ENABLING TERMINAL TESTING FOR NEW SPACE

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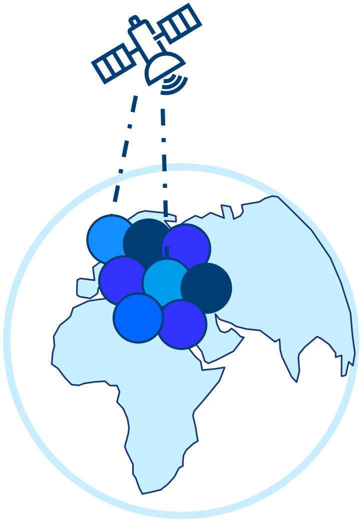
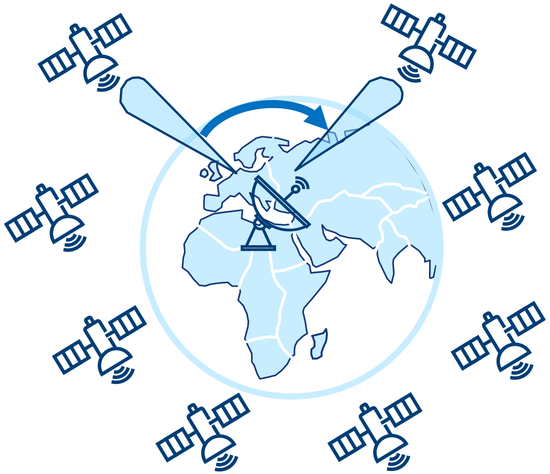
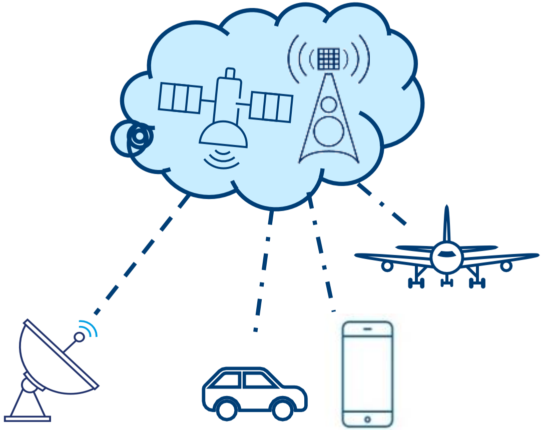
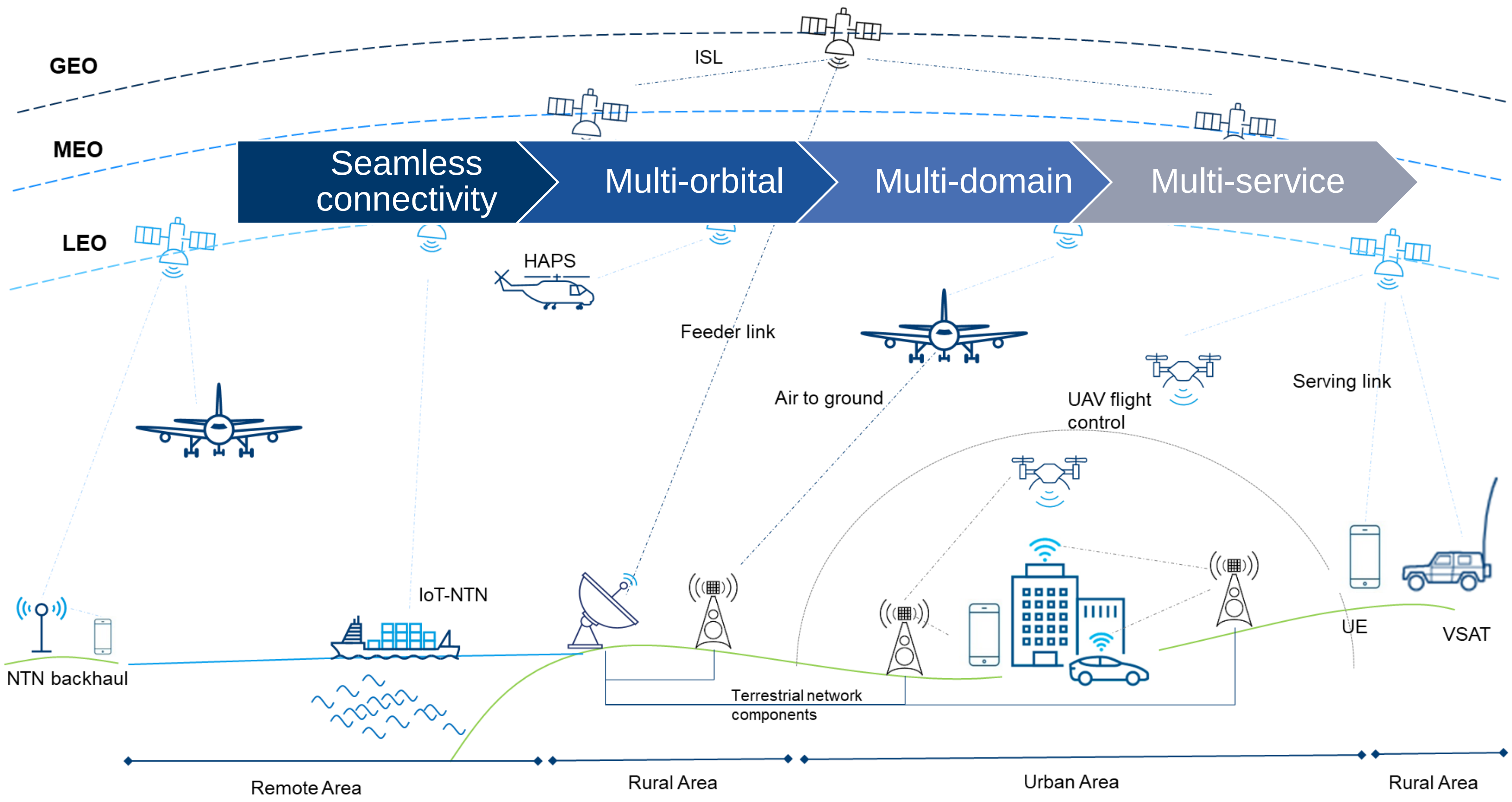
ROHDE&SCHWARZ

Make ideas real

TRENDS IN THE SATELLITE INDUSTRY

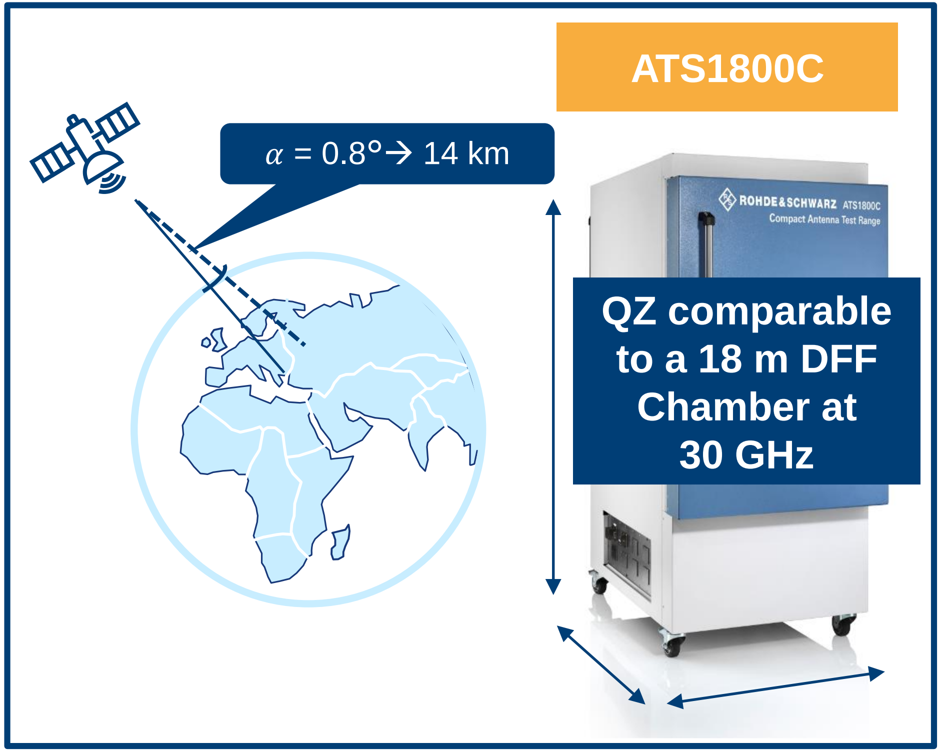
HTS / VHTS	Mega-constellations / New Space	Non-terrestrial NWs in terrestrial NWs
		

USER TERMINALS ARE KEY TO ESTABLISH LINKS

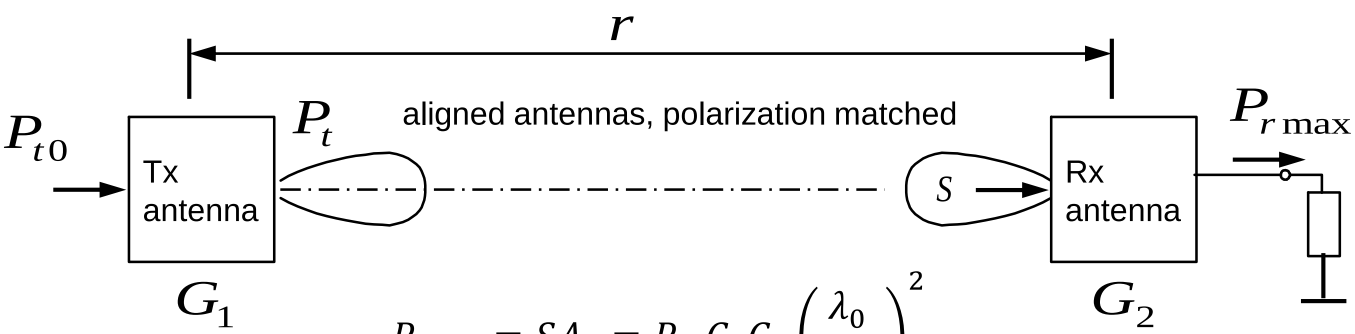


CHARACTERISATION OF ANTENNAS UNDER CONSTANT CONDITIONS

- ❑ Independent of environmental conditions
- ► High reproducibility of accurate measurement results, long-term stability
- ► Ensuring confidentiality
- ► R&D: Practical verification of simulation results
- ► Antenna diagnostics
- ► 3GPP compliance criteria



RADIO LINK UNDER FAR FIELD CONDITIONS



$$P_{rmax} = SA_e = P_{t0}G_1G_2\left(\frac{\lambda_0}{4\pi r}\right)^2$$

Radio Link Attenuation

$$\frac{a}{dB} = -10\log_{10}\frac{P_{rmax}}{P_{t0}} = 20\log_{10}\left(\frac{4\pi r}{\lambda_0}\right) - 10\log_{10}G_1 - 10\log_{10}G_2$$

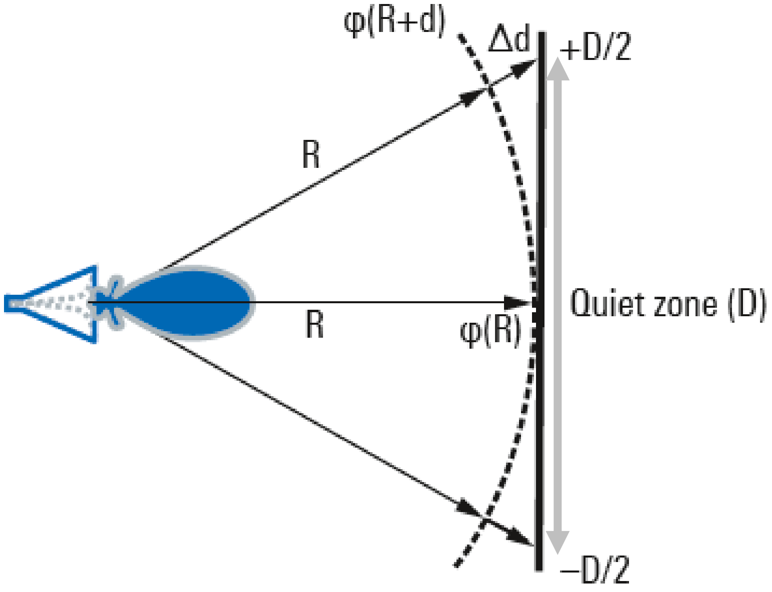
For antenna with $D > \frac{\lambda}{2}$, the rule of thumb is $R \geq \frac{2D^2}{\lambda}$ for far field conditions but the maximum phase error is still 22.5°.

$D = 0.6$ m
$f_{max} = 30$ GHz
→ FF Distance $\frac{2D^2}{\lambda} = 72$ m

→ a = - 100 dB

WHAT IS THE QUIET ZONE?

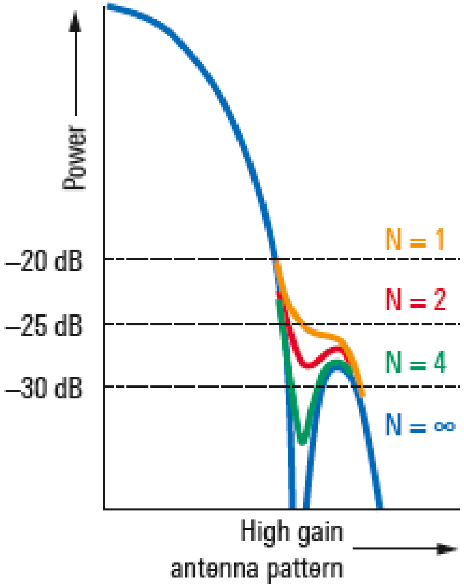
Definition of Fraunhofer distance



Quiet zone phase deviation and magnitude error

$$R_{FFmin} = \frac{ND^2}{\lambda}$$

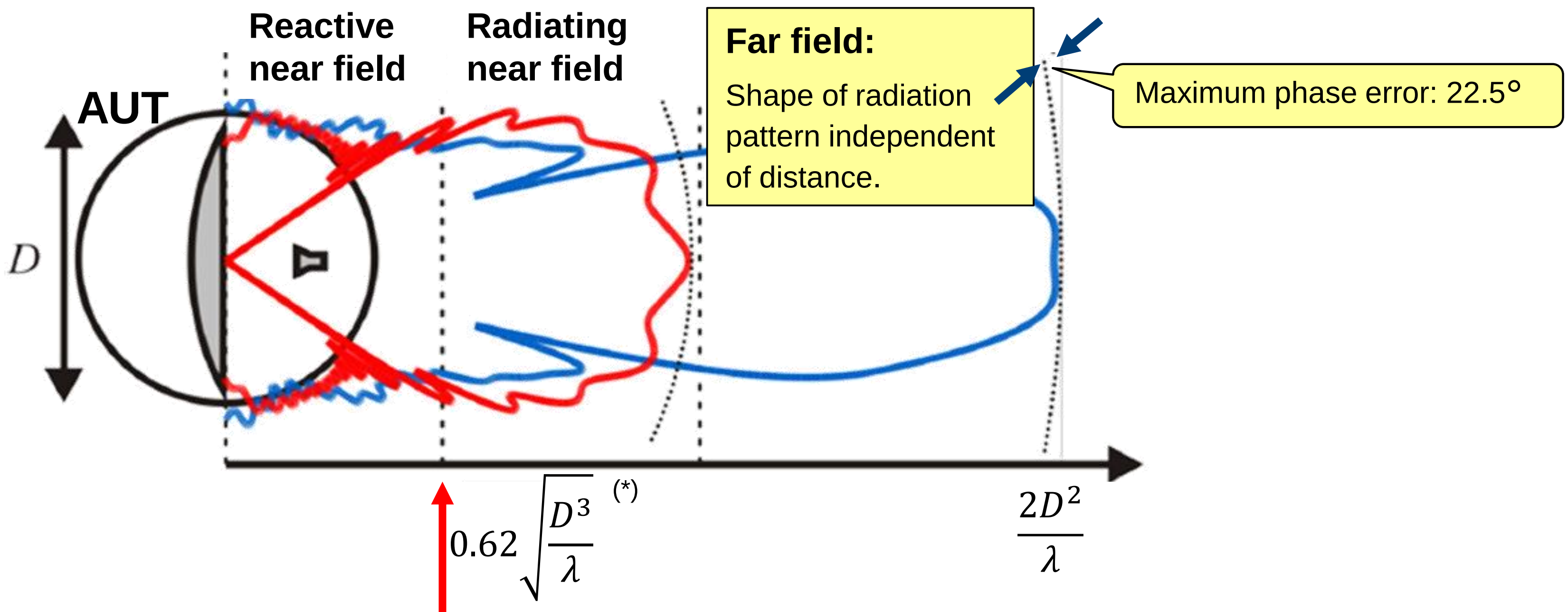
R_{FFmin} (N)	Phase deviation (φ)
D^2/λ	45°
$2D^2/\lambda$	22.5°
$4D^2/\lambda$	11.2°
$8D^2/\lambda$	5.6°



IEEE Standard Test Procedures for Antennas

The Fraunhofer distance presents the best compromise between a compact test setup, acceptable phase deviation and measurable null

ANTENNA FIELD ZONES



near-field measurements

Distance from antenna under test (AUT)

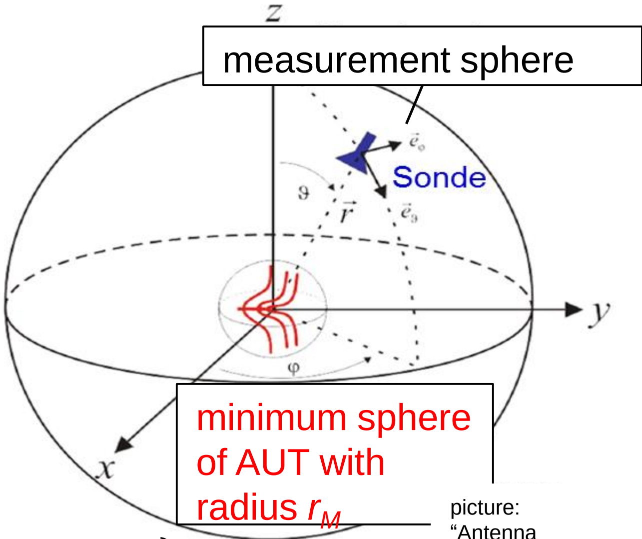
Image source: TU Munich

* = formula commonly taken for radiators with D > $\frac{\lambda}{2}$

NEAR-FIELD DATA: EXPANSION IN SPHERICAL MODES

- Electric field by a superposition of spherical waves.
- $Q_{smn}^{(c)}$ = spherical modes

$$\boldsymbol{E}(\varphi,\vartheta,r) = k\sqrt{Z_{F0}}\sum_{c=3}^{4}\sum_{s=1}^{2}\sum_{n=1}^{N}\sum_{m=-n}^{n} Q_{smn}^{(c)}\boldsymbol{F}_{smn}^{(c)}(\varphi,\vartheta,r)$$



picture: "Antenna Measurements", HFT, TU München

AUT fields in coordinate system of the probe :

$$\boldsymbol{E_t}(\varphi,\vartheta,r) = k\sqrt{Z_{F0}}\sum_{\substack{smn\\ \sigma\mu\nu}} a_0\, T_{smn} e^{jm\varphi_0} d_{\mu m}^{n}(\vartheta_0)\, e^{j\mu\chi_0} C_{\sigma\mu\nu}^{sn(3)}(kA)\frac{1}{2}\left\{\boldsymbol{F}_{\sigma\mu\nu}^{(3)} + \boldsymbol{F}_{\sigma\mu\nu}^{(4)}\right\}$$

Spherical transmission equation with introduction of probe via scattering matrix approach:

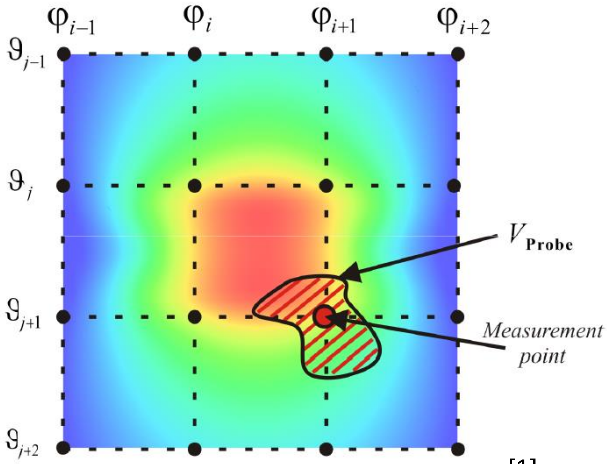
$$b_0'(\varphi,\vartheta,r,\chi) = \frac{a_0}{2}\sum_{\substack{smn\\ \sigma\mu\nu}} T_{smn} e^{jm\varphi_0} d_{\mu m}^{n}(\vartheta_0)\, e^{j\mu\chi_0} C_{\sigma\mu\nu}^{sn(3)}(kr) R_{\sigma\mu\nu}^{p}$$

s = 1: TE modes, s =2: TM modes, a_0: AUT input signal, T_{smn}: AUT spherical wave transmitting function

PROBES

Real field probe

- ❑ Finite geometrical extent
- ❑ Receiving characteristic
- ❑ Probe integrates field around measurement point.



[1]

Measurement of electric near-field and probe output voltage at discrete points

➢ Probe output voltage is obtained by appropriately weighting the electric field strength or transmitted mode from the AUT, respectively.

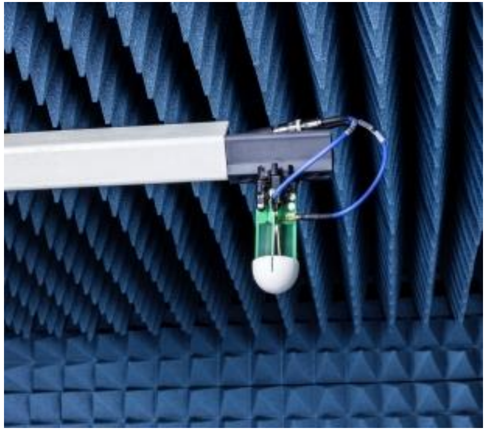
[1] Lecture: Antenna Measurements, C. Schmidt, Lehrstuhl für Hochfrequenztechnik, TU München

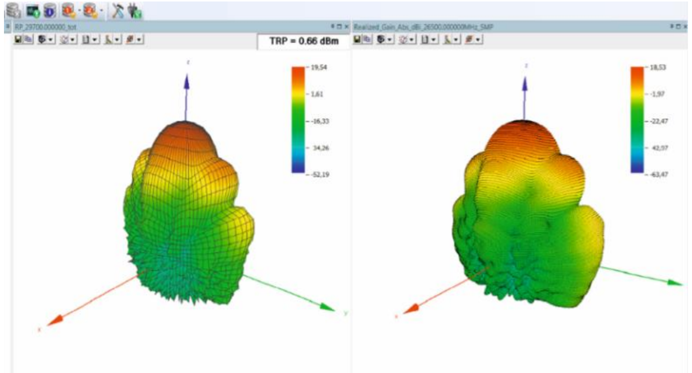
THE R&S®AMS32 SOFTWARE

In the AMS32, two NF2FF algorithms are implemented:

- ❑ The expansion in spherical modes
- ❑ The equivalent current principle.

► Broadband measurement probe by integrated full probe correction.



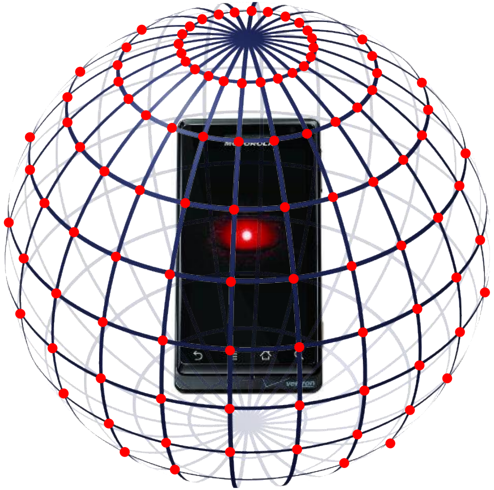


Measurement Antenna
Patented dual-polarized Vivaldi probe
Minimal radar cross section
Wide frequency range: 4 – 87 GHz

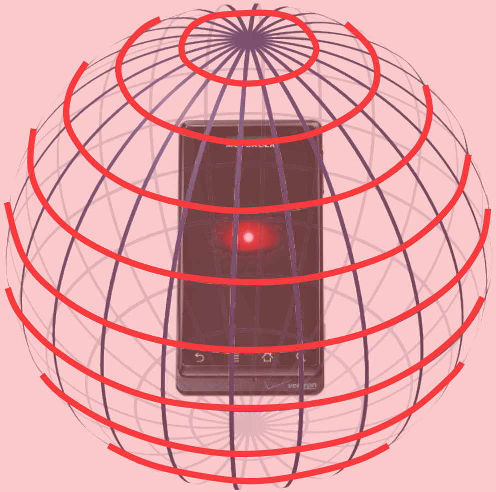
CTIA TRP MEASUREMENT OPTIONS AND TEST TIMES

Not CTIA compliant

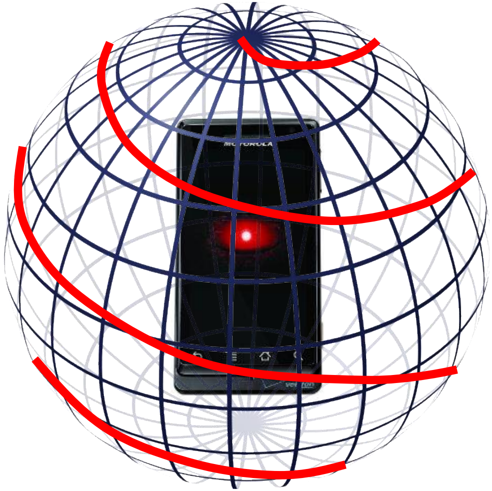
Step-Step (~6 min/ch)



Step-Swept (~2 min/ch)



Spiral Scan (~1.5 min/ch)

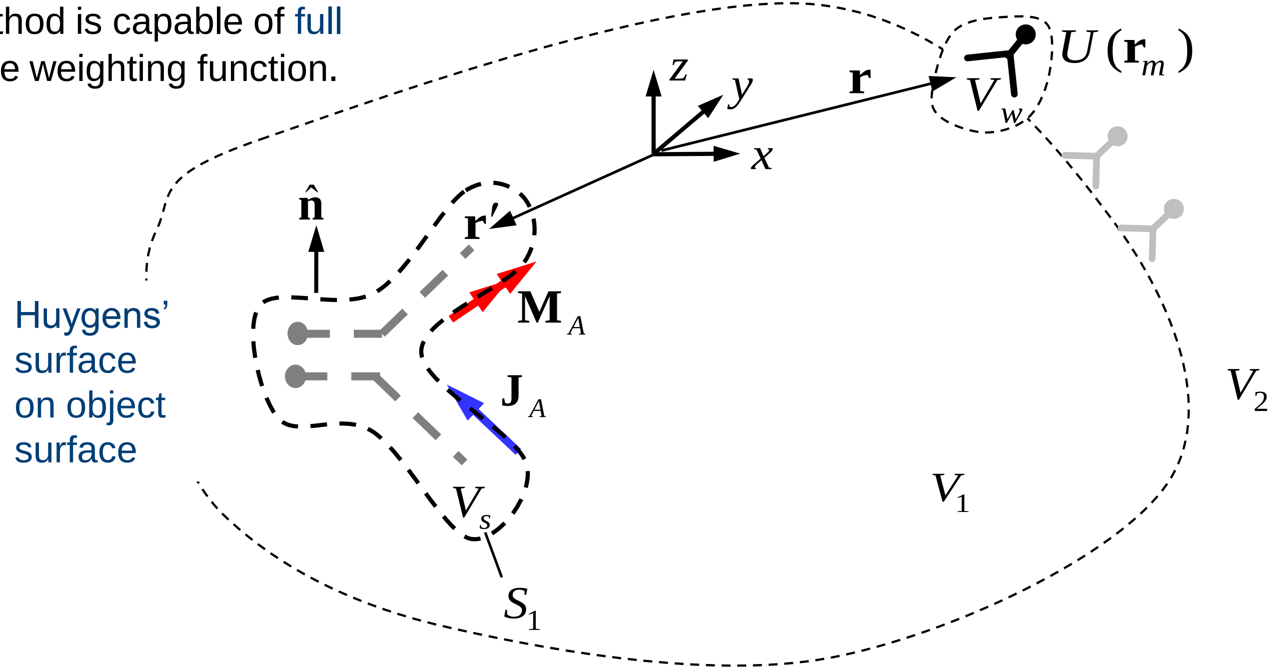


Refer to Annex B 3.1.2 of CTIA OTA -Testplan for details on spiral scan

EQUIVALENT CURRENT PRINCIPLE

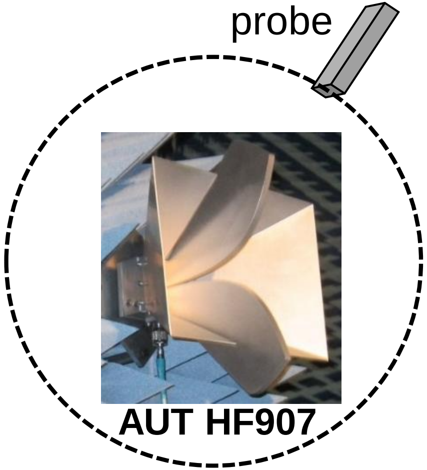
$$U(\mathbf{r}_m) = \iiint_{Vw} \mathbf{w}(\mathbf{r} - \mathbf{r}_m) \cdot \iiint_{V_s} [\overline{\mathbf{G}}_E^J(\mathbf{r}, \mathbf{r}') \cdot \mathbf{J}(\mathbf{r}') + \overline{\mathbf{G}}_E^M(\mathbf{r}, \mathbf{r}') \cdot \mathbf{M}(\mathbf{r}')] \, dv' dv$$

- Inverse equivalent current method is capable of full probe correction by appropriate weighting function.



ANTENNA DIAGNOSTICS

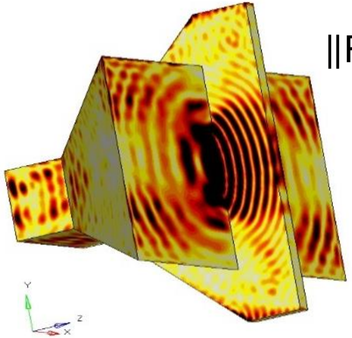
► By the inverse equivalent current principle:



1. Near-field measurement

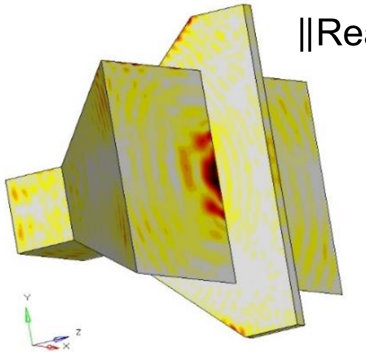
2. Choice of representing surface

$\|\mathrm{Real}\{\boldsymbol{J}_A\}\|$

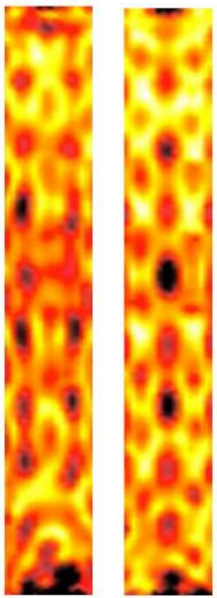


3. Reconstructed equivalent surface current densities

$\|\mathrm{Real}\{\boldsymbol{M}_A\}\|$



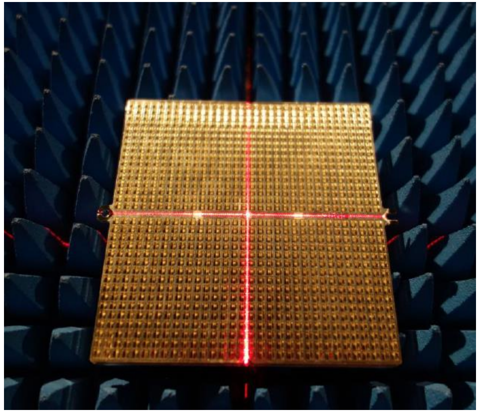
$|\boldsymbol{J}_A|$ $|\boldsymbol{M}_A|$

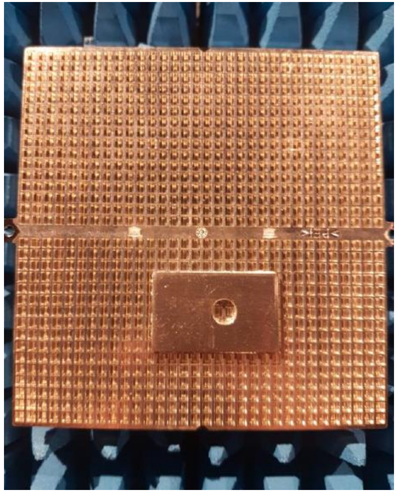


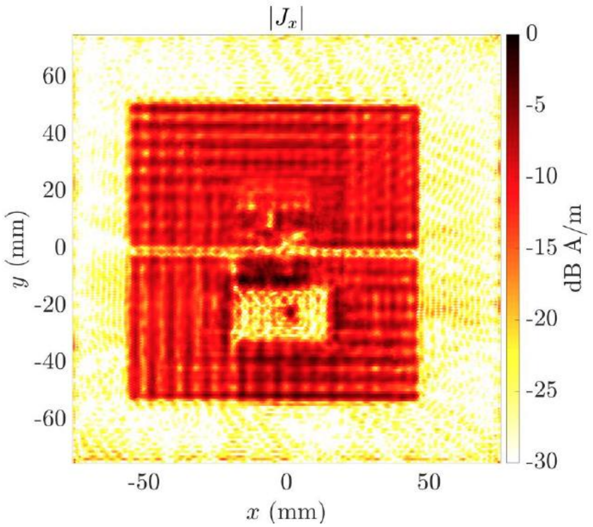
Array antennas

ANTENNA DIAGNOSTICS

- Ideal for the identification of erroneous elements in antenna arrays by the equivalent current principle

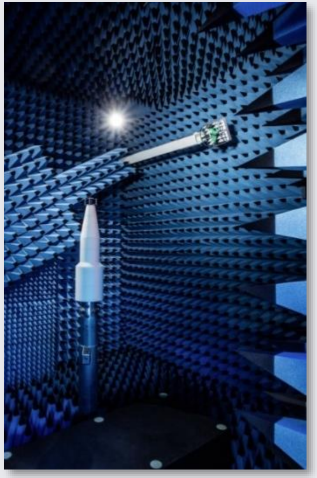


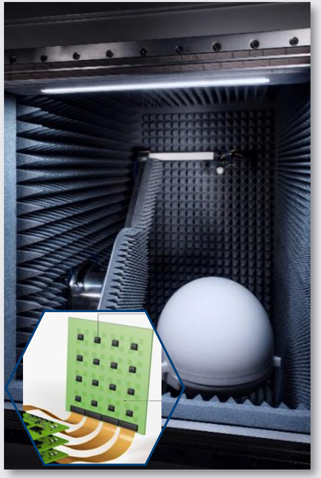


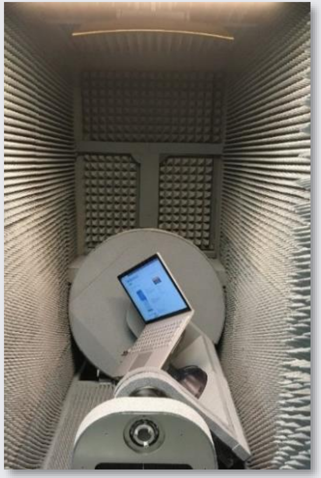


G. F. Hamberger et al., „Near-field techniques for millimeter-wave antenna array calibration,“ AMTA, Oct. 2019.

OTA RANGES – mmWAVE CAPABLE SOLUTIONS







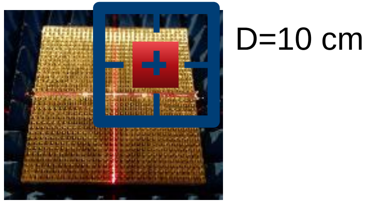
The R&S®WPTC	The R&S®ATS1000	The R&S®ATS1800C	The R&S®ATS800B/R
R&D, antenna measurements	Antenna AiP + chip tests Thermal testing -40°C-85°C	R&D	R&D
DFF / NF	DFF / NF	CATR	CATR
0.4 - 90 GHz	18 - 87 GHz	77 GHz and 79 GHz	77 GHz and 79 GHz
3D conical cut	3D conical cut	3D great circle	

For passive and active antenna testing

Rohde & Schwarz devices in third-party solutions available! Contact Rohde & Schwarz!

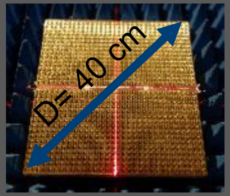
DISTANCE REDUCTION REQUIRES KNOWLEDGE OF ANTENNA LOCATION AND SUB-ARRAY TESTING

Quiet zone size (white box)

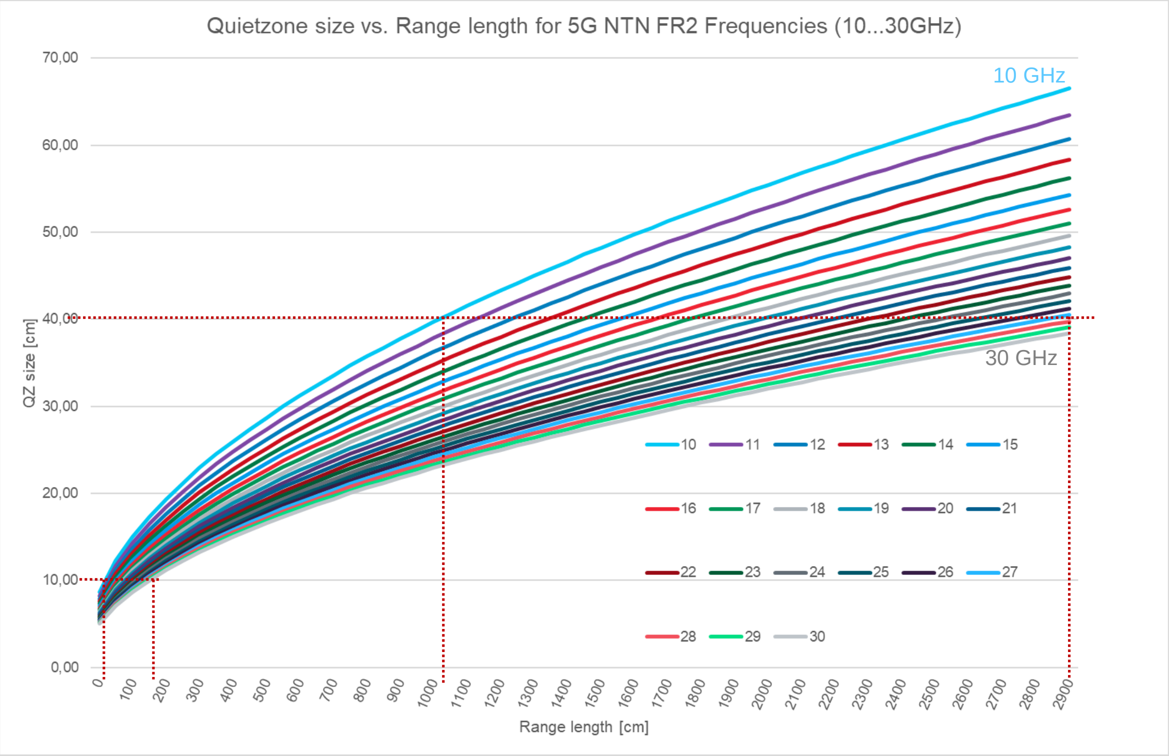


Chamber size < 3 m

Quiet zone size (black box)

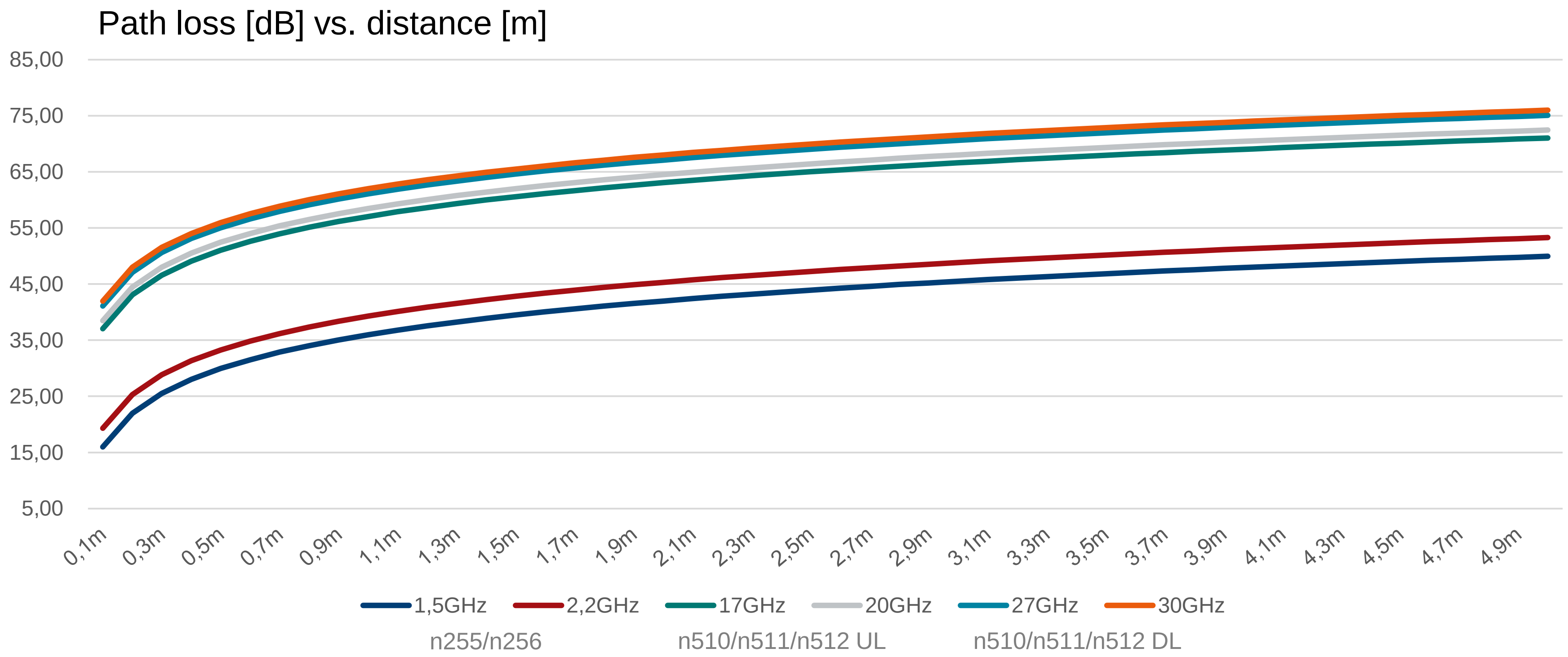


Chamber size ~ 15 m…35 m



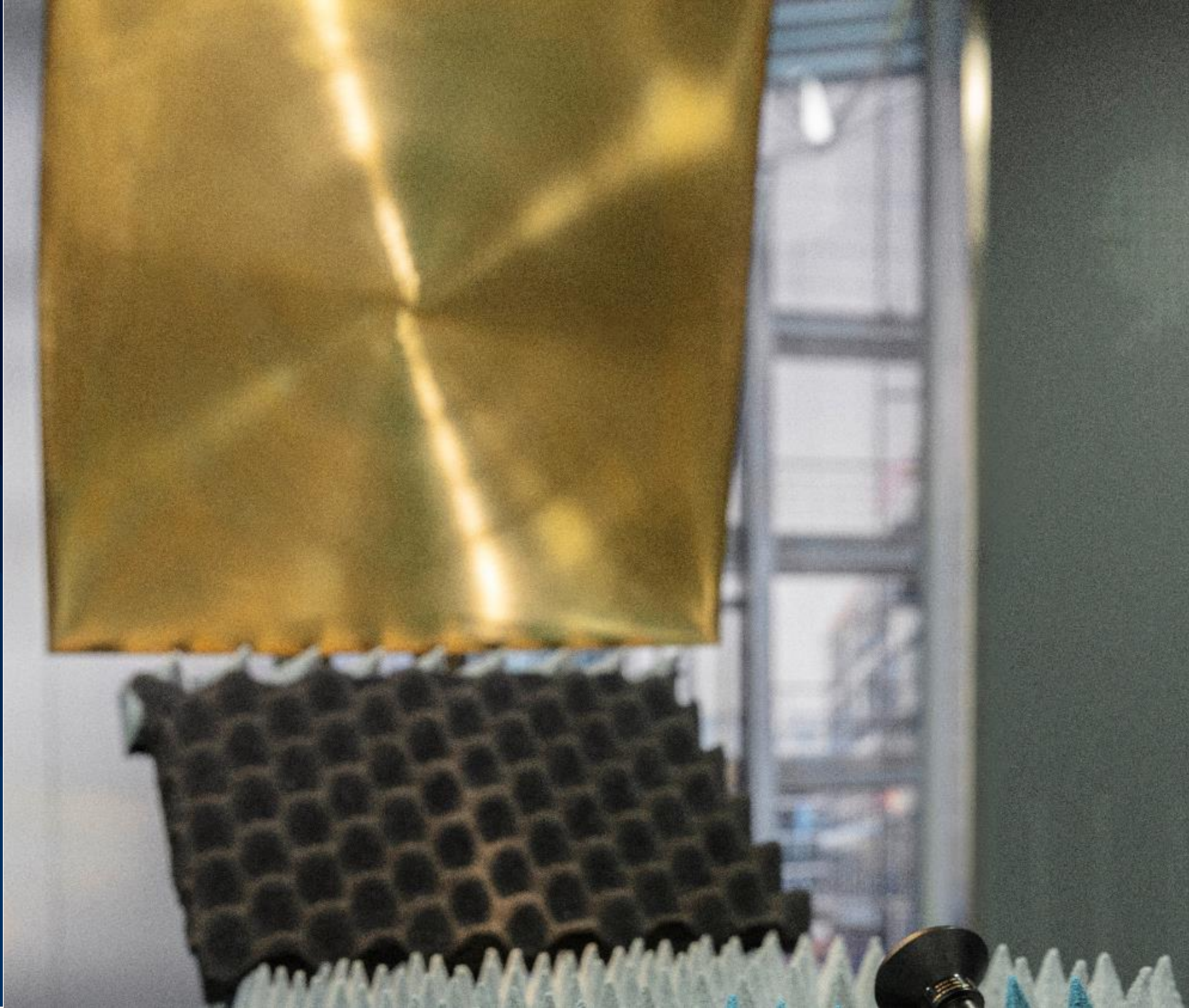
DISTANCE MEANS PATHLOSS

Path loss of free space: $$\frac{a_0}{dB} = 22 + 20\log_{10}\left(\frac{r}{\lambda_0}\right)$$



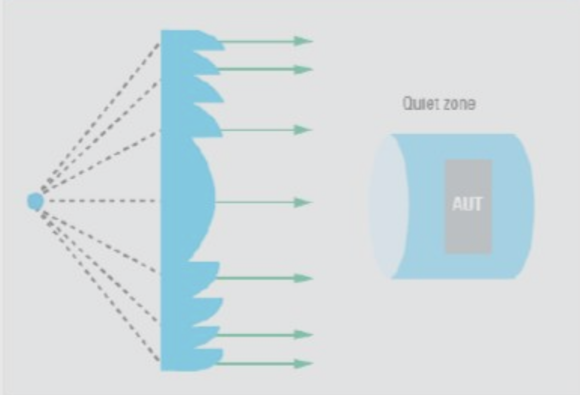
INDIRECT FAR FIELD

- CATR Concept and benefits
- Frequency ranges
- Fast, accurate beam verification
- Extreme temperature testing environment

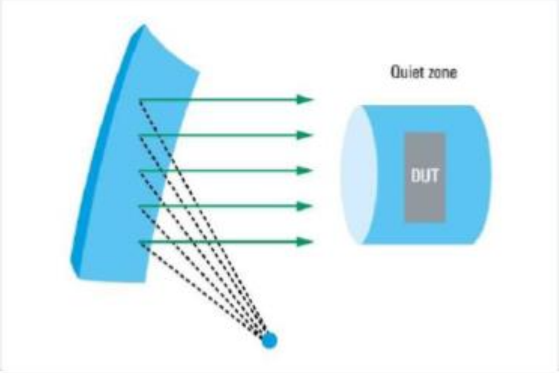


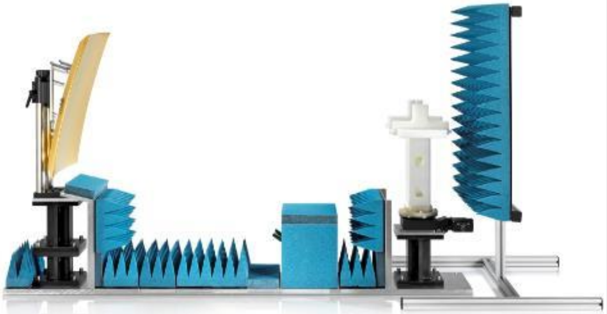
HOW TO REDUCE THE FAR FIELD DISTANCE?

Fresnel lens (Fourier optics)

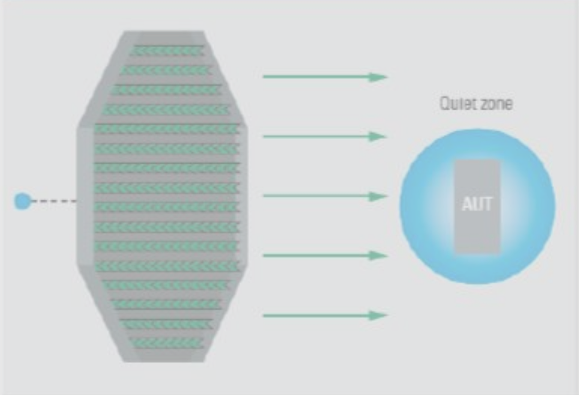


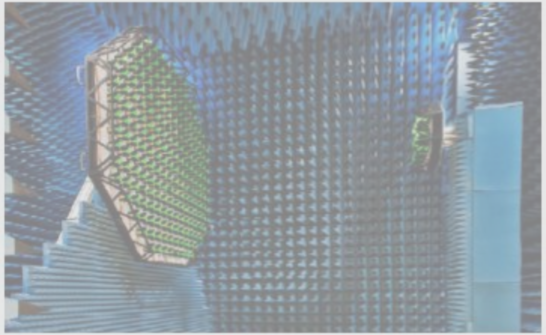
Reflector: compact antenna test range (CATR)



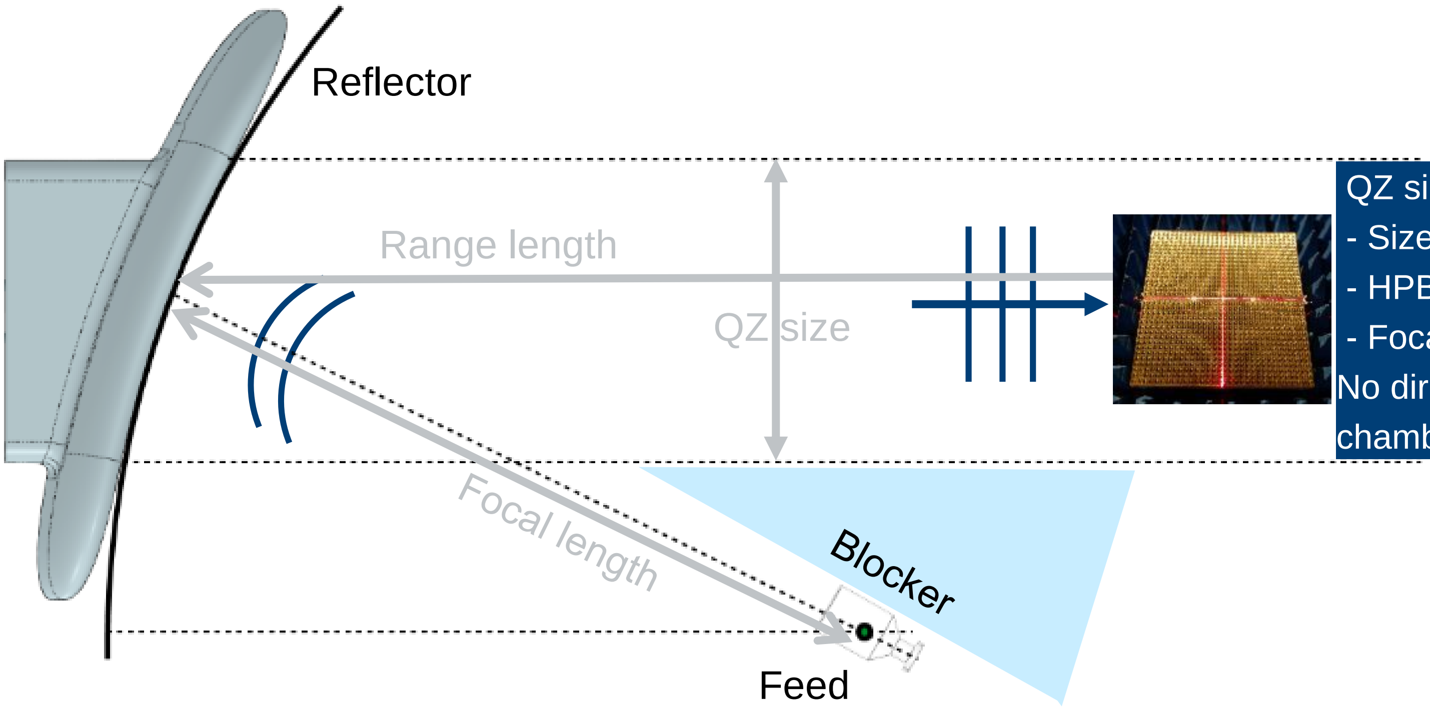


Plane wave converter (PWC)





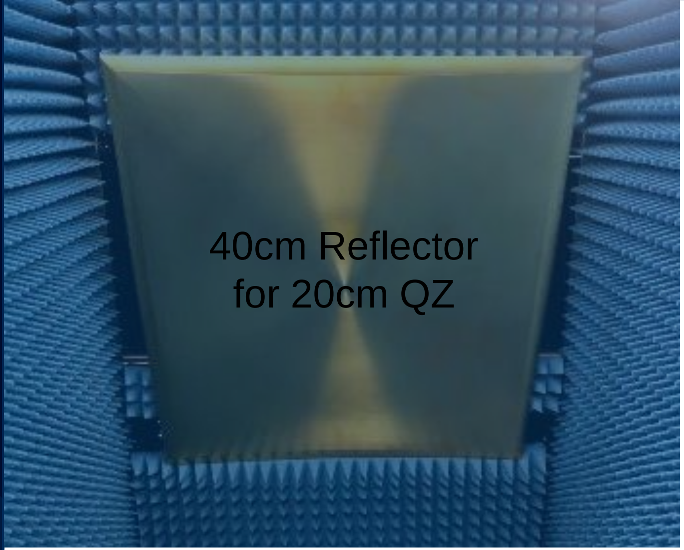
CATR – REAL TIME FAR FIELD IN NEAR FIELD DISTANCE

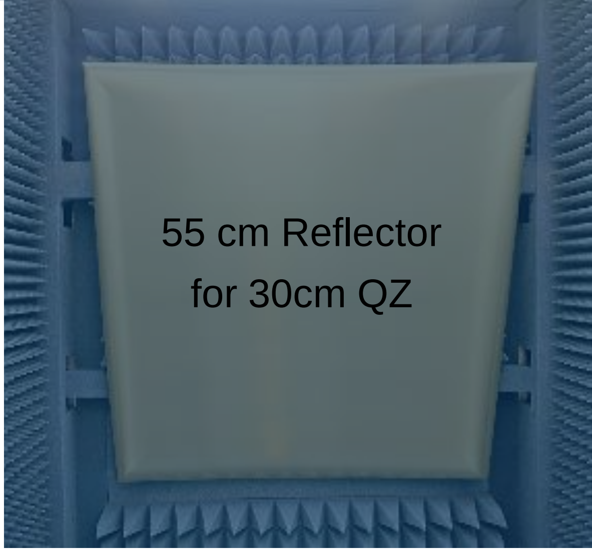


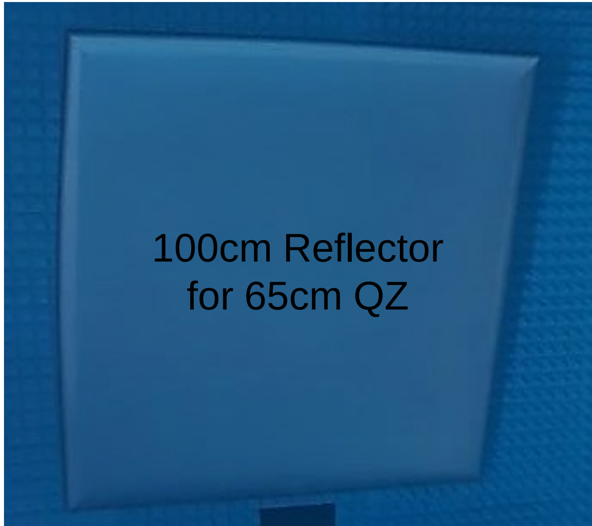
QZ size depends on
- Size of reflector
- HPBW of feed antenna
- Focal length

No direct relation between chamber size and QZ size

QZ SIZE DEPENDS ON REFLECTOR SIZE





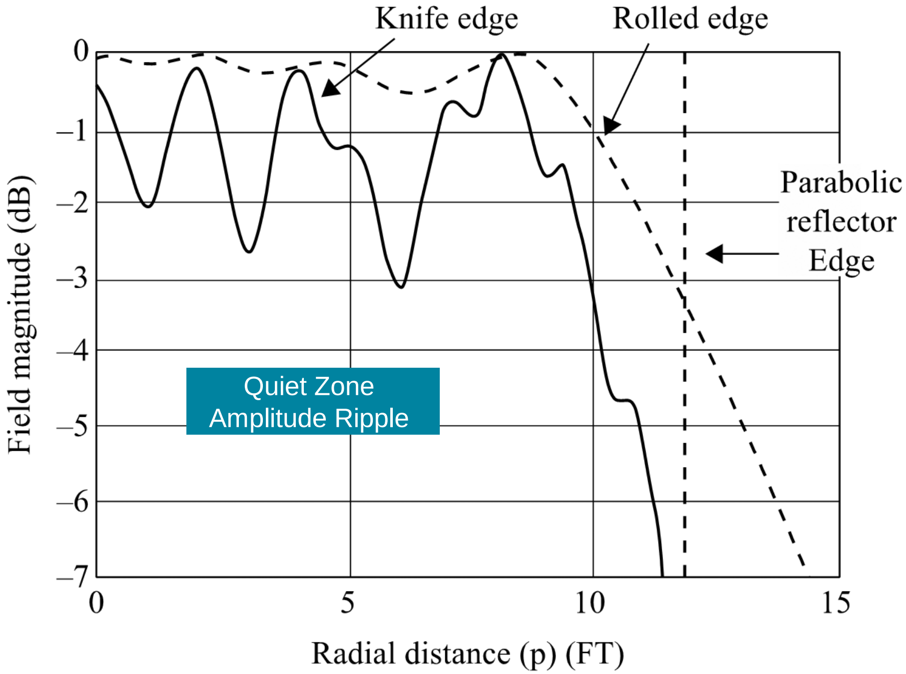


FREQUENCY RANGE LIMITERS IN CATR

- Useable frequency range mainly depends on
  - Mechanical reflector properties
  - Used feed antennas, cables, feedthroughs

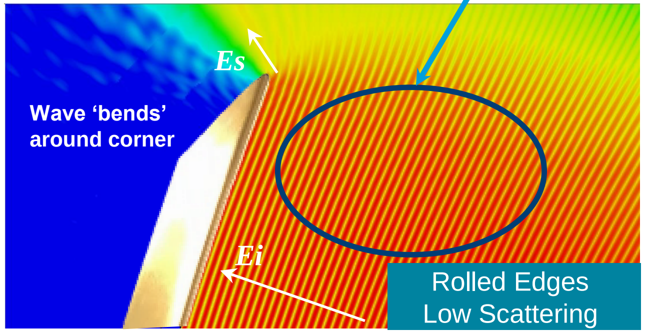
- Lower frequency limit additionally depends on
  - Chambers size
  - Used absorbers
  - Other mechanical details of chamber (e.g. blocker design)

CATR REFLECTOR ERROR: EDGE TREATMENT (LOW FREQUENCY)

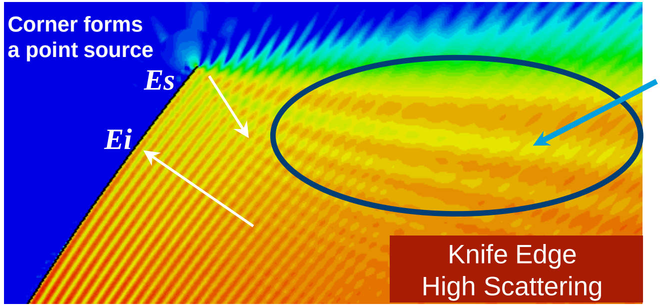


W. Burnside "Curved Edge Modification of Compact Range Reflector", IEEE 1987

No scattering of energy back into quiet zone



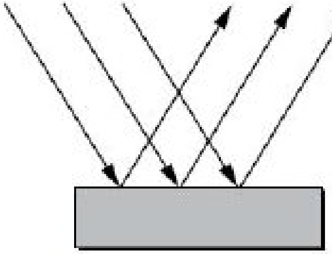
Ei: Initial EM field (from feed horn)



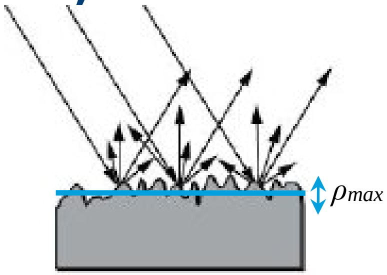
High scattering of energy into quiet zone

Es: Scattered EM field (from edges)

CATR REFLECTOR ERRORS: SURFACE ROUGHNESS (HIGH FREQUENCY)

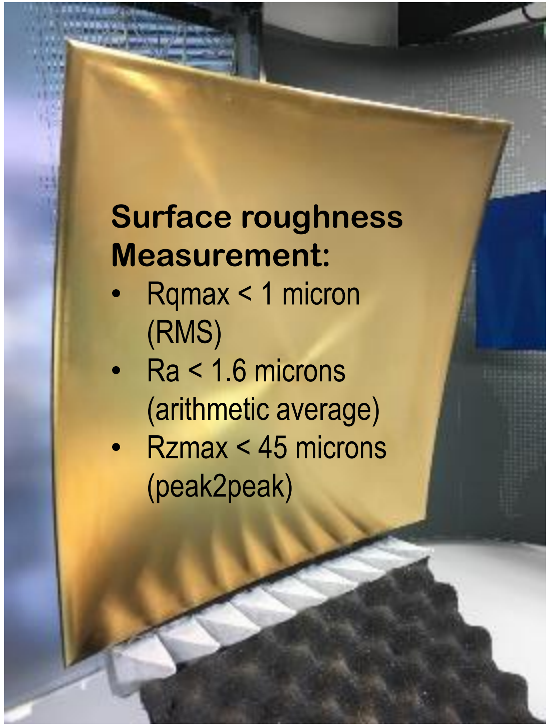


Ideal

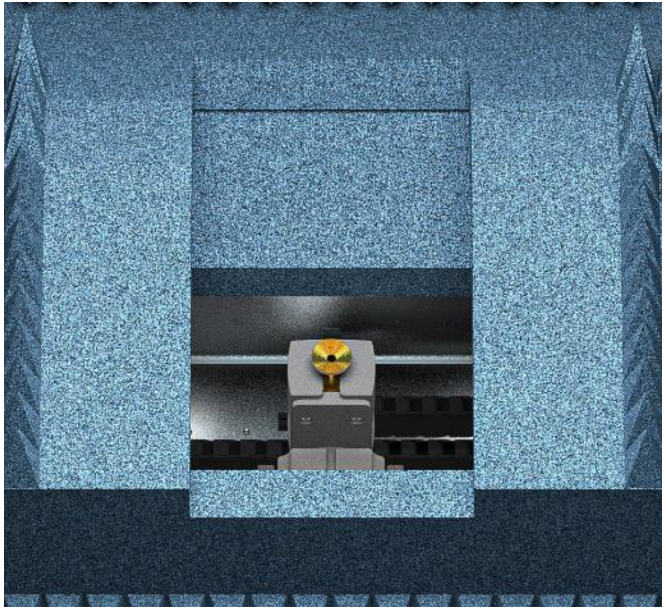


Actual

Maximum Frequency	Surface Roughness (microns)
28 GHz	75
43 GHz (in band)	49
87 GHz (spurious emissions)	24
220 GHz (FCC 5th Harmonic)	< 1



CATR – RF FEED ANTENNA



Choose between different dual polarized feed antennas

Feed	Frequency range
CATR-FE30	6 GHz to 33 GHz
CATR-FE40	23.5 GHz to 44 GHz
CATR-FE60	37 GHz to 61 GHz
CATR-FE90	59 GHz to 92 GHz
…	
CATR-FE170	*110 GHz to 170 GHz*

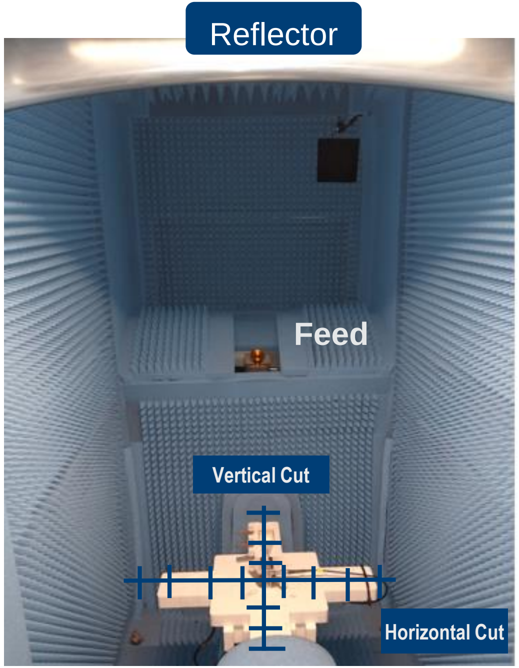
Italic: planned

SUPPORTED MEASUREMENTS

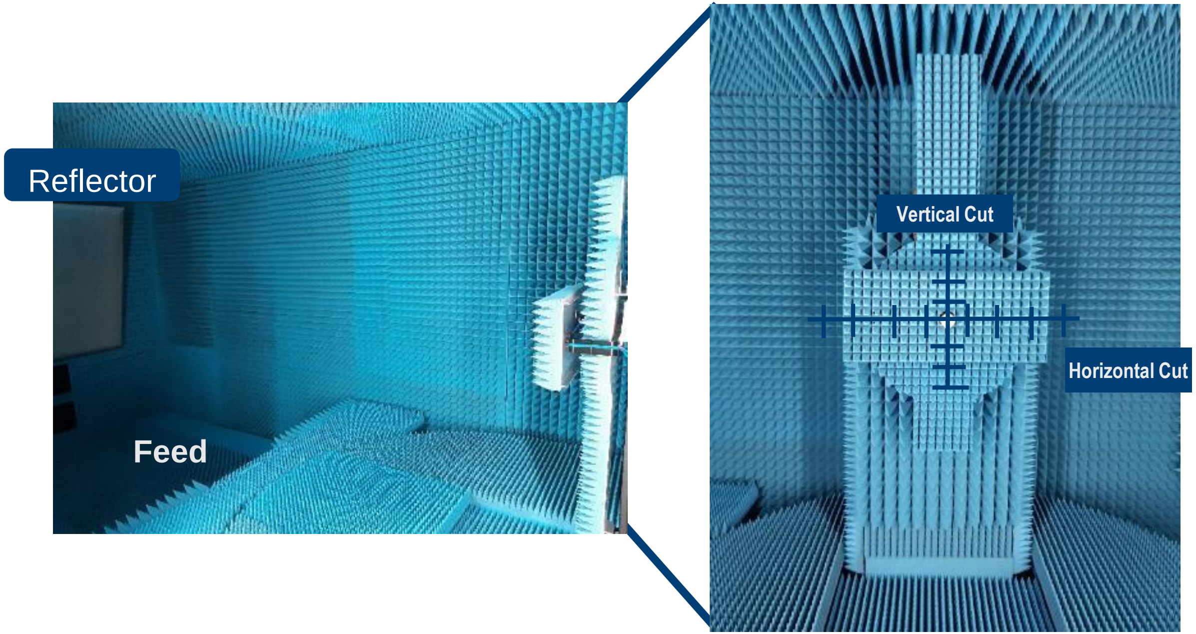
- Typical Antenna measurements using VNA (CW)
  - Radiation pattern
  - Directivity
  - Gain
  - …
- RF parametric measurements using modulated signals or custom waveforms
  - EVM
  - ACLR
  - Power
  - …
- Beam verification

BEAM VERIFICATION –
DUAL AXIS (3D) POSITIONER REQUIRED

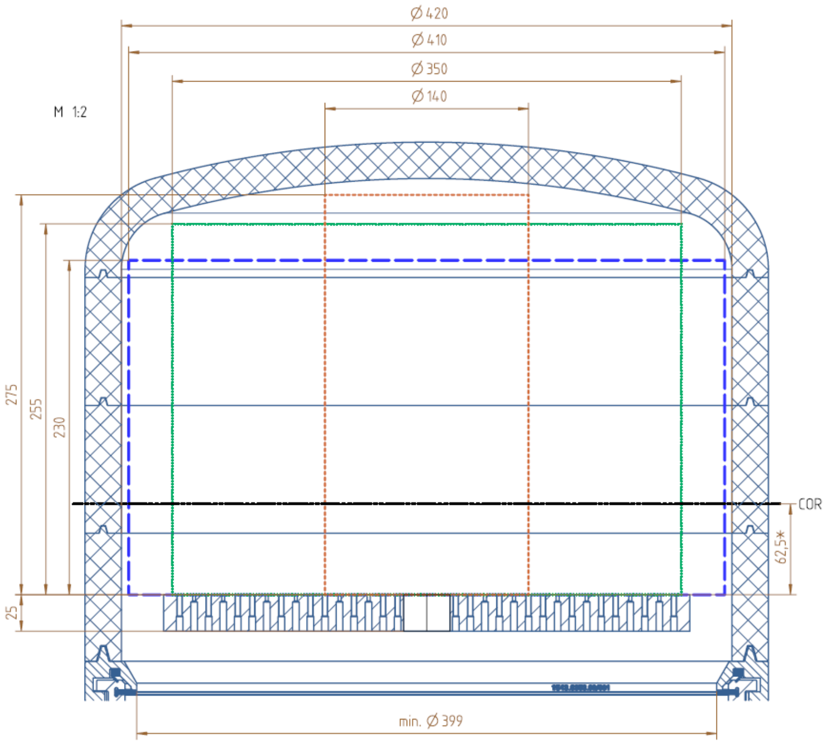
Horizontal arrangement



Vertical arrangement



EXTREME TEMPERATURE TEST SOLUTION

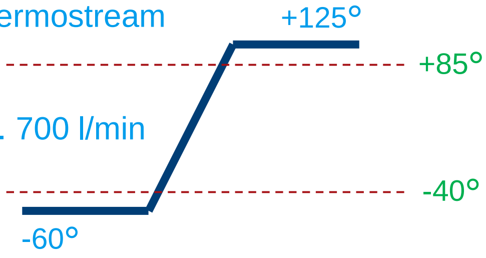


Specification	Value
Frequency Range	6-90 GHz
Temperature Range	-40 to +85 °C
Movement Range	no limitation to positioner movement

AIRFLOW CHAIN

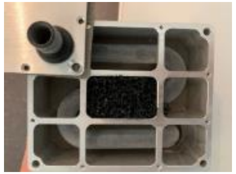
Set limits in Thermostream

Max. 700 l/min

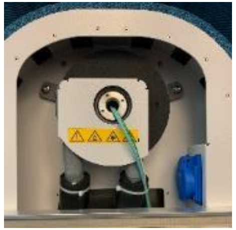


Target temperature range in bubble

Thermo stream

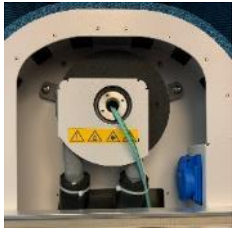


Air Feedthrough RF filtered

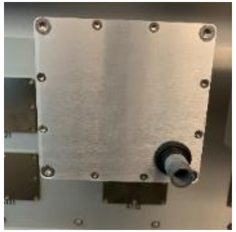


Air rotary joint for full 3D movement

Bubble RF transparent foam material

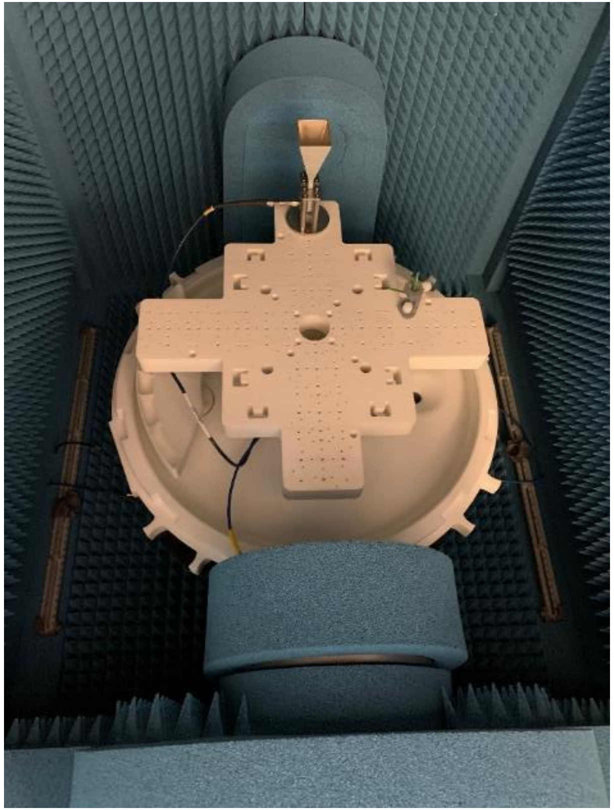


Air rotary joint for full 3D movement

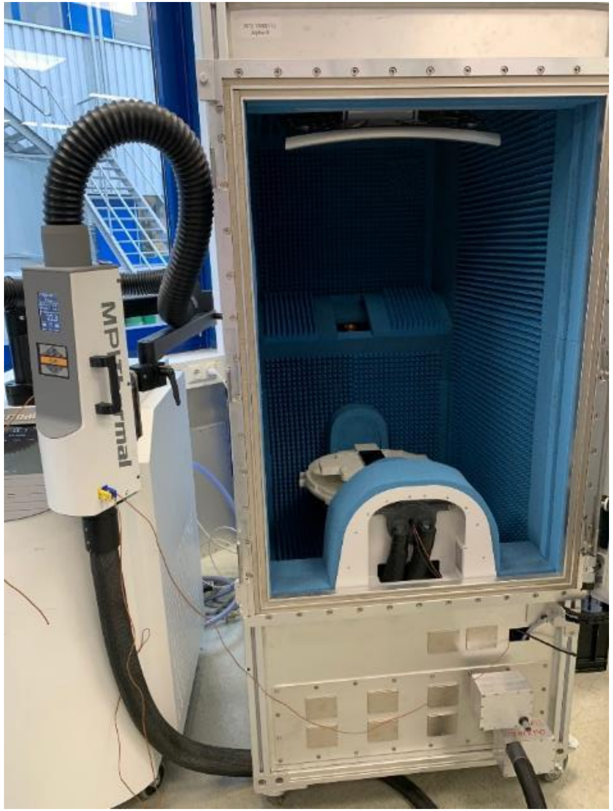


Air Feedthrough RF filtered

TEMPERATURE TEST SOLUTIONS



TEMPERATURE TEST SOLUTIONS



R&S FR2 OTA DFF / NF SOLUTIONS OVERVIEW

	WPTC	ATS1000	CMQ200	CMQ500
				
Dim. (WxHxD)	5.2 x 4.1 x 4.3 (L)	1 x 2.1 x 1.5	0.45 x 0.7 x 0.72	0.45 x 0.7 x 0.72
Max. DUT size	Ø 1.2 m (L)	Ø 28 cm	35 x 35 x 30 cm	35 x 35 x 30 cm
Max. DUT weight	50 kg	20 kg	5 kg	5 kg
Type	White box DFF/NF	White box DFF/NF	White box DFF/NF	DFF(FR2)/NF(FR1)
Freq. Range	0.4 - 90 GHz	18 - 67 GHz	20 - 77 GHz	0.7 - 77 GHz
Supported freq. Range	Full range	Full range	Full range	Full range
Quiet zone	Ø 7 cm @ 40GHz	Ø 4 cm @ 40GHz	Ø 2 cm @ 40GHz	Ø 2 cm @ 40GHz
Positioner	3D conical cut	3D conical cut	-	-
Shielding Eff.	100 dB	>50 dB	>60 dB	>60 dB
Extreme Temp.	-	3D	-	-

R&S FR2 OTA IFF CATR SOLUTIONS OVERVIEW

	ATS800B	ATS800R	ATS1800C	ATS1800XL (under development)
				
Dim. (WxHxD)	1.2 x 0.8 x 0.6	0.6 x 2.0 x 1.2	0.9 x 2.0 x 1.5	~ 5 x 2.2 x 2.2
Max. DUT size	Ø xx cm	Ø 36cm (Posi.)	Ø 52cm	85 x 85 x 40cm
Max. DUT weight	2.5 Kg	2.5 kg (Posi.)	20 kg	50 kg
Type	Black box CATR	Black box CATR	Black box CATR	Black box CATR
Freq. Range	20 - 50 GHz	20 - 50 GHz	(6) ~12 - 90 GHz (+)	(6) ~14 - 90 GHz (+)
Supported freq. Range	Full range (Vivaldi Antenna)	Full range (Vivaldi Antenna)	Full range (feed switcher)	Full range (feed switcher)
Quiet zone	Ø 20 cm	Ø 20 cm	Ø 30 /40 cm	Ø 65 cm
Positioner	2D positioner (opt.)	3D Az over El (opt.)	3D Az over El	3D GCC
Shielding Eff.	N/A	>60dB	>90 dB	>70dB
Extreme Temp.	N/A	1D	3D	N/A

THANK YOU!
QUESTIONS?