NR NEW OTA TEST METRICS

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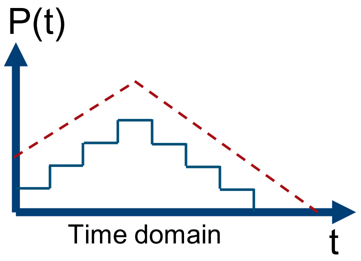
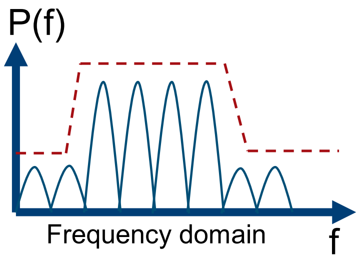
ROHDE & SCHWARZ
Make ideas real

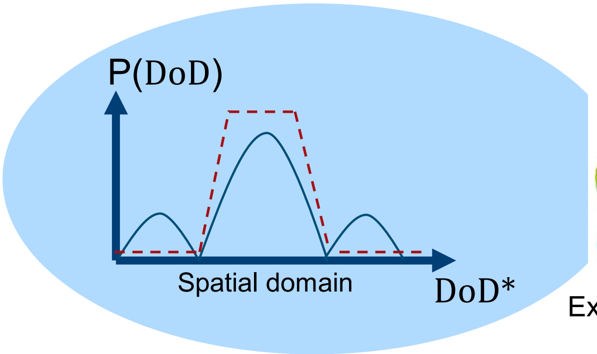
NR NEW OTA TEST METRICS SCOPE

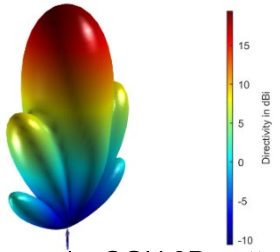
- ► The measurement of radiated power
- ► Spherical coverage – the operators favorite metric
- ► OTA Mobile receiver performance assessment

POWER MEASUREMENT DOMAINS









Example: SGH 3D pattern

Limit line (requirement)

*Direction of Departure

CONDUCTED AND TOTAL RADIATED POWER

P_{feed} →

$$TRP = \oiint \left|\vec{E} \times \vec{H}\right| dS$$

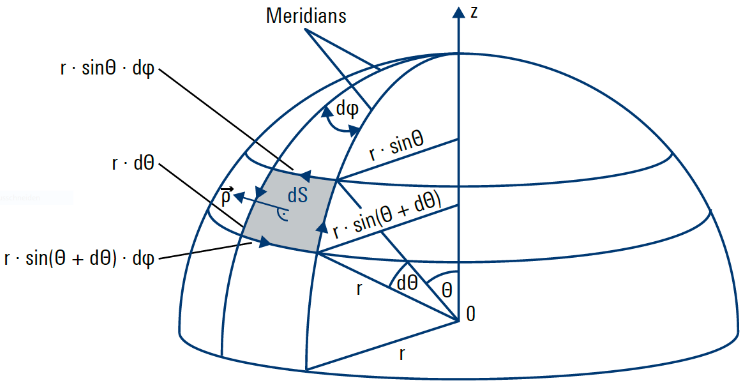
$\vec{\rho} = \vec{E} \times \vec{H}$ in far field

$$TRP = \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} |\vec{\rho}| r^2 sin\theta d\theta d\phi$$

$$|\vec{\rho}(\theta, \phi)| = \frac{EIRP(\theta, \phi)}{4\pi\, r^2}$$

$$TRP = \frac{1}{4\pi} \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} EIRP(\theta, \phi) sin\theta d\theta d\phi$$

measureable

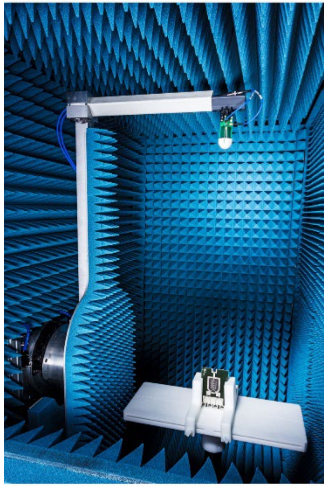


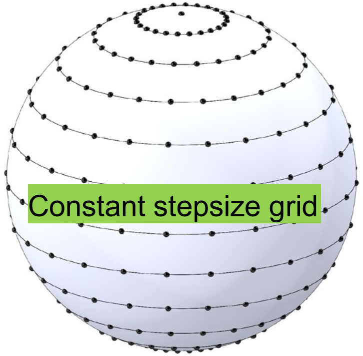
Azimuth ϕ range 0 .. 360° (2π)
Elevation θ range 0 .. 180° (π)

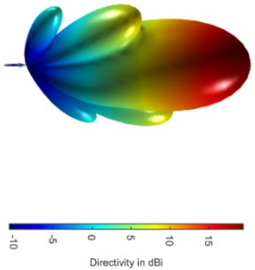
CLASSICAL NUMERICAL APPROXIMATION OF TRP

Source: 3GPP TSG RAN WG4 Meeting #88 R4-1801427

$$TRP = \frac{1}{4\pi}\int_{\theta=0}^{\pi}\int_{\phi=0}^{2\pi} \boldsymbol{EIRP(\theta,\phi)sin\theta d\theta d\phi}$$







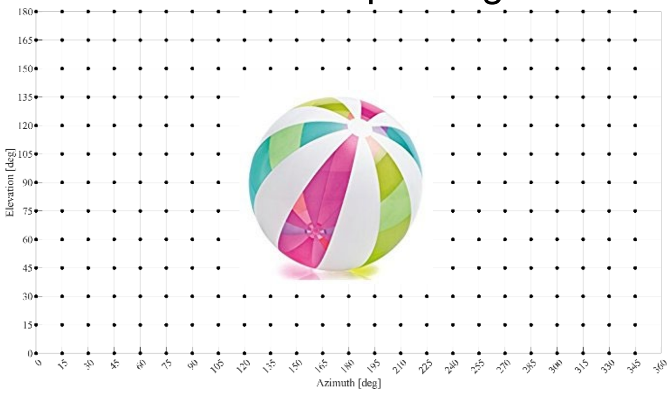
$$TRP \approx \frac{\pi}{2\,NM}\sum_{i=1}^{N-1}\sum_{j=0}^{M-1} EIRP(\theta_i,\phi_j)\sin(\theta_i)$$

Problem: Approximation fails when most power points towards the poles ($\theta_i = \{0,\pi\}$), as $\sin(\theta_i)$ ignores them

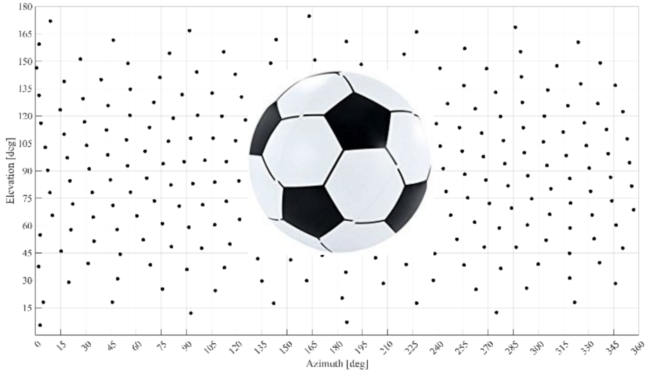
Issue: Systematic Measurement Uncertainty depending on (a-priori unknown) radiation pattern alignment

CONSTANT DENSITY GRID SAMPLING

Constant step size grid



Constant density grid



Constant DENSITY grid: $$TRP \approx \frac{1}{N}\sum_{i=0}^{N-1}\left[EIRP_{\theta}(\theta_i,\phi_i)+EIRP_{\phi}(\theta_i,\phi_i)\right]$$

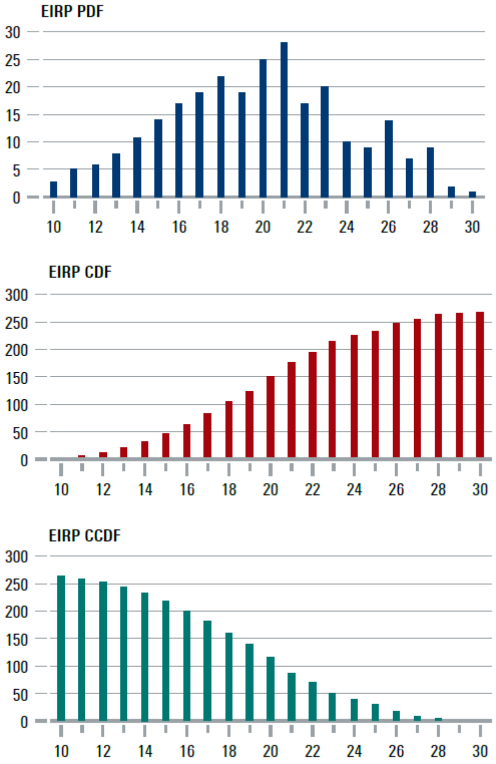
No weighting needed! No risk to ignore significant power portions!

Source: 3GPP TR 38.810 V16.6.1 (2020-09)

SPHERICAL COVERAGE
RANGE OF SOLID ANGLES THE RADIATING DEVICE CAN COVER

- mmW frequency operation requires **high directional antenna systems** for compensating the **free space path loss** between base and mobile station:
  - antenna arrays to be used with high gain - but limited spherical coverage
- **Randomness** of mobile radio channels requires **large spherical coverage**
  - Direction of incoming signal and device orientation is random
  - Isotropic antenna characteristics would be needed
- „As usual“: **Contrasting requirements** to meet at the same time !
  - Consequently, multiple, cooperating arrays needed
  - High speed beam adjustment
- Need for conformance requirements and **metric „spherical coverage“**
  - Applies to transmitter and receiver
  - Spherical coverage is a **statistical** metric
  - Constant density grid sampling is the preferred approach

SPHERICAL COVERAGE STATISTICAL METRICS



The **PDF** of a series of measurements X (e.g. EIRP(θ_i, φ_j) or EIS (θ_i, φ_j)) illustrates the frequency of individual measurement values.

$$CDF(x) = P(X \le x) = \int_{-\infty}^{x} PDF(X)dX$$

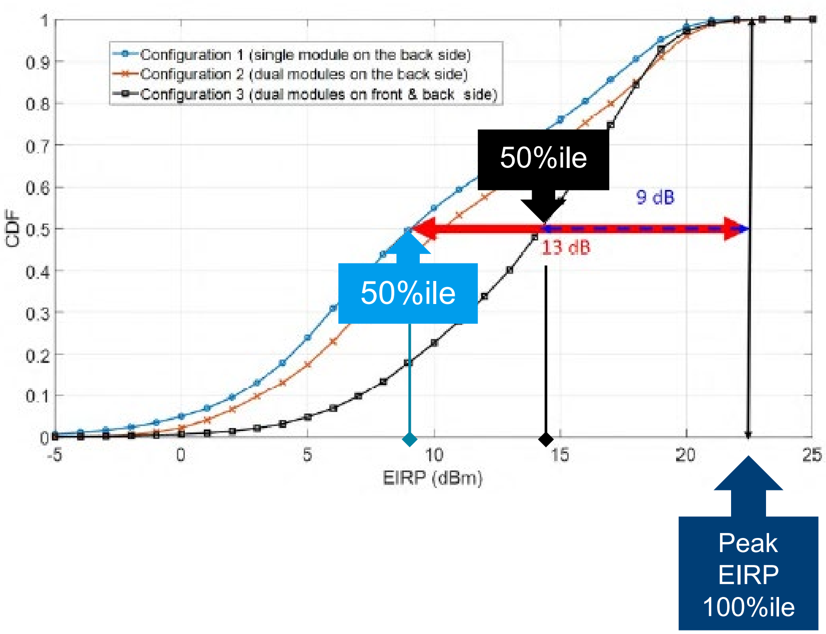
Suitable to specify an UPPER (e.g. power) threshold x (%ile that shall not exceed limit x)

$$CCDF(x) = P(X > x) = \int_{x}^{\infty} PDF(X)dX = 1 - CDF(x)$$

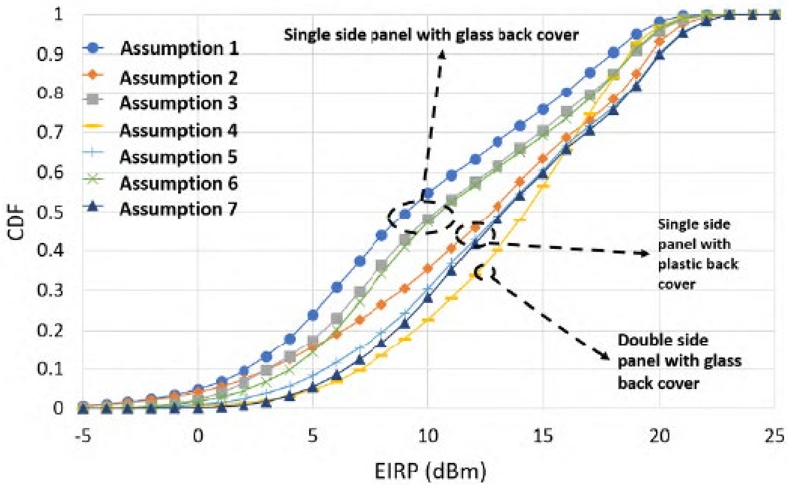
Suitable to specify a LOWER (e.g. sensitivity level) threshold x (%ile that shall not drop below limit x)

SPHERICAL COVERAGE DESIGN DEPENDENCIES

Different antenna configurations



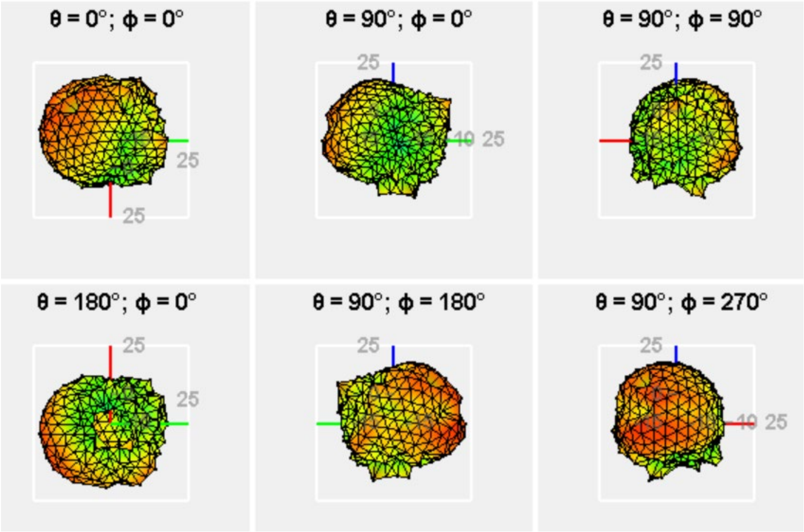
Different form factors



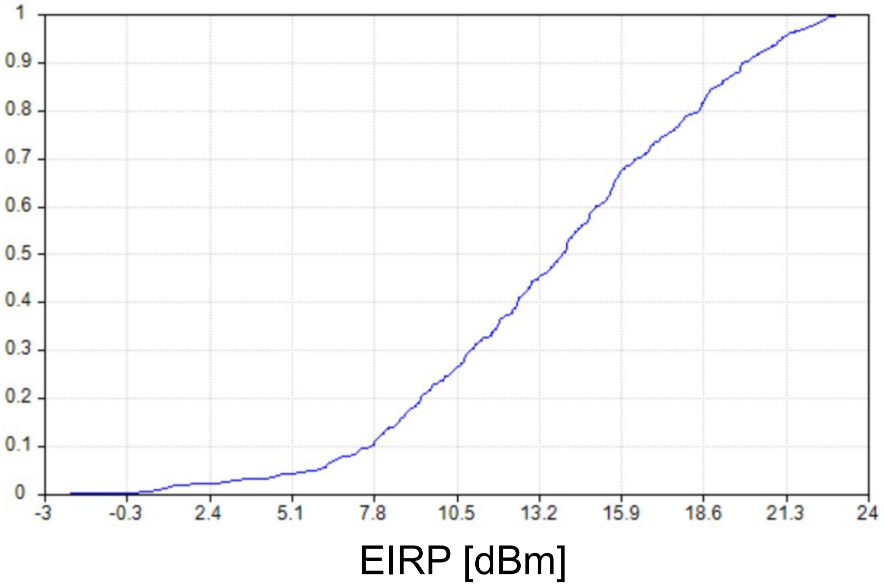
Source: IEEE Access; K. Zhao *et al.*: Spherical Coverage Characterization of 5G mmWave UE

R&S TX SPHERICAL COVERAGE MEASUREMENT SAMPLE

3D views of measured EIRP values



CDF of measured EIRP values distribution



Recorded with R&S©CONTEST conformance test software, 400 samples, constant density grid

TX OUTPUT POWER LIMITS AND DYNAMICS

FR2 operating band	Min peak EIRP	Maximum (Minimum) EIRP	Maximum TRP	Min EIRP at 85%-tile CDF
Power class 1: Fixed wireless access (FWA) UE				
n257	40 dBm	55 (4) dBm	35 dBm	32 dBm
n258	40 dBm	55 (4) dBm	35 dBm	32 dBm
n260	38 dBm	55 (4) dBm	35 dBm	30 dBm
n261	40 dBm	55 (4) dBm	35 dBm	32 dBm

FR2 operating band	Min peak EIRP	Maximum (Minimum) EIRP	Maximum TRP	Min EIRP at 60%-tile CDF
Power class 2: Vehicular UE				
n257	29 dBm	43 (-13) dBm	23 dBm	18 dBm
n258	29 dBm	43 (-13) dBm	23 dBm	18 dBm
N/A				
n261	29 dBm	43 (-13) dBm	23 dBm	18 dBm

FR2 operating band	Min peak EIRP	Maximum (Minimum) EIRP	Maximum TRP	Min EIRP at 50%-tile CDF
Power class 3: Handheld UE				
n257	22.4 dBm	43 (-13) dBm	23 dBm	11.5 dBm
n258	22.4 dBm	43 (-13) dBm	23 dBm	11.5 dBm
n260	20.6 dBm	43 (-13) dBm	23 dBm	8 dBm
n261	22.4 dBm	43 (-13) dBm	23 dBm	11.5 dBm

FR2 operating band	Min peak EIRP	Maximum/ Minimum EIRP	Maximum TRP	Min EIRP at 20%-tile CDF
Power class 4: High power non-handheld UE				
n257	34 dBm	43 (-13) dBm	23 dBm	25 dBm
n258	34 dBm	43 (-13) dBm	23 dBm	25 dBm
n260	31 dBm	43 (-13) dBm	23 dBm	19 dBm
n261	34 dBm	43 (-13) dBm	23 dBm	25 dBm

Transmit OFF power -35 dBm for any FR2 operating band and bandwidth

Maximum – Minimum EIRP = Output power dynamics

3GPP TS 38.521-2 V16.3.0 (2020-03)

RX SPHERICAL COVERAGE CONFORMANCE LIMITS

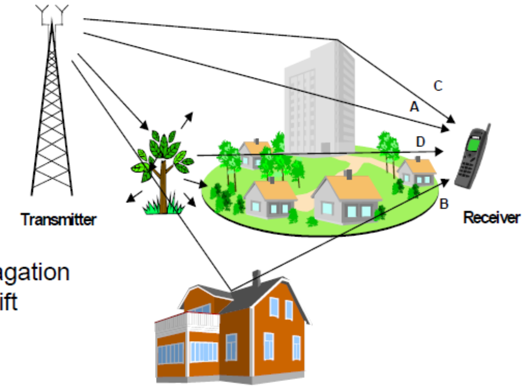
FR2 operating band	50 MHz	100 MHz	200 MHz	400 MHz
Power class 1: EIS at 85th%ile CCDF (dBm)				
n257	-89.5 dBm	-86.5 dBm	-83.5 dBm	-80.5 dBm
n258	-89.5 dBm	-86.5 dBm	-83.5 dBm	-80.5 dBm
n260	-86.5 dBm	-83.5 dBm	-80.5 dBm	-77.5 dBm
n261	-89.5 dBm	-86.5 dBm	-83.5 dBm	-80.5 dBm

FR2 operating band	50 MHz	100 MHz	200 MHz	400 MHz
Power class 2: EIS at 60th%ile CCDF (dBm)				
n257	-83.5 dBm	-80.5 dBm	-77.5 dBm	-74.5 dBm
n258	-83.5 dBm	-80.5 dBm	-77.5 dBm	-74.5 dBm
N/A				
n261	-83.5 dBm	-80.5 dBm	-77.5 dBm	-74.5 dBm

FR2 operating band	50 MHz	100 MHz	200 MHz	400 MHz
Power class 3: EIS at 50th%ile CCDF (dBm)				
n257	-77.4 dBm	-74.4 dBm	-71.4 dBm	-68.4 dBm
n258	-77.4 dBm	-74.4 dBm	-71.4 dBm	-68.4 dBm
n260	-73.1 dBm	-70.1 dBm	-67.1 dBm	-64.1 dBm
n261	-77.4 dBm	-74.4 dBm	-71.4 dBm	-68.4 dBm

FR2 operating band	50 MHz	100 MHz	200 MHz	400 MHz
Power class 4: EIS at 20th%ile CCDF (dBm)				
n257	-88 dBm	-85 dBm	-82 dBm	-79 dBm
n258	-88 dBm	-85 dBm	-82 dBm	-79 dBm
n260	-83 dBm	-80 dBm	-77 dBm	-74 dBm
n261	-88 dBm	-85 dBm	-82 dBm	-79 dBm

UE RECEIVER PERFORMANCE

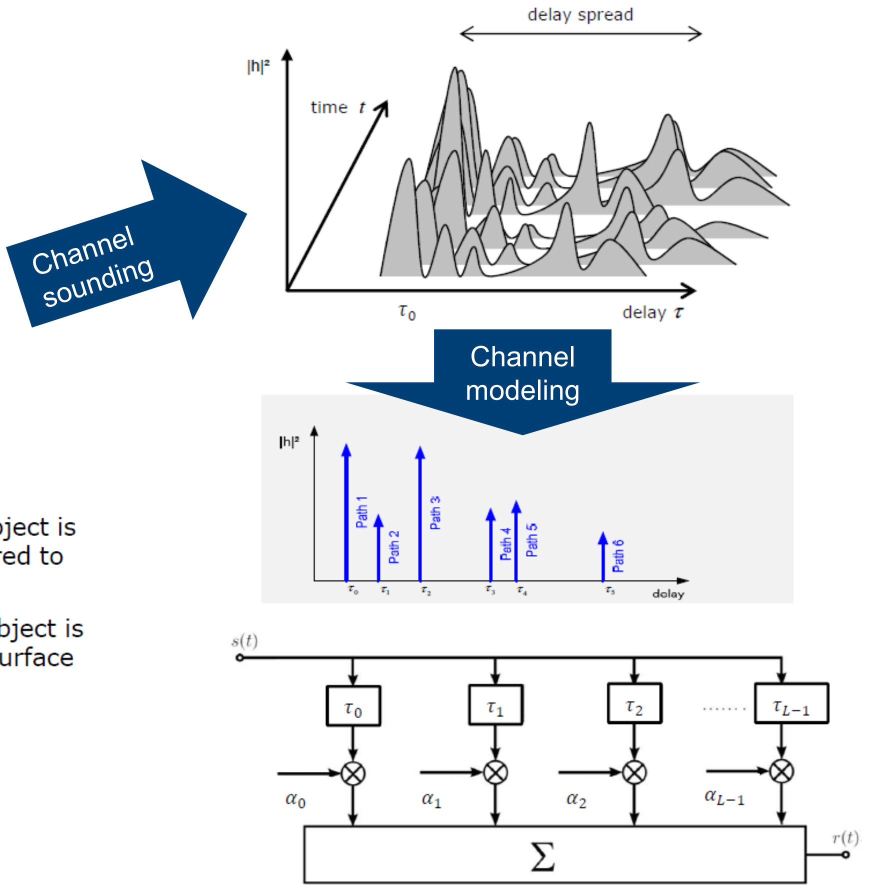


A: free space
B: reflection
C: diffraction
D: scattering

Multipath Propagation and Doppler shift

reflection: object is large compared to wavelength

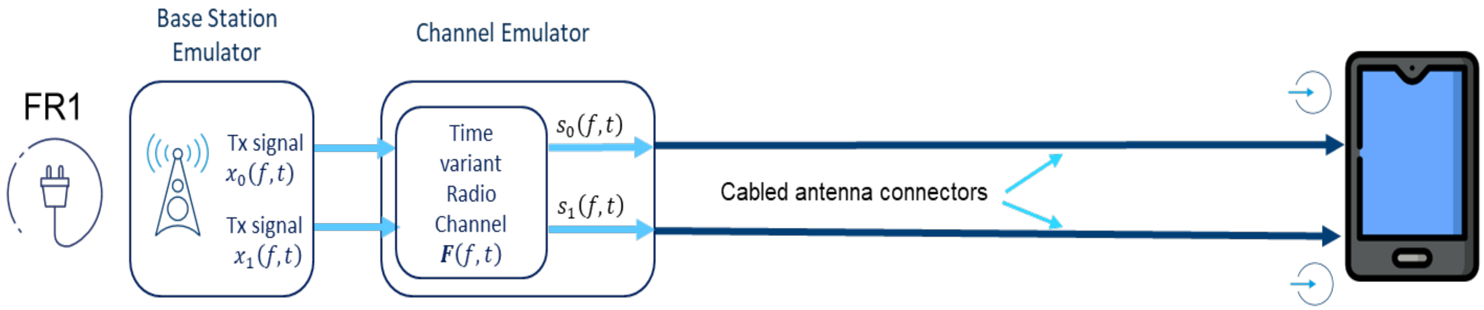
scattering: object is small or its surface irregular



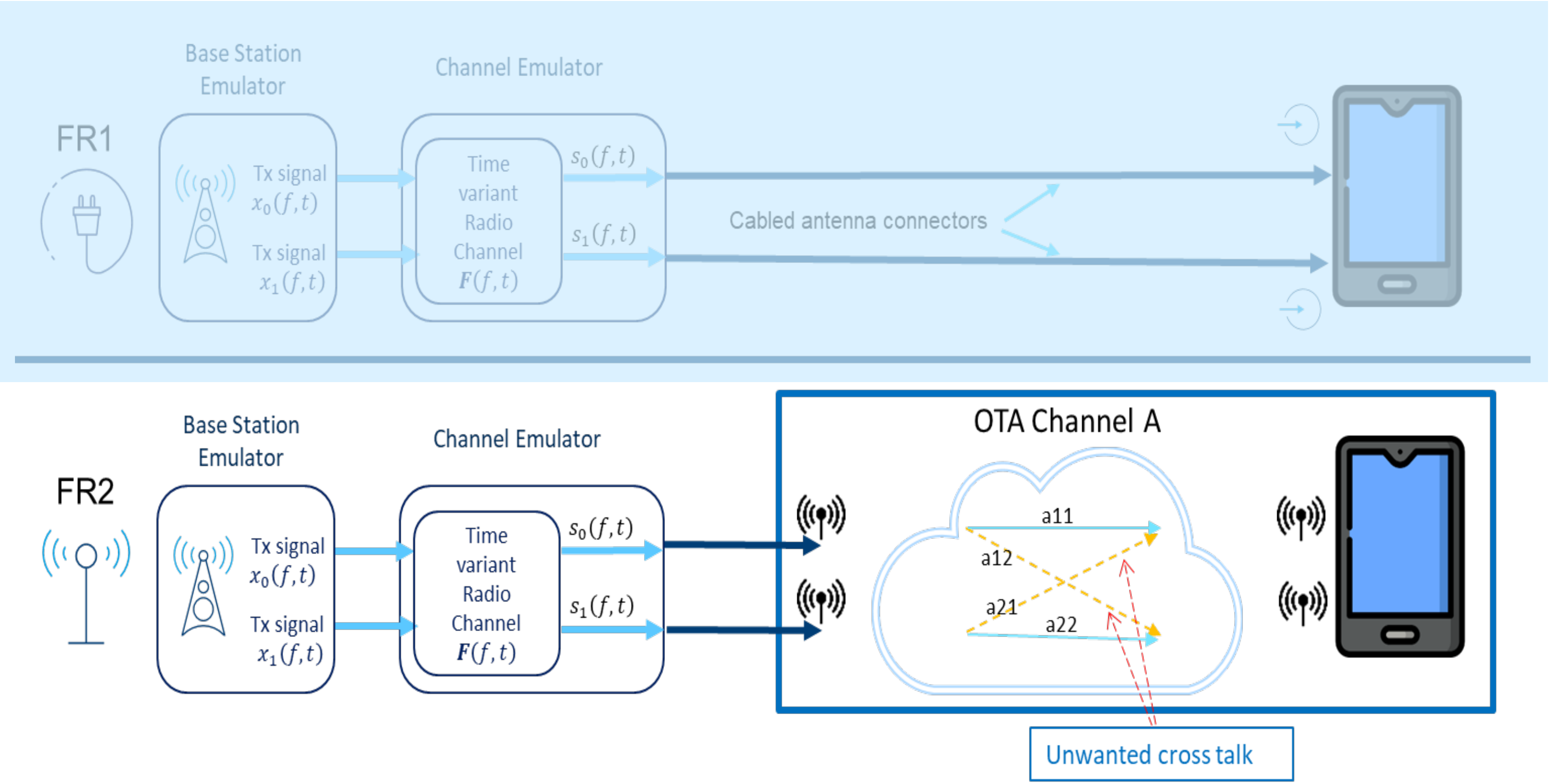
WSSUS*: Tapped delay line modeling

*Wide Sense Stationary Uncorrelated Scattering

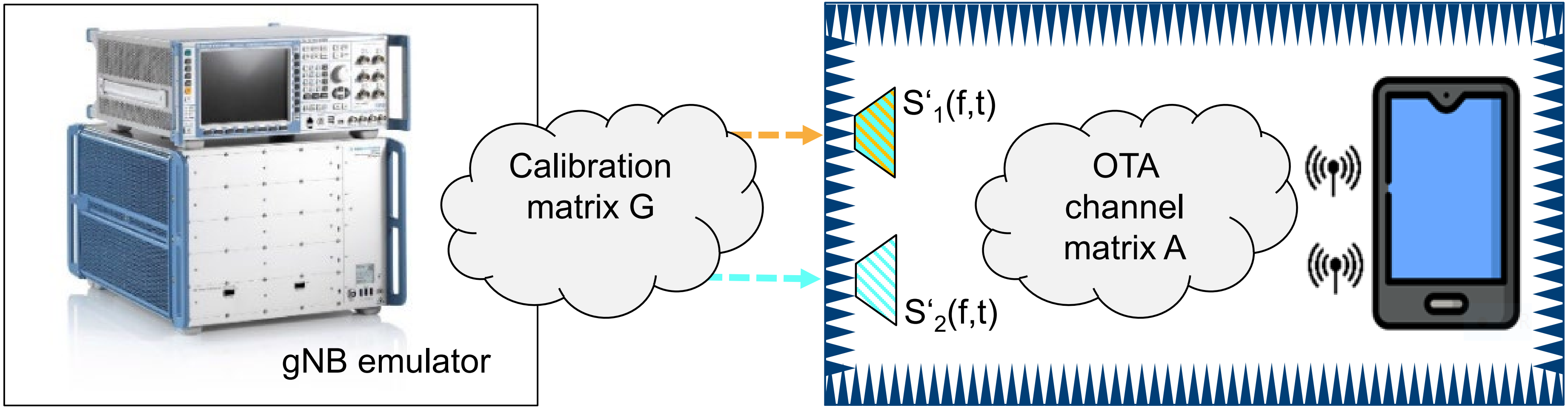
UE FR1 RECEIVER PERFORMANCE ASSESSMENT



UE FR2 RECEIVER PERFORMANCE ASSESSMENT



VIRTUAL CABLE CALIBRATION (VCC)

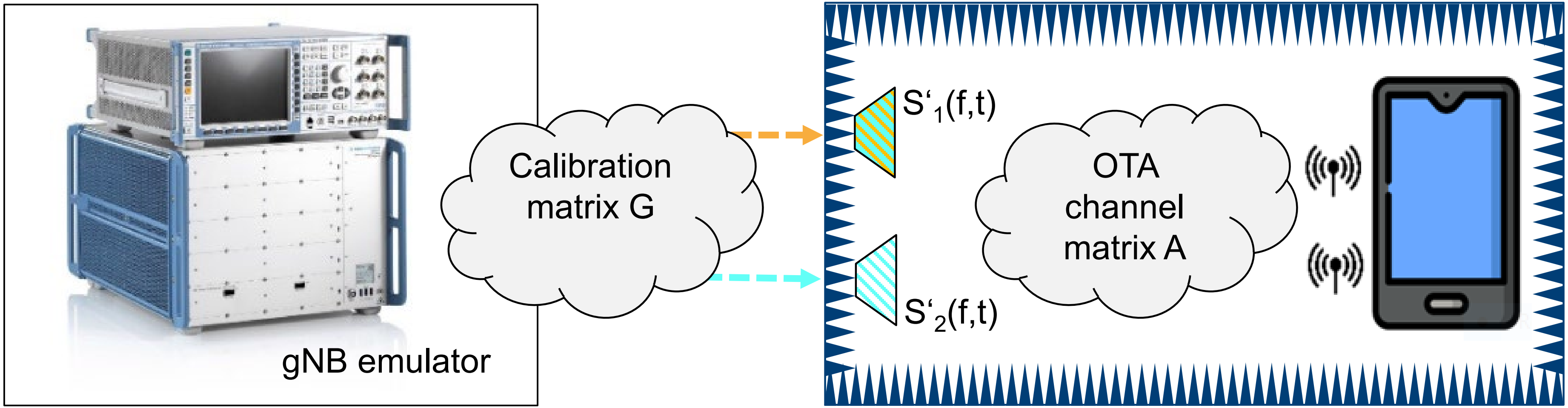


Goal: Calibrate channel matrix G·A to become **I** = $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

Standard solution: ZF or MMSE based on complex knowledge of channel matrix A

Challenge:
- No complex knowledge about A based on feedback from UE
- UE RSRPB power feedback with limited resolution only

VIRTUAL CABLING IN OTA ENVIRONMENT



Rephrase Goal:

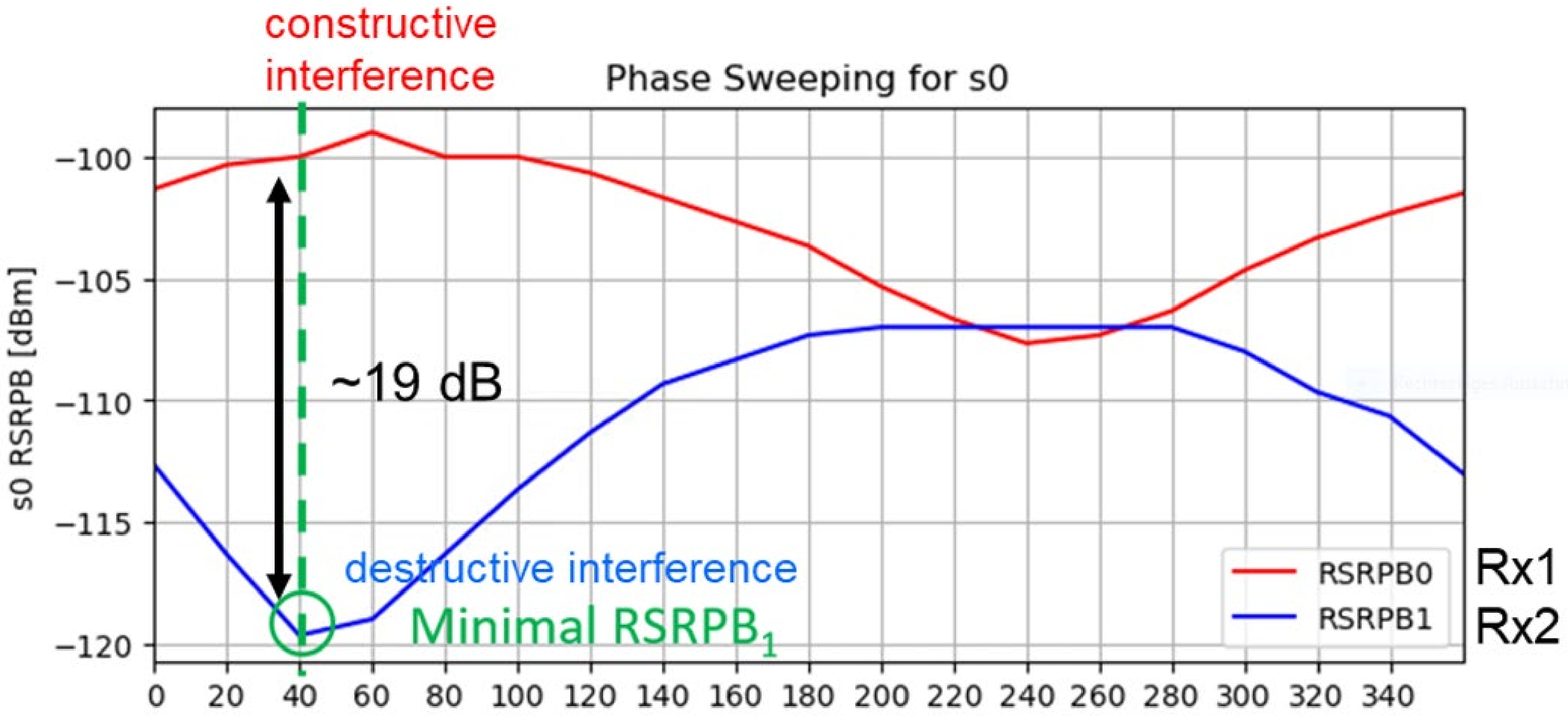
- Minimize cross-talk (i.e. maximize isolation) for A·G
- Balance remaining paths of A·G

Solution:

Solve $\min_{g_1,\varphi_1,g_2,\varphi_2} \|A \cdot G - I\| \quad with\ G = \begin{bmatrix} g_1 & g_2 e^{-j\varphi_2} \\ g_1 e^{-j\varphi_1} & g_2 \end{bmatrix}$

Phase shift φ_i to maximize isolation
Gain g_i to balance remaining paths

MINIMIZING CROSSTALK BY VCC



SUMMARY

- ► Conducted measurement metrics do not necessarily work for OTA measurements
  - – New metrics or adaptation of metrics required
- ► Some metrics allow transformation into „OTA space“
  - – e.g. conducted power → total radiated power
- ► Some metrics require „virtual“ cable connections
  - – e.g. receiver multipath performance measurements
- ► Some metrics are unique for radiated measurements
  - – e.g. spherical coverage metric
- ► Some measurements require active support by device under test
  - – e.g. per receive branch receive power reports by UE

THANK YOUR FOR YOUR ATTENTION!

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