EASA
European Aviation Safety Agency

Large Antennas

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Large Antennas / General

The following structural provisions for specific antennas are commonly used:

- a skin feed through for the antenna cable and an involved skin doubler with its mounting provisions like nuts or plates for the antenna hardware

- additional substructure below the skin (like frame intercostals) to carry increased, antenna induced aerodynamic and inertia loads as well as inertia loads for black boxes

- large skin doubler acting as a mounting substructure for the antenna and its radome

- adapter plates on top of aircraft structure to carry antenna hardware and radome, mounted by dedicated attachment lugs. These lugs are minimizing the fatigue loads on the external skin transferring the majority of fatigue loads into the frames

Large Antennas / General

- skin doubler size and cut-out is within aircraft SRM limits for an approved repair doubler - > reduced justification efforts on the doubler itself. But the doubler hole for the feed through still has to be considered due to stress concentration
- radome or other protruding antenna parts are within / beyond the boundary layer of the designated location and its typical flow
- unpressurized / pressurised compartment below antenna
- Location: centre fuselage / front or aft fuselage

The installation of large antennas on aircraft may also impact its initial certification basis from structural point of view

Large Antennas / General

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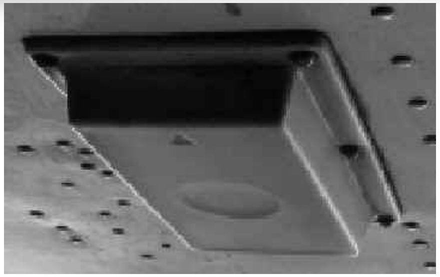

ADF LOOP

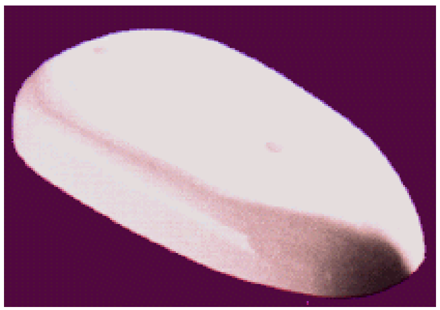

GLIDESLOPE


ELT


COM WHIP BENT


COM WHIP


TRANSPONDER/DME PROBE


ADF COMBINED SENSE LOOP

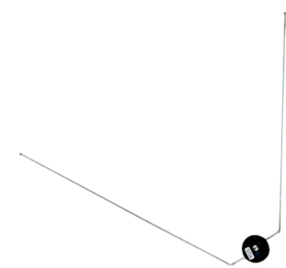

MARKER

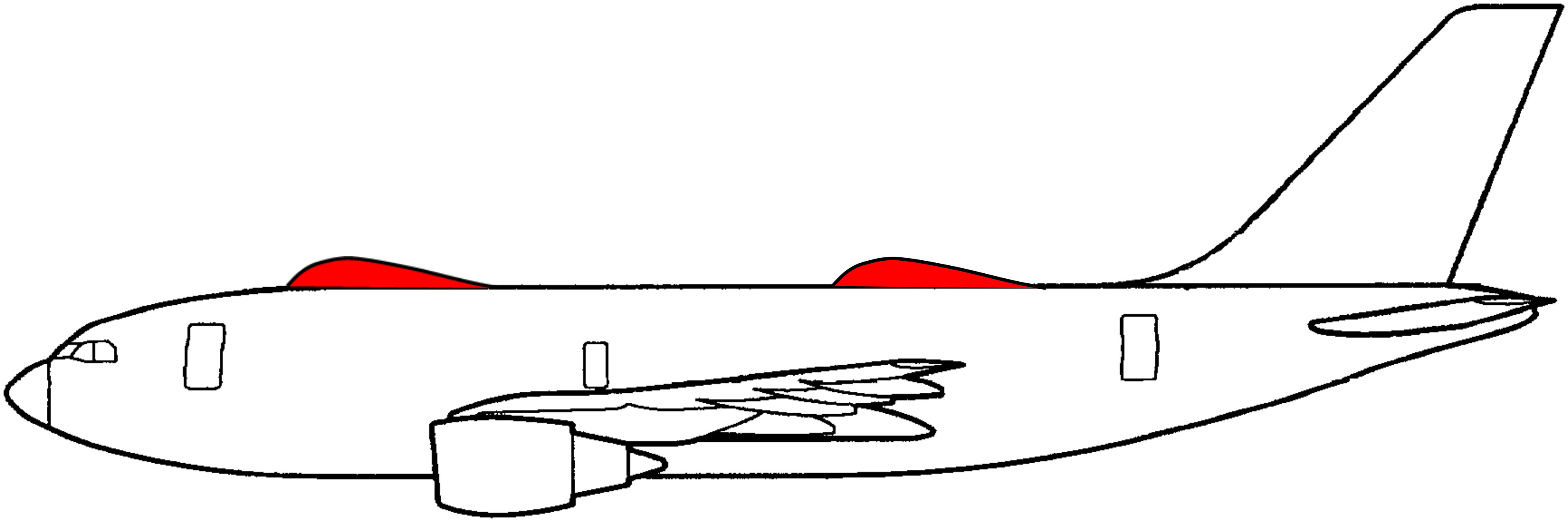

COMBINED COM/VOR


GPS


DME/TRANSPONDER BLADE


VOR BLADES


VOR RABBIT EAR



Large Antennas / Requirements

Requirement	Title
25.23	Load distribution limits
25.29	Empty weight and corresponding centre of gravity
25.251	Vibration and buffeting
25.301(b)	Loads
25.303, 25.305, 25.307	Static Strength
25.305(e)	Vibration & Buffeting
25.365	Pressurized Compartments
25.561	Emergency landing conditions
25.571	Fatigue & Damage Tolerance
25.581	Lightning Protection
25.601	General (Design and Construction)
25.603	Materials
25.605	Fabrication Methods
25.607	Fasteners
25.609	Protection of structure
25.611	Accessibility provisions
25.613	Material Strength Properties and Material Design values
25.619	Special Factors
25.629	Aeroelasticity
25.631	Bird Strike
25.901(c)	Sustained engine imbalance
25.841	High Altitude
25.1419	Ice Protection
25.1529	Instructions for Continued Airworthiness

Large Antennas / Requirements

- ***25.301(b) Flight Loads Validation***

Methods used to determine load intensities and distribution must be validated by flight load measurement unless the methods used for determining those loading conditions are shown to be reliable, or conservative.

- **CS 25.305(e) Vibration and Buffeting**

The effects of vibration and buffeting on the aeroplane must be considered, as well as on the antenna/radome installation itself. CS 25.251 also applies, and needs to be complied with.

- ***CS 25.571 Damage Tolerance and Fatigue Evaluation of Structure***

A damage tolerance evaluation must be performed on any radome/antenna structure whose failure due to fatigue, corrosion or accidental damage could result in loss of the antenna/radome and subsequent tail strike, or other hazard such as rapid decompression of the aeroplane. Any inspection that is determined necessary as a result of this evaluation must be addressed as per CS 25.1529 and Appendix H.

- **CS 25.365(e) Pressurized Compartment Loads[1]**

Rapid pressurization of the antenna compartment (radome) must be considered as outlined in CS 25.365(e)(3) if loss of the radome/antenna could interfere with continued safe flight and landing. CS 25.365(e)(3) requires the consideration of "the maximum opening caused by aeroplane or equipment failures not shown to be extremely improbable."

EASA's interpretation of CS 25.365(e)(3) is that to address structural failures, the opening size resulting from a skin bay failure (bounded by two adjacent frames and two adjacent stringers) should generally be considered (i.e. is not extremely improbable) as a minimum opening size, unless a smaller opening can be justified based upon the maximum level of cracking that can be conservatively expected when a directed inspection for the structure under the radome exists in the ALS. (The assumed crack size and resulting opening should account for bulging affects and the possibility of missed opportunities for detection.) Failures to equipment and items such as seals should also be considered separately and in combination with structural failures as appropriate.

- **CS 25.365(e) Pressurized Compartment Loads[2]**

Consideration of CS 25.365(e)(1) is not required as the engine disintegration is assumed to adequately “vent” any remaining section of radome if the compartment beneath is penetrated. Application of the formula hole size requirement of CS 25.365(e)(2) is also not required, since, for the size of radome being considered, the majority of hole sizes up to the maximum stated in the formula will exceed the boundary of the antenna/radome. Furthermore, the potential for such large openings to create debris problems equivalent to or worse than the loss of the antenna alone supports the position that application of CS 25.365(e)(2) to such antenna would be beyond the accepted intent of the rule. Rather, the focus for compliance to the decompression requirement should be consideration of any airframe or equipment failures not shown to be extremely improbable, as explained above.

Large Antennas / Requirements

- **CS 25.581 Lightning Strike**

The antenna and radome installation must be designed such that the aeroplane is protected against catastrophic effects from lightning.

- **CS 25.629 Aeroelastic Stability Requirements**

The applicant must demonstrate by analysis and/or test that the aeroplane is free from aeroelastic instability with the antenna and radome installed. This may be accomplished by a comparative analysis showing that the aeroelastic stability of the aeroplane will be unaffected by the change. If the antenna/radome installation is not conformal to the fuselage, such as an antenna/radome mounted above the fuselage, the installation itself must also comply with CS 25.629.

- **CS 25.631 Bird Strike**

The applicant must show that a bird strike on the antenna/radome, including attachments, will not prevent continued safe flight and landing. This includes consideration of parts that may separate from the aeroplane. This requirement need not be considered if it can be demonstrated that a bird cannot strike the antenna/radome, including attachments, within the normal flight envelope.

Large Antennas / Requirements

- **CS 25.901(c) Sustained Engine Imbalance**

The applicant may need to consider the effects of sustained engine imbalance (windmilling) if the antenna/radome design is such that it would be susceptible to structural failure due to vibration. It must be shown that the resulting vibration will not cause a structural failure of the antenna/radome installation that would result in a foreseeable hazard, either at the point of failure or downstream (AMC 25-24 provides further guidance on this subject).

- **CS 25-1419 Icing**

Ice shedding from the antenna/radome installation should be considered. It must be shown that such shedding and the resulting damage to other parts of the aeroplane does not interfere with continued safe flight and landing.

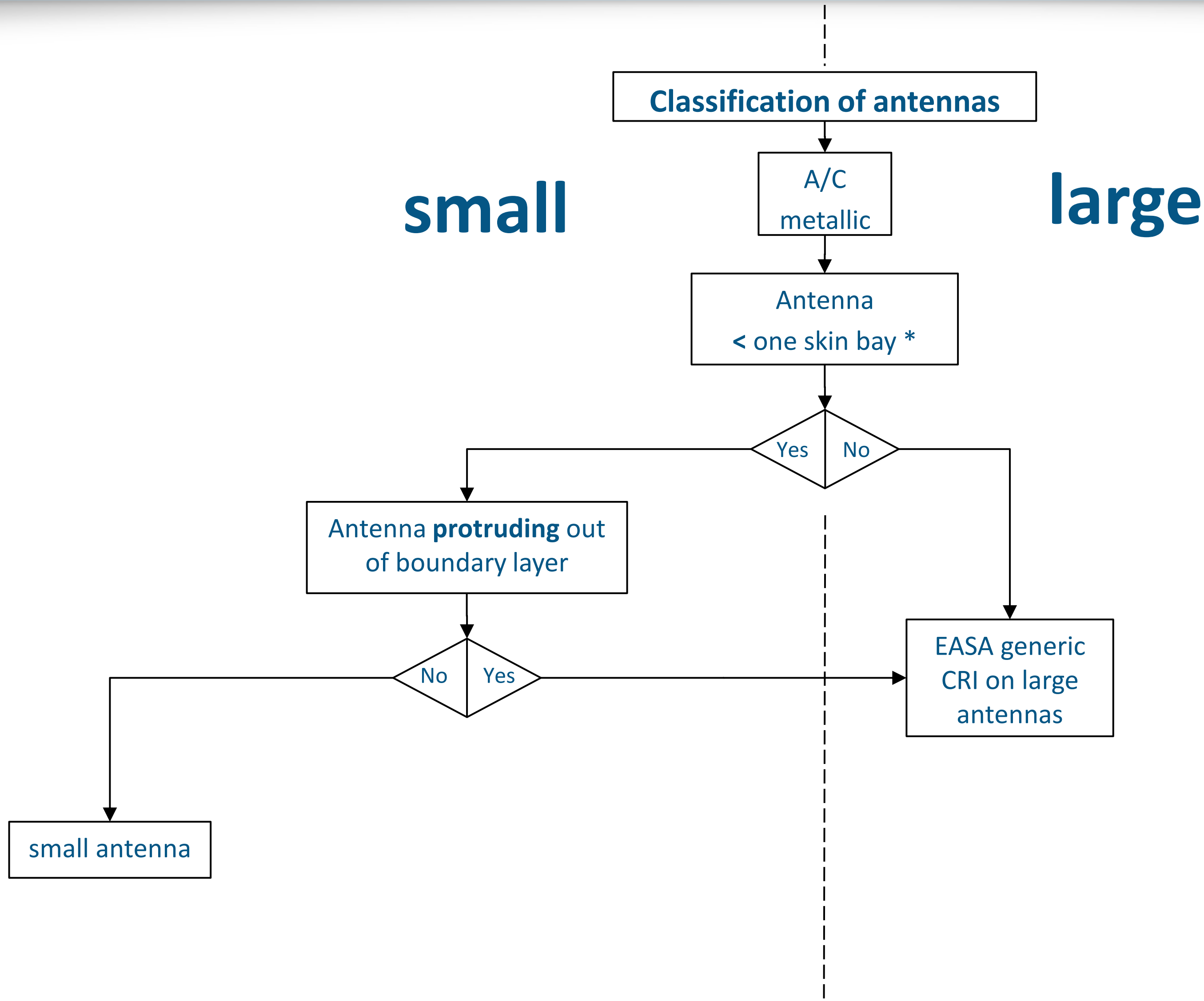
- **CS 25.1529 & Appendix H Instructions for Continued Airworthiness**

The applicant must demonstrate compliance by developing an appropriate maintenance and inspection program.

- **Airworthiness Directives**

The applicant should address any Airworthiness Directive(s) applicable to the area of the antenna/radome installation.

Large Antennas / Classification for Large / Small



* area between 2 adjacent frames and stringers

- radome or other protruding antenna parts are within / beyond the boundary layer of the designated location and its typical flow. (**boundary layer criteria**)

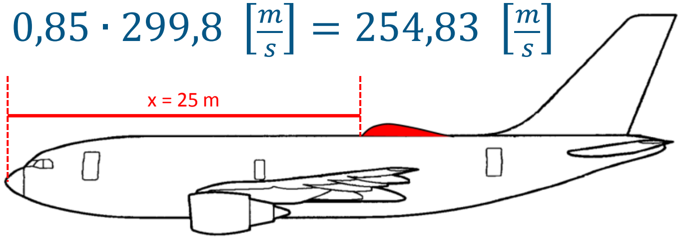
- pressurised structure below antenna: (**stress criteria**)
  - importance of circumferential stress

- location of antenna: centre fuselage / front or aft fuselage (**stress criteria**)

Boundary layer criteria (cruise flight small α and β):

Assumption: A/C is flying at an altitude of 10 km with a speed of M_a= 0,85

$$M = \frac{u_\infty}{a} \quad \rightarrow \quad u_\infty = M \cdot a \rightarrow \; = 0{,}85 \cdot 299{,}8 \left[\frac{m}{s}\right] = 254{,}83 \left[\frac{m}{s}\right]$$



u_∞ = true airspeed in $\left[\frac{m}{s}\right]$

$a = 299{,}8 \left[\frac{m}{s}\right]$ (speed of sound in $\left[\frac{m}{s}\right]$ at an altitude of 10 km and a temperature of T = -50°C)

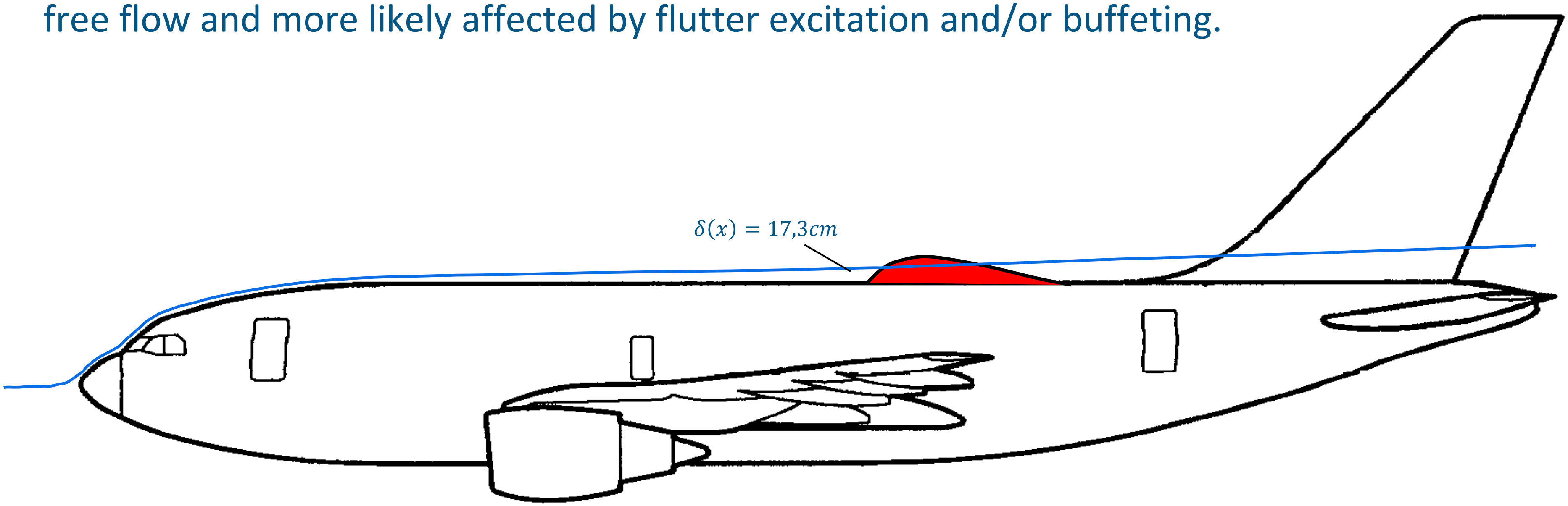
Reynolds number: $$Re_x = \frac{(u_\infty \cdot x)}{v} = \frac{254{,}83 \cdot 25}{1{,}49 \cdot 10^{-5}} = 427\,567\,114\,[-]$$

Kinematic viscosity: $$\boldsymbol{v} = 1{,}49 \cdot 10^{-5} \left[\frac{m^2}{s}\right]$$

Lengthwise trajectory (antenna location on fuselage): $x = 25\,[m]$

1. Boundary Layer Criteria:

The boundary layer thickness should give us a hint if the antenna is fully exposed to the free flow and more likely affected by flutter excitation and/or buffeting.



Thickness of turbulent boundary layer at $x = 25\ [m]$:

$$\delta(x) = \frac{0{,}37 \cdot x}{\sqrt[5]{Re_x}} = \frac{0{,}37 \cdot 25}{\sqrt[5]{427567114}} = 0{,}173\ [\mathrm{m}] \qquad \textbf{eq.1}$$

Need for Flight Testing

Vibration and buffeting / flutter excitation could be caused at radome location and at the empennage through a flow separation at the antenna radome and subsequent propagation of non-laminar flow.

- CS 25.301(b) requests **Flight Loads Validation**
  - Analysis needs to be validated - if needed - by Flight Test (Flight Load Survey)
  - Except a validated and approved analysis method is available

- CS 25.251 and CS 25.305(e) accounts for **Vibration and Buffeting**
  - Evaluate effect of modification on vibration and buffeting by validated analysis
  - In case of an effect a Flight Test is needed as the only acceptable MOC (means od compliance) for 25.251
  - It has been determined, that generally large antennas have an effect on vibration and buffeting, thus flight test is typically required

- Relevant Flight Conditions for testing (example)
  - Cruise condition flight (small α and β)
    - A flight testing up to V_{mo} is deemed necessary and reasonable
  - Approach/Take-Off condition (large α and β)
    - A flight testing up to V_{FE} with a variation in α and β is deemed necessary and reasonable

Appendix

Used Abbreviations:

A/C	Aircraft
AMC	Alternative Means of Compliance
ALS	Airworthiness Limitation Section
CM	Certification Memorandum
CFD	Computational Fluid Dynamics
DTI	Damage Tolerance Inspection
FCBS	Fatigue Critical Baseline Structure
skin bay	area between 2 adjacent frames and stringers
MOC	Means OF Compliance
TC / TCH	Type Certificate / Type Certificate Holder
SRM	Structure Repair Manual
V_{fe}	Maximum Speed with Flaps Extended
V_{ne}	Never (n) Exceed (e) Speed.
V_{mo}	Maximum Operating Speed
α	Angle of Attack
β	Yaw Angle

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Any Questions please ?

Back-up Slides

Classification of antennas

↓

A/C composite

↓

Honeycomb sandwich / monolithic:

Strongly recommended: use of dedicated TCH repair documentation with <u>hard points/reinforcement plates</u> provided for post TC installations.

Advise to consider approved OEM repair documentation

involvement of A/C manufacturer strongly advised!

Back-up Slides

Considering equation 1 (slide 17) and the logarithmic increase of the flow velocity from zero (at fuselage surface) up to 99% of flow speed of the unpertubated flow velocity (per definition at the end of the boundary layer), a conservative calculation of the aerodynamic drag force – by using the maximum flow velocity - can be performed as follows:

Drag Load Calculation

$$D = 6.045 \times 10^{-8} \cdot A \cdot V_{ne}^{2} \quad [daN]$$

D = drag load on the antenna in [daN]

A = frontal area of antenna in [cm^2]

V = V_{ne} of aircraft in [km/h]

(The formula includes a 90% reduction factor for streamline shape of antenna)