Multibeam Antennas for Emerging Satellite and Terrestrial Applications

Giovanni Toso

European Space Agency

giovanni.toso@esa.int

RF Summit Finland 2024

March 12th 2024

esa

ESA ESTEC


European Space Research and Technology Center,
ESTEC
Europe’s largest
space centre,
technical heart of
the European
Space Agency

Summary

- **Something about the European Space Agency (ESA)**
- **Multibeam Antennas**

  Reflector-based architectures

  (Single-Feed-per-Beam, Multiple-Feed-per-Beam)

  Direct Radiating Arrays

  Hybrid Digital/Analogue Beamforming

  Lens-based architectures (free space and constrained)
- **ESA Courses & Workshops**

Purpose of The European Space Agency

"To provide for and promote, for exclusively peaceful purposes, cooperation among European states in space research and technology and their space applications."

Article 2 of ESA Convention

ESA Facts and Figures

- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2300 staff
- 5.6 billion Euro budget (2018)
- Over 80 satellites designed, tested and operated in flight

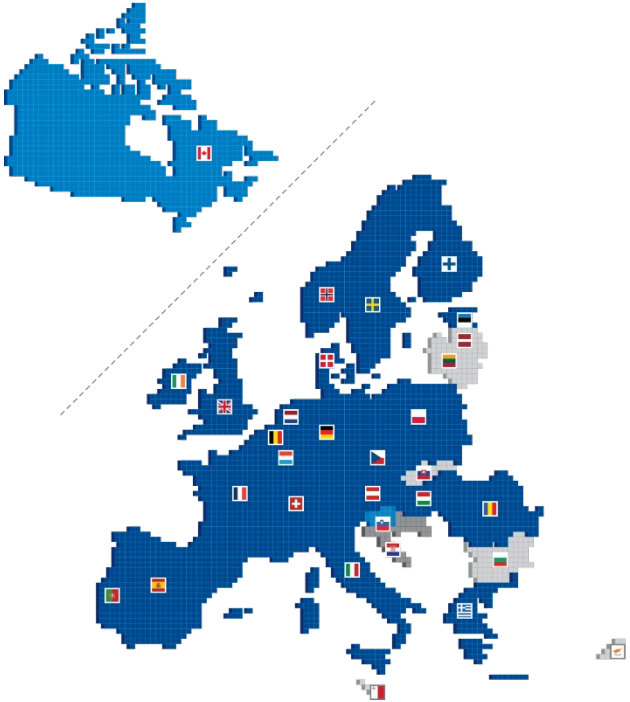
Member States

ESA has 22 Member States: 20 states of the EU (AT, BE, CZ, DE, DK, EE, ES, FI, FR, IT, GR, HU, IE, LU, NL, PT, PL, RO, SE, UK) plus Norway and Switzerland.

Seven other EU states have Cooperation Agreements with ESA: Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Malta and Slovakia.

Slovenia is an Associate Member.

Canada takes part in some programmes under a long-standing Cooperation Agreement.



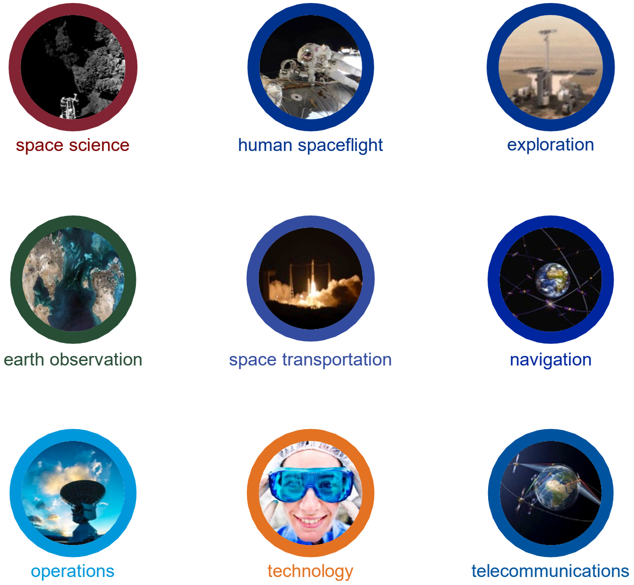
Activities

ESA is one of the few space agencies

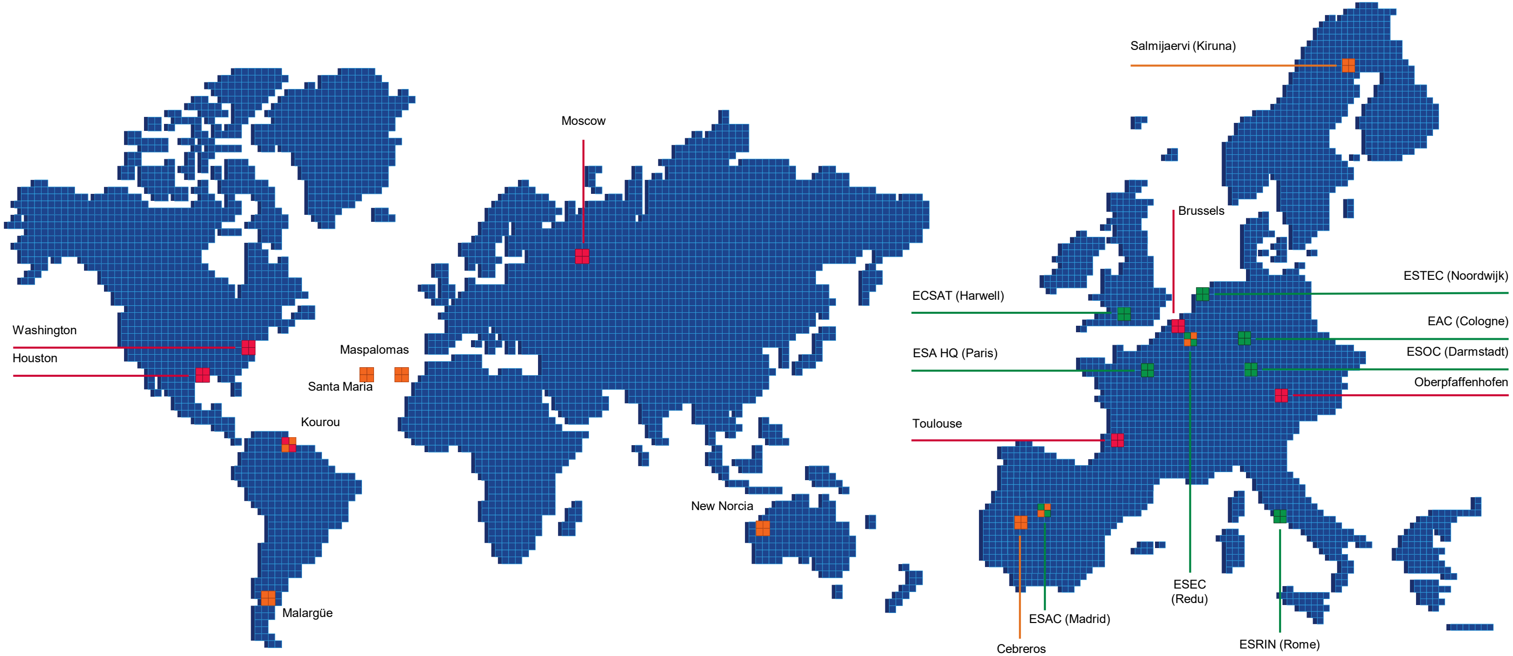
in the world to combine responsibility

in nearly all areas of space activity.

* Space science is a Mandatory programme, all Member States contribute to it according to GNP. All other programmes are Optional, funded ‘a la carte’ by Participating States.



ESA's Locations

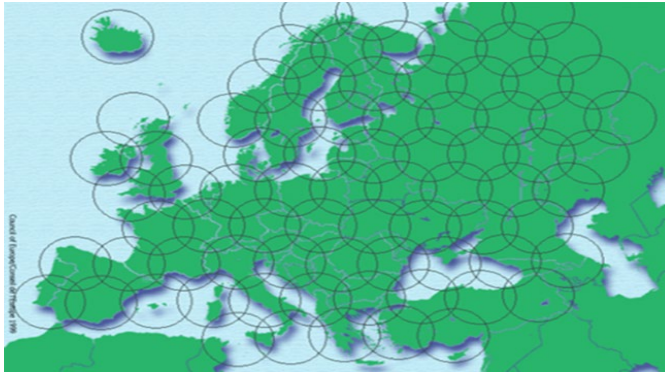


- ESA sites
- Offices
- ESA Ground Station
- ESA Ground Station + Offices
- ESA sites + ESA Ground Station

Multi-Beam Antennas (MBAs)

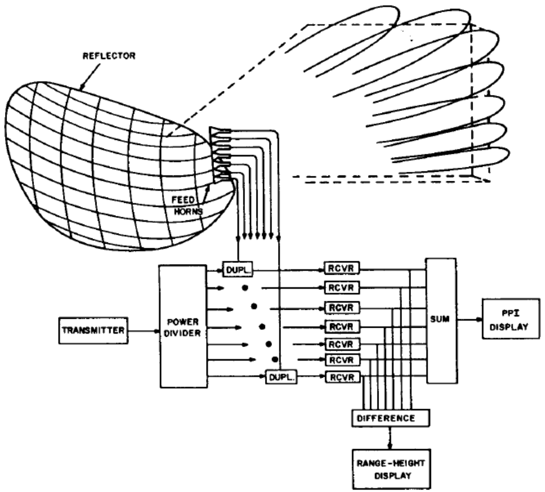
2.240 multi-beam antenna. An antenna capable of creating a family of major lobes from a single non-moving aperture, through use of a multiport feed, with one-to-one correspondence between input ports and member lobes, the latter characterized by having unique main beam pointing directions.
NOTE—Often, the multiple main beam angular positions are arranged to provide complete coverage of a solid angle region of space.

IEEE Std 145-1993, IEEE Standard Definitions of Terms for Antennas



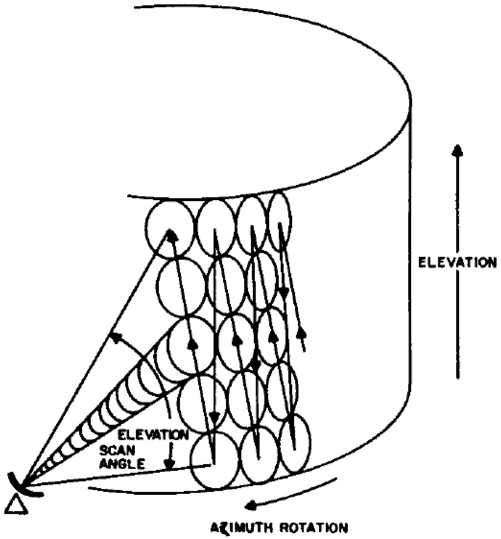
MBAs play increasingly important roles, e.g. in mobile base stations, on-board satellites and in advanced radars.
They add more functions, increase the capacity of the systems, preserve the available frequency spectrum, etc.

Stacked beams RADAR - example of Passive Antenna Solution



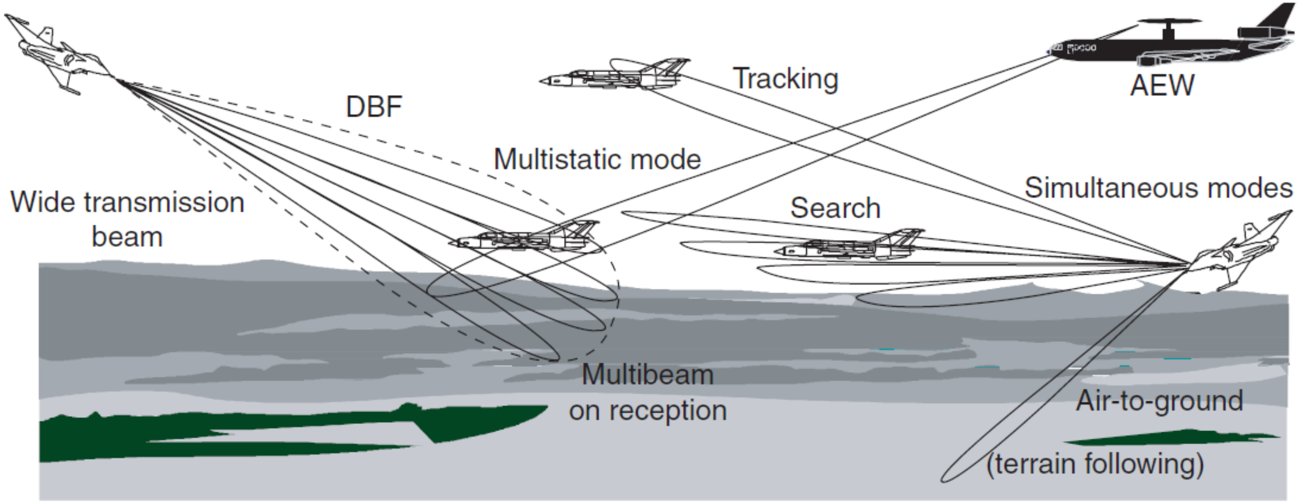
- Volumetric coverage is obtained through the use of a vertical stack of overlapped pencil beams continuously rotating in azimuth.

- In transmission all the beams are fed in phase such to produce a composite transmit pattern with cosecant squared power distribution.



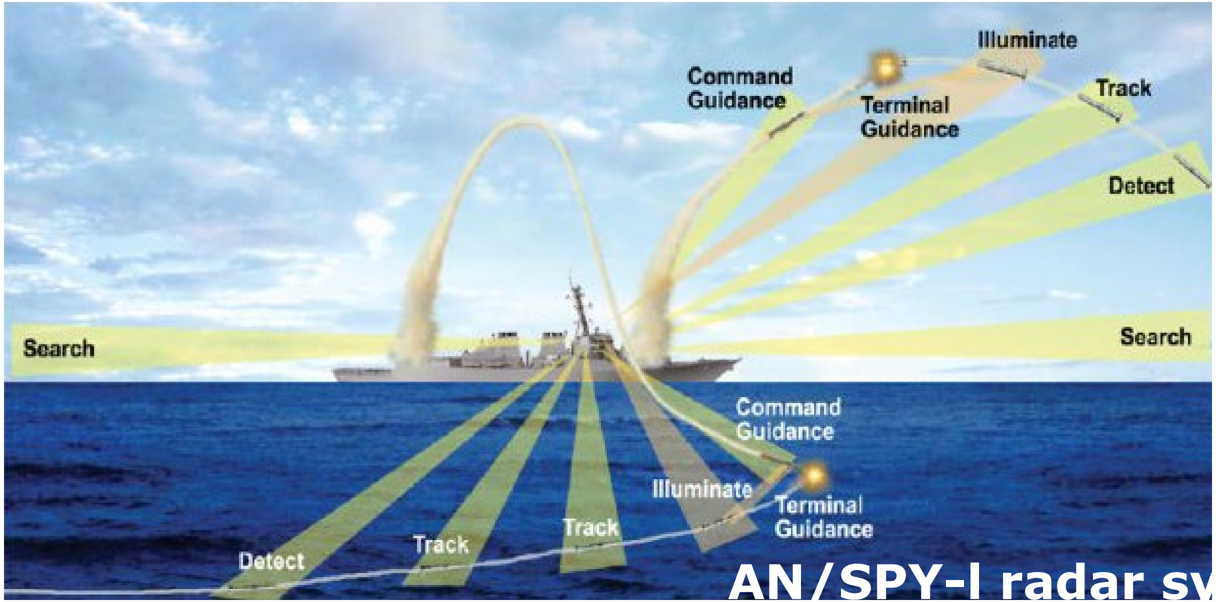
Skolnik M I, Radar Handbook, McGraw-Hill, 1970

Multibeam Antennas in Airborne Multifunction RADARs



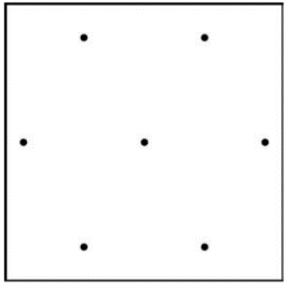
Lacomme P et al, Air and Spaceborne Radar Systems - An Introduction, SciTech, 2001

Multibeam Antennas in Maritime Multifunction RADARs

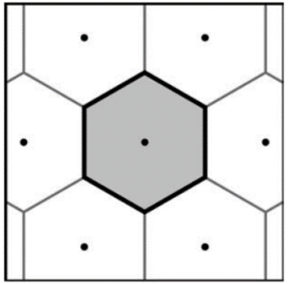


Multibeam Antennas in Cellular Communication Systems

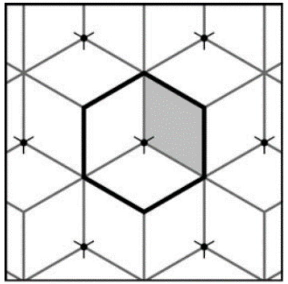
Base Stations



Cellular Coverage

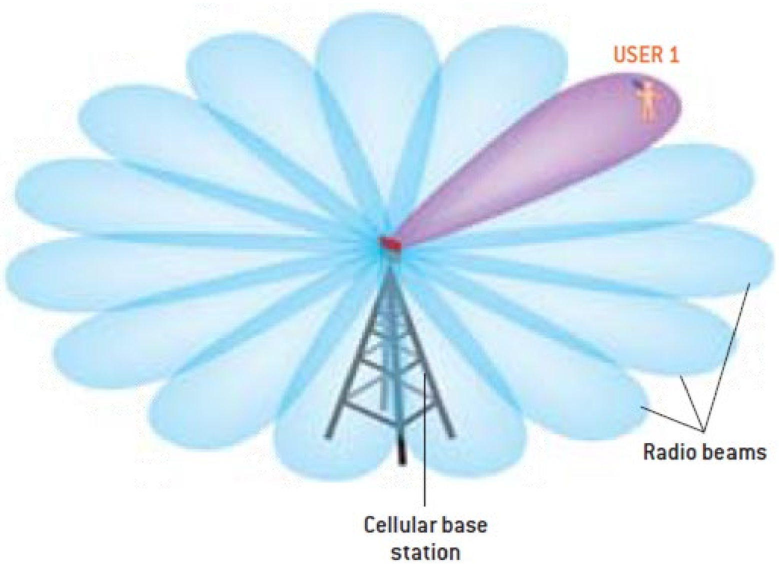


Sectorization



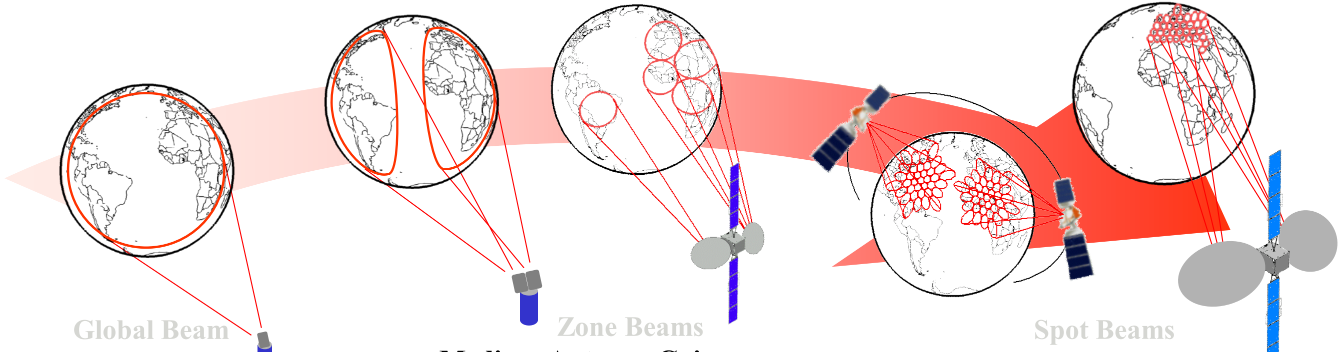
Chen Z N, Luk K-M, Antennas for Base Stations in Wireless Communications, McGraw-Hill, 2009

Multibeam Antennas in Cellular Communication Systems



Cooper M, "Antennas get Smart", Scientific American, pp. 49-55, July 2003

Multibeam Antennas in Telecommunication Satellite Systems



Global Beam

- Low Antenna Gain
- Low Data Rates

- Low Capacity
- World Broadcasting
- Full interconnectivity

- Easily Accommodate Traffic Variability

Zone Beams

- Medium Antenna Gain
- Medium Data Rates

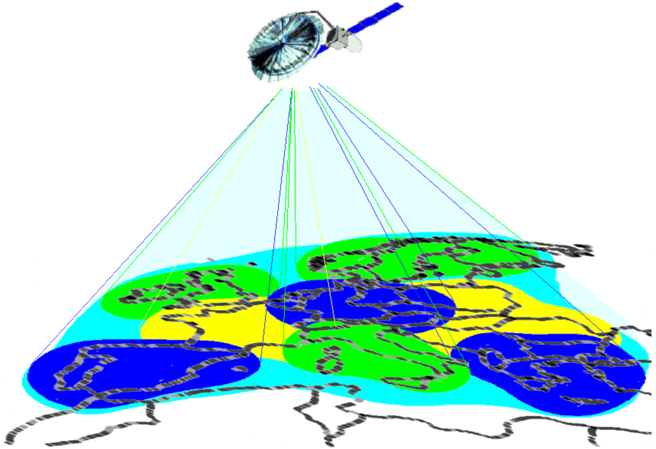
- Medium Capacity
- Domestic Broadcasting
- Reduced Interconnectivity

- Difficult Accommodation of Traffic Variability

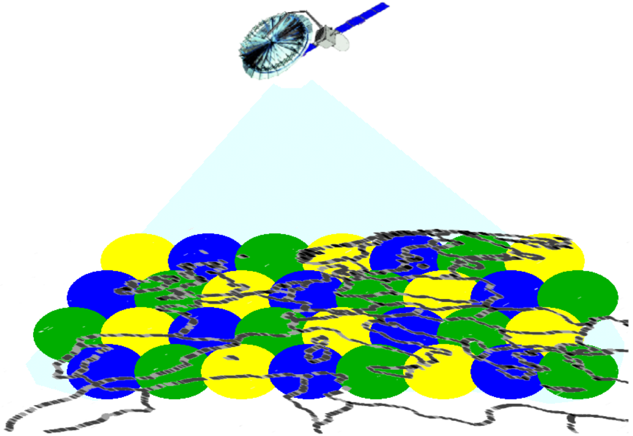
Spot Beams

- High Antenna Gain
- High Data Rates
- Small User Terminals
- High Capacity
- Inefficient Broadcasting
- Segregated Interconnectivity (OK for multi-star topology)
- Difficult Accommodation of Traffic Variability

Multibeam Antennas in Telecommunication Satellite Systems



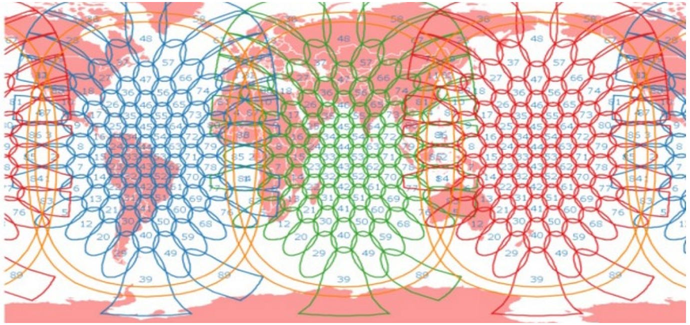
Multiple Shaped (Linguistic) Beams



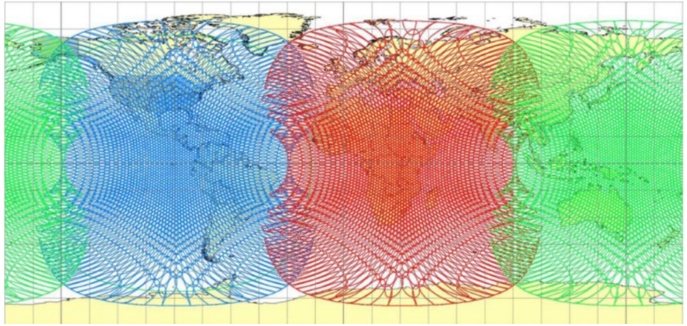
Multi Spot Beams
(Cellular-Like)

the Challenges Ahead

Terabit(ps) GEOs



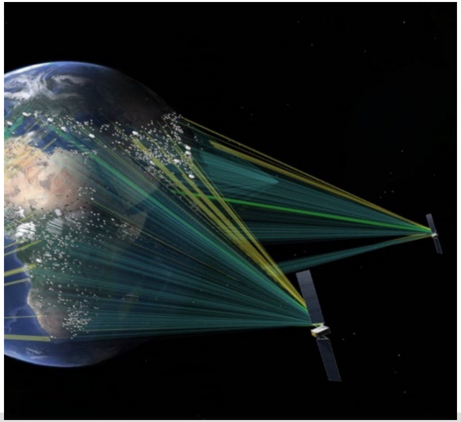
Inmarsat 5



ViaSat 3
(Announced)

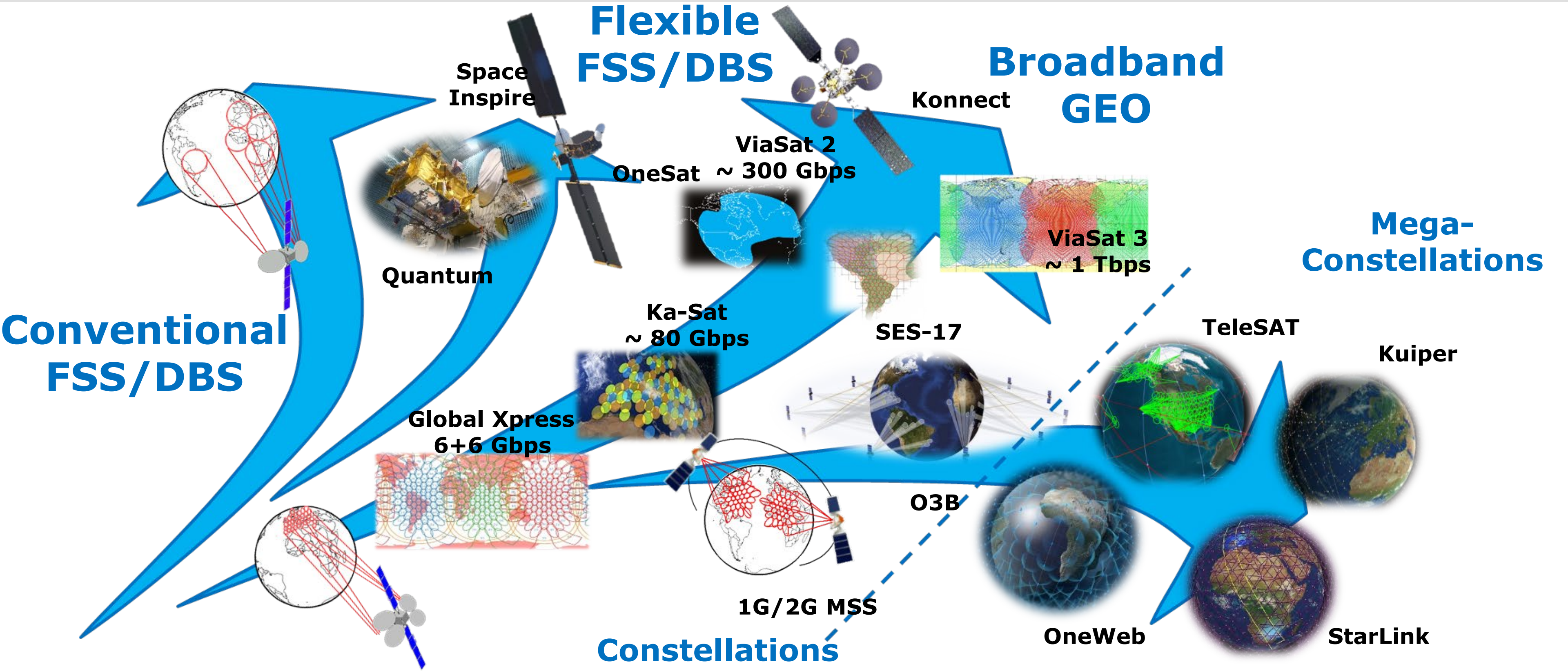
NG Constellations

Boeing
FCC Filing

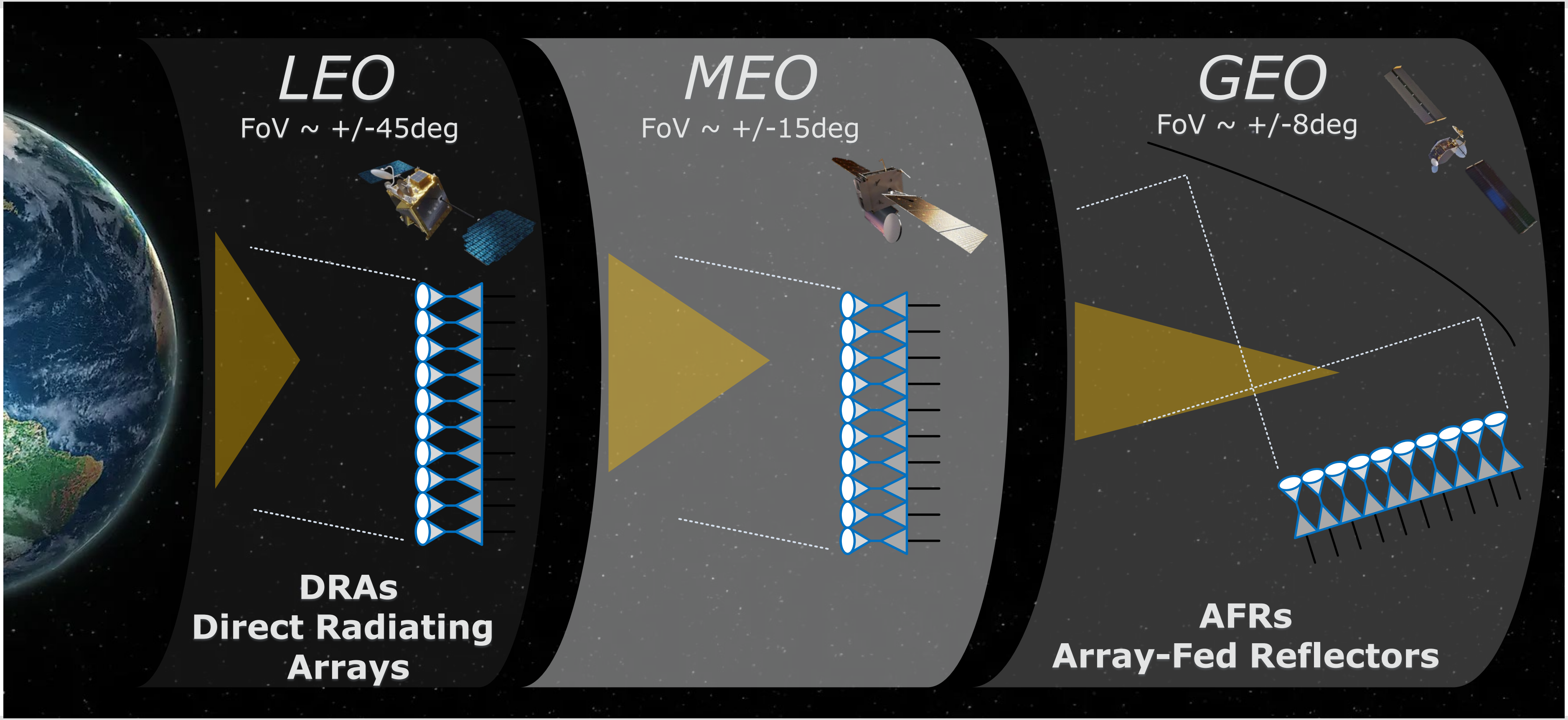


O3b mPower
(Boeing)

Evolution of SATCOM systems



Active Antennas in LEO, MEO and GEO

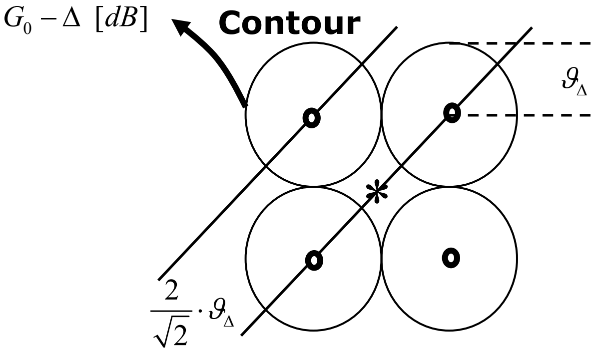


Bidimensional Beam Arrangement

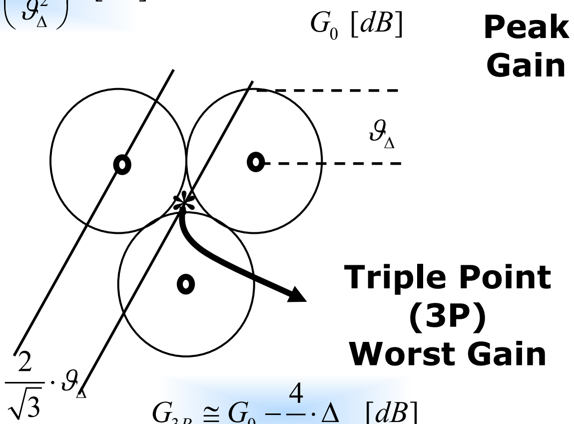
Assuming a radiation pattern with circular symmetry it can be approximated in dB to the second order radial derivative,

$$G(\vartheta) \cong G_0 - \Delta \cdot \left(\frac{\vartheta^2}{\vartheta_\Delta^2} \right) \quad [dB]$$

$$G(\vartheta_\Delta) \cong G_0 - \Delta \quad [dB]$$



$$G_{4P} \cong G_0 - 2 \cdot \Delta \quad [dB]$$



$$G_{3P} \cong G_0 - \frac{4}{3} \cdot \Delta \quad [dB]$$

1st Gen Ka-band Satellites Requirements

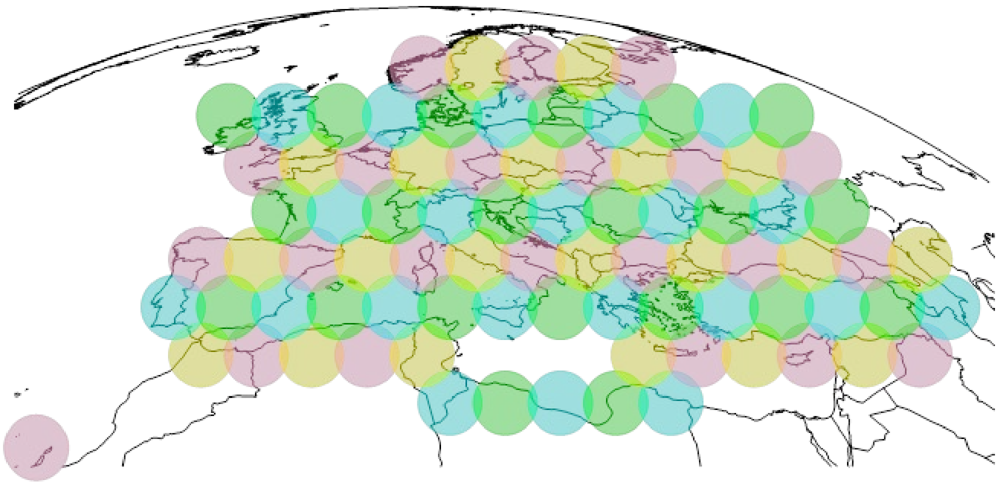
Frequency centre = 30 GHz with 2% BW

Minimum directivity at EOC = 43.5 dBi

Maximum roll-off (EOC) = 4.3 dB

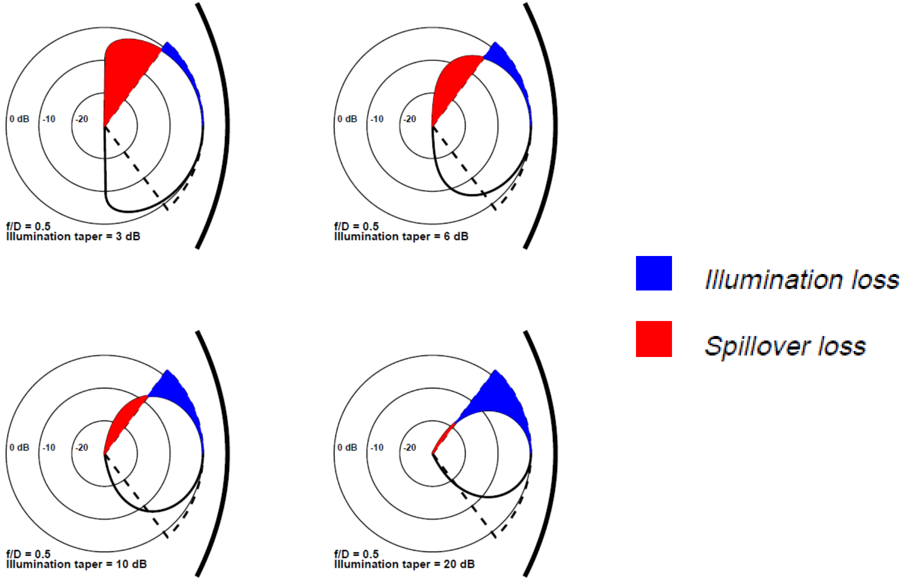
Minimum single entry C/I = 20 dB

BW=0.56°



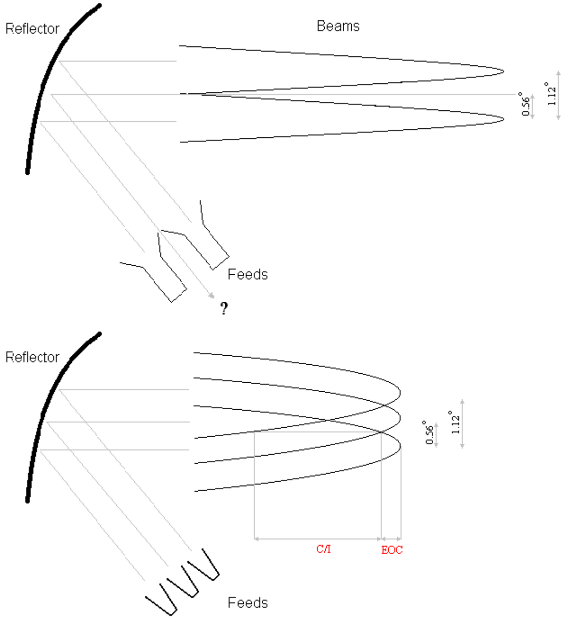
Reflector-based Architectures

Reflector Antennas
Illumination Efficiency vs Spillover



Paul Wade, The W1GHZ Online Microwave Antenna Book

Reflector Antennas - Small vs Large Feeds



Directive Horns

Large diameter

=> Large spacing

=> $\Delta\theta > 0.56°$

=>Low reflector efficiency

Small Horns

- All feeds in one cluster
- Low directivity
- High spill-over losses
- High reflector efficiency
- EOC Gain and C/I not meeting requirements

Reflector Antennas - Small vs Large Feeds

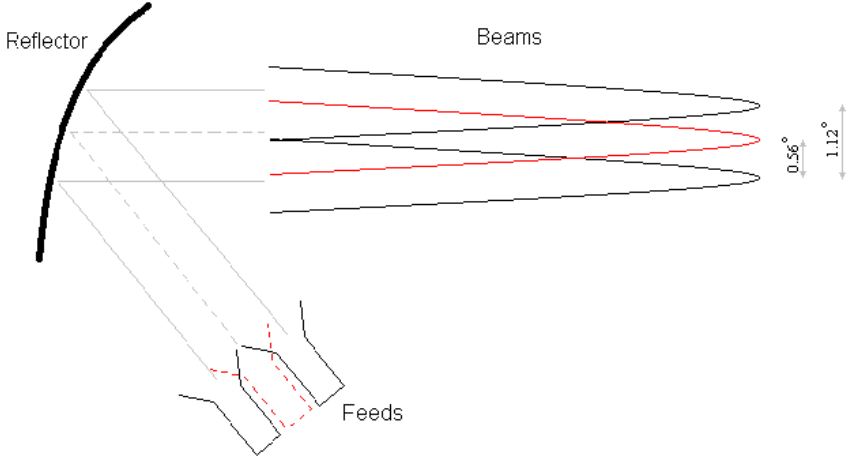
The ideal solution would require:

large feeds with the spacing of the small ones

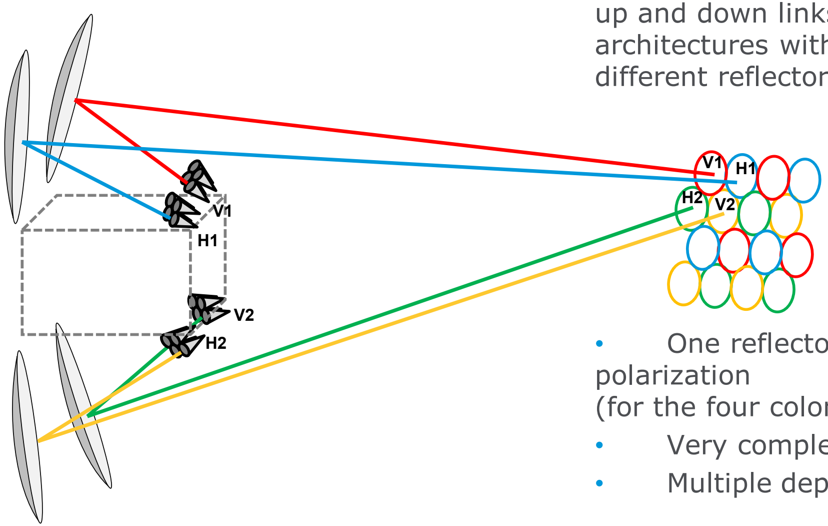
Interleaving Multiple reflectors

or

Feed overlapping



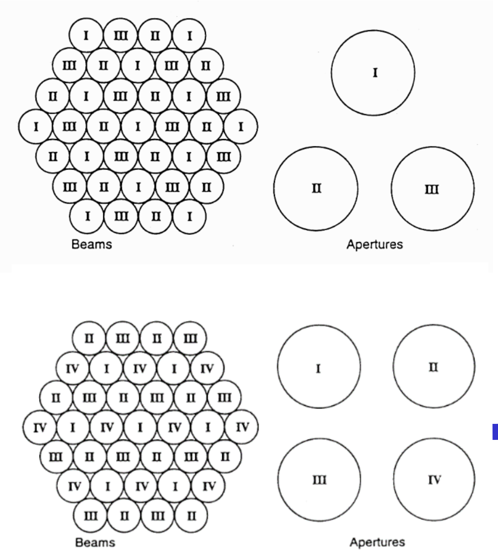
Multiple spot beam coverage using single feed per beam architectures

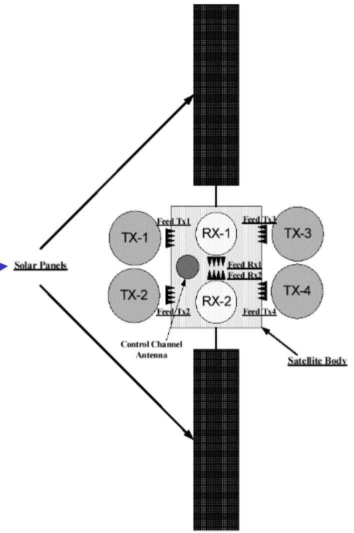


Operational multimedia payloads based on multiple beams with frequency reuse adopt, for up and down links, ***ONE FEED PER BEAM*** architectures with adjacent beams generated by different reflectors

- One reflector per frequency and polarization
(for the four colors frequency reuse)
- Very complex antenna farm
- Multiple deployment requested

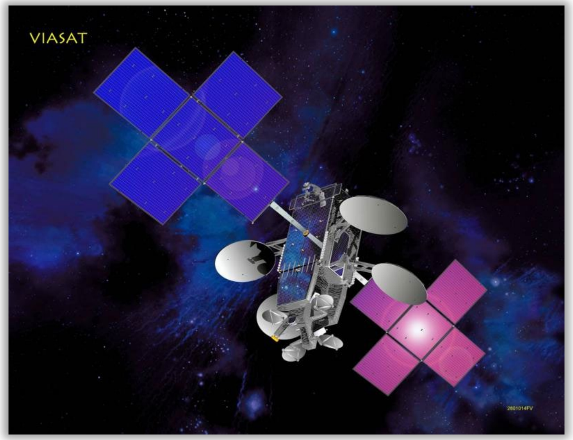
Multiple spot beam coverage using single feed per beam architectures

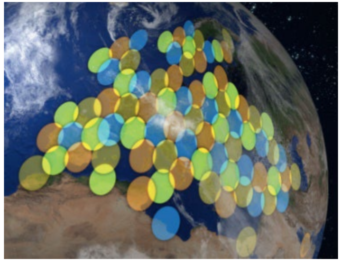




KaSat and Viasat-1 multibeam antenna systems

Ka-SAT undergoing electromagnetic testing in Astrium facilities



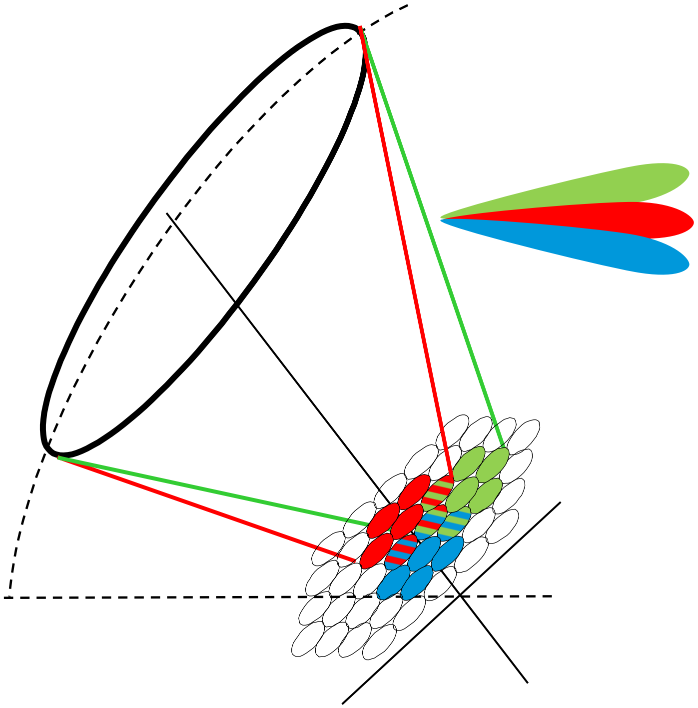


KaSat

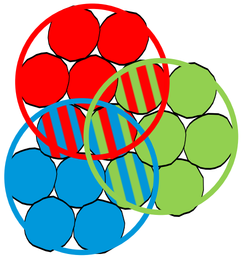
Viasat-1

More than 80 beams by 4 Tx/Rx reflectors of 2.6 meters

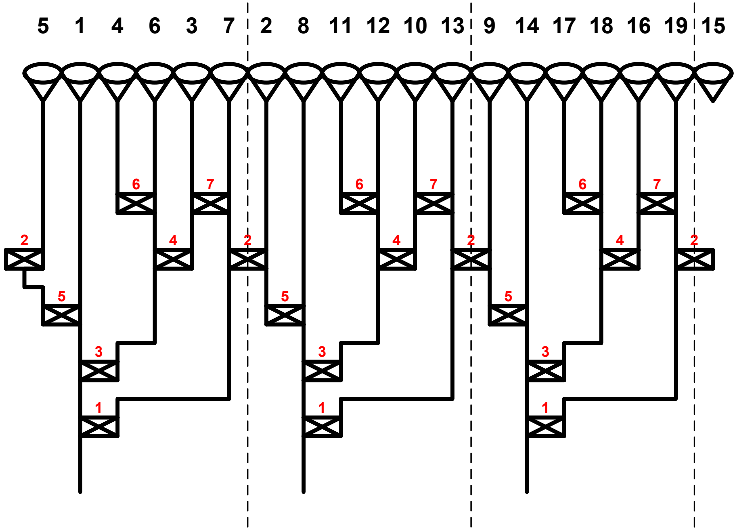
Multi-Feeds-per-Beam Solutions

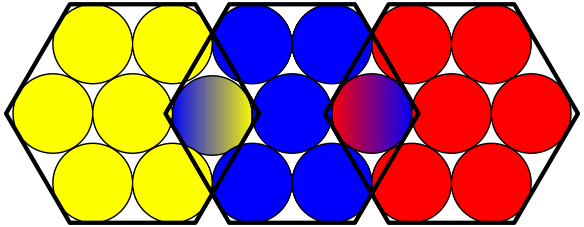


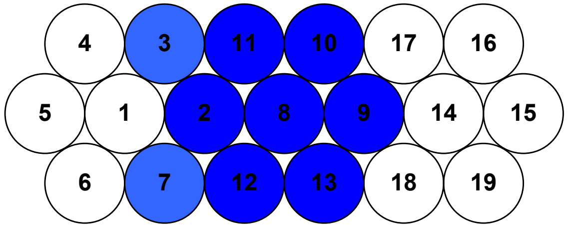
- Provide an increase of the effective primary feeding aperture and reduce the spillover losses.
- Allow to generate a multiple shaped beam coverage with a single dish.
- Need complex beamforming networks



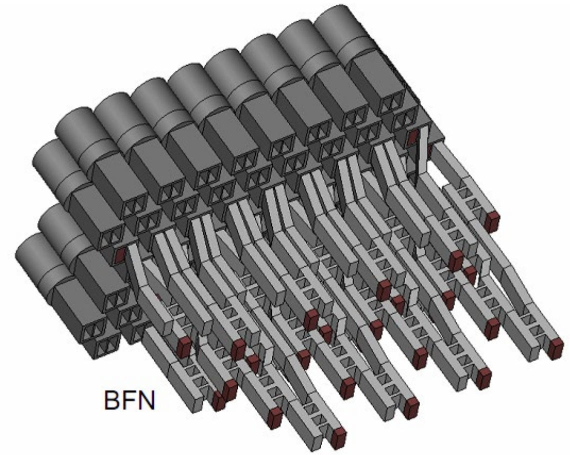
MEDUSA
Astrium GmbH (2007-to date)

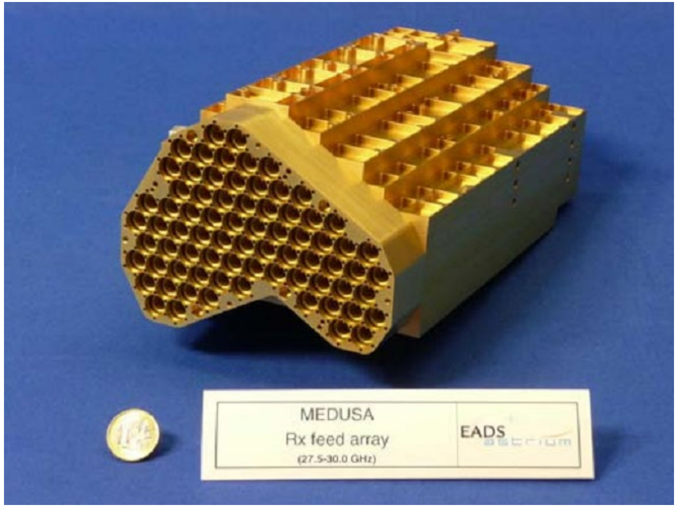






MEDUSA (Astrium GmbH)

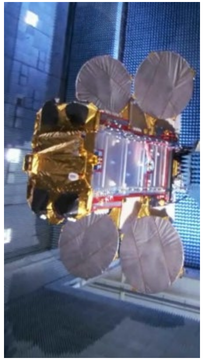




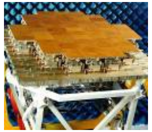
Courtesy of ASTRIUM GmbH

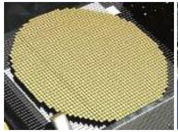
Array-based architectures

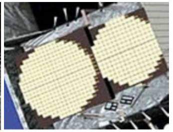
Array *vs.* Reflector Antennas

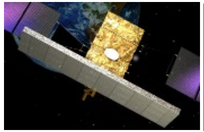


Reflector Antennas	Array Antennas
low cost low mass & weight large bandwidth, high gain,	modularity/scalability, flexibility, wide angle scanning graceful degradation, planarity, multi-beam generation RF Power Pooling steering/pointing agility
limited scanning, no reconfigurability	cost & complexity (10÷100 times higher)









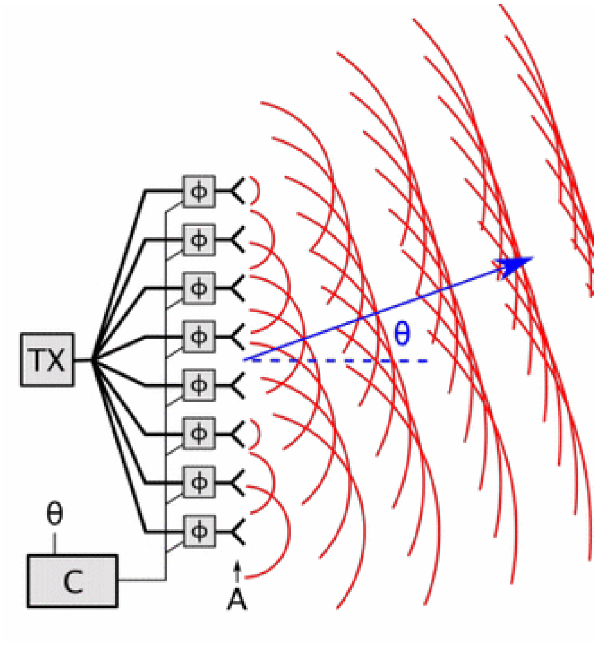
Phased Arrays

A PHASED ARRAY antenna is a system obtained connecting a group radiators and organizing them in such a way that their transmitted signals are in the correct electrical relationship (phase and amplitude) with each other.

Scan/shaping of the beam is obtained by changing the complex weighting of its elements.

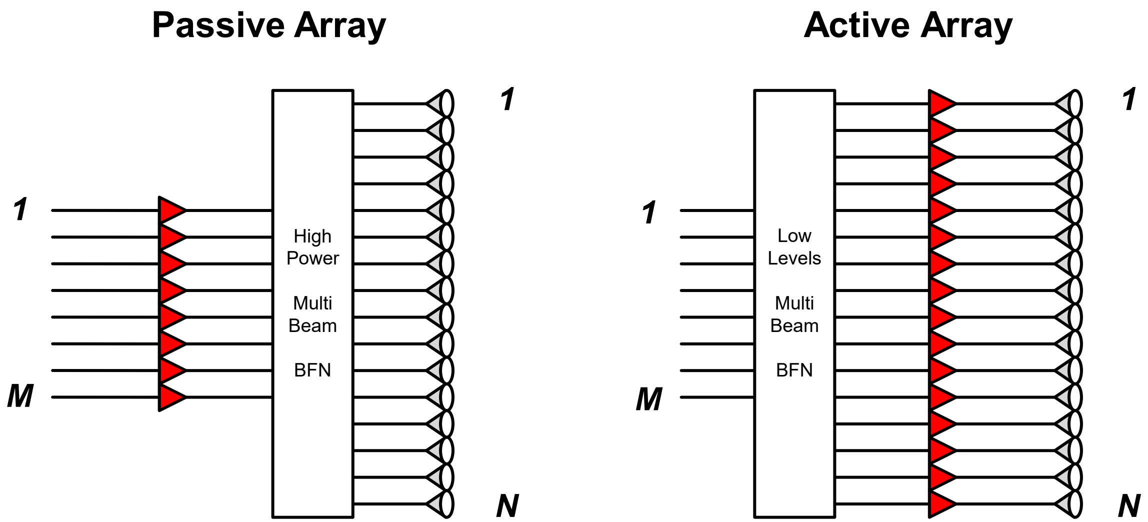
Primary reason for using phased arrays is to produce beams that can be modified (scanned or shaped) electronically.

The circuitry which controls the excitation of elements in the array is called the Beam Forming Network (BFN).



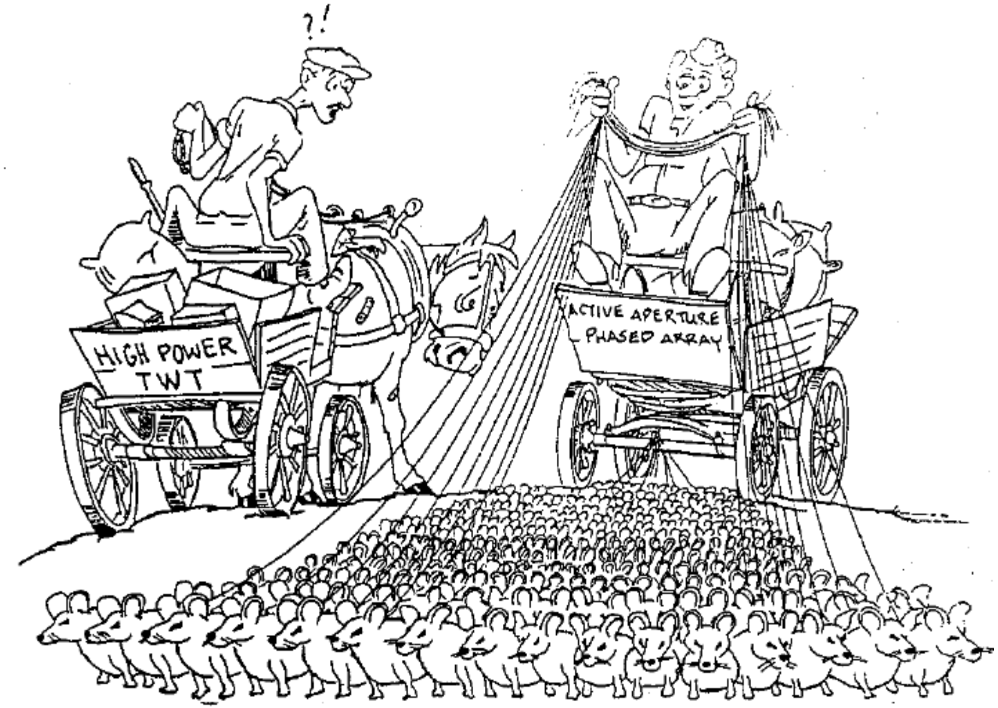
https://en.wikipedia.org/wiki/Phased_array

Passive *vs* Active Arrays

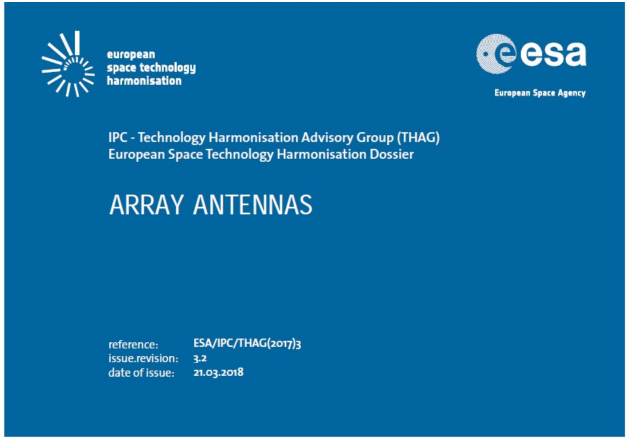


esa

Active Arrays



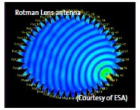
European Heritage in Active Array Antennas

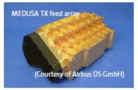


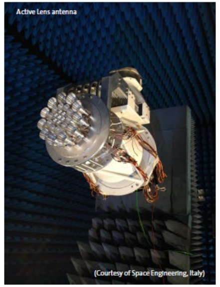
IPC - Technology Harmonisation Advisory Group (THAG)
European Space Technology Harmonisation Dossier

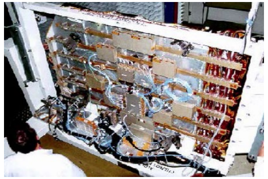
ARRAY ANTENNAS

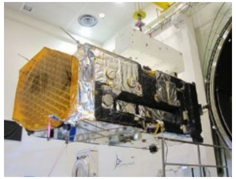
reference: ESA/IPC/THAG(2017)3
issue.revision: 3.2
date of issue: 21.03.2018

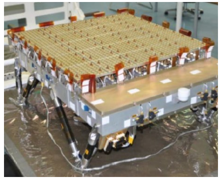


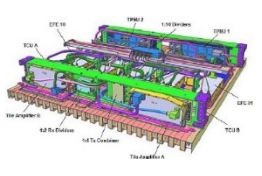




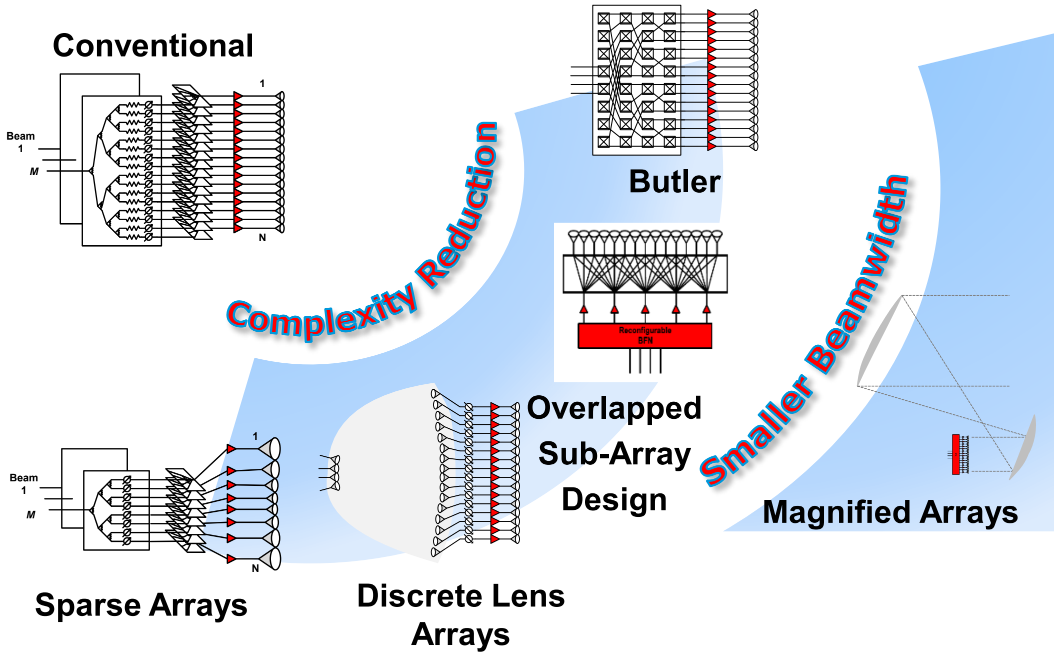






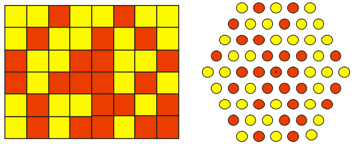


Array-based Multibeam Antennas/Beamforming



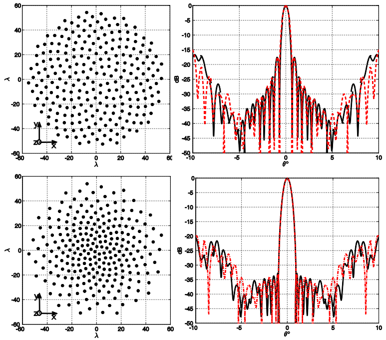
Irregular Arrays

Thinned Arrays:
elements in a regular lattice



Sidelobe controls
Grating lobes control

Sparse Arrays:
elements with arbitrary location



Grating lobes control
Sidelobe controls

Sidelobe controls
Grating lobes control

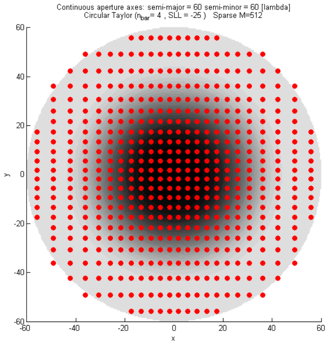
G. Toso, C. Mangenot, A.G. Roederer, "Sparse and Thinned Arrays for Multiple Beam Satellite Applications", 29th ESA Antenna Workshop on Multiple Beams and Reconfigurable Antennas, Apr.18-20 2007

M.C. Vigano', G. Toso, G. Caille, C. Mangenot. H. Lager, "Sunflower array antenna with adjustable density taper", Hindawi Special Issue on Active Antennas for Satellite Applications, 2009

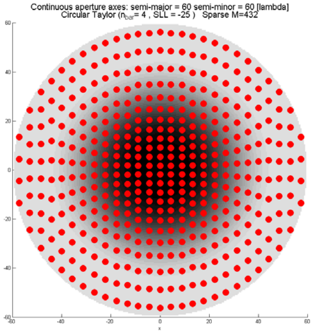
Planar Sparse Arrays

1st example: 120λ Circular Aperture, SLL = 25 dB

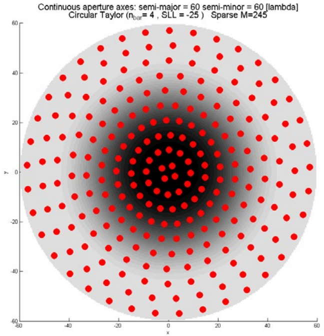
Rows and Columns



Rows or Columns



Rings



512 **432** **245**

Synthesis performed with similar scan requirements (European Coverage)

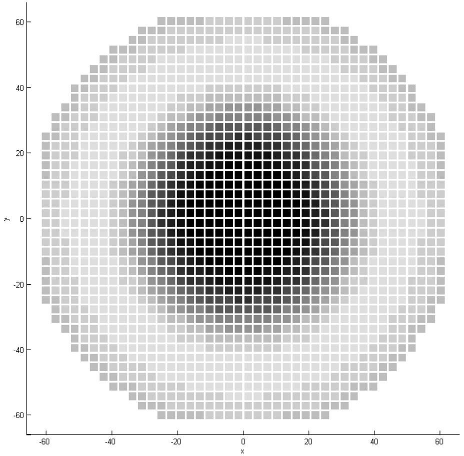
G. Toso, P. Angeletti, A Method of Designing and Manufacturing an Array Antenna, US Patent 7797816, filed on 21/02/ 2008

P. Angeletti, G. Toso, "Aperiodic Arrays for Space Applications: A combined Amplitude/Density Synthesis Approach", EuCAP2009

P. Angeletti, G. Toso, "Synthesis of Circular and Elliptical Sparse Arrays", Electronics Letters, Vol. 47, No. 5, March 2011

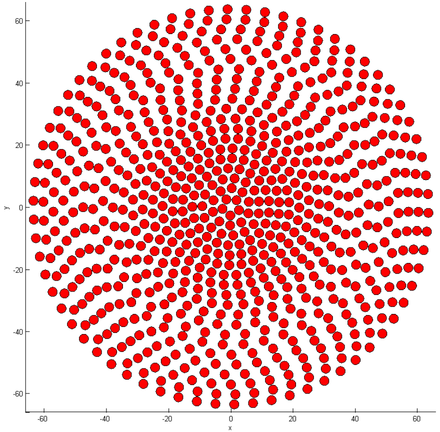
Planar Sparse Arrays

2nd example: 132λ Circular Aperture, Earth Coverage



Periodic Array (3λ spacing)

- Radiating Elements **1500**
- DC-RF Efficiency **14%**
  (SSPA Eff = 30%@SAT)



Aperiodic Array (3λ min spacing)

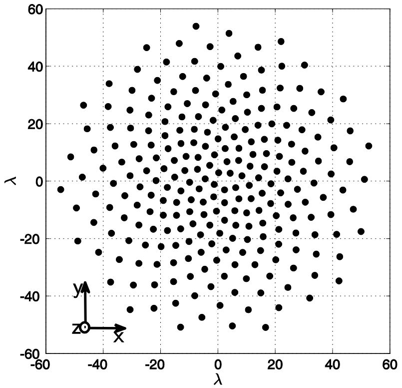
- Radiating Elements **743**
- DC-RF Efficiency **30%**
  (SSPA Eff = 30%@SAT)

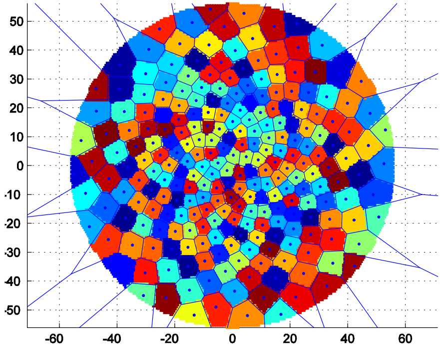
G. Toso, P. Angeletti, A Method of Designing and Manufacturing an Array Antenna, US Patent 7797816, filed on 21/02/ 2008

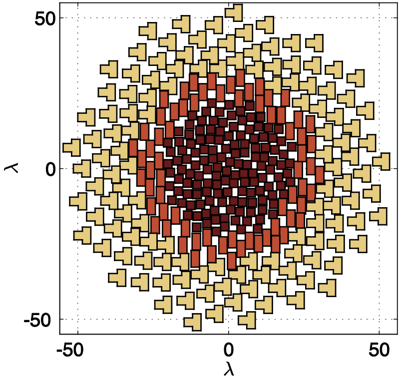
P. Angeletti, G. Toso, "Aperiodic Arrays for Space Applications: A combined Amplitude/Density Synthesis Approach", EuCAP2009

P. Angeletti, G. Toso, "Synthesis of Circular and Elliptical Sparse Arrays", Electronics Letters, Vol. 47, No. 5, March 2011

a Sunflower array implementation







M.C. Vigano', G. Toso, G. Caille, C. Mangenot. H. Lager, "Sunflower array antenna with adjustable density taper", Hindawi Special Issue on Active Antennas for Satellite Applications, 2009

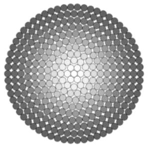
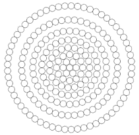
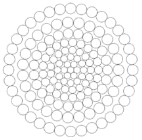
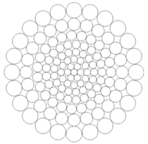
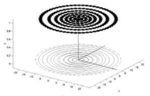
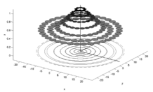
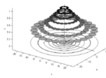
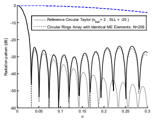
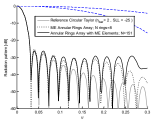
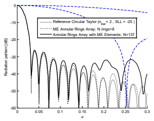
Number of elements =332

Small=138;

Medium=69;

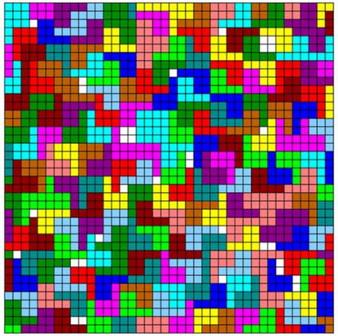
Large=125

Array Antennas with jointly Optimized Elements Positions and Dimensions

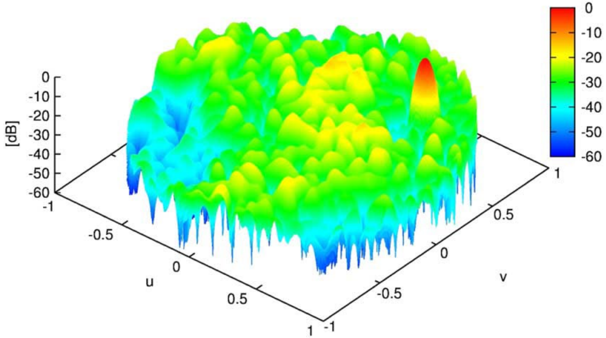
Array layout				
Aperture distribution				
Radiative Patterns				
Number of elements	**314 elements**	**209 elements**	**151 elements**	**130 elements**

P. Angeletti, G. Toso, G. Ruggerini, "Array Antennas with jointly Optimized Elements Positions and Dimensions. Part I: Linear Arrays; Part II: Planar Circular Arrays", ***IEEE Transactions on Antennas and Propagation***, Special Section on "Innovative phased array antennas based on non-regular lattices and overlapped subarrays", April 2014

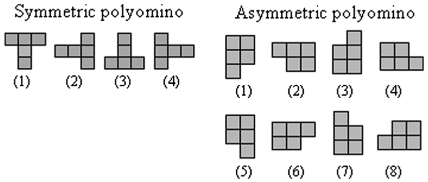
Polyomino Arrays

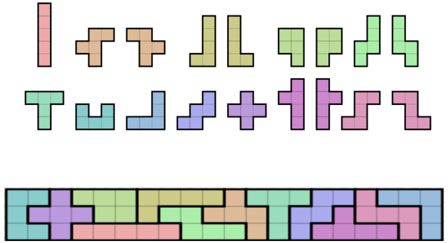


(a)



(b)



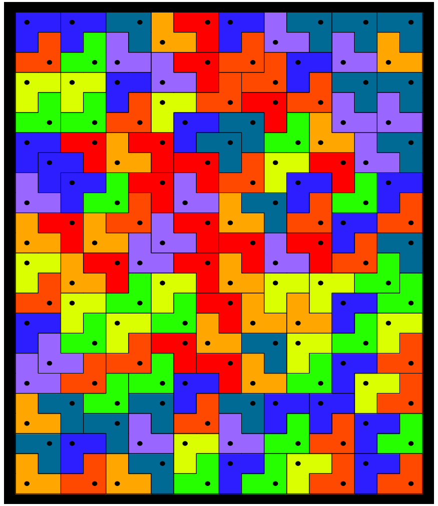


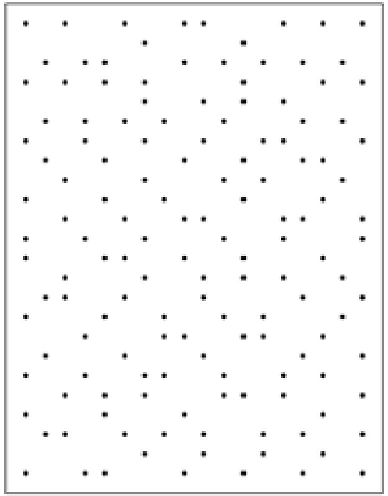
S.W. Golomb, ***Tiling with Polyominoes***, Journal of Combinatorial Theory 1, 280-296 (1966)

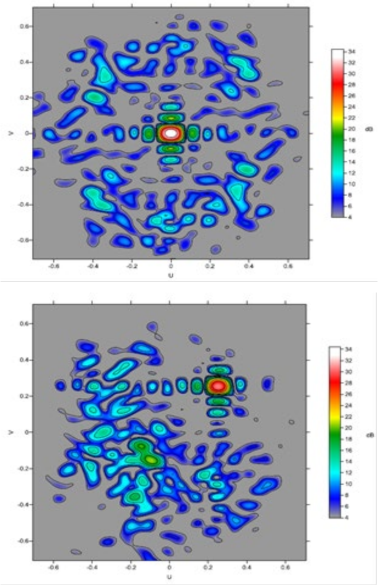
P. Rocca, R. J. Mailloux, G. Toso, ***GA-Based Optimization of Irregular Subarray Layouts for Wideband Phased Arrays Design***, IEEE Antennas and Wireless Propagation Letters, VOL. 14, 2015 131

P. Angeletti, G. Pelosi, S. Selleri, R. Taddei, G. Toso, ***Unequal Polyomino Layers for Reduced SLL Arrays with Scanning Ability,*** *Progress In Electromagnetics Research, Vol. 162, 31–38, 2018*

Polyomino Arrays



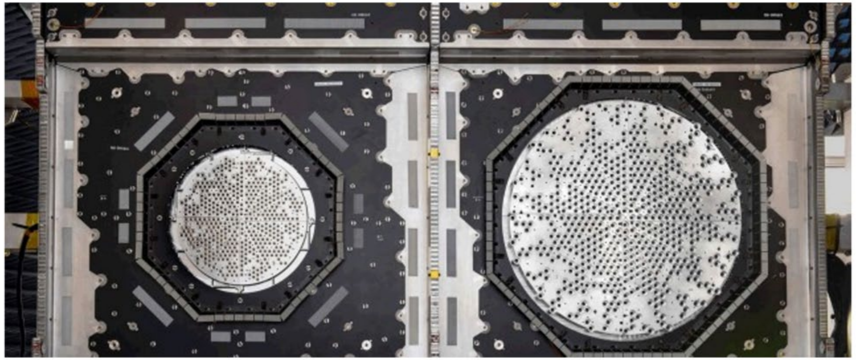




- V-shaped Triomino Array with 144 controls
- Layout and two possible patterns (courtesy of Space Engineering)

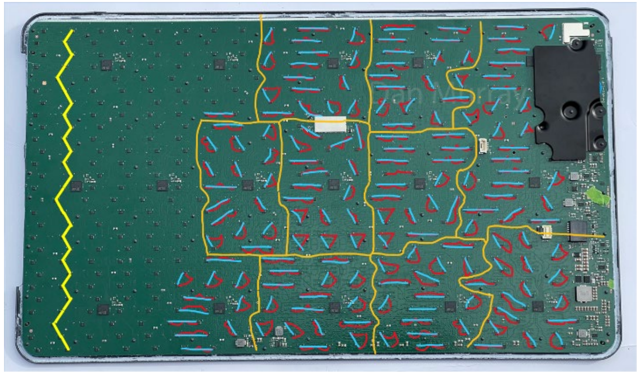
Industrial Applications of Sparse Arrays

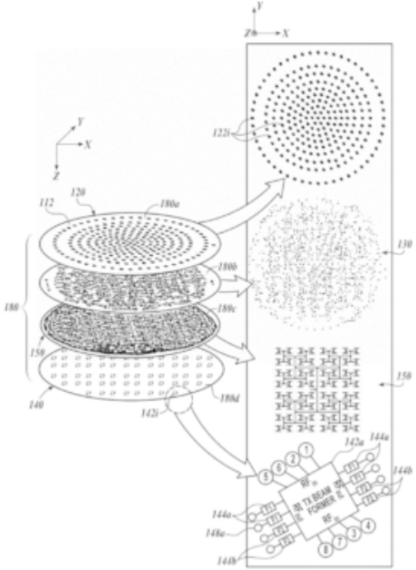
SES/Boeing mPower ... Sparse arrays becoming a reality



December 2022: Boeing delivers first two O3b m-POWER satellites to SES

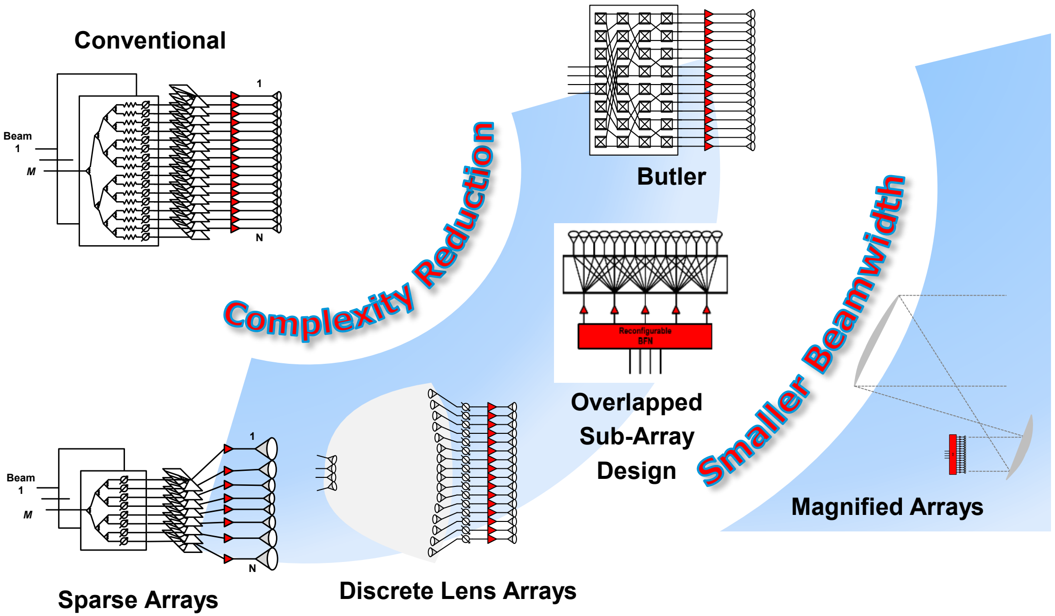
Industrial Applications of Sparse Arrays





Starlink Onboard and Terminal Antenna
Sparse and Polyominoes Subarrays

Multibeam Antennas/Beamforming



Hybrid Beamforming

It is desirable to generate multibeam beams to cover a given field of view with increased gain and isolation.

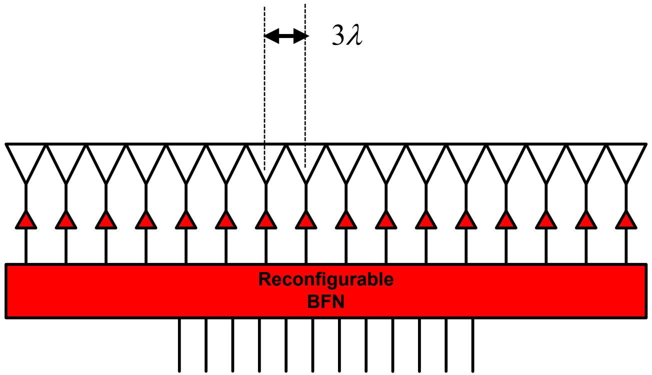
A fully reconfigurable beamforming network is impractical for many applications with high number of elements and/or beams.

Simpler solutions retaining sufficient (although not complete) flexibility are therefore necessary.

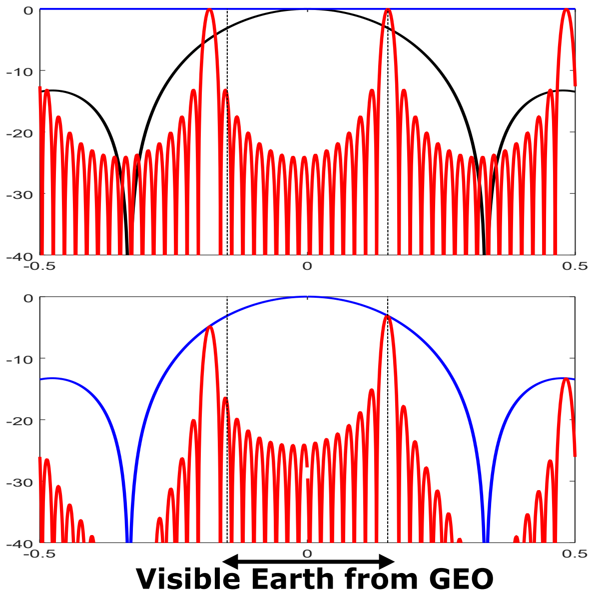
Solutions permitting to **increase the number of beams and radiating elements** are furthermore necessary.

P. Angeletti, G. Toso, D. Petrolati (ESA/PAT/705) "**A reconfigurable multibeam antenna system**" European Patent EP 654 544 A1, filing date: 13-11-2018.

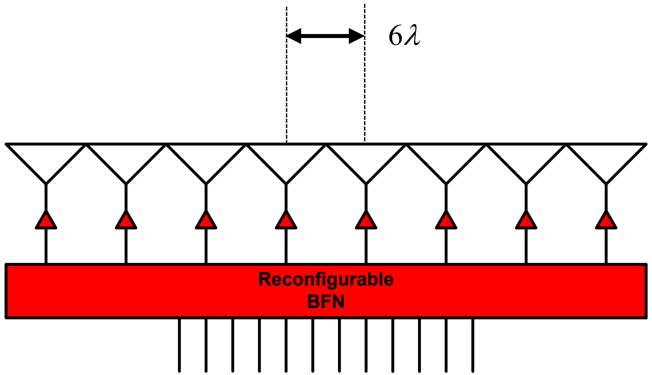
Prior-Art Design

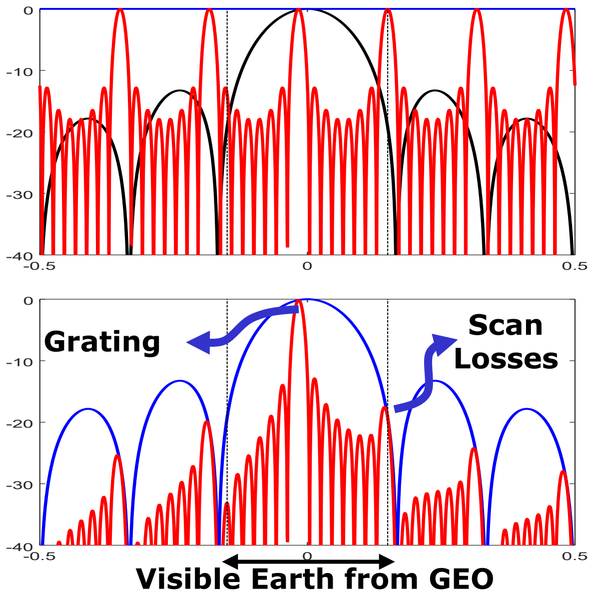


- **Number of BFN element ports is minimized maximizing element dimension with grating-lobes outside the Field-of-View**



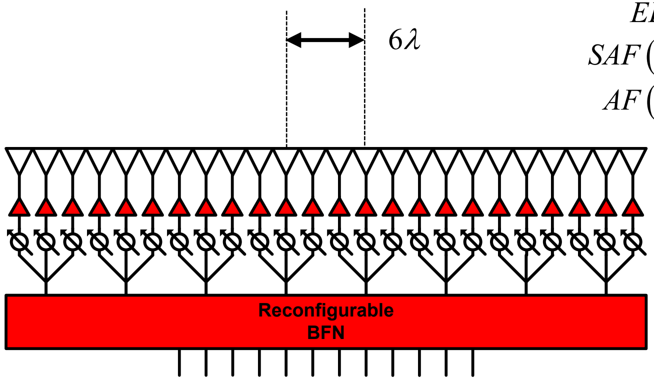
Desired Objective :
reduction of Number of Radiating Element Ports

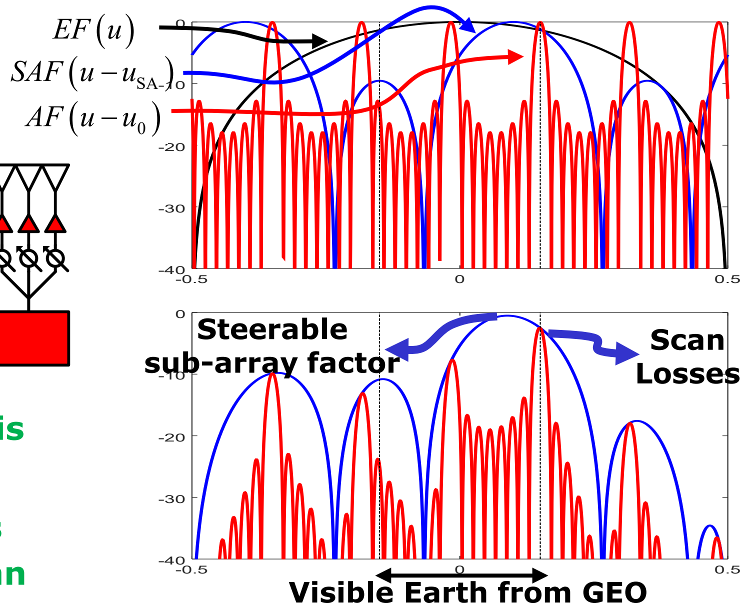




- **Number of BFN element ports is reduced**
- **Field-of-View is reduced and the scan losses increased.**
- **Grating-lobes appear in the Field-of View**

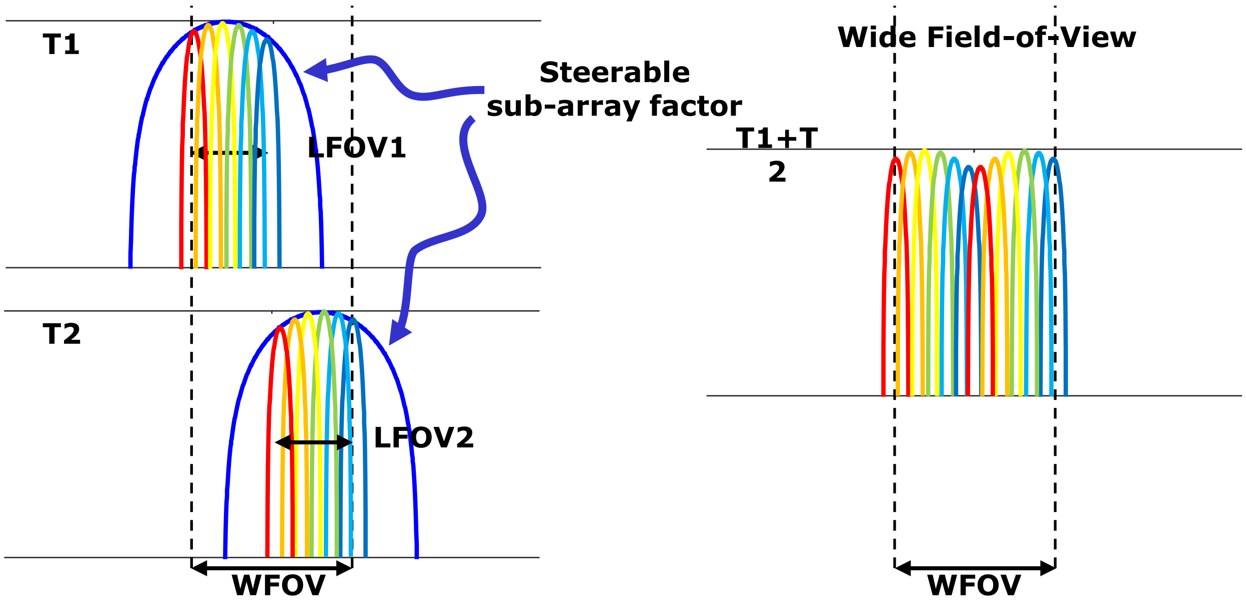
Proposed Approach : steerable Sub-Arrays





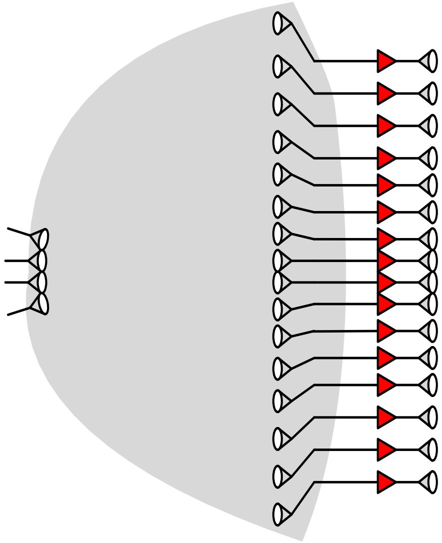
- Number of BFN element ports is reduced
- Instantaneous Field-of-View is reduced without additional scan losses.
- Controlled grating-lobes are kept outside the instantaneous Field-of View

Proposed Approach : steerable Sub-Arrays



Active Discrete Lens BFN/Antennas

Single Feed per Beam antenna based on Active Discrete Lens BFN



Extremely simplified BFN (1:1 connections)

Large Frequency Bandwidth (True Time Delay)

Multifocal Antenna ➔ large field of view

single main aperture for multi spot contiguous beams

Complexity marginally dependent on the number of beams;

2 polarizations (3D lens), **1 polarization** (2D lens)

No blockage

DRAWBACKS

accommodation

cooling

beams created in fixed directions

difficult to combine the Tx and Rx functionalities

Degrees of freedom

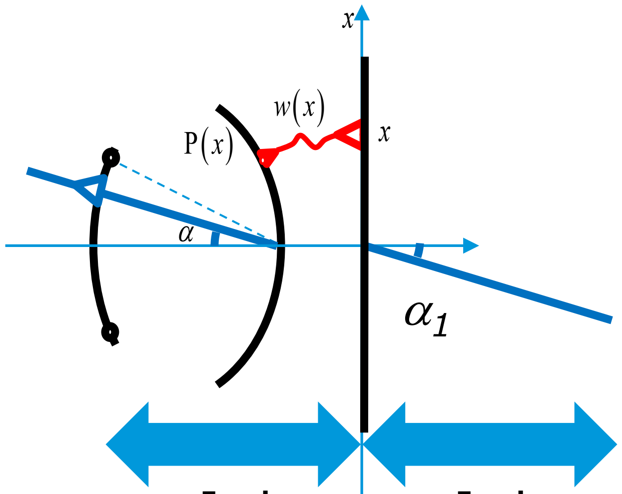
Metallic reflector: 1 degree of freedom (1 d.o.f)
Z=Z(x) or Z=Z(x,y)

Reflectarray or Transmitarray: 2 d.o.f
Z and Phase

2D Discrete Lenses: Xback, Zback, Phase, Zfront as a function of Xfront
➔ 4 d.o.f ➔ 4 max focal points

3D Discrete Lenses: Xback, Yback, Zback, Phase, Zfront as a function of Xfront, Yfront
➔ 5 d.o.f ➔ 5 max focal points

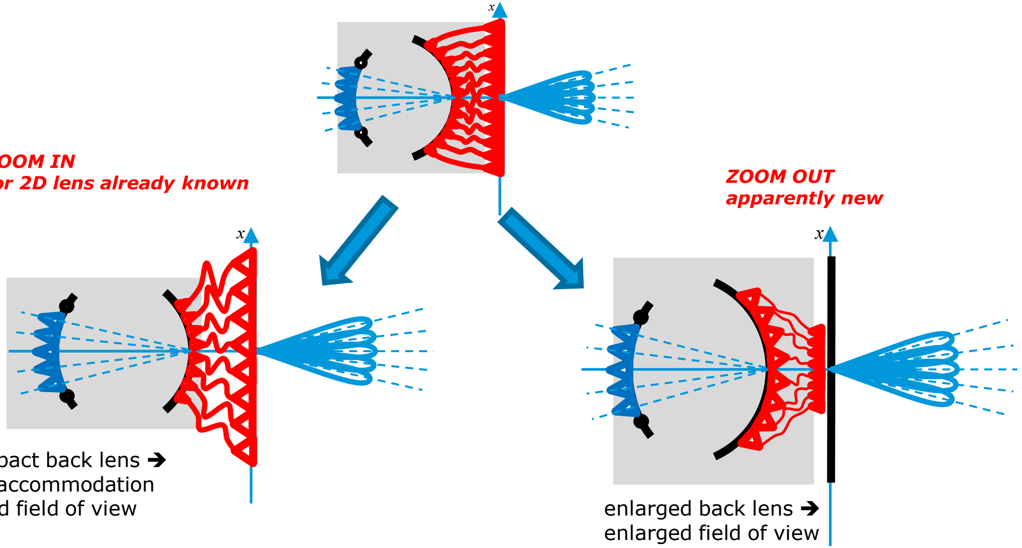
Lens Based Beamformers



≈ Fourier Transform

= Fourier Transform

ZOOM IN & OUT



ZOOM IN
for 2D lens already known

ZOOM OUT
apparently new

more compact back lens ➔
- easier accommodation
- reduced field of view

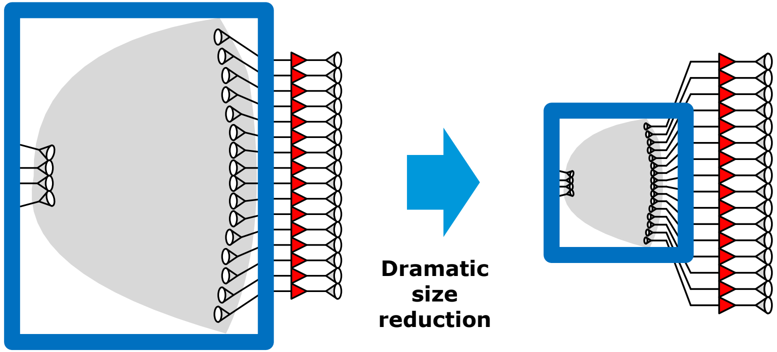
enlarged back lens ➔
enlarged field of view
Suitable for professional ground antennas

G. Toso, P. Angeletti, "Two-dimensional and three-dimensional discrete constrained lenses with minimised optical aberrations", International Patent Application No. PCT/EP2021/052202, 29 January 2021

ZOOM IN

Discrete Lens Classical Approach

Discrete Lens Innovative Approach

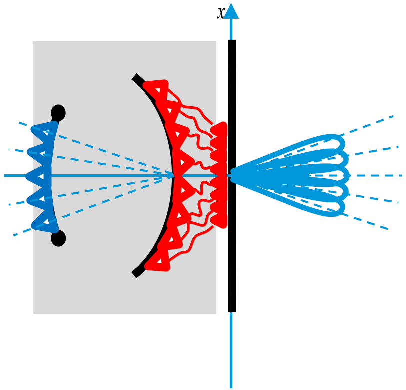


Lens' Back Array size comparable with DRA

Reduction of Lens`size and volume

G. Toso, P. Angeletti, "Two-dimensional and three-dimensional discrete constrained lenses with minimised optical aberrations", International Patent Application No. PCT/EP2021/052202, 29 January 2021

ZOOM OUT

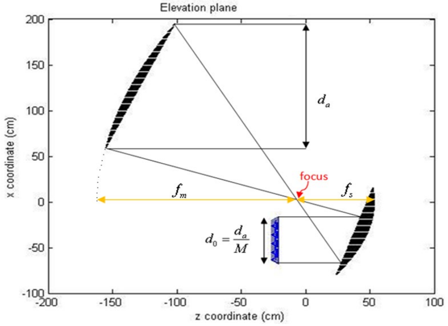


Active antennas have a larger field of view as compared to reflectors and do not need mechanisms. Easy to scan from boresight up to 30-40 degrees. Difficult to scan from boresight up to 70-90 degrees ➔ a BFN lens with the back 2-3 times larger allows to scan 2-3 times more !!!

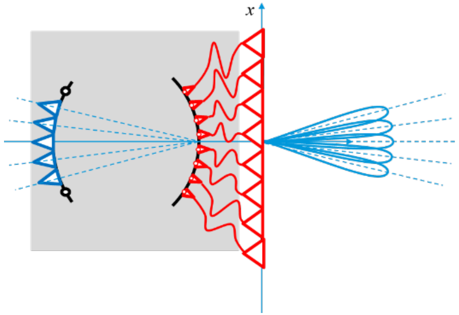
ZOOM-in property of Lenses equivalent to magnification properties in Reflector systems

Aperture Magnification

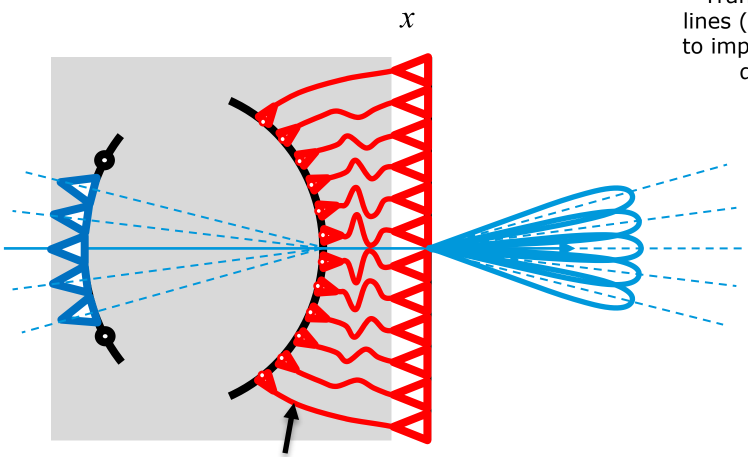
Reduced scanning



$$M = \frac{d_0}{d_a} = \frac{f_m}{f_s}$$

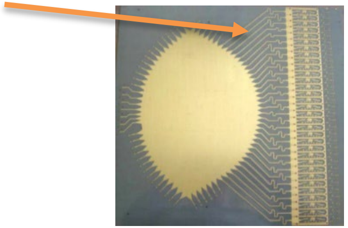


Lens Based Beamformers

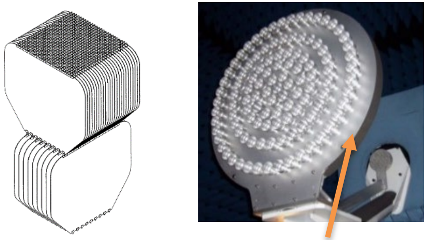


Transmission lines
to implement the
delays

Transmission
lines (microstrip)
to implement the
delays



2D

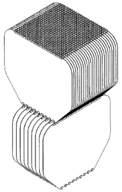


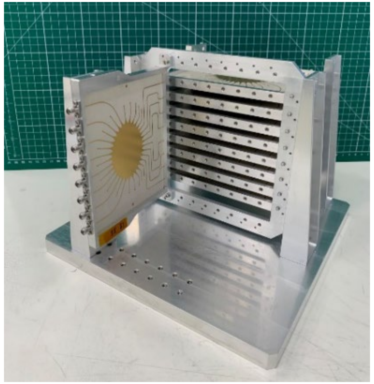
3D

Transmission lines (coaxial cables or
waveguides) to implement the delays

3D lenses: 2 possible architectures

cascade of 2D lenses
in rows & columns



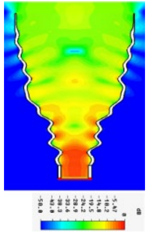


Courtesy of Airbus Italia

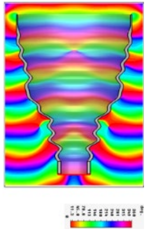
or

single 3D lens

US patent 2010/0207833 A1, Multibeam active discrete lens antenna, G. Toso, P. Angeletti, G. Ruggerini, G. Bellaveglia

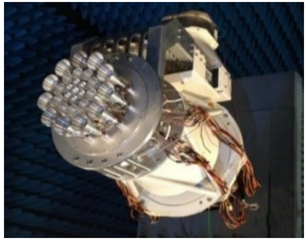


E-field amplitude

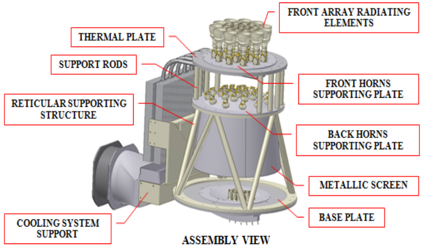


E-field phase

Breadboarding of Ka band Active Lenses

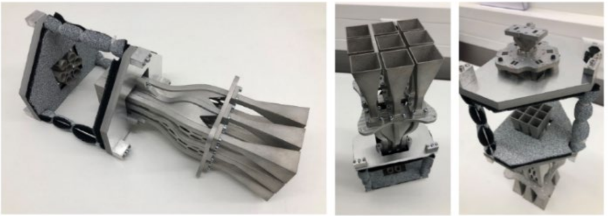


Active module with 2SSPAs



L-shaped Heat Pipes

Courtesy of Airbus Italia



Courtesy of SWISSto12

esa

Recent results on the synthesis of 2D and 3D constrained lens antennas

G. Toso, P. Angeletti, An Optimal Procedure for the Design of Discrete Constrained Lens Antennas with Minimized Optical Aberrations, Part I: Two-Dimensional Architectures, Electronics 2022, 11(3), 493; https://doi.org/10.3390/electronics11030493

G. Toso, P. Angeletti, An Optimal Procedure for the Design of Discrete Constrained Lens Antennas with Minimized Optical Aberrations. Part II: Three-Dimensional Multifocal Architectures, Electronics 2022, 11(3), 503; https://doi.org/10.3390/electronics11030503

G. Toso, P. Angeletti, An Optimal Procedure for the Design of Discrete Constrained Lens Antennas with Minimized Optical Aberrations. Part III: Three-Dimensional Architectures with an Extended Field of View, Electronics 2022, 11(3), no. 5: 687. https://doi.org/10.3390/electronics11050687

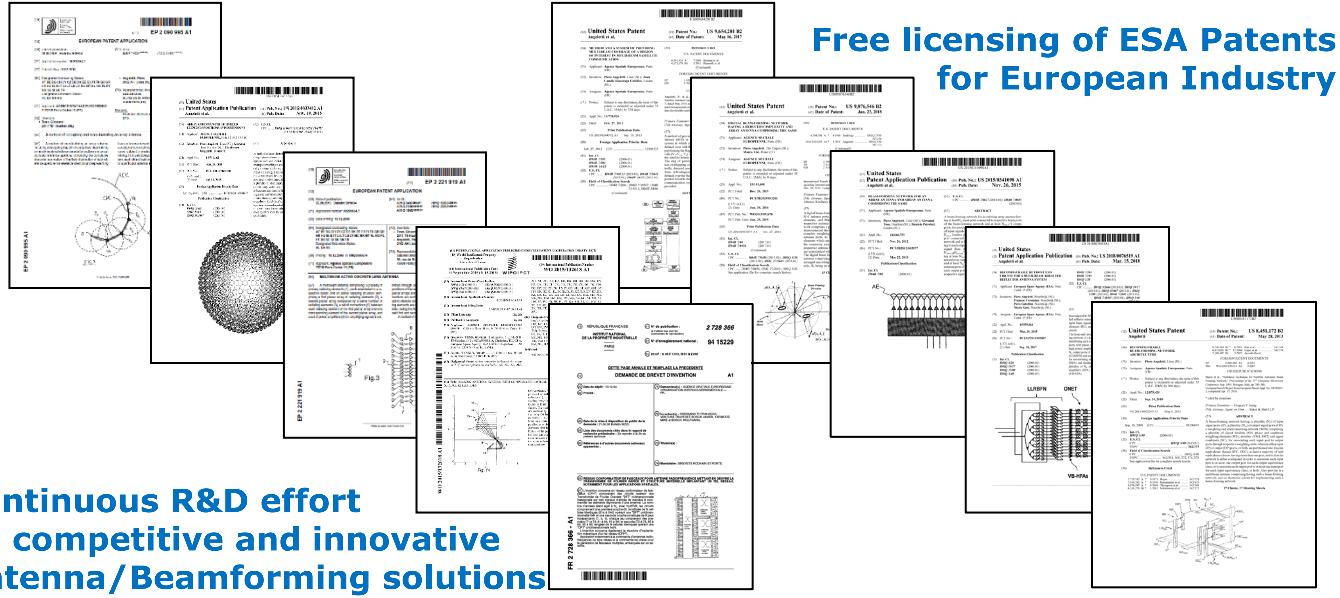
Our Course on Multibeam Antennas and Beamforming Networks

[1]	G. Toso, P. Angeletti,	Universidad Politecnica de Madrid (UPM), Madrid,	Jun. 2009	40
[2]	G. Toso, P. Angeletti,	IEEE APS, Chicago,	July 2012	12
[3]	P. Angeletti, G. Toso,	IEEE ICWITS 2012, Hawaii,	Nov. 2012	10
[4]	G. Toso, P. Angeletti,	EUCAP2013, Gotheborg,	2013	9
[5]	G. Toso, P. Angeletti,	University of Florence,	June 2013	45
[6]	P. Angeletti, G. Toso,	EUCAP2014, Den Haag,	2014	25
[7]	P. Angeletti, G. Toso, J.S. Williams,	EuMW 2014, Rome,	2014	55
[8]	G. Toso, P. Angeletti,	University of Trento,	May 2014	10
[9]	G. Toso, P. Angeletti,	EUCAP2015, Lisbon,	2015	23
[10]	P. Angeletti, G. Toso,	Universita` Politecnica delle Marche, Ancona,	June 2015	45
[11]	P. Angeletti, G. Toso,	EuMW 2015, Paris, France,	Sep. 2015	45
[12]	P. Angeletti, G. Toso,	IMS 2016, San Francisco,	May 2016	55
[13]	G. Toso, P. Angeletti,	EUCAP2016, Davos, Switzerland,	April 2016	15
[14]	G. Toso, P. Angeletti,	IEEE APS 2016, Puerto Rico,	June 2016	21
[15]	P. Angeletti, G. Toso,	European Microwave Week, London,	Oct. 2016	25
[16]	G. Toso, P. Angeletti,	EUCAP2017, Paris,	March 2017	12
[17]	G. Toso, P. Angeletti,	IEEE APS 2017, San Diego,	July 2017	27
[18]	P. Angeletti, G. Toso,	EuMW 2017, Nuremberg,	Oct. 2017	26
[19]	P. Angeletti , G. Toso,	ESA Internal University	Jan. 2018	25
[20]	G. Toso, P. Angeletti,	EUCAP 2018, London	April 2018	25
[21]	G. Toso, P. Angeletti,	EuMW 2018, Madrid	Sept. 2018	42
[22]	G. Toso, P. Angeletti,	EUCAP 2019, Krakow	Apr. 2019	22
[23]	P. Angeletti, G. Toso,	EuMW 2019, Paris	Oct. 2019	39
[24]	P. Angeletti, G. Toso,	APMC 2019, Singapore	Dec. 2019	45
[25]	P. Angeletti, G. Toso,	ESA Internal University	Jan. 2020	19
[26]	P. Angeletti, G. Toso	EUCAP 2020, online	Mar. 2020	21
[27]	G. Toso, P. Angeletti	IEEE APS 2020, online	Jul. 2020	31
[28]	G. Toso, P. Angeletti	EUCAP2021, online	Mar. 2021	40
[29]	G. Toso, P. Angeletti	University of Florence, online	Mar. 2021	12
[30]	G. Toso, P. Angeletti	ISAW, online	Dec. 2021	150
[31]	G. Toso, P. Angeletti	INCAP, online	2021	23
[32]	G. Toso, P. Angeletti	EUCAP2022, online	Apr. 2022	28
[33]	G. Toso, P. Angeletti	EUCAP2023	Mar. 2023	15
[34]	G. Toso, P. Angeletti	ESoA Course on Active Antennas	Sept. 2023	46
[35]	P. Angeletti, G. Toso	ESA Internal Course Multibeam Antennas and BFN	Dec. 2023	15

> 1100

ESA R&D on Active Antennas / Beamforming

Free licensing of ESA Patents for European Industry



Continuous R&D effort on competitive and innovative Antenna/Beamforming solutions

ESA ESoA Course on Antennas for Satellite Applications 2016-……-2024

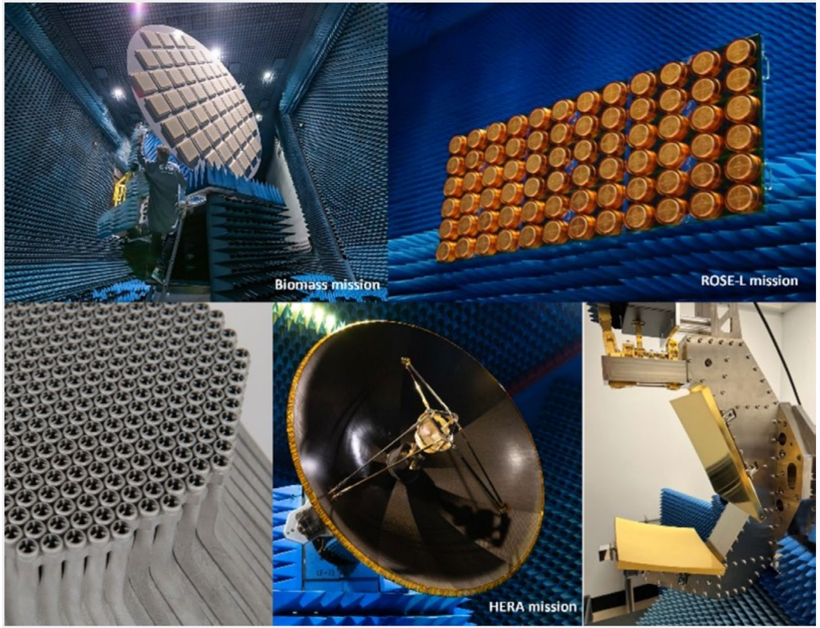
ESA ESoA Course on ANTENNAS for SPACE APPLICATIONS organised by G. Toso, E. Gandini

10th edition 27-31 May 2024, ESA-ESTEC, The Netherlands

	Day1 May 27th 2024		**Day 2 May 28th 2024**		**Day 3 May 29th 2024**		**Day 4 May 30th 2024**		**Day 5 May 31st 2024**
9:00	1. Introducing ESA ESTEC and the Course (G. Toso, E. Gandini, ESA-ESTEC)	**9:00**	6. Earth observation instrument antennas (L. Salghetti Drioli, ESA-ESTEC)	**9:00**	11. Navigation Antennas (D. Trenta, ESA-ESTEC)	**9:00**	15. User Segment Antennas (E. Gandini, ESA-ESTEC)	**9:00**	21. Mechanical & Thermal Analysis of satellite antennas (G. Rodrigues, A. Ihle, ESA-ESTEC)
9:40	2. Basic of Antennas, frequencies, orbits (E. Gandini, ESA-ESTEC)	**10:40**	Coffee break	**10:40**	Coffee break	**10:50**	Coffee break	**10:15**	Coffee break
	with Coffee break in the middle	**11:00**	7. High Frequency Earth Observation (E. Saenz, ESA-ESTEC)	**11:00**	12. Ground Station Antennas (P.M. Besso, ESA-ESOC)	**11:10**	16. Additive Manufacturing (M. van der Vorst, ESA-ESTEC)	**10:30**	22. Mechanical & Thermal Test of satellite antennas (G. Rodrigues, A. Ihle, ESA-ESTEC)
13:00	Lunch	**12:00**	8. Science Antennas and Instruments (E. Saenz, ESA-ESTEC)	**13:00**	Lunch	**12:00**	17. Large Reflector Antennas (P. Moseley, ESA-ESTEC)	**11:30**	23. ESA Antenna Measurements Facilities, (I. Barbary, E. Van Der Houwen, A. Riccardi, ESA-ESTEC)
		13:00	Lunch			**13:00**	Lunch	**13:00**	Lunch
					Lunch Break				
14:00	3. Feed systems and radiators (H. Nematollahi, ESA-ESTEC)	**14:00**	9. RF Antenna Measurements (L. Rolo, ESA-ESTEC)	**14:00**	13. Multibeam Antennas Architectures, part II, Overlapped Subarrays and Discrete Lenses (G. Toso, ESA-ESTEC)	**14:00**	18. Service Antennas (V. Iza, ESA-ESTEC)	**14:00**	24. Future Trends and Research Lines (P. de Maagt, ESA-ESTEC)
15:00	Coffee break	**15:15**	Coffee break	**16:20**	Coffee break	**15:00**	19. Low Frequency Antennas (B. Byrne, ESA-ESTEC)	**15:00**	Closure of the Course.
15:20	4. Reflector Antennas (S. Mercader-Pellicer, ESA-ESTEC)	**15:35**	10. Multibeam Antennas Architectures, part I, Single Feed per Beam, Multi Feed per Beam, Active Arrays (G. Toso, ESA-ESTEC)	**16:40**	14. Beam Forming Networks and Digital Beam Forming (P. Angeletti, ESA-ESTEC)	**16:00**	Coffee break		Final Questionnaire: online homework
16:20	5. Overview of satellite payload architectures and needs (S. D'Addio, ESA-ESTEC)			**18:40**	Social Dinner	**16:20**	20. New Space Antennas (C. Tienda, ESA-ESTEC)		
18:00	Welcome cocktail								

ESA ESoA Course on ACTIVE ANTENNAS, organised by G. Toso, P. Angelett
2021- 2023 -2025 ….

Day1 September 11th 2023		Day 2 September 12th 2023		Day 3 September 13th 2023		Day 4 September 14th 2023		Day 5 September 15th 2023	
9:15	1. Introducing ESA ESTEC, Active Antennas, Course Organization (Giovanni Toso, Piero Angeletti, ESA-ESTEC)	9:15	6. MMIC for Active Antennas, (Frank van Vliet, TNO)	9:15	11. Broadband Arrays (Daniele Cavallo, TU Delft)	9:15	16. Active antennas for LEO Telecom Satellites and Constellations (Maria Garcia Vigueras, INSA Rennes, Esteban Menargues, Swissto12)	9:15	21. Design of Active Antennas for Receive and Interference Localization (Antonio Montesano, Airbus Spain) [in remote]
9:45	2. Payload architectures and payloads needs for Active Antennas (Salvatore D'Addio, ESA-ESTEC)	10:45	Coffee break	10:45	Coffee break	10:45	Coffee break	10:45	Coffee break
11:15	Coffee break	11:05	7. Beam Forming Networks and Digital Beam Forming (Piero Angeletti, Giovanni Toso, ESA-ESTEC)	11:05	12.TR modules (Iain Davies, ESA-ESTEC)	11:05	17. Through-life Verification and Calibration of Active Antennas (Marco Lisi, Salvatore D'Addio, Piero Angeletti, ESA-ESTEC)	11:05	22. Active Antennas for Gateways (Ed Totten, Celestia UK) [in remote]
11:35	3. Antenna Element Technology and Modelling Methods, (Stefania Monni, TNO)			12:05	13. Technologies for Transmit Front-Ends (Vaclav Valenta, ESA-ESTEC)	12:30	18. Active Phased Arrays for Ground Terminals (Maria Carolina Vigano', Viasat Switzerland)		
13:00 – 14:00	Lunch Break	13:00 – 13:45	Lunch Break	13:00 – 14:00	Lunch Break	13:30 – 14:30	Lunch Break	12:20 – 13:20	Lunch Break
14:00	4. Active Antennas Architectures, part I, Irregular Arrays and Magnified Arrays (Giovanni Toso, Piero Angeletti, ESA-ESTEC)	13:45	8 Active Antennas System Engineering in TAS-I: a focus on Noise Temperature (Giovanni Gasparro. Active Antennas Systems, TAS-I)	14:00	14. Convex Optimization and Applications to Active Antenna Design (Murat Veysoglu, Amazon)	14:30	19. Active Antennas for Telecom Satellites (Glyn Thomas, Airbus UK	13:20	23. Active Antennas Architectures, part II, Overlapped Subarrays and Discrete Lenses (Giovanni Toso, Piero Angeletti, ESA-ESTEC)
15:30	Coffee break	15:15	Coffee break	16:15	Coffee break	16:15	Coffee break	15:00	24. Final Questionnaire
15:50	5. Millimeter-wave and sub-TeraHz technology and research trends for 5G and 6G Antennas, an industrial view (Renato Lombardi, Roberto Flamini, Huawei)	15:30	9. Overview of Adaptive Array Processing Techniques for Radars, History, Theoretical Foundations and Applications (Alfonso Farina, Selex ES (retired))	16:35	15. Thermal Aspects (Emmanuel Caplanne, ESA-ESTEC) OK	16:35	20. Satellite antenna for telecom with mobiles from GEO to LEO (Benoit Lejay, TAS-France) [in remote]	17:30	Closure of the Course.
17:20 – 20:30	Welcome to ESA ESTEC, Robert Willemsen	17:00 – 18:20	10. Elena Saenz ESA Antenna Measurements Facilities	17:45 – 22:30	Social Dinner				



42nd ESA Antenna Workshop

11 – 15 November 2024 | ESA-ESTEC | The Netherlands

Antenna Technologies for Future Space Missions

esa

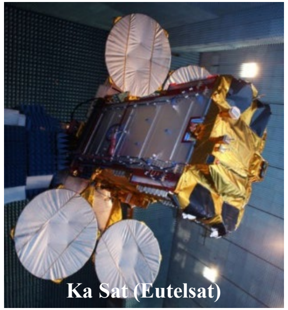
Home Scientific Content Abstract Submission Calendar of Events Registration Sponsors/Exhibitors Venue Committees Contact

The Antenna and Sub-Millimetre Waves Section of the Radio Frequency Payloads and Technology Division of the Directorate of Technology, Engineering and Quality (D/TEC) of the European Space Agency announces the 42nd ESA Antenna Workshop.

The Workshop will be held from the 11th to the 15th of November 2024 at the European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands.

The workshop will include sessions focused on technologies, techniques and applications with the intent to foster the exchange of knowledge and ideas between experts. A dedicated area will be available for poster presentations. A visit to the ESTEC Antenna Test Facilities will be organised*.

Multibeam Antennas



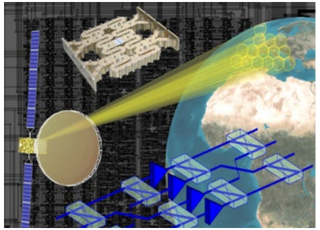
Ka Sat (Eutelsat)

Ka Active Lens
(Space Engineering)

- Combine Electrical, Thermal, Mechanical Expertise;
- Combine Antennas, Microwaves, Optics, ..
- Depending on the application Reflectors, Arrays, Lenses, … may be used;
- The design problem to solve seems so easy …. but can keep one busy for years ….

Inmarsat 5

Anik F2 (Boeing)



Multibeam Antennas

Combine the most Advanced Technologies & Design Procedures ….

… but there is always room for ***Deterministic Design Solutions***
possibly supported by ***Analytical Equations***


Would you like to know more?
giovanni.toso@esa.int