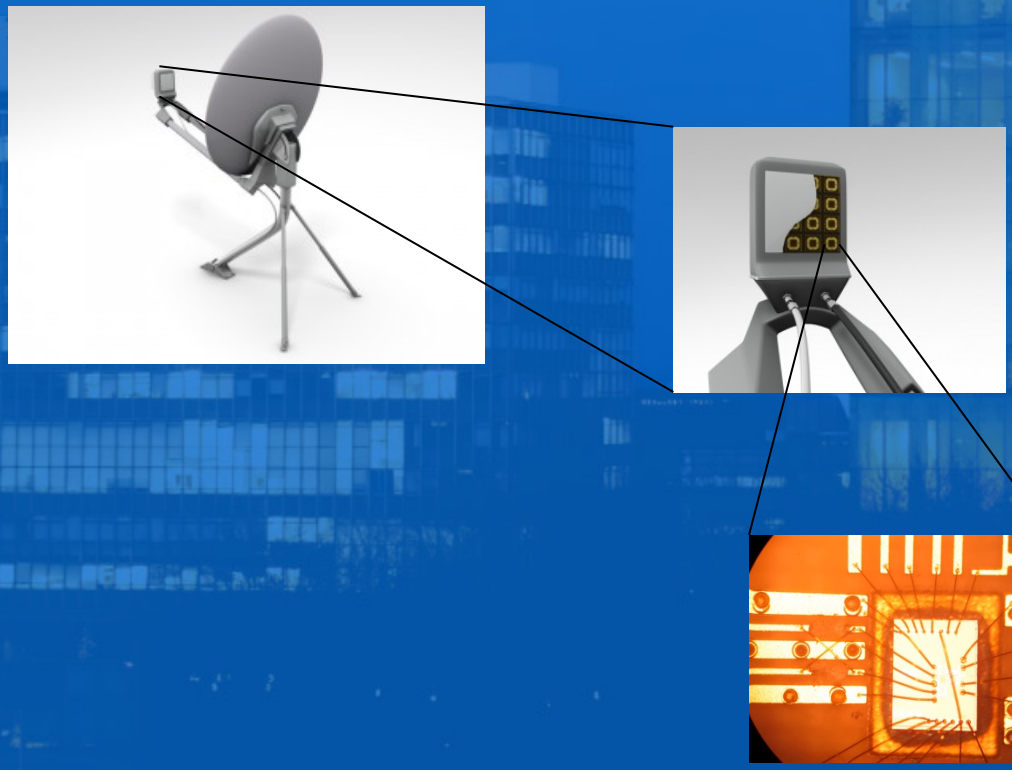
Towards the future of satellite communication: The Focal Plane Array Antenna



Mojtaba Zamanifekri

Prof. A.B. Smolders

EM group

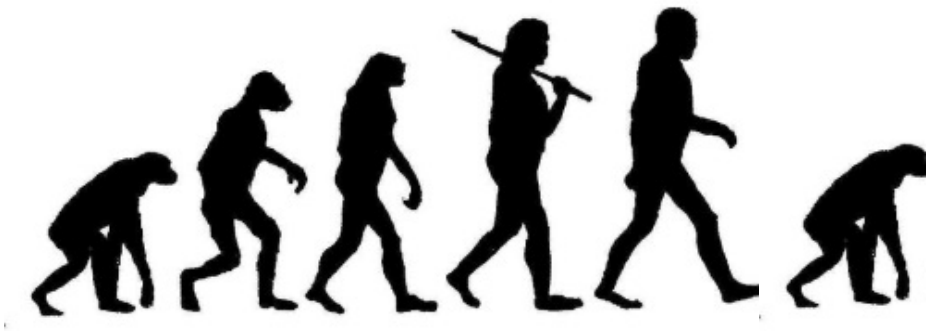
Electrical Engineering Department

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

Side Story……

- **What is the future of antenna engineers?!**



Is it just matter of iterative use of the commercially electromagnetic solver?

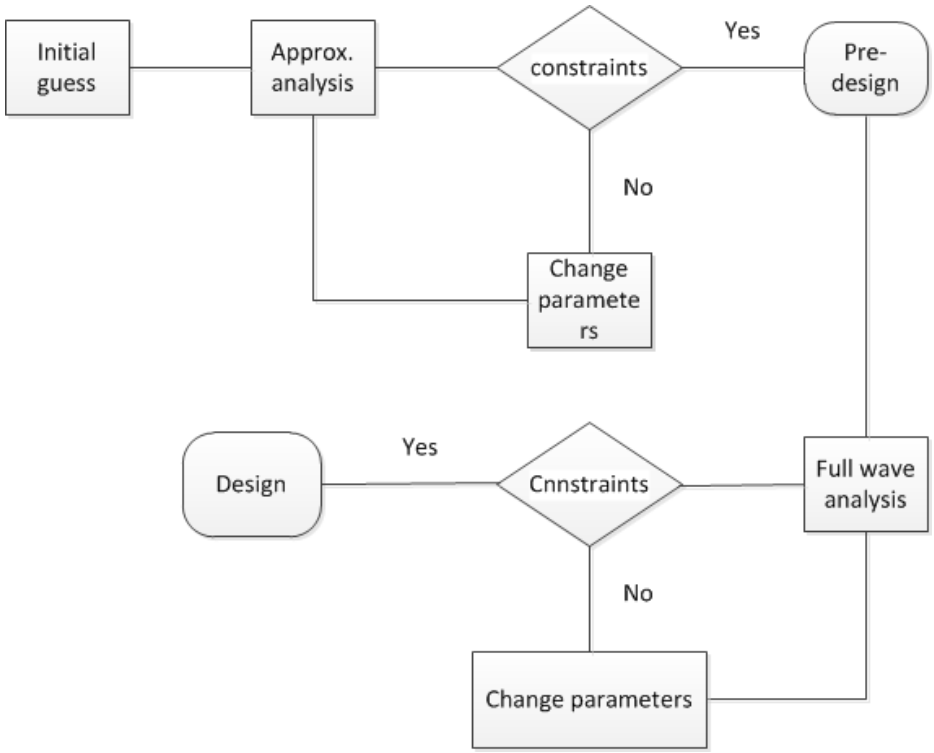
CST

EMPIRE XCcel

FEKO
Comprehensive Electromagnetic Solutions

TU/e Technische Universiteit Eindhoven University of Technology

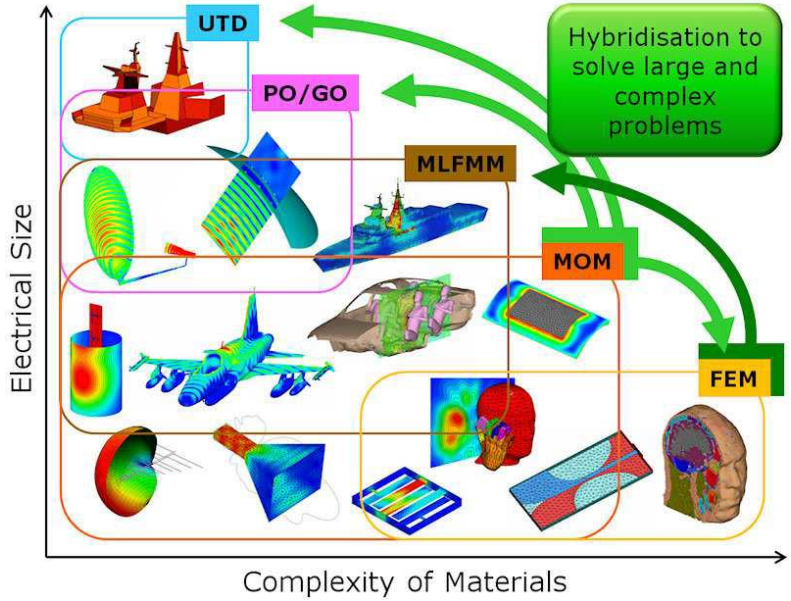
Antenna analyses



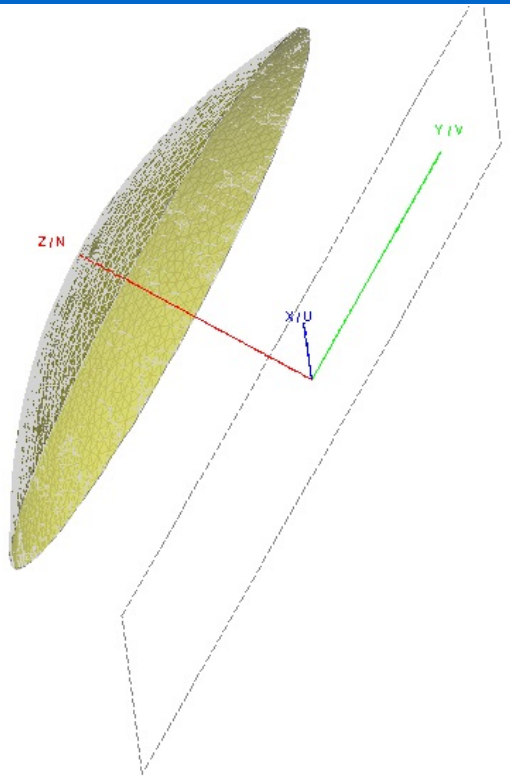
Which commercial solver ?

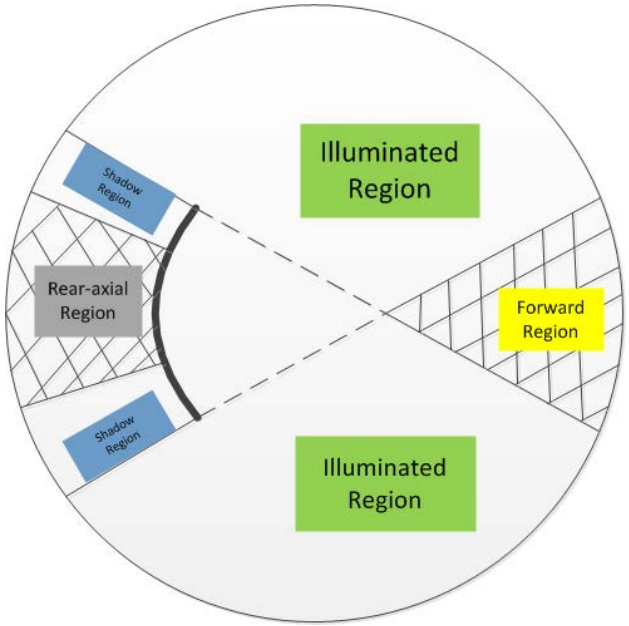
“ No single EM tool can solve all problems; an informed designer must select the appropriate tool for the appropriate problem ”

‘James Rautio, founder of Sonnet software’

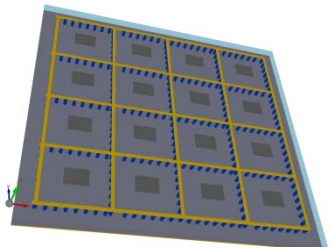


Example : Reflector antenna analysis





Regions	Techniques
Forward Region	PO
Illuminated R	GTD/APO
Shadow Region	GTD/APO
Rear-axial Region	EEC
Feed	FDTD/FEM



Content

- Motivation
- Background
- Requirements
- Design procedure
- Measurement campaign
- Enhanced feed

Current situation for commercial satellite broadcasting

Possible Alternatives

Scanning capability
Compact solution

Low gain
costly

Discreet scanning
High gain

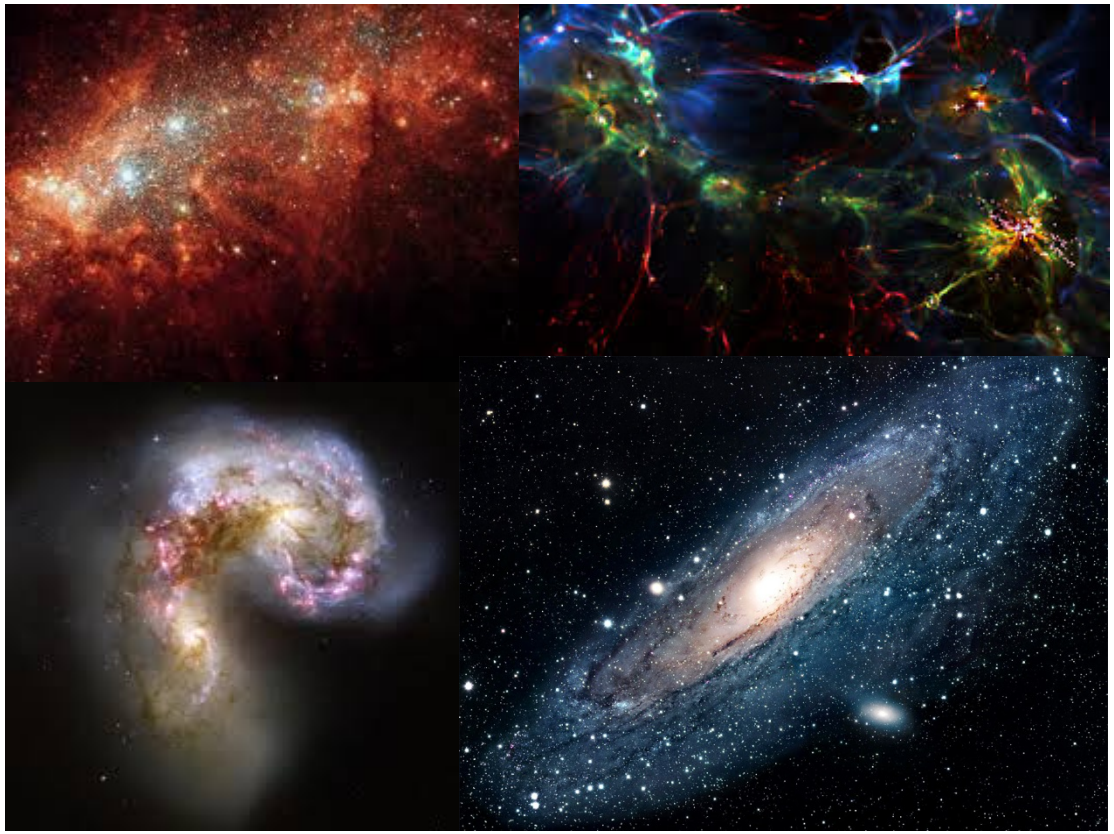
Limited flexibility
bulky

What is the Focal plane array?

The Idea is to illuminate the reflector dish in the smart way to be able to :

- Steer the beam
- Compensate for any degradation

Background- Radio astronomy



How can we make such pictures?!

What is the state of art in this field?

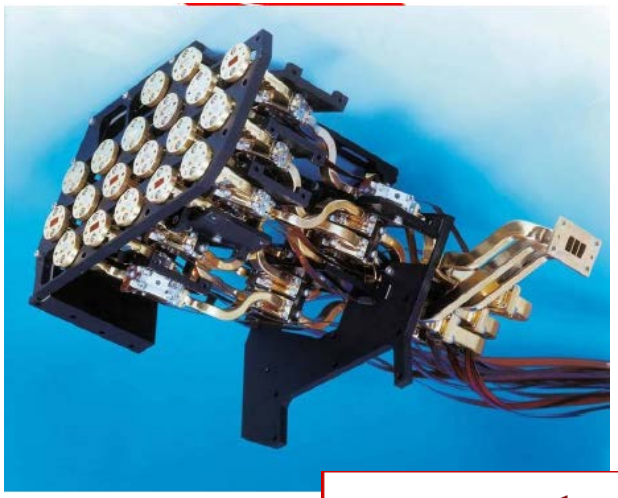
Background- Radio astronomy

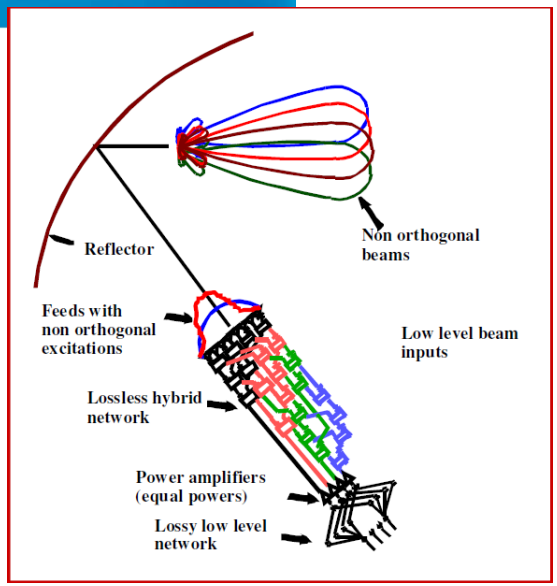
Background- Radio astronomy

- **The technology is available in Radio astronomy**

By increasing the field of view (FOV) the scanning speed will increase dramatically

Background- Space Application



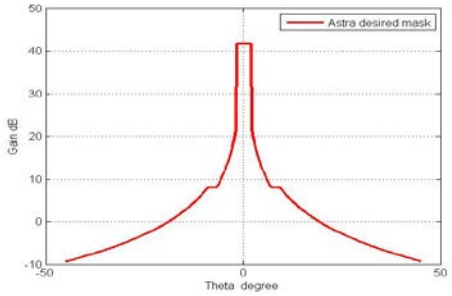


How about the normal satellite TV receiver?

- Tracking satellites
- Improve the quality of signal in the case of any degradation due to the harsh weather, like heavy snow or rain
- Improving signal to noise ratio
- Simultaneous multi satellite access (TV and internet access)

Specification

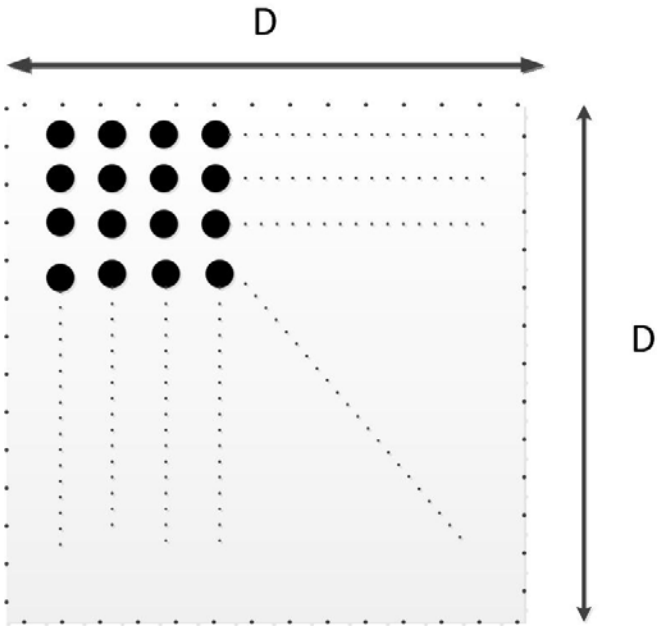
Requirement	
Frequency	Rx: [18.8,20.2 GHz]…[21.4,22 GHz] Tx=[29.4..30 GHz]
Multi-satellite reception	3 satellite signals whiten fixed point on the earth
Beam nulling	2 degree offset from the desired satellite
Output frequency IF	950,2150 MHz
Cross polarization rejection	22 dB
Polarization	LHCP, RHCP
Gain Mask	According to ETSI EN 301459 V1.2.1 Satellite earth stations and systems (SES)



Background

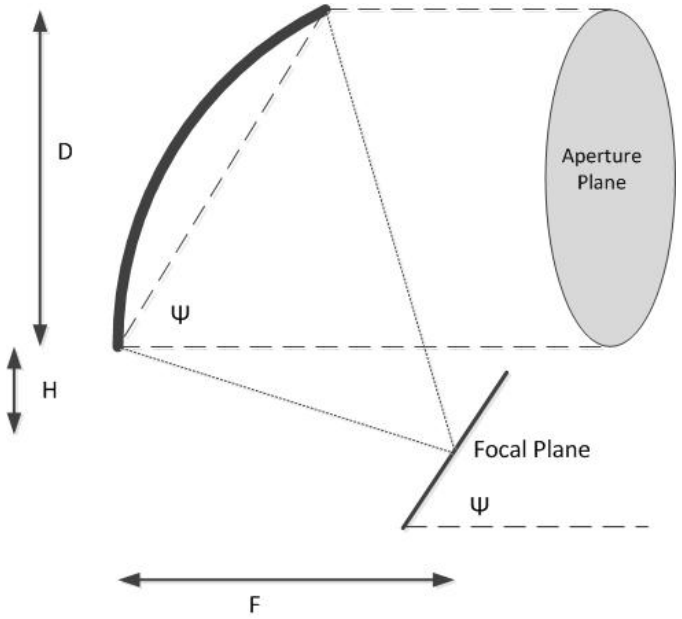
- **Some basic question should be answered :**

- What is the required aperture size ?
- How many elements do we need?
- What is the proper characteristic of the dish?
- What is the optimum configuration?
- What is the required phase accuracy ?



Offset Reflector Model

- **The required parameters for offset definition :**

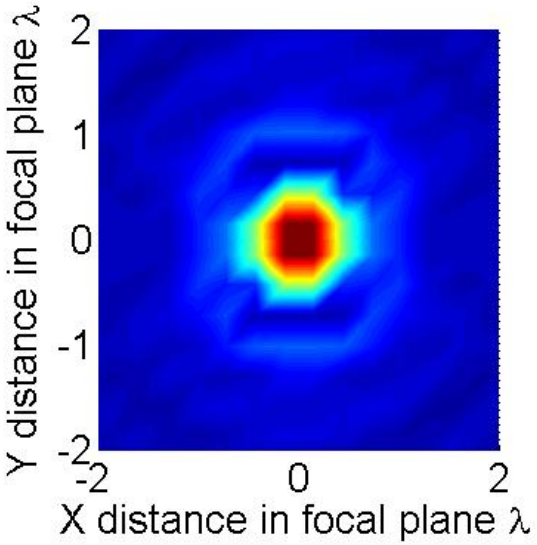


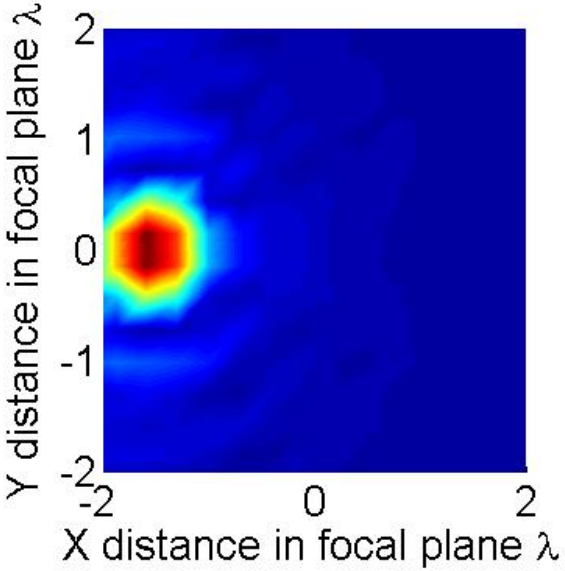
H, D and $\frac{F}{D_p}$ are the parameters

The problem is, for offset reflector antenna with changing $\frac{F}{D_p}$ the shape of the reflector will change.

D=70 cm, $\frac{F}{D_p} = 0.3$, $H = 14\ cm$

Reconstruction of Focal Plane Field





	A	B	C	D	E	F	G	H	I
A	0.02	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.03
B	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.05	0.02
C	0.05	0.05	0.02	0.04	0.06	0.06	0.06	0.07	0.05
D	0.06	0.06	0.12	0.22	0.26	0.22	0.12	0.06	0.05
E	0.06	0.09	0.20	0.33	0.39	0.33	0.20	0.06	0.06
F	0.06	0.06	0.13	0.23	0.27	0.23	0.13	0.06	0.05
G	0.06	0.05	0.02	0.05	0.06	0.06	0.06	0.07	0.05
H	0.02	0.04	0.04	0.04	0.05	0.05	0.06	0.05	0.02
I	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03

Elements in Y axis

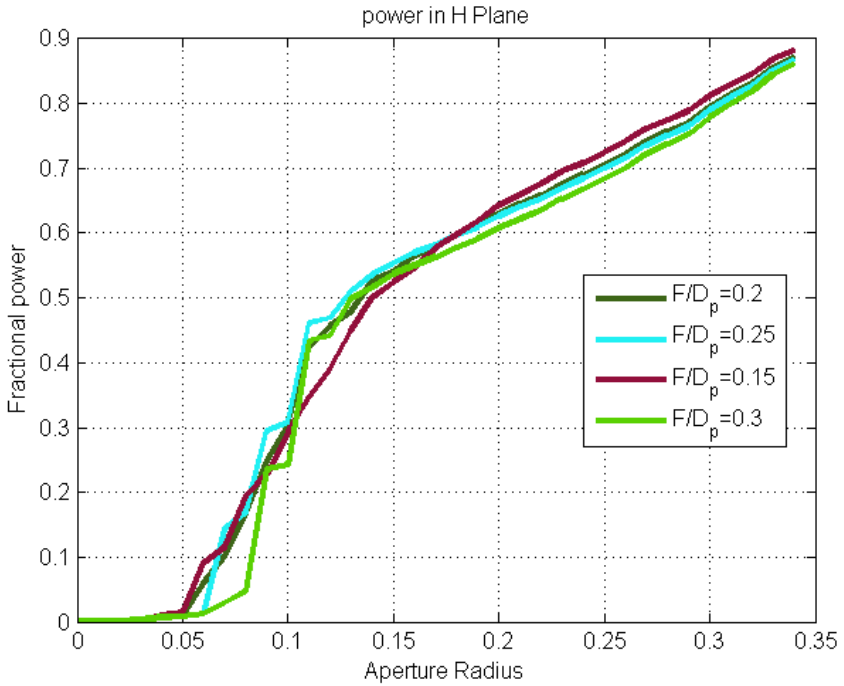
Elements in X axis

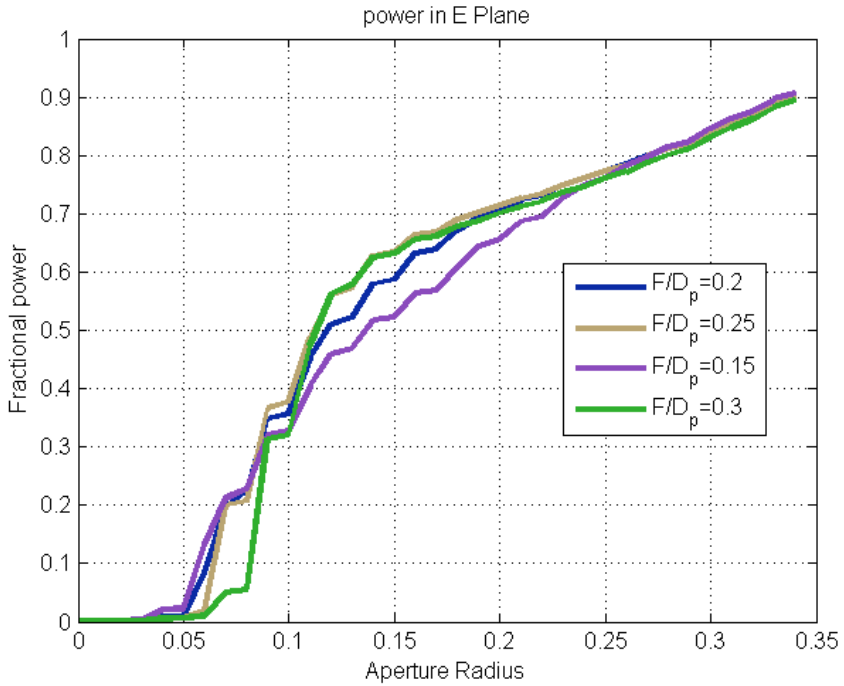
	A	B	C	D	E	F	G	H	I
A	0.07	0.09	0.07	0.05	0.02	0.03	0.04	0.03	0.01
B	0.12	0.06	0.06	0.07	0.07	0.04	0.04	0.05	0.03
C	0.13	0.14	0.07	0.03	0.09	0.03	0.03	0.06	0.01
D	0.22	0.26	0.23	0.14	0.10	0.03	0.05	0.01	0.05
E	0.41	0.33	0.28	0.15	0.07	0.05	0.02	0.03	0.03
F	0.24	0.23	0.21	0.12	0.06	0.06	0.04	0.03	0.05
G	0.08	0.13	0.05	0.05	0.09	0.04	0.06	0.07	0.02
H	0.12	0.07	0.02	0.09	0.09	0.02	0.08	0.06	0.01
I	0.04	0.06	0.06	0.02	0.02	0.04	0.02	0.02	0.06

Elements in Y axis

Elements in X axis

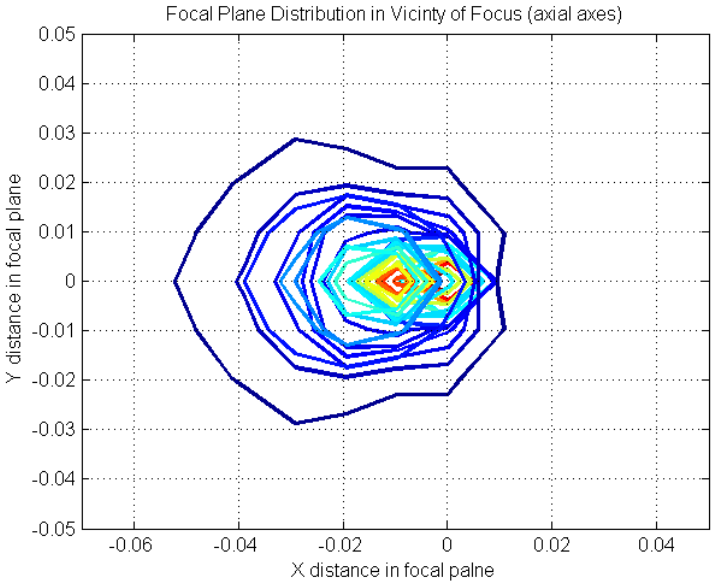
Encircled power curves

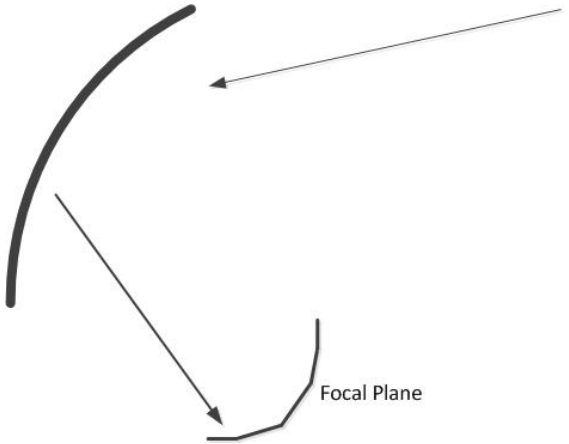




Encircled power curves for different F/D ratio in E & H Plane (8 degree scanning)

Vicinity of focus

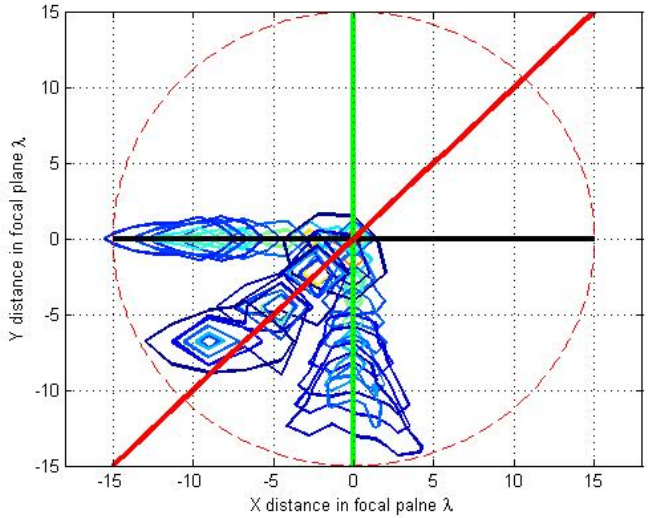




Changes in focal plane contour when focal plane moves from 0 to 7 lambda towards reflector

In Agreement with petzval surface

Focal-plane size estimation

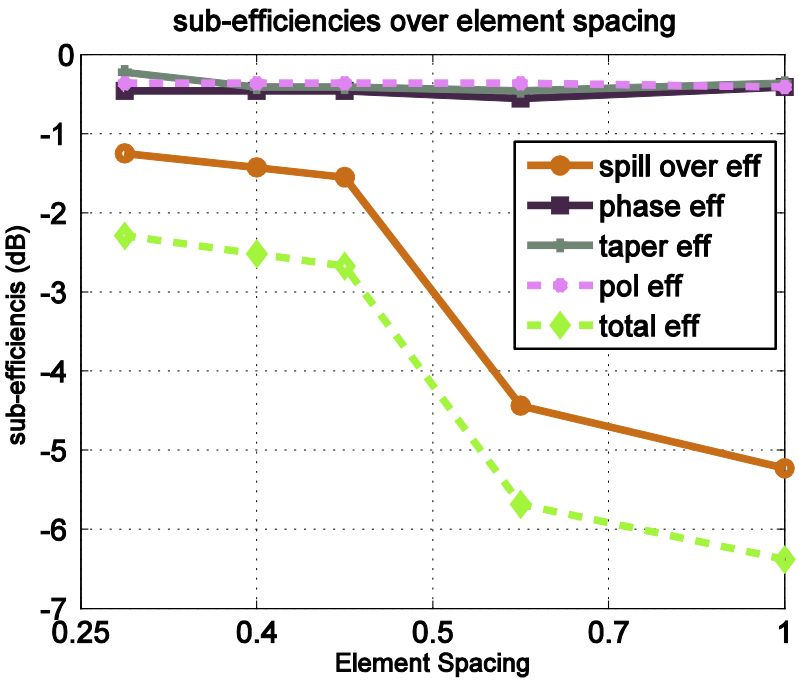


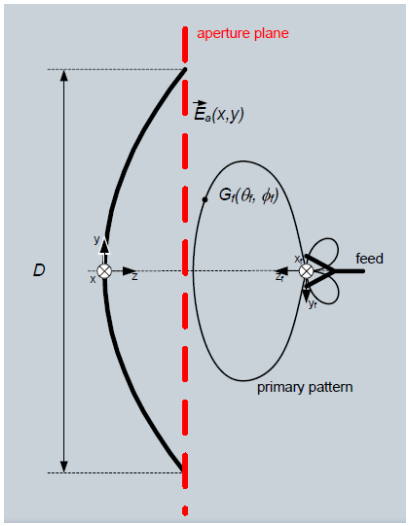
This figure shows the importance of having appropriate beam-forming network

Results for 8 degree scanning

Type of the feed	width	length
E Plane scanning	4 cm	24 cm
H Plane scanning	8 cm	24 cm
Full array	24 cm	24 cm

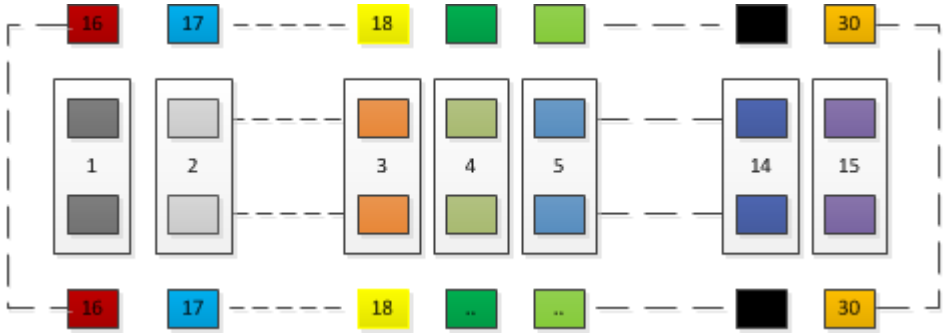
Efficiency investigation





In agreement with Nyquist rate

Number of Channels

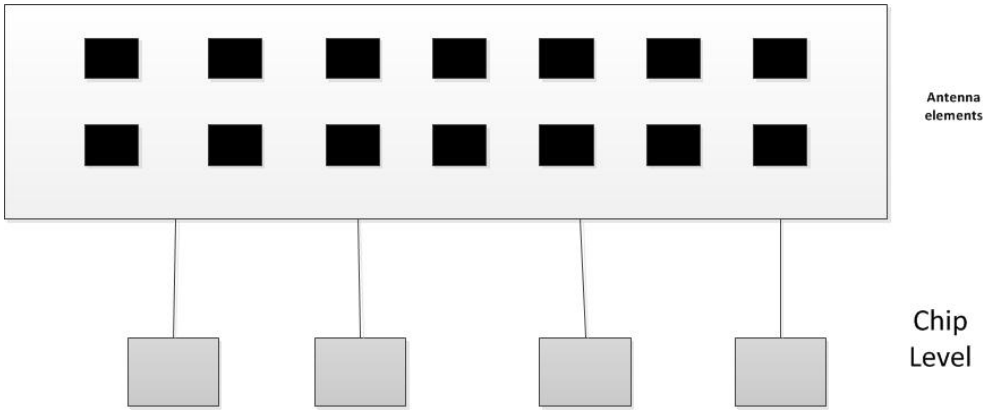


- Complexity reduction
- Cost reduction

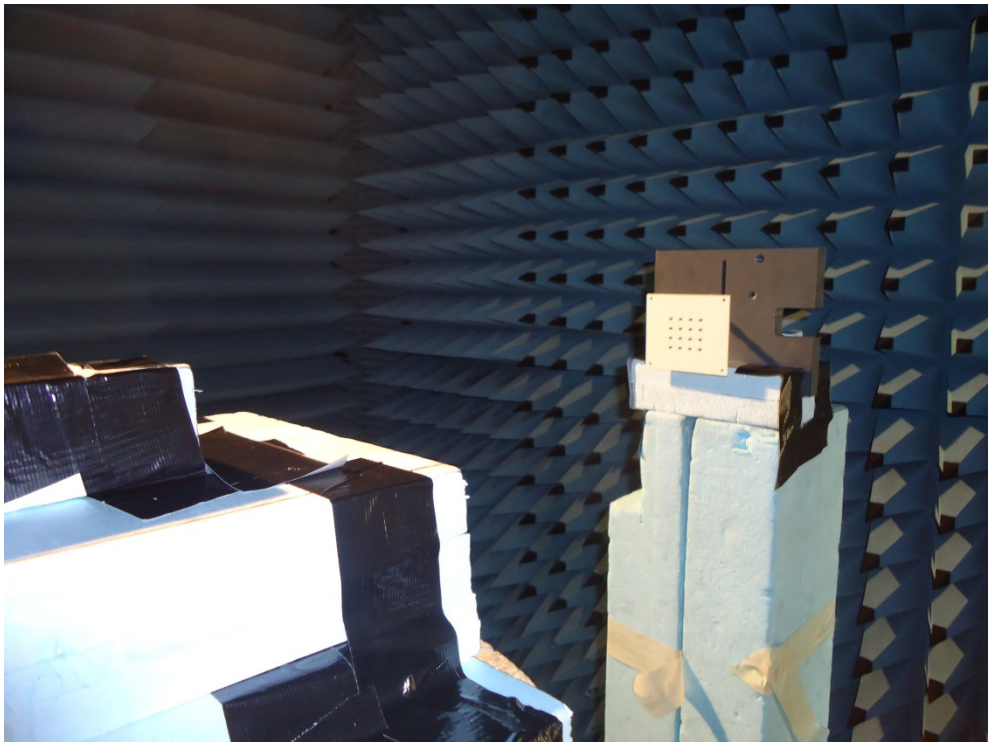
Intelsat IX C-Band TEM Line BFN
(Courtesy EADS-Astrium GmbH)

Updated requirement Table

Characteristic	Value/description
Aperture size	$12 \times 6\ cm^2 \pm 5\ degrees\ scanning$
F/Dp	0.3
Orientation of the Feed	60 degrees (targeted center of the projected diameter)
Position of the feed	Curved like structure (bended at the edges)
Number of elements	60
Number of chips	30



Measurement



Measurement Process

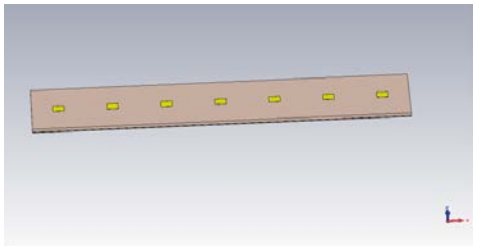
concept investigation

Passive array measurement ✓ antenna performance

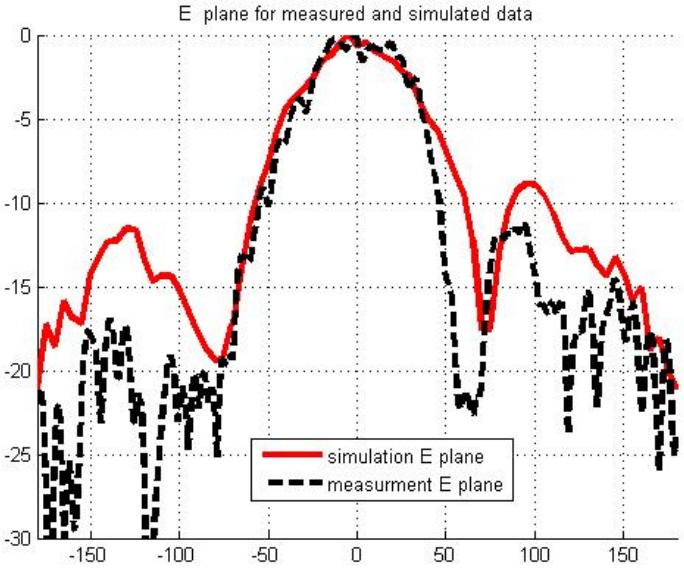
Passive array + reflector × proof of concept (in progress)

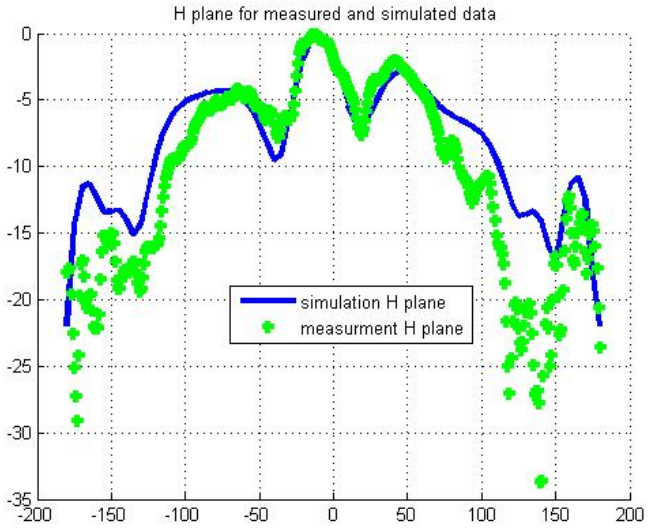
Active array measurement (integrated version performance) ✓

Linear array



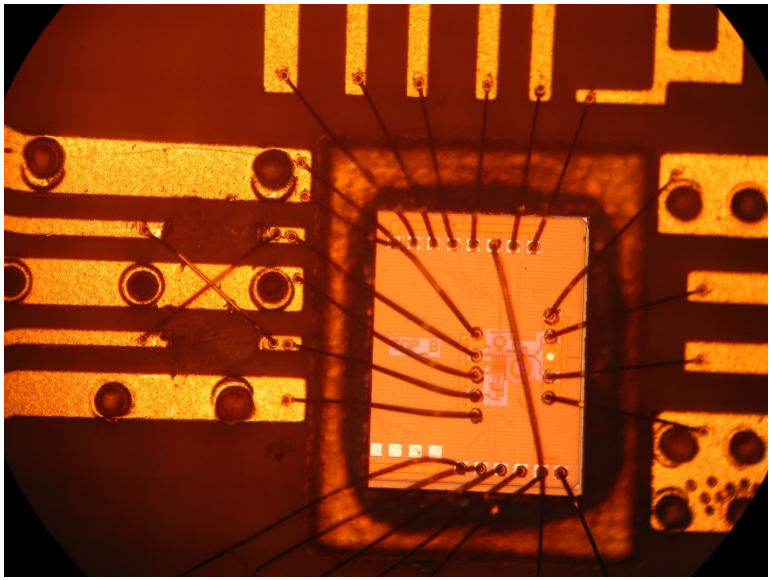
Element 1

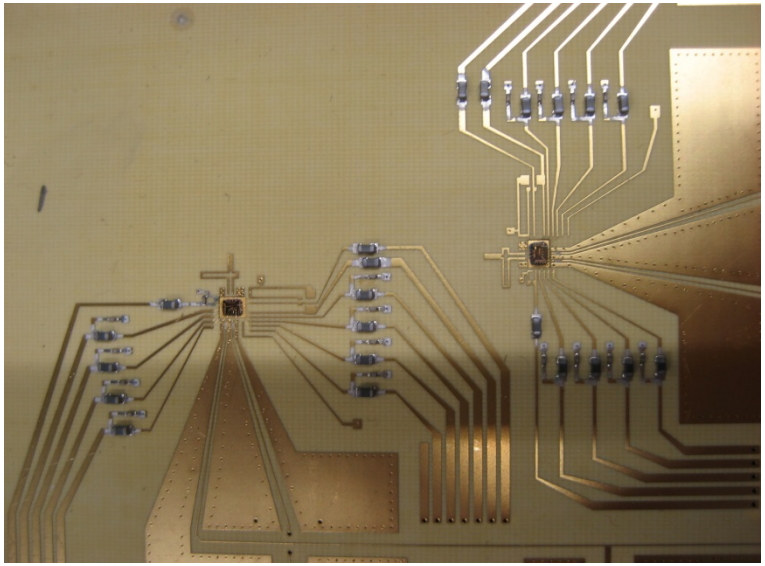




Active array

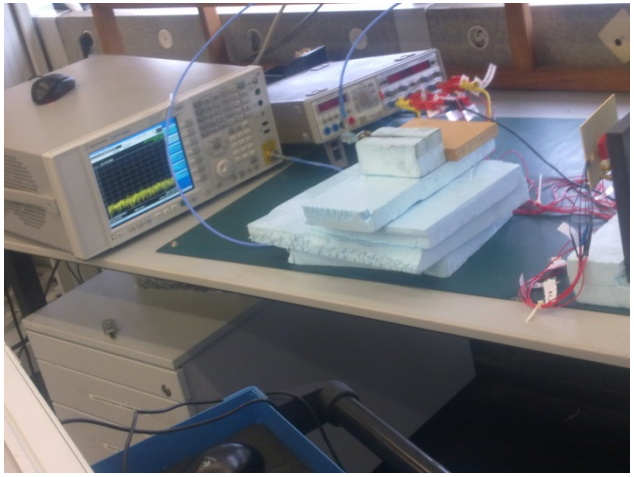
- **Measurements :**

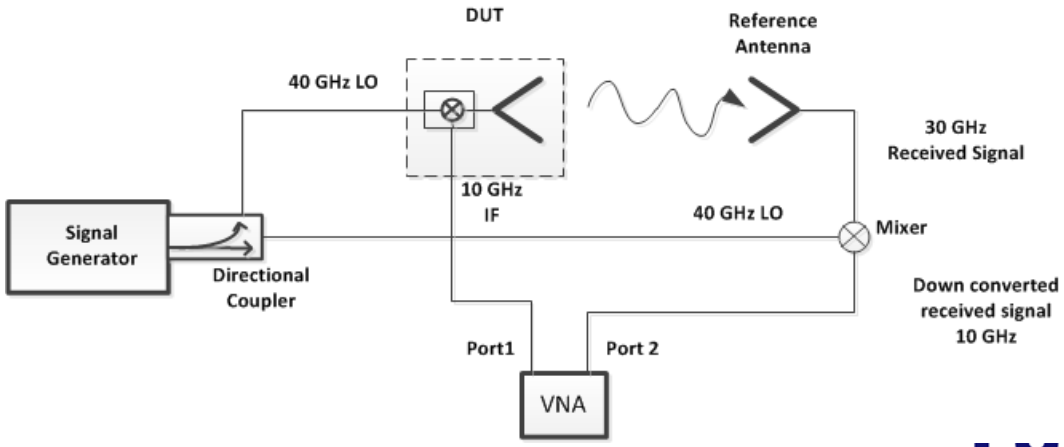




Measurement Setup!

Active array





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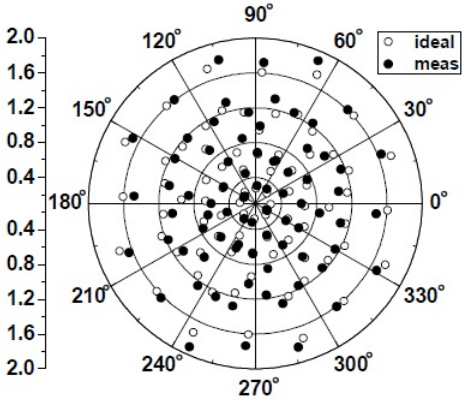
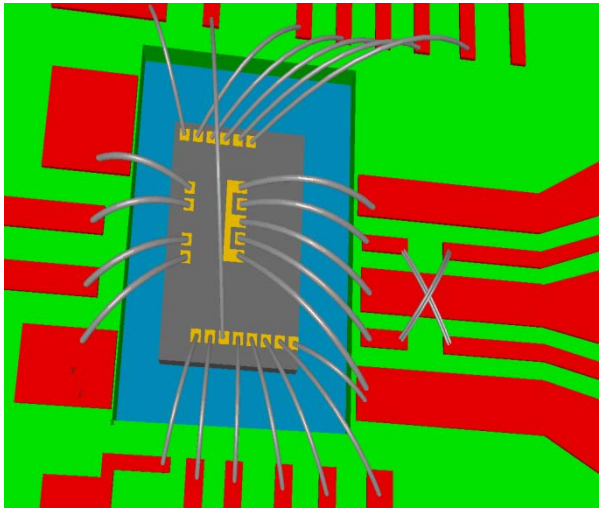
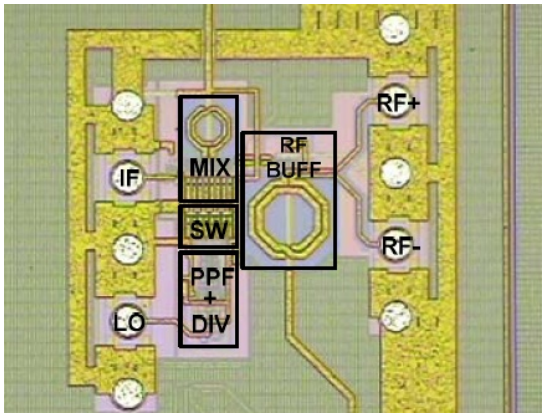
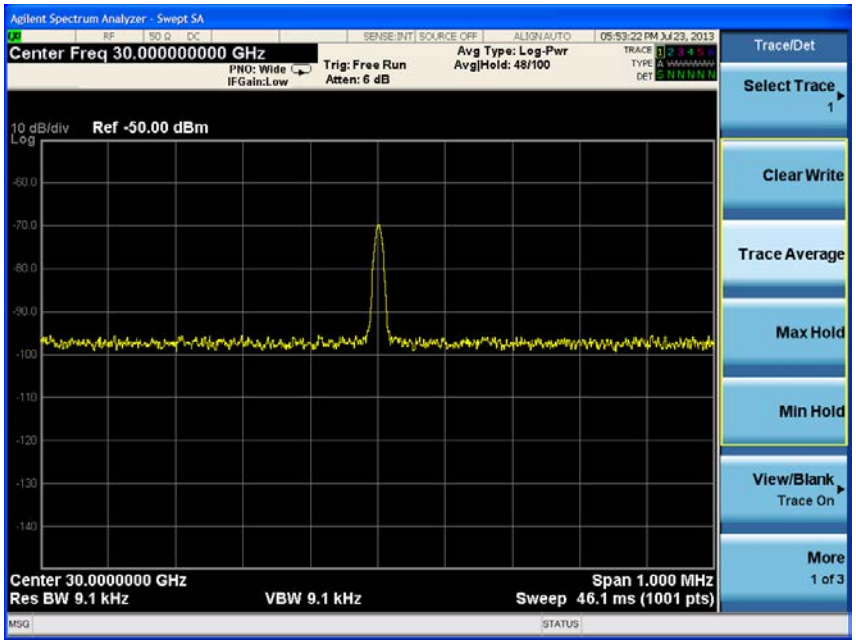
Demonstrator update

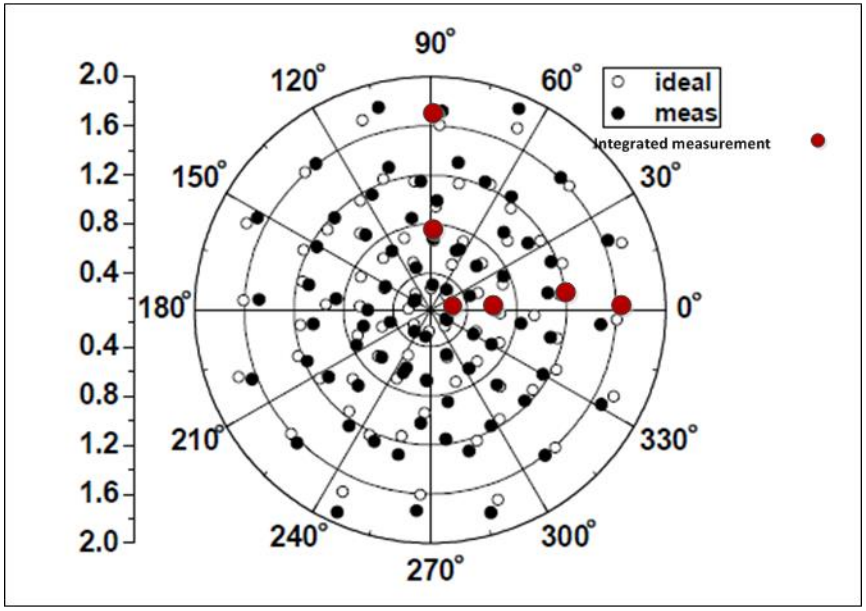






Integrated Antenna Measurement

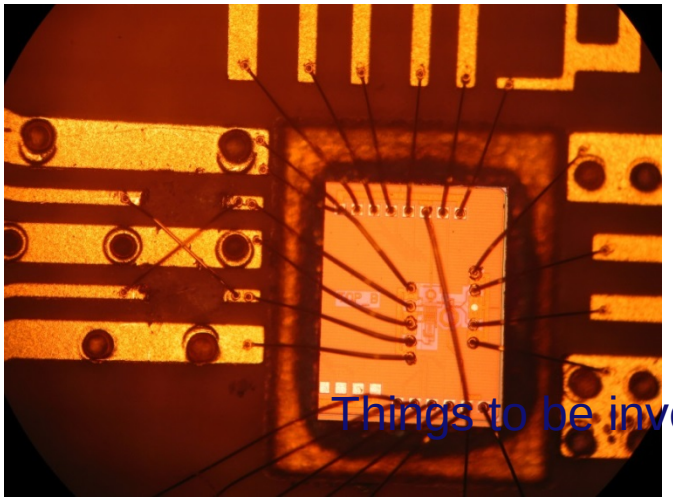




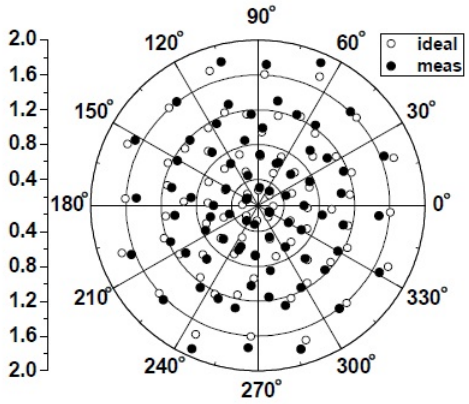
Received signal at 30 GHz

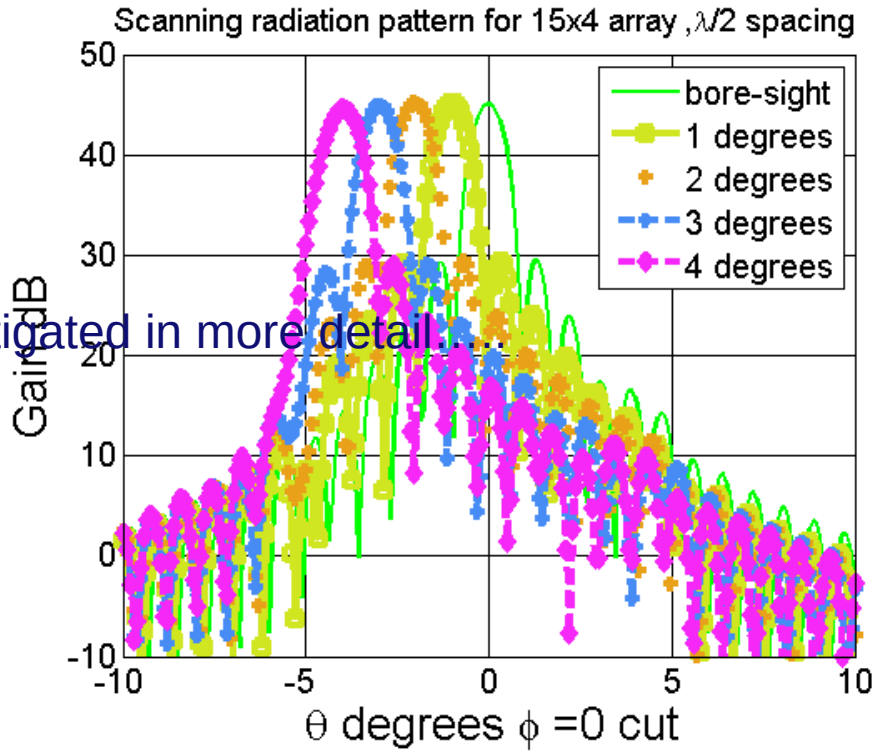
No phase information!
Amplitude measurement

Integrated Antenna Measurement



Things to be investigated in more detail……

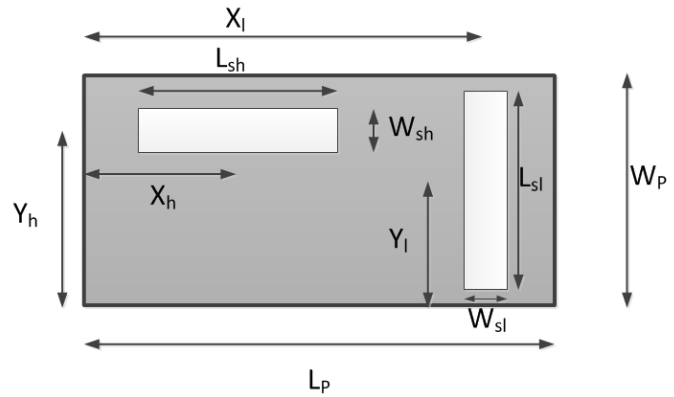


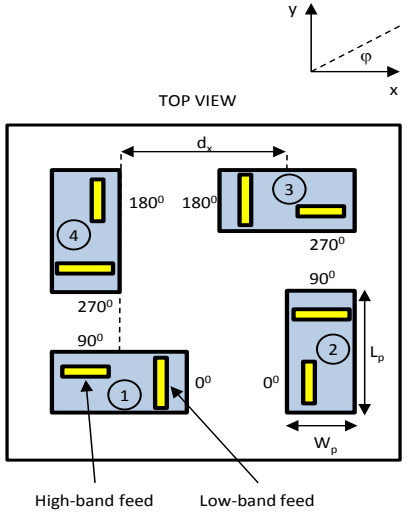


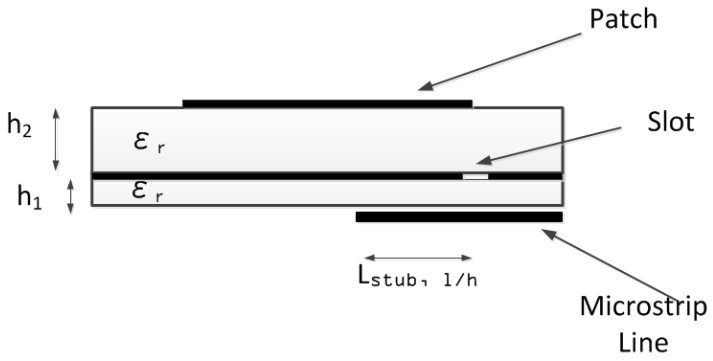
Things to be investigated in more detail…..

- Dual frequency element
- Circular polarization
- Surface waves
- Isolation

Enhanced Feed Design

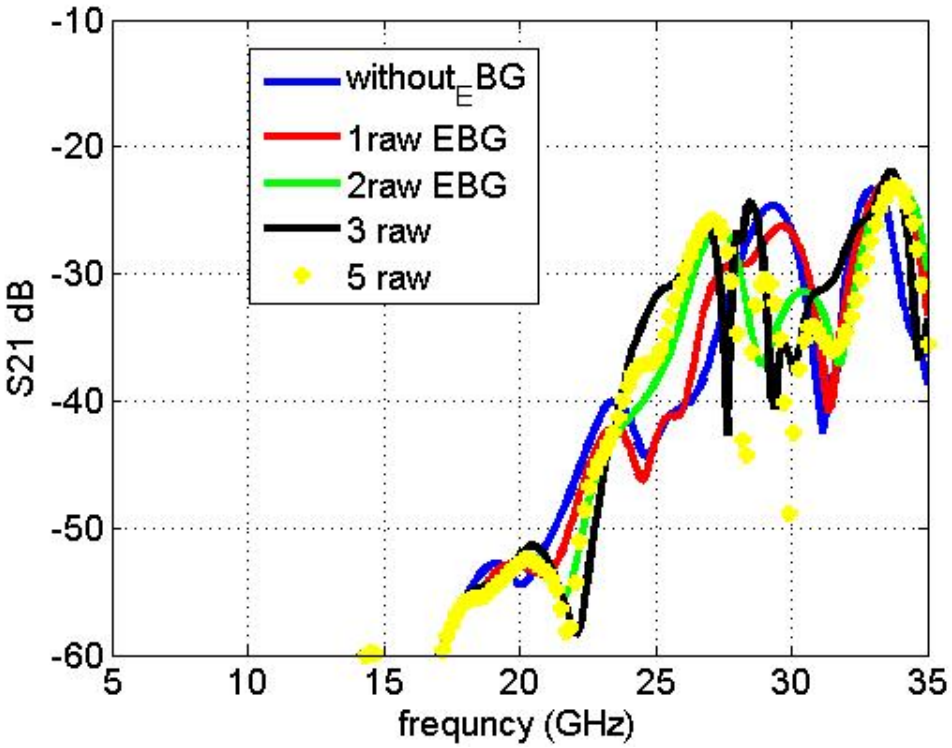


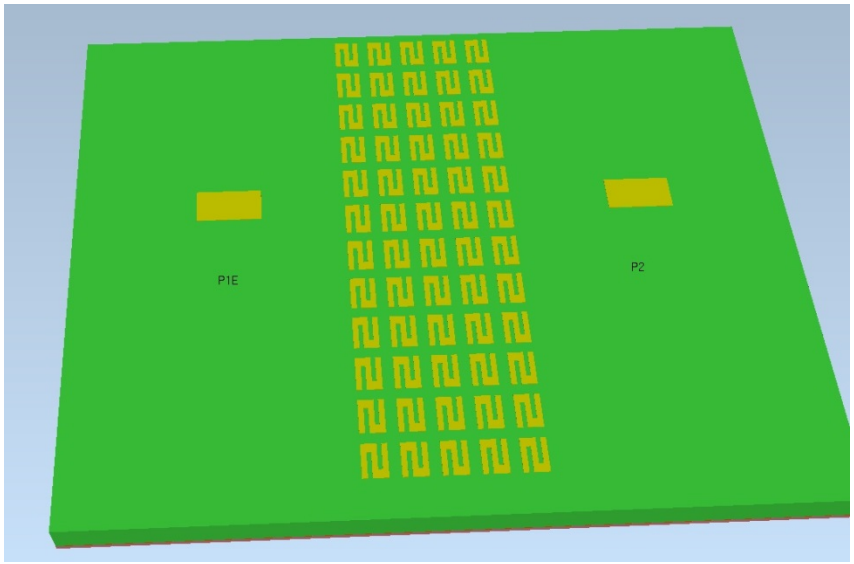




Dual Frequency circular polarized feed

Finite 2D EBG

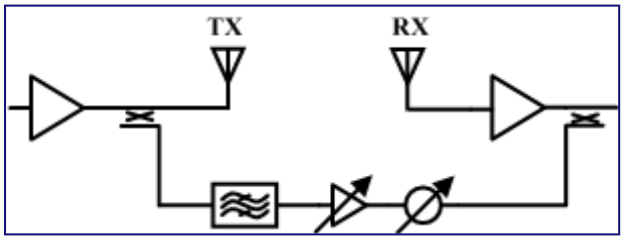




Improving coupling at 30 GHz

Isolation

Approaching problem :



Active cancelling

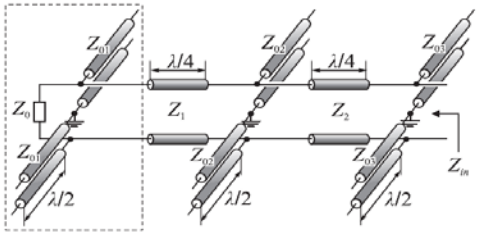
- **Narrow band**
- **Design complexity**

(Homan Habibi in SPS group)

Active filtering (Chuang Lu in MSM group)

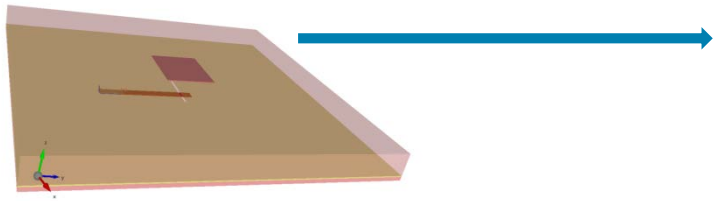
- **Narrow band**
- **Loss/NF contribution to the LNA/PA (>1dB)**

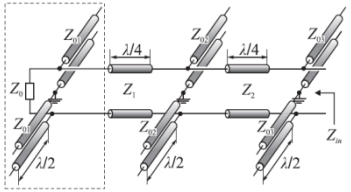
Passive filtering (EM group)



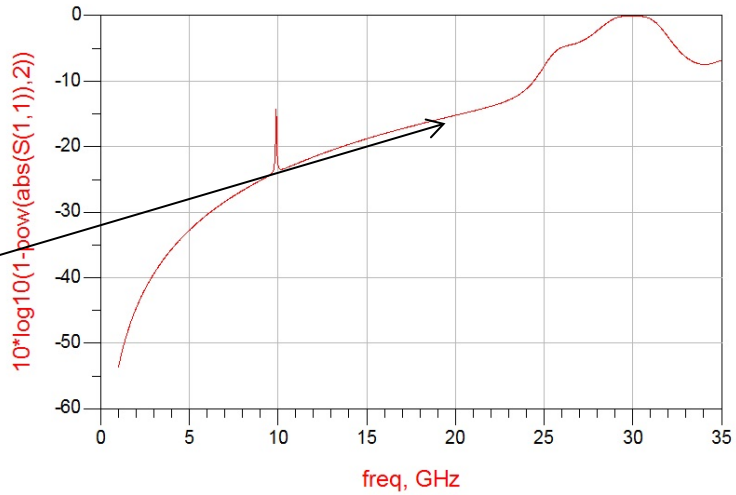
- **Low loss**
- **Compact solution**

Filtenna Design





- **Band pass at 30 GHz**
- **Attenuating at 20 GHz**



Conclusion

- **We have developed a model to calculate the properties of focal-plane arrays.**
- **A prototype integrated antenna with IC was developed and measured.**
- **Still some challenges remain, like dual-polarization and isolation.**
- **Enhanced feed design is on progress.**

That’s it folks……

Thank you for your attention