example RL Design at 50-70 GHz

Evaluated Array Factor using ideal patch antennas

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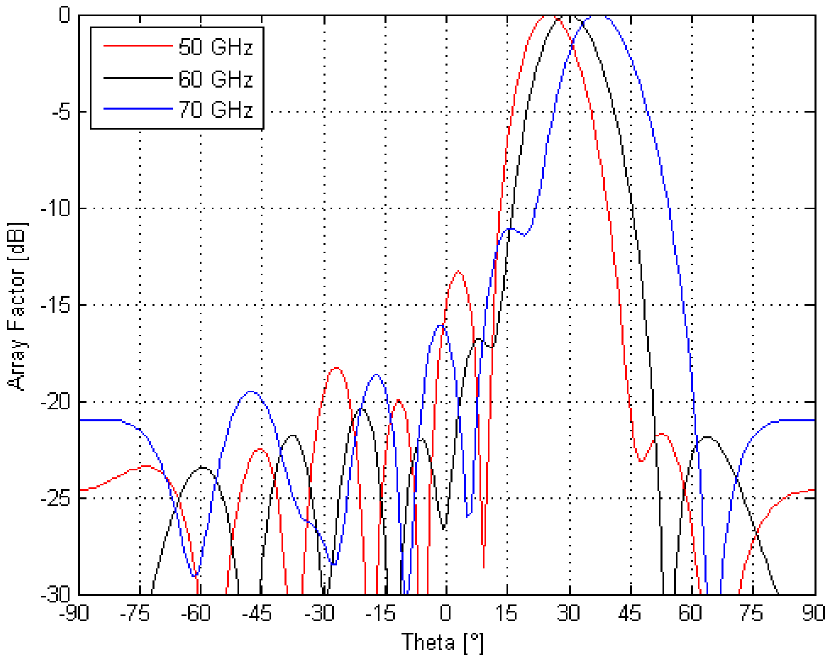
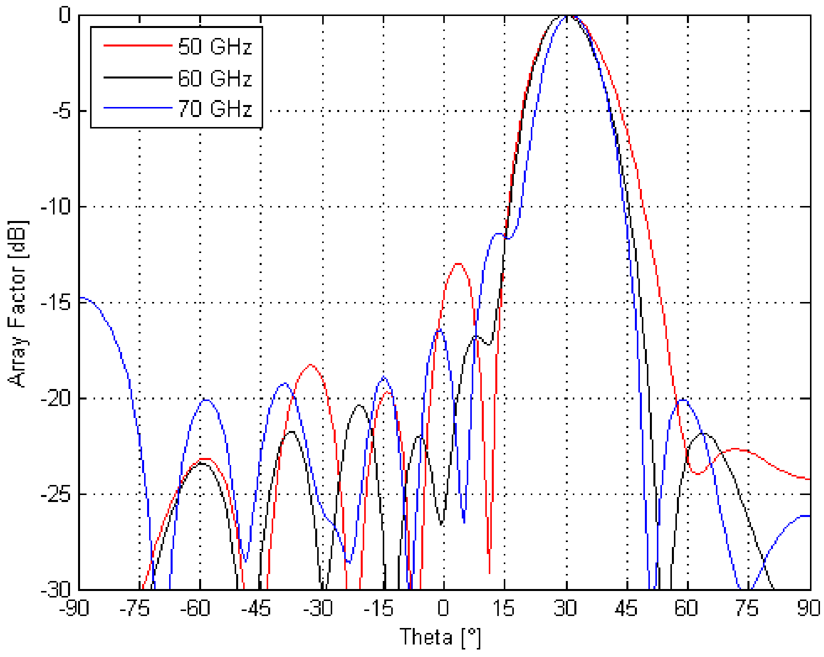
# Example RL Design at 50-70 GHz

## Stability of Scanning Angle in Frequency



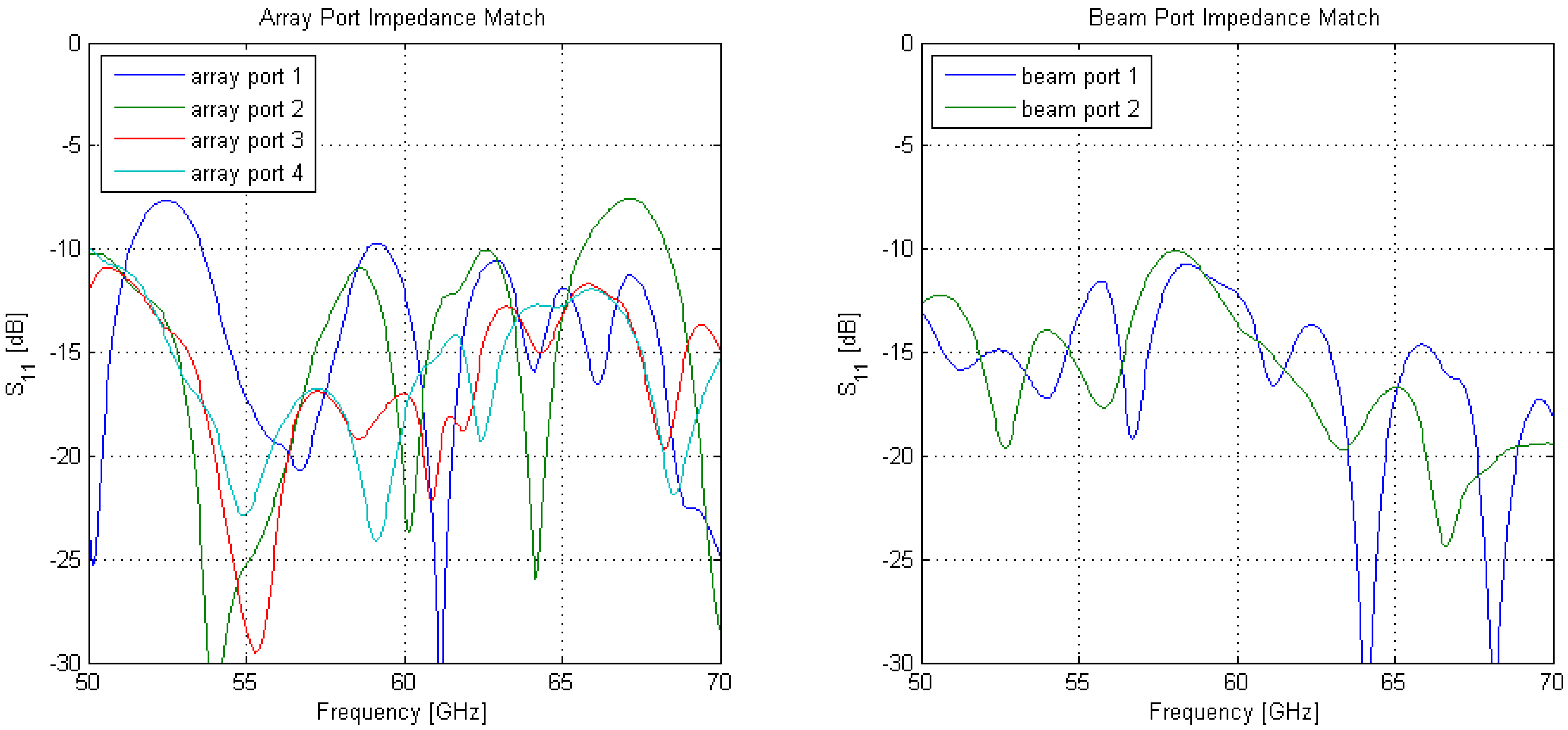

Antenna spacing $\lambda/2$ yielded at 60GHz




Antenna spacing $\lambda/2$ yielded at specific operation frequency

# Example RL Design at 50-70 GHz

## Impedance Match of the Ports

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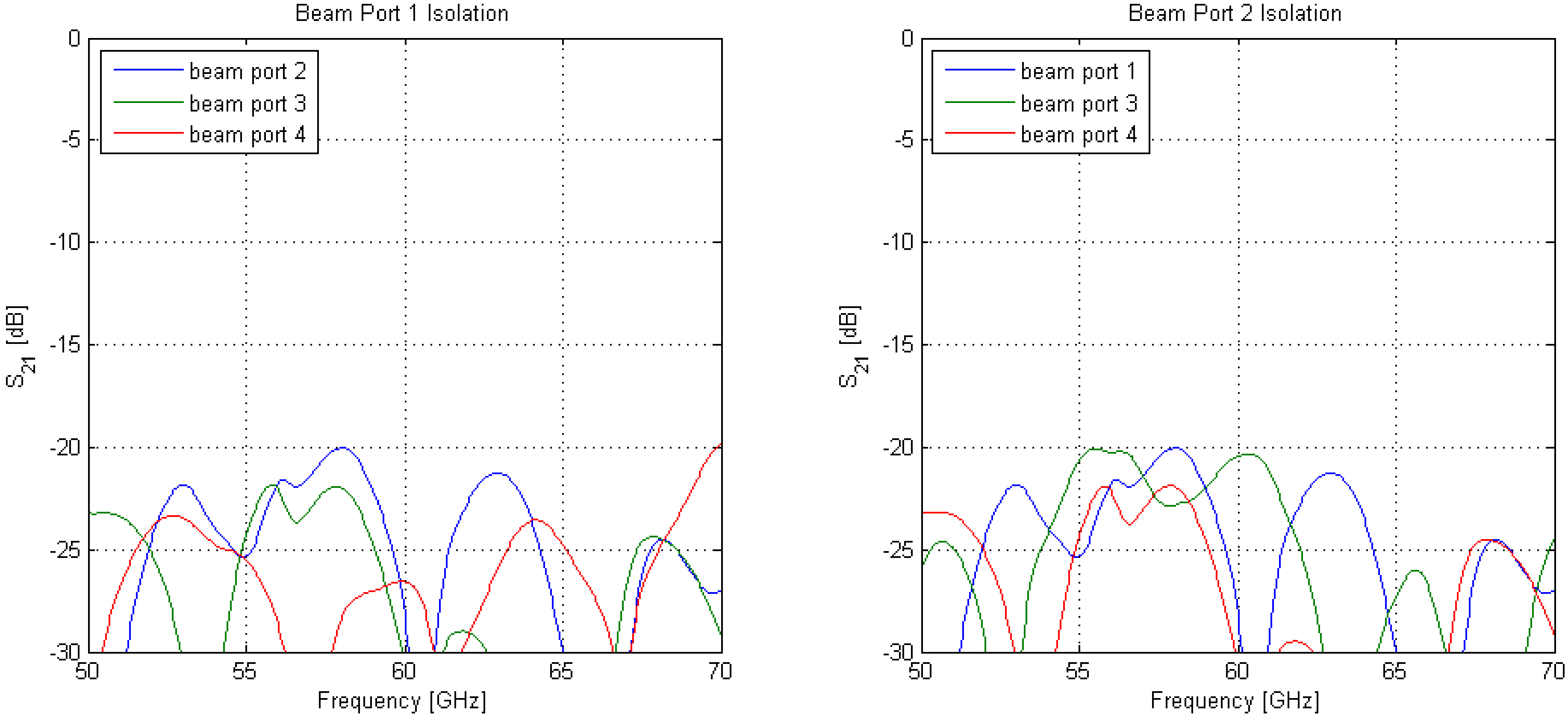
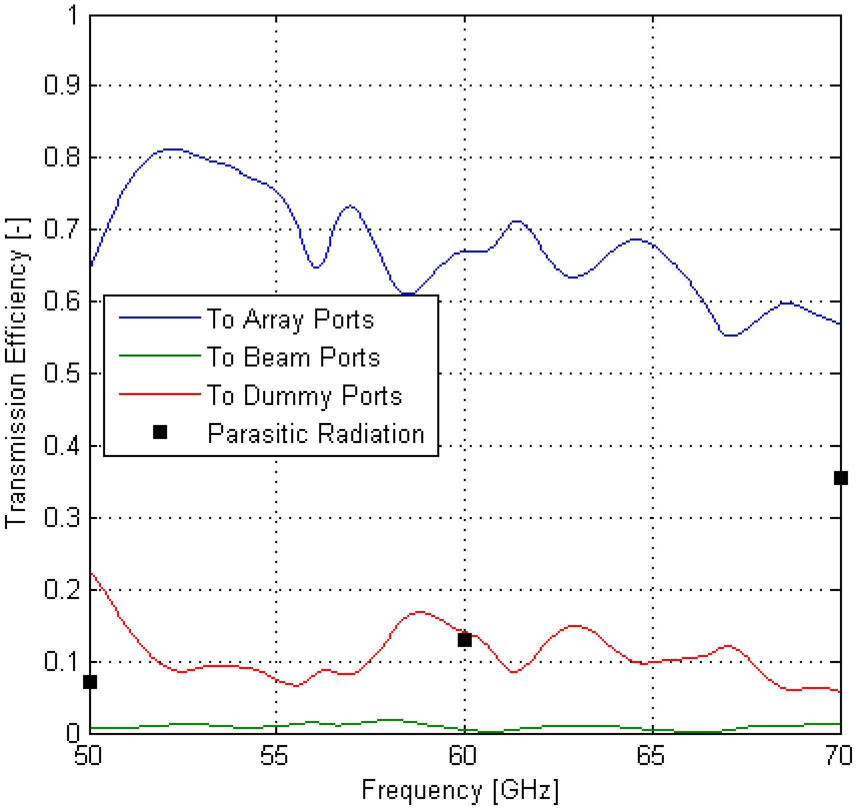
# Example RL Design at 50-70 GHz

## Beam Port Isolation

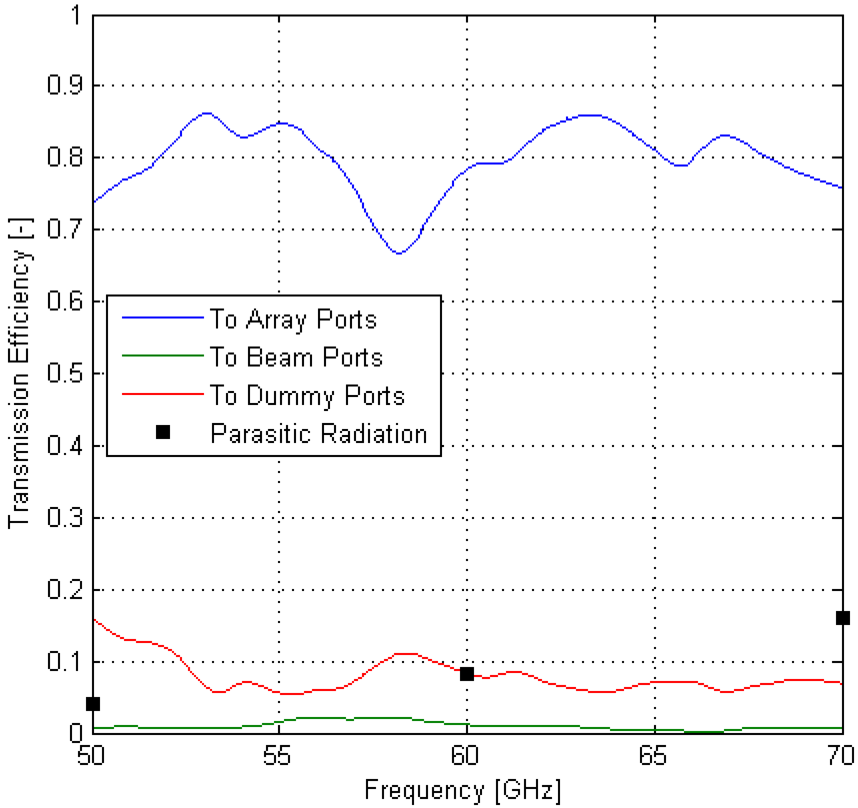


# Example RL Design at 50-70 GHz

## Beam Port 1 Efficiency




## Beam Port 2 Efficiency



# Difficulties in Practical Implementation

## Lens feeding

- SP4T, non-reflective switch (not available on the market)
- Switching network using  non-reflective SPST switches (additional losses)
- Extra radio at each beam port (interesting for MIMO)

## Losses due to

- Substrate tangent delta (not included in this presentation)
- Illumination of the dummy ports
- Parasitic radiation (could be reduced in case of SIW realization)

## Dummy port matched load

- Absorbing material
- Small package resistors
- Printed resistors

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# Thank you for your attention