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ASSESSING THE IMPACT OF WIND FARMS ON AERONAUTICAL RADAR SYSTEMS

Tuesday 28 April 2026

11:00 – 12:00 UTC

MODERATOR

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Safety Programme Manager

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PRESENTER

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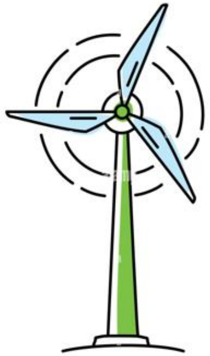

Impact of Wind Farms on Radars

By Yahya Khaled – GM, ATDI Limited

April 2026

A technical webinar on wind turbine interference with primary and secondary surveillance radars

Welcome to ATDI

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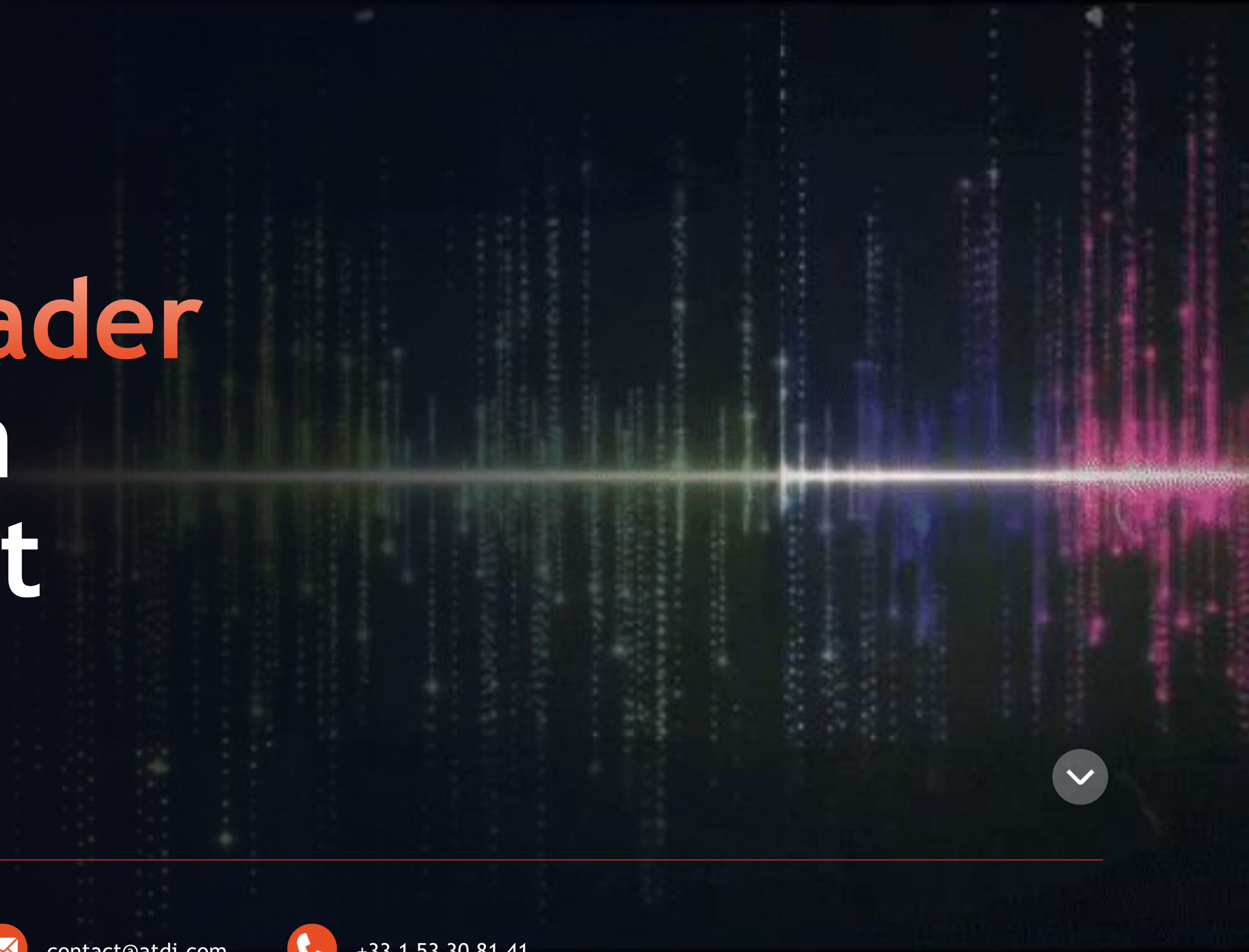

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Agenda

- Introduction & context — wind energy expansion and radar impact
- Radar fundamentals — PSR vs SSR, bands, receiver behaviour
- Mechanisms of wind turbine interference — reflection, shadowing, Doppler
- Operational impact on air traffic surveillance
- Assessment approaches — screening vs detailed analysis
- EUROCONTROL PSR/SSR quick assessment framework
- NTIA TR-08-454 and the combined methodology
- Modelling techniques and a detailed impact study
- Mitigation options and key takeaways

Why this matters – renewables meet airspace

- Wind capacity is scaling fast – national plans target tens of GW of wind near existing radar infrastructure
- Turbines within radar line of sight can generate clutter, false targets, tracking instability, and coverage loss
- UK MoD flight trials (2005) and US DoD report (2006) first quantified the operational effects
- EUROCONTROL GUID-0130 (2014) and NTIA TR-08-454 (2008) are the reference assessment frameworks
- The engineering is well understood – structured assessment lets wind and aviation coexist safely

Radar fundamentals – PSR vs SSR

- Primary Surveillance Radar (PSR) – transmits RF energy and detects the **reflected** return from the target skin
- Relies on target radar cross section; vulnerable to any reflected energy from the environment
- Secondary Surveillance Radar (SSR) – interrogates an aircraft transponder on 1030 MHz; receives coded reply on 1090 MHz
- Does not rely on reflected energy – but interrogation and reply paths can still be blocked or reflected
- PSR and SSR are differently susceptible to wind turbine interference – the assessment must treat them separately. PSR/SSR often co-located.

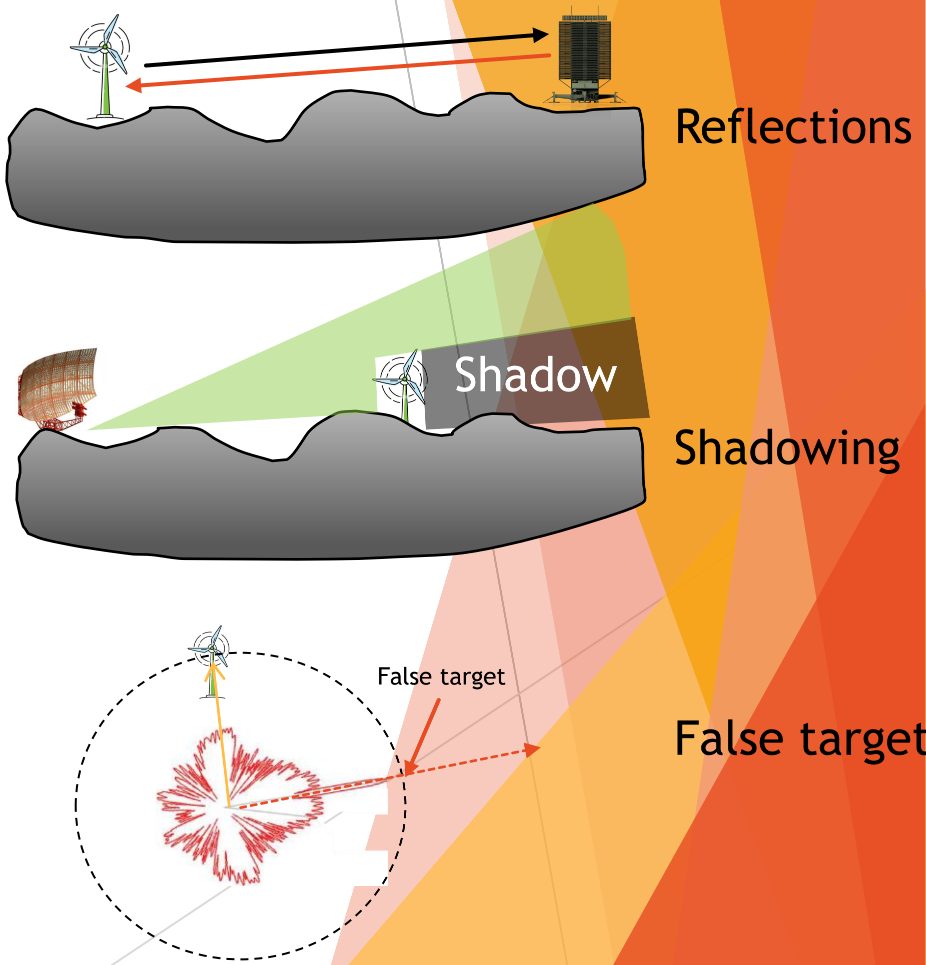
Radar bands – primary radar services (radionavigation)

- Long range 23cm **(L-band)** radar (*Good propagations, big targets*)
  - 1215 – 1300MHz Radionavigation (Primary allocation)
  - 1300 – 1350MHz Aeronautical Radionavigation (Primary allocation)
- Medium range 10cm **(S-band)** radar
  - 2700-2900 MHz Aeronautical Radionavigation (Primary allocation)
  - 2900-3100MHz Radionavigation (Primary allocation)
- Short Range Precision 3cm **(X-band)** radar
  - 9000 – 9200MHz Aeronautical Radionavigation (primary allocation)
  - 9300 – 9500 MHz Radionavigation (Primary allocation)

Smaller wave-length means higher RCS for the same target and typically lower range.

How wind turbines interact with radar

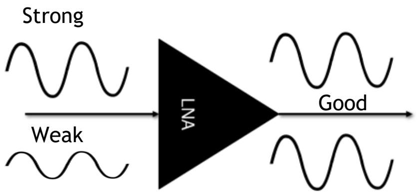
- Reflection and I/N degradation — turbine RCS raises the local noise floor, lifting the detection threshold
- False target generation — direct echoes from the tower and blades, and ghost targets via multipath (*main and side lobes*)
- Shadow zone and beam blockage — two-way path attenuation creates a wedge of reduced detection behind the turbine
- Doppler contamination — rotating blades produce Doppler returns that slip through MTI/MTD filters as false moving targets
- Receiver and processing overload — strong returns or high false-plot counts can saturate the receiver or overwhelm the tracker



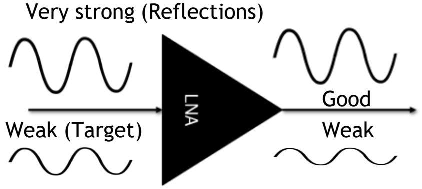
Receiver behavior – AGC (saturation)

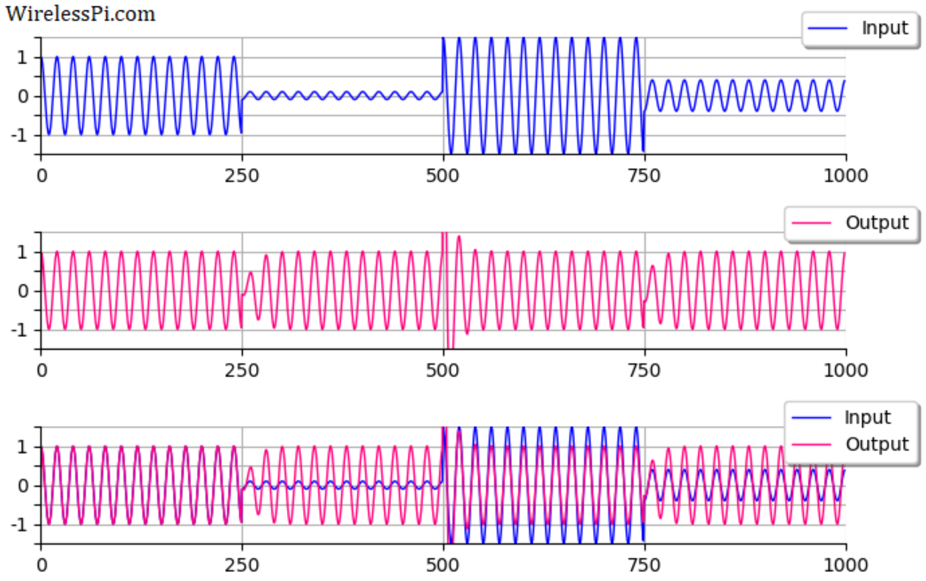
- Hardware level
- Adaptive gain – detect weak signal and deal with strong signals
- Saturation/overload

Wanted



Wanted + Unwanted

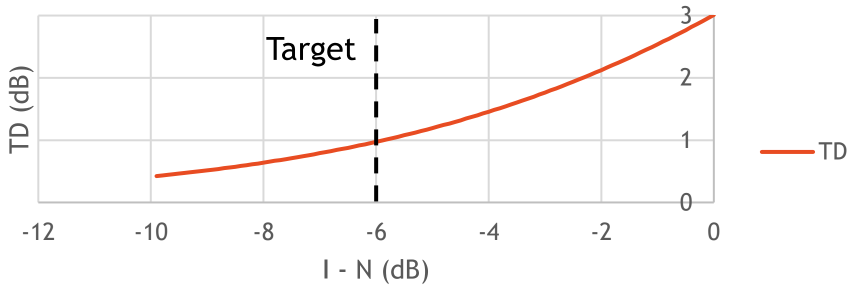


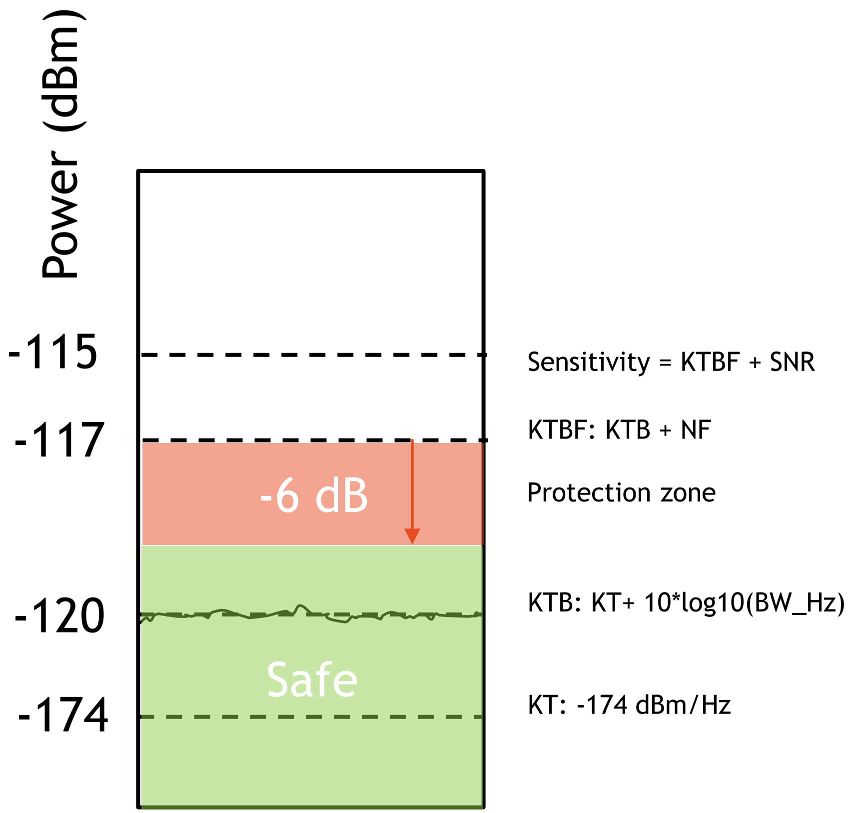


Receiver behavior – Noise degradation

- Noise/threshold degradation
- N = KTBF
  - KT: -174 dBm/Hz
  - B: Receiver bandwidth (1/Pulse duration)
  - F: Noise figure
- I/N = I (dBm) – N (dBm)
- $TD(dB) = 10\ x\ Log_{10}(1 + 10^{\frac{I/N}{10}})$
- Degradation > loss of sensitivity > loss of range

Threshold degradation calculations





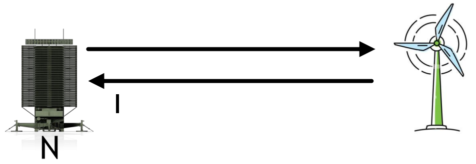
Sensitivity = KTBF + SNR

KTBF: KTB + NF

Protection zone

KTB: KT+ 10*log10(BW_Hz)

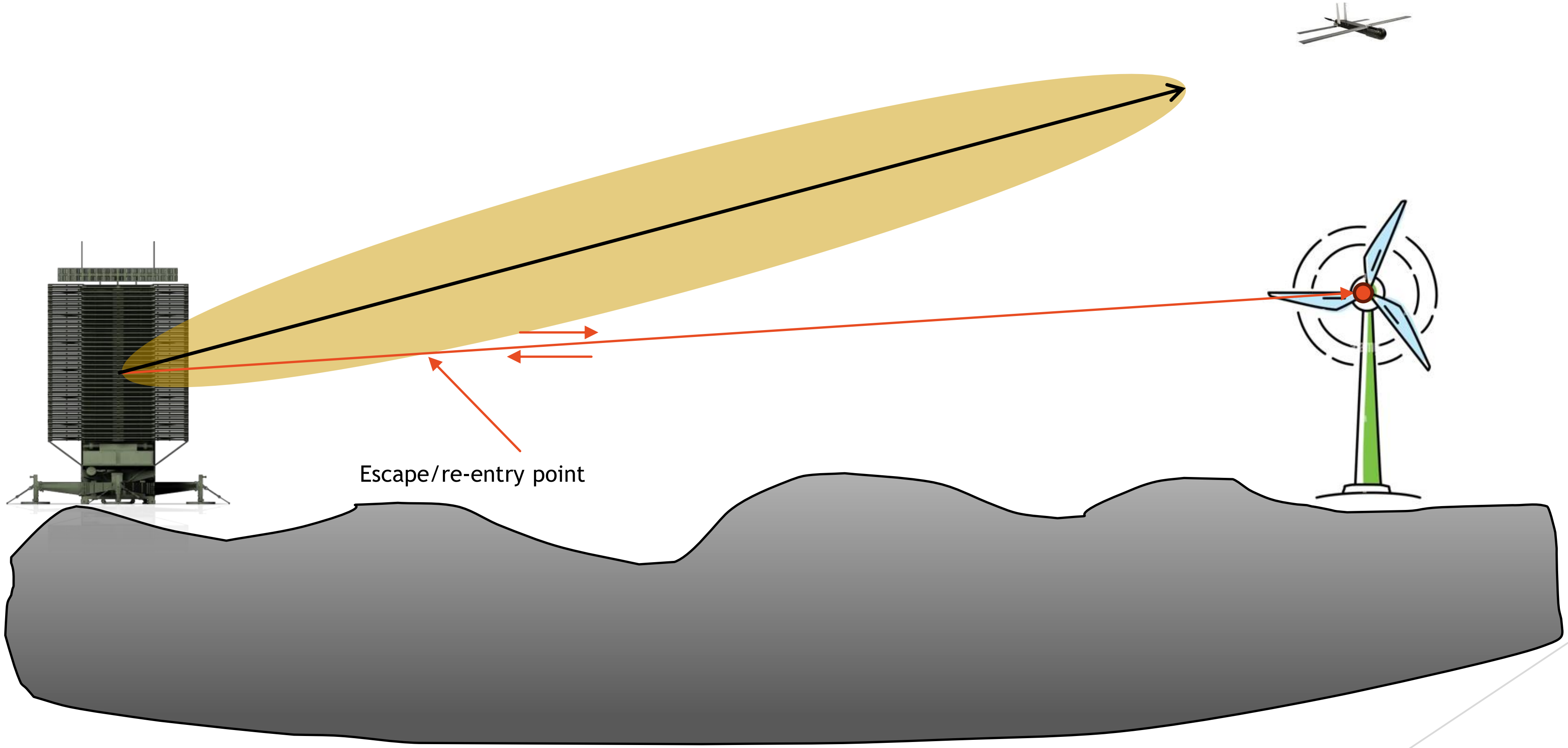
KT: -174 dBm/Hz



Receiver behavior

- Noise floor and detection threshold — set above receiver thermal noise to control false alarms
- CFAR (Constant False Alarm Rate) — threshold adapts locally to keep false-alarm probability constant in varying clutter
- MTI / MTD filters — suppress stationary returns by comparing successive pulses in the time or Doppler domain
- Doppler discrimination — moving targets pass the filter; stationary terrain and buildings are rejected
- Plot extractor and tracker — group detections into plots and tracks; have finite processing capacity

Radar antenna radiation pattern - relevance



Antenna discrimination in the direction of WT can be computed from vertical antenna pattern

Radar antenna radiation patterns

Modern air-defense radars use phased-array antennas — a grid of radiating elements whose individual phases and amplitudes set the beam shape.

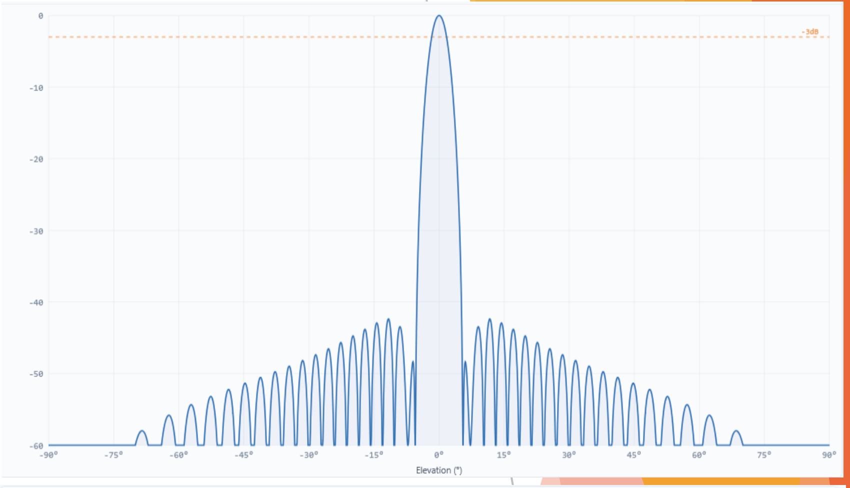
The radiation pattern — main lobe width, sidelobe levels and gain — is determined by the number of elements, their spacing, amplitude tapering and element pattern.

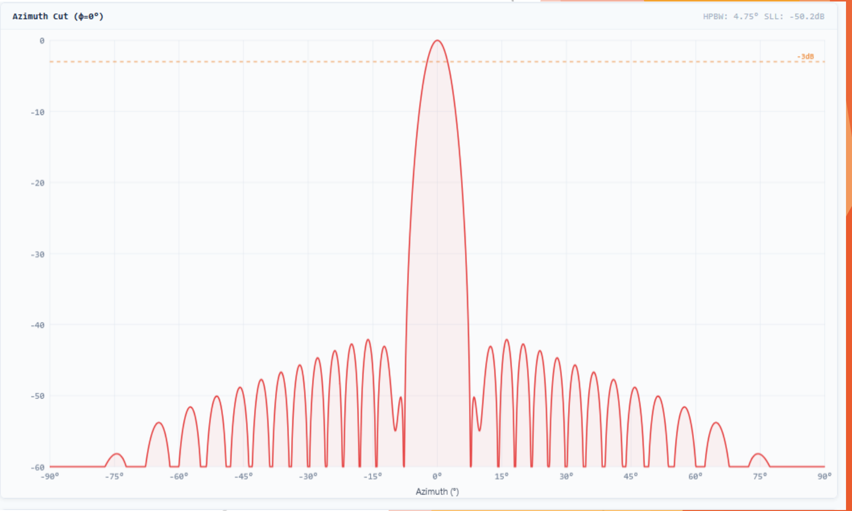
Key parameters drive the result:

- Element count (Nx × Ny) — sets aperture and peak gain
- Spacing (typically 0.5 λ) — avoids grating lobes
- Amplitude taper — trades sidelobe level against beamwidth

Patterns matter for this assessment: the vertical 3 dB beamwidth sets the shadowing clearance criterion, and the sidelobe level bounds off-axis reflection susceptibility.

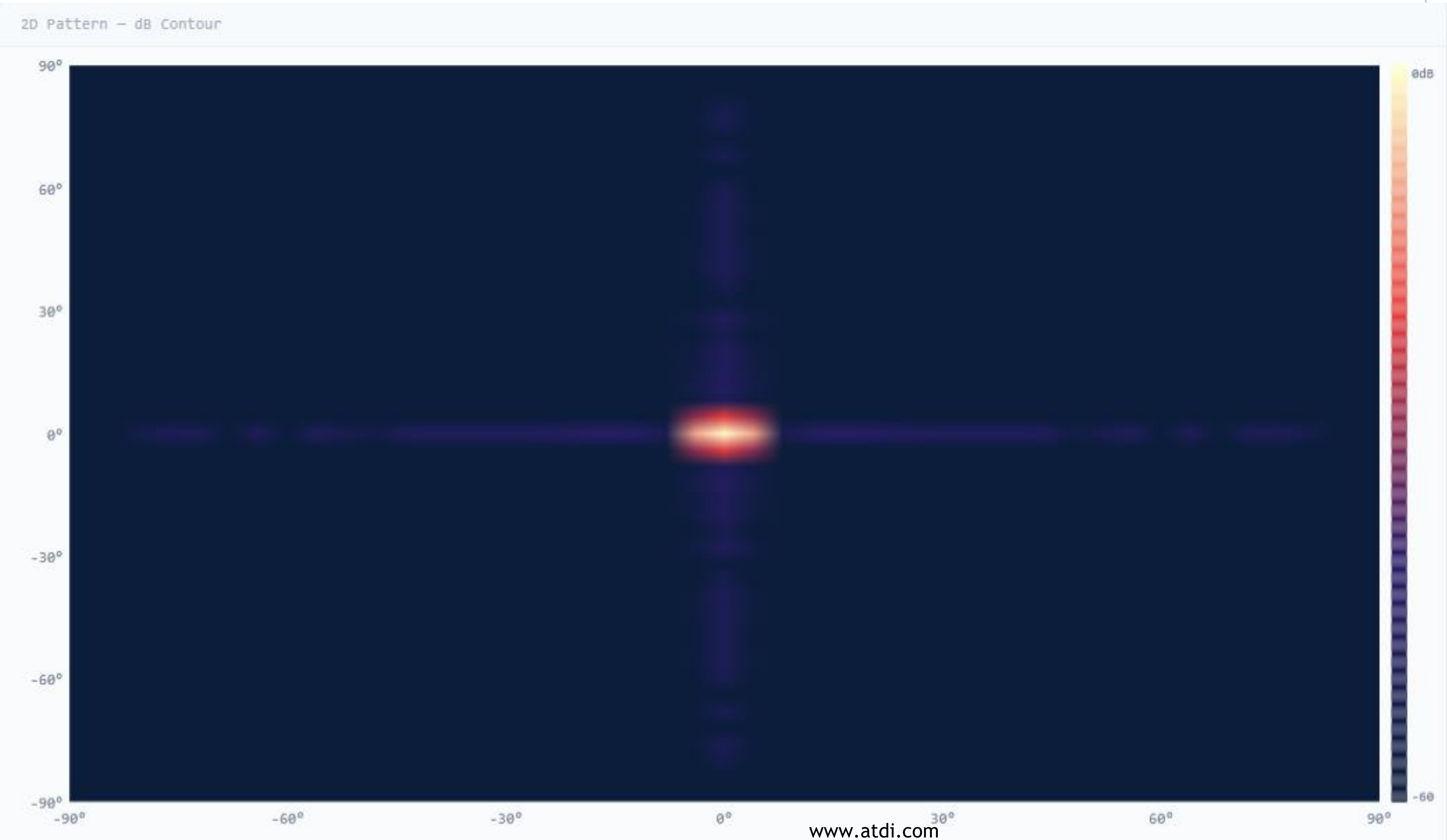
Radar	Spacing (λ)	Vert. elements	Horiz. elements
FPS-117	0.5	44	32
TPS-77	0.5	34	32
TPS-78	0.5	22	48
GM200	—	30	40



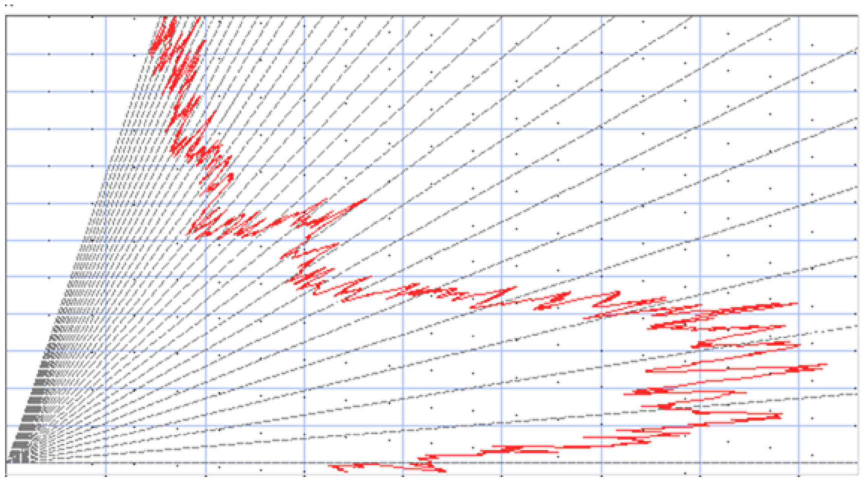


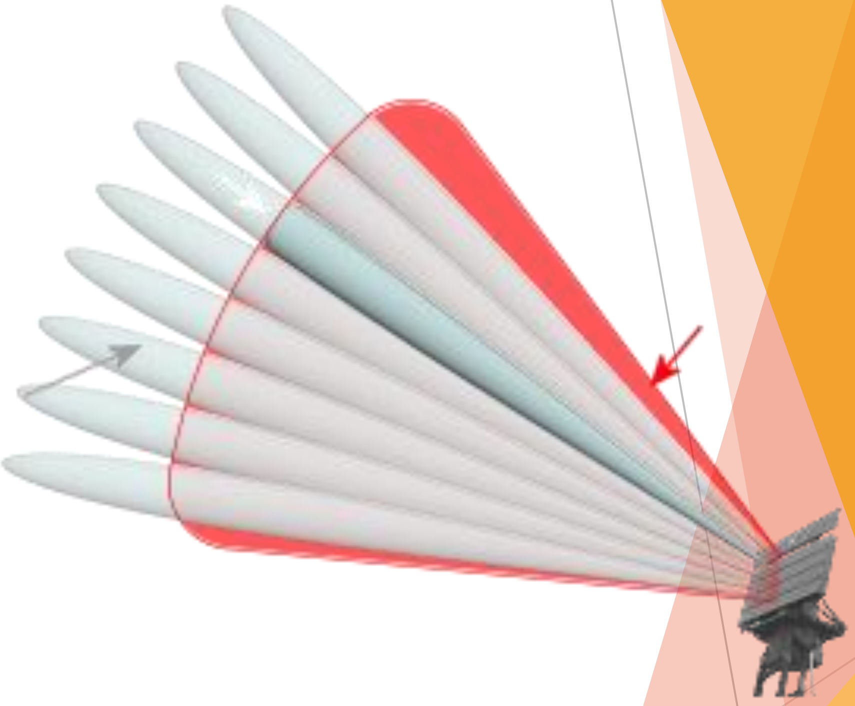
radar_pattern_tool.html

2D: main beam, side lobes



ATC Radars Vs modern radars





- Single broad vertical beam – single collision domain
- Multi-beams (Pencil beams) – multi collision domain
- Mitigation ready

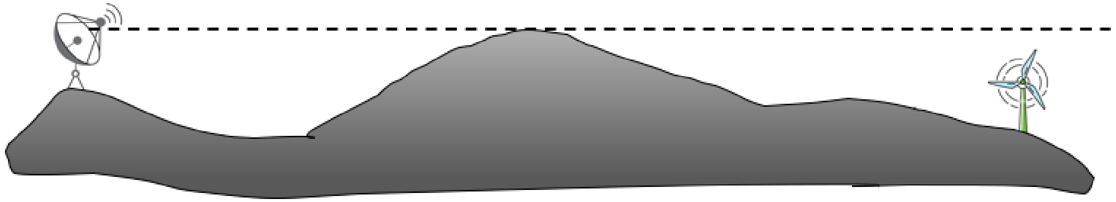
Propagation model

- Free space loss
- Visibility (FSL or nothing, K factor 1.33)
- Area – sub-path attenuation

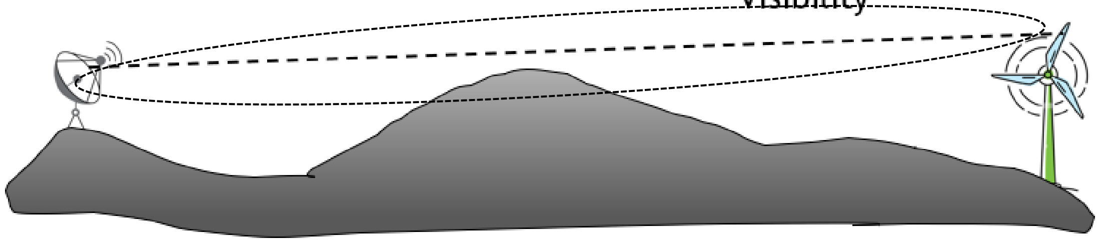
$$L_{sp} = 6.4 + 20 \log_{10}[v + \sqrt{(1 + v^2)}]$$

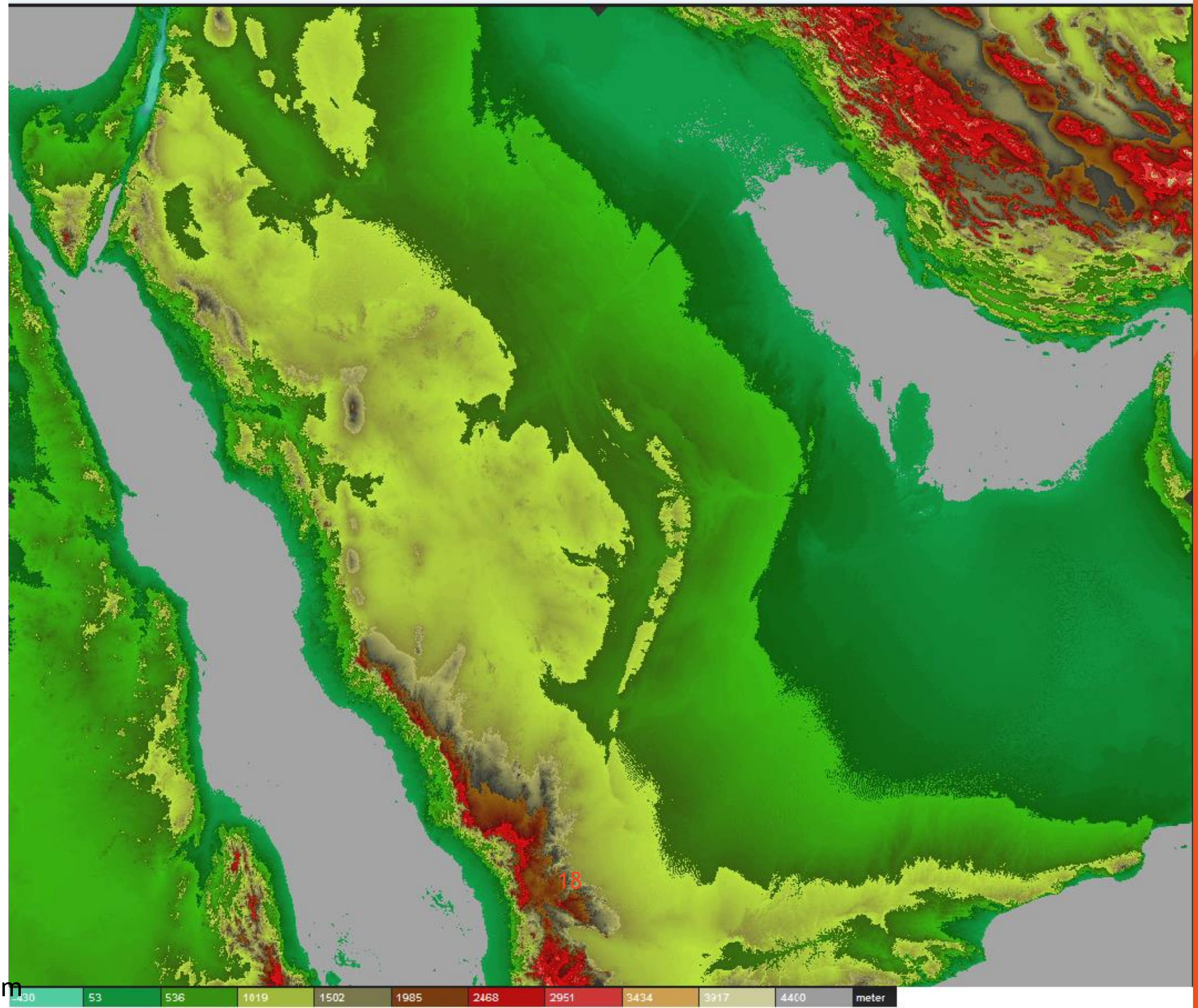
$$v = \sqrt{2} \cdot (H / R)$$

No visibility



Visibility



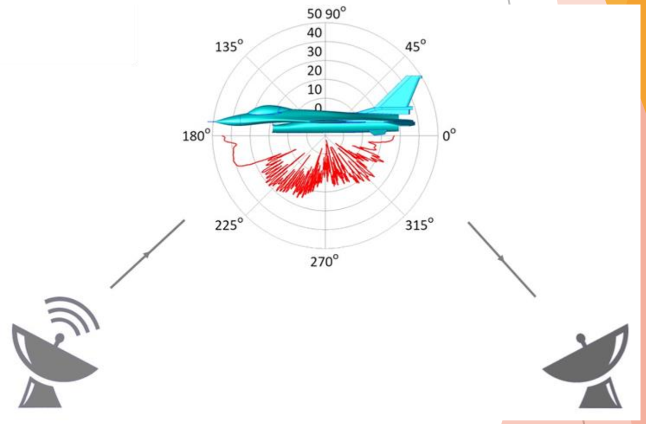


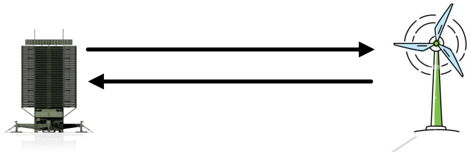
Bistatic geometry and self-interference

- Bistatic radar — transmitter and receiver at different locations, linked by a common scattering target (the wind turbine)
- The bistatic radar equation, expressed in logarithmic (dB) form as a link budget:

$$P_r[dBm] = P_t + G_t + G_r + \sigma_b - 20\,log_{\{10\}(f_{\{MHz\}})}$$
$$- 20\,log\_\{10\}(R\_\{1,km\}) - 20\,log\_\{10\}(R\_\{2,km\}) - L$$
$$- 103.4$$

- Self-interference — the radar's own transmission bounces off the turbine back to the same receiver, so R_1 = R_2 and Gt = Gr
- The monostatic collapse doubles the path loss (2·FSL) — this is the dominant term driving the I/N calculation





Wind Turbine RCS Prediction

- Frequency, rotation and angle dependent
- Higher frequency is higher RCS
- Bigger size is bigger RCS

Parameter	L-Band	S-Band
Reference measured RCS (dBsm), 113 m rotor	40	48
Scaled RCS, 200 m rotor (dBsm)	44.6	52.5
Scaled RCS, 200 m rotor (m²)	28,916	176,367

$$\sigma_{\text{target}} = 10 \cdot \log_{10}\left(10^{\frac{\sigma_{\text{ref}}}{10}} \cdot \left(\frac{D_{\text{target}}}{D_{\text{ref}}}\right)^{2} \cdot \frac{f_{\text{target}}}{f_{\text{ref}}}\right) \; [dBsm]$$

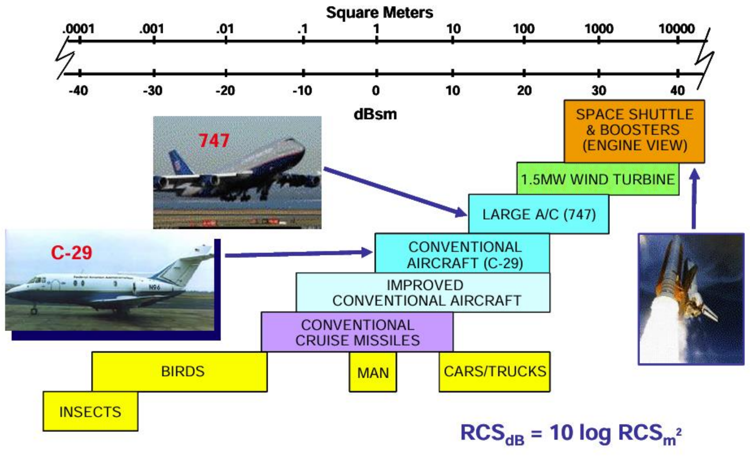
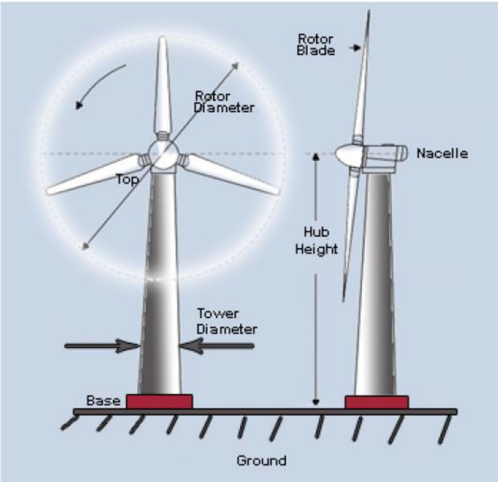
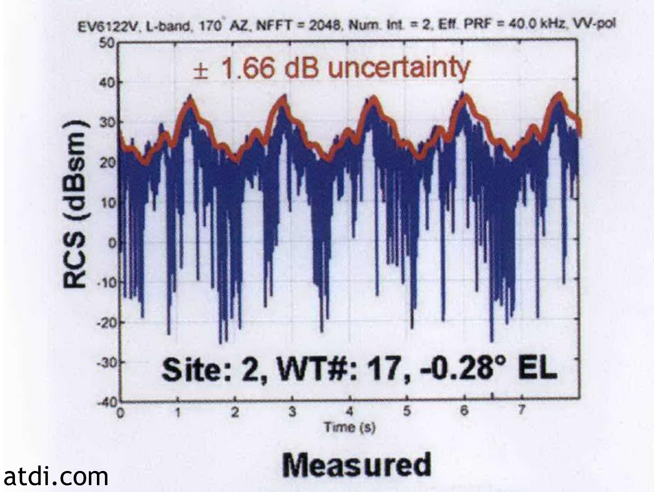


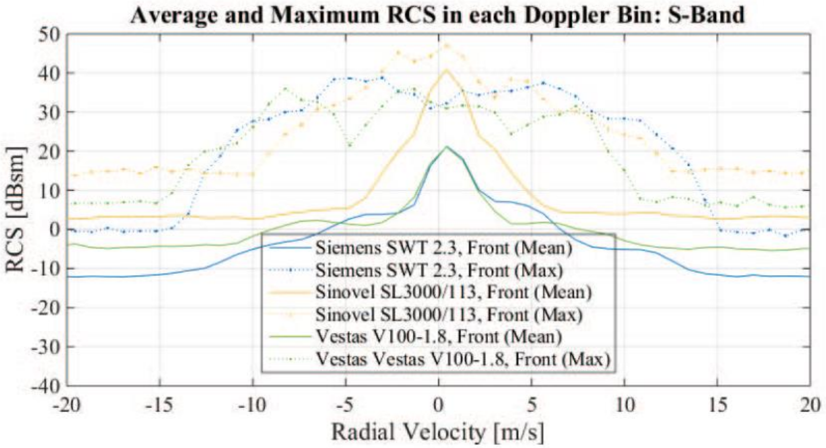
Figure 7. RCS values for several common objects

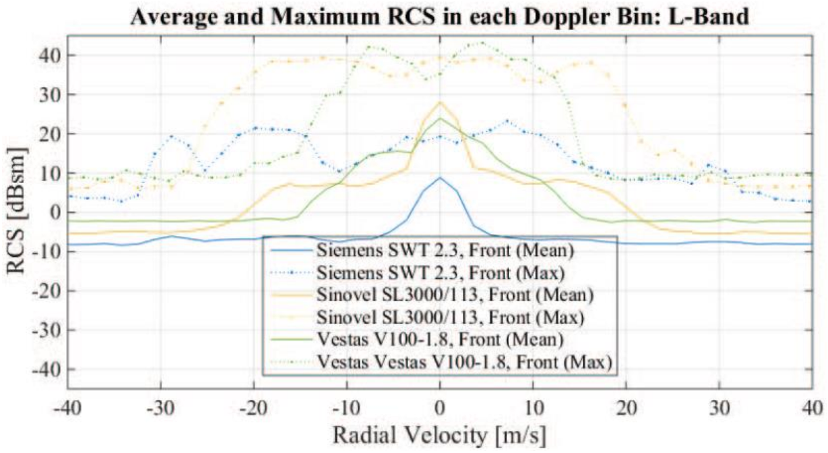




130 m 146.5 m 130-200 m
2.3 MW 3.0 MW 1.8 MW

Fig. 2. a) Siemens SWT 2.3 MW b) Sinovel SL3000/113-HH90 c) Vestas V100-1.8 MW.



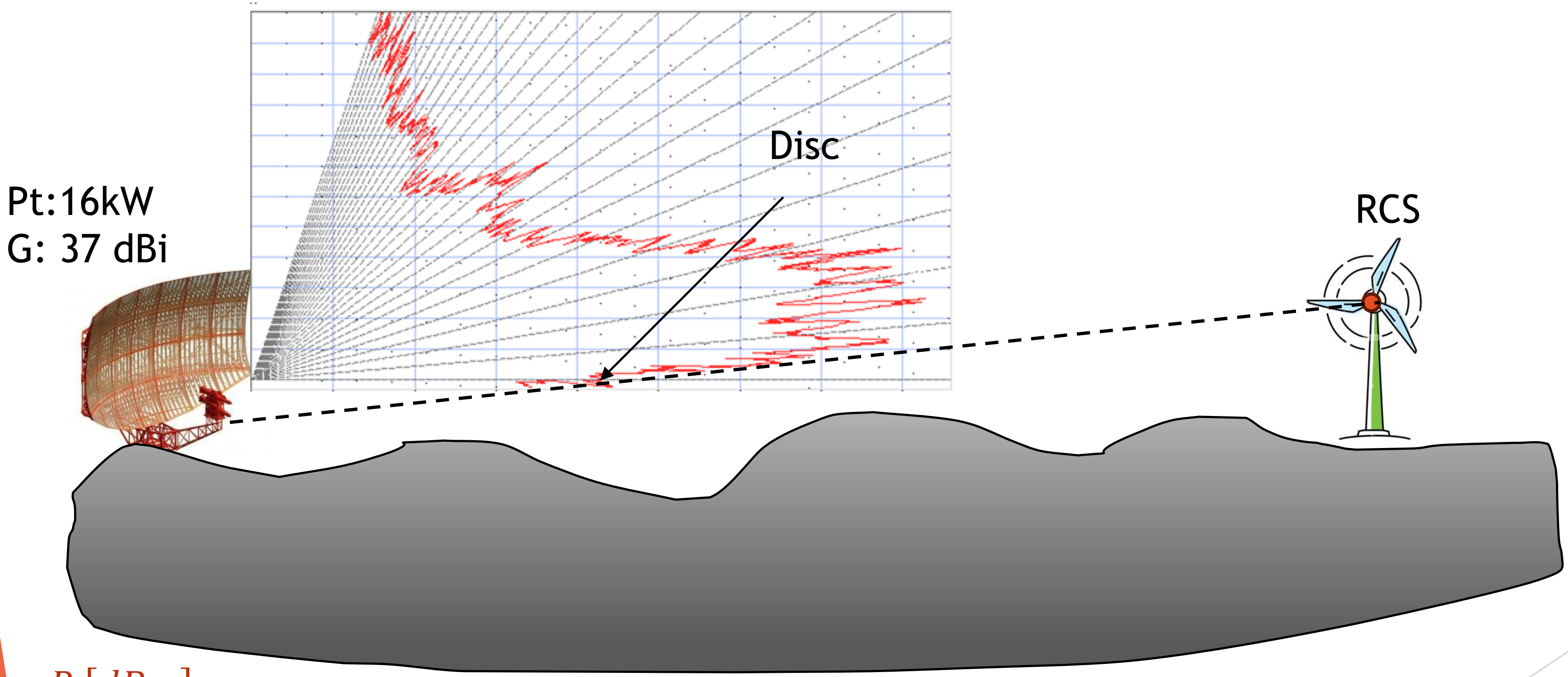


Source: Comparison of the Recorded RCS and Spectra of Three Different Wind Turbines on L- and S-band

Measured RCS

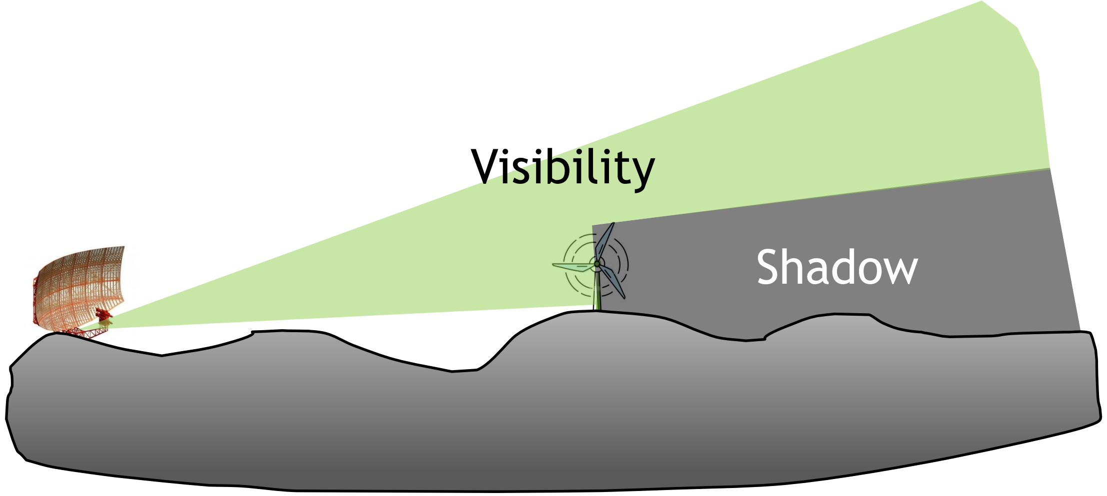
- Industrial sized wind turbines and corresponding RCS measurements

Reflection and I/N degradation



$$P_r[dBm] = P_t + G_t + G_r + \sigma_b - 20\, log_{\{10\}(f_{\{MHz\}})} - 20\, log\_\{10\}(R\_\{1,km\}) - 20\, log\_\{10\}(R\_\{2,km\}) - L - 103.4$$

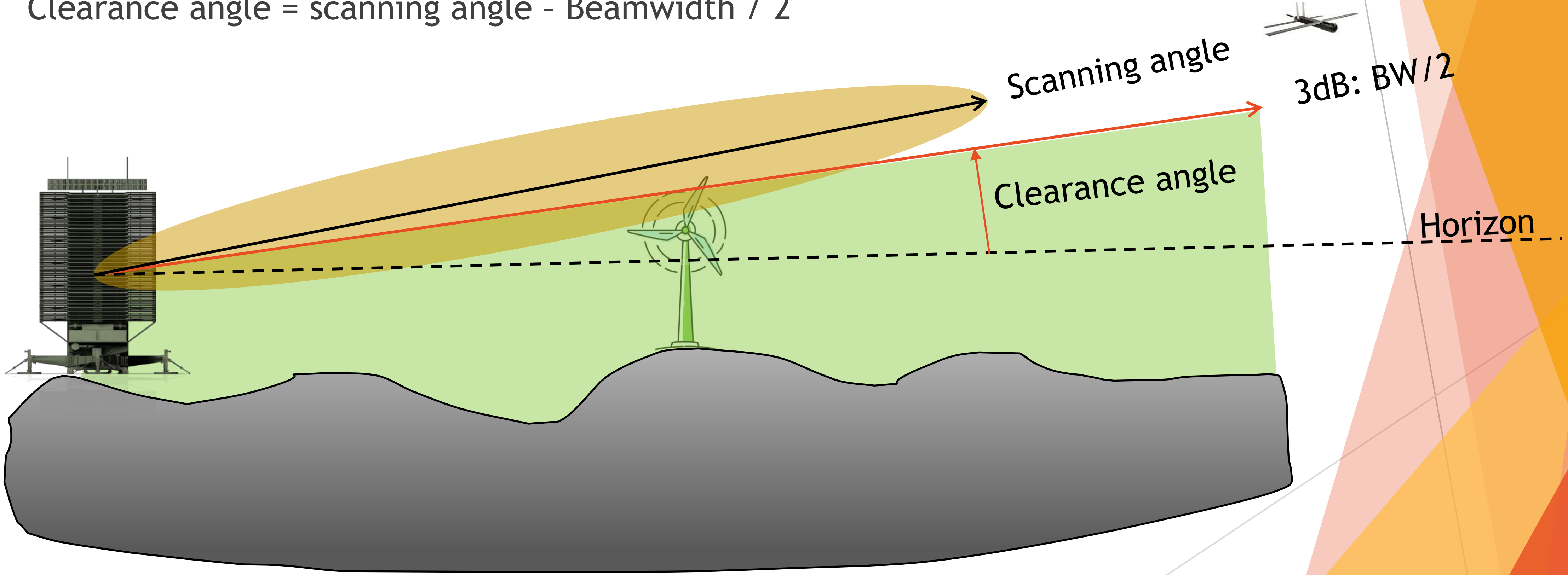
Shadow zone and beam blockage



- A turbine in the radar line of sight attenuates the signal on both the outbound and return paths (*considering terrain, earth curvature and K factor*)
- The shadow extends behind the turbine as a wedge; angular width depends on turbine size vs wavelength
- PSR suffers two-way path attenuation — detection loss is compounded on both legs of the round trip
- SSR loses the interrogation or reply path — aircraft in the shadow may fail to respond
- Severity depends on turbine height, range from the radar, and the minimum target altitude that must be protected

Clearance analysis

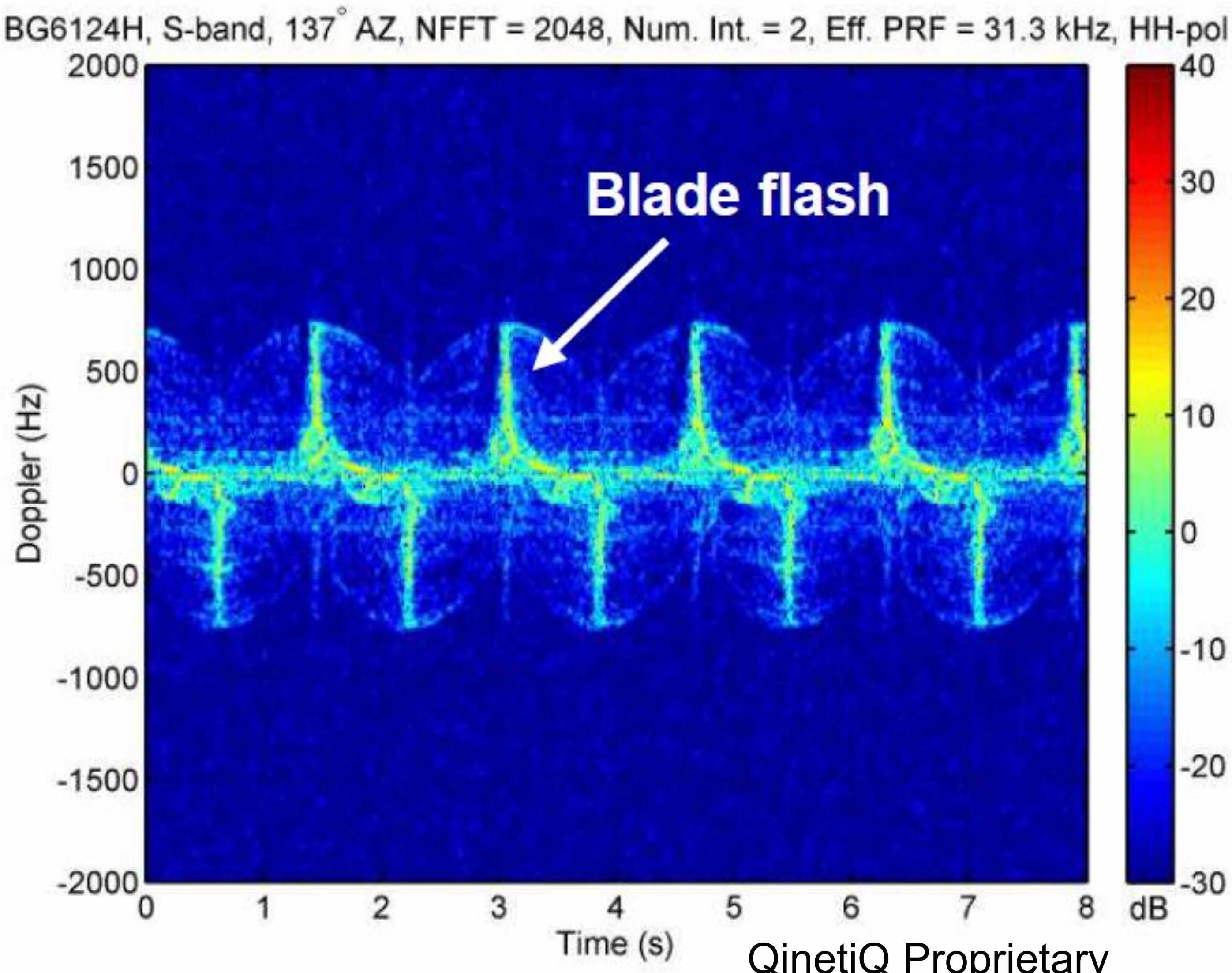
- The further away the WT the higher it can be before blocking
- Clearance angle = scanning angle – Beamwidth / 2



Doppler contamination from rotating blades

- Rotating blades impart Doppler shifts to the reflected signal — the spectrum spreads across harmonics of the rotation rate
- Modern multi-megawatt turbines reach blade tip speeds of 50–80 m/s — well above typical MTI velocity thresholds
- Blade returns pass through the filter and appear as moving targets, generating false plots and tracks
- Affects PSR only — SSR does not use Doppler processing and is immune to this mechanism
- Mitigation via the I/N criterion — if the reflected return is below the noise floor, the spectrum is irrelevant

Doppler



QinetiQ Proprietary

- 750 Hz doppler is
  - ~ 135 km/hr at 3 GHz
  - ~ 405 km/hr at 1 GHz
- For false target to take place
  - Reflected signal >= threshold AND
  - Rotational AND
  - Line-of-sight

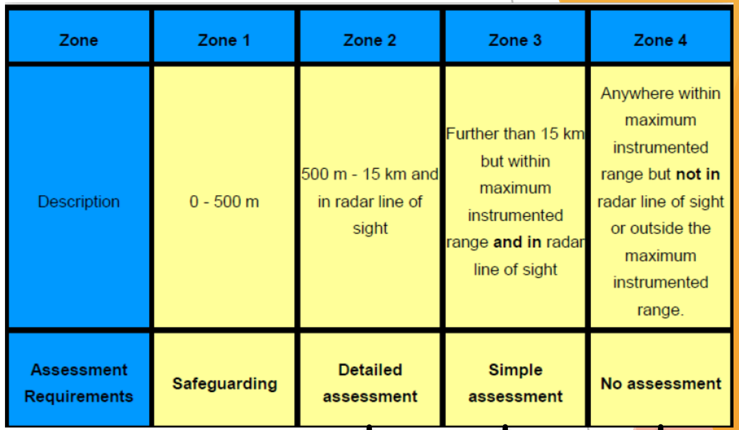
Operational impact on air traffic surveillance

- Detection degradation — raised CFAR threshold reduces probability of detecting genuine low-RCS targets
- False plots and tracks — blade Doppler returns and ghost echoes trigger spurious aircraft reports
- Tracking instability — swap, split or lost tracks on real aircraft in the affected range-azimuth cells
- Coverage gaps — shadow wedges create altitude bands where targets are not seen
- Controller workload — more plots to resolve, lower trust in the picture, safety case impacted

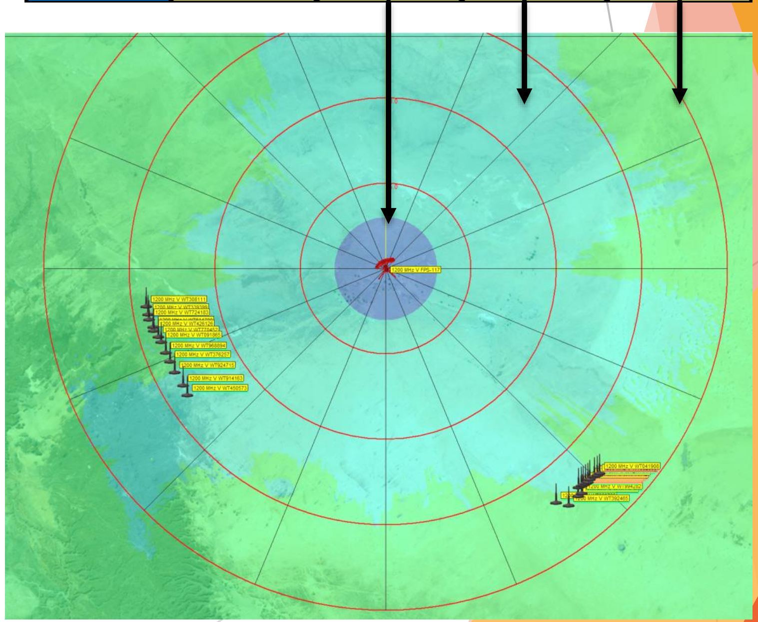
Assessment approaches – screening vs detailed

- Not every turbine needs a full engineering study – assessment is layered to focus effort where it matters
- Safeguarding – a small exclusion zone around the radar where no turbine is permitted
- Screening – geometric checks on range, line of sight and terrain to clear benign cases early
- Simple engineering assessment – tractable calculations for turbines in intermediate zones
- Detailed analysis – full I/N and beam-clearance simulation for turbines close in or in clear line of sight

EUROCONTROL GUID-0130

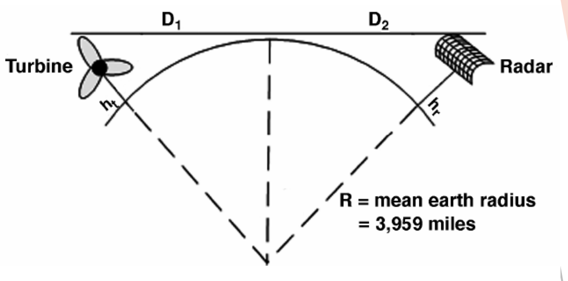


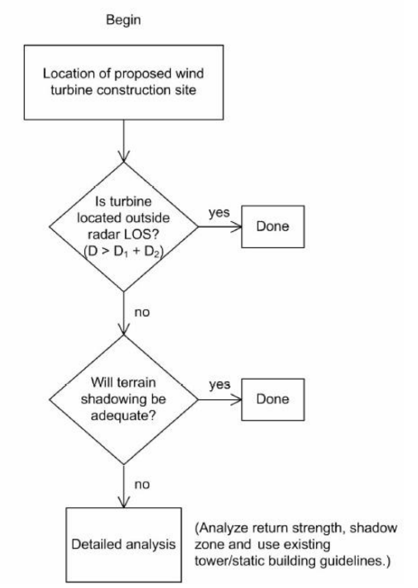
Zone	Zone 1	Zone 2	Zone 3	Zone 4
Description	0 - 500 m	500 m - 15 km and in radar line of sight	Further than 15 km but within maximum instrumented range **and in** radar line of sight	Anywhere within maximum instrumented range but **not in** radar line of sight or outside the maximum instrumented range.
Assessment Requirements	**Safeguarding**	**Detailed assessment**	**Simple assessment**	**No assessment**



NTIA TR-08-454 — sequential screening

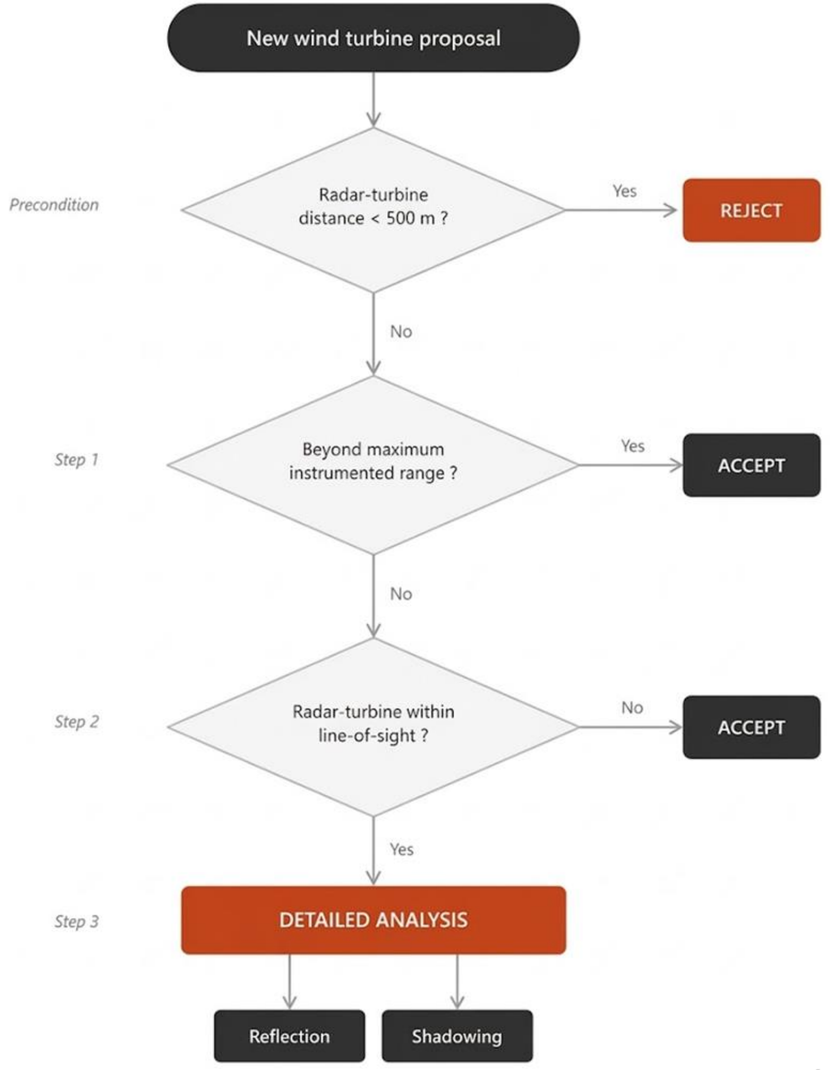
- Stage 1 — line of sight screening using a 4/3 effective earth radius model; cleared if beyond LOS
- Stage 2 — terrain shielding check including Fresnel zone clearance; cleared if adequately shielded
- Stage 3 — detailed engineering analysis of the two physical mechanisms: reflection and shadowing
- I/N acceptance thresholds — ultra-conservative ≤ −9 dB, conservative ≤ −6 dB



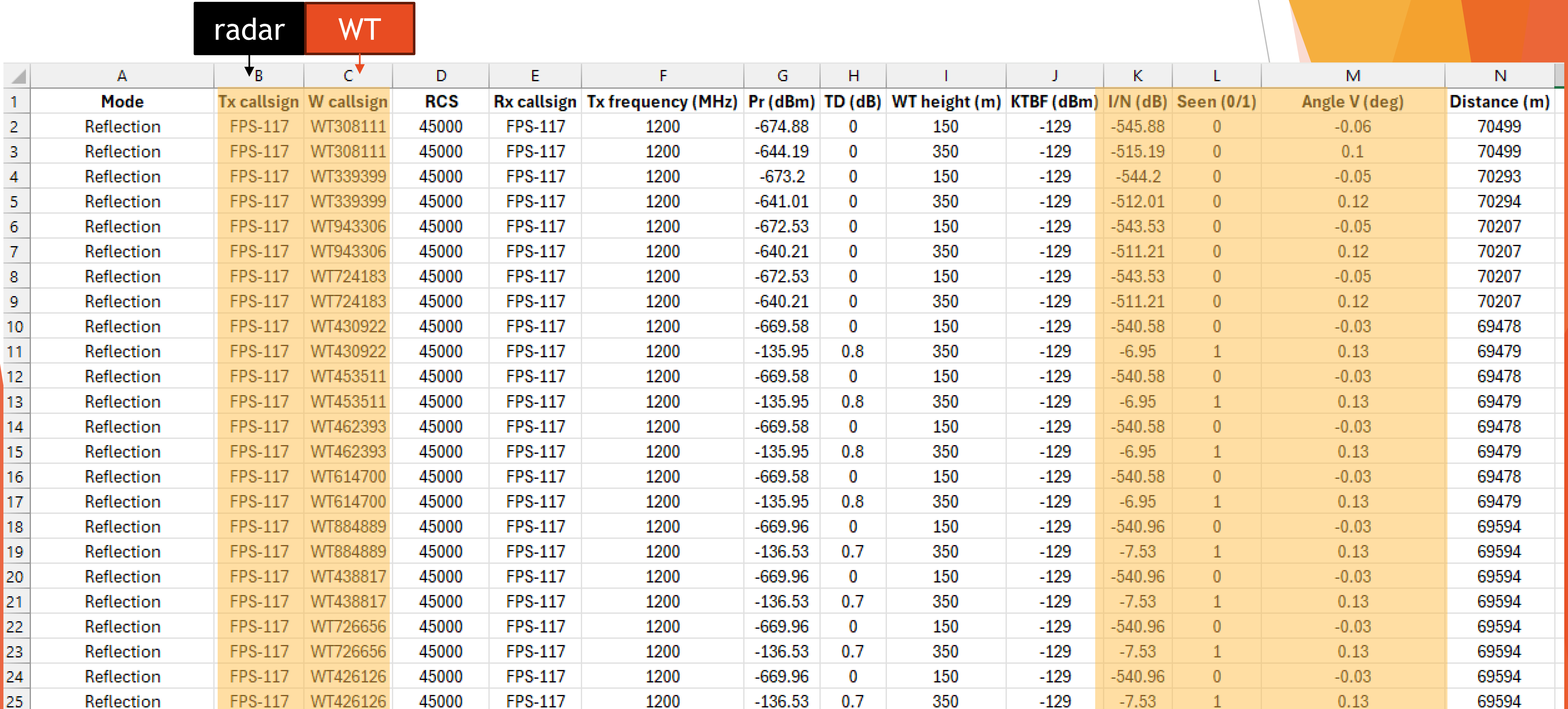


Proposed work-flow

- Fully automated using HTZ software
- Batch visibility analysis
- Batch I/N analysis
- Batch clearance analysis
- Final verdict
- Mitigation measurements



Single report with all computations



radar

WT

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Mode	Tx callsign	W callsign	RCS	Rx callsign	Tx frequency (MHz)	Pr (dBm)	TD (dB)	WT height (m)	KTBF (dBm)	I/N (dB)	Seen (0/1)	Angle V (deg)	Distance (m)
2	Reflection	FPS-117	WT308111	45000	FPS-117	1200	-674.88	0	150	-129	-545.88	0	-0.06	70499
3	Reflection	FPS-117	WT308111	45000	FPS-117	1200	-644.19	0	350	-129	-515.19	0	0.1	70499
4	Reflection	FPS-117	WT339399	45000	FPS-117	1200	-673.2	0	150	-129	-544.2	0	-0.05	70293
5	Reflection	FPS-117	WT339399	45000	FPS-117	1200	-641.01	0	350	-129	-512.01	0	0.12	70294
6	Reflection	FPS-117	WT943306	45000	FPS-117	1200	-672.53	0	150	-129	-543.53	0	-0.05	70207
7	Reflection	FPS-117	WT943306	45000	FPS-117	1200	-640.21	0	350	-129	-511.21	0	0.12	70207
8	Reflection	FPS-117	WT724183	45000	FPS-117	1200	-672.53	0	150	-129	-543.53	0	-0.05	70207
9	Reflection	FPS-117	WT724183	45000	FPS-117	1200	-640.21	0	350	-129	-511.21	0	0.12	70207
10	Reflection	FPS-117	WT430922	45000	FPS-117	1200	-669.58	0	150	-129	-540.58	0	-0.03	69478
11	Reflection	FPS-117	WT430922	45000	FPS-117	1200	-135.95	0.8	350	-129	-6.95	1	0.13	69479
12	Reflection	FPS-117	WT453511	45000	FPS-117	1200	-669.58	0	150	-129	-540.58	0	-0.03	69478
13	Reflection	FPS-117	WT453511	45000	FPS-117	1200	-135.95	0.8	350	-129	-6.95	1	0.13	69479
14	Reflection	FPS-117	WT462393	45000	FPS-117	1200	-669.58	0	150	-129	-540.58	0	-0.03	69478
15	Reflection	FPS-117	WT462393	45000	FPS-117	1200	-135.95	0.8	350	-129	-6.95	1	0.13	69479
16	Reflection	FPS-117	WT614700	45000	FPS-117	1200	-669.58	0	150	-129	-540.58	0	-0.03	69478
17	Reflection	FPS-117	WT614700	45000	FPS-117	1200	-135.95	0.8	350	-129	-6.95	1	0.13	69479
18	Reflection	FPS-117	WT884889	45000	FPS-117	1200	-669.96	0	150	-129	-540.96	0	-0.03	69594
19	Reflection	FPS-117	WT884889	45000	FPS-117	1200	-136.53	0.7	350	-129	-7.53	1	0.13	69594
20	Reflection	FPS-117	WT438817	45000	FPS-117	1200	-669.96	0	150	-129	-540.96	0	-0.03	69594
21	Reflection	FPS-117	WT438817	45000	FPS-117	1200	-136.53	0.7	350	-129	-7.53	1	0.13	69594
22	Reflection	FPS-117	WT726656	45000	FPS-117	1200	-669.96	0	150	-129	-540.96	0	-0.03	69594
23	Reflection	FPS-117	WT726656	45000	FPS-117	1200	-136.53	0.7	350	-129	-7.53	1	0.13	69594
24	Reflection	FPS-117	WT426126	45000	FPS-117	1200	-669.96	0	150	-129	-540.96	0	-0.03	69594
25	Reflection	FPS-117	WT426126	45000	FPS-117	1200	-136.53	0.7	350	-129	-7.53	1	0.13	69594

Acceptance criteria — I/N and shadowing

- Not within LOS? Accept
- Two criteria must hold for a Conditional Accept — reflection (I/N) and shadowing (beam clearance)
- I/N ≤ −6 dB — reflected turbine return stays at least 6 dB below the receiver noise floor
- Covers all reflection effects — false targets, Doppler contamination and receiver overload all sit below detection
- Shadowing — elevation angle from radar to blade tip must be below the lower edge of the main beam
- Lower edge = scanning angle minus half the 3 dB vertical beamwidth, so blade tips sit under the main lobe

Mitigation options for rejected turbines

- Layout redesign — move or drop turbines to pull them out of the radar main beam or off the affected bearing
- Radar-absorbing cladding on tower and nacelle — reduces structural RCS and the I/N margin
- Stealth or radar-absorbing blade coatings — attenuates blade returns and limits Doppler contamination
- Fill-in radar — a supplementary sensor restores coverage inside the shadow wedge behind a wind farm
- Operational — PSR sector blanking, range-azimuth gating, antenna elevation adjustment where the operator accepts the trade-off

Key takeaways and questions

- Wind and radar can coexist — the engineering is well understood, and the assessment frameworks are mature
- Three mechanisms matter — reflection, shadowing, Doppler contamination
- Use a layered workflow — safeguarding, range and LOS screening before expensive detailed analysis
- Acceptance criteria — I/N ≤ −6 dB reflection and beam-clearance shadowing, worst-case across all radars

To access the HTZ demo

▶ click here

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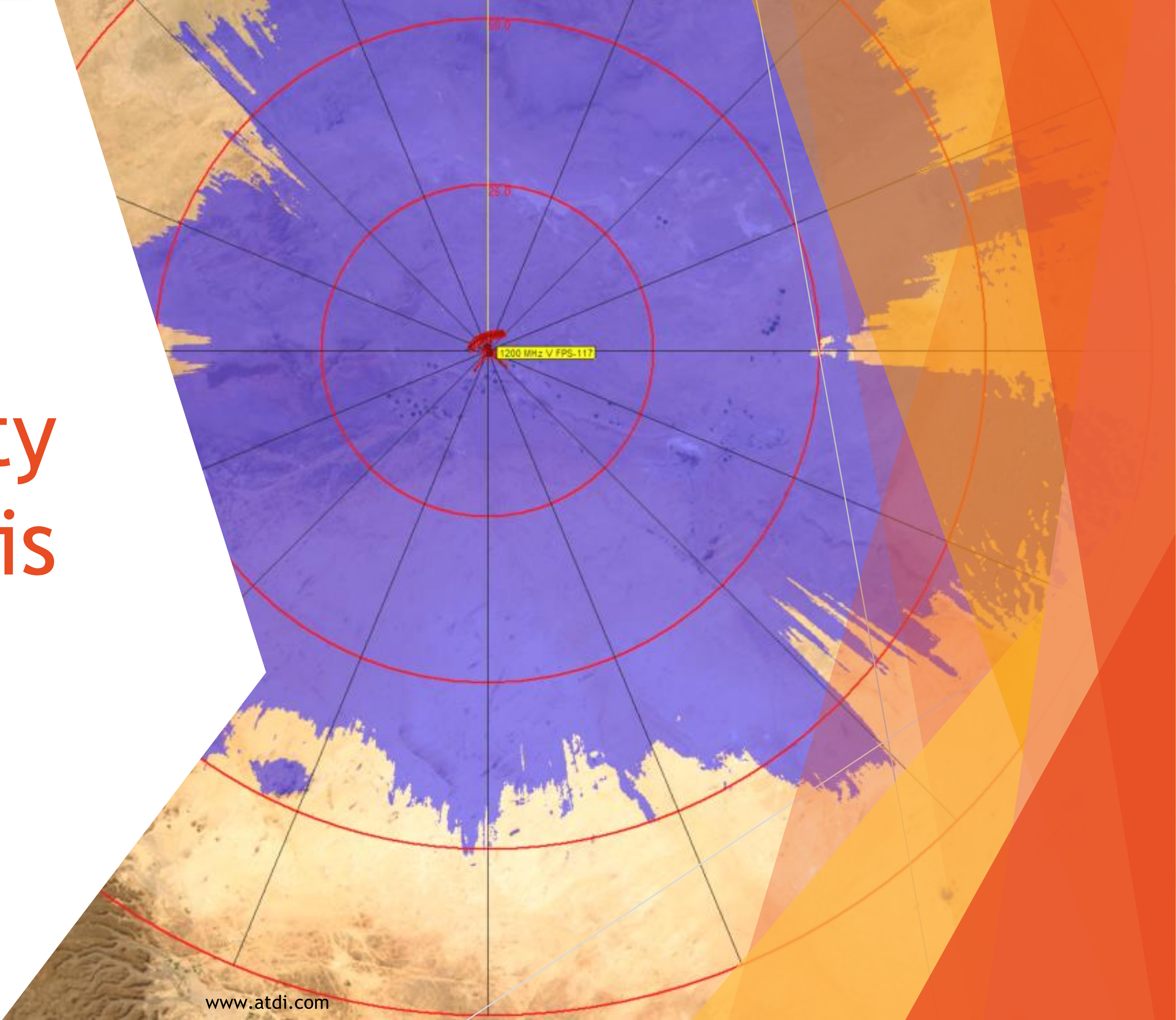
HTZ Communications
CNS Network Design & Optimisation

- Dedicated aeronautical propagation models
- Automated site network coverage, interference analysis and frequency planning
- Identifying shadowing/black spots and automatic site search
- Traffic analysis and network capacity management
- Surveillance functions including multi-lateration (TDOA)
- Ability to model ATC radars (VOR, ILS, MLAT, RADAR)
- Functions to model wind turbine interference or
- 5G towers on aeronautical radars
- ICAO building restriction compliance analysis and exclusion zones around the airports

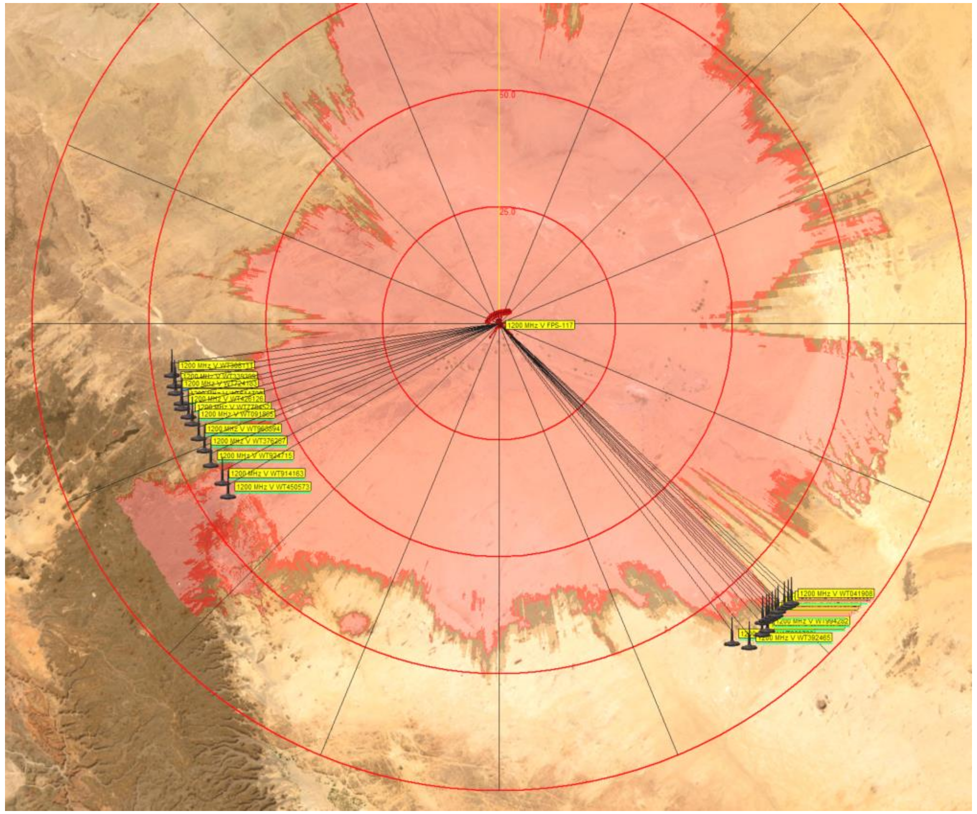
SCAN ME

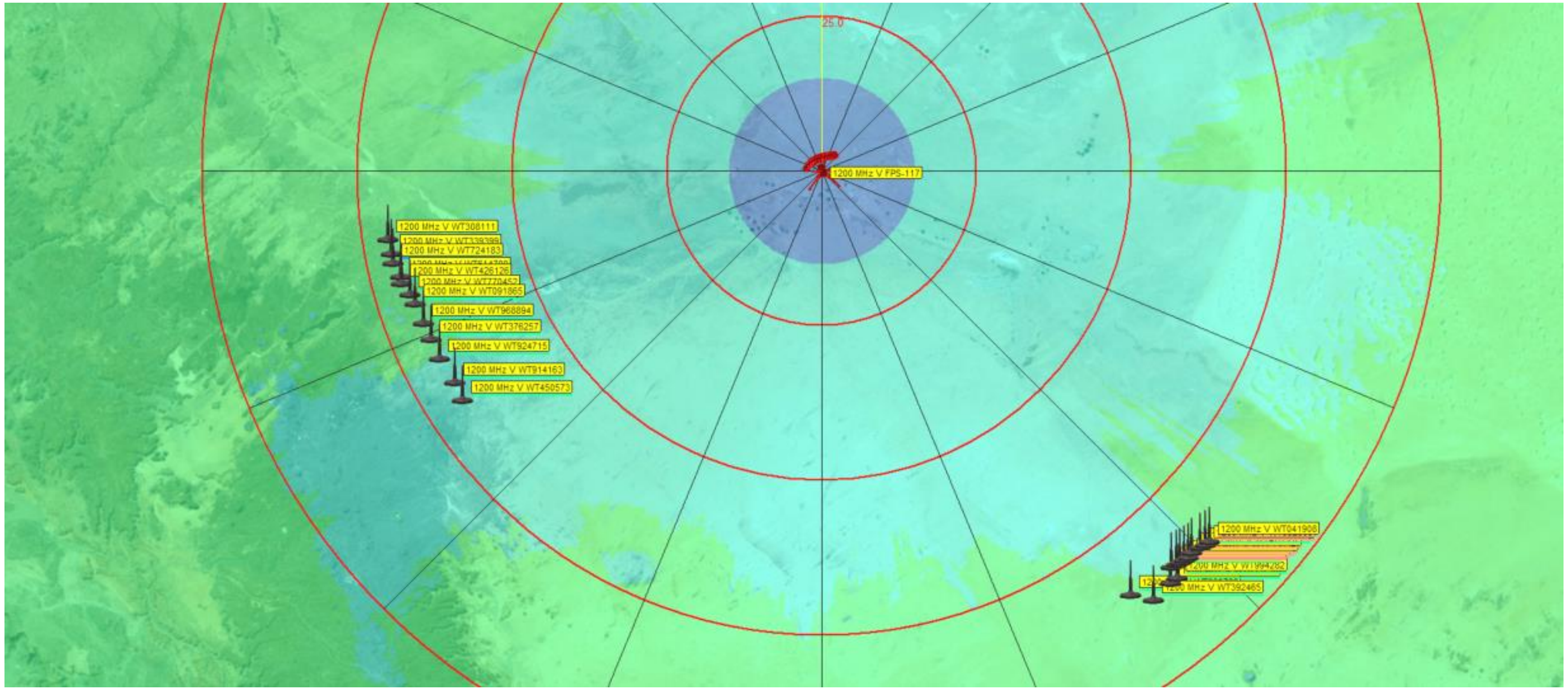
Visibility analysis



I/N analysis

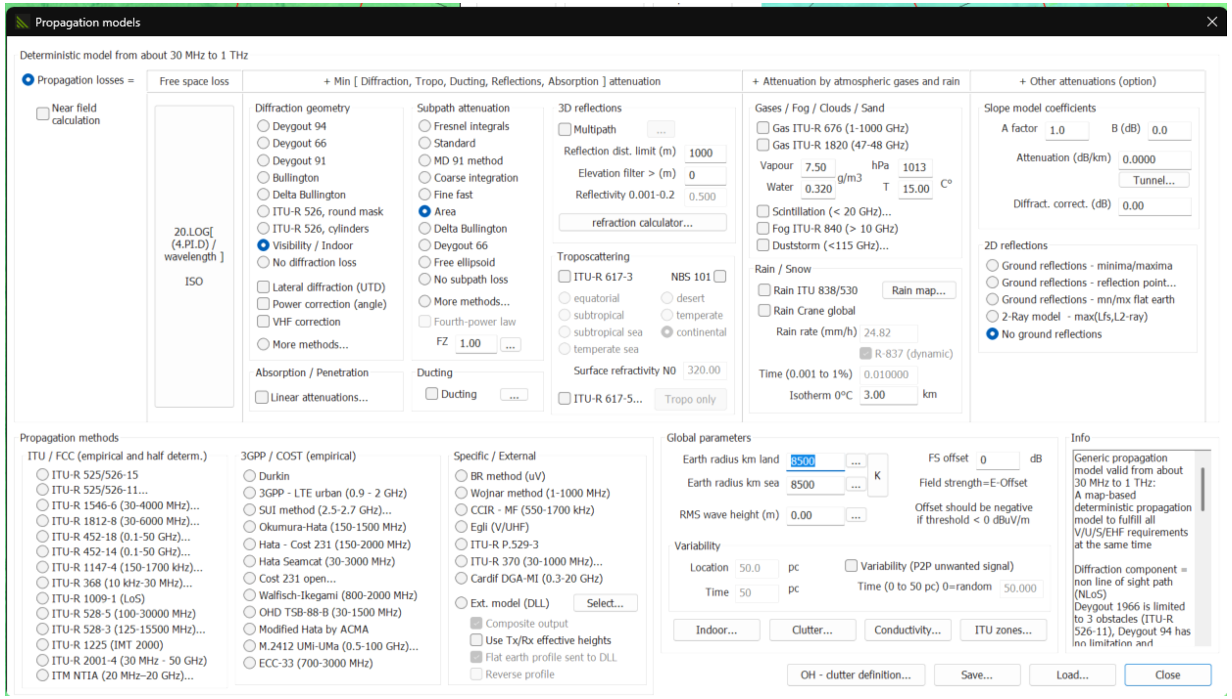
- Full visibility, I/N and shadowing analysis





Euro-control zones

Propagation models



Propagation models

Deterministic model from about 30 MHz to 1 THz

● Propagation losses = | Free space loss | + Min [Diffraction, Tropo, Ducting, Reflections, Absorption] attenuation | + Attenuation by atmospheric gases and rain | + Other attenuations (option)

☐ Near field calculation

20.LOG[(4.PI.D) / wavelength]

ISO

Diffraction geometry
- ○ Deygout 94
- ○ Deygout 66
- ○ Deygout 91
- ○ Bullington
- ○ Delta Bullington
- ○ ITU-R 526, round mask
- ○ ITU-R 526, cylinders
- ● Visibility / Indoor
- ○ No diffraction loss
- ☐ Lateral diffraction (UTD)
- ☐ Power correction (angle)
- ☐ VHF correction
- ○ More methods...

Subpath attenuation
- ○ Fresnel integrals
- ○ Standard
- ○ MD 91 method
- ○ Coarse integration
- ○ Fine fast
- ● Area
- ○ Delta Bullington
- ○ Deygout 66
- ○ Free ellipsoid
- ○ No subpath loss
- ○ More methods...
- ☐ Fourth-power law

FZ 1.00

3D reflections
- ☐ Multipath

Reflection dist. limit (m) 1000

Elevation filter > (m) 0

Reflectivity 0.001-0.2 0.500

refraction calculator...

Troposcattering
- ☐ ITU-R 617-3
- NBS 101 ☐
- ○ equatorial
- ○ desert
- ○ subtropical
- ○ temperate
- ○ subtropical sea
- ● continental
- ○ temperate sea

Surface refractivity N0 320.00

☐ ITU-R 617-5... Tropo only

Absorption / Penetration
- ☐ Linear attenuations...

Ducting
- ☐ Ducting

Gases / Fog / Clouds / Sand
- ☐ Gas ITU-R 676 (1-1000 GHz)
- ☐ Gas ITU-R 1820 (47-48 GHz)

Vapour 7.50 g/m3 hPa 1013

Water 0.320 T 15.00 C°

- ☐ Scintillation (< 20 GHz)...
- ☐ Fog ITU-R 840 (> 10 GHz)
- ☐ Duststorm (<115 GHz)...

Rain / Snow
- ☐ Rain ITU 838/530 Rain map...
- ☐ Rain Crane global

Rain rate (mm/h) 24.82

☑ R-837 (dynamic)

Time (0.001 to 1%) 0.010000

Isotherm 0°C 3.00 km

Slope model coefficients

A factor 1.0 B (dB) 0.0

Attenuation (dB/km) 0.0000

Tunnel...

Diffract. correct. (dB) 0.00

2D reflections
- ○ Ground reflections - minima/maxima
- ○ Ground reflections - reflection point...
- ○ Ground reflections - mn/mx flat earth
- ○ 2-Ray model - max(Lfs,L2-ray)
- ● No ground reflections

Propagation methods

ITU / FCC (empirical and half determ.)
- ○ ITU-R 525/526-15
- ○ ITU-R 525/526-11...
- ○ ITU-R 1546-6 (30-4000 MHz)...
- ○ ITU-R 1812-8 (30-6000 MHz)...
- ○ ITU-R 452-18 (0.1-50 GHz)...
- ○ ITU-R 452-14 (0.1-50 GHz)...
- ○ ITU-R 1147-4 (150-1700 kHz)...
- ○ ITU-R 368 (10 kHz-30 MHz)...
- ○ ITU-R 1009-1 (LoS)
- ○ ITU-R 528-5 (100-30000 MHz)
- ○ ITU-R 528-3 (125-15500 MHz)...
- ○ ITU-R 1225 (IMT 2000)
- ○ ITU-R 2001-4 (30 MHz - 50 GHz)
- ○ ITM NTIA (20 MHz–20 GHz)...

3GPP / COST (empirical)
- ○ Durkin
- ○ 3GPP - LTE urban (0.9 - 2 GHz)
- ○ SUI method (2.5-2.7 GHz)...
- ○ Okumura-Hata (150-1500 MHz)
- ○ Hata - Cost 231 (150-2000 MHz)
- ○ Hata Seamcat (30-3000 MHz)
- ○ Cost 231 open...
- ○ Walfisch-Ikegami (800-2000 MHz)
- ○ OHD TSB-88-B (30-1500 MHz)
- ○ Modified Hata by ACMA
- ○ M.2412 UMi-UMa (0.5-100 GHz)...
- ○ ECC-33 (700-3000 MHz)

Specific / External
- ○ BR method (uV)
- ○ Wojnar method (1-1000 MHz)
- ○ CCIR - MF (550-1700 kHz)
- ○ Egli (V/UHF)
- ○ ITU-R P.529-3
- ○ ITU-R 370 (30-1000 MHz)...
- ○ Cardif DGA-MI (0.3-20 GHz)
- ○ Ext. model (DLL) Select...
  - ☑ Composite output
  - ☐ Use Tx/Rx effective heights
  - ☑ Flat earth profile sent to DLL
  - ☐ Reverse profile

Global parameters

Earth radius km land 8500

Earth radius km sea 8500

K

RMS wave height (m) 0.00

FS offset 0 dB

Field strength=E-Offset

Offset should be negative if threshold < 0 dBuV/m

Variability

Location 50.0 pc

Time 50 pc

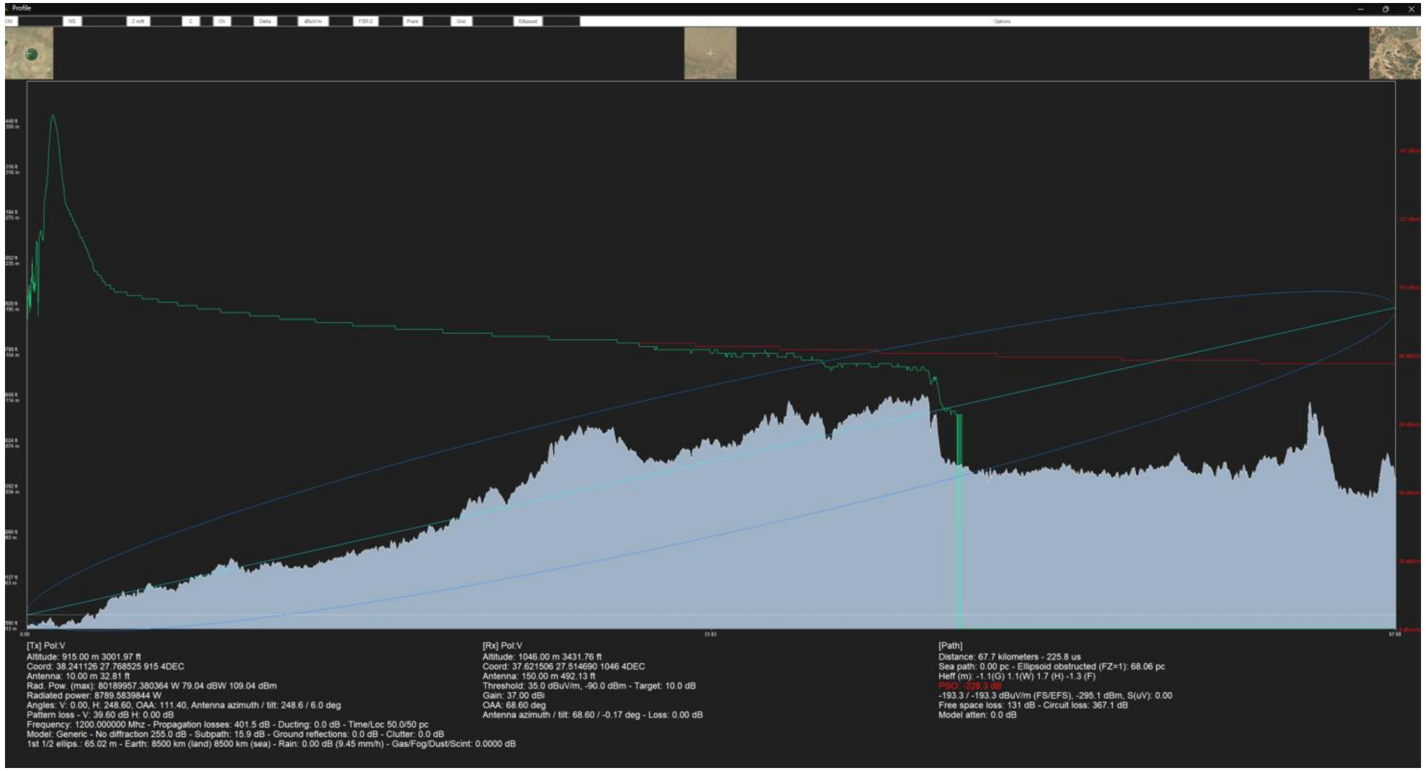
☐ Variability (P2P unwanted signal)

Time (0 to 50 pc) 0=random 50.000

Info

Generic propagation model valid from about 30 MHz to 1 THz:
A map-based deterministic propagation model to fulfill all V/U/S/EHF requirements at the same time

Diffraction component = non line of sight path (NLoS)
Deygout 1966 is limited to 3 obstacles (ITU-R 526-11), Deygout 94 has no limitation and



```
[Tx] Pol:V
Altitude: 915.00 m 3001.97 ft
Coord: 38.241126 27.768525 915 4DEC
Antenna: 10.00 m 32.81 ft
Rad. Pow. (max): 80189957.380364 W 79.04 dBW 109.04 dBm
Radiated power: 8789.5839844 W
Angles: V: 0.00, H: 248.60, OAA: 111.40, Antenna azimuth / tilt: 248.6 / 6.0 deg
Pattern loss - V: 39.60 dB H: 0.00 dB
Frequency: 1200.000000 Mhz - Propagation losses: 401.5 dB - Ducting: 0.0 dB - Time/Loc 50.0/50 pc
Model: Generic - No diffraction 255.0 dB - Subpath: 15.9 dB - Ground reflections: 0.0 dB - Clutter: 0.0 dB
1st 1/2 ellips.: 65.02 m - Earth: 8500 km (land) 8500 km (sea) - Rain: 0.00 dB (9.45 mm/h) - Gas/Fog/Dust/Scint: 0.0000 dB

[Rx] Pol:V
Altitude: 1046.00 m 3431.76 ft
Coord: 37.621506 27.514690 1046 4DEC
Antenna: 150.00 m 492.13 ft
Threshold: 35.0 dBuV/m, -90.0 dBm - Target: 10.0 dB
Gain: 37.00 dBi
OAA: 68.60 deg
Antenna azimuth / tilt: 68.60 / -0.17 deg - Loss: 0.00 dB

[Path]
Distance: 67.7 kilometers - 225.8 us
Sea path: 0.00 pc - Ellipsoid obstructed (FZ=1): 68.06 pc
Heff (m): -1.1(G) 1.1(W) 1.7 (H) -1.3 (F)
PSO: -228.3 dB
-193.3 / -193.3 dBuV/m (FS/EFS), -295.1 dBm, S(uV): 0.00
Free space loss: 131 dB - Circuit loss: 367.1 dB
Model atten: 0.0 dB
```

Propagation losses

THANK YOU