“Gap Waveguide technology using higher symmetries”

COST ACTION CA16223
SYMAT
FUTURE COMMUNICATIONS WITH HIGHER-SYMMETRIC ENGINEERED ARTIFICIAL MATERIALS

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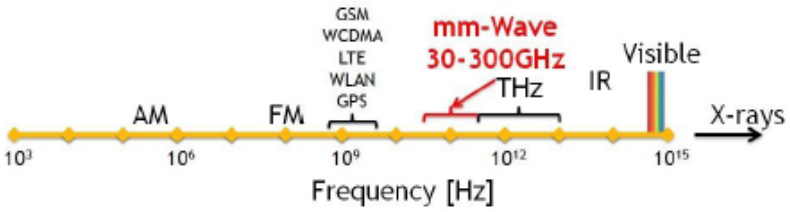
Contents

- Introduction to GAP waveguide technology
- Options to implement the stop-band of PPW modes
- Glide symmetrical holey structure
- Antenna Designs
- Conclusions

Motivation for a new technology

mm-wave band



Requirements:
High reliability technology

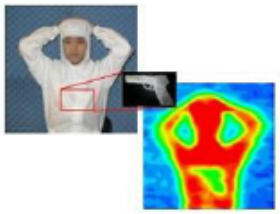
Easy/Direct way:
Scale microwave components

PROBLEMS

Undesired effects due to bad metal contact between pieces

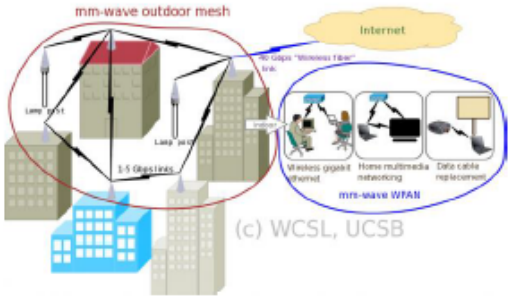
Dielectric losses increases

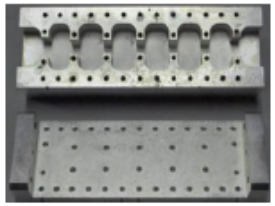
Imaging

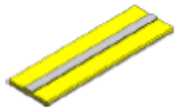


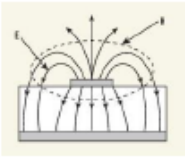
Automotive radars

Ultra-fast radio link & indoor communications



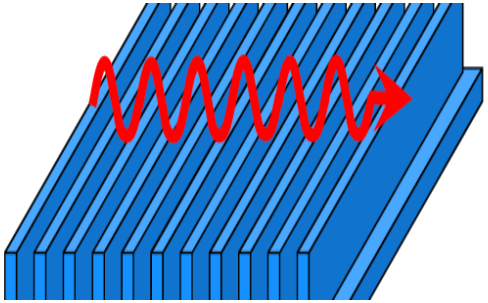


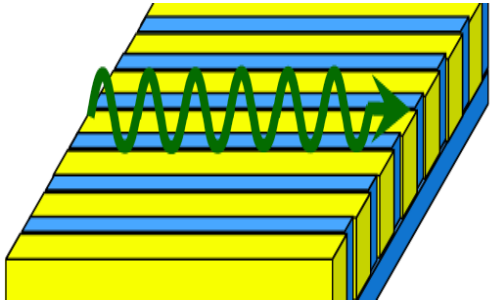




Origin of this Technology

- Originated in Chalmers University of Technology (Sweden)
- Precursor: artificial *soft* and *hard* surfaces





- More in particular a work in collaboration with Technical University of Valencia (UPV, Spain): slot arrays in oversized waveguides

Late Prof. Per-Simon Kildal

- *Main visionary*

84 IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS, VOL. 8, 2009

Local Metamaterial-Based Waveguides in Gaps Between Parallel Metal Plates

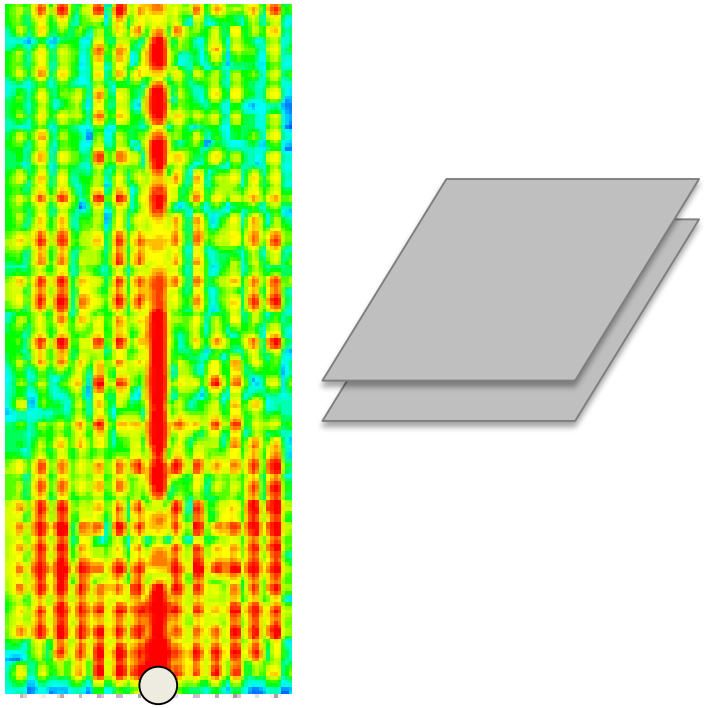
Per-Simon Kildal, *Fellow, IEEE*, E. Alfonso, *Student Member, IEEE*, A. Valero-Nogueira, *Member, IEEE*, and Eva Rajo-Iglesias, *Senior Member, IEEE*

2009

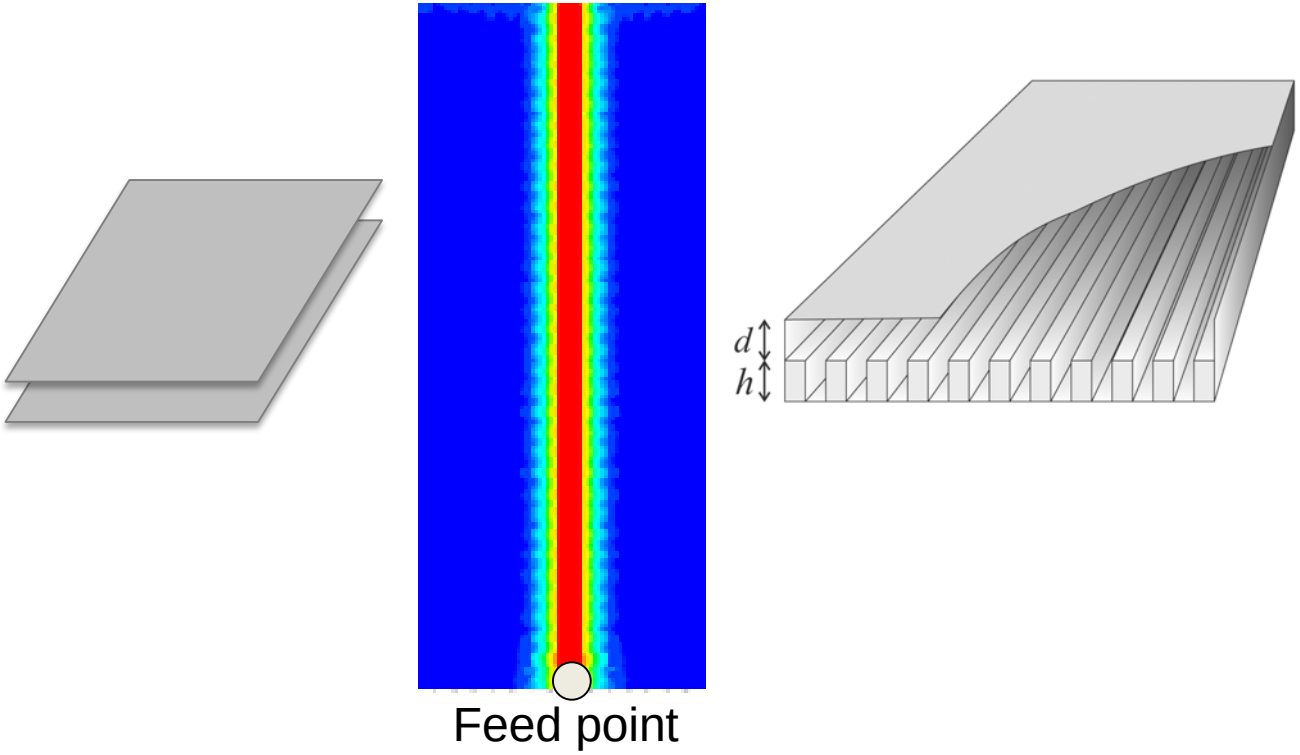
***Abstract*—This letter presents a new metamaterial-based waveguide technology referred to as ridge gap waveguides. The main advantages of the ridge gap waveguides compared to hollow waveguides are that they are planar and much cheaper to manufacture,** so-called substrate integrated waveguide (SIW), as described in [1]. The SIW is made in the substrate of a printed circuit board (PCB) by using metalized via holes as walls. These waveguides

Origin of this Technology

- Classical oversized waveguide:

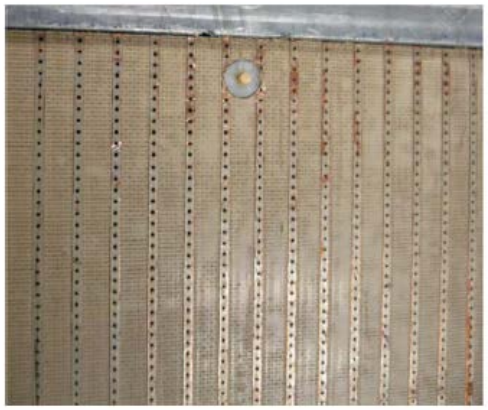


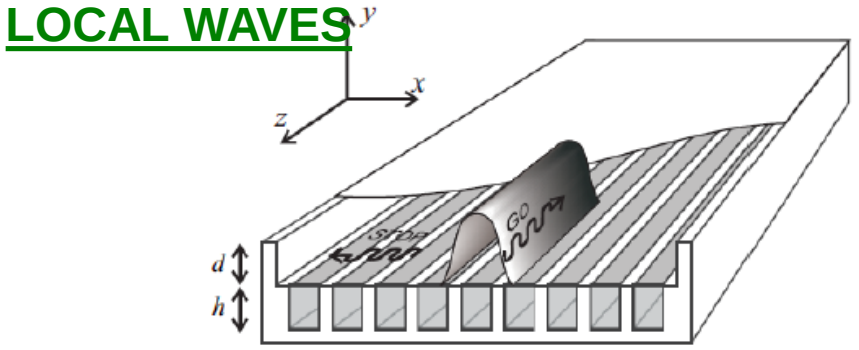
- Oversized waveguide with periodic texture (corrugations):

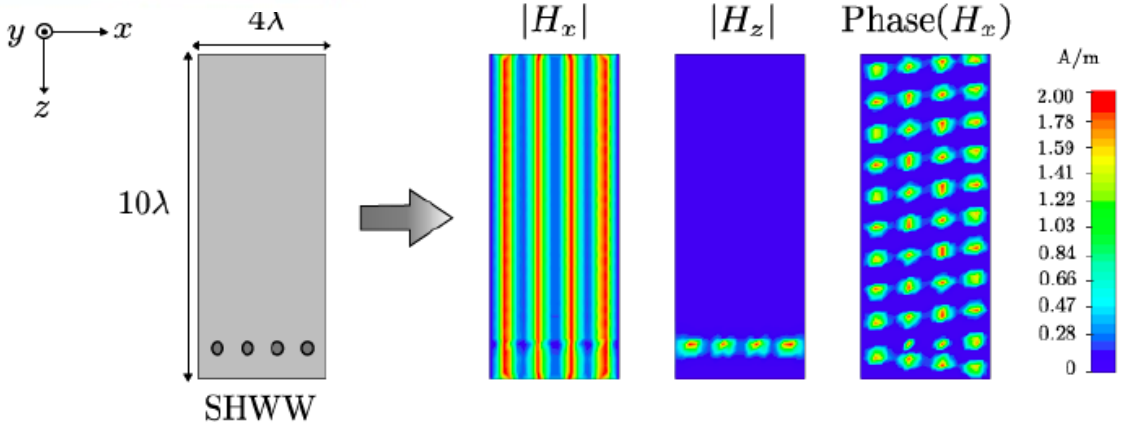


In E. Alfonso et al. "Slot array fed by an oversized TEM waveguide" in EuCAP 2006

Origin of this Technology





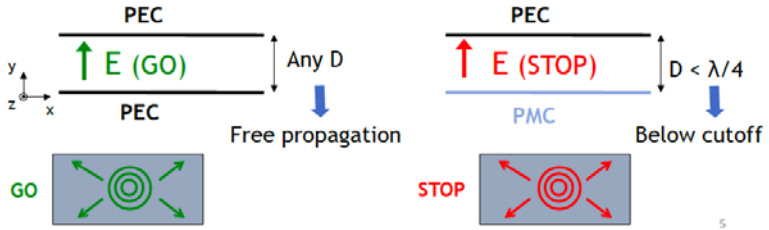


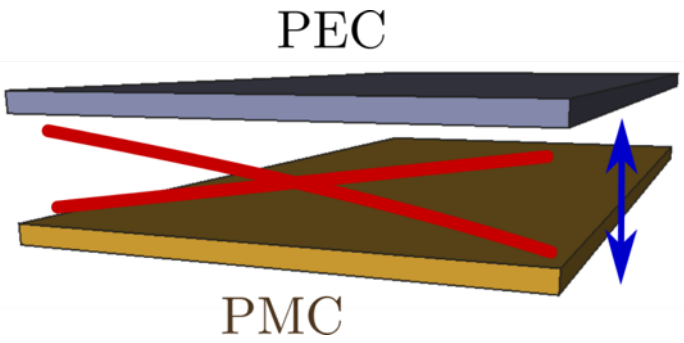
A. Valero-Nogueira, E. Alfonso, J. I. Herranz and M. Baquero, "Planar Slot-array Antenna Fed by an Oversized Quasi-tem Waveguide," in *Microwave and Optical Technology Letters*, vol. 49, no. 8, pp. 1875-1878, Aug. 2007.

A. Valero-Nogueira, E. Alfonso, J. I. Herranz and P. S. Kildal, "Experimental Demonstration of Local Quasi-TEM Gap Modes in Single-Hard-Wall Waveguides," in *IEEE Microwave and Wireless Components Letters*, vol. 19, no. 9, pp. 536-538, Sept. 2009.

Basic Concepts :gap waveguide technology

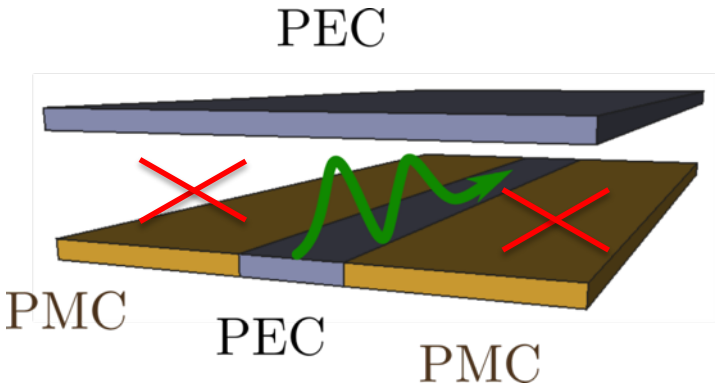
PEC: Perfect Electric Conductor
PMC: Perfect Magnetic Conductor





$$h < \frac{\lambda}{4}$$

No waves can propagate in any direction in the gap between PEC and PMC layer

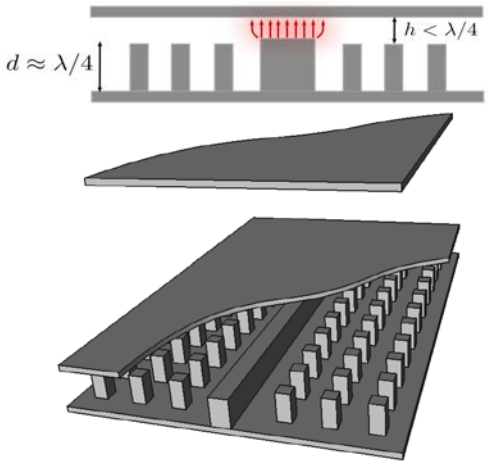


TEM mode can propagate along the PEC strip (parallel plate concept)

Waves in other direction are in cutoff

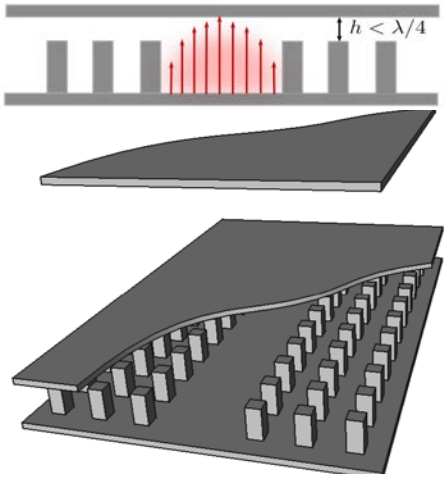
P.-S. Kildal, E. Alfonso, A. Valero-Nogueira, E. Rajo-Iglesias. *Local metamaterial based waveguides in gaps between parallel metal plates* IEEE Antennas and Wireless Propagation Letters, Vol. 8 pp. 84-89, 2009.

Initially: three different versions



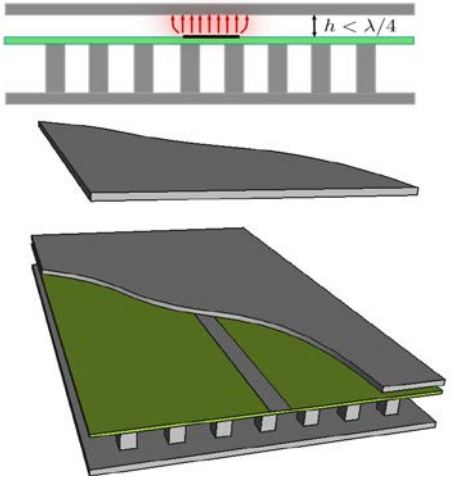
Ridge Gap Waveguide

Quasi-TEM mode



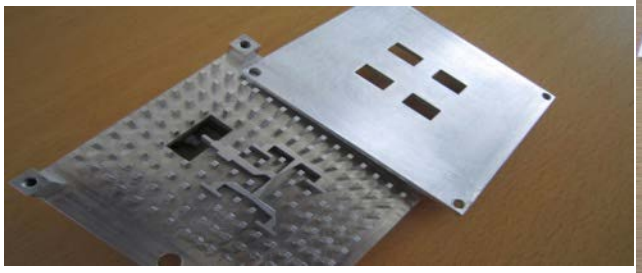
Groove Gap Waveguide

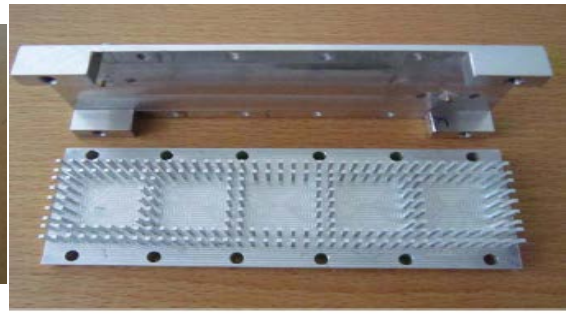
TE/TM mode

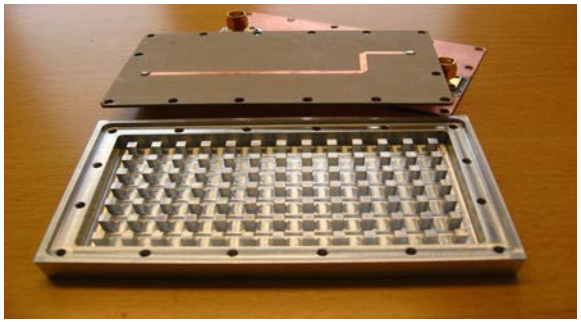


Inverted Microstrip Gap Waveguide

Quasi-TEM mode

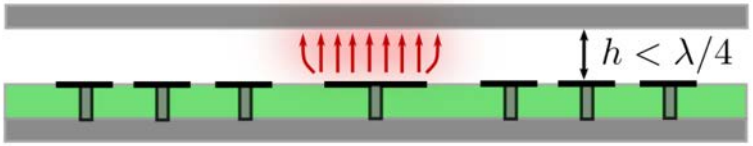


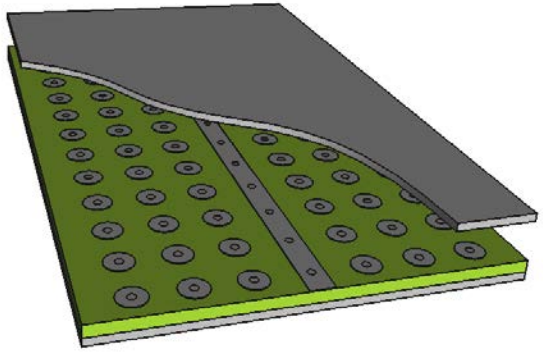




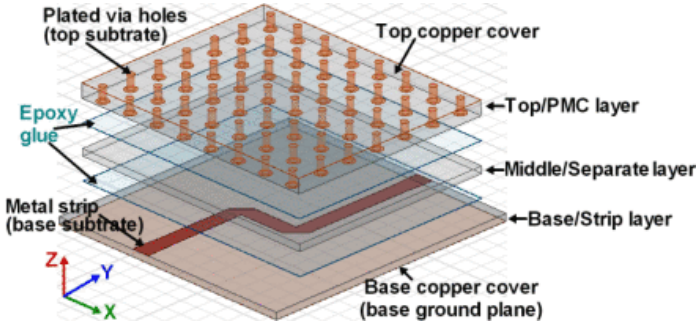
More versions

- Microstrip ridge



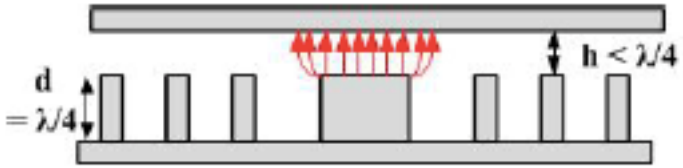


- Microstrip packaged

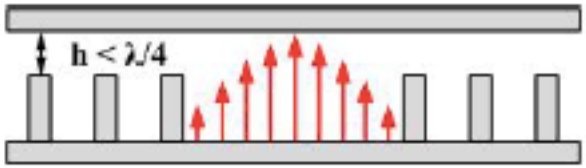


J. Zhang, X. Zhang, D. Shen and A. A. Kishk, "Packaged Microstrip Line: A New Quasi-TEM Line for Microwave and Millimeter-Wave Applications," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 65, no. 3, pp. 707-719, March 2017.

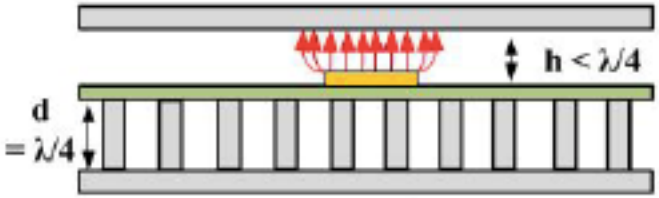
All versions: field on the air



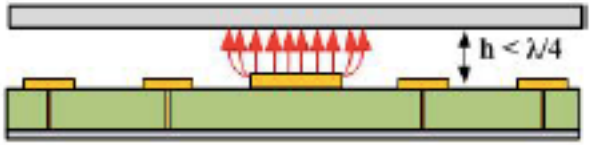
Q-TEM mode in
Ridge gap waveguide



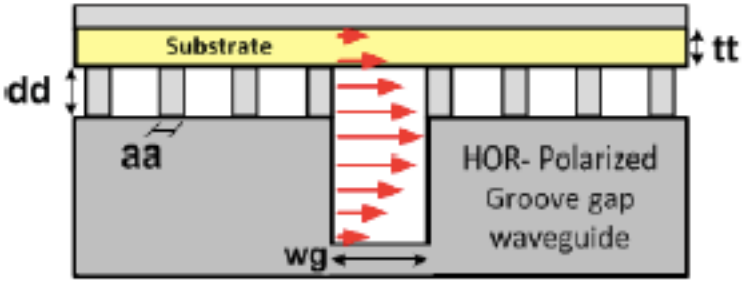
TE_{10} like mode in
Groove gap waveguide

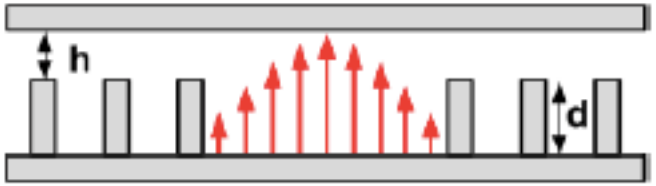


Q-TEM mode in
Inverted-microstrip gap waveguide



Q-TEM mode in
Microstrip ridge gap waveguide

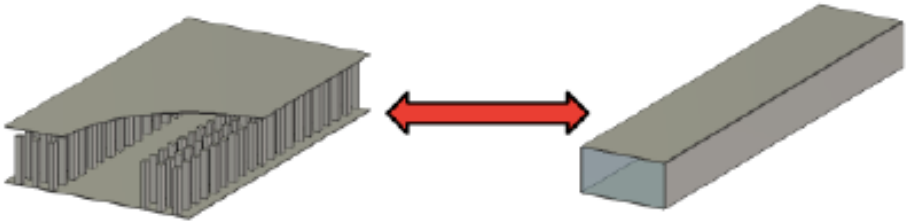




VER- Polarized
Groove gap waveguide

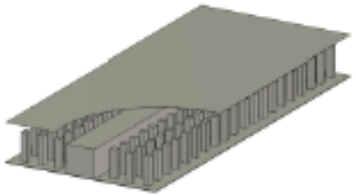
Gap waveguide versions

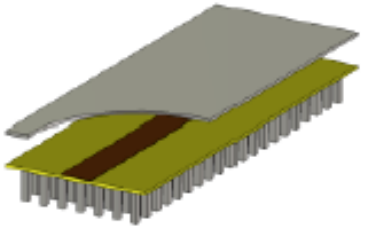
- Groove version can easily replace standard rectangular waveguide technology, it is a conventional rectangular waveguide whose lateral walls have been replaced by pins not touching the upper lid ➔ very easy manufacturing



Rectangular Waveguide

- Ridge and inverted microstrip versions can replace printed technology at millimeter frequencies.

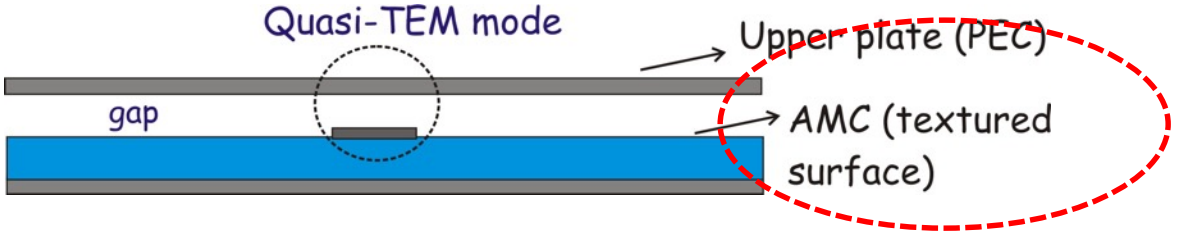




Maximum bandwidth limited by the STOPBAND of pins

How to design it

A key aspect of all GAP waveguides is the textured Surface that provides the **cut-off of PPW modes**



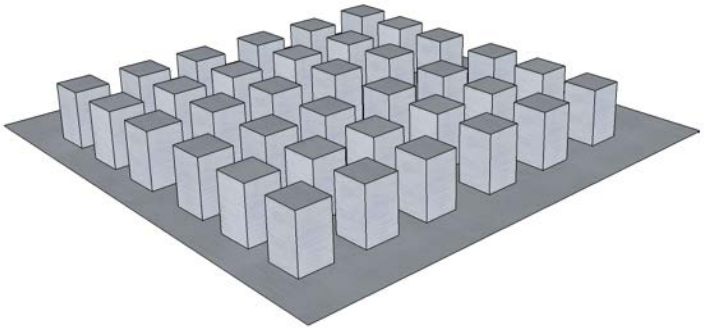
- It determines the bandwidth of the GAP waveguide
- Manufacturing limits and cost

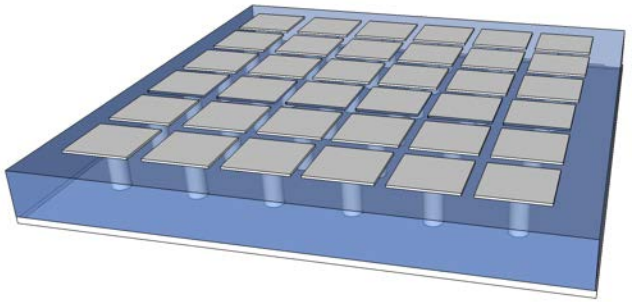
It is of interest to study how **different artificial surfaces** behave in this application, i.e., covered by a close metallic upper plate… (without the ridge or strip)

Periodic structures or metasurfaces

Which kind of AMC to use

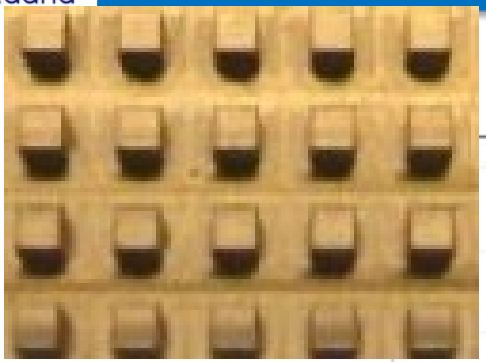
- The PMC condition can be realized by using artificial magnetic conductors (AMCs), such as textured surface made of metal pins or mushrooms-type EBG among others

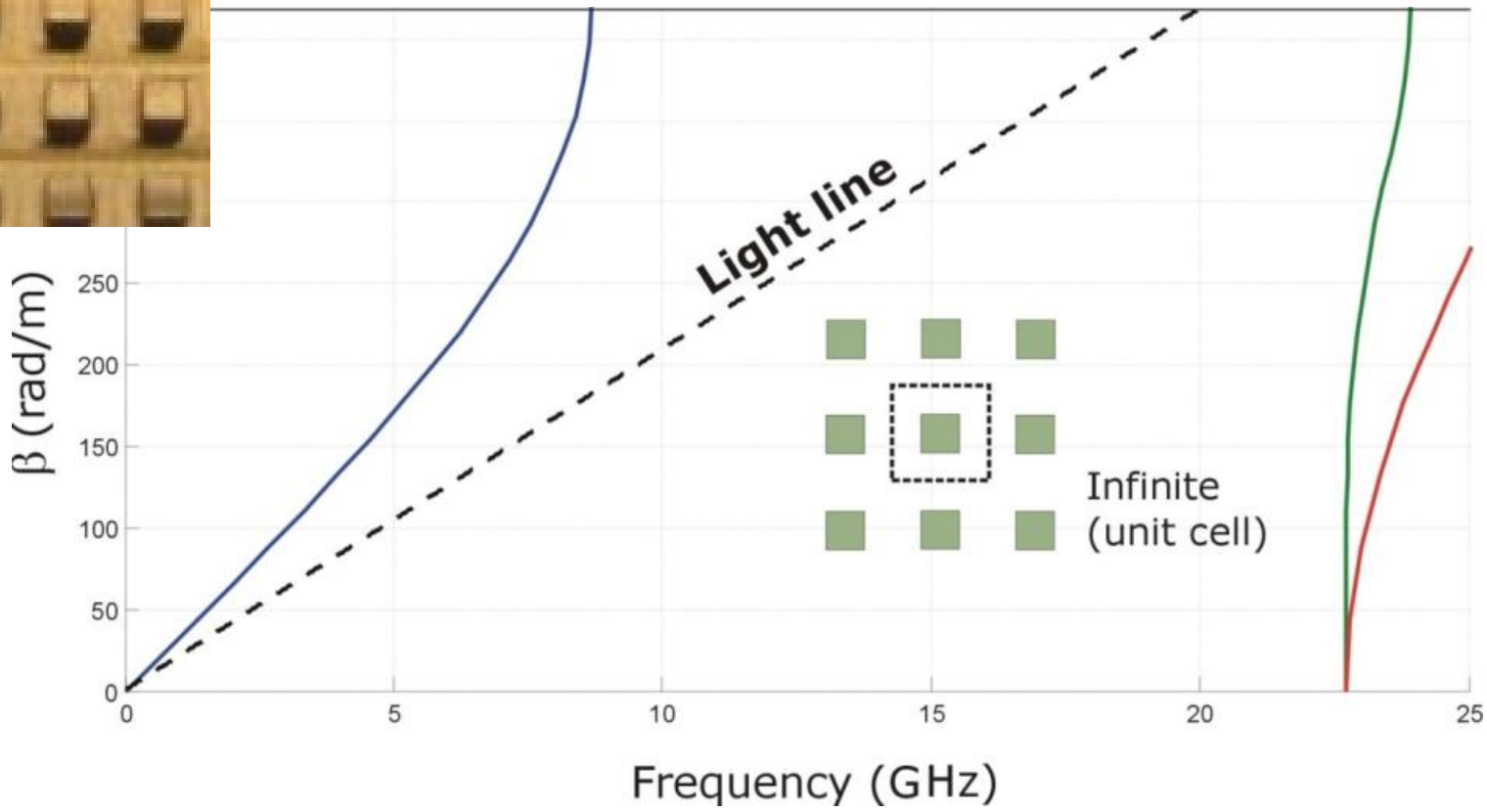




- One of the key points in designing GAP waveguide technology is how to implement the textured surface that gives the PMC condition as this determines:
  - Losses
  - Bandwidth
  - Manufacturing Cost
  - Size
  - Potential integration with other components

First design using bed of nails (pins)

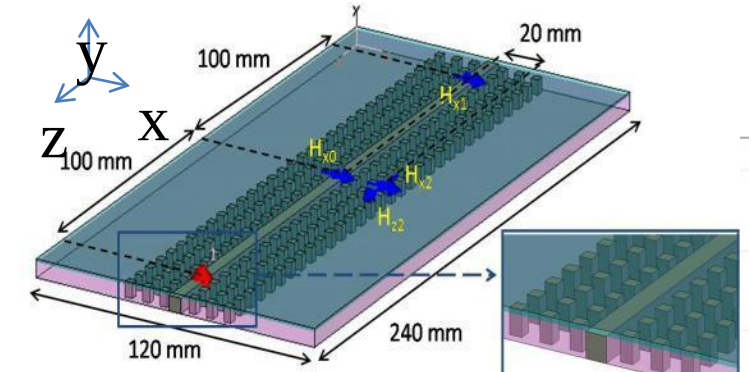


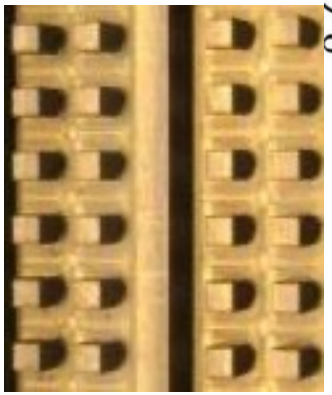


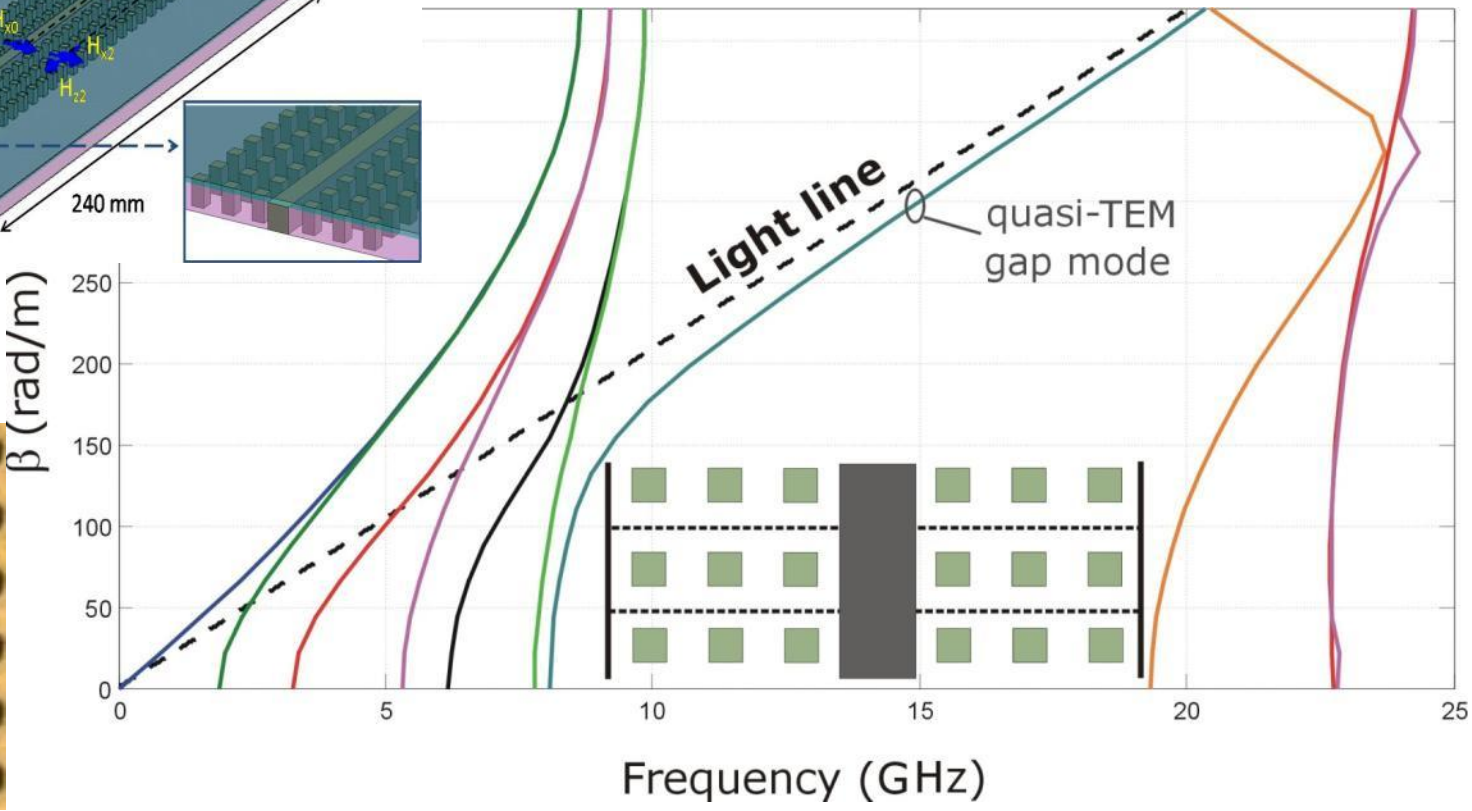
Dispersion diagram showing
cut-off bandgap with bed of nails as EBG/PMC surface (10 to 20 GHz)

First design using bed of nails

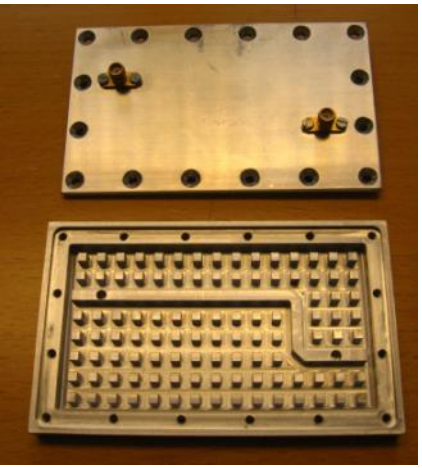
Dispersion diagram of ridge gap waveguide with PMC sidewalls

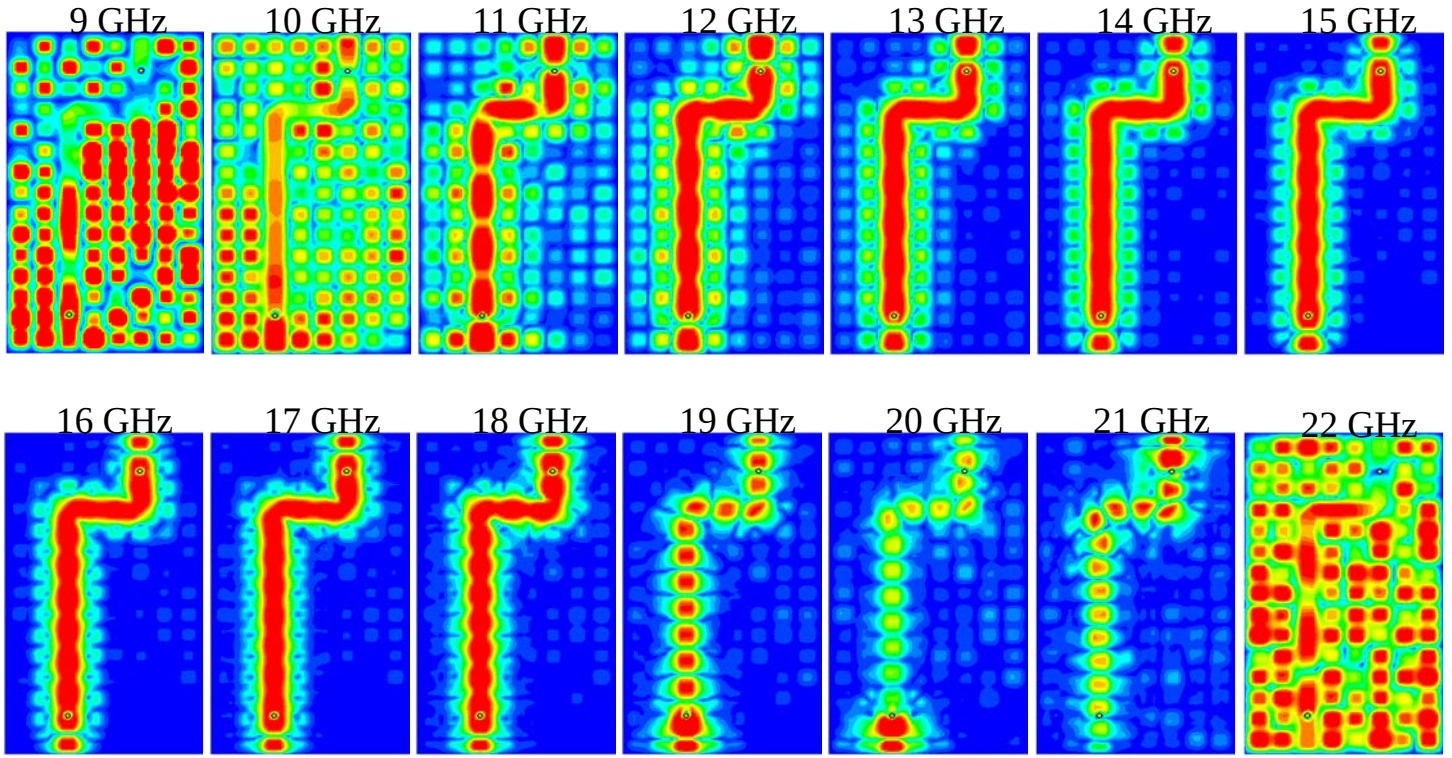




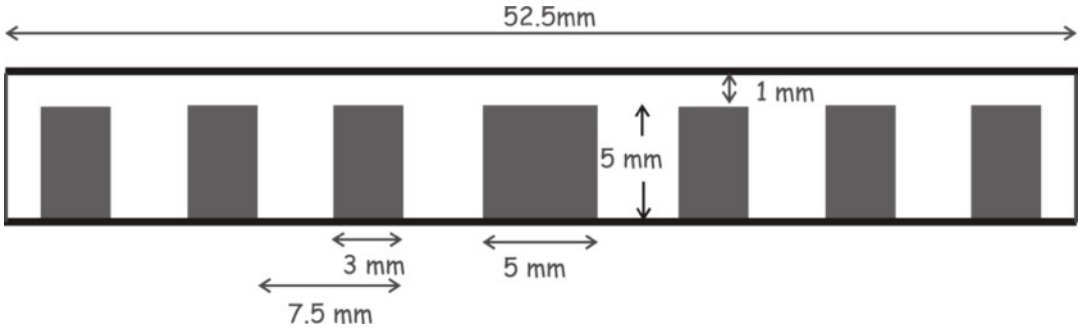


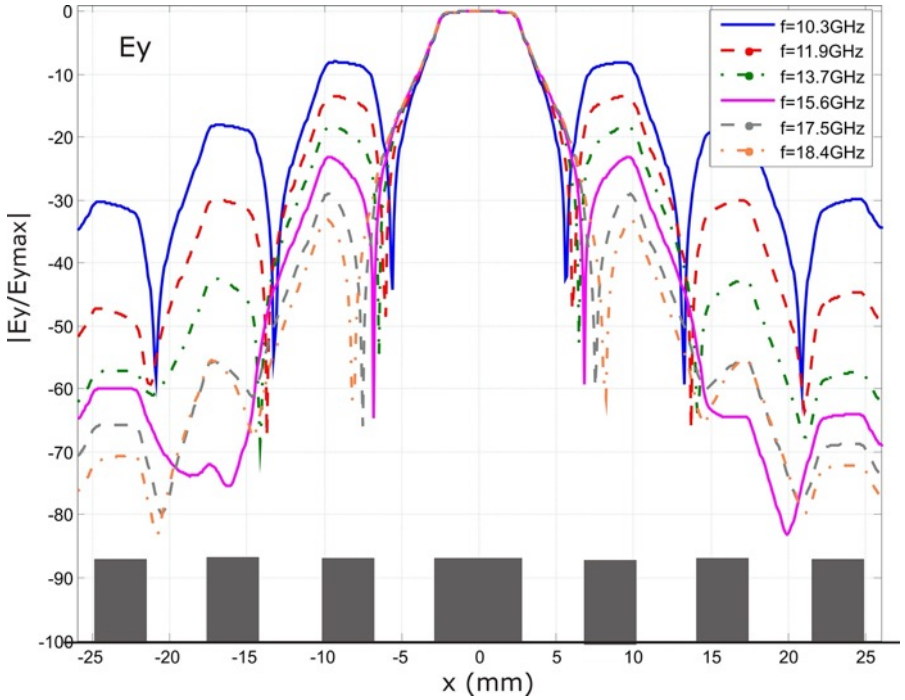
2D-color plots





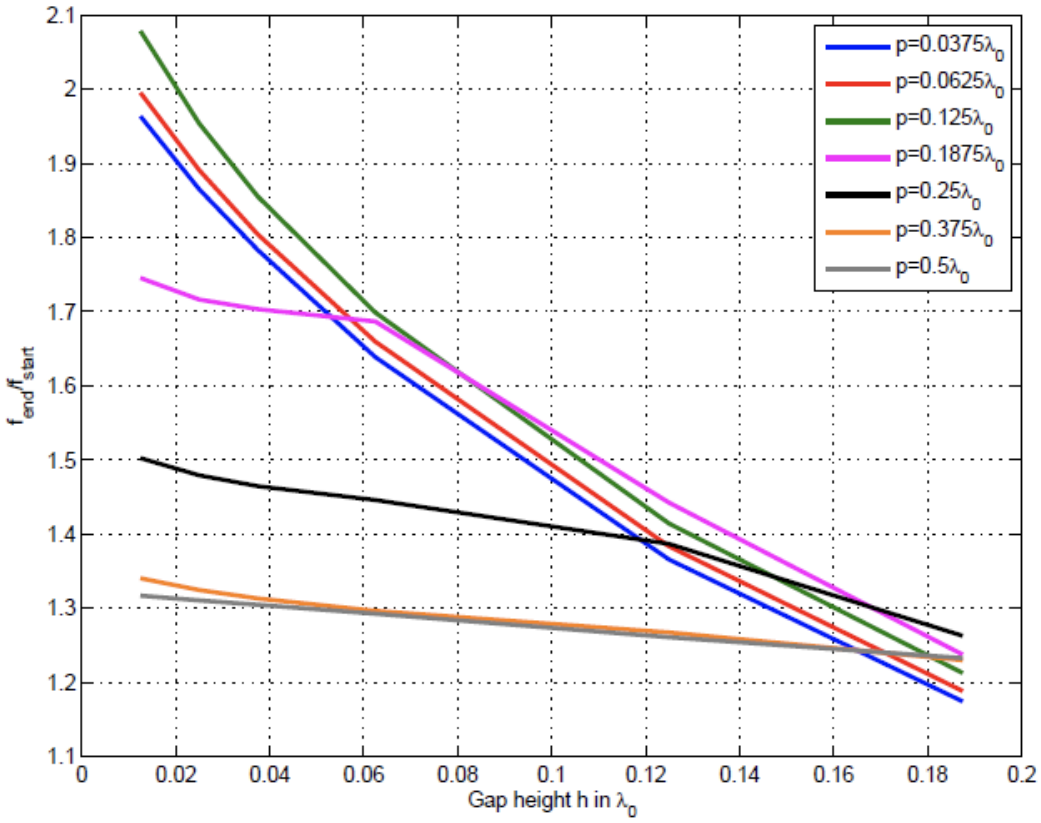
Lateral field decay

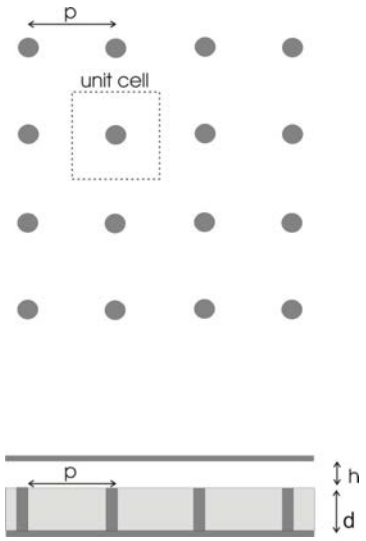




More than 10dB per pin!

Performance of pins for stop band

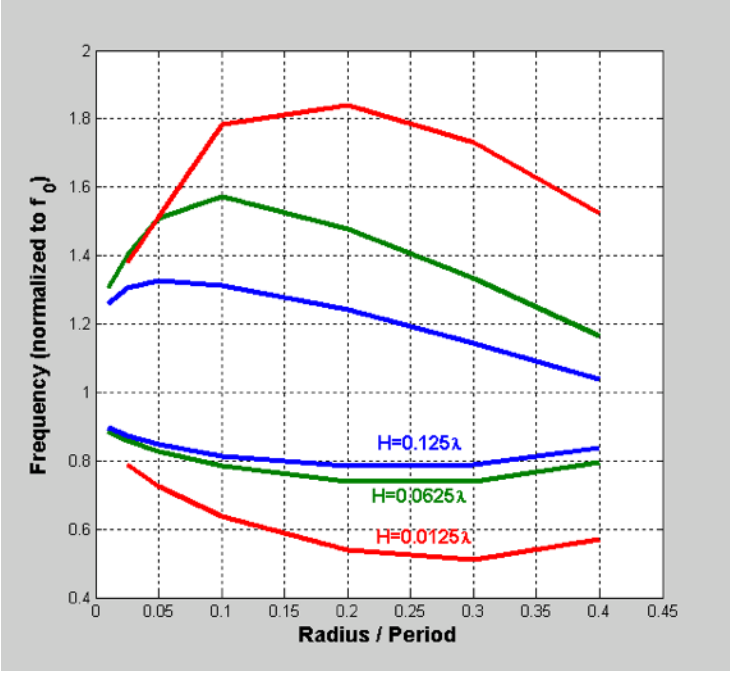


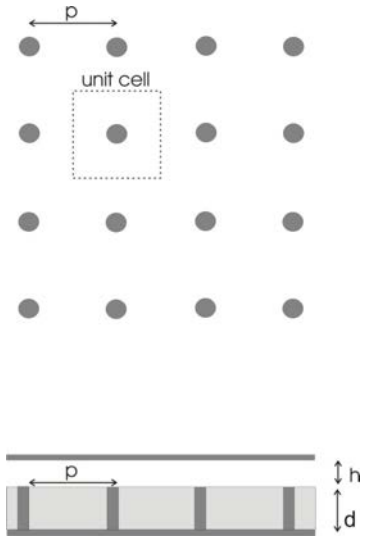


E. Rajo-Iglesias and P.-S. Kildal, "Numerical studies of bandwidth of parallel-plate cut-off realised by a bed of nails, corrugations and mushroom-type electromagnetic bandgap for use in gap waveguides," IET Microw., Antennas Propag., vol. 5, no. 3, pp. 282–289, Feb. 2011.

Performance of pins for stop band

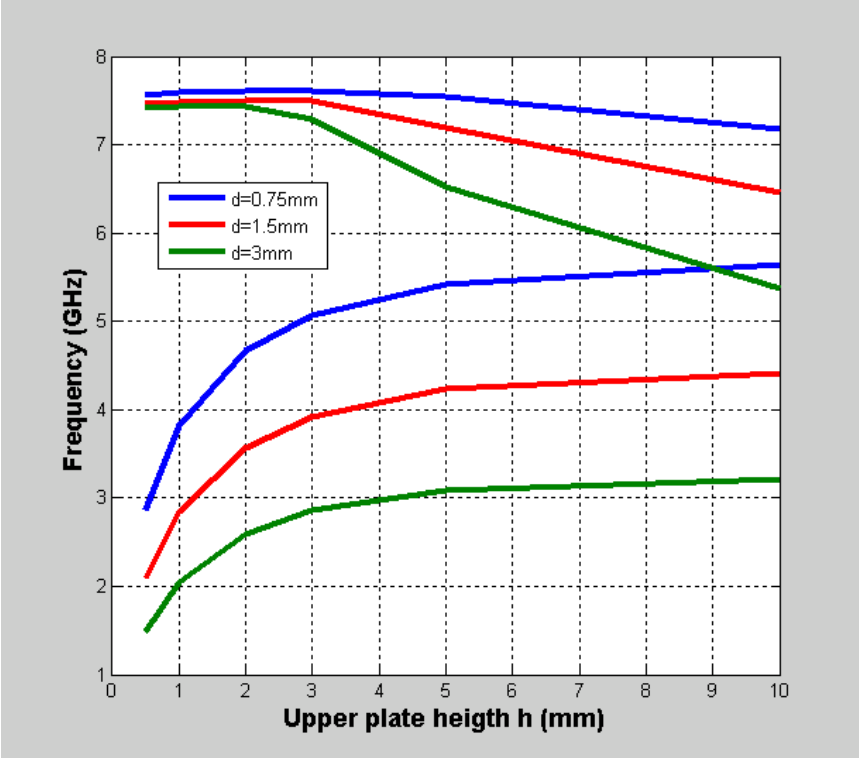
- ✓ The gap to the upper plate **h, strongly** affects the stopband: The smallest the gap, the largest the bandgap.
- ✓ Bandwidths of 2:1 are easily achieved with the pin surface.
- ✓ The structure is quite versatile as the different parameters can be used to modify the stopband (position and size):
  - ❖ Radius/period strongly affects the stopband size
  - ❖ Larger period moves down the lower limit of the stopband

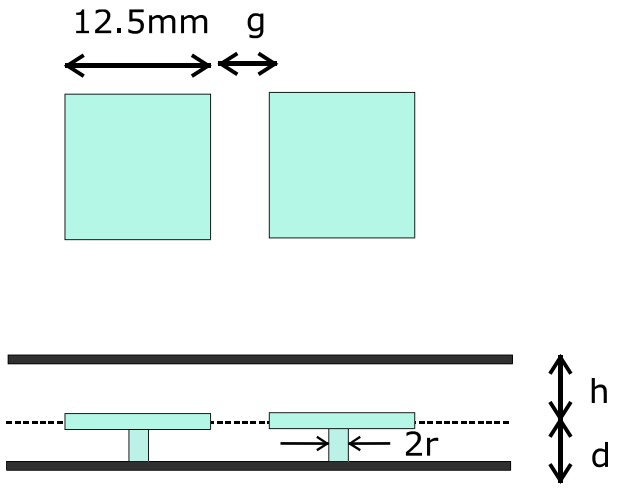




Performance of mushrooms for stop band

Gap **h** for different thickness **d**

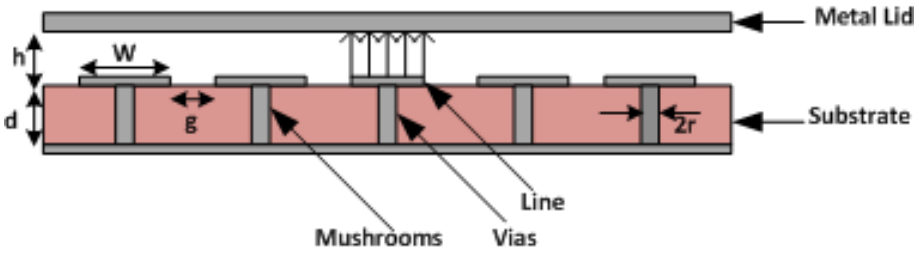


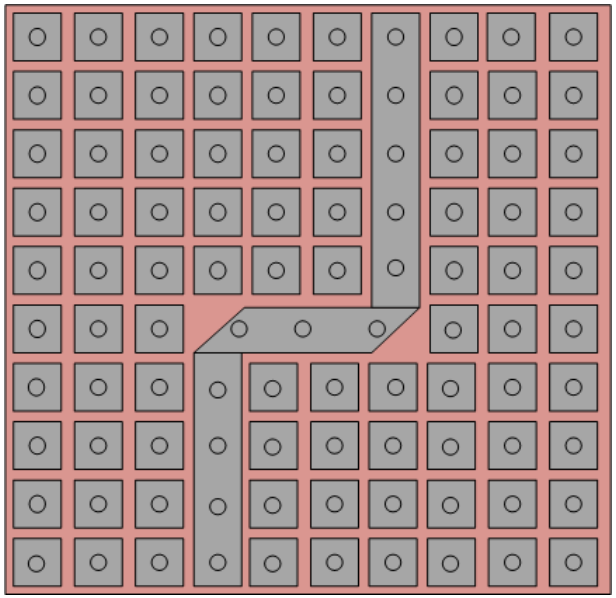


Mushroom-type EBG:

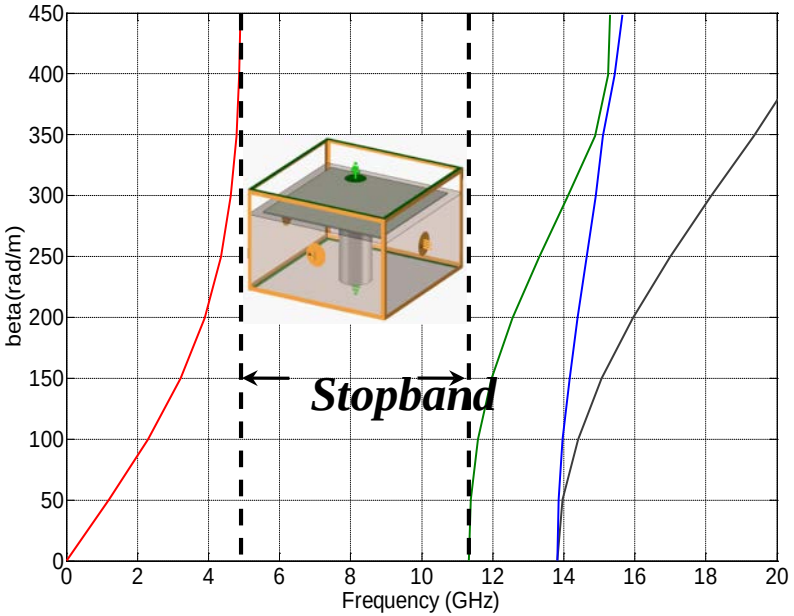
- Increasing the thickness ➔increases the stopband
- Increasing the radius➔ the stopband moves up in frequency

Microstrip-ridge gap waveguide





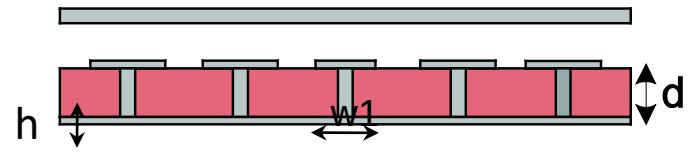
h = 1 mm
d = 3.2 mm
r = 0.75 mm
w = 6 mm
g = 1 mm
εr = 2.2
Tanδ = 0.0009



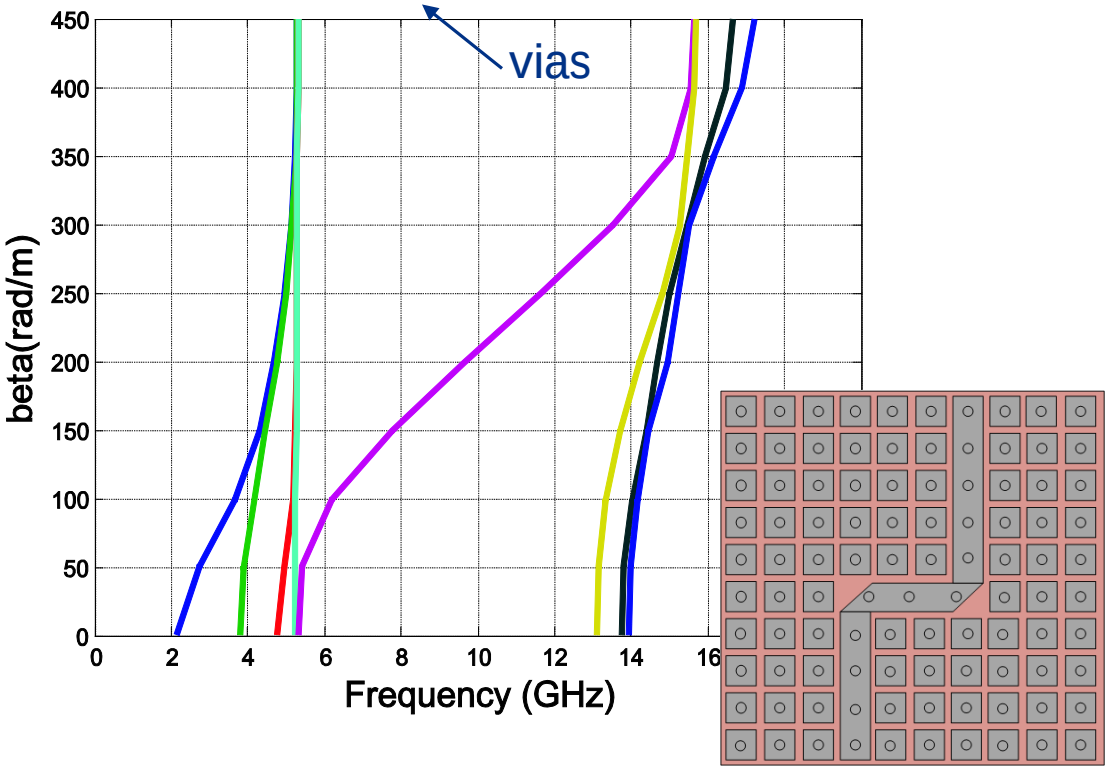
The field travels on air
➔ Less losses

Microstrip-ridge gap waveguide

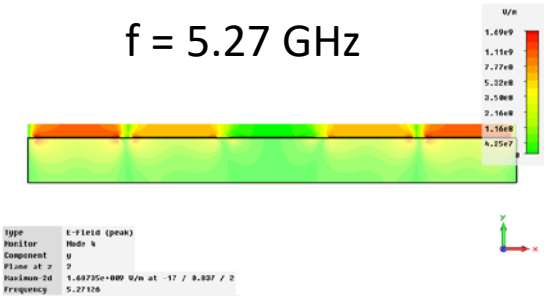
A classical metamaterial structure: mushroom-type EBG



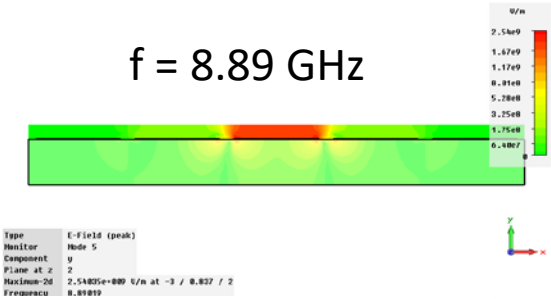
d=3.2mm
w1 = 5 mm
h = 1 mm



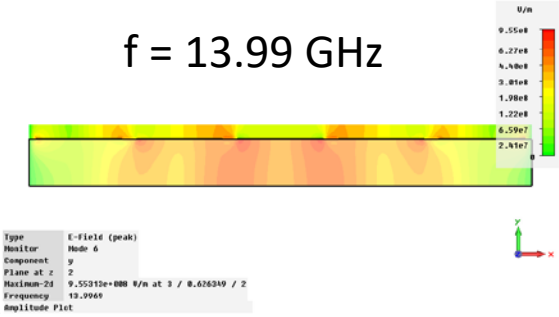
f = 5.27 GHz



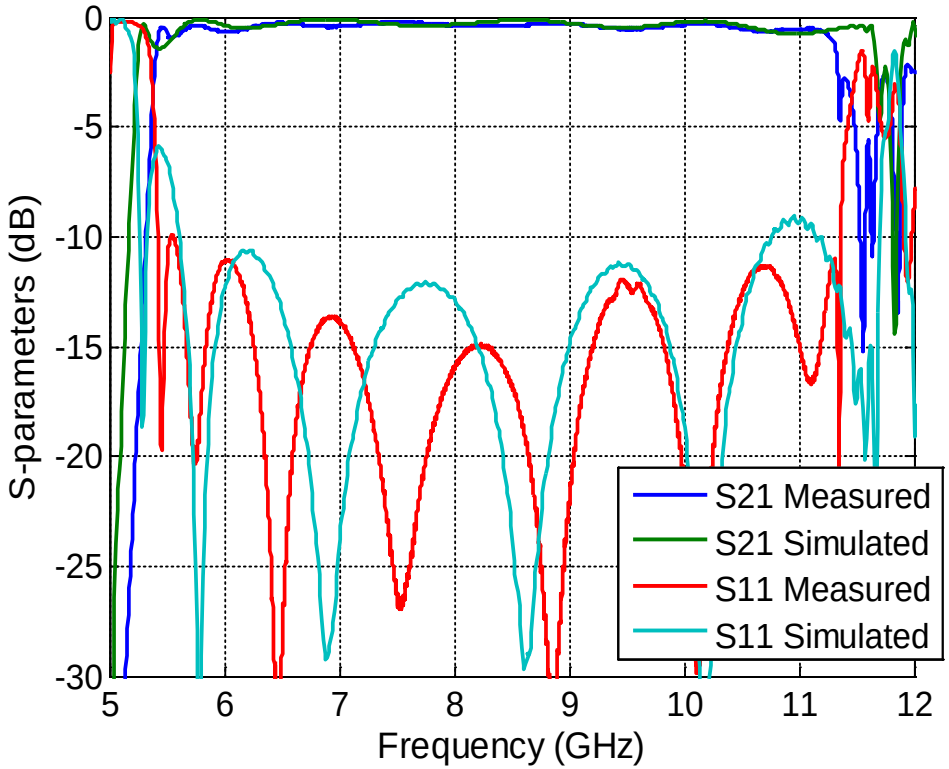
f = 8.89 GHz

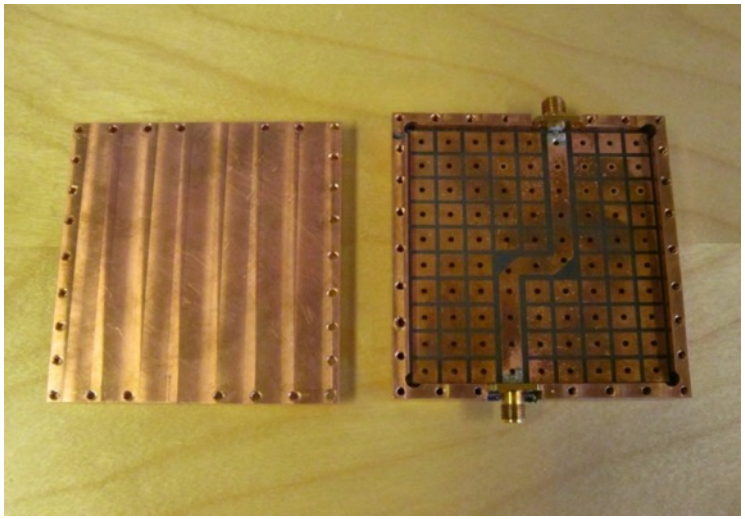


f = 13.99 GHz



Microstrip ridge gap

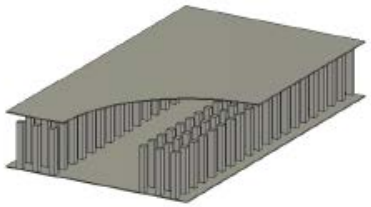
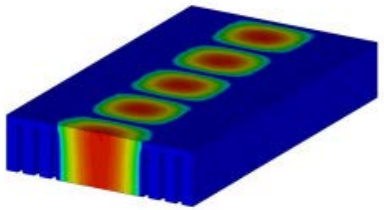
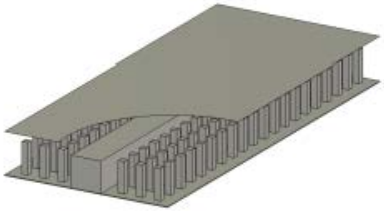
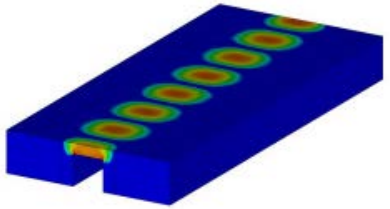
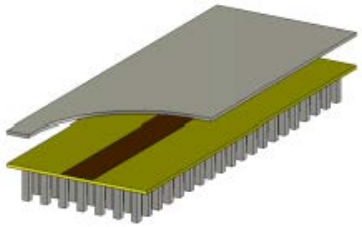
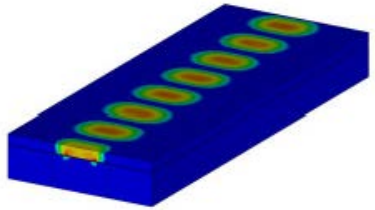




- They can be manufactured in printed technology (**cheap** ☺)
- They require dielectric (**losses** ☹)
- They can be very thin ☺
- The unit cell (area) is not too compact 😐

Key aspects

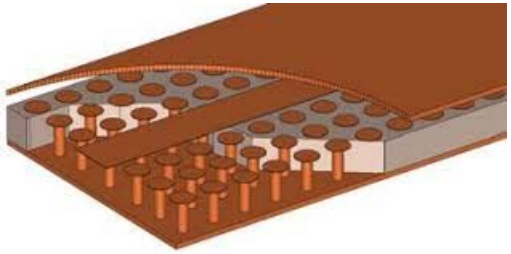
- Contactless technology (manufacturing in two pieces)
- Field travelling mostly on air (very low losses)
- Wideband
- Packaging of circuits is providing: no leakage, no coupling, no cavity modes, only field in the strip/rigde/groove
- Easy to integrate with components
- Aperture antennas can be integrated straightforward
- Different level of complexity depending on the version

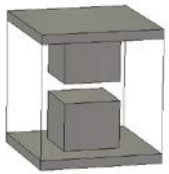







Manufacturing

- For the AMC other options have been explored besides pins:
  - Printed Mushrooms
  - Half pins

A. Dadgarpour, M. S. Sorkherizi, T. A. Denidni and A. A. Kishk, "Passive Beam Switching and Dual-Beam Radiation Slot Antenna Loaded With ENZ Medium and Excited Through Ridge Gap Waveguide at Millimeter-Waves," in IEEE Trans. on Antennas and Propagation, vol. 65, no. 1, pp. 92-102, Jan. 2017.





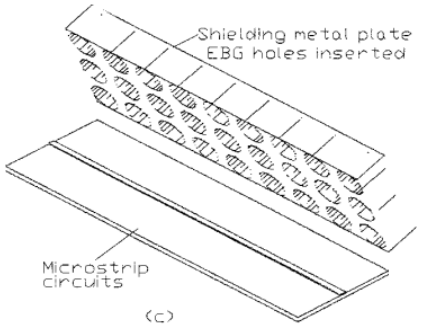
F. Fan, J. Yang, V. Vassilev, and A. U. Zaman, “Bandwidth investigation on half-height pin in ridge gap waveguide," IEEE Transactions on Microwave Theory and Techniques, vol. 66, pp. 100-108, Jan 2018.

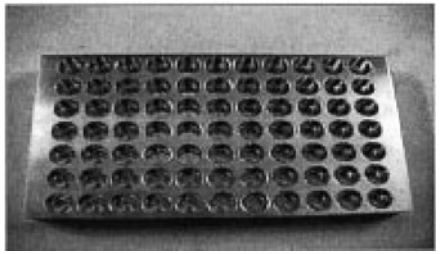
- Manufacturing techniques:
  - CNC Milling
  - Die Forming
  - Die-sink EDM
  - Metal 3D printing
  - MEMS

Periodic holey structure

Periodic structures with holes

- Holey structures have been used before for packaging:





166 IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, VOL. 12, NO. 5, MAY 2002

A Novel Electromagnetic Bandgap Metal Plate for Parallel Plate Mode Suppression in Shielded Structures

Debasis Dawn, *Member, IEEE*, Yoji Ohashi, *Member, IEEE*, and Toshihiro Shimura

***Abstract*—A novel type of metal plate structure incorporated with electromagnetic bandgap holes for use as metal shields with the capability of suppressing the propagation of unwanted parallel plate mode has been proposed. The holes can be of any shape and the periods of those holes should be selected to half the guided wavelength of the parallel plate mode at a desired center frequency of suppression. To show the validity of the proposal, inert electromagnetic wave simulation, results of a shielded microstrip structure designed for application in the 76 GHz frequency band are demonstrated. Experiments are performed with a prototype designed in the 10 GHz frequency band and parallel plate mode suppression is verified successfully with the excellent agreement between experimental and simulation results.**

***Index Terms*—Electromagnetic bandgap holder, metal shields, parallel plate mode.**

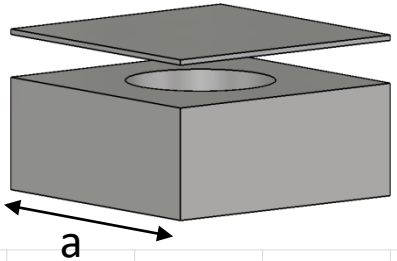
I. Introduction

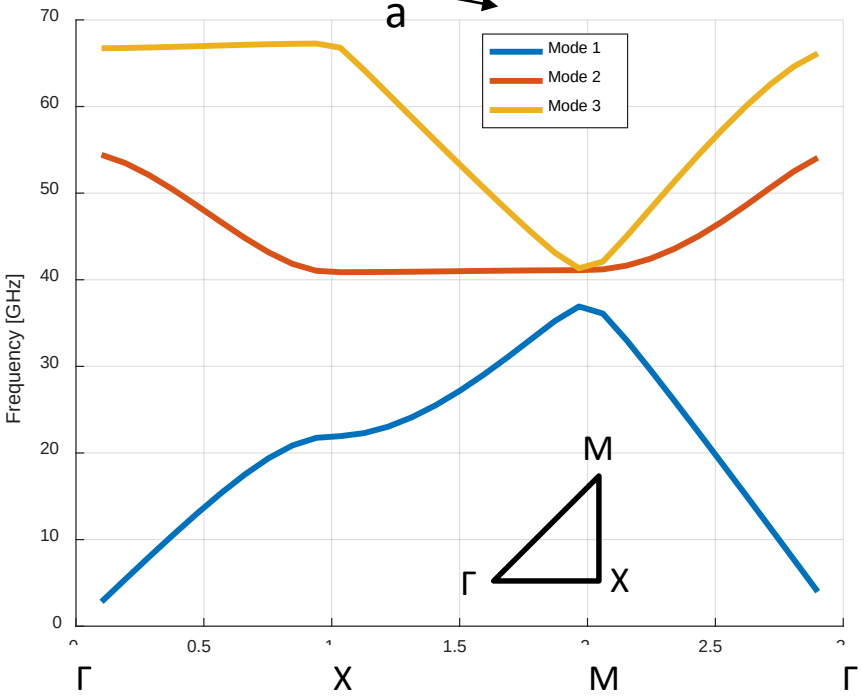
causes the problem of unwanted parallel plate mode transmission and, hence, the unavoidable crosstalk appears.

In this paper, a new type of metal plate structure with EBG holes inside for the use as a metal shield with the capability of suppressing the propagation of unwanted parallel plate mode has been proposed. The validity of the proposal has been demonstrated with simulation for a metal plate of a shielded microstrip structure designed for the application in the 76 GHz frequency band. Experiments are performed with a prototype designed in 10 GHz frequency band to verify the design accuracy.

II. Principle of Operation and Design

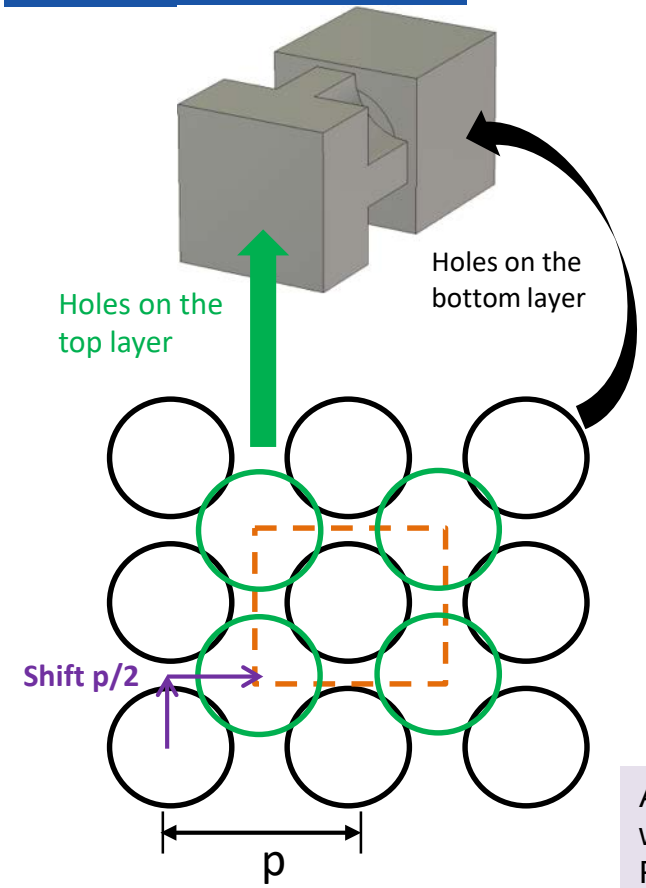
It is well known that any electromagnetic bandgap structure produces the phenomena of stopband in which propagation is prohibited if the period of EBG elements is chosen to be half



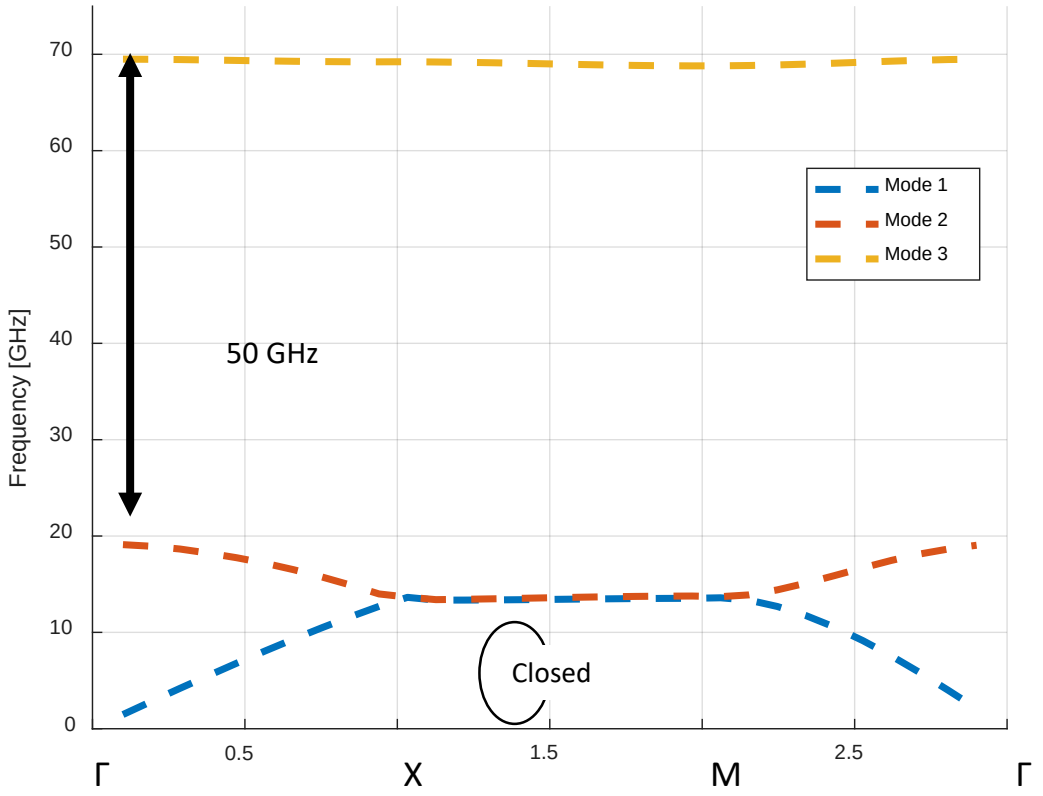


Periodic structures with glide symmetrical holes

Glide symmetry

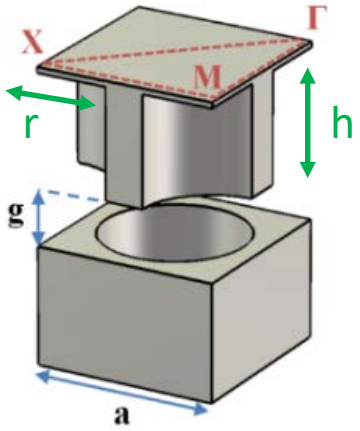


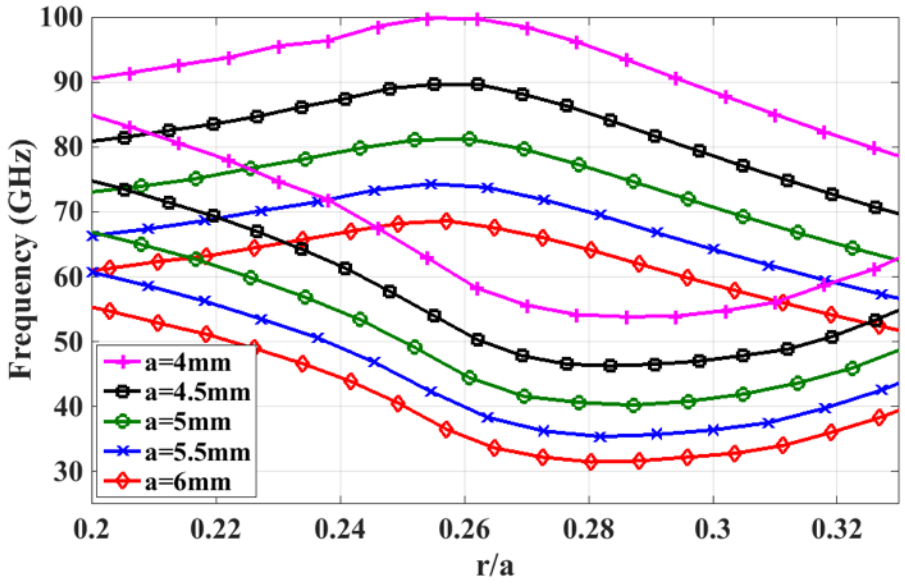
Dispersion Diagram

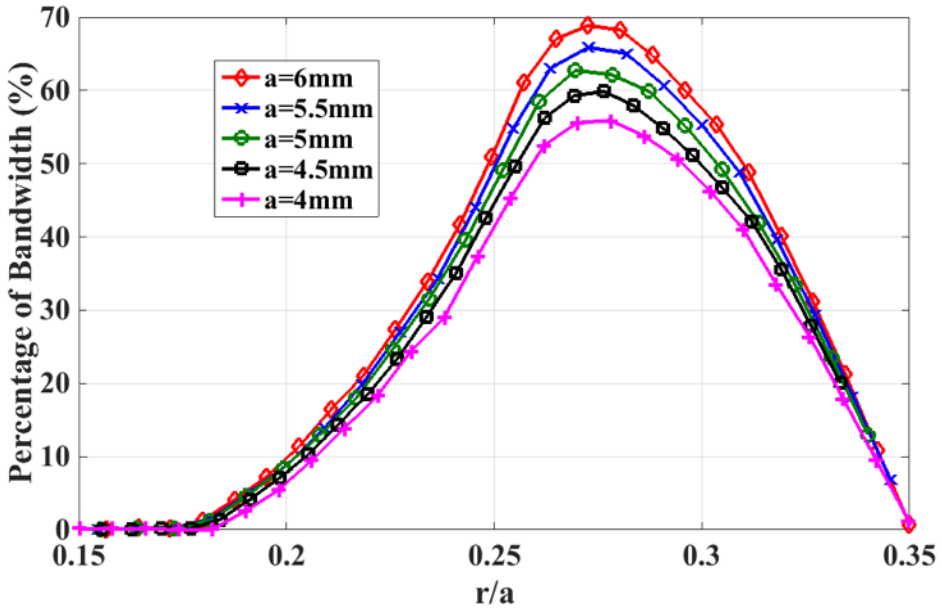


A. Hessel, M. H. Chen, R. C. M. Li, and A. A. Oliner, “Propagation in periodically loaded waveguides with higher symmetries," Proceedings of the IEEE, vol. 61, pp. 183-195, Feb 1973.

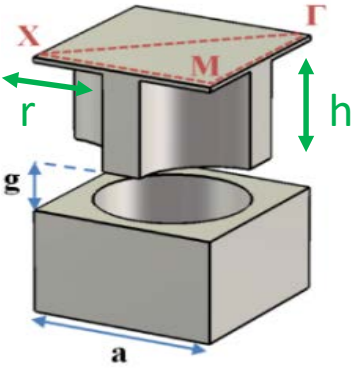
Periodic structures with glide symmetrical holes: parametric study

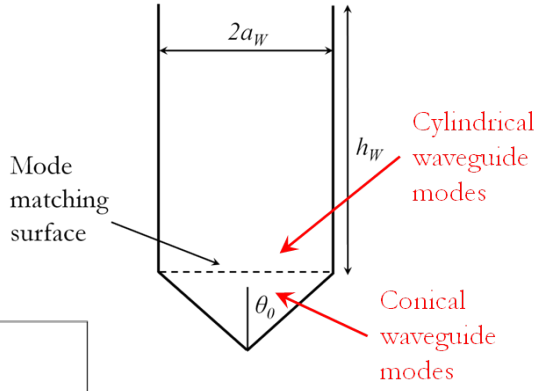


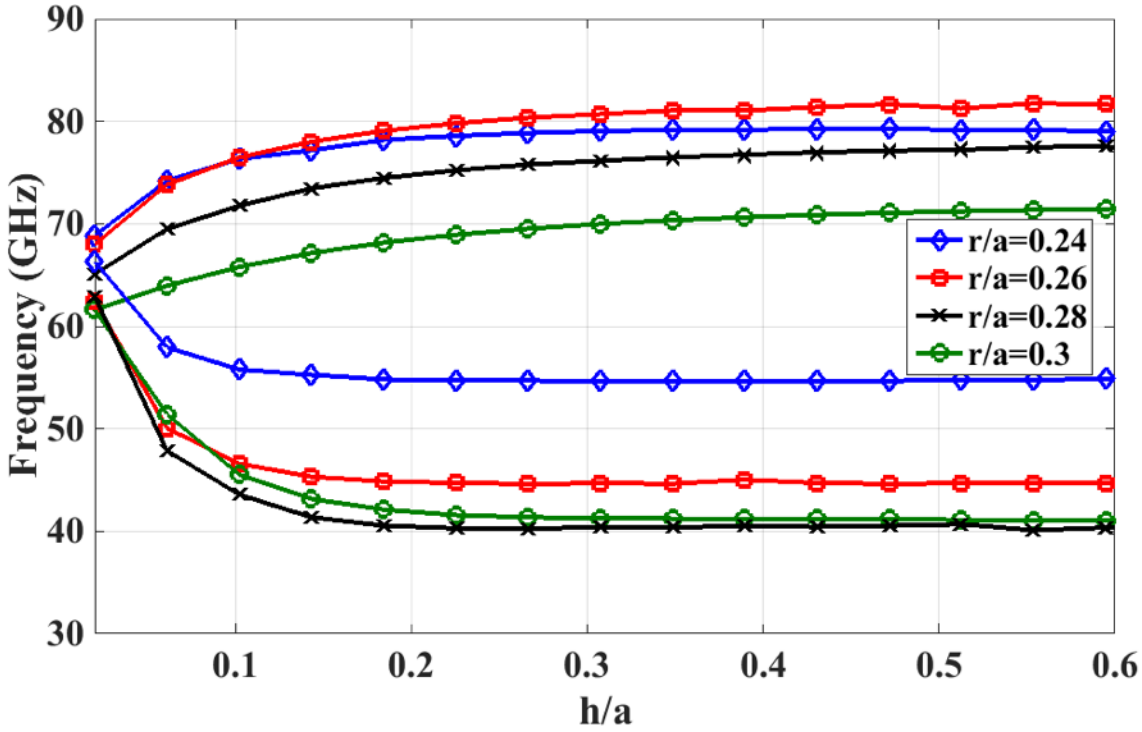




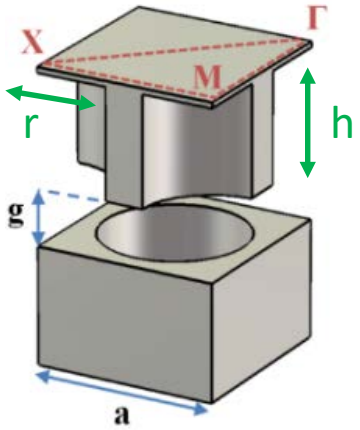
Periodic structures with glide symmetrical holes: parametric study

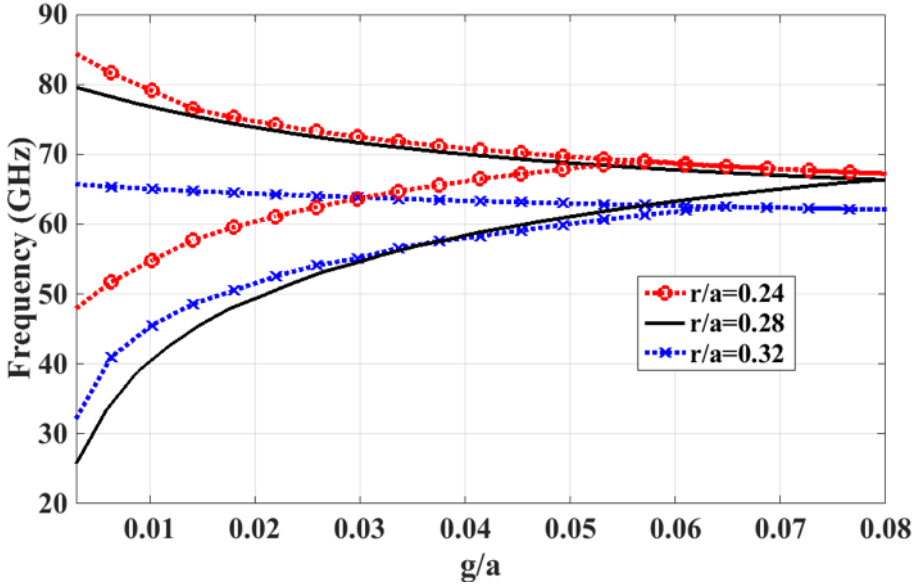


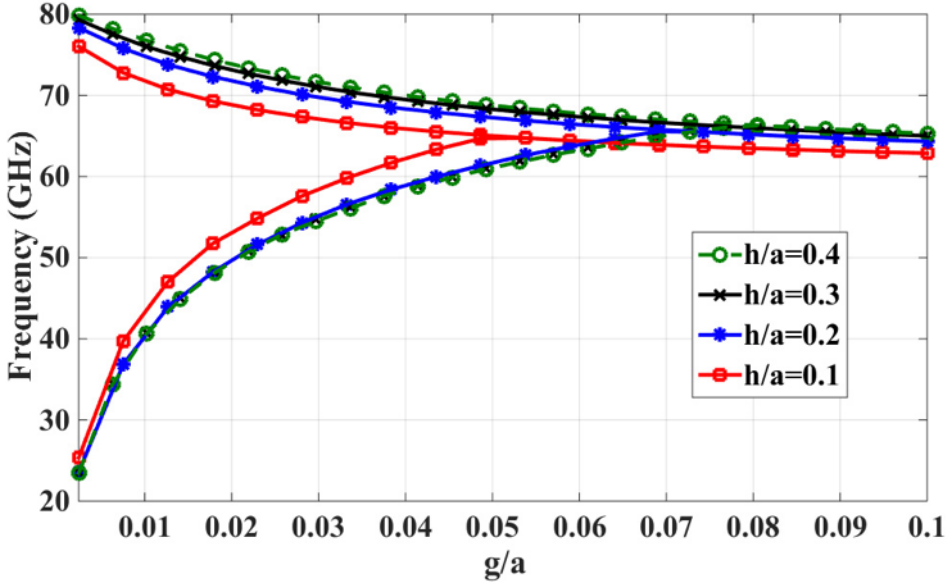




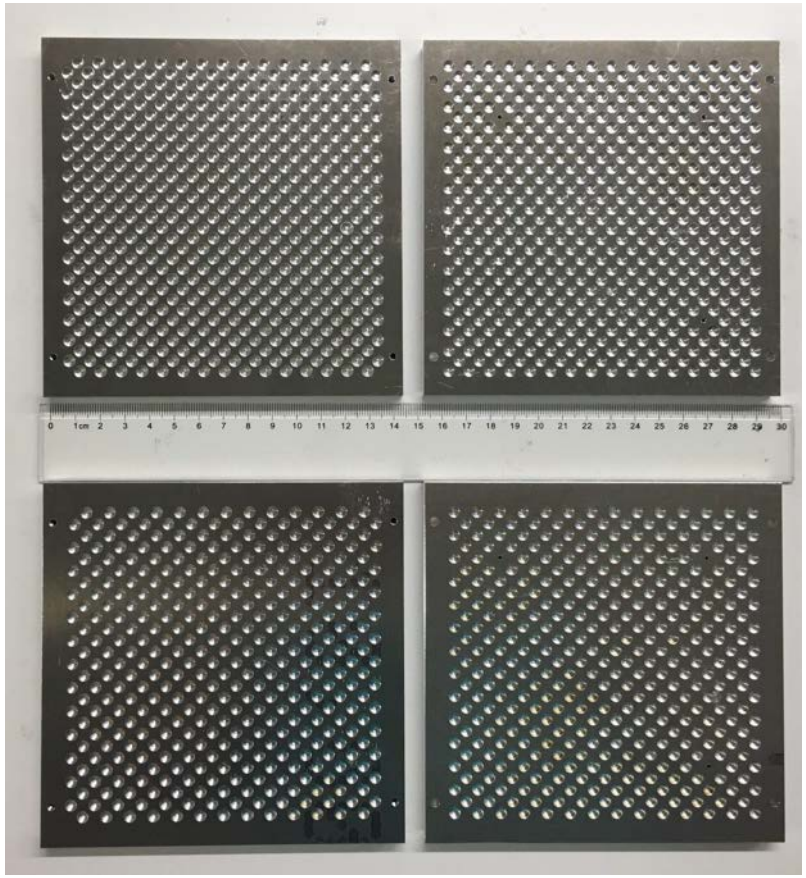
Periodic structures with glide symmetrical holes: parametric study

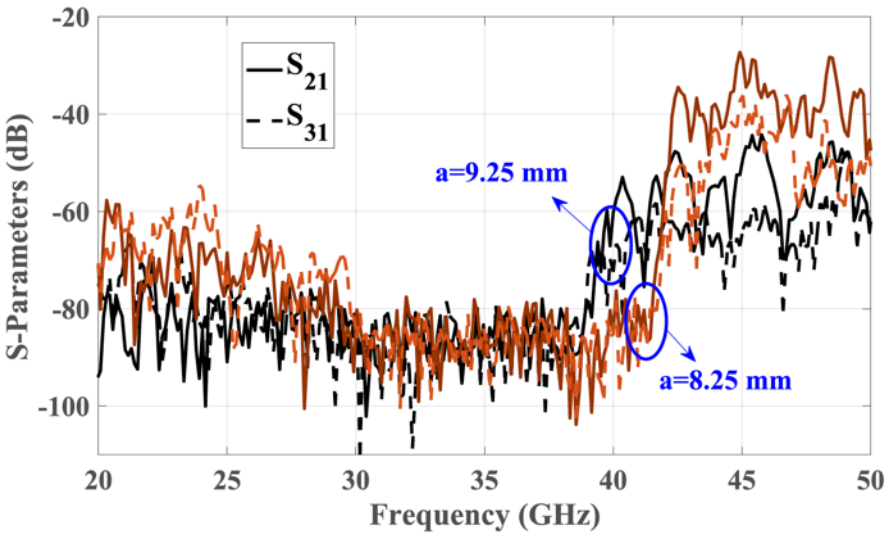






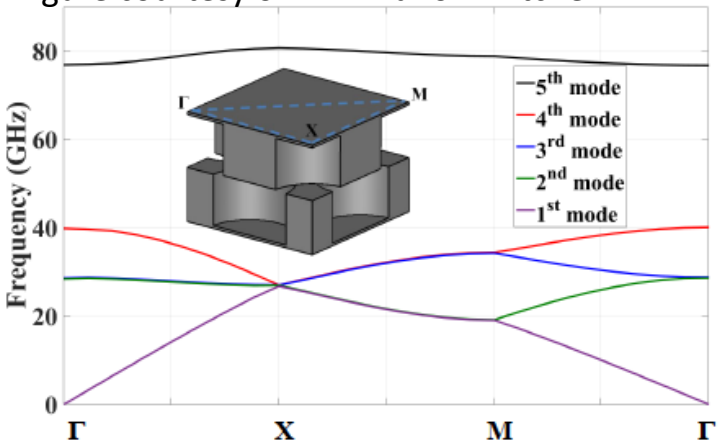
Periodic structures with glide symmetrical holes: parametric study





Holey glide symmetrical structure

Figure courtesy of Dr. Rhianon Mitchell

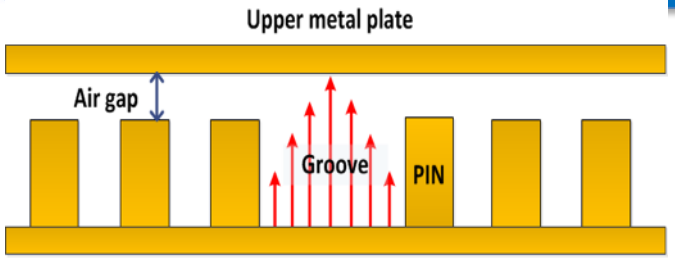


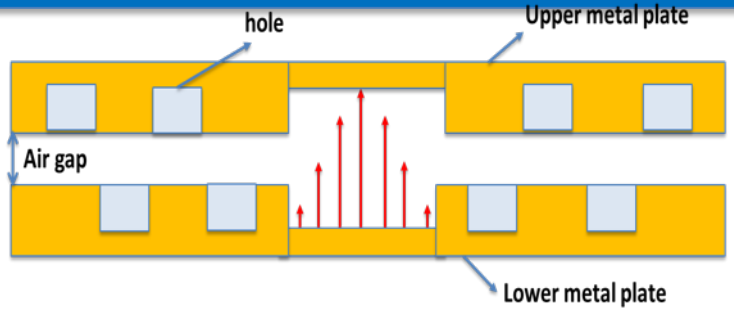
Main parameters:

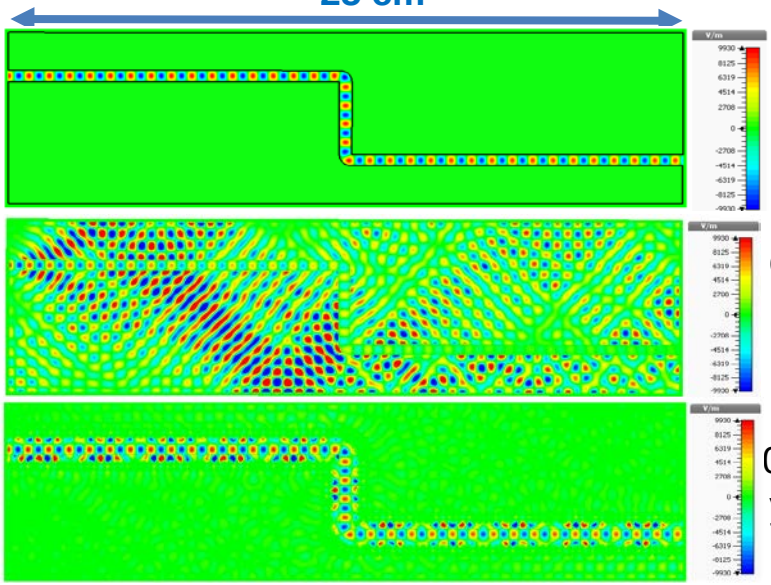
- The periodicity determines the central frequency of the band
- r/a defines the perfectage of BW, max. BW obtained when r/a=0.275
- When the gap decreases the BW increases
- There is a minimum value for the depth of the hole, after it, it has no effect.

M. Ebrahimpouri, O. Quevedo-Teruel, E. Rajo-Iglesias "*Design Guidelines for Gap Waveguide Technology Based on Glide-Symmetric Holey Structures"* in *IEEE Microwave and Wireless Components Letters*, vol. 27, no. 6, pp. 542-544, June 2017.

Application to groove gap waveguide







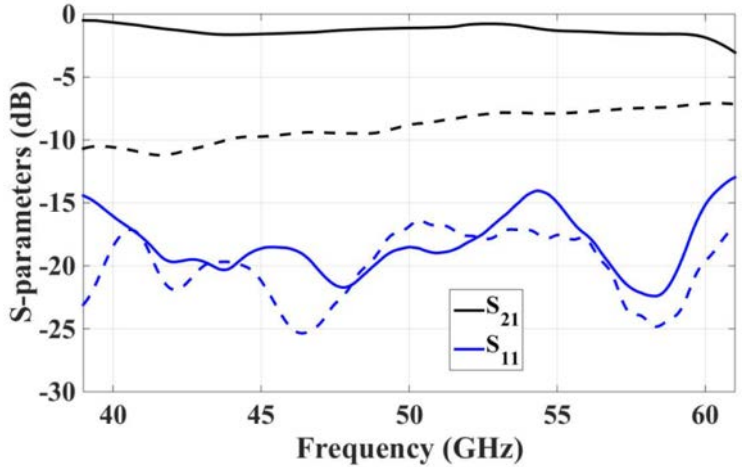
ideal

Guía con un gap de 0.05mm en las paredes laterales

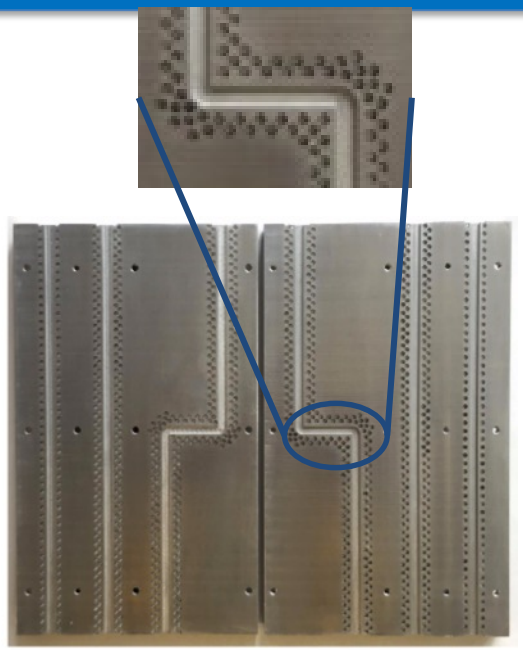
Guía con un gap de 0.05mm en las paredes y la estructura EBG de agujeros

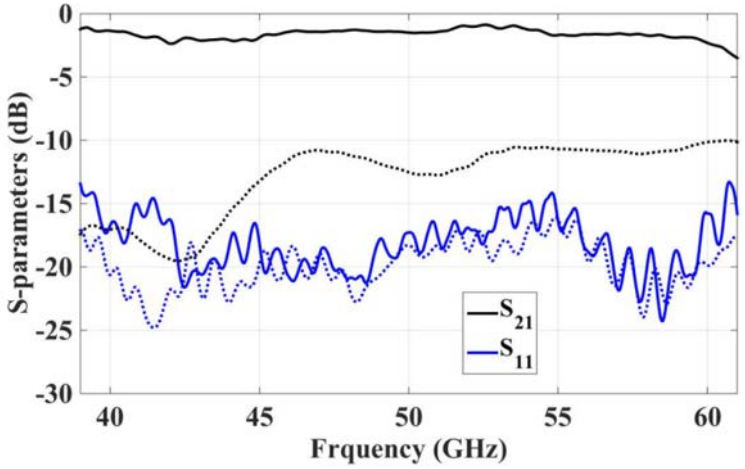
M. Ebrahimpouri, E. Rajo-Iglesias, Z. Sipus, and O. Quevedo-Teruel, "Cost-effective Integrated Waveguide Circuits Based on Glide-Symmetric Holey EBG Structures", *IEEE Trans. on Microwave, Theory and Techniques*, vol. 66, pp. 927-934, Feb 2018.

Application for groove gap waveguide: initial studies



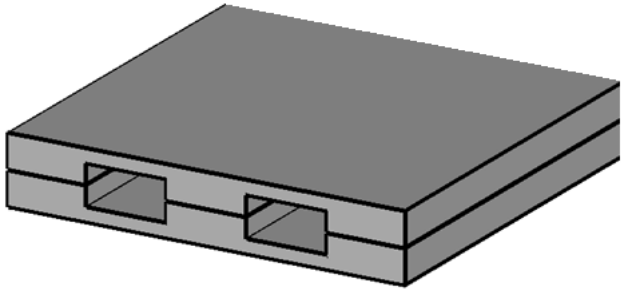
Straight line
Dashed lines: without EBG
Solid lines: with EBG

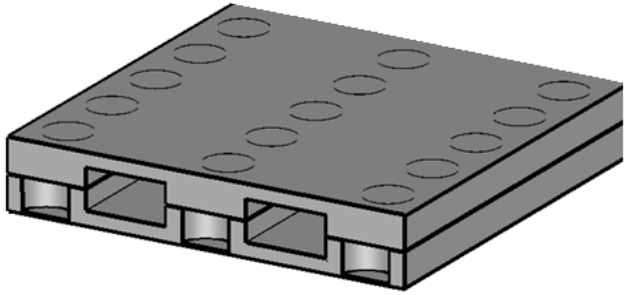




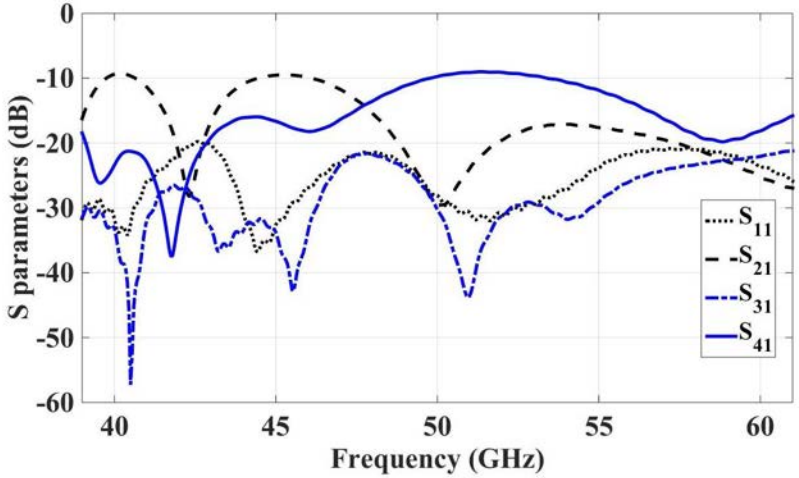
Double bend line
Dashed lines: without EBG
Solid lines: with EBG

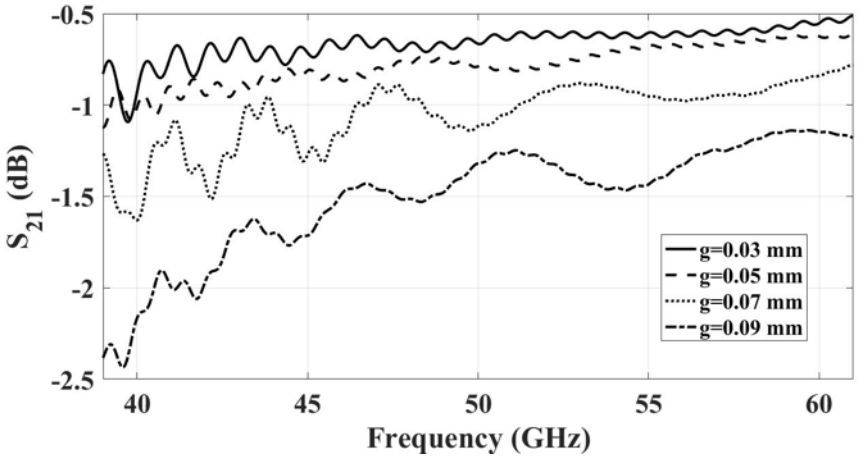
Application for groove gap waveguide: initial studies





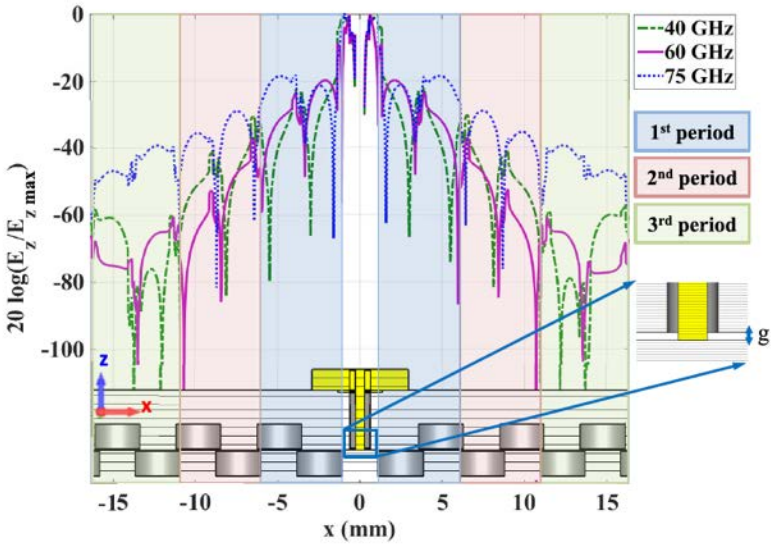
g=0.05 mm



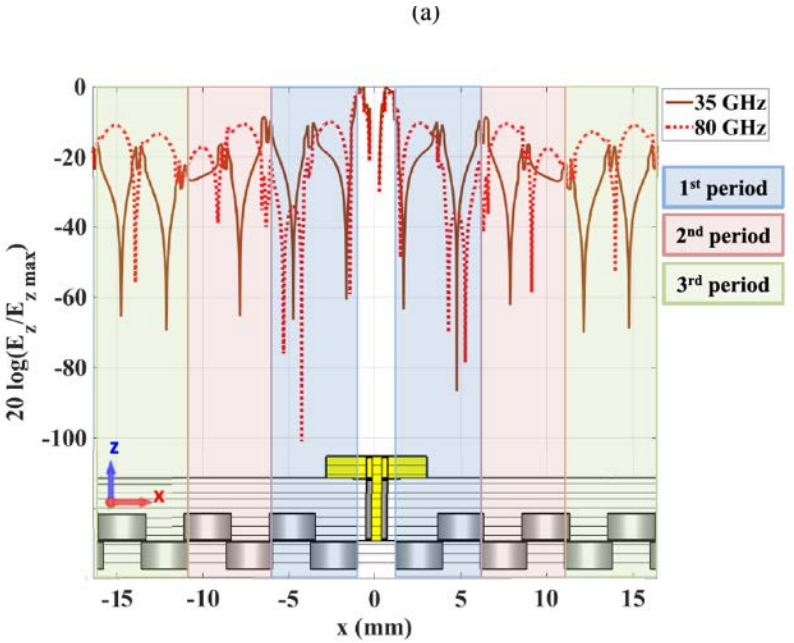


Application for groove gap waveguide: initial studies

Inside the stop-band



Outside the stop-band



Some Considerations

- In this first experimental validation the gap was in the middle of the vertical wall. Other options are possible and convenient for some designs.

- The holes are alined top and bottom which corresponds to the diagonal direction of the glide unit cell.

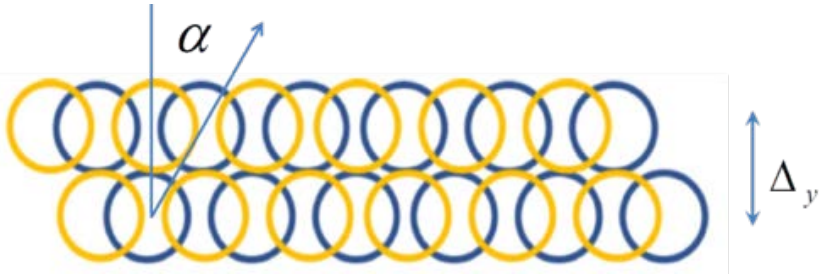
- Gap tends to zero and in practice no gap will be intentionally implemented (difference with most of the versions with pins).

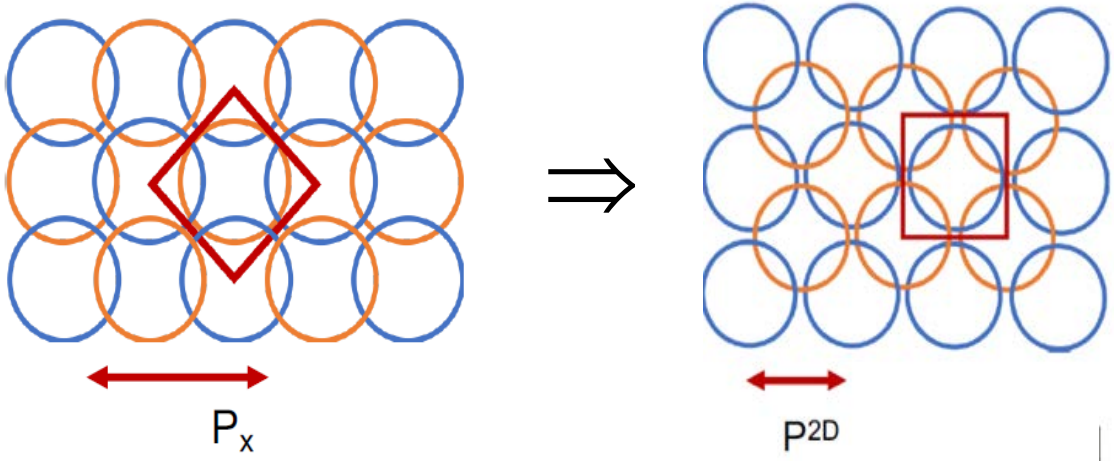
Considerations for application in GGW

- Manufacturing simplicity
- Non-compact unit cell → Difficulties for some designs

Considerations for application in GGW

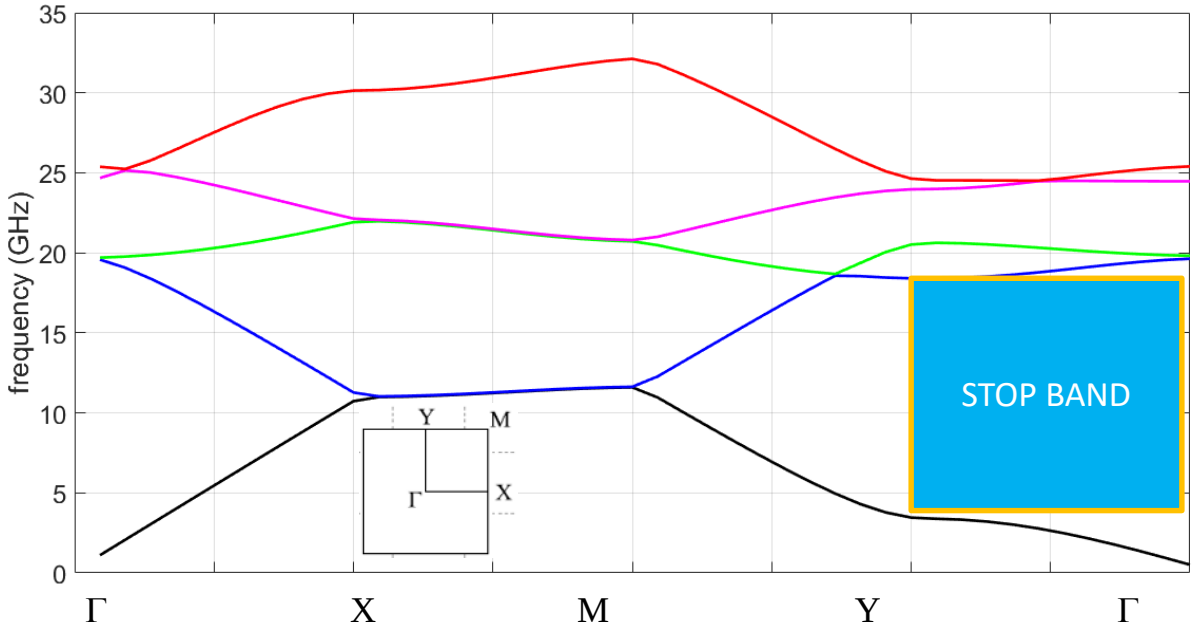
- We will consider two versions of glide operators:
  - 1D: $\begin{cases} (x,y) \rightarrow (x+\frac{P_x}{2}, y) \\ z \rightarrow -z \end{cases}$
  - 2D: $\begin{cases} (x,y) \rightarrow (x+\frac{P_x}{2}, y+\frac{P_y}{2}) \\ z \rightarrow -z \end{cases}$





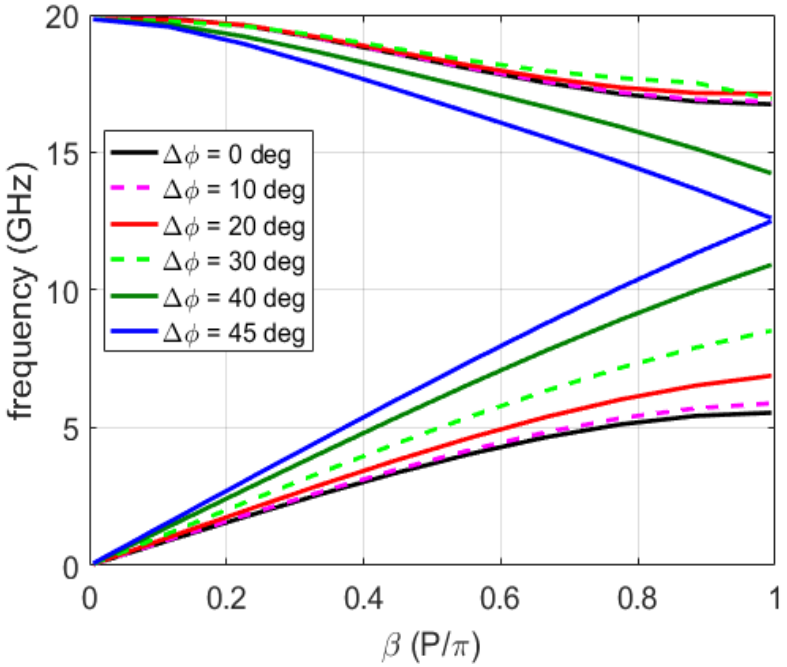
Considerations for application in GGW

- When $\alpha=0$
- No overlapping with contiguous rows
- Structure acts as a soft surface:



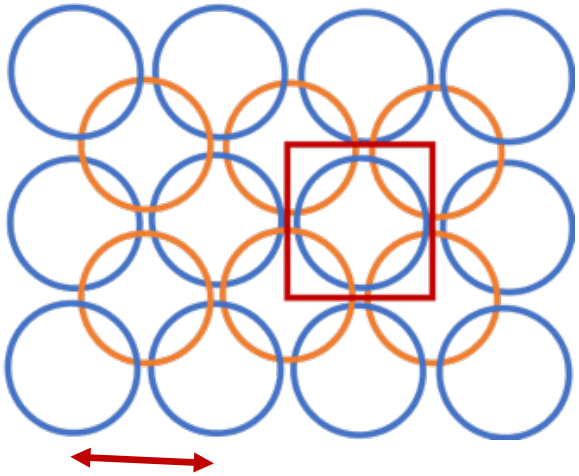
Considerations for application in GGW

- Struture acts as a soft surface.
- Dispersion diagram of first two propagating modes for different propagation directions of EM wave:

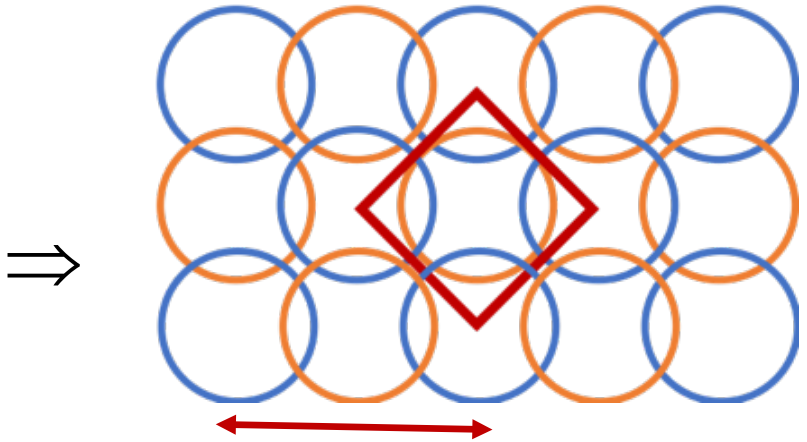


Considerations for application in GGW

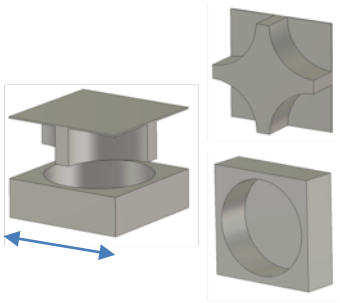
Blue holes: top plate
Orange holes: bottom plate



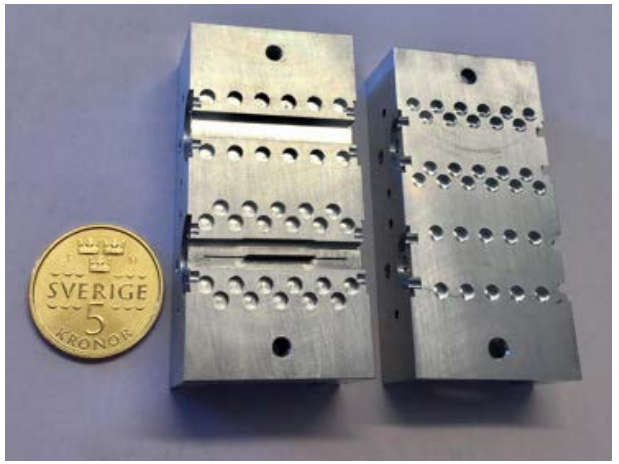
P^{2D}



P_x

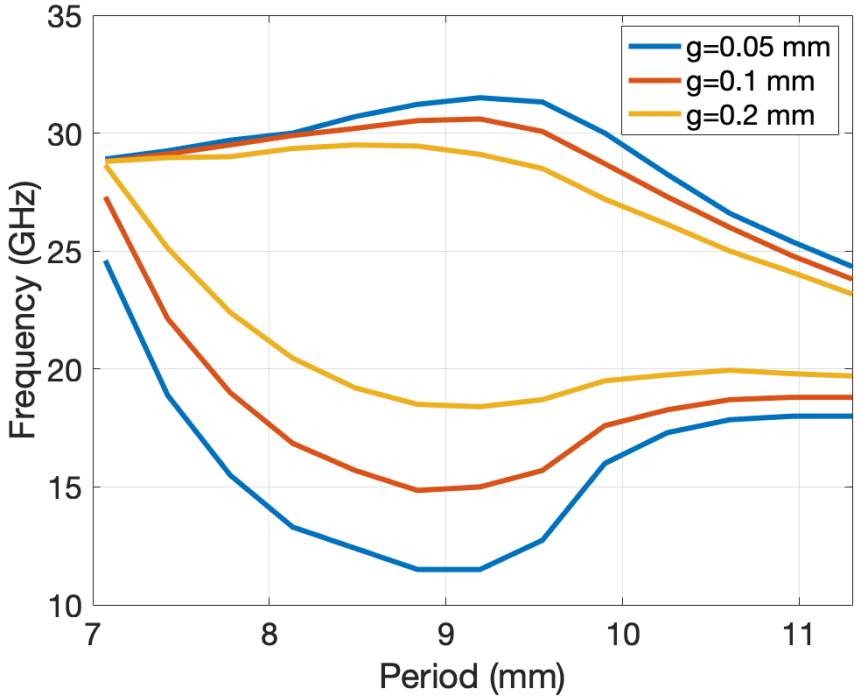


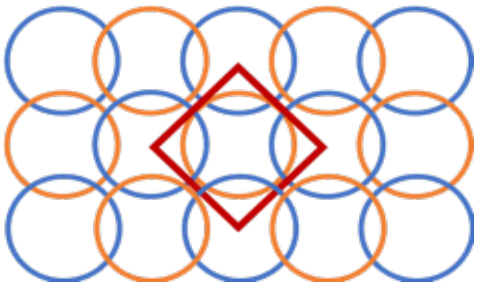
$$P_x \quad (P^{2D} = P_x / \sqrt{2})$$

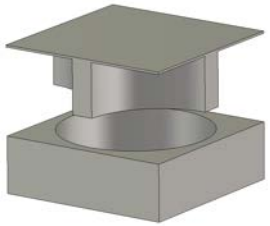


Considerations for application in GGW

- Design example – waveguide components in K-band (18.0 – 26.5 GHz)
- First step: to select dimensions that would maximize the range of the bandgap.





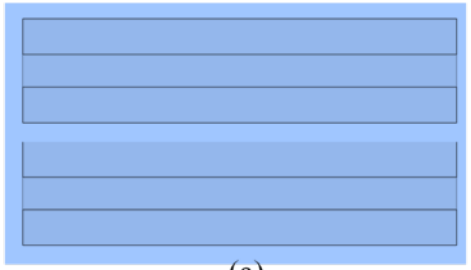


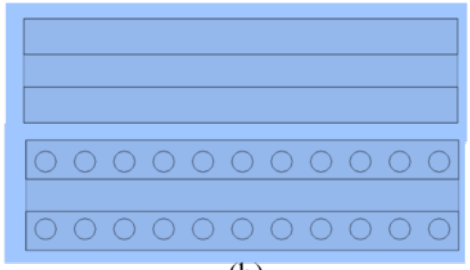
d_{hole} = 7 mm
h_{hole} = 3 mm

Considerations for application in GGW

- Practical question – how many rows of holes we need?

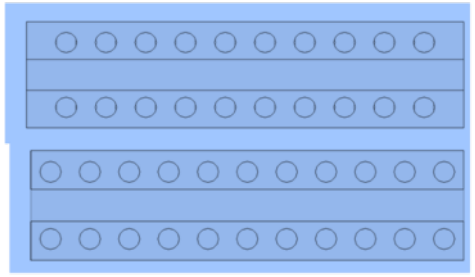
Reference case
→ no holes

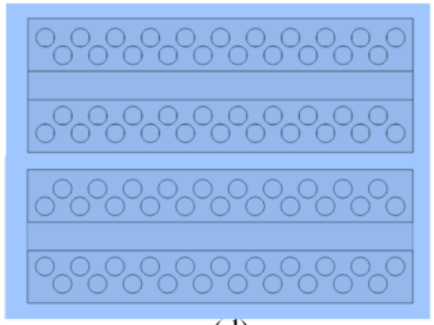




Case 1
→ one row of holes at bottom plate

Case 2
→ one row of holes at top and bottom plate



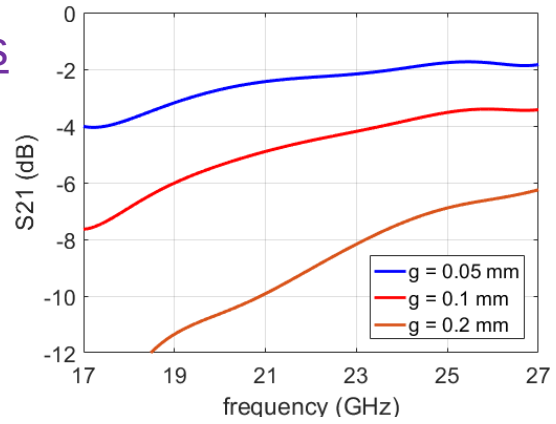


Case 3
→ two rows of holes at top and bottom plate

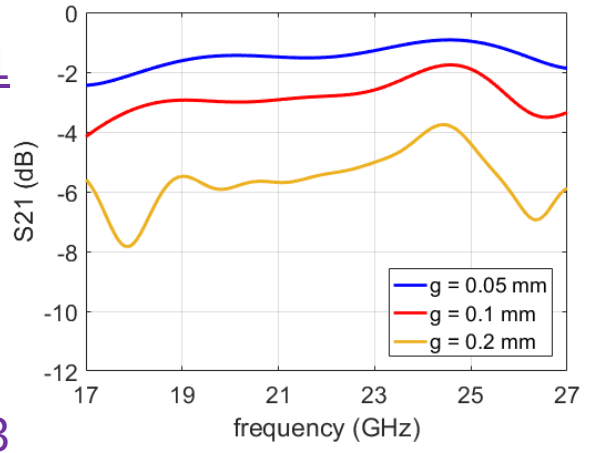
Considerations for application in GGW

- The selected period is the one with the maximum bandgap (P_x = 13 mm)

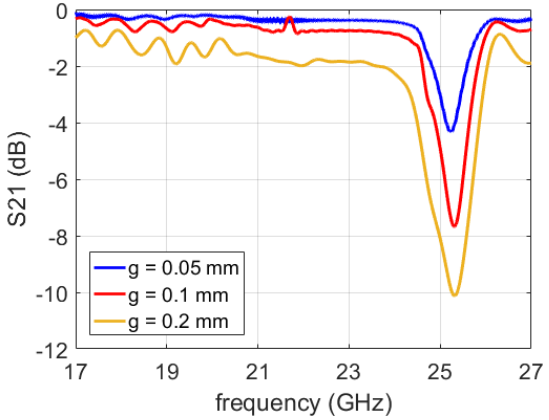
No holes



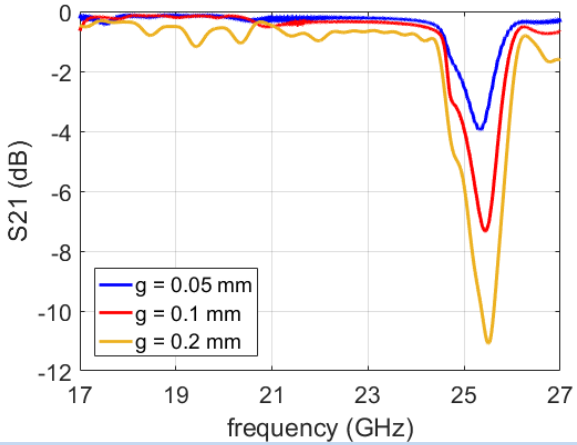
Case 1



Case 2

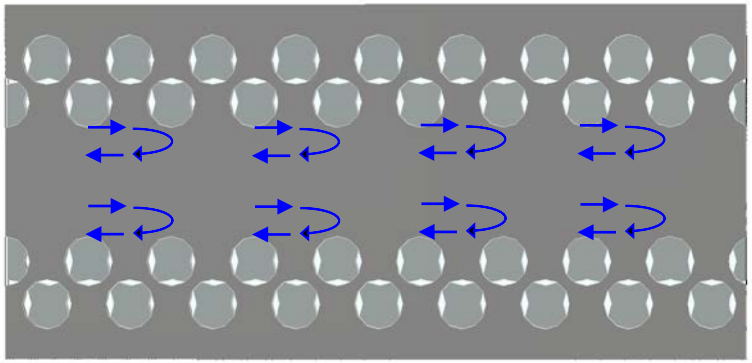


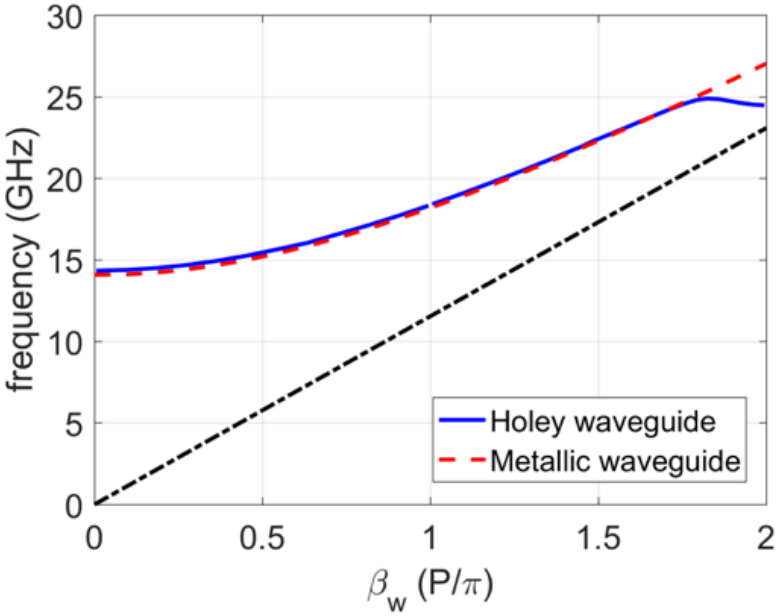
Case 3



Considerations for application in GGW

- Problem with the Bragg frequency ($\lambda_w = P_x$):
  - Small reflections from the hole discontinuities are added in phase, resulting in a strong reflected wave

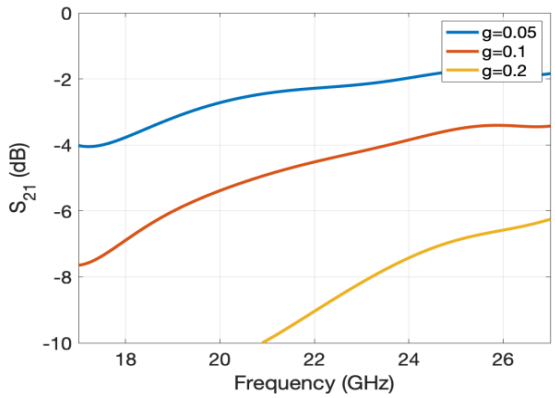




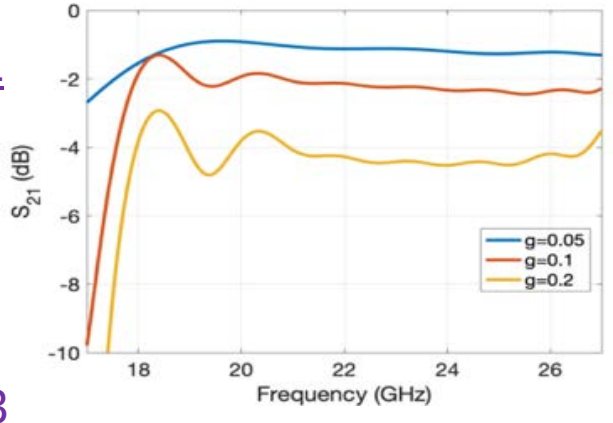
Considerations for application in GGW

- The selected period is smaller than the one with the maximum bandgap (P_x = 11 mm)

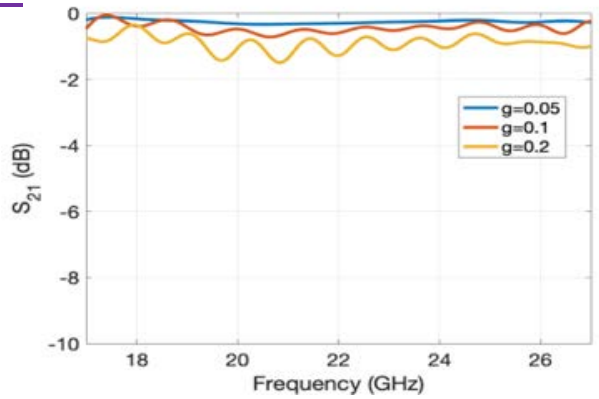
No holes



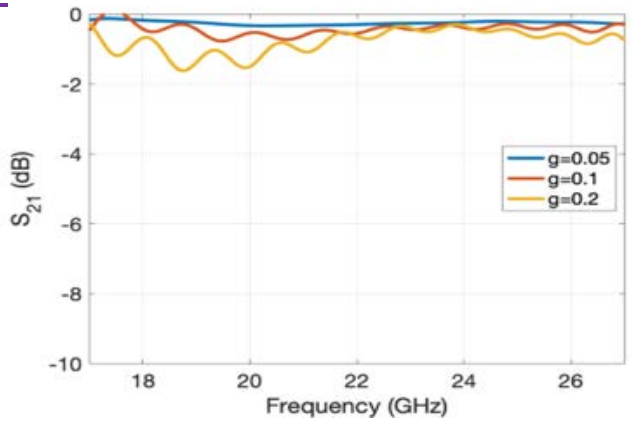
Case 1



Case 2

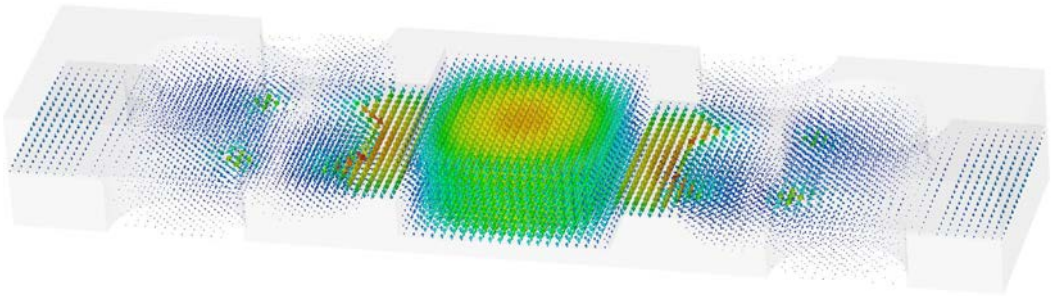


Case 3

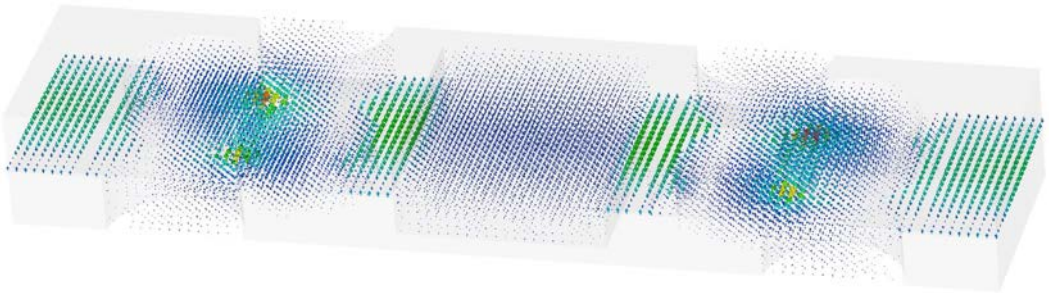


Considerations for application in GGW

- Higher order modes in holey glide-symmetric waveguide:
  - Dominant mode:



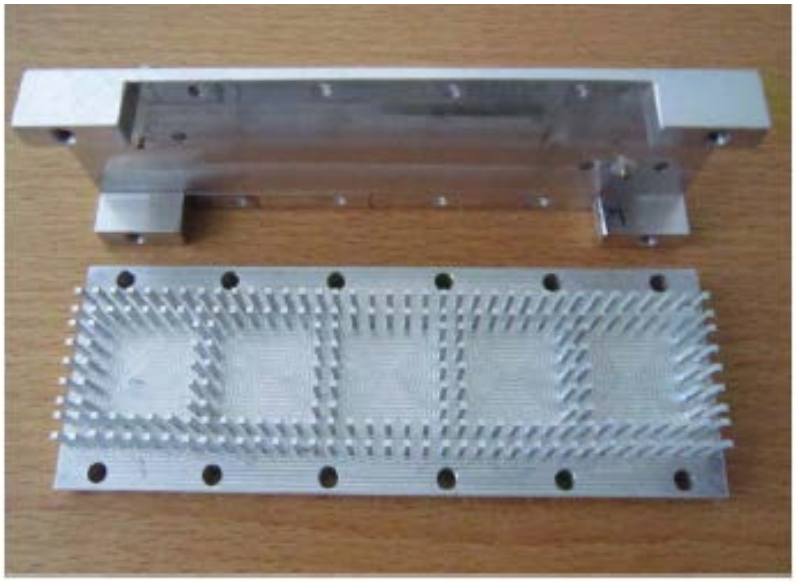
  - First higher-order mode:

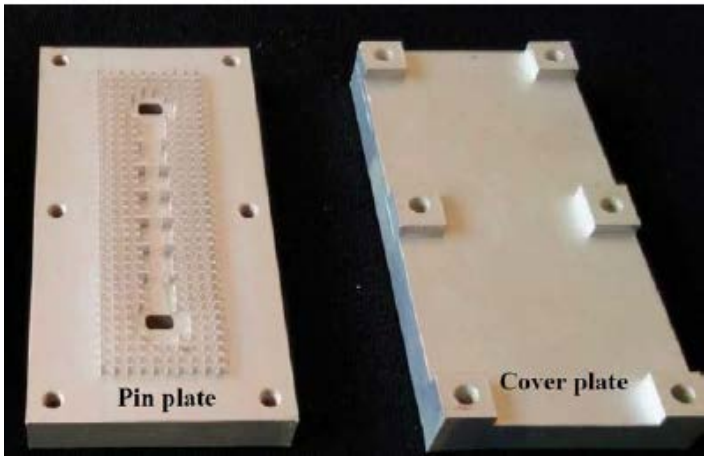


Design of Passive components

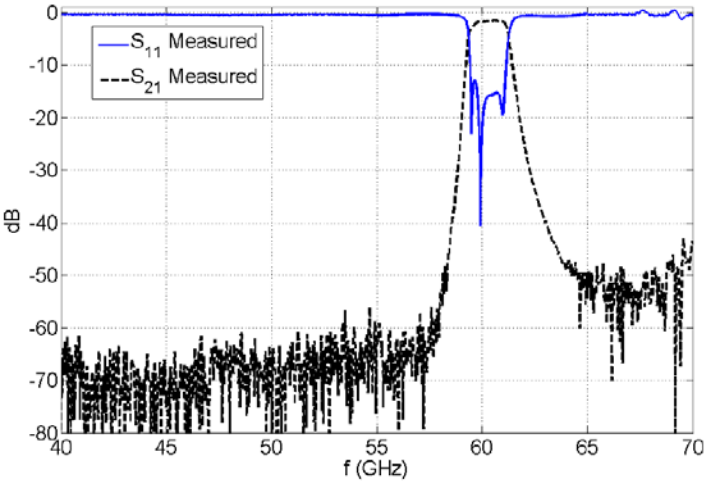
Examples with pins

A. U. Zaman, P.-S. Kildal and A. Kishk *Narrow-Band Microwave Filter Using High-Q Groove Gap Waveguide Resonators with Manufacturing Flexibility and No Sidewalls* IEEE Trans. On Packaging and Manufacturing Technology, Volume: 2 , Issue: 11 Novembre 2012 , Page(s): 1882- 1889

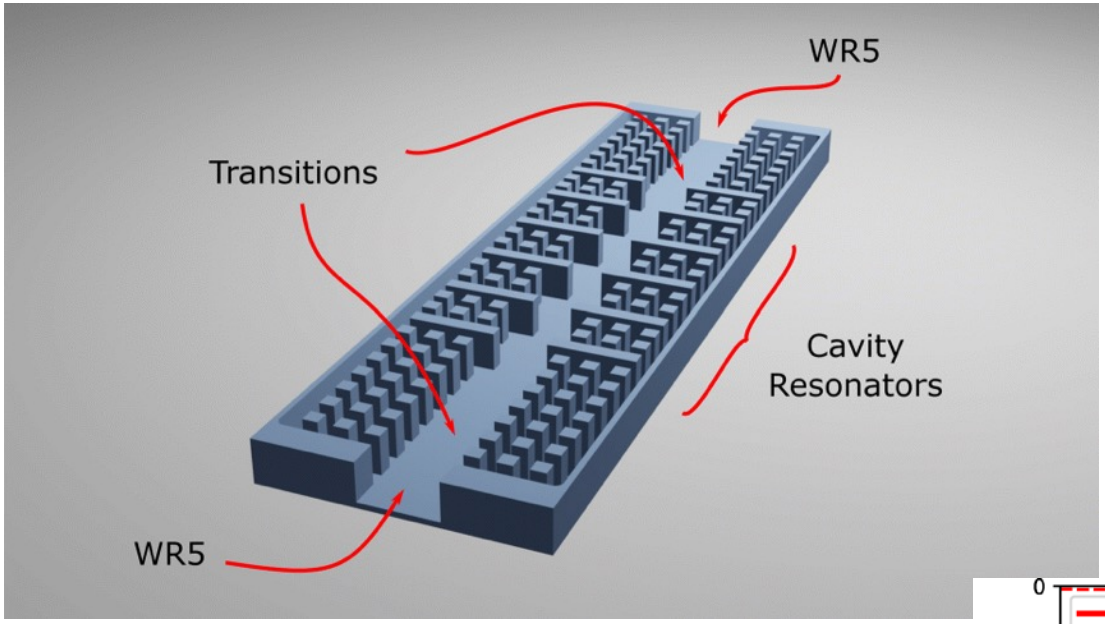


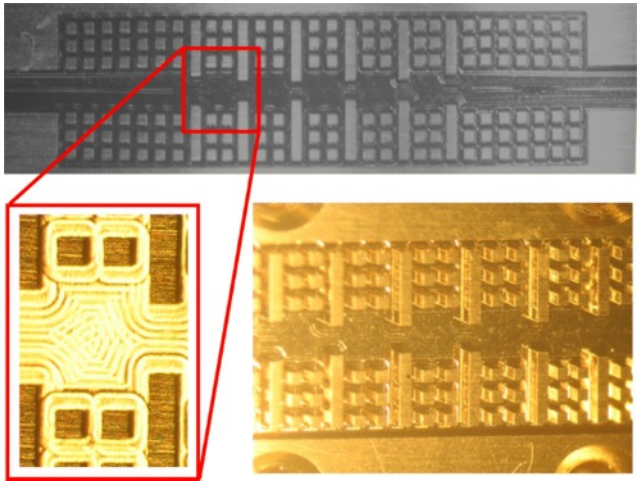


A. Berenguer, M. Baquero-Escudero, D. Sanchez-Escuderos, B. Bernardo-Clemente and V. E. Boria-Esbert, "Low insertion loss 61 GHz narrow-band filter implemented with Groove Gap Waveguides," *2014 44th European Microwave Conference*, Rome, 2014.

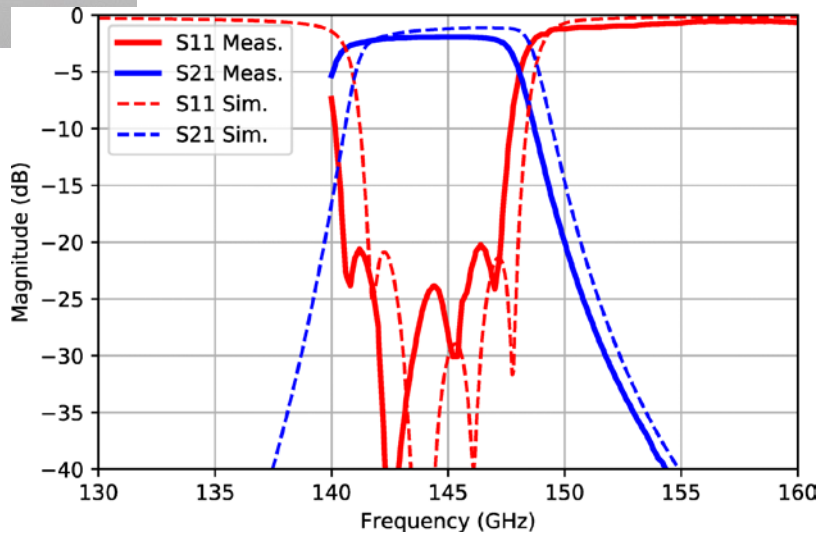


Passband filter in D-band



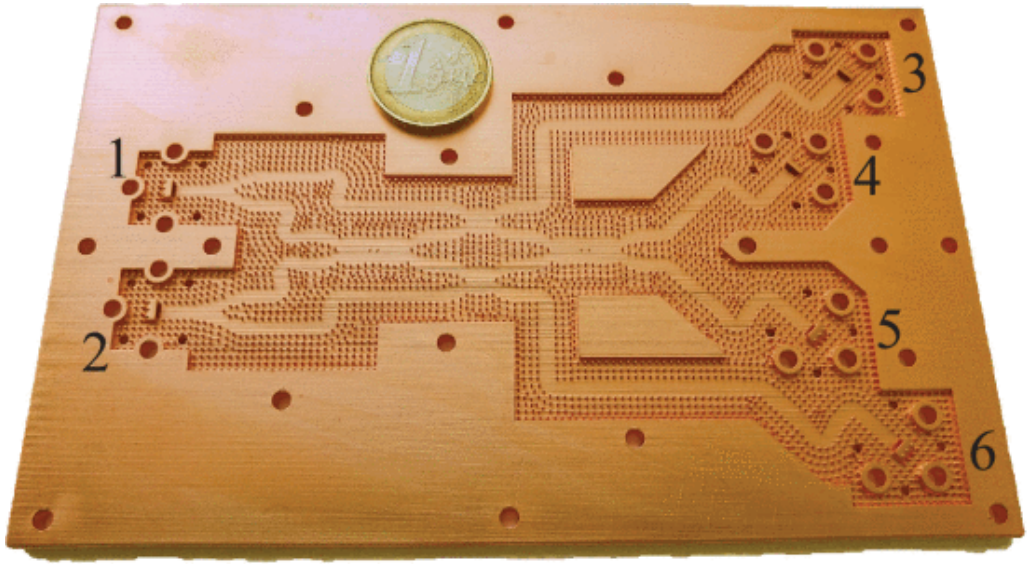


- ***Conventional CNC milling and gold plating of 1µm***



Vazquez-Roy, J.L., Rajo-Iglesias, E., Ulisse, G. *et al.* "Design and Realization of a Band Pass Filter at D-band Using Gap Waveguide Technology". *J Infrared Milli Terahz Waves* (2020). https://doi.org/10.1007/s10762-020-00729-8

Butler matrix @ 94 GHz

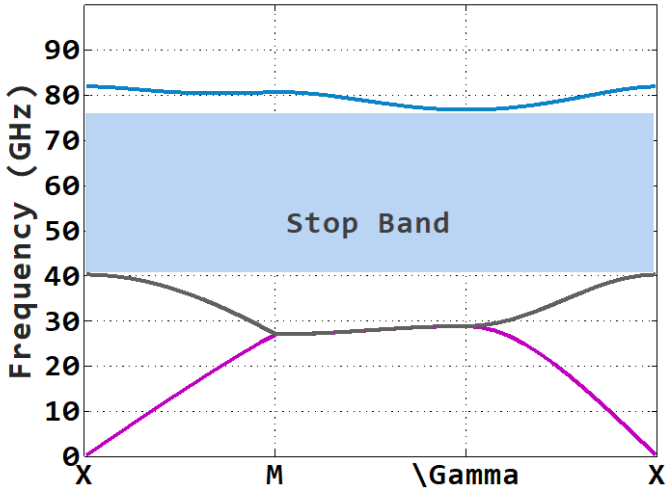


A. Tamayo-Domínguez, J. Fernández-González and M. Sierra-Castañer, "3-D-Printed Modified Butler Matrix Based on Gap Waveguide at W-Band for Monopulse Radar," in IEEE Transactions on Microwave Theory and Techniques, vol. 68, no. 3, pp. 926-938, March 2020, doi: 10.1109/TMTT.2019.2953164.

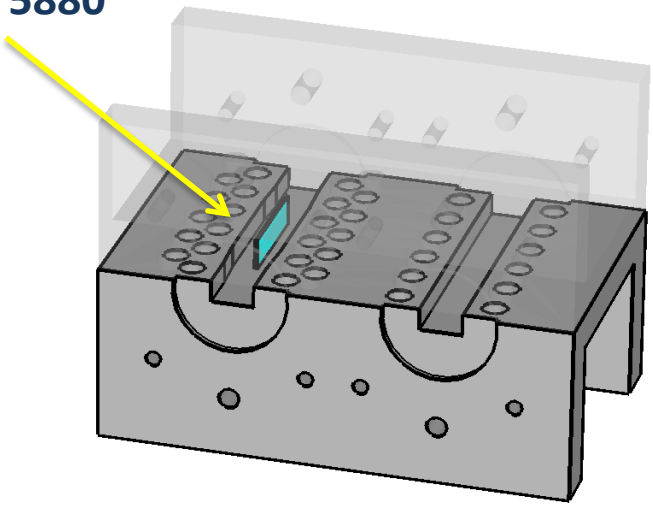
Design example: wideband phase shifter

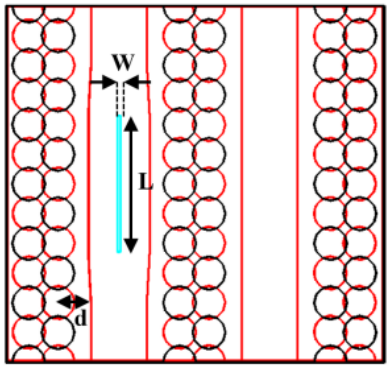
RGW WR19

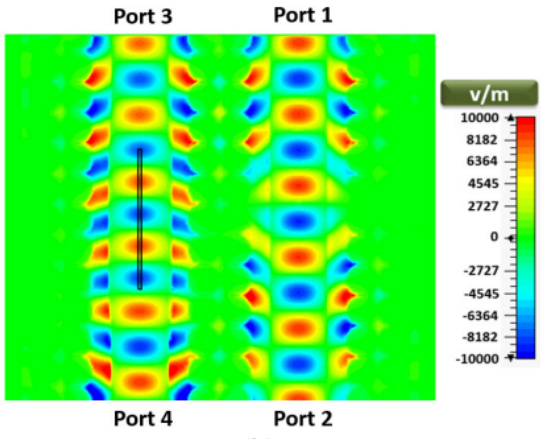
90º phase shifter



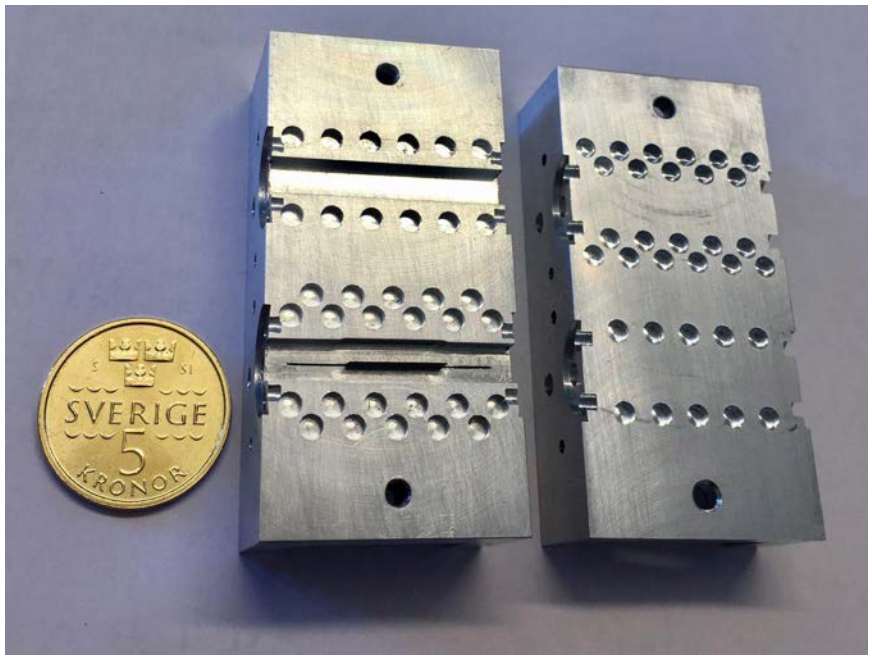
RT 5880

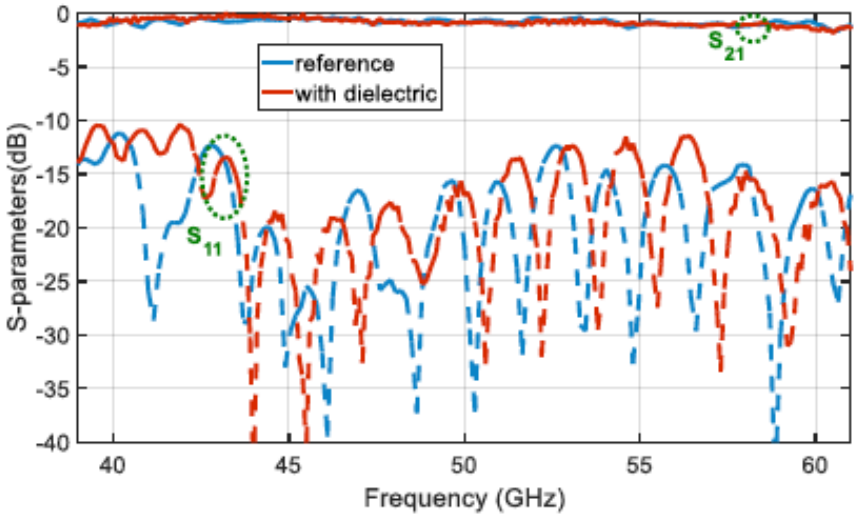


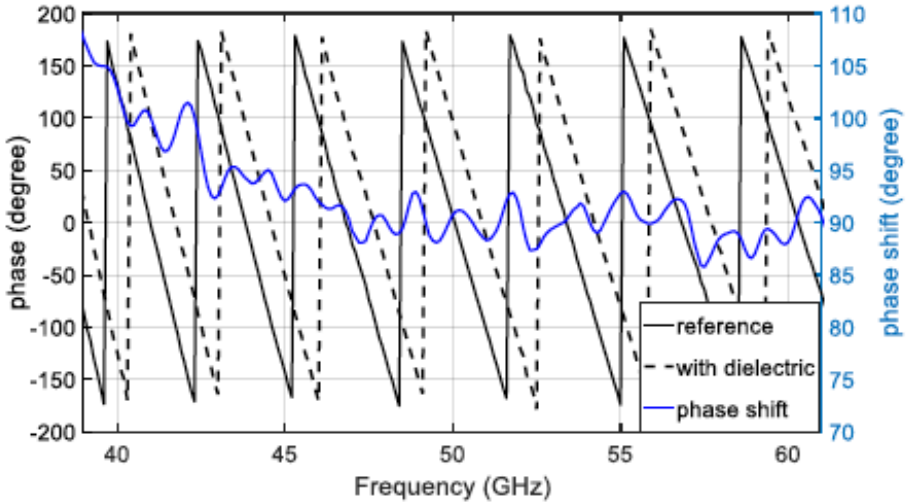




Manufactured phase shifter



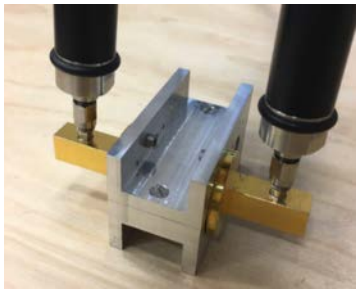


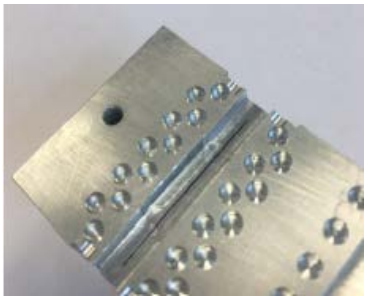


- **Wideband (30%)**
- **Low insertion losses**

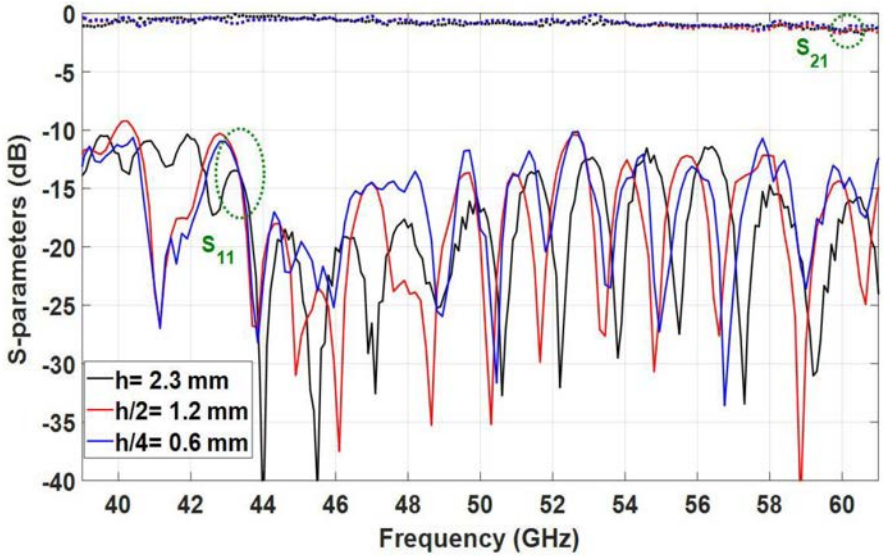
‘Variable’ phase shifter

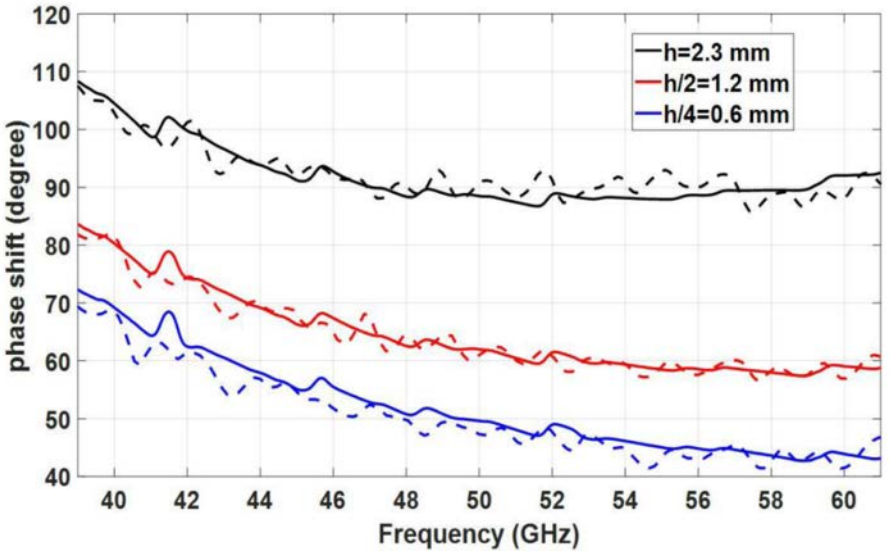
- Broadband response
- Low losses.





Using different heights

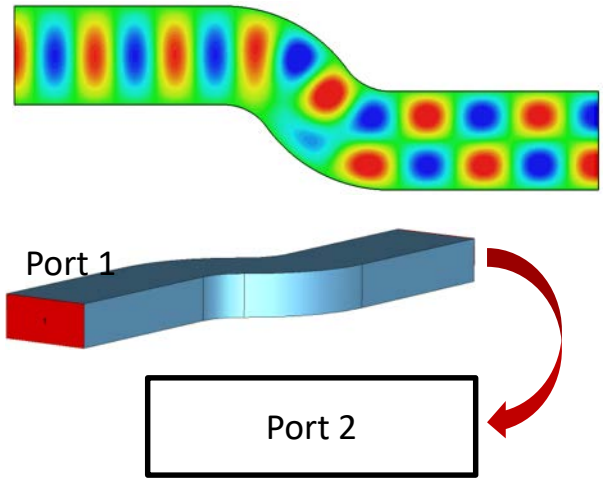


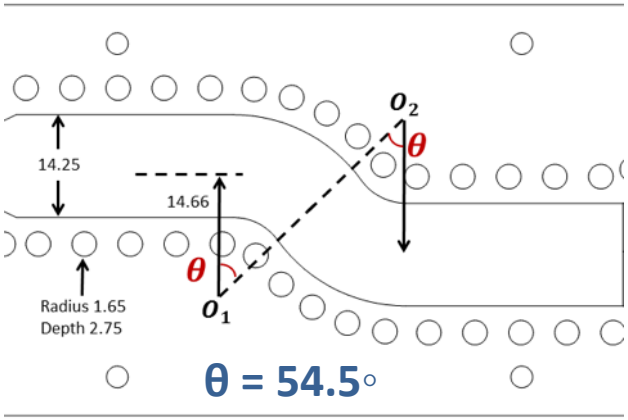


17) E. Rajo-Iglesias, M. Ebrahimpouri, O. Quevedo-Teruel, “Wideband phase shifter in groove gap waveguide technology implemented with glide-symmetric holey EBG”, *IEEE Microwave and Wireless Component Letters*, vol. 28, no. 6, pp. 476-478, June 2018.

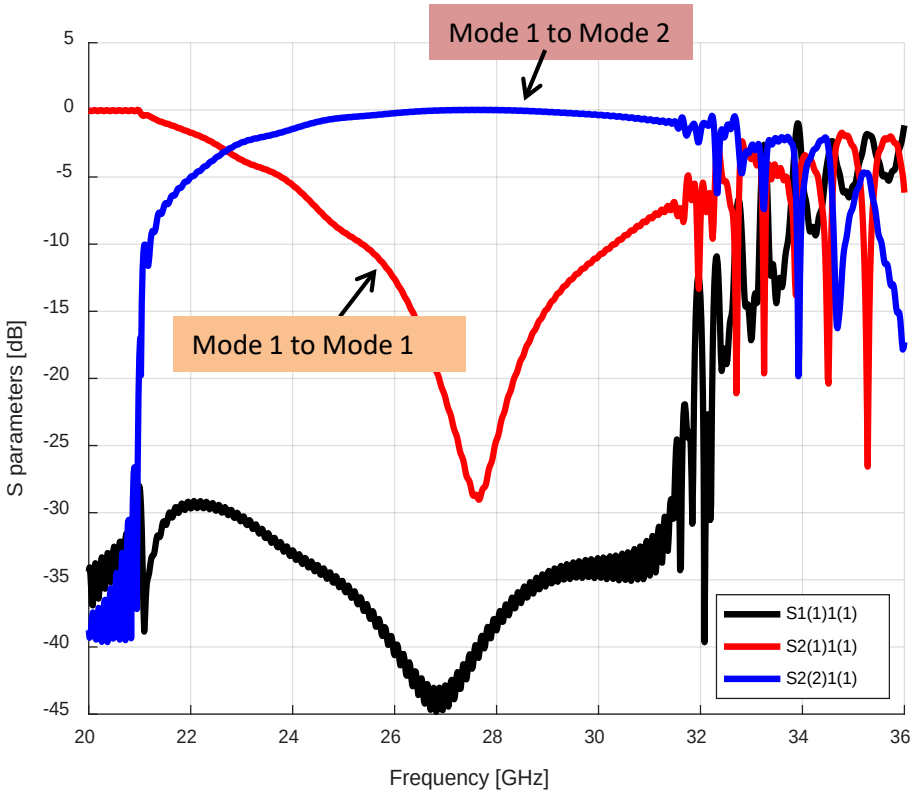
Mode converter @ 28 GHz

Waveguide: WR34





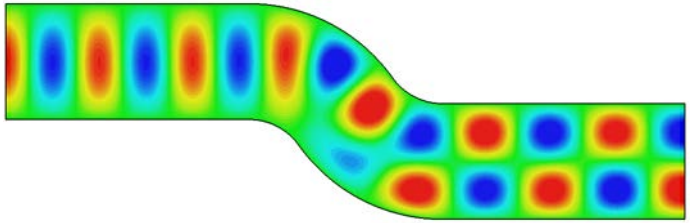
θ = 54.5°



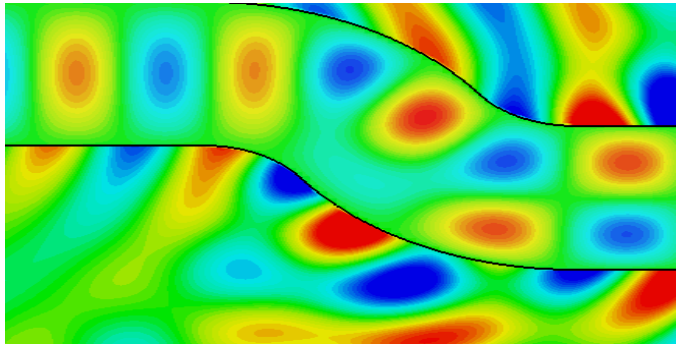
Mode converter @ 28 GHz

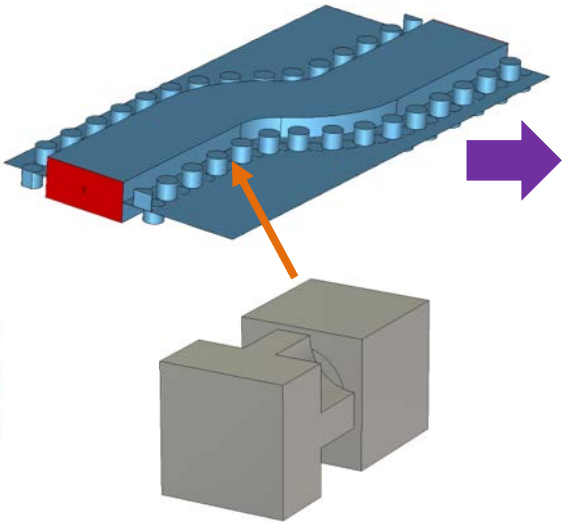
E field, comparison

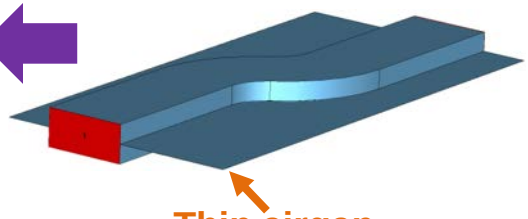
1. Classical waveguide



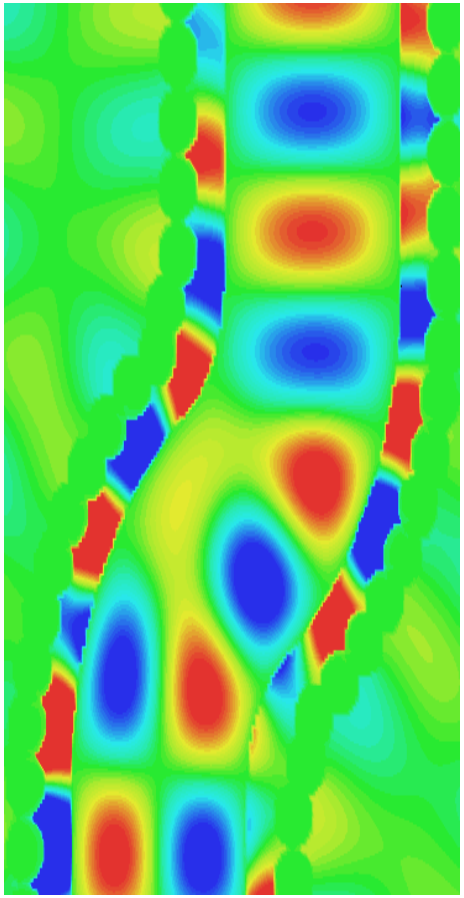
2. Waveguide with a thin air gap



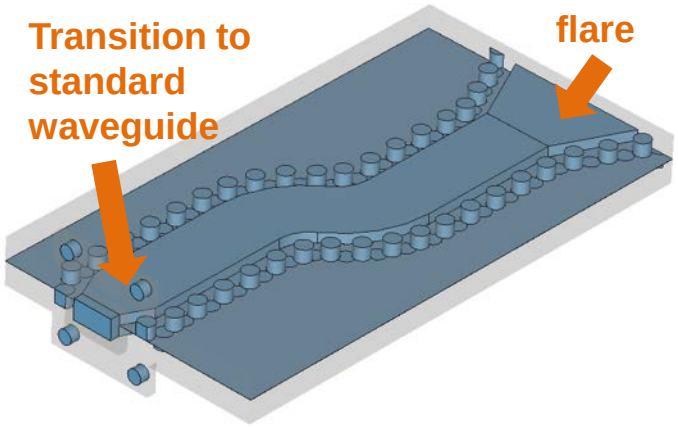


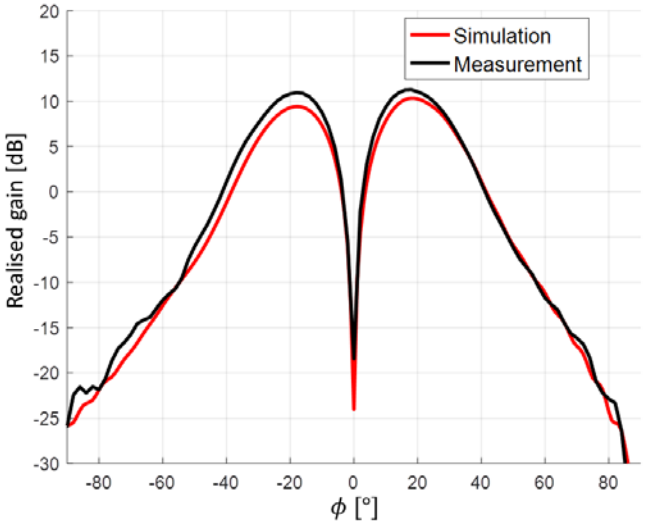


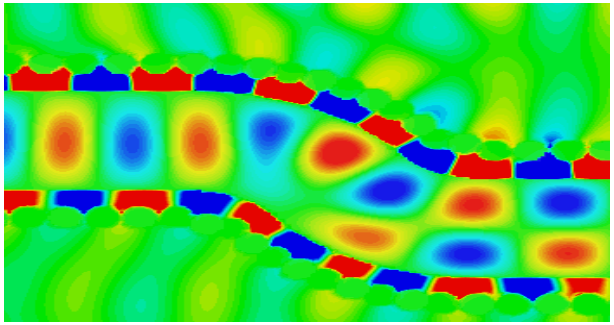
3. Glide symmetry

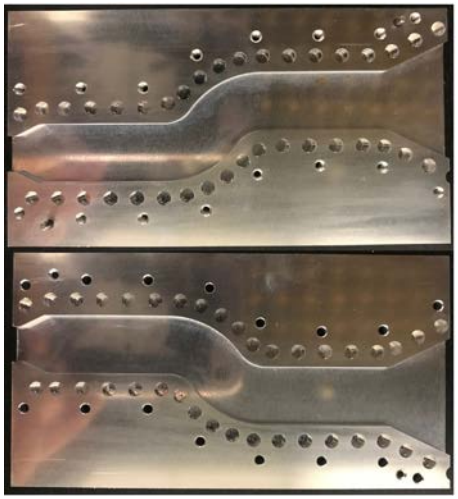


Verification with an antenna



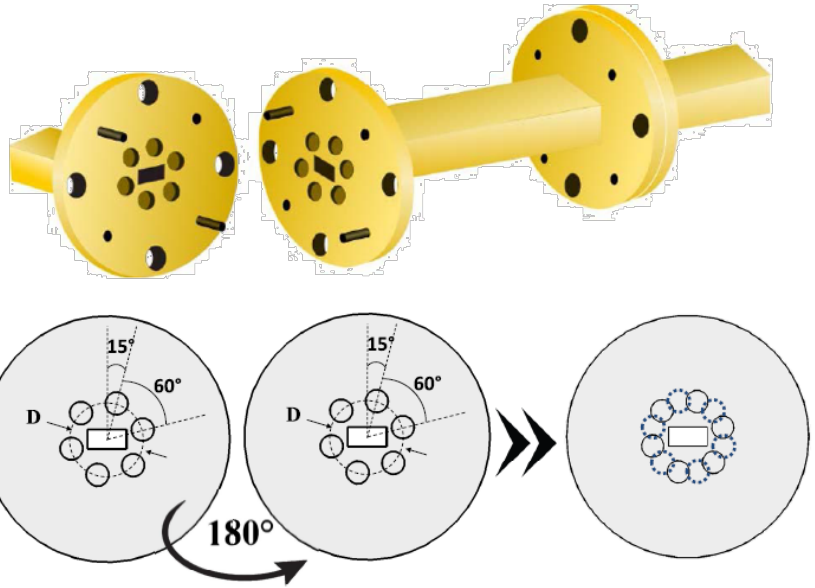






Other examples of applications: FLANGES

- Connections at high frequency:
  - Low leakage in commercial flanges.
  - Idea is patented by Ericsson in collaboration with KTH.



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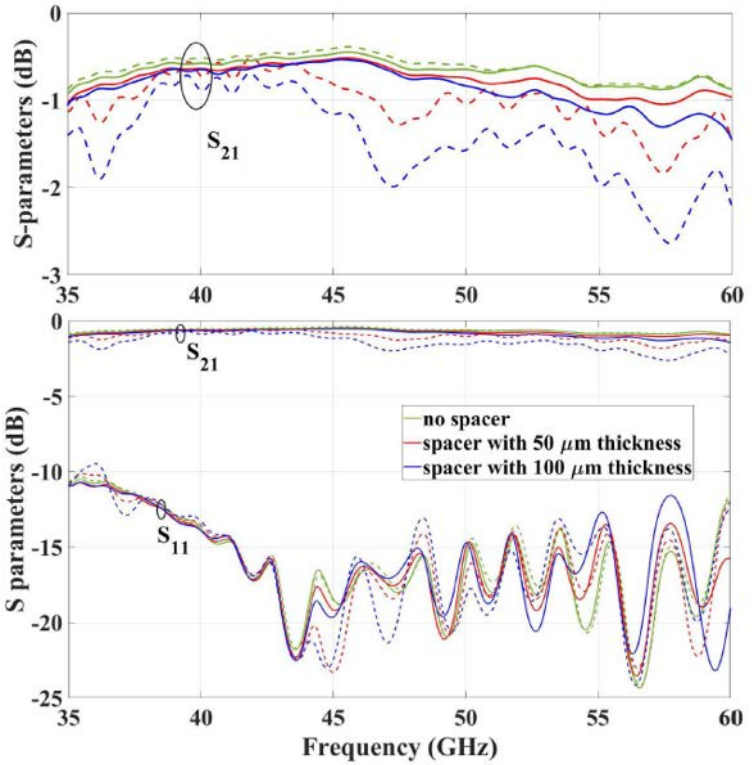


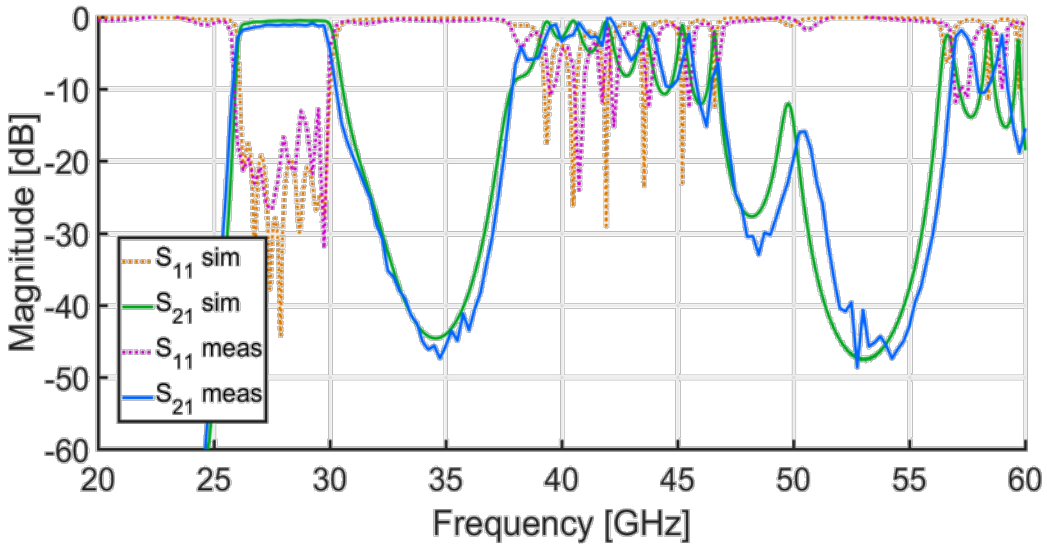
M. Ebrahimpouri, A. Algaba Brazalez, L. Manholm, O. Quevedo-Teruel, "Using Glide-symmetric Holes to Reduce Leakage between Waveguide Flanges", *IEEE Microwave and Wireless Component Letters*, vol. 28, no. 6, pp. 473-475, June 2018.

Other examples of applications: FILTERS

- Alternative to waffle-iron filters.

L. Young, B. M. Schiffman, ”New and improved types of waffle-iron filters”, *PROC. IEE*, vol. 110, no. 7, July 1963.

- Idea is patented by Ericsson in a collaboration with the ESA and KTH.
- Experimental results:



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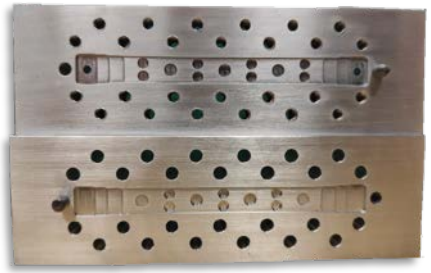
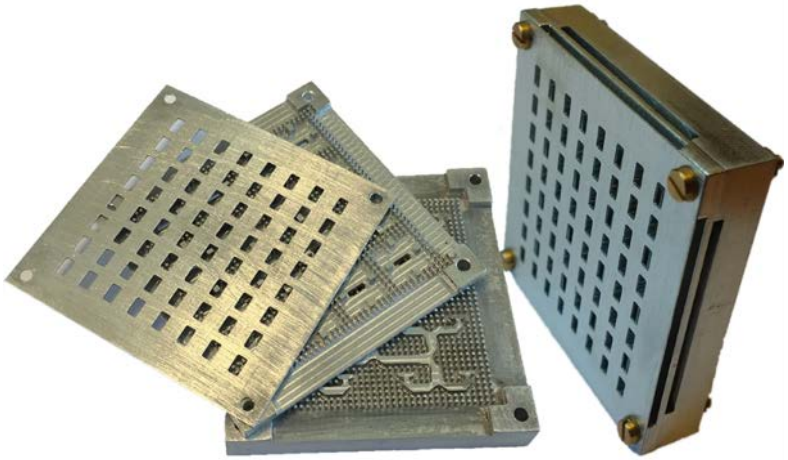
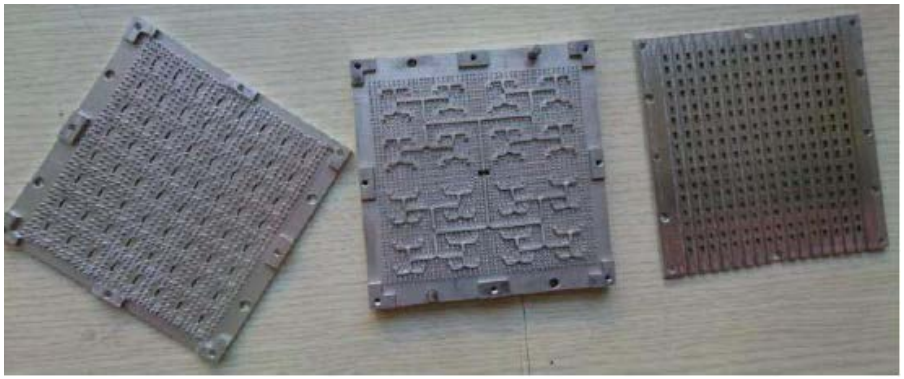


A. Monje-Real, N. J. G. Fonseca, O. Zetterstrom, E. Pucci, O. Quevedo-Teruel, ”Holey Glide-Symmetric Filters for 5G Millimetre Wave”, *IEEE Microwave and Wireless Propagation Letters*, vol. 30, no. 1, pp. 31-34, Jan. 2020.

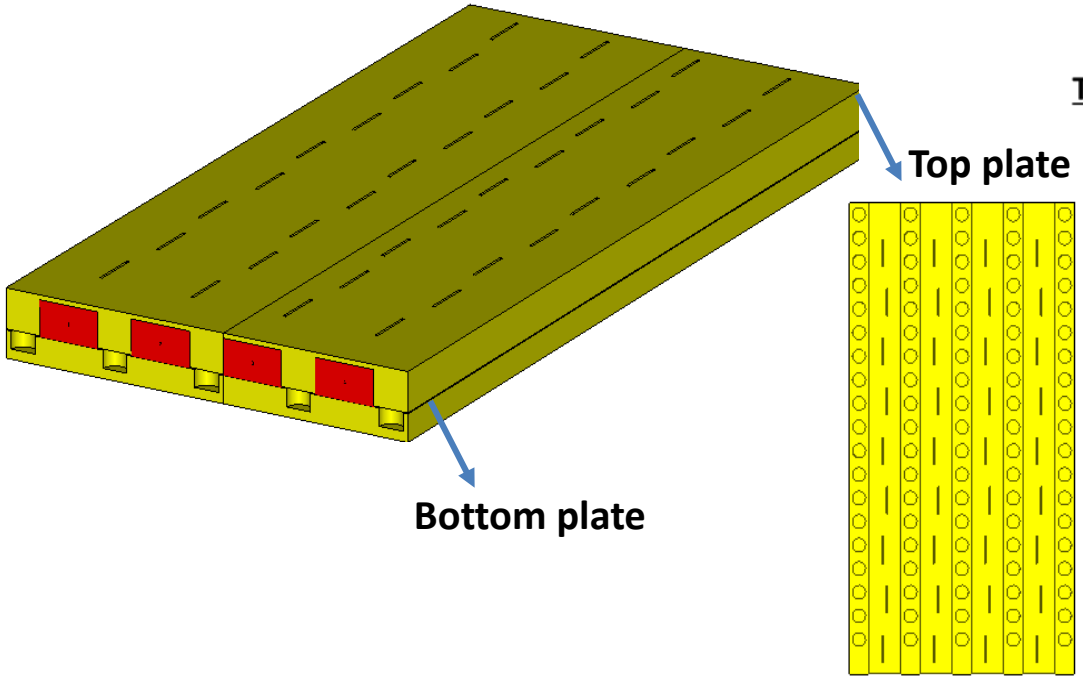
- Can we do antennas like these ones with holes instead of pins?

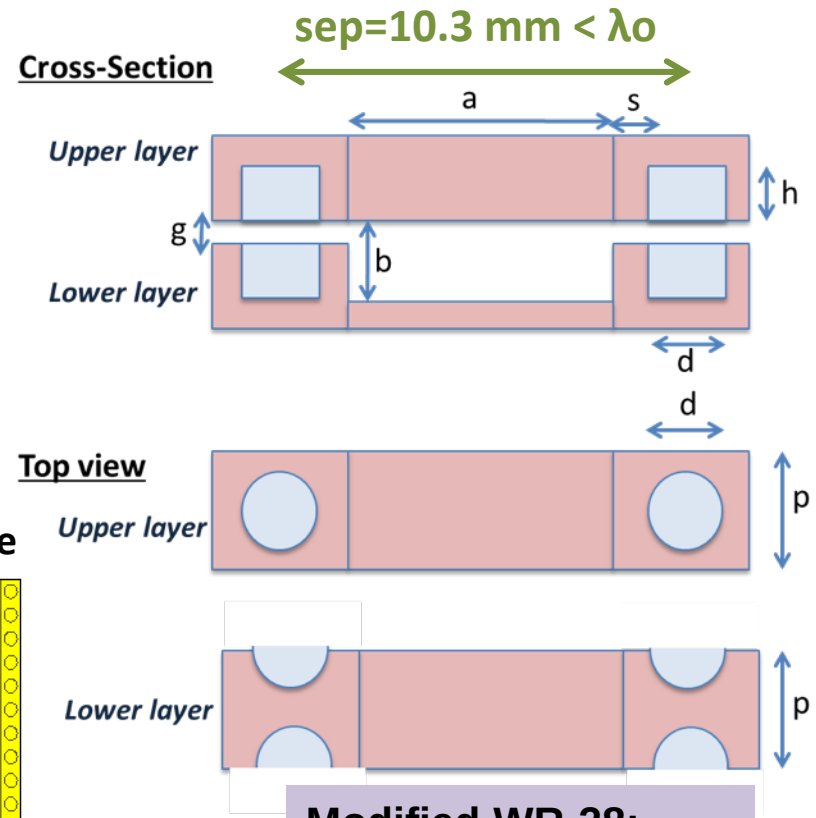




Design of the feed network

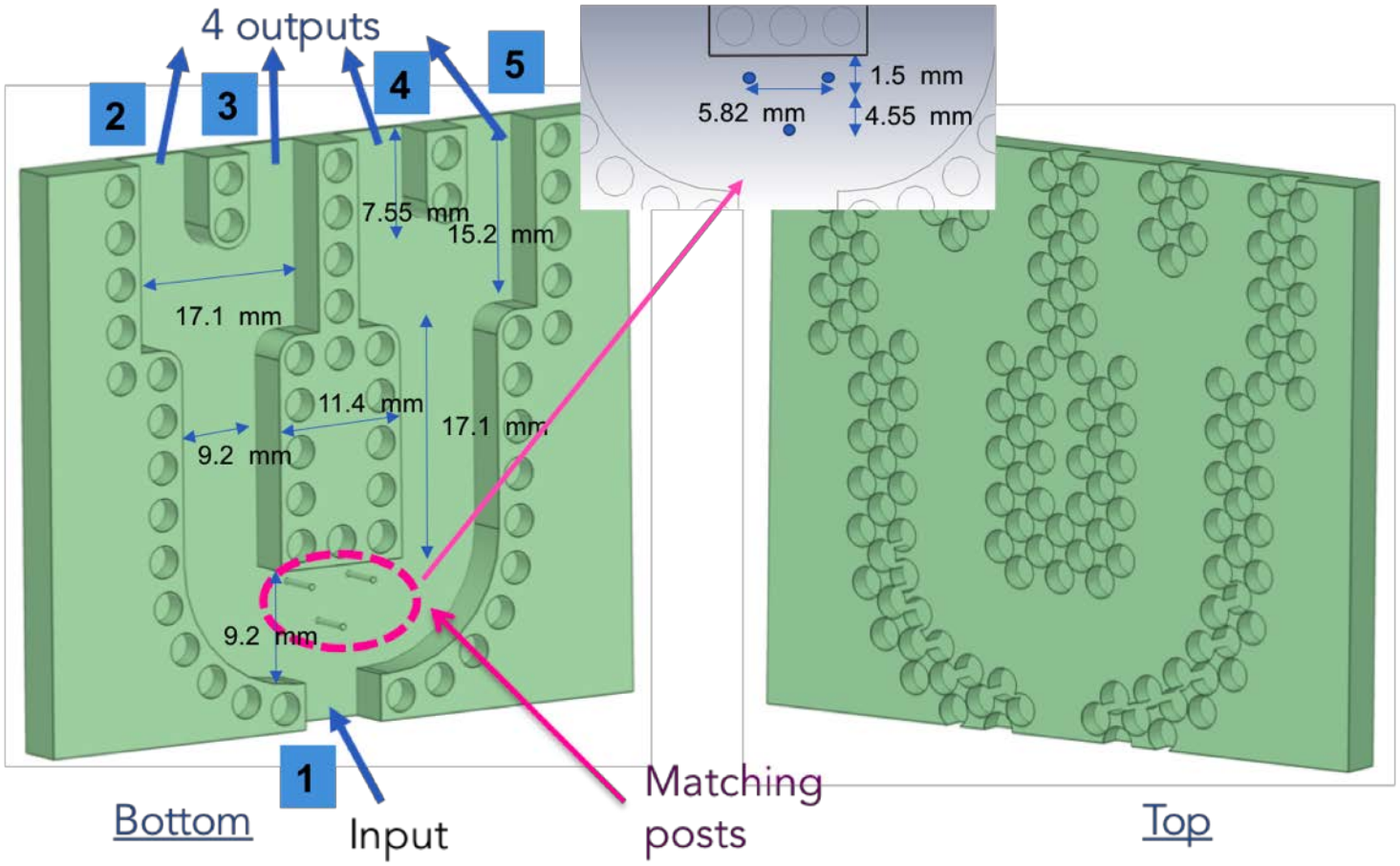
- ✓ Holes designed as compact as possible for the 28 GHz band
- ✓ Size of the waveguide combined with holes has to be smaller than λo= 10.714 mm
- ✓ Four rows of slots



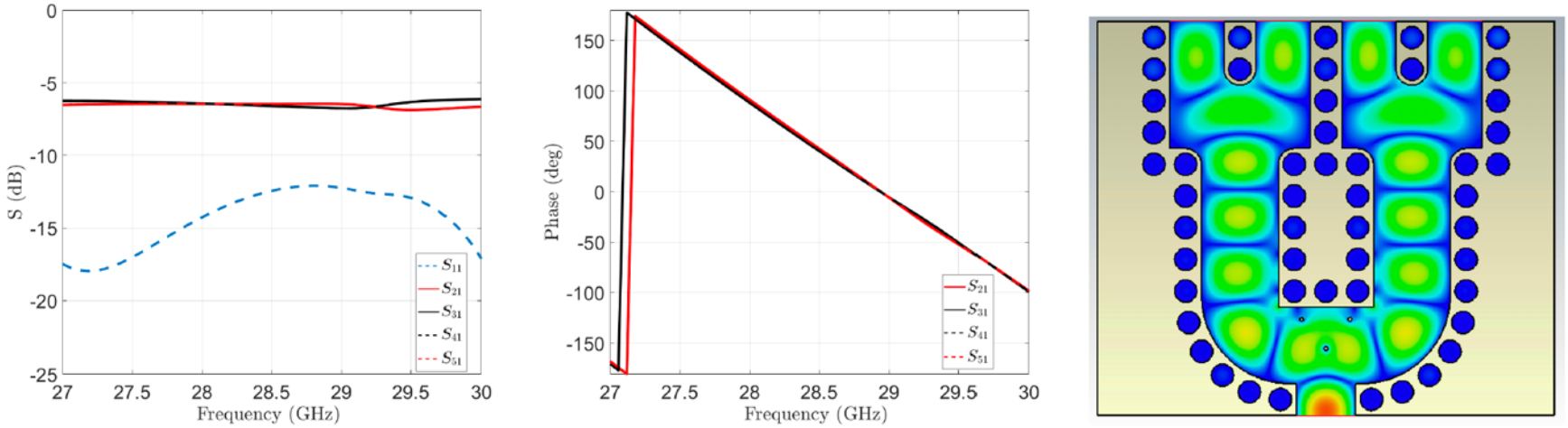


Modified WR-28:
a= 6.5 mm
b= 3.556 mm
s= 0.56 mm
fcutoff= 23.08 GHz

Feed network design



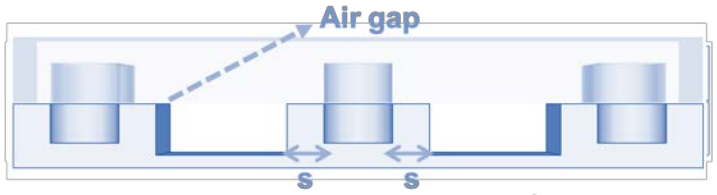
Feed network design

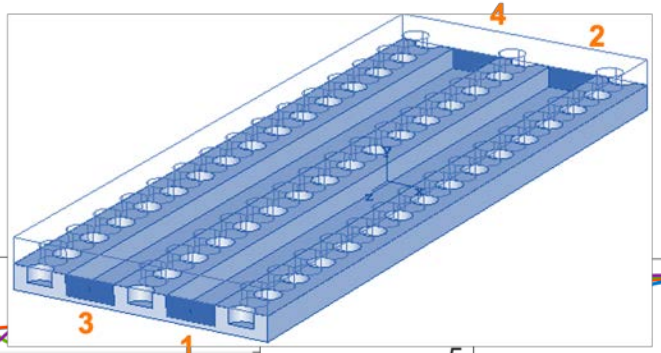


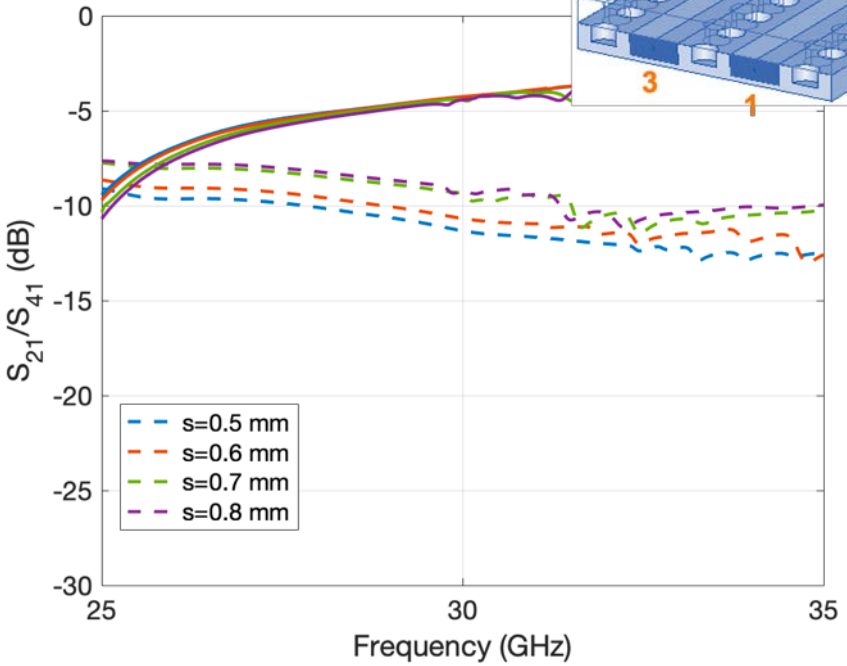
(a) S parameters (b) S parameters (c) E-field at 28 GHz parameters

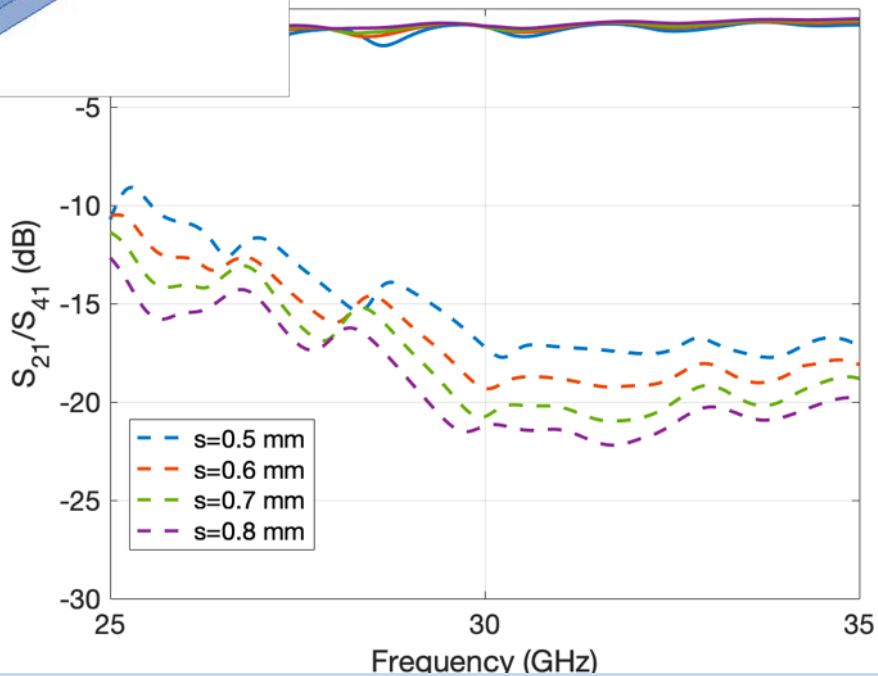
Figure 4. S-parameters of the simulated power divider described in Fig. 3 and instantaneous E field in the cross-section

Designing the slot array



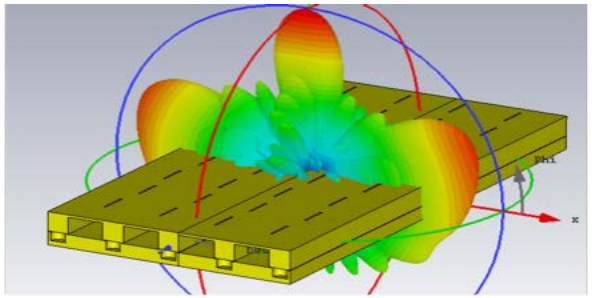






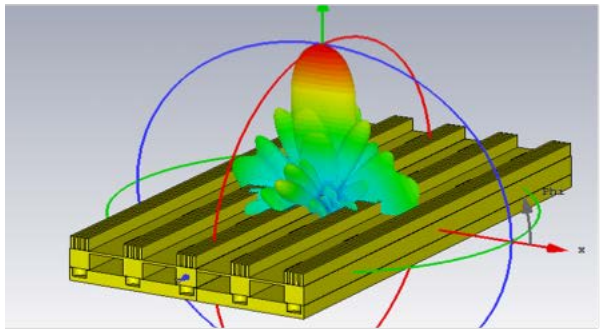
Designing the slot array

Gain =19 dB
SLL E-plane = -2.8 dB

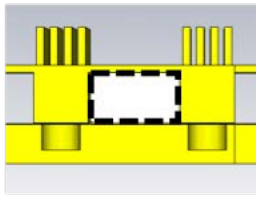


a)

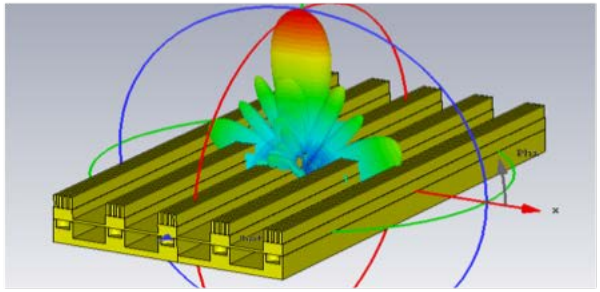
Gain =23.3 dB
SLL E-plane = -15.4 dB



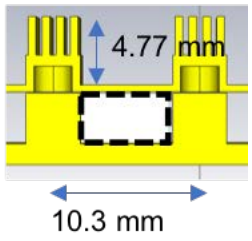
b)



Gain =23.6 dB
SLL E-plane = -16.2 dB

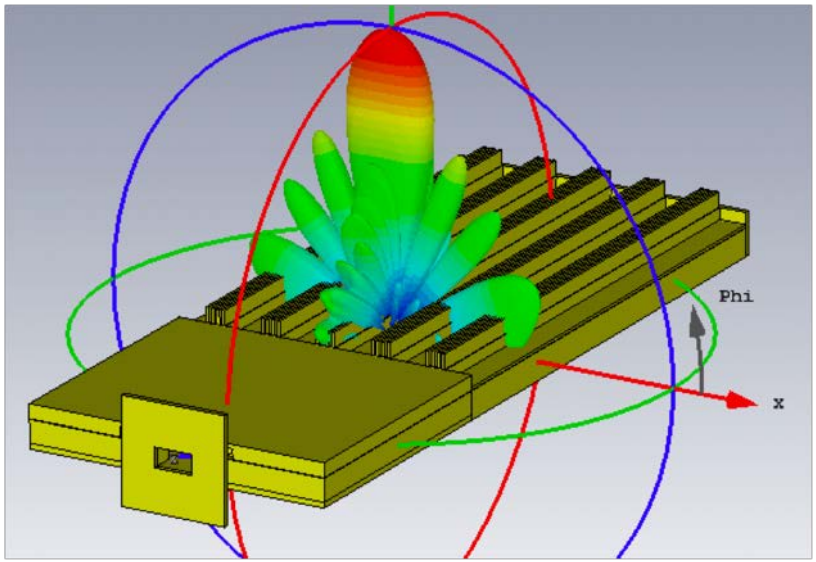


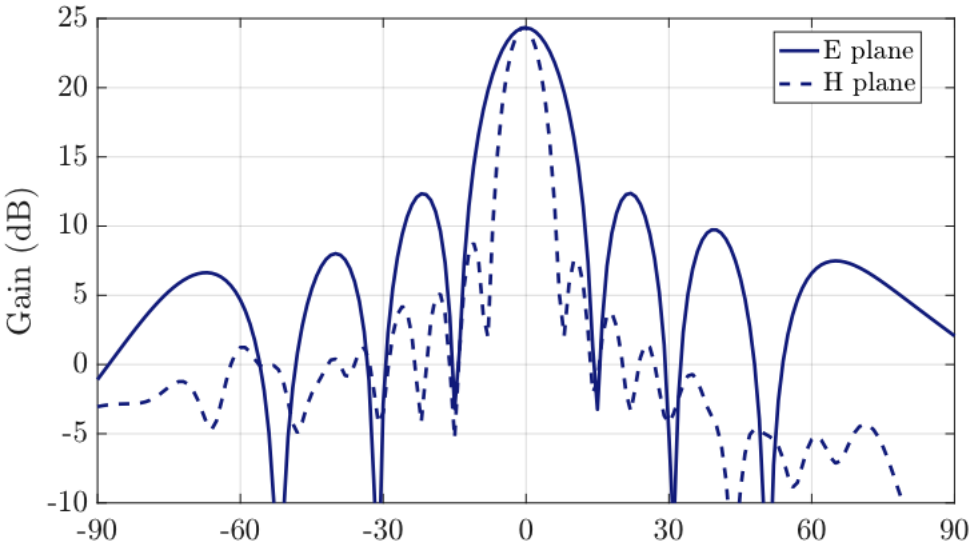
c)

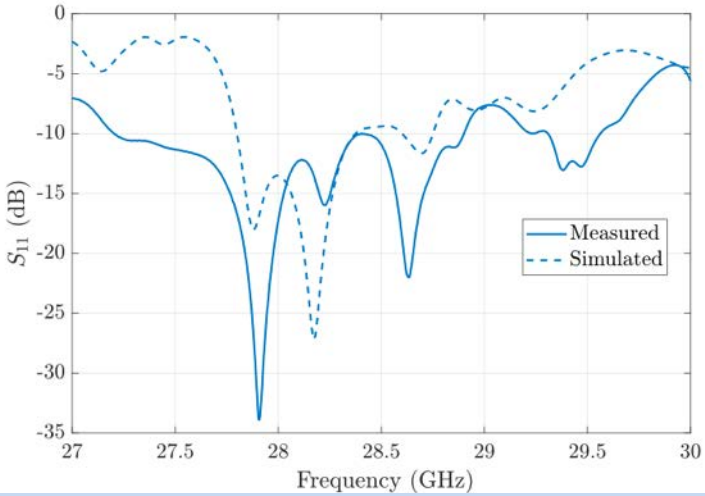


- ✓ Four rows with 9 slots each
- ✓ Designed for uniform amplitude
- ✓ Corrugations to reduce sidelobes

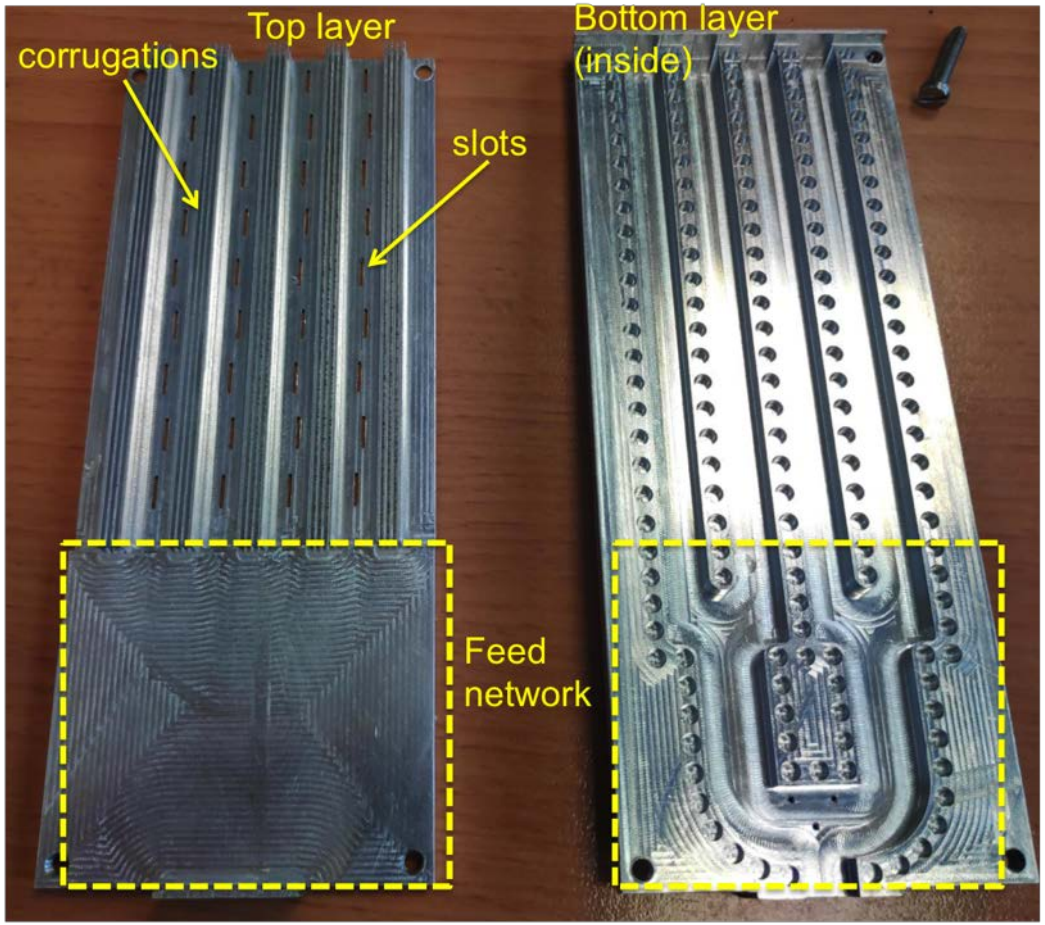
Designing the slot array







Manufactured prototype

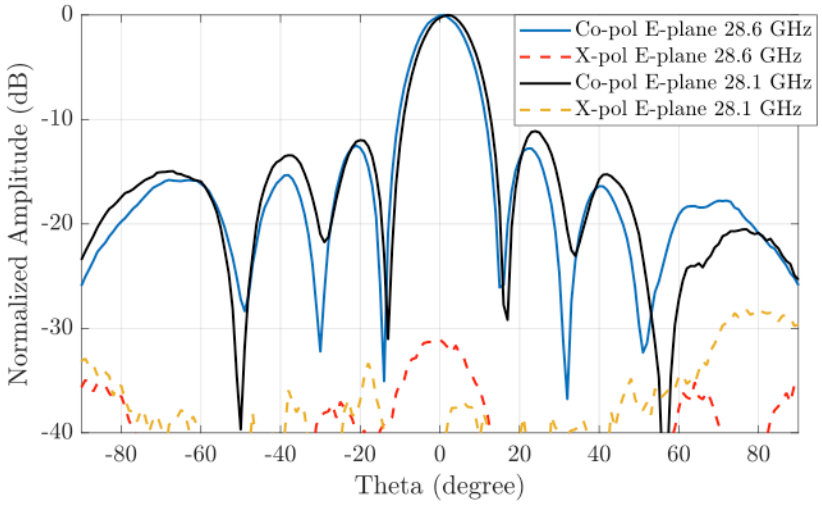


L. F. Herrán, A. Algaba Brazalez, and E. Rajo-Iglesias, "Ka-band planar slotted waveguide array based on groove gap waveguide technology with a glide-symmetric holey metasurface," *Sci Rep*, vol. 11, no. 1, Art. no. 1, Apr. 2021, doi: 10.1038/s41598-021-88054-5

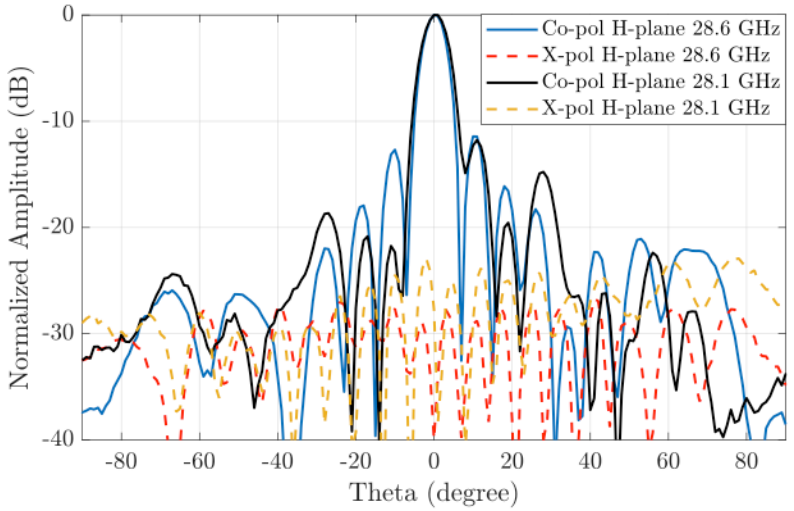
Slotted waveguide array @ 28 GHz

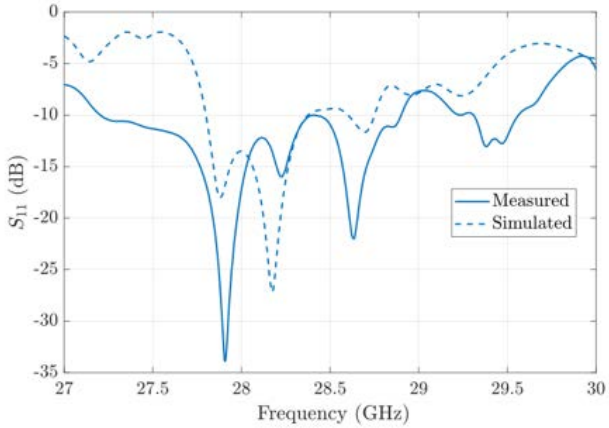
Experimental results

E-plane



H-plane

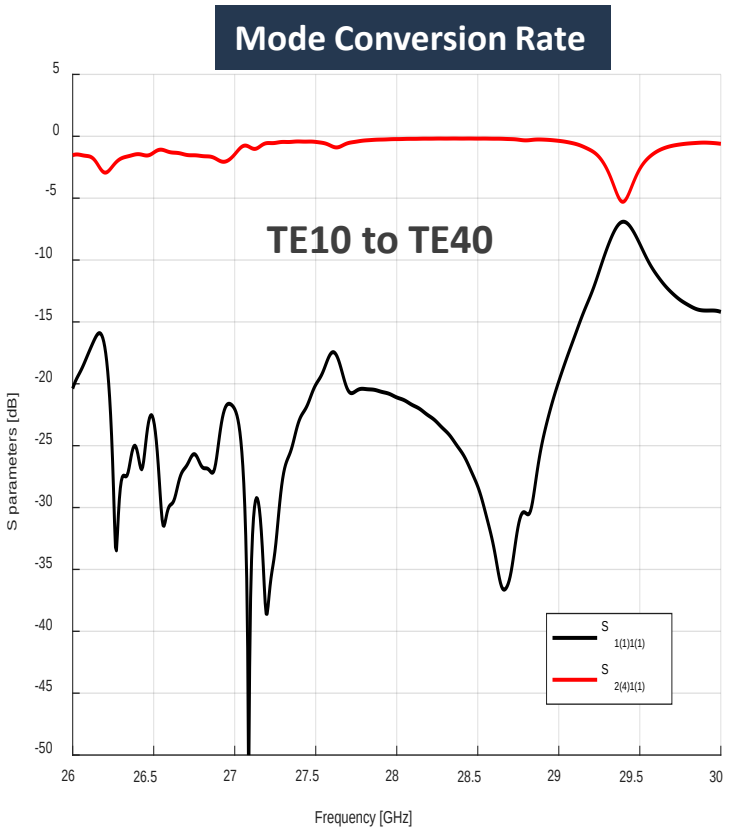


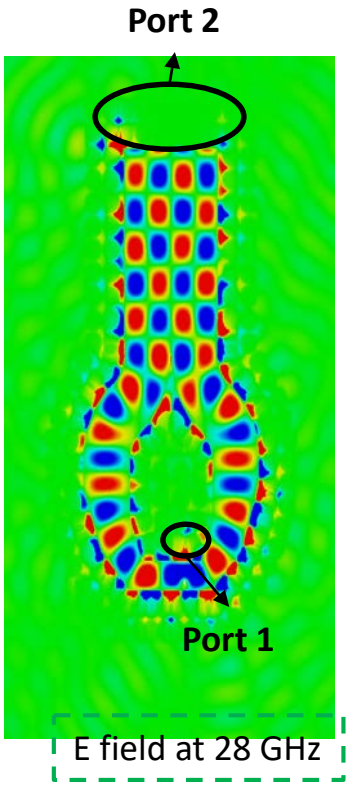


Almost 25 dBi gain

4x4 array with symmetrical pattern

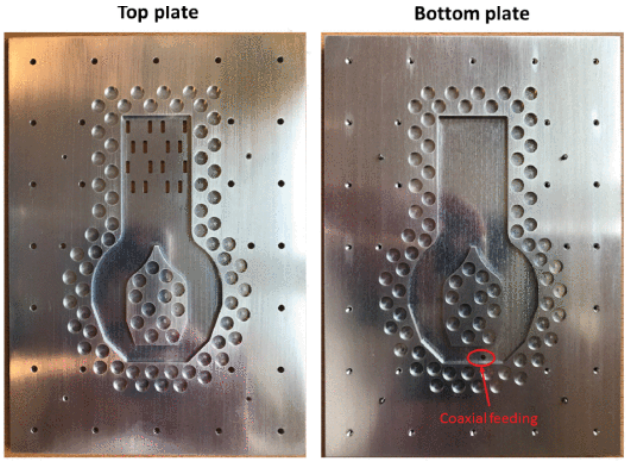
Q. Liao, E. Rajo-Iglesias and O. Quevedo-Teruel, "Ka-Band Fully Metallic TE40 Slot Array Antenna With Glide-Symmetric Gap Waveguide Technology," in *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 10, pp. 6410-6418, Oct. 2019.





E field at 28 GHz

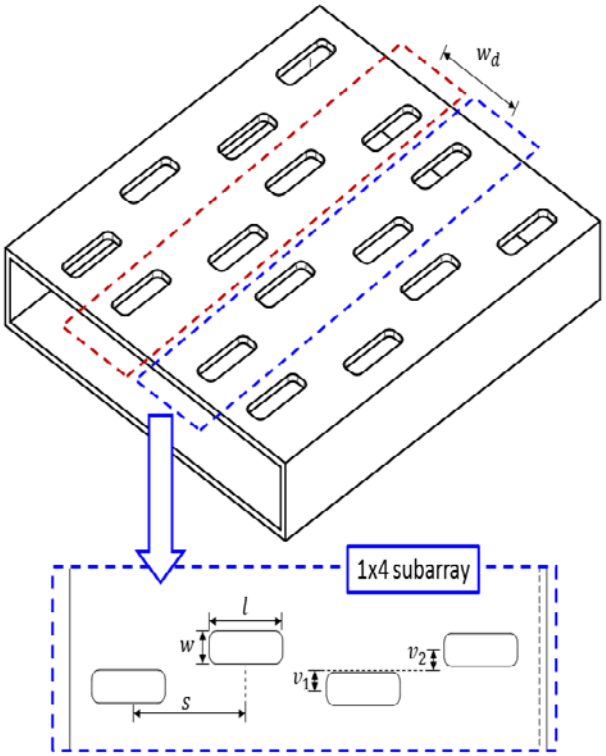
- ✓ Mode conversion efficiency TE_{10} to TE_{40} mode above 95% from 27.3 to 29 GHz (small decay at 27.6 GHz, but conversion rate still larger than 90%).
- ✓ Port 1 is a coaxial connector into waveguide

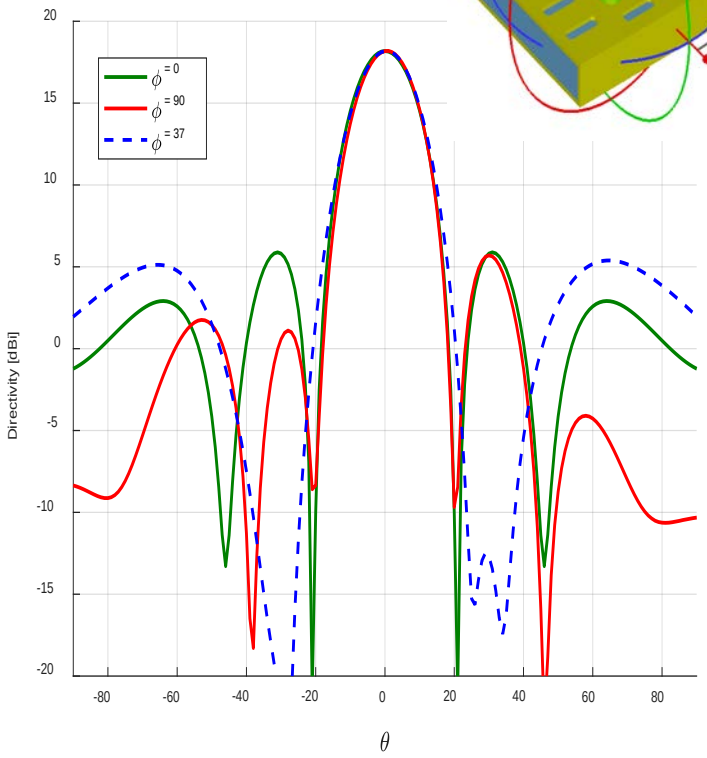


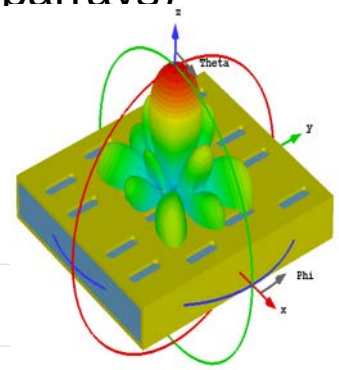
4x4 array with symmetrical pattern

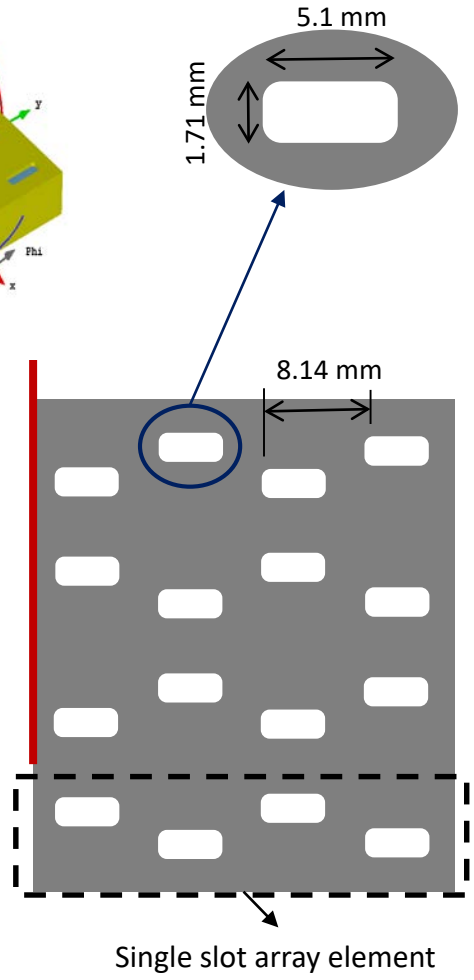
- ✓ Glide-symmetric mode converter feeding a 4x4 slot array antenna (made of 1x4 Chebyshev subarrays)

Array with ideal TE_{40} mode feeding

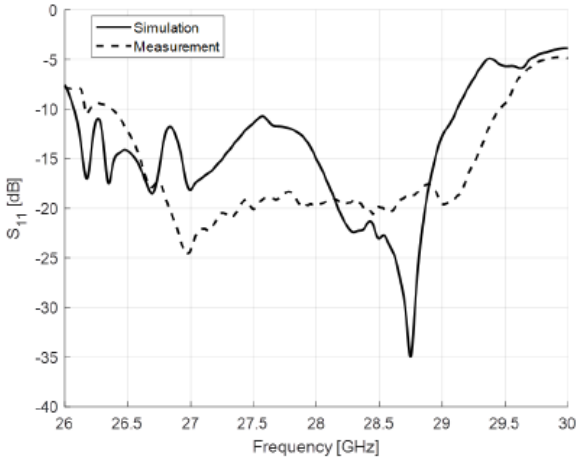


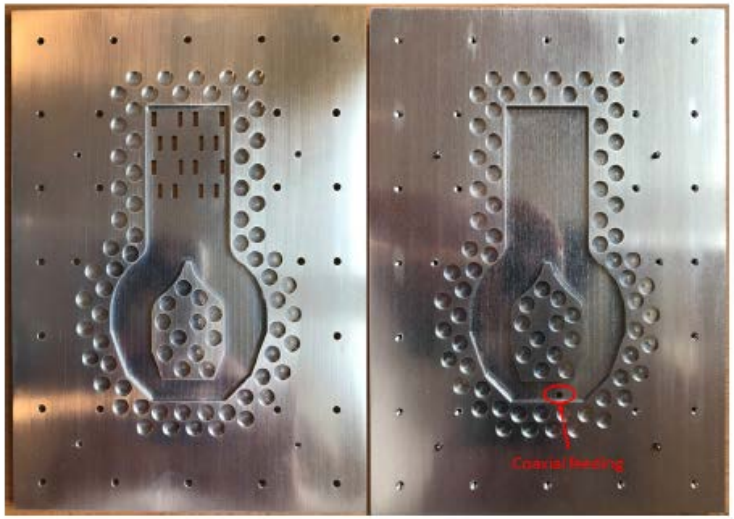


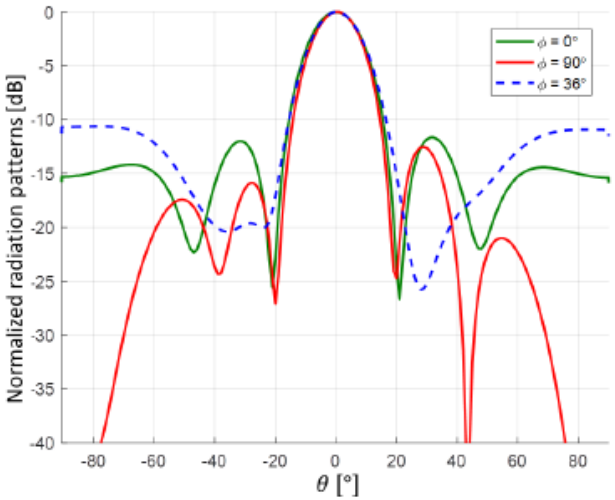




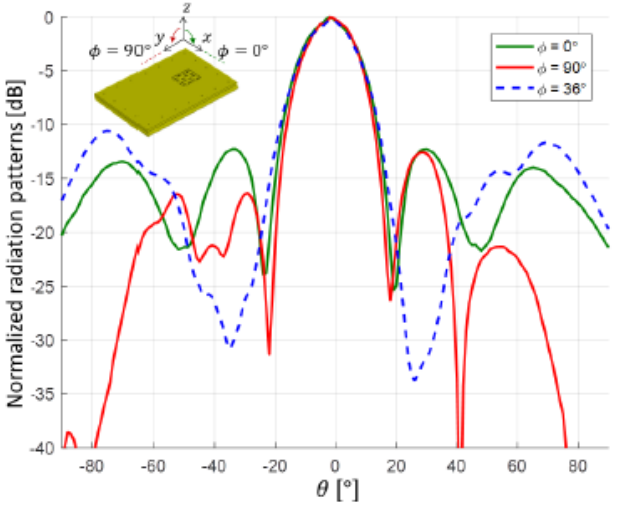
4x4 array with symmetrical pattern







(a) Simulación



(b) Medida

Array of low profile horns

1st high gain inverted microstrip gap waveguide antenna at 10 GHz

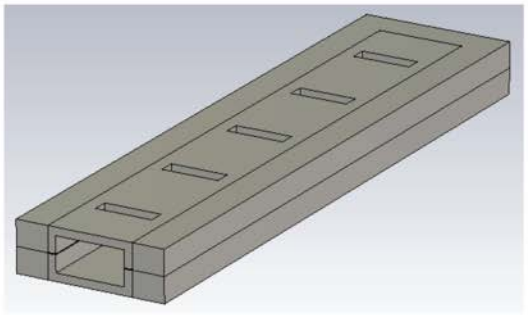
Directive 2λ × 2λ planar dual-mode horns excited by slots

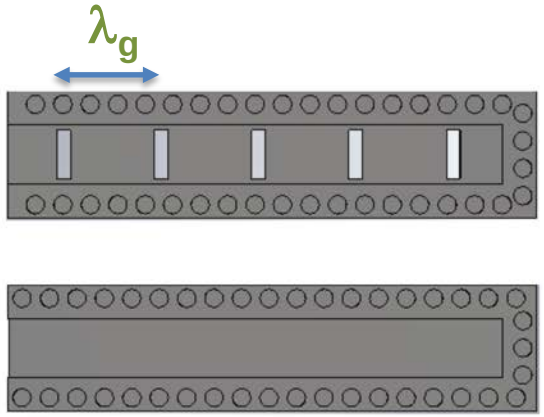
Corporate feed network with wide strip lines

Bed of nails

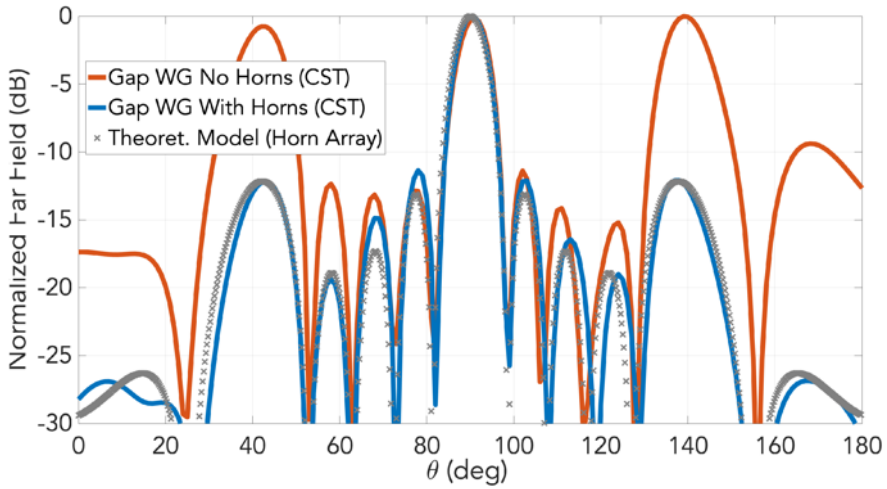
Pucci, E.; Rajo-Iglesias, E.; Vazquez-Roy, J.-L.; Kildal, P.-S., *"Planar Dual-Mode Horn Array With Corporate-Feed Network in Inverted Microstrip Gap Waveguide*," IEEE Trans. on Antennas and Propagation, vol.62, no.7, pp.3534-3542, July 2014

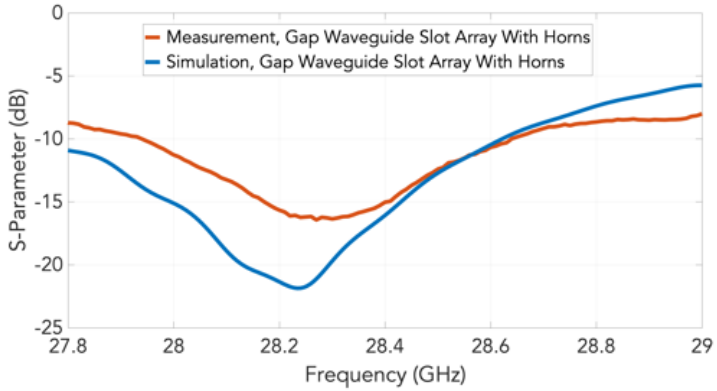
Array of low profile horns



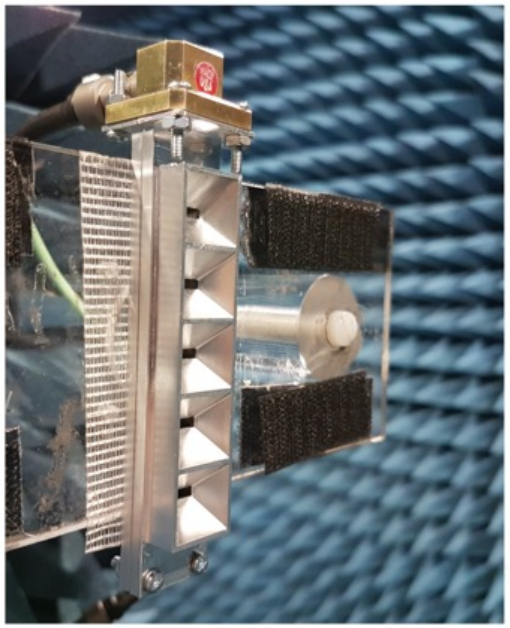


- Feeding by transverse slots
- Size of the horns in E-plane defined by λ_g
- Linear array
- Height of horns $0.5\lambda_g$
- WR-34
- Narrow band



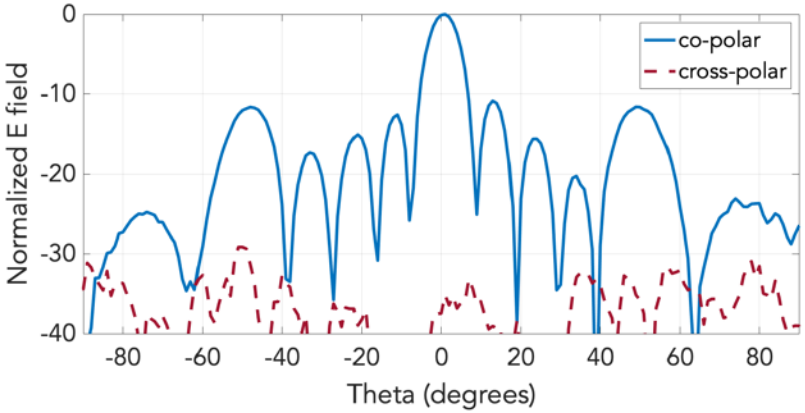


Array of low profile horns

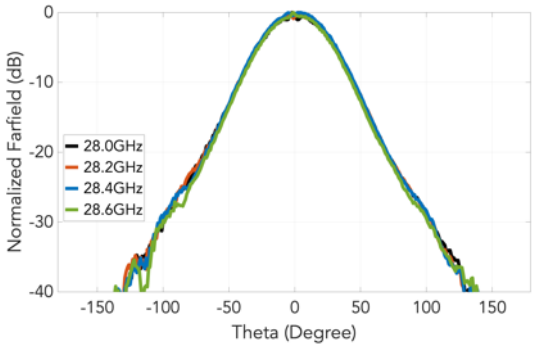


18 dBi measured gain

Measured E-plane



Measured H-plane



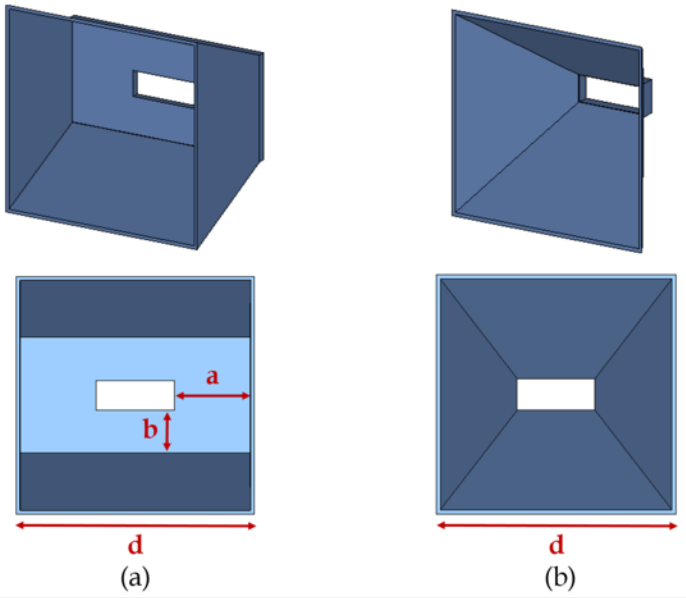
Array of low profile horns: planar array

Low profile horn antennas

- Standard pyramidal horn: 4 flaring sides (both E and H planes)
- Flare: transition to free space, critical for the performance of the horn

  angle: not too large
  length: not too small ➡ *To avoid phase error!*

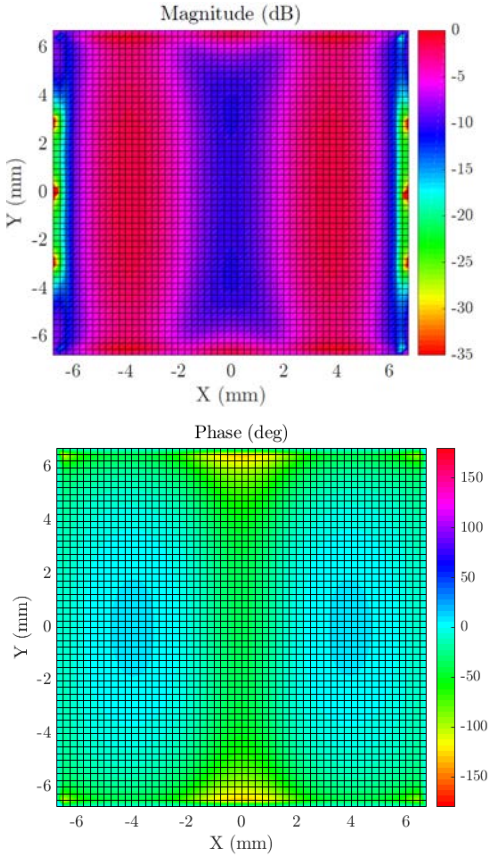
- Dual mode horn antenna presented in [1]
- Step in H plane, flaring only in E plane
- Simultaneous excitation of modes TE_{10} and TE_{30}
- Achieves more uniform distribution ➡ higher aperture efficiency



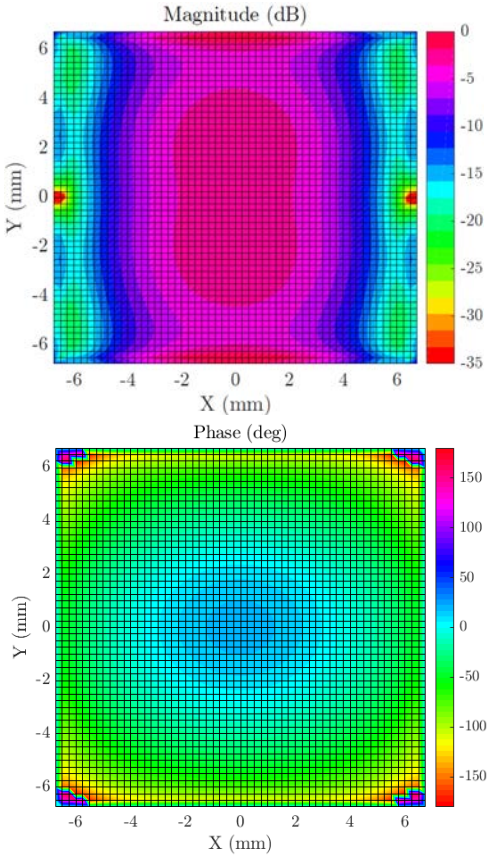
[1] E. Pucci, E. Rajo-Iglesias, J. Vazquez-Roy, and P.-S. Kildal, "Planar dual-mode horn array with corporate-feed network in inverted microstrip gap waveguide," IEEE Transactions on Antennas and Propagation

Array of low profile horns: planar array

Dual mode horn



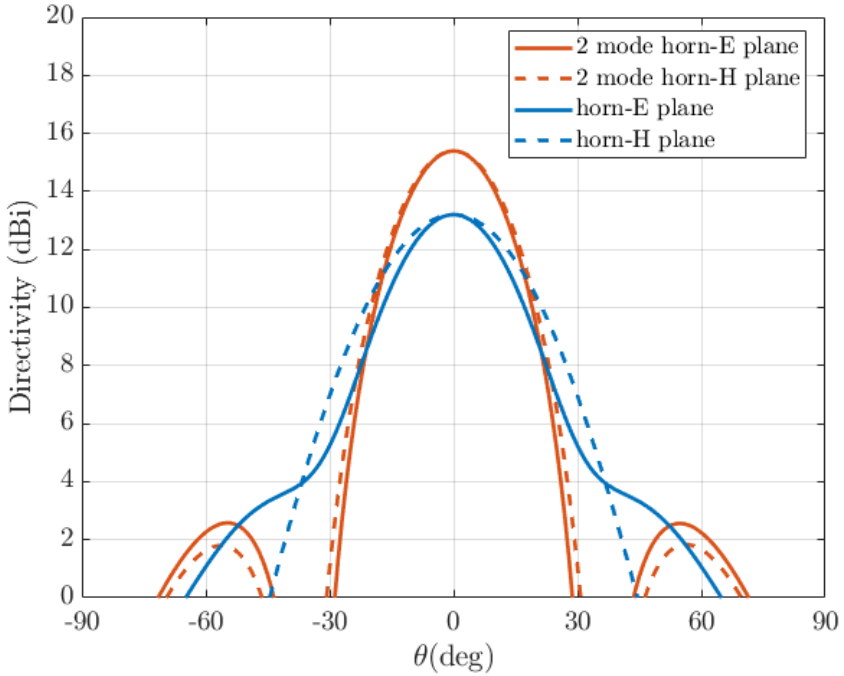
Pyramidal horn



- Pyramidal horn: phase increasing from the edges to the center ➞ phase error
- Dual mode horn: more uniform distribution ➞ phase error decreases

Array of low profile horns: planar array

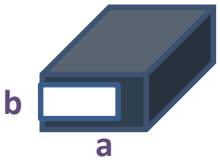
- Difference also in radiation patterns: designed @ 38 GHz
- Pyramidal horn : 13.2 dBi directivity, 56% aperture efficiency
- Dual mode horn: 15.4 dBi directivity, 93% aperture efficiency
- Size of aperture ***d*** defined by inter-element distance



Array of low profile horns: planar array

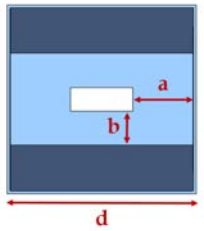
Linear array of horn antennas

- Inter-element distance ➡ defines size of horn antennas aperture
- Inter-element distance intentionally set as $\lambda_{g1} = 1.7\lambda_0$ (=*d* size of horn) — 9.5 mm @ 38 GHz
- Standard WR28 waveguide: **a**=7.1 mm, b=3.56 mm



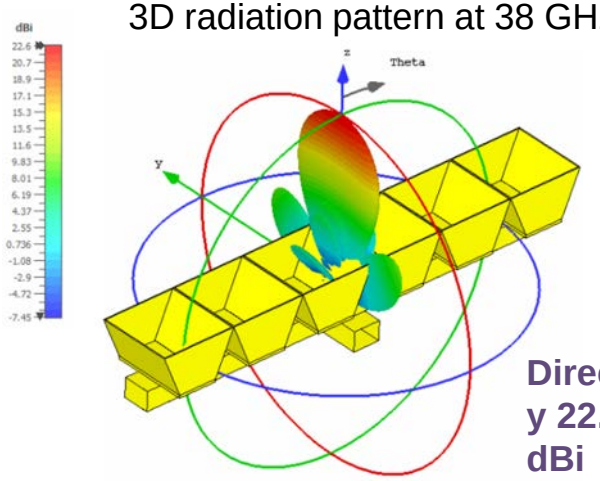
- $\lambda_{g1} = \frac{\lambda_0}{\sqrt{1-(\frac{c_0}{2af})^2}} = 1.7\lambda_0.$ ➡ calculation of **a**
- For new size of horn calculation of directivity

Size horn	Directivity (dBi)
1.3 λ_0	13.27
1.5 λ_0	14.51
1.7 λ_0	15.6



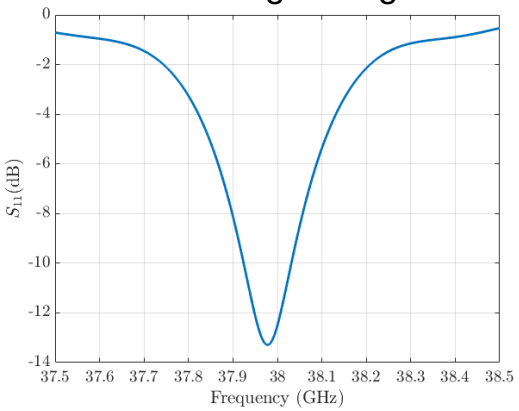
a	b	d	h
4.3	1.9	13.57	λ_0

3D radiation pattern at 38 GHz



Directivity 22.6 dBi

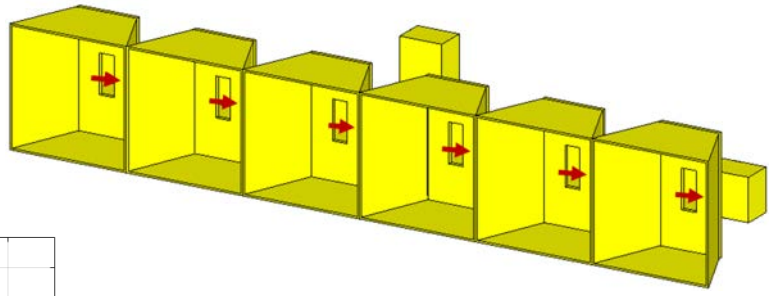
S11 of feeding waveguide

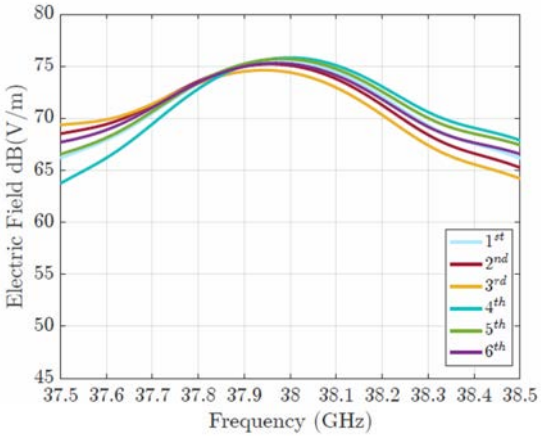


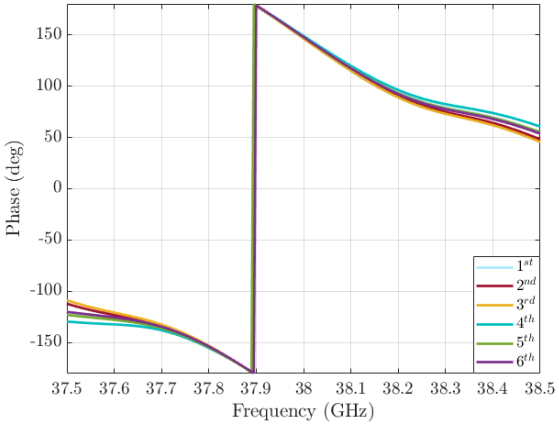
Array of low profile horns: planar array

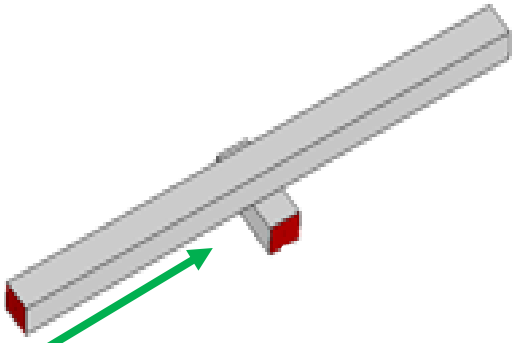
Linear array of horn antennas

- Field probes at each transverse slot
  - ✓ Uniform amplitude
  - ✓ Same phase

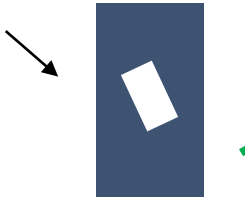


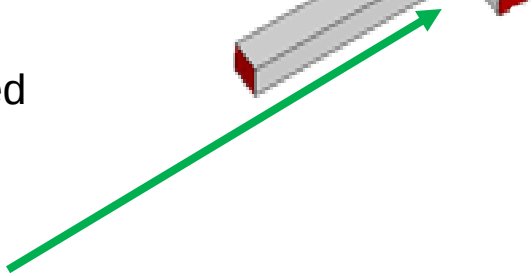






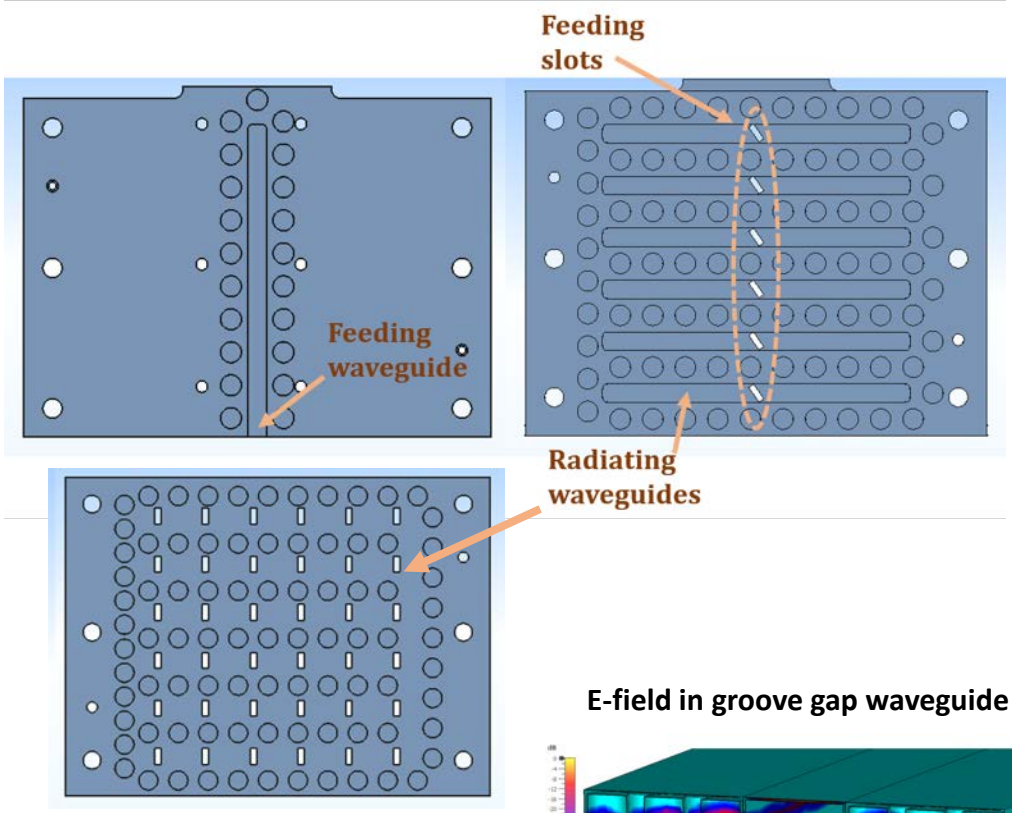
- These slots, will be fed by a waveguide with inclined longitudinal slots



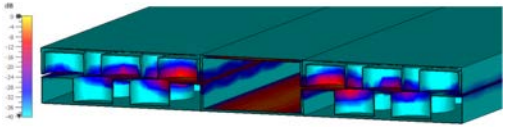


Array of low profile horns: planar array

Feeding network in groove gap waveguide

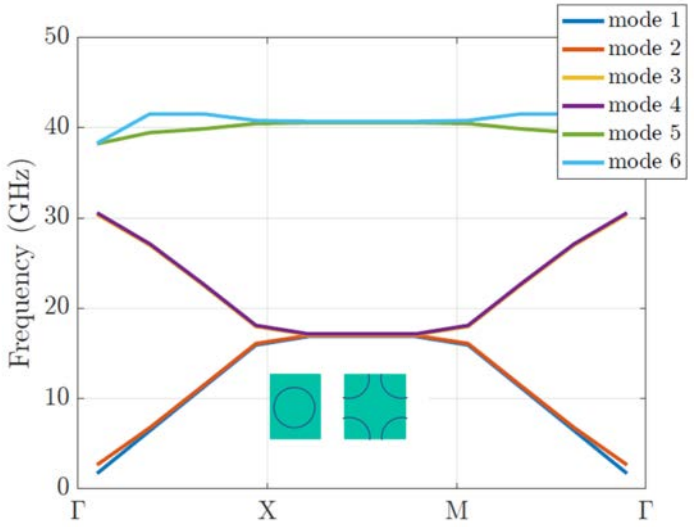


E-field in groove gap waveguide



- Glide symmetric holes prevent radiation
- EBG covers the central freq. 38 GHz
- Dimensions of holes:

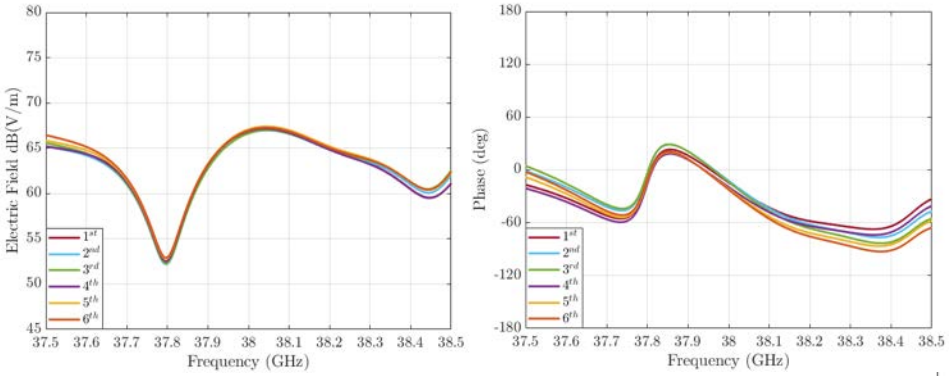
per	radius	depth	air gap
8.5 mm	2.7 mm	3 mm	0.01 mm



Array of low profile horns: planar array

- Field probes at the radiating slots

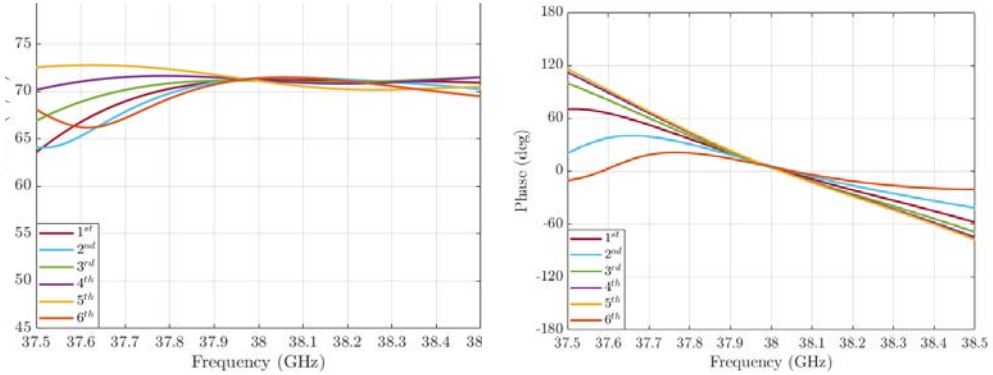
transverse



✓Uniform amplitude
✓Uniform phase

- Field probes at the feeding slots

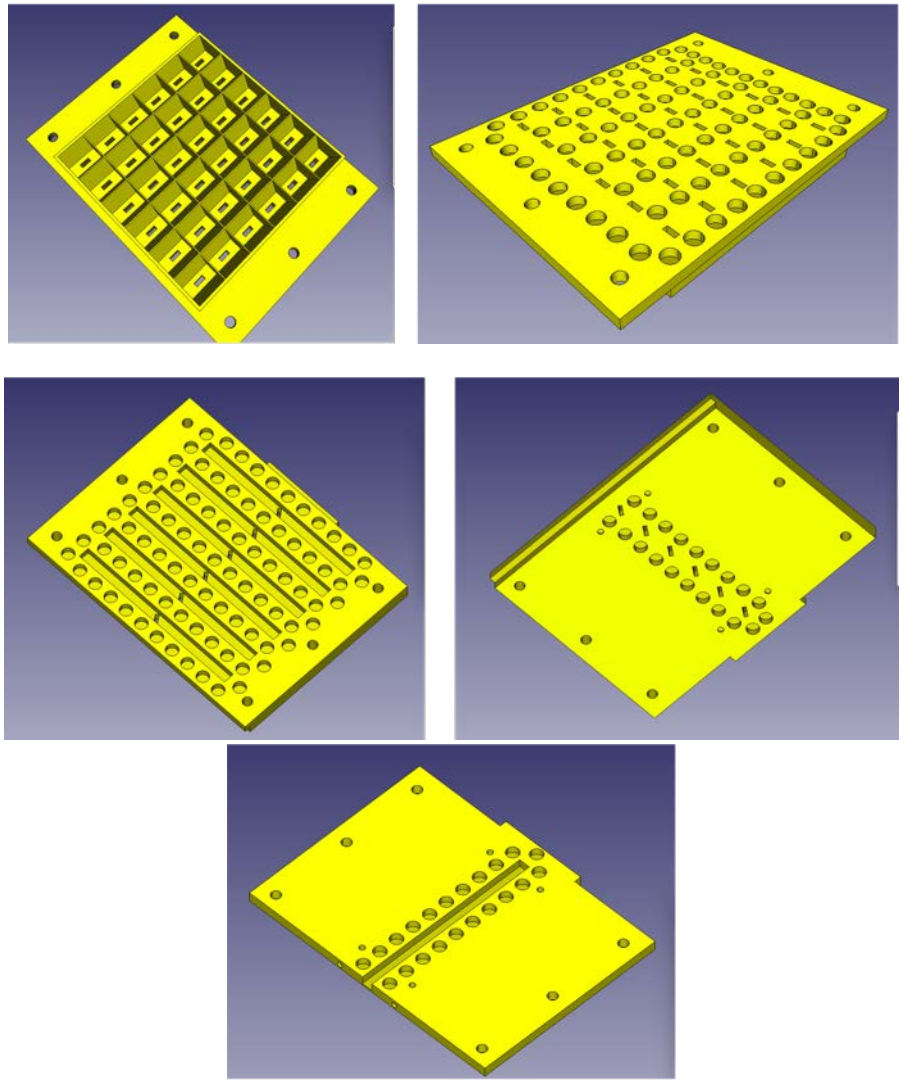
inclined



Array of low profile horns: planar array

Simulated model

- Consists of 3 layers
- No need for direct metal contact due to EBG
- Fully metallic structure
-
- Single direct feeding port



Array of low profile horns: planar array

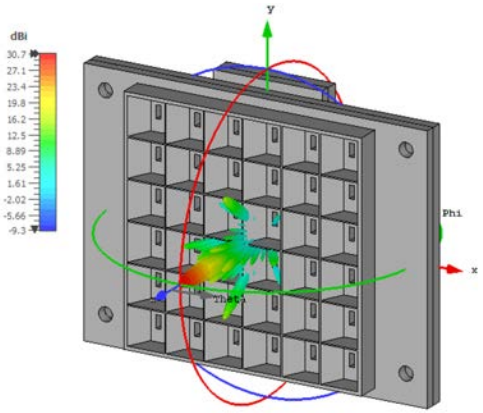
Simulations results

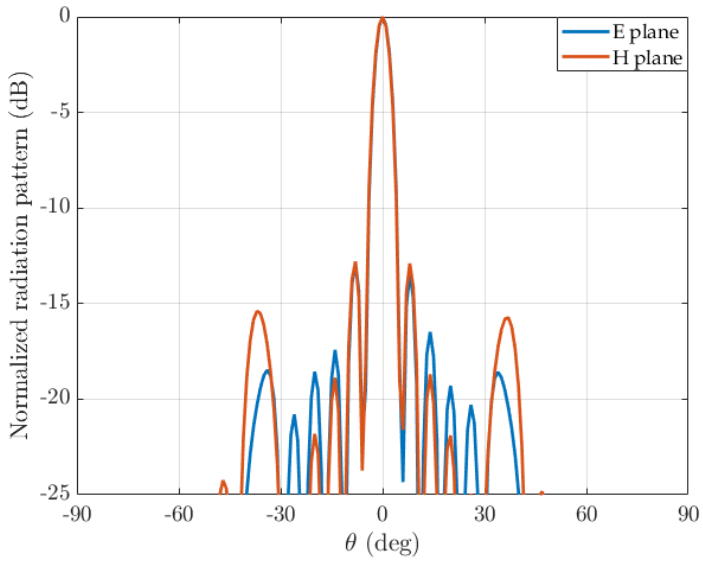
✓ Very good matching at the central frequency

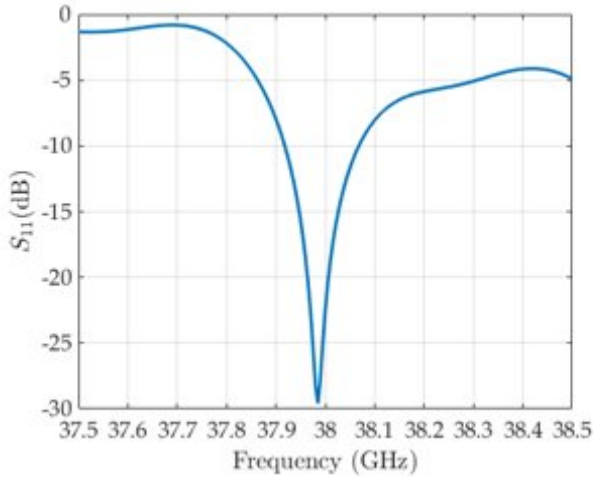
✓ Pencil beam at broadside ➡ confirms in-phase Radiation through the slots

✓ Directivity 30.7 dBi ➡ aperture efficiency 90%

✓ cross polarization is approx. -38 dB





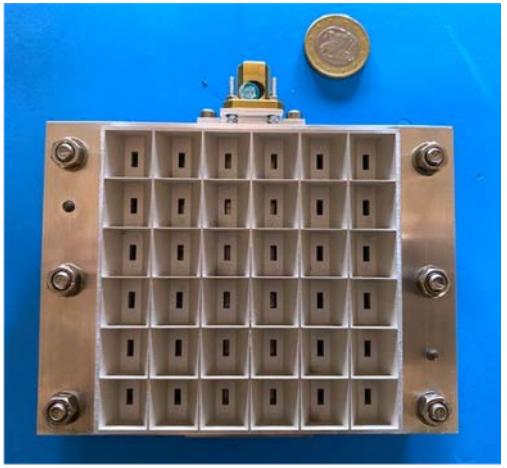


Array of low profile horns: planar array

Fabricated prototype

Top view

Bottom view

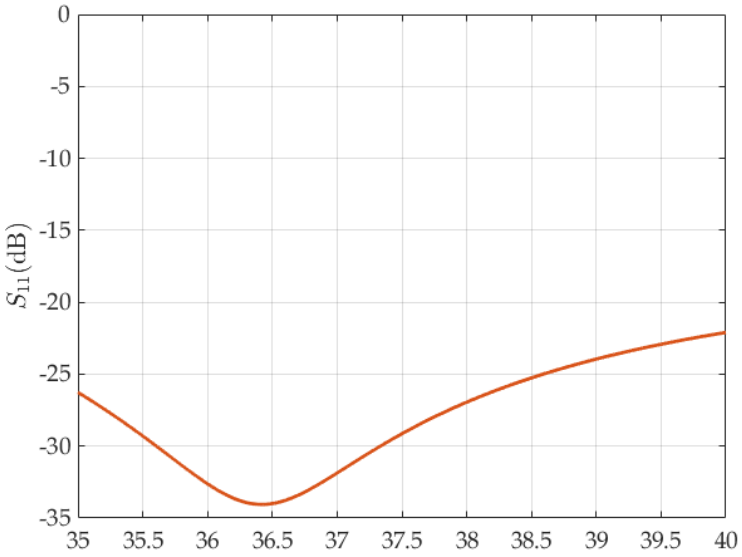


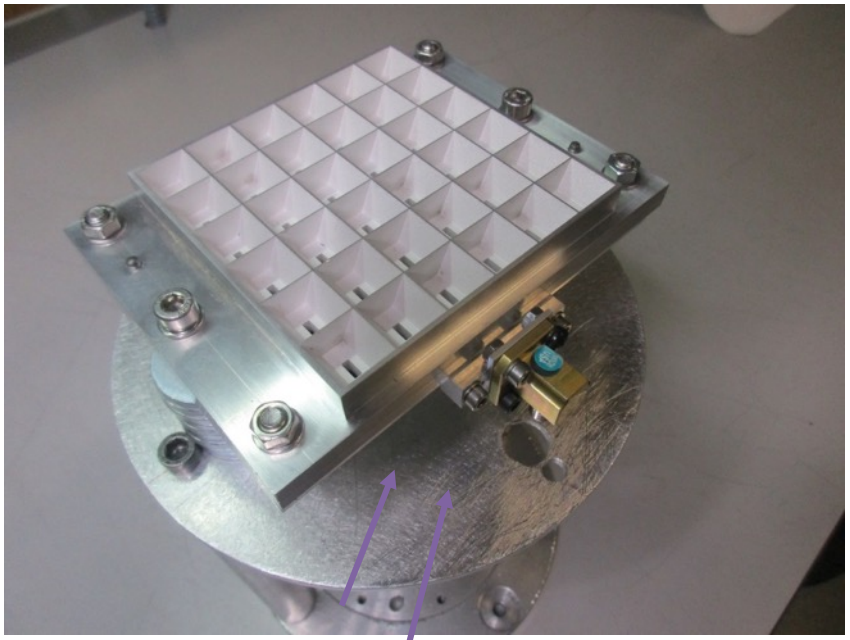
Array of low profile horns: planar array

Experimental results

- To use a WR28 feed, waveguide transition necessary

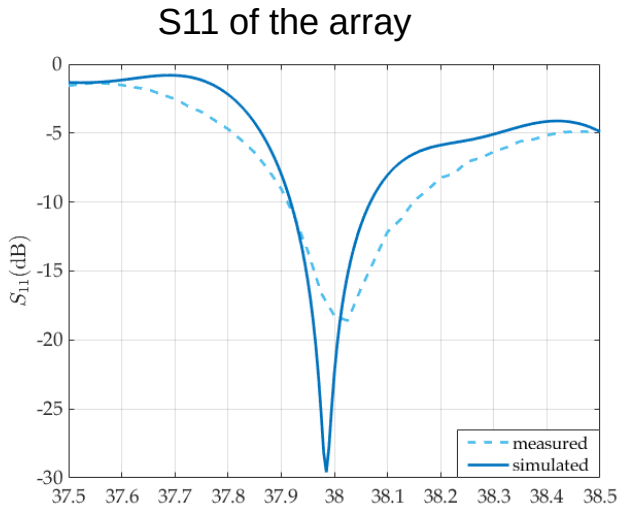
S11 of the transition (width from 7.1 mm to 4.88 mm)

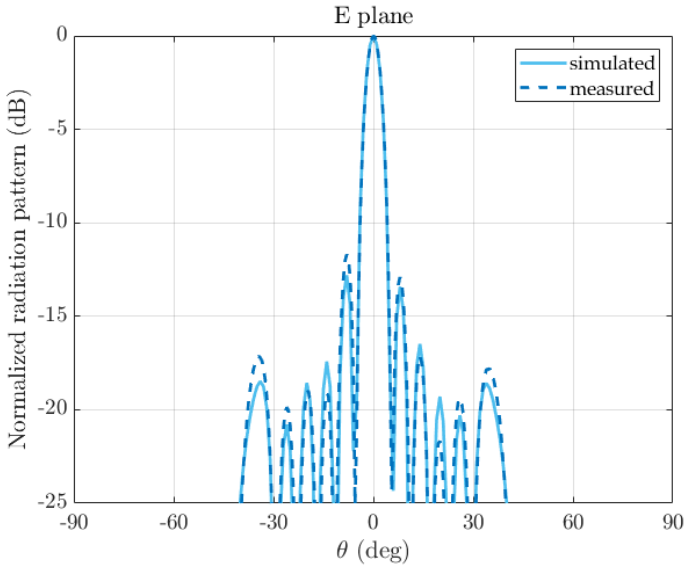


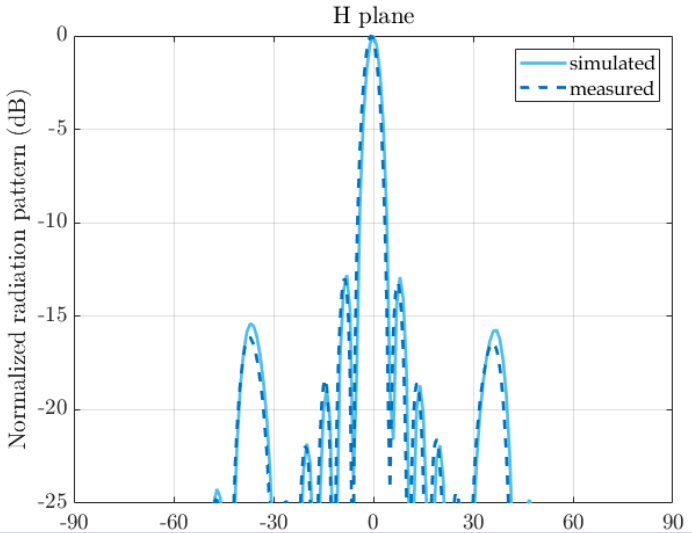


Array of low profile horns: planar array

Experimental results



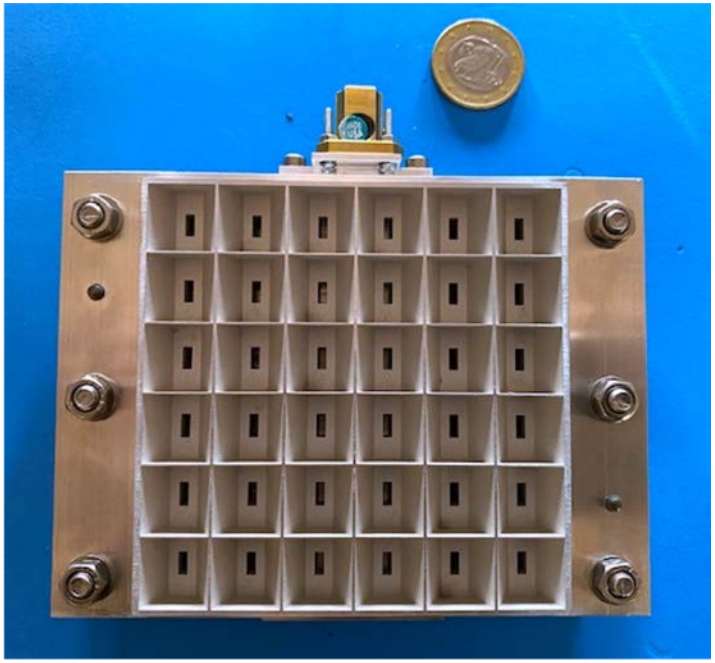


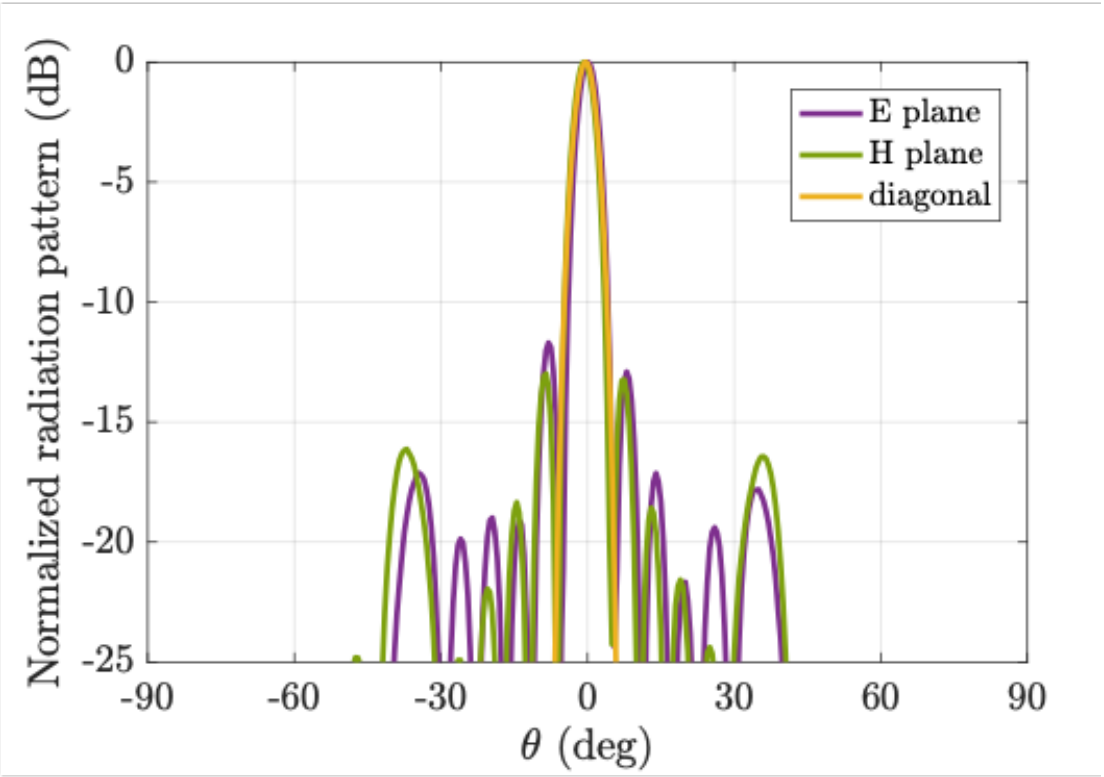


- ✓ Good agreement with simulations
- ✓ R.Gain 29.3 dB (simulations 30.4 dB)

Difference due to ohmic losses or loosely connected feed

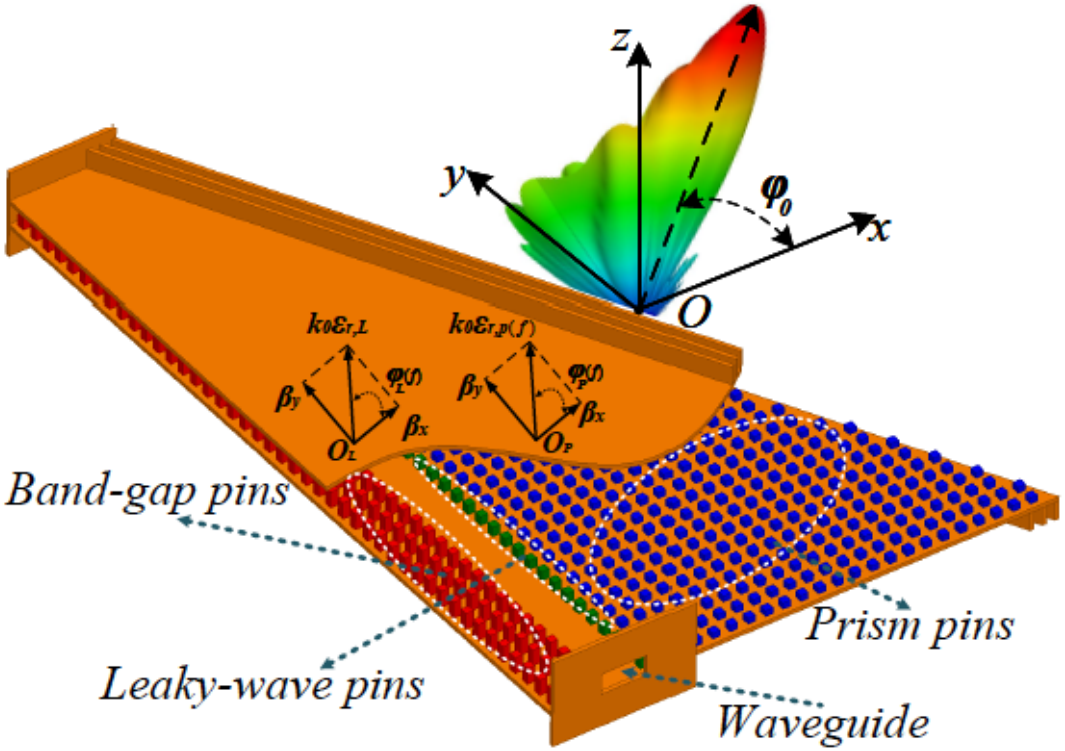
Horn array fed by groove at 38 GHz





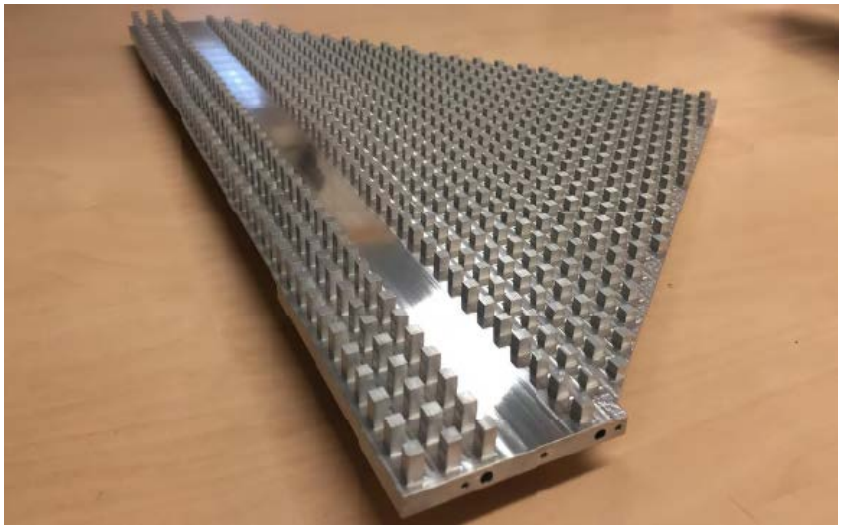
Measured radiation pattern almost 30 dBi

Non-dispersive leaky wave antenna

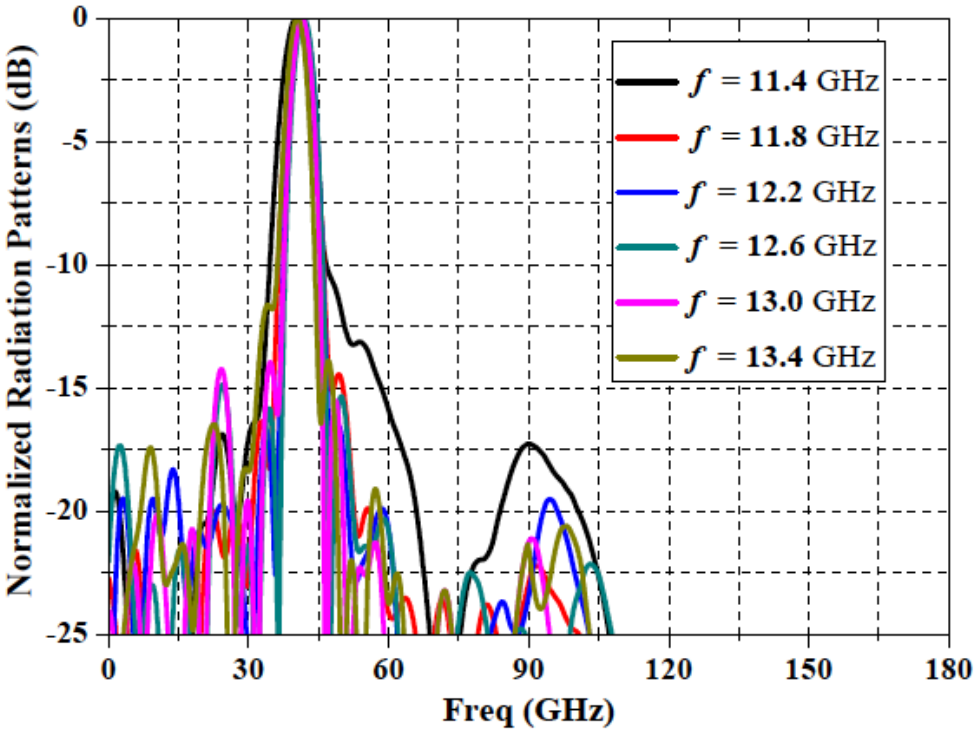


L. Wang, J.L. Gomez-Tornero, E. Rajo-Iglesias, O. Quevedo-Teruel, *Low-dispersive Leaky-wave antenna integrated in Groove Gap waveguide technology.* IEEE Trans. On Antennas and Propagation, Nov. 2018.

A non-dispersive version



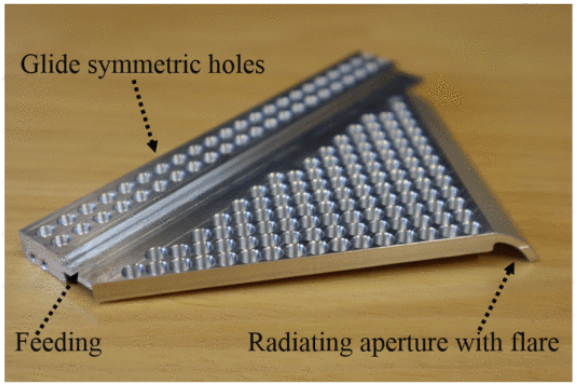
More than 20% bandwidth



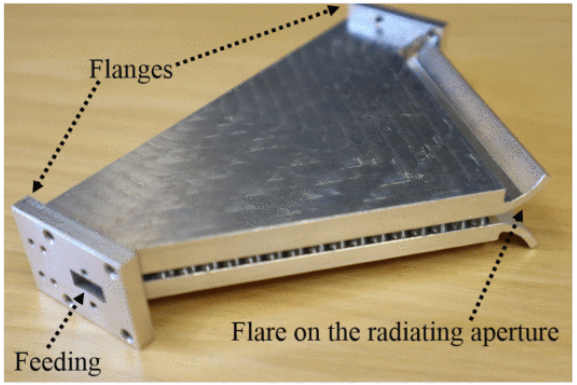
L. Wang, J.L. Gomez-Tornero, E. Rajo-Iglesias, O. Quevedo-Teruel, *Low-dispersive Leaky-wave antenna integrated in Groove Gap waveguide technology*. IEEE Trans. On Antennas and Propagation, Nov. 2018

Low dispersive leaky wave antennas

30 GHz

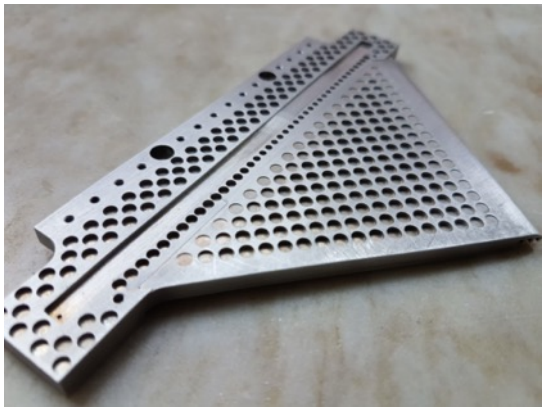


(a)



(b)

60 GHz



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Conclusions

- ✓ Glide symmetrical holey structure can be used to stop parallel plate modes
- ✓ This allows its use for gap waveguide technology. For the groove version is quite straightforward
- ✓ The size and disposition of the holes complicate the design of some components
- ✓ The simplification in terms of manufacturing when compared to pins is enormous for high frequencies
- ✓ Designs of antennas and components in the millimeter wave band using this structure have been presented

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THANK YOU !!!!