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Comparing Directive Antenna Patterns: Regulation and Standards

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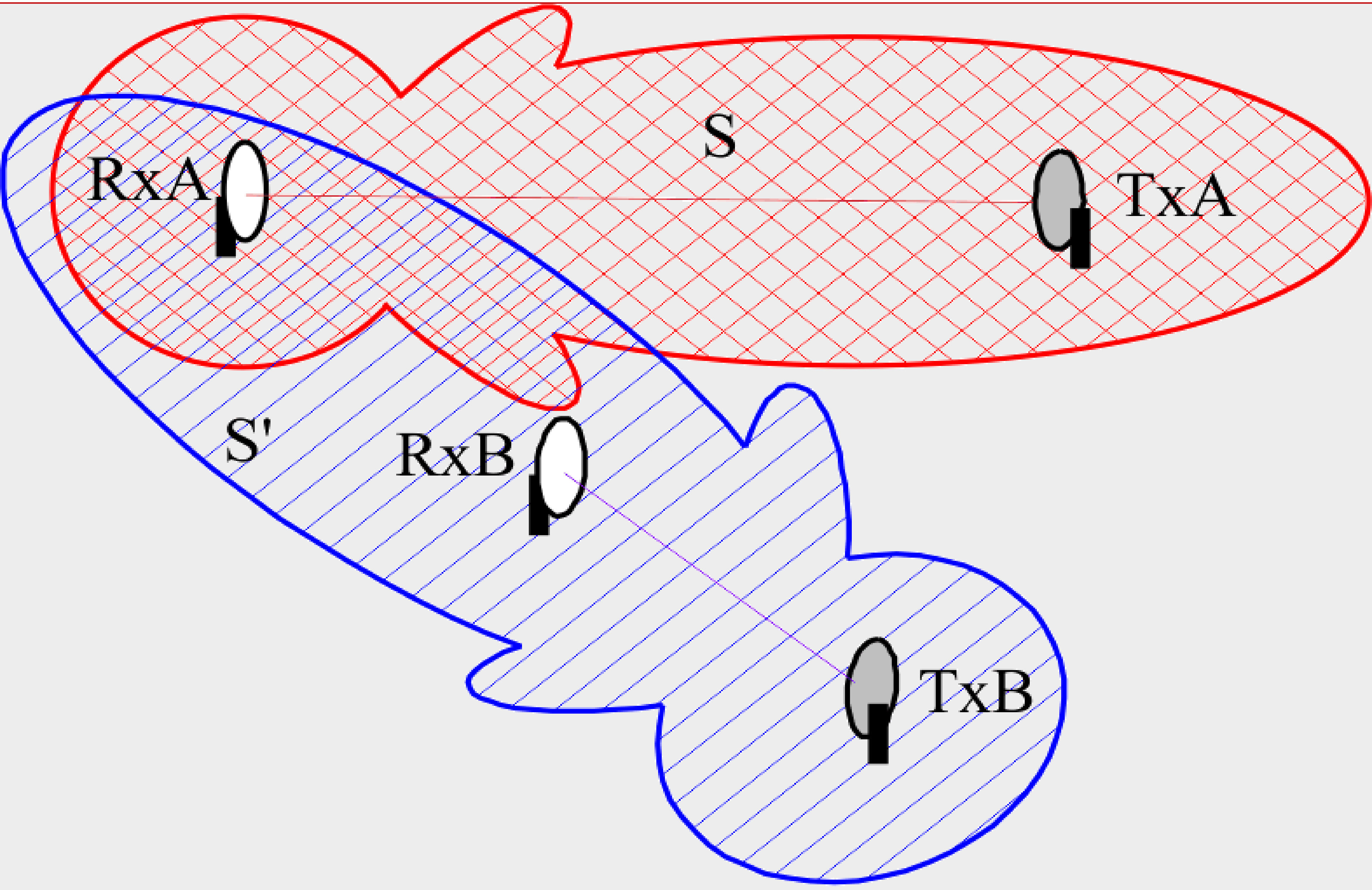
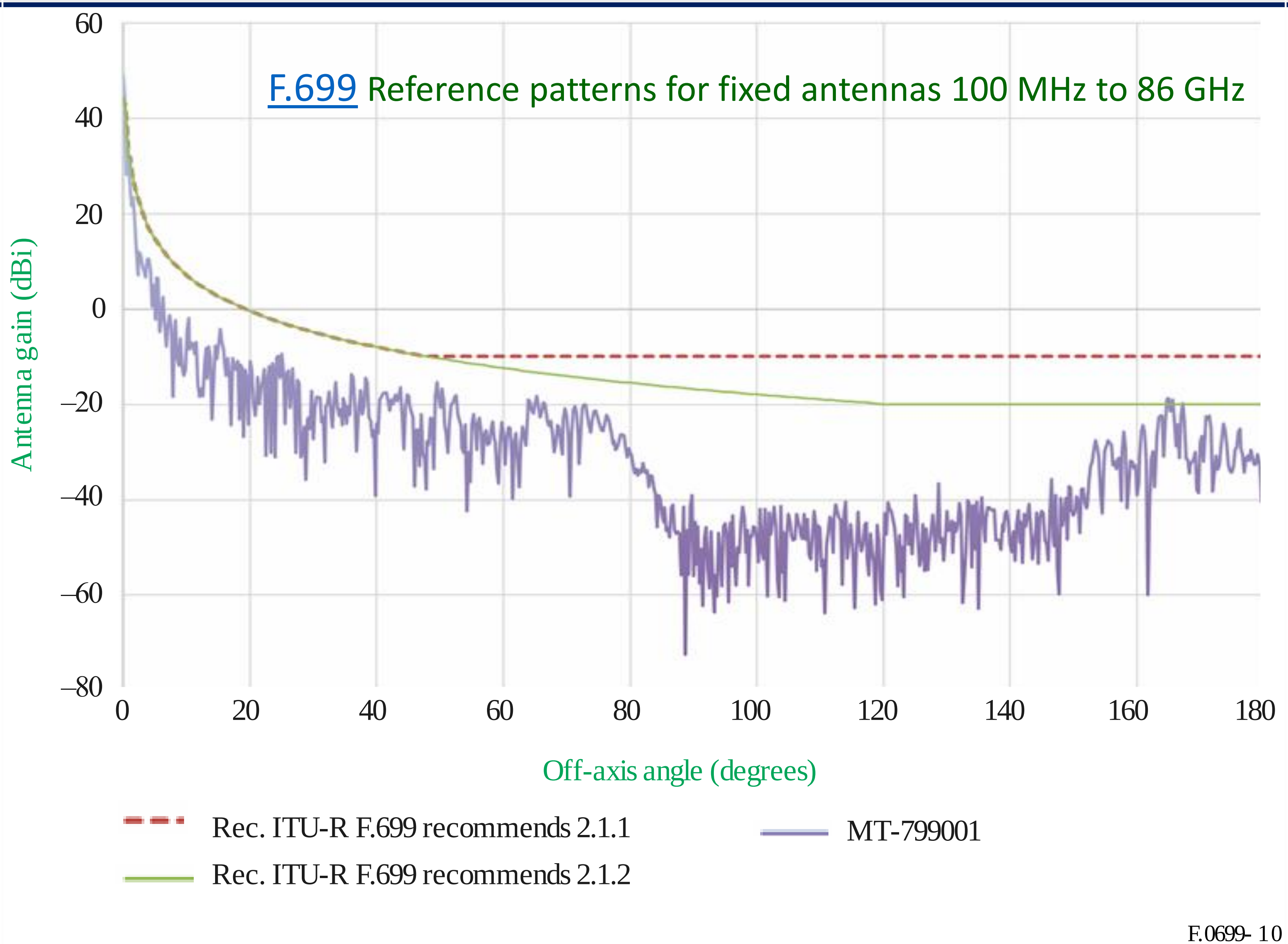
Outline

- Regulation & standardization of ant. patterns are essential to optimize the RF spectrum re-usage
- ITU, ETSI & FCC provide the most useful reference envelopes around the world; as there are no regional standards in Asia & Africa for directional point-to-point antennas. Reference envelopes defined by ITU, ETSI & FCC are adopted globally
- ETSI limits are more restrictive than FCC
- 2019 revisions of ITU patterns are significant
- New theoretical evidence for the proposed revisions of ITU Recommendations.
- Proposals to restrict FCC & to loosen ETSI standards
- Based on ITU equations, law of conservation of energy explains why:
  - higher gains are related to lower sidelobes
  - circular ant. provide deeper decay than square ant.
  - Cos illuminations provide deeper decay than uniform illumination

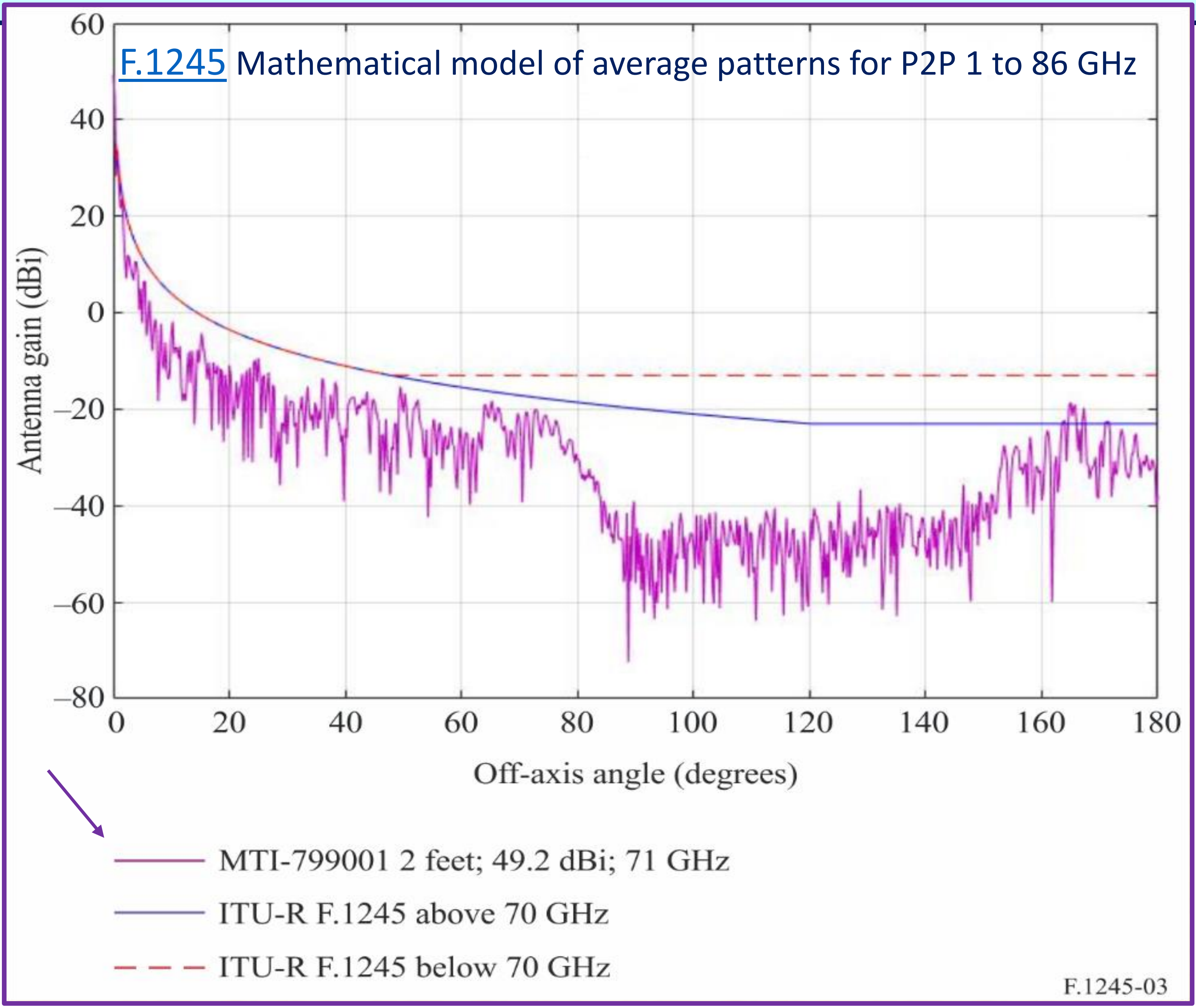
Rx_A ant sidelobe gets interference from Tx_B signal



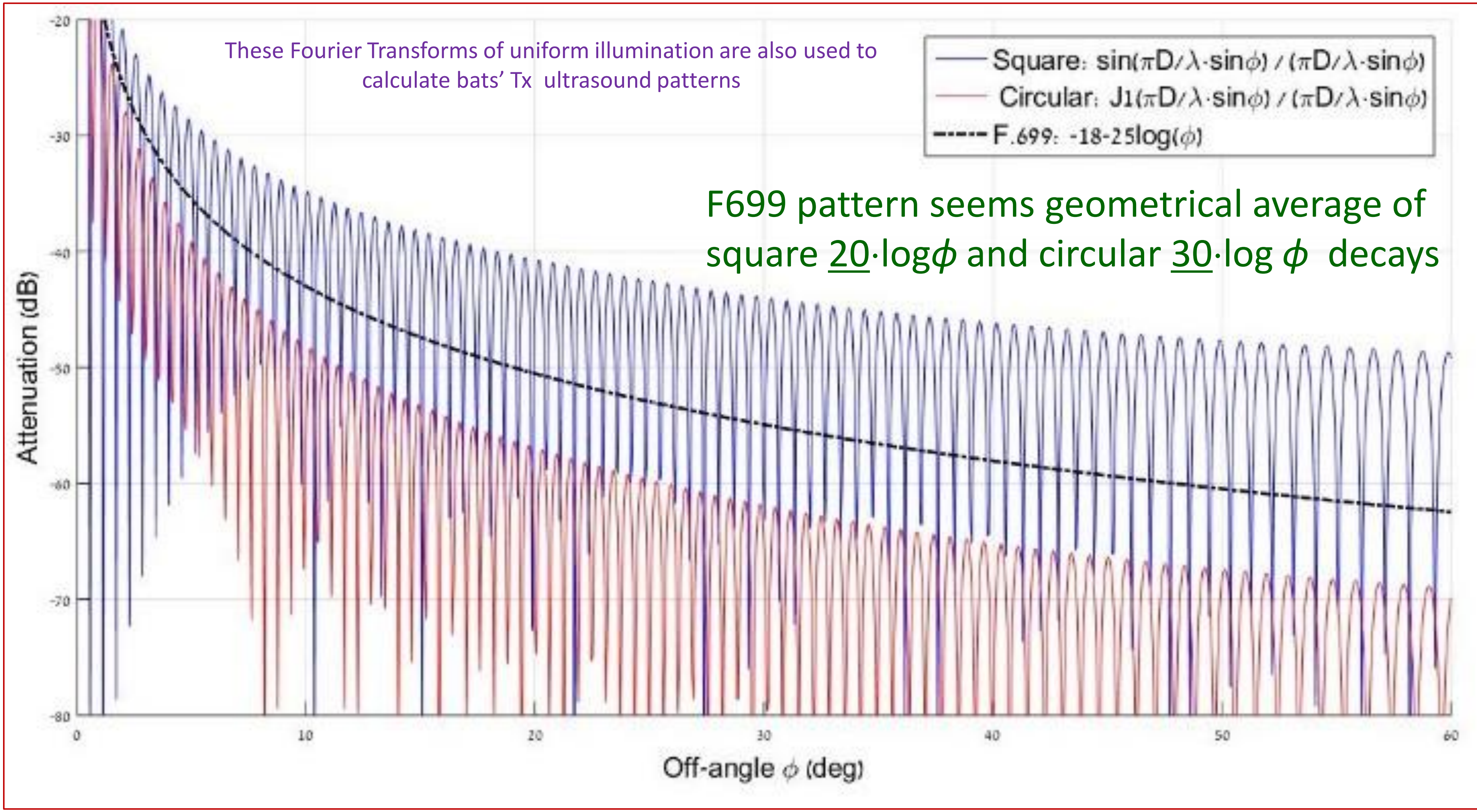
Mti-799001 (2', 49.2 dBi, 71 GHz D/λ=154 θ_3=0.5^0) after update; see off-axis above 48^0



Measured pattern at 71 GHz, vs. equations below/above 70 GHz



F.699 patterns between square & circular apertures explained **25**log φ decay for $\varphi < 120^0$



Explaining engineering relations

What are the relations between

1) higher gains & lower sidelobes (steeper decay)?

2) steeper decay & increase the 3dB beamwidth (BW)?
-for the same uniform illumination of the reflector, circular aperture provides wider beam & lower 1st sidelobe, compared to square aperture
-uniform illumination has the gentler decay?

1. For simplification, referring to circular aperture, for the same dual band antenna (same Diameter D, different λ), lower beamwidth in higher RF (higher D/λ) is related to higher gain, as the max ant gain; see F.699 *Recommends 3:* $G_{max} \sim 20 \log D/\lambda + 7.7$.

See also Balanis definition of directivity1997 p.46 [and Mazar's 2016 equation (5.32)]

$$d_0 = \frac{4\pi}{\Omega_A(steradian)} \approx \frac{4\pi}{\phi(radian)\theta(radian)} \approx \frac{4\pi}{(\lambda/D)(\lambda/D)} \approx 4\pi\left(\frac{D}{\lambda}\right)^2$$

Inserting F.699 *Rec 4.1:* $D/\lambda \sim 70/\varphi$ *in Rec 2.11*, we get $G(\varphi) = 32 - 25\log\phi = 32 - 25\log(70\lambda/D)$.

Gain (dBi) relative to 20 log(D/λ) & decay relative to 25log(70 D/ λ); hence, gain and decay are directly related

2. The uniform illuminated square aperture offers lower decay $20\cdot\log\varphi$, lower beamwidth $51\cdot\lambda/D$ (the case of MATLAB figure, precedent slide & higher gain). In the circular aperture, for the same EIRP as the square antenna, more energy is directed via a larger beamwidth $58\cdot\lambda/D$, hence, the sidelobes are lower and decay faster: $30\cdot\log\varphi$ versus $20\cdot\log\varphi$. M.1851 Table 2 (next slide) depicts how Cos illuminations relative to uniform increase ant BW & decrease 1st sidelobe at radar ant

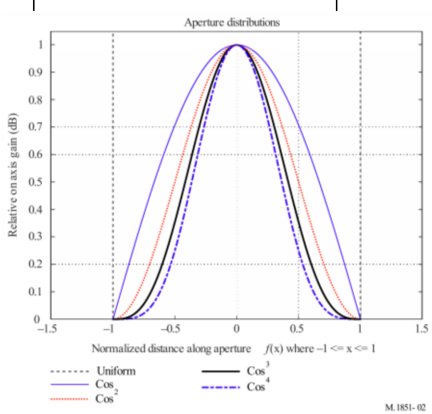
Higher anenna BW is related to higher first sidelobe and softer decay

Relations 1 & 2 can be explained by the law of conservation of energy

More analysis at Mazar's IEEE MTT 2018 Texas Symposium on Wireless & Microwave Circuits & Systems, Baylor University, April 5-6, 2018 & Mazar's Wiley 2016 book 'Radio Spectrum Management: Policies, Regulations and Techniques' Chapter 5 Section 5.5.

M.1851 Table 2 Theoretical Ant. directivity parameters

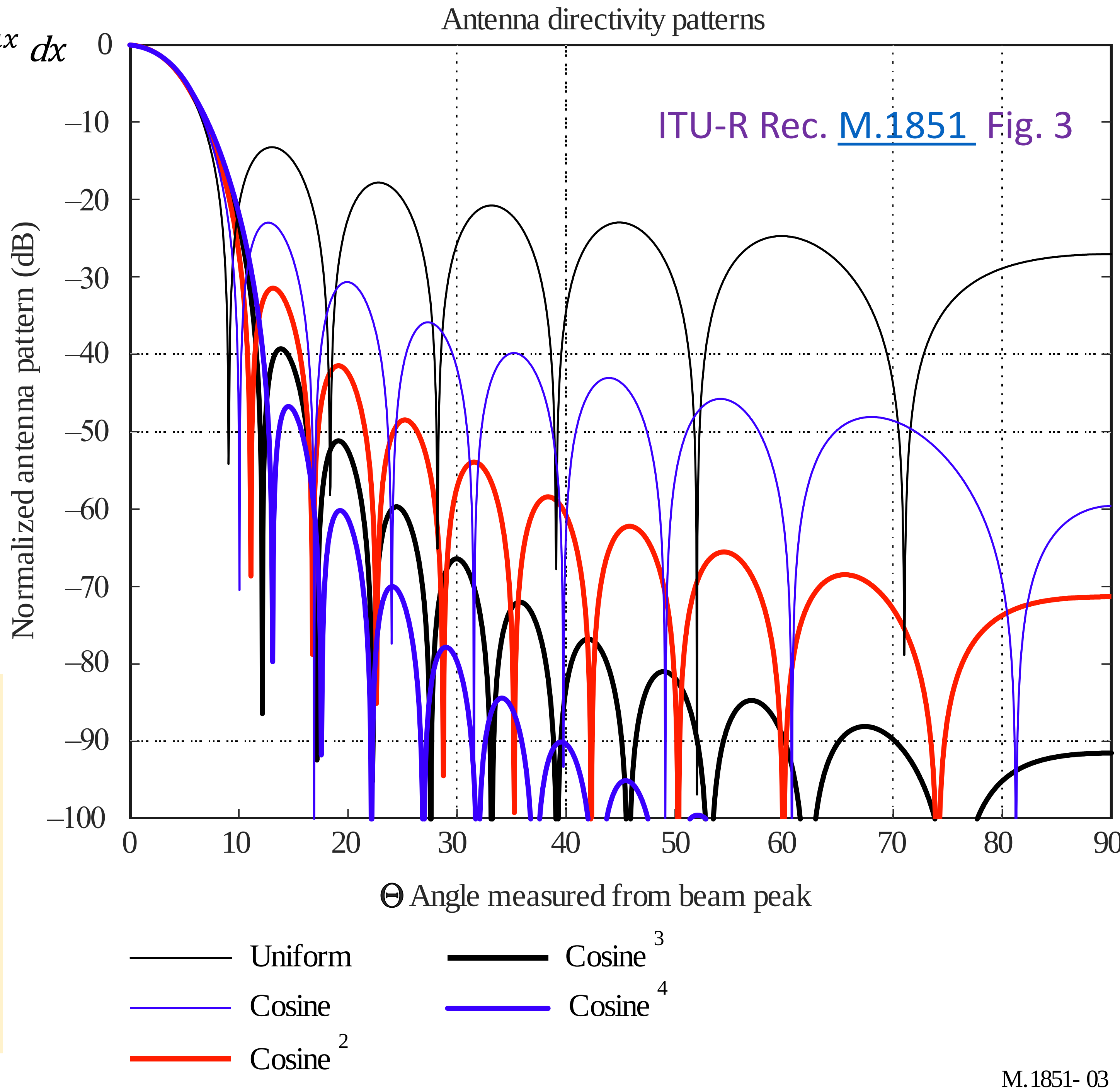
Relative shape of field distribution $f(x)$ where $-1 \leq x \leq 1$	Directivity pattern $F(\mu)$	θ_3 half power beam-width (degrees)	First side-lobe level (dB)
Uniform value of 1	$\frac{\sin(\mu)}{\mu}$	$50.8\left(\frac{\lambda}{l}\right)$	−13.2
COS($\pi * x/2$)	$\frac{\pi}{2}\left[\frac{\cos(\mu)}{\left(\frac{\pi}{2}\right)^2 - \mu^2}\right]$	$68.8\left(\frac{\lambda}{l}\right)$	−23
COS ^{2}($\pi * x/2$)	$\frac{\pi^2}{2 \cdot \mu}\left[\frac{\sin(\mu)}{(\pi^2 - \mu^2)}\right]$	$83.2\left(\frac{\lambda}{l}\right)$	−32
COS ^{3}($\pi * x/2$)	$\frac{3 \cdot \pi \cdot \cos(\mu)}{8}\left[\frac{1}{\left(\frac{\pi}{2}\right)^2 - \mu^2} - \frac{1}{\left(\frac{3 \cdot \pi}{2}\right)^2 - \mu^2}\right]$	$95\left(\frac{\lambda}{l}\right)$	−40
COS ^{4}($\pi * x/2$)	$\frac{3\pi^4 \sin(\mu)}{2\mu(\mu^2 - \pi^2)(\mu^2 - 4\pi^2)}$	$106\left(\frac{\lambda}{l}\right)$	−47



Recommendation ITU-R M.1851 'Mathematical models for radar antenna patterns for use in interference analyses': how Cos illuminations relative to uniform increase ant BW & decrease first sidelobe, at radar antennas

$$F(\mu) = \frac{1}{2}\int_{-1}^{+1} f(x) \cdot e^{j\mu x}\, dx$$

$$\mu = \pi \left(\frac{l}{\lambda}\right) \sin(\theta)$$

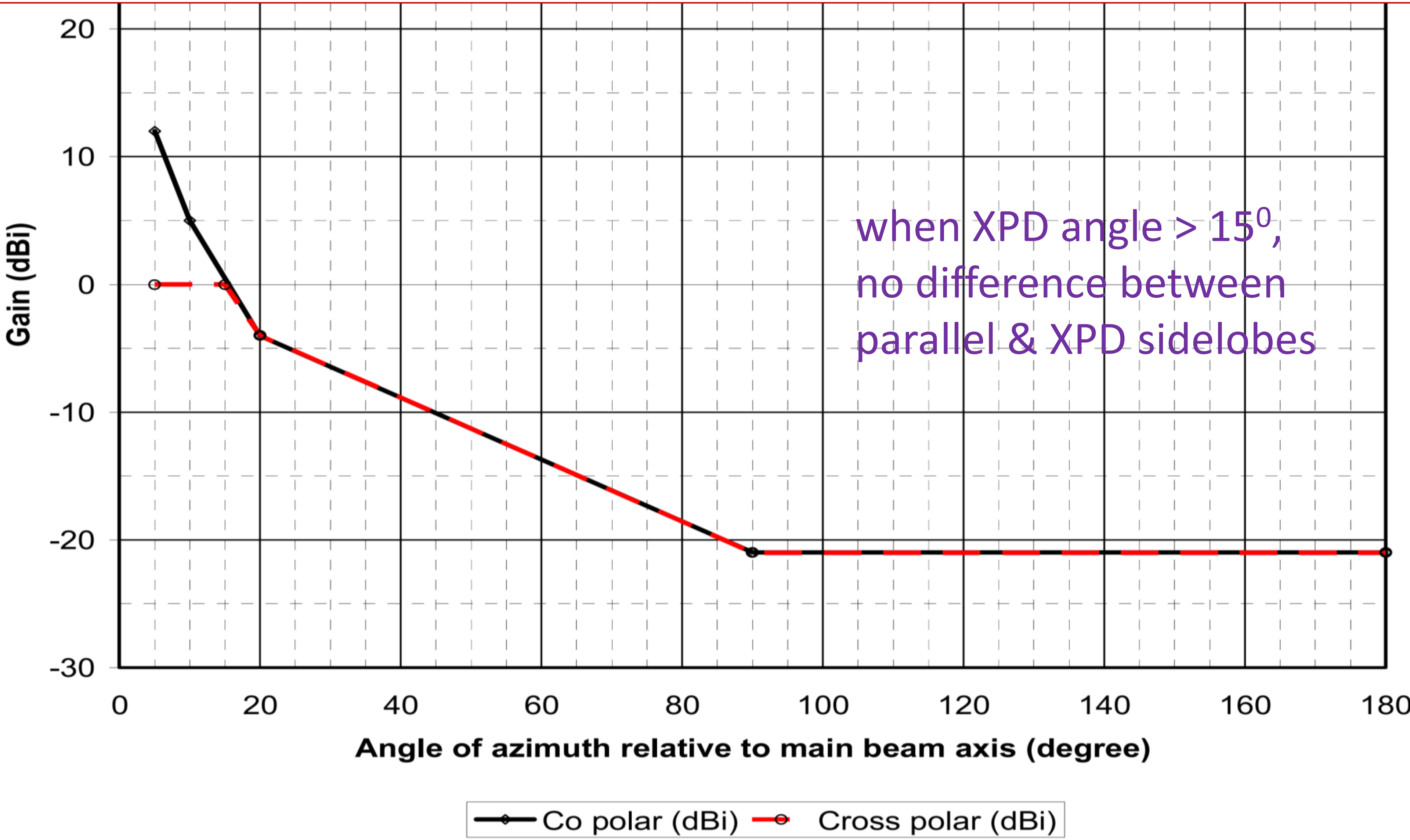


For the same ant. 3 dB beamwidth 6.0⁰, uniform illumination provides gentler decay, relative to Cosine's illuminations

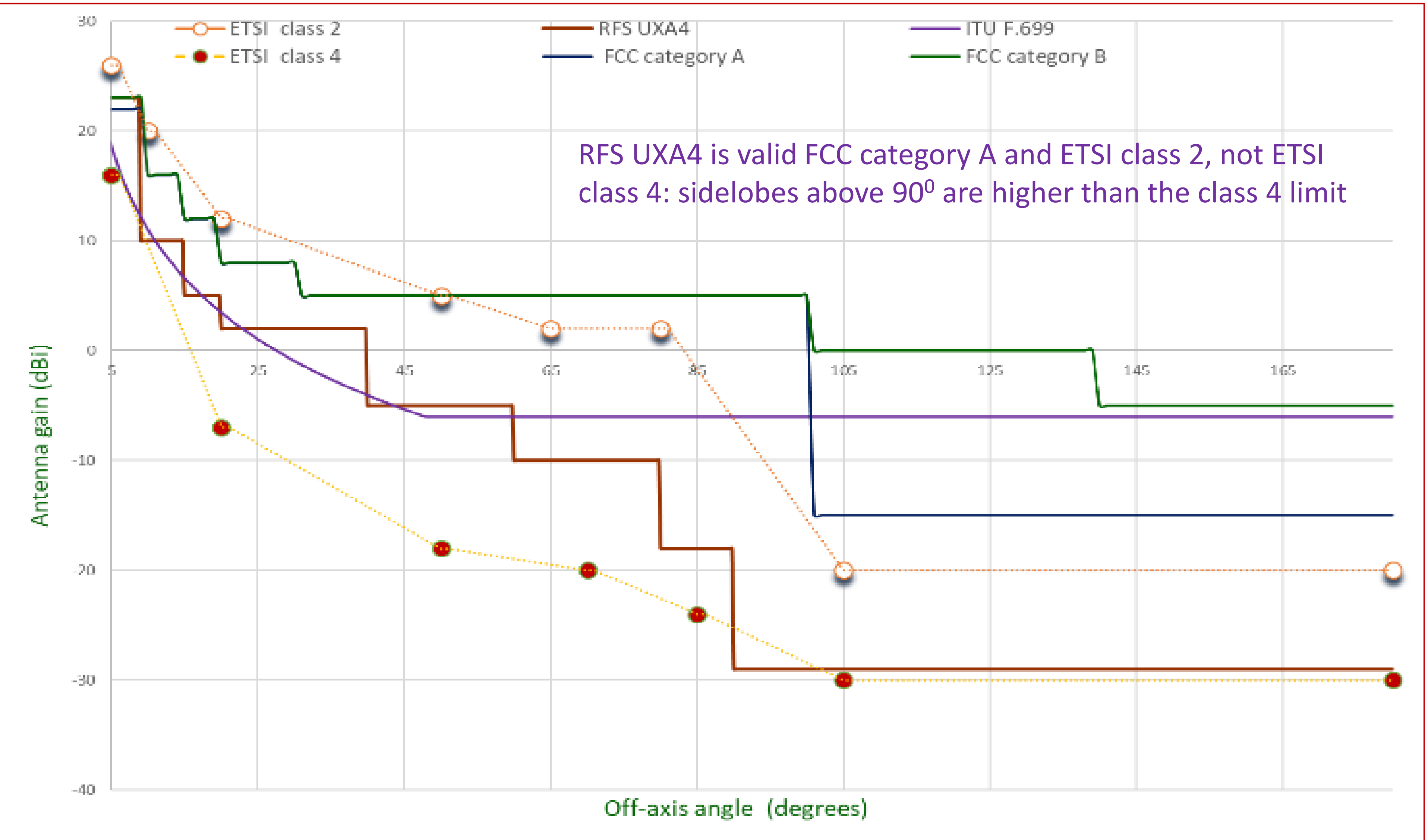
symmetric pattern

prepared by SCE students: Tamir, Aflalo, Elya

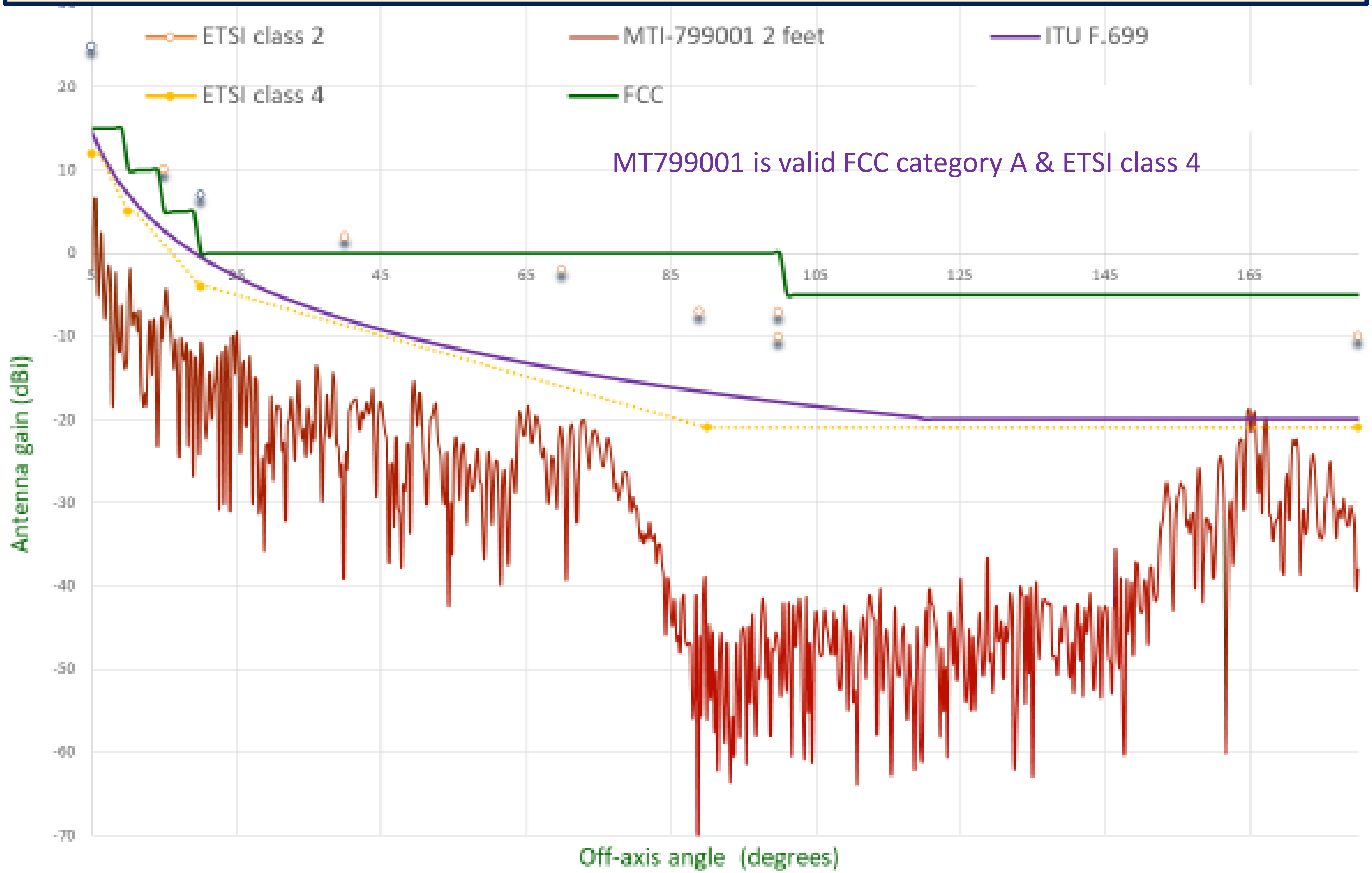
ETSI RPEs for class 4 antennas in 71– 86 GHz



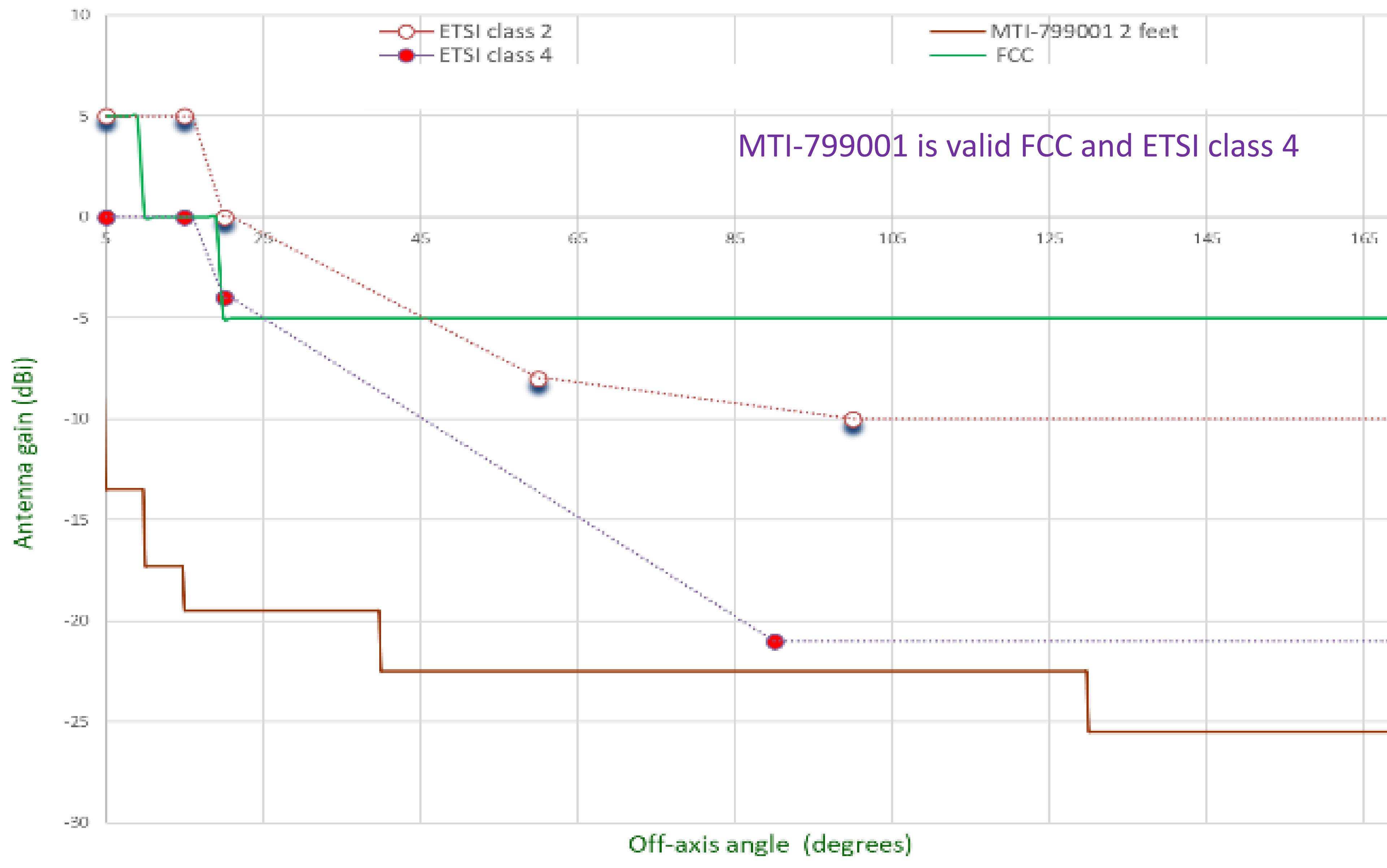
Co-polar ant. patterns; **10.6** GHz; ITU F.699 , ETSI EN 302 217-4, FCC §101.115 Directional antennas vs. RFS-UXA4

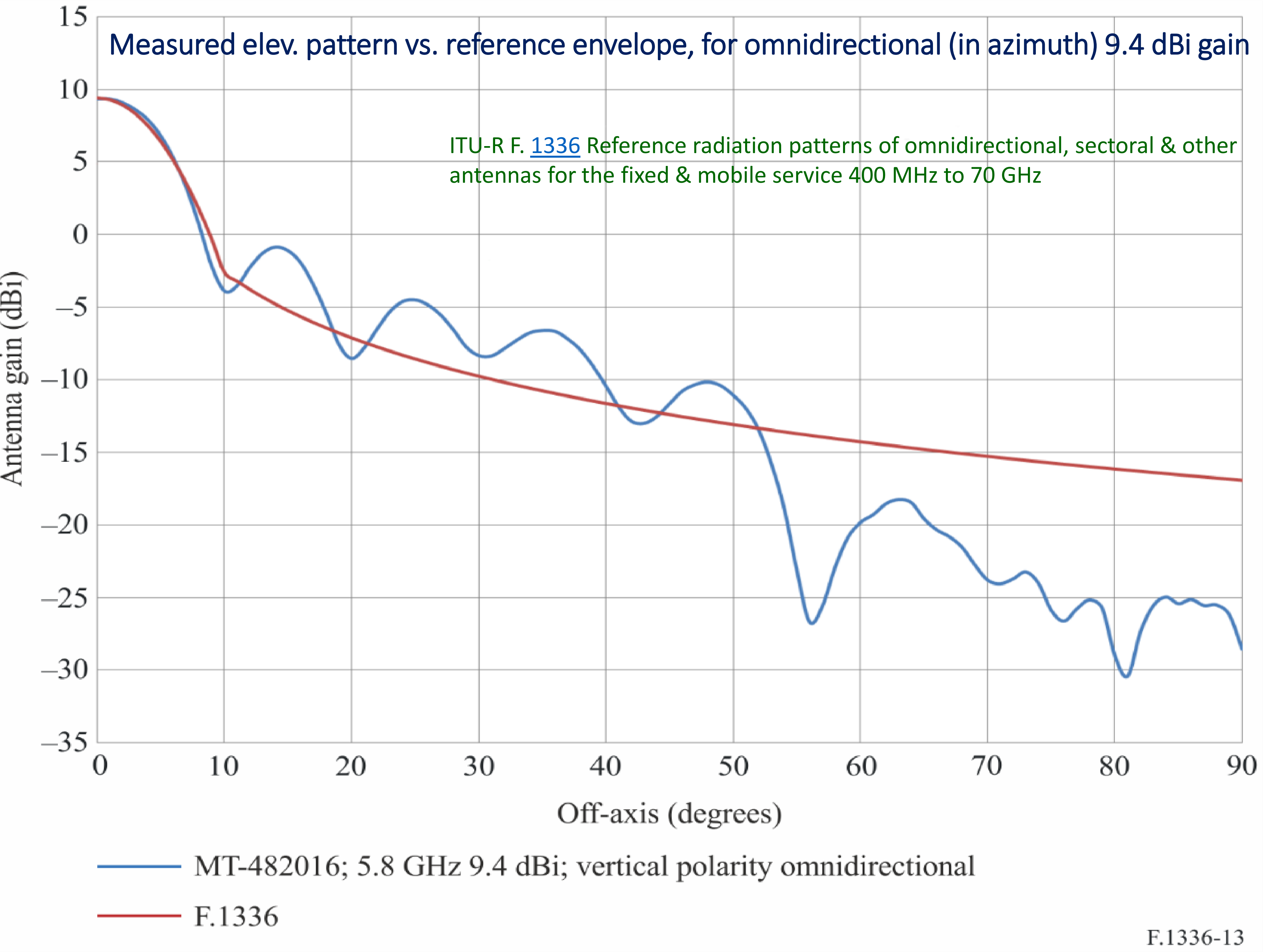


CP; **72 GHz**; ITU, ETSI, FCC, MT-799001



XPD; 72 GHz; ETSI, FCC, measurement




Measured elev. pattern vs. reference envelope, for omnidirectional (in azimuth) 9.4 dBi gain
ITU-R F. 1336 Reference radiation patterns of omnidirectional, sectoral & other antennas for the fixed & mobile service 400 MHz to 70 GHz
Antenna gain (dBi)
15
10
5
0
–5
–10
–15
–20
–25
–30
–35
0
10
20
30
40
50
60
70
80
90
Off-axis (degrees)
MT-482016; 5.8 GHz 9.4 dBi; vertical polarity omnidirectional
F.1336
F.1336-13

Summary

- Similar to US policy of '*laissez faire laissez passer*' for Tx spurious emissions (& RF-EMF from base stations), for antenna patterns, Europe is more restrictive than USA & Japan
- Europe having many borders among countries (relative to US & Japan) & Europe being more population condensed than US
- US real antenna patterns are more restrictive than FCC masks; Americas may aim to category A limits
- More restrictive 2019 ITU Recommendations F.699 and F.1245 envelopes, proposed by the author, offer improved spectrum sharing (also for 5G backhaul networks), while maintaining system performance & implementation feasibility
- Explanations provided to the relations ant. gain & decay of sidelobes

Questions? U may visit my website http://mazar.atwebpages.com/