TECHNISCHE UNIVERSITÄT DRESDEN
Faculty of Electrical and Computer Engineering, Communications Laboratory
Chair for RF and Photonics Engineering

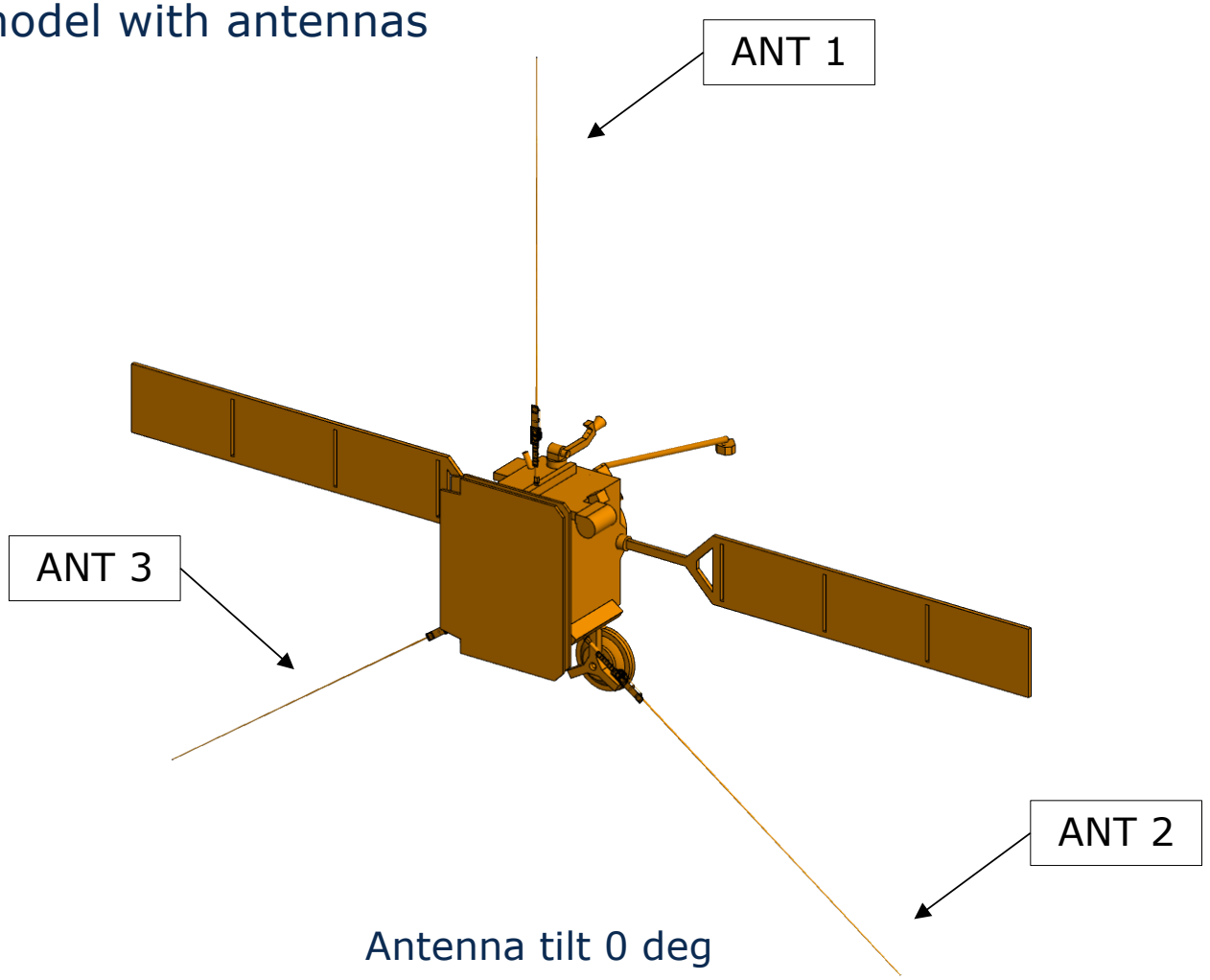
Solar Orbiter

Effective Antenna Length

Dirk Plettemeier, Ronny Hahnel

Stockholm, 20.06.2017

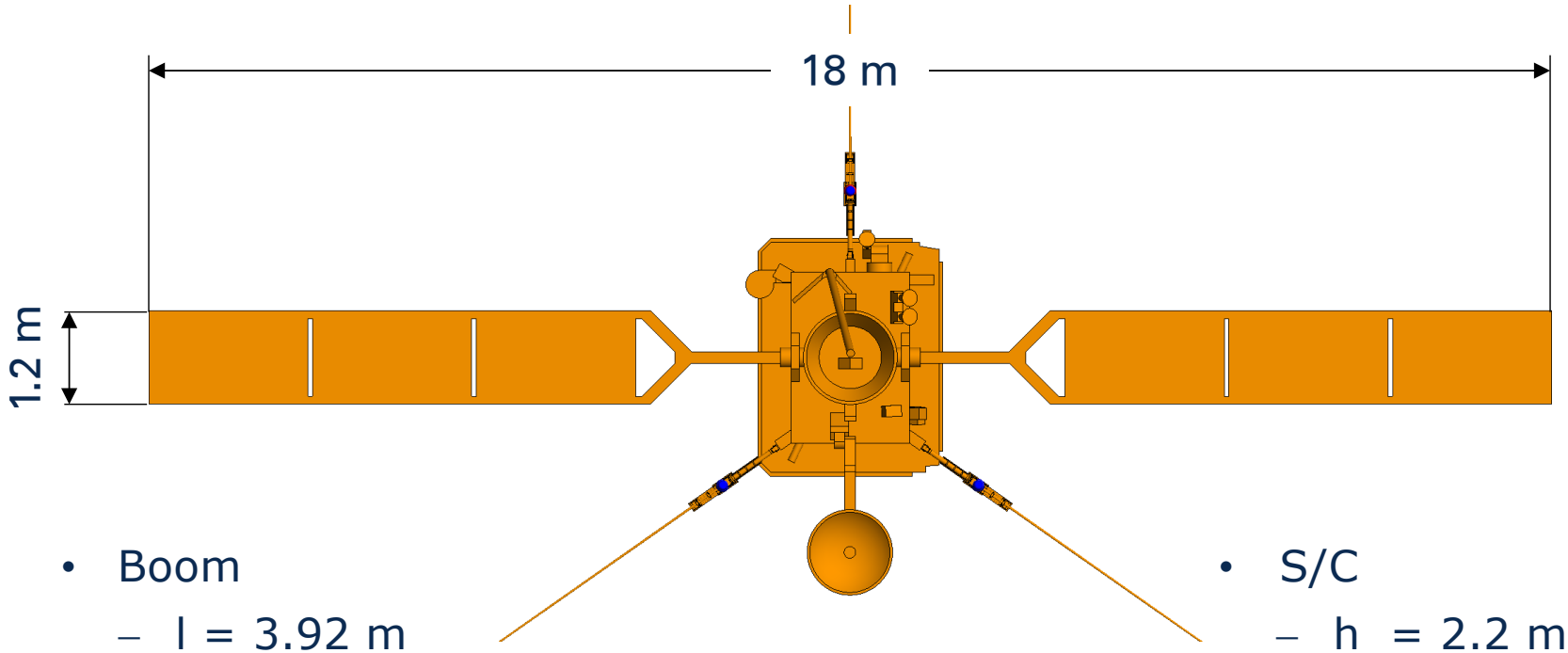
Orbiter model with antennas



Antenna tilt 0 deg

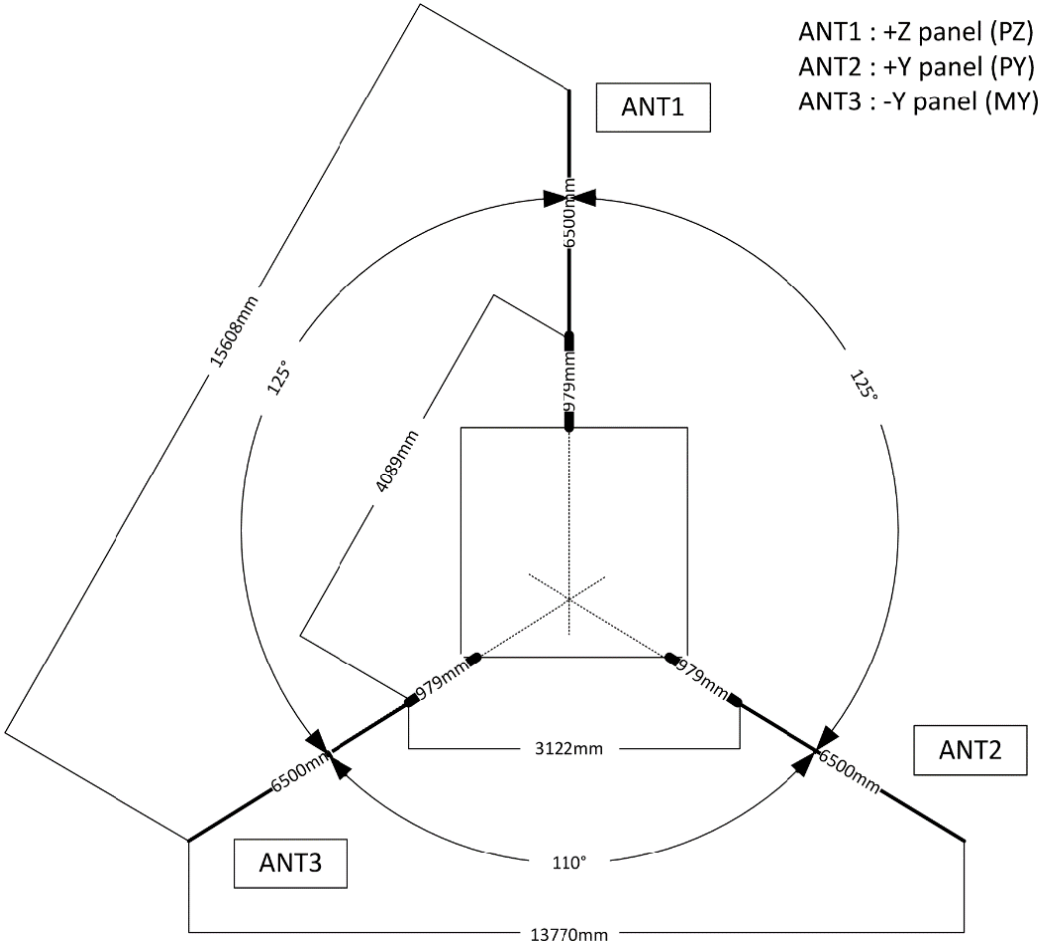
Simulation Setup

S/C dimensions



- Boom
  - l = 3.92 m
- HGA
  - diameter = 1.1 m

- S/C
  - h = 2.2 m
  - w = 1.52 m
  - d = 1.82 m

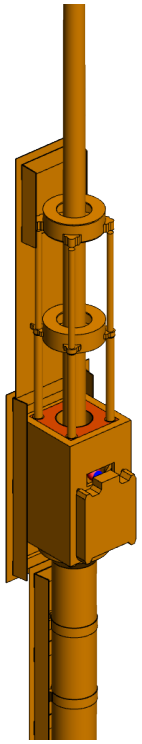


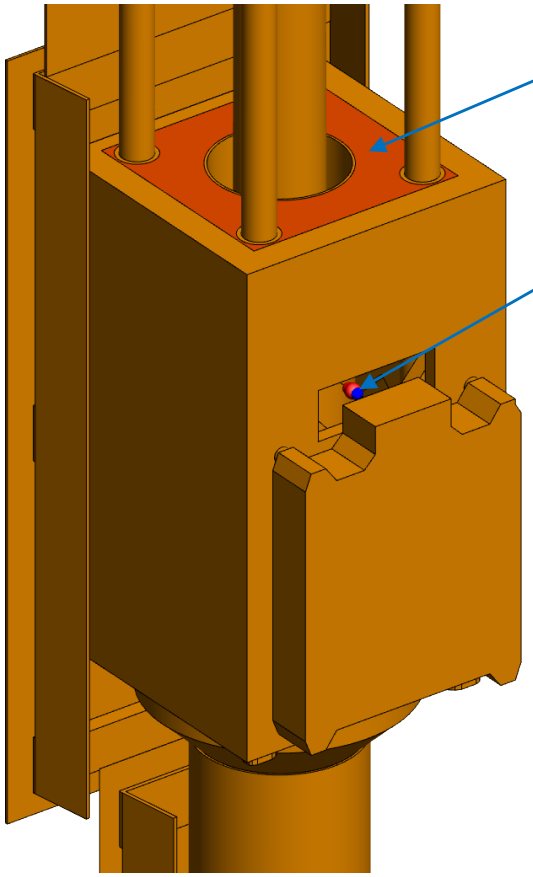
Antenna configuration.

Reference: M. Maksimovic "Inputs for RPW ANT simulation by the group of Dirk Plettemeier", 23/02/2016

Simulation Setup

Antenna simulation model



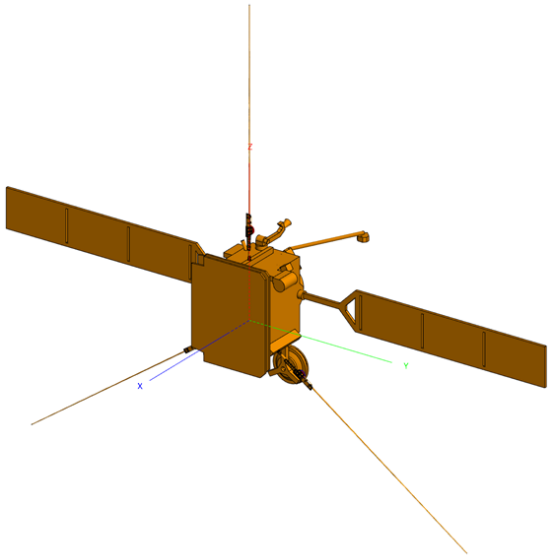


- Frequency: 300 kHz
- Antenna length: 6.5 m

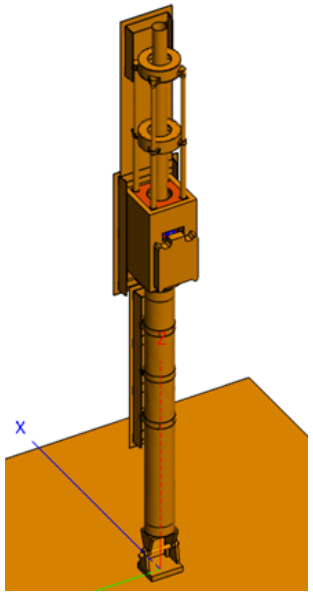
$$h_{eff} = \frac{V_{feed}}{E_i}$$

Simulation parameter

- f = 300 kHz
- insulators with ε_r = 3.3 and tan δ = 0.0048
- antenna length 6.5 m
- parallel circuit in the feeding point: R = 40 MΩ and C = 30 pF
- solar panel orientation like shown below



FEKO-model with complete Solar Orbiter antenna on S/C.



Antenna in shortened configuration.

Definitions

- Simulations already include base capacitance C_B and capacitance of the amplifier C_{PA}= 30 pF
- Capacitance of the coaxial cable C_c has to be taken account by the parameter Γ_c

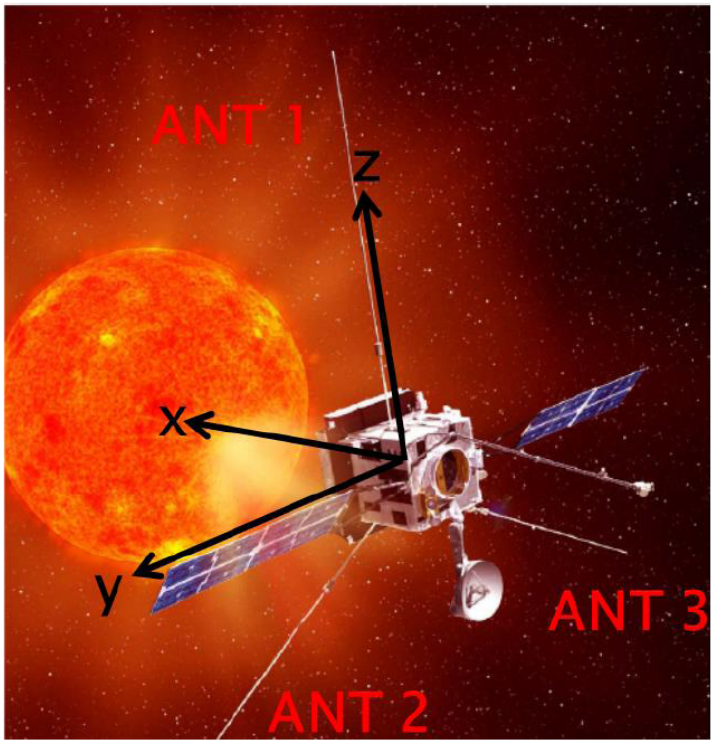
Variables and formulas

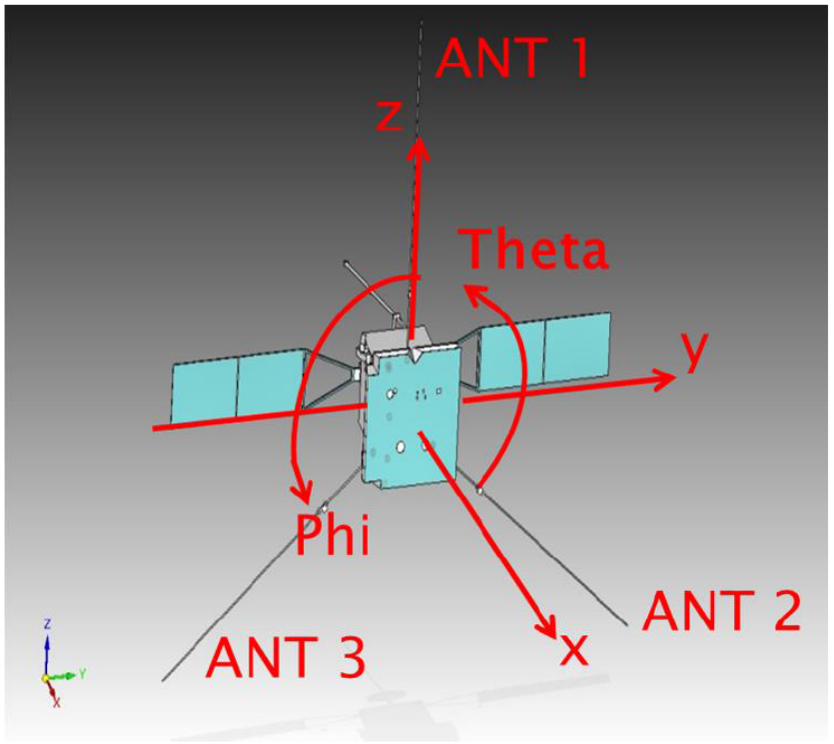
- $C_A^{complete}$: Antenna capacitance of the complete antenna (6.5 m) aboard the S/C
- C_A^{cut} : Antenna capacitance of the shortened antenna aboard the S/C
- C_C : Capacitance of the coaxial cable

$$\Gamma_c = \frac{C_A^{complete}}{C_A^{complete} + C_c}$$

Simulation Setup

Coordinate system



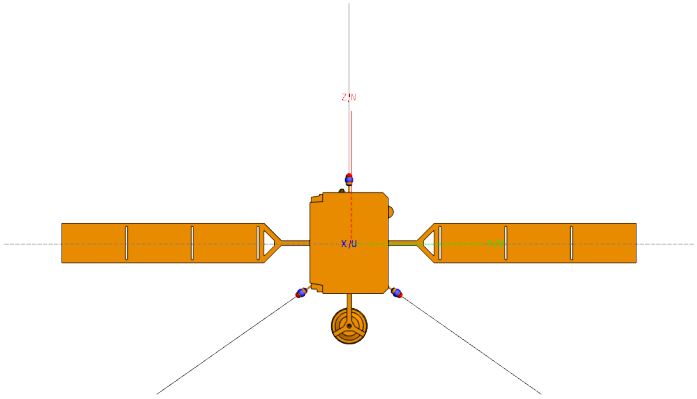


Reference frame coordinate system for Solar Orbiter spacecraft. Antenna 1 extends in the positive z-axis while the heat shield faces into the positive x-axis.

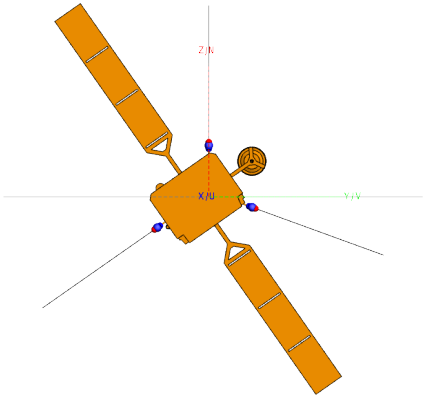
Reference: M. Sampl , D. Plettemeier *"Anechoic chamber measurements of spaceborne antennas (CM/ANT) - Final Report", 30/09/2013*

Simulation steps for effective length

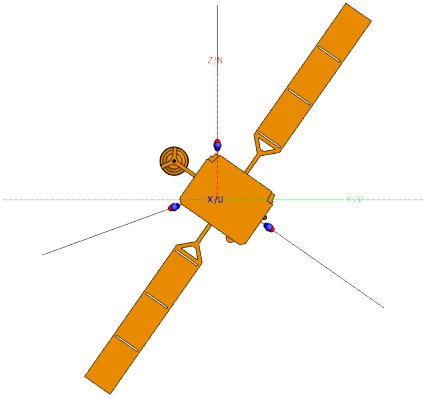
1. Antenna works as transmitter in order to determine the direction of the maximum electric field value and polarization angle
   → each antenna is rotated into the z-axis



Antenna 1



Antenna 2

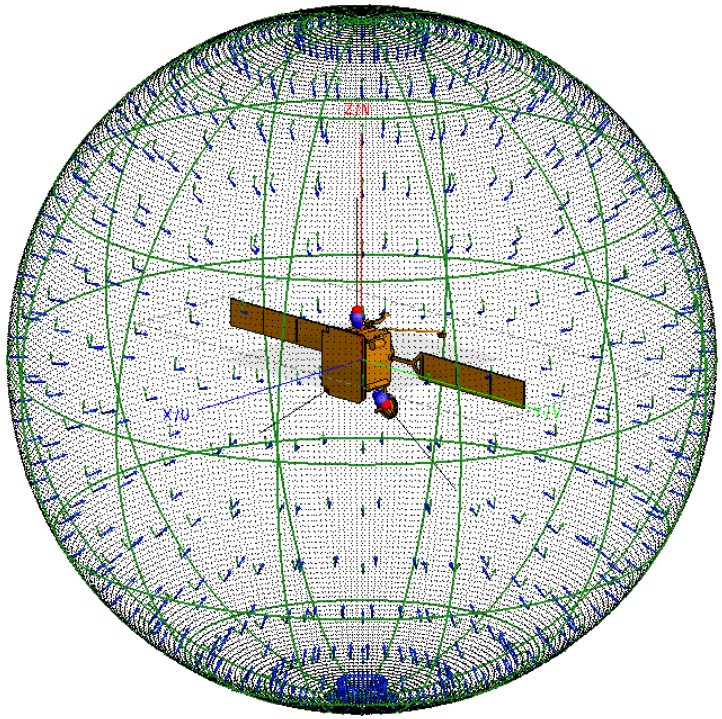


Antenna 3

→ for the simulations it is necessary that each antenna is rotated into the z-axis

Simulation steps for effective length

2. Source for the simulation is a plane wave (E=1 V/m) with angle of incident and polarization angle like determined in step 1



Simulation model for antenna 1 with plane wave sources from every direction

Simulation steps for effective length

3. Angle of incident, which generates maximum voltage on terminal is determined

   - Effective length L_{eff} can be theoretically calculated by

$$L_{eff} = \frac{V_{feed}}{E_i} \quad \text{with} \quad E_i = 1\,{}^{V}/_{m}$$

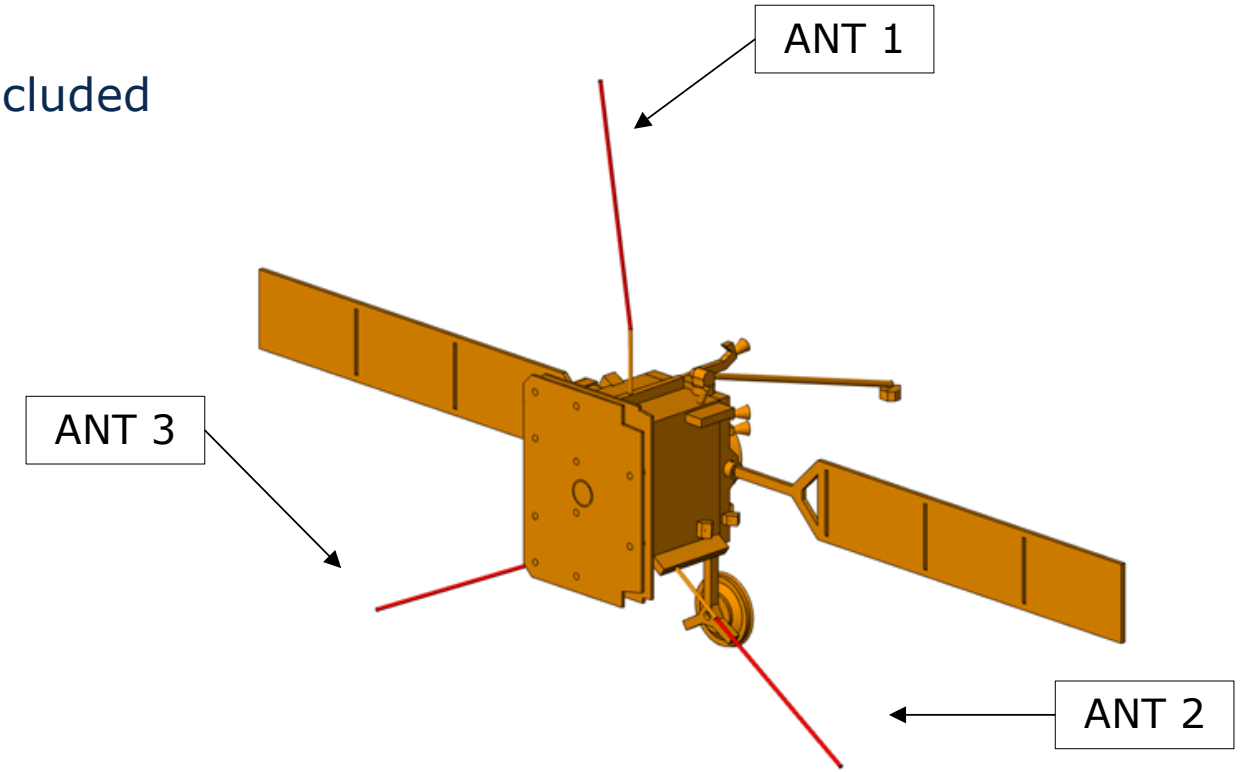
   - This formulation doesn't consider the capacitance of the coaxial cable C_c and is related to the pre-amplifier

   - The influence of the coaxial cable can be taken into account by

$$L_{eff}^{c} = \Gamma_c \cdot L_{eff} = \Gamma_c \cdot \frac{V_{feed}}{E_i} \quad \text{with} \quad \Gamma_c = \frac{C_A^{complete}}{C_A^{complete} + C_c}$$

total maximum length

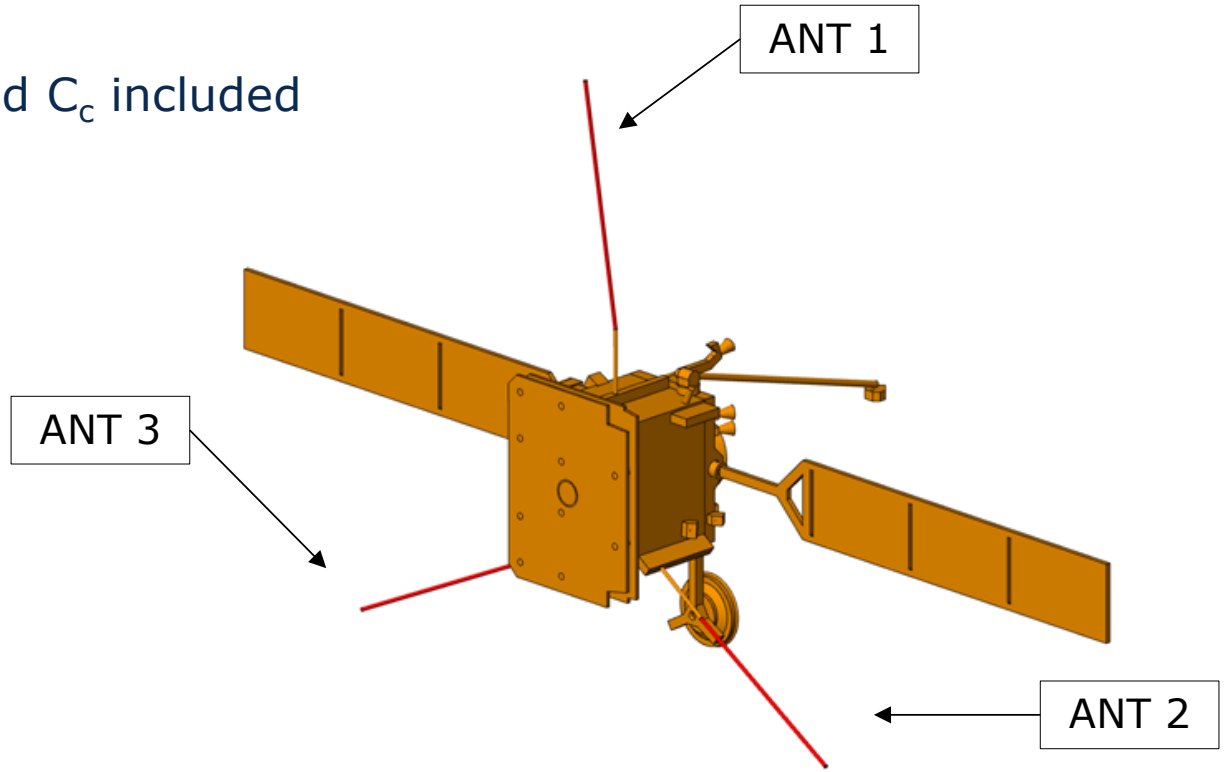
C_{PA} included



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	1.844	81.34	-0.22
Antenna 2	1.660	79.81	-132.98
Antenna 3	1.599	79.87	117.11

total maximum length

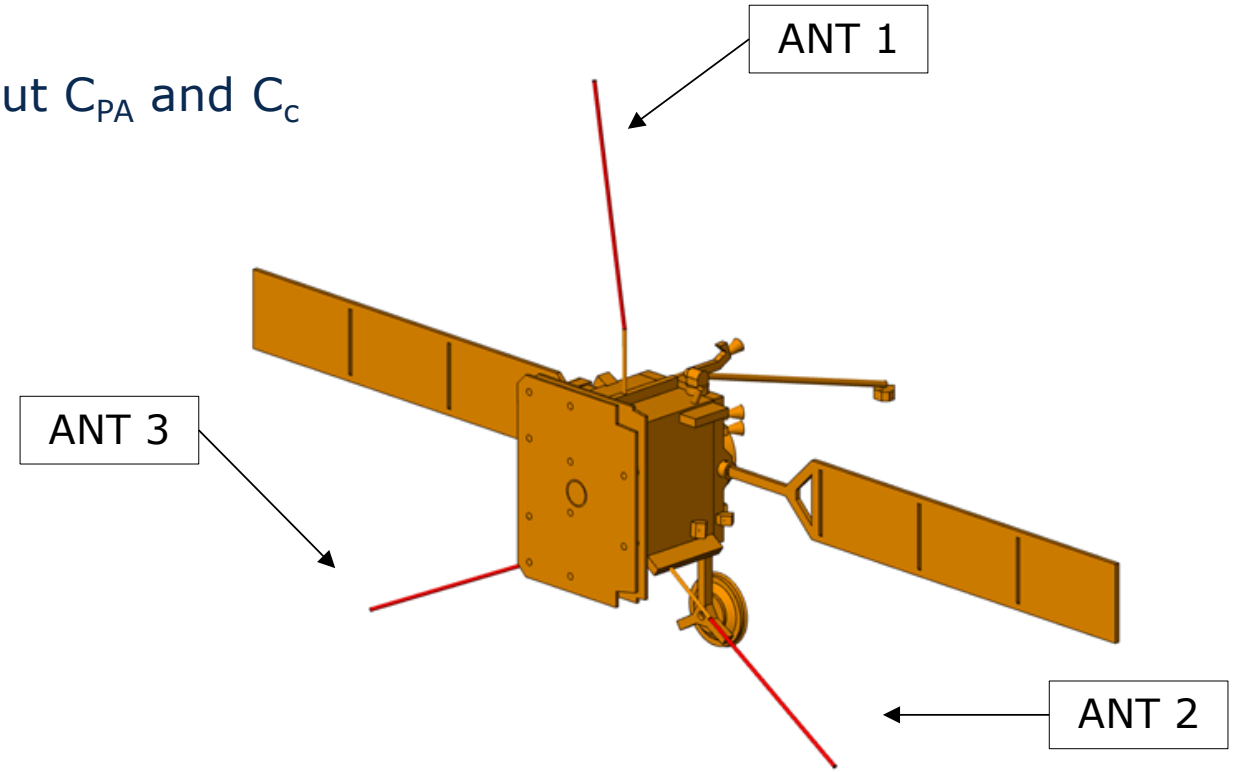
C_{PA} and C_c included



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	1.715	81.34	-0.22
Antenna 2	1.546	79.81	-132.98
Antenna 3	1.486	79.87	117.11

total maximum length

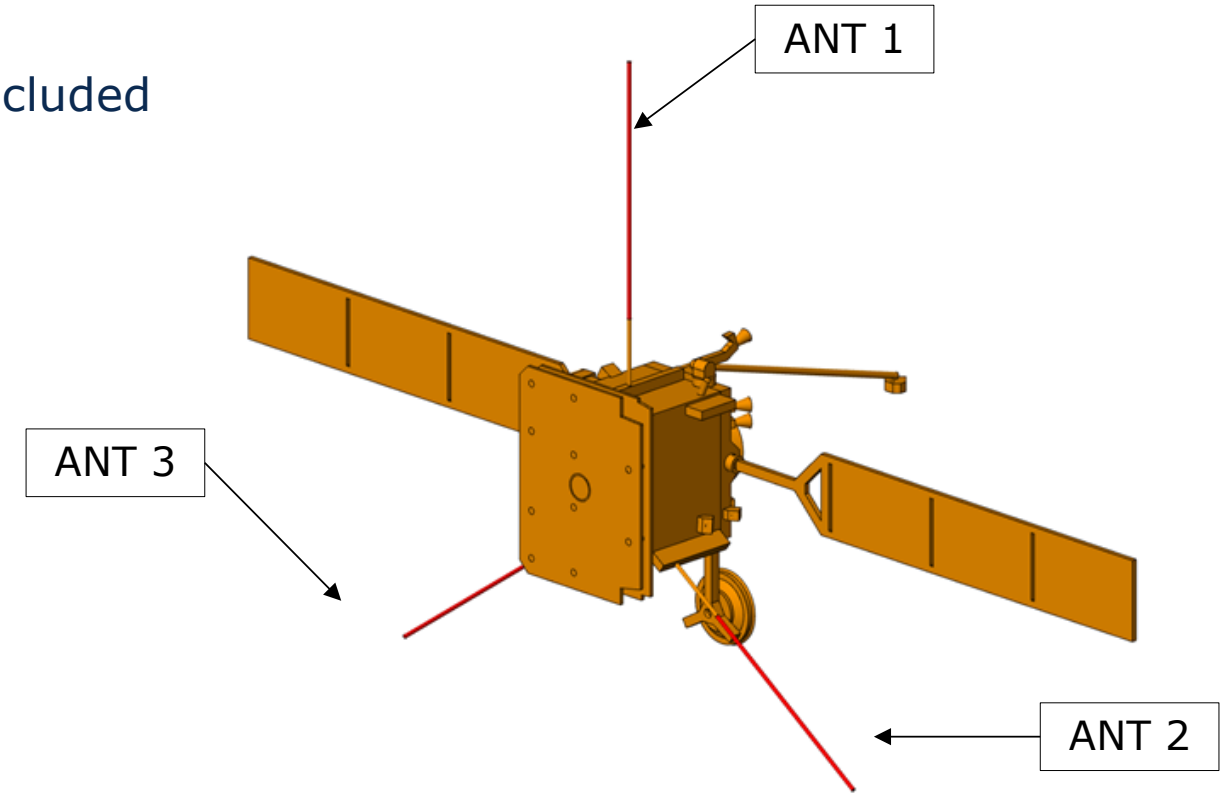
Without C_{PA} and C_c



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	2.675	81.34	-0.22
Antenna 2	2.396	79.81	-132.98
Antenna 3	2.332	79.87	117.11

maximum length for sun direction

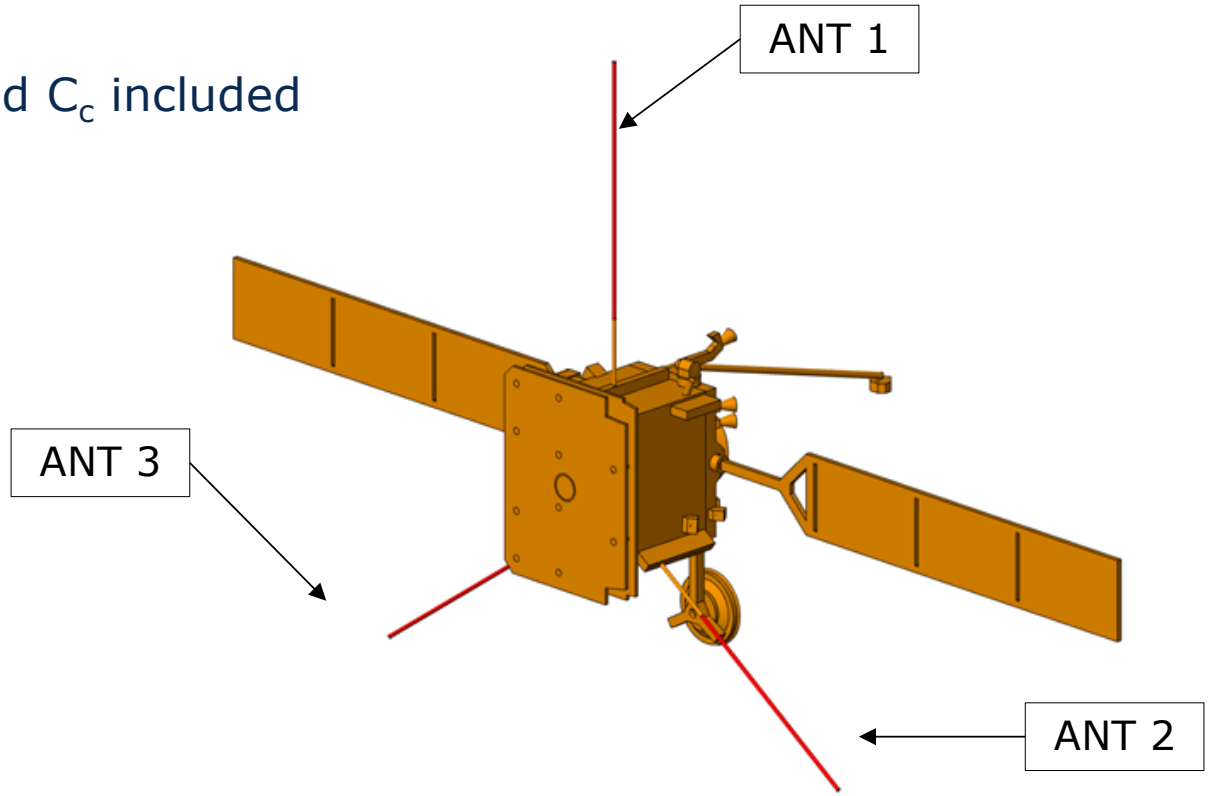
C_{PA} included



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	1.824	90	-0.09
Antenna 2	1.635	90	-132.99
Antenna 3	1.575	90	117.11

maximum length for sun direction

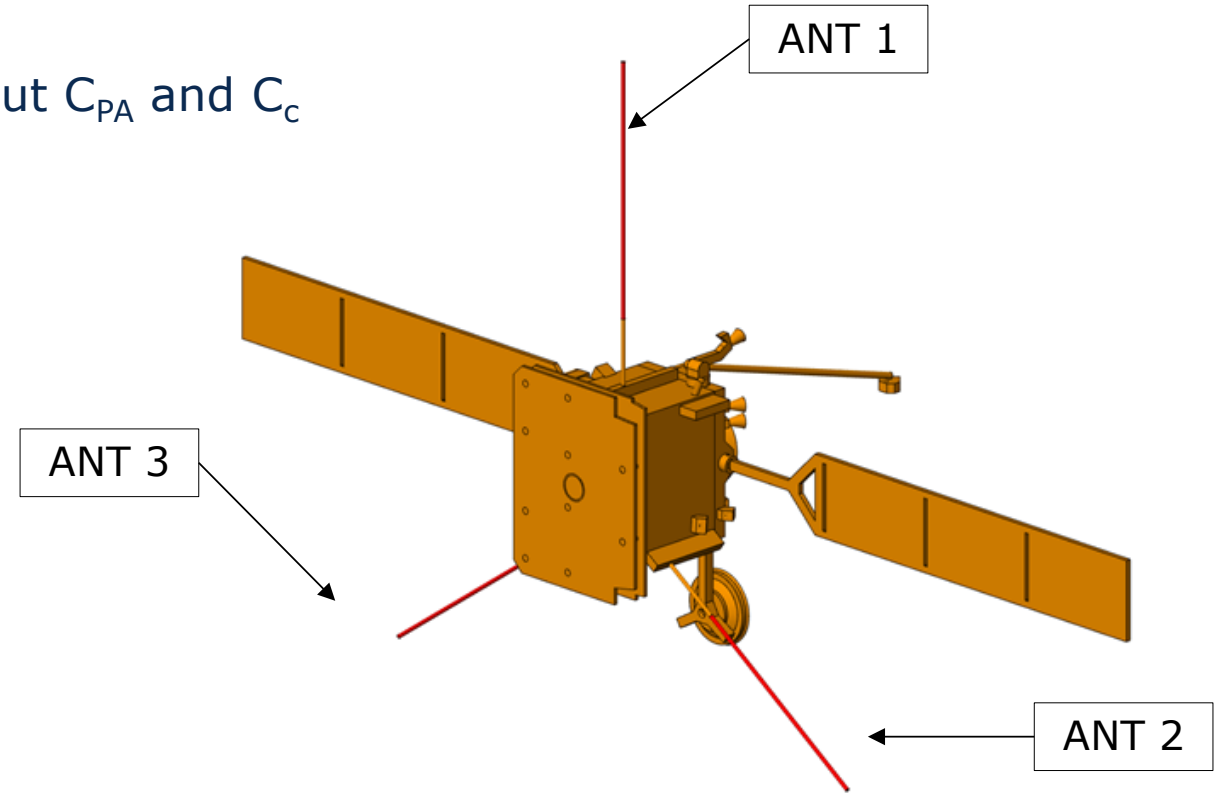
C_{PA} and C_c included



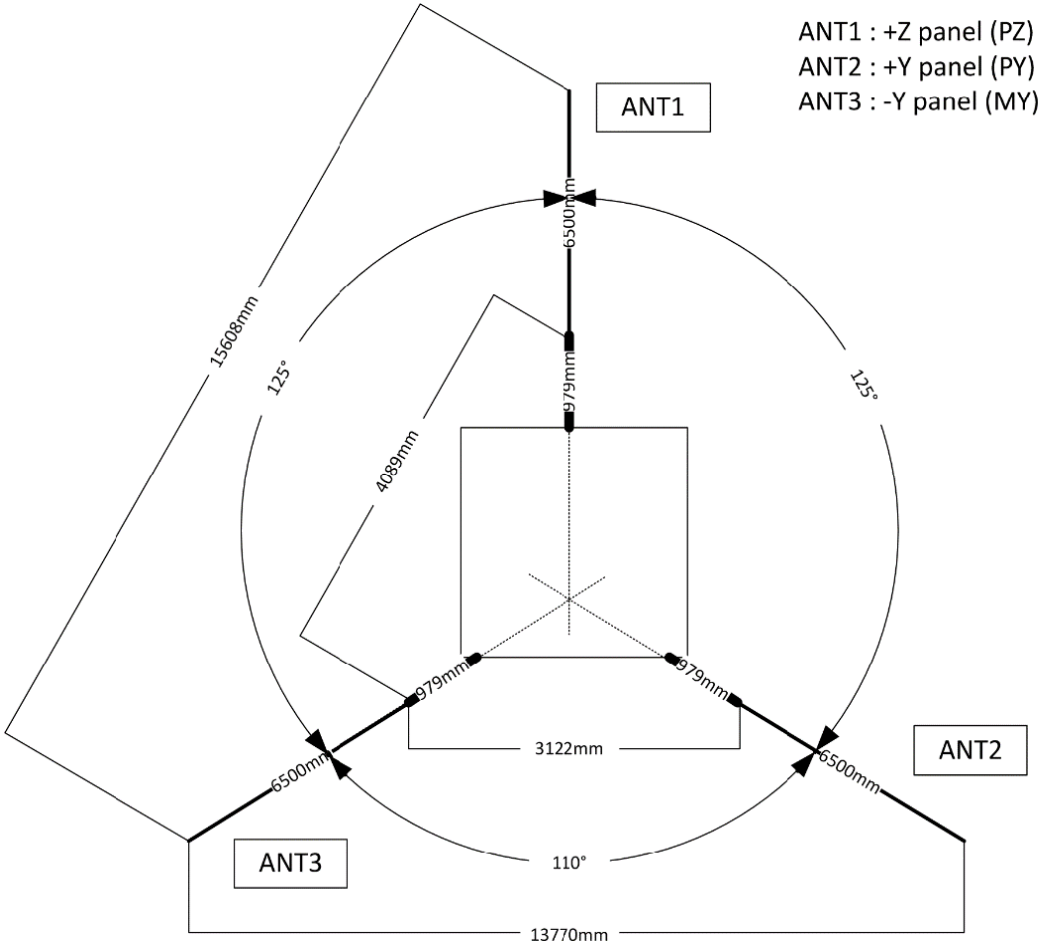
	Effective length in m	ϑ in degree	φ in degree
Antenna 1	1.696	90	-0.09
Antenna 2	1.522	90	-132.99
Antenna 3	1.463	90	117.11

maximum length for sun direction

Without C_{PA} and C_c



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	2.645	90	-0.09
Antenna 2	2.360	90	-132.99
Antenna 3	2.297	90	117.11



Antenna configuration.

Reference: M. Maksimovic "Inputs for RPW ANT simulation by the group of Dirk Plettemeier", 23/02/2016

L_{eff} for dipole configuration without C_c

Total maximum length

	Effective length in m	ϑ in degree	φ in degree
Antenna 1-2	3.167	89.73	22.12
Antenna 1-3	3.042	89.98	-22.66
Antenna 2-3	2.341	89.65	88.88

Length for sun direction

	Effective length in m	ϑ in degree	φ in degree
Antenna 1-2	3.167	90	22.12
Antenna 1-3	3.042	90	-21.66
Antenna 2-3	2.341	90	88.88

L_{eff} for dipole configuration with C_c

Total maximum length

	Effective length in m	ϑ in degree	φ in degree
Antenna 1-2	2.946	89.73	22.12
Antenna 1-3	2.832	89.98	-22.66
Antenna 2-3	2.175	89.65	88.88

Length for sun direction

	Effective length in m	ϑ in degree	φ in degree
Antenna 1-2	2.946	90	22.12
Antenna 1-3	2.832	90	-21.66
Antenna 2-3	2.175	90	88.88

L_{eff} for dipole config. without C_{PA} and C_c

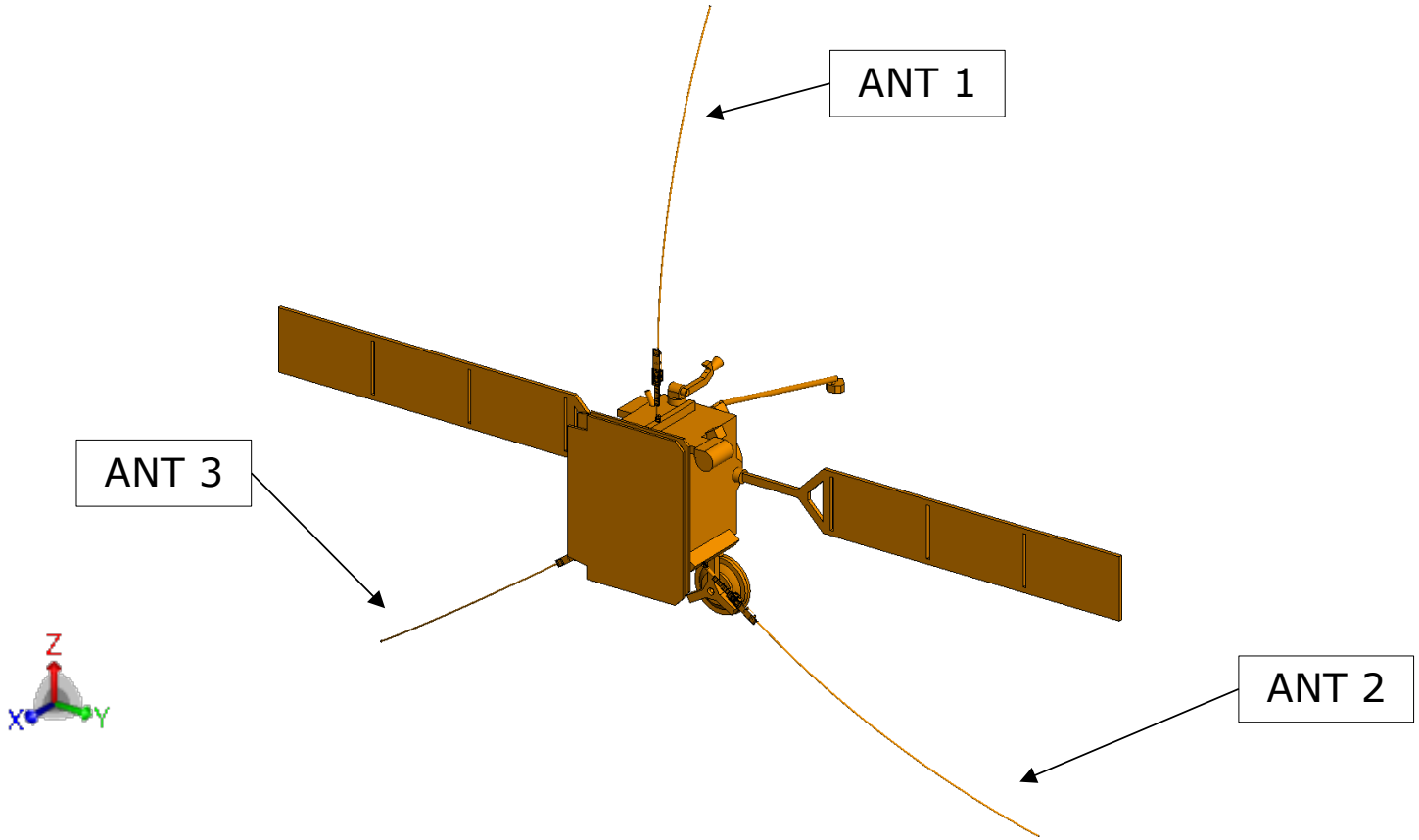
Total maximum length

	Effective length in m	ϑ in degree	φ in degree
Antenna 1-2	4.594	89.73	22.12
Antenna 1-3	4.391	89.98	-22.66
Antenna 2-3	3.415	89.65	88.88

Length for sun direction

	Effective length in m	ϑ in degree	φ in degree
Antenna 1-2	4.594	90	22.12
Antenna 1-3	4.391	90	-21.66
Antenna 2-3	3.415	90	88.88

Antenna bending – total maximum



L_{eff} for bended configuration without C_c

Total maximum length

	Effective length in m	ϑ in degree	φ in degree
Antenna 1	2.386	86.63	-0.20
Antenna 2	2.021	87.24	-131.0
Antenna 3	1.560	69.5	111.79

Length for sun direction

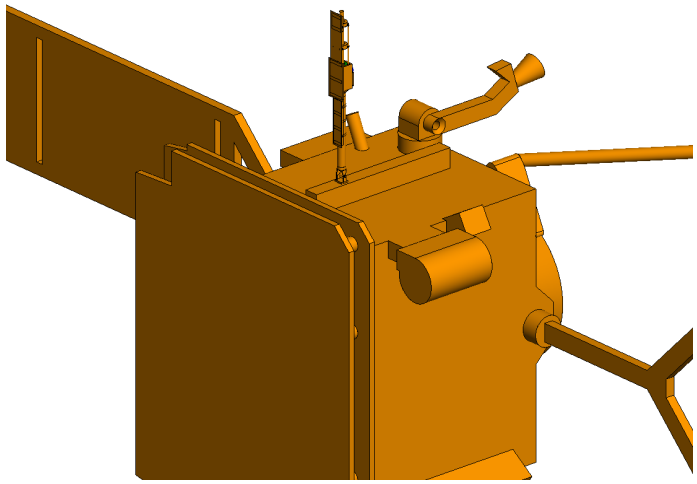
	Effective length in m	ϑ in degree	φ in degree
Antenna 1	2.051	90	-0.03
Antenna 2	1.837	90	-131.15
Antenna 3	1.450	90	111.79

Computation of base capacitance C_B

1. Computation of the capacitance of the complete antenna $C_A^{complete}$
2. Computation of the capacitance of the shortened antenna C_A^{cut}

$$C_B = C_A^{complete} - C_A^{cut}$$

Configuration	Antenna	C in pF
Complete solar orbiter antenna on S/C → $C_A^{complete}$	ANT1	66.576
	ANT2	67.625
	ANT3	65.434
Shortened solar orbiter antenna on S/C → C_A^{cut}	ANT1	34.051
	ANT2	35.356
	ANT3	34.757



Model with shortened antenna on S/C

Improved simulation model

What's new?

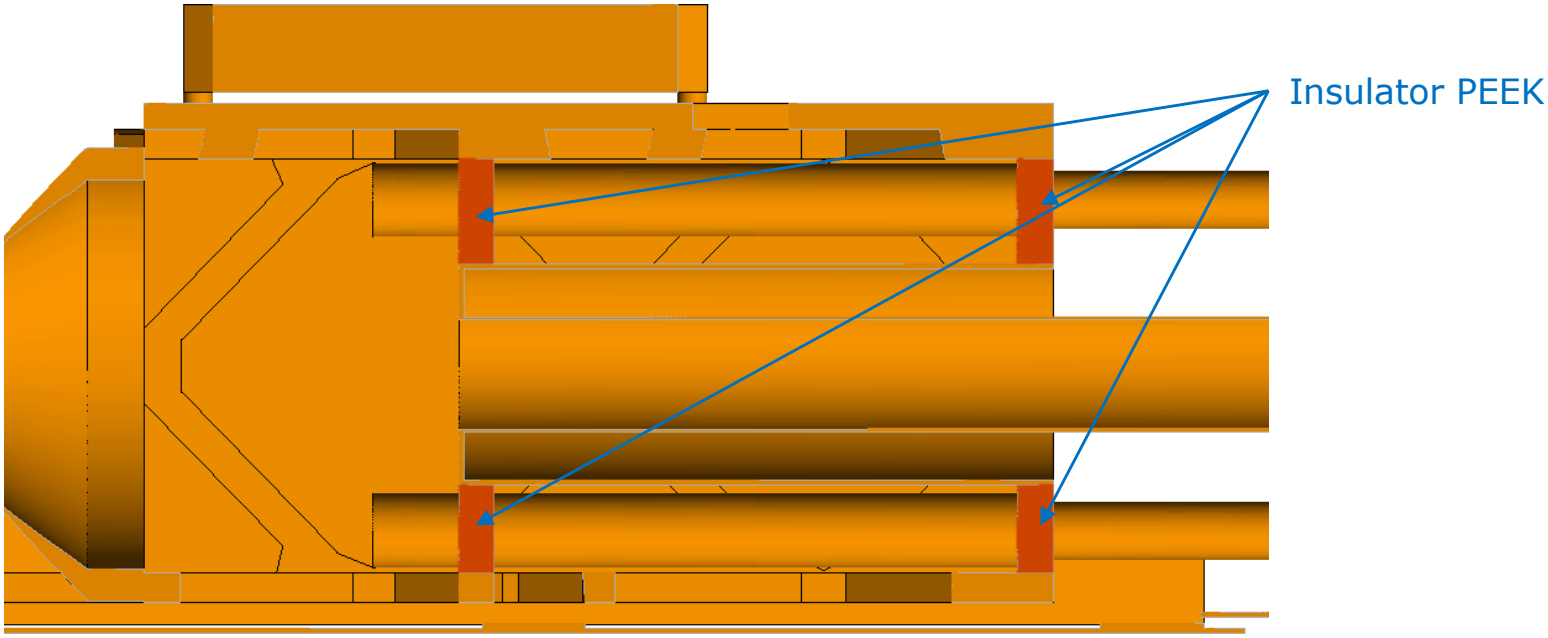
- Input impedance of pre-amplifier: parallel circuit of 40 MΩ and 30 pF at all antenna ports (contributing to antenna coupling)
- Significant higher complexity of the simulated model
  → much more details of the CAD-model are included
  - Updated S/C-geometry -> influence of staycer thickness
  - Dielectric insulators are considered
    → L_{eff} is getting smaller (≈5%)
  - Impact of coaxial cable included by shortening factor
    → L_{eff} is getting smaller (≈7%)
- Dipole configuration -> length increase of about a factor of ≈ 1.7
- Influence of antenna bending -> bending is increasing the length

Future work

- Solar panel rotation
- Bended dipole configuration
- Influence of further non metallic materials
- Connection between S/C and solar panel / booms
- …

BACKUP

Antenna simulation model - cut



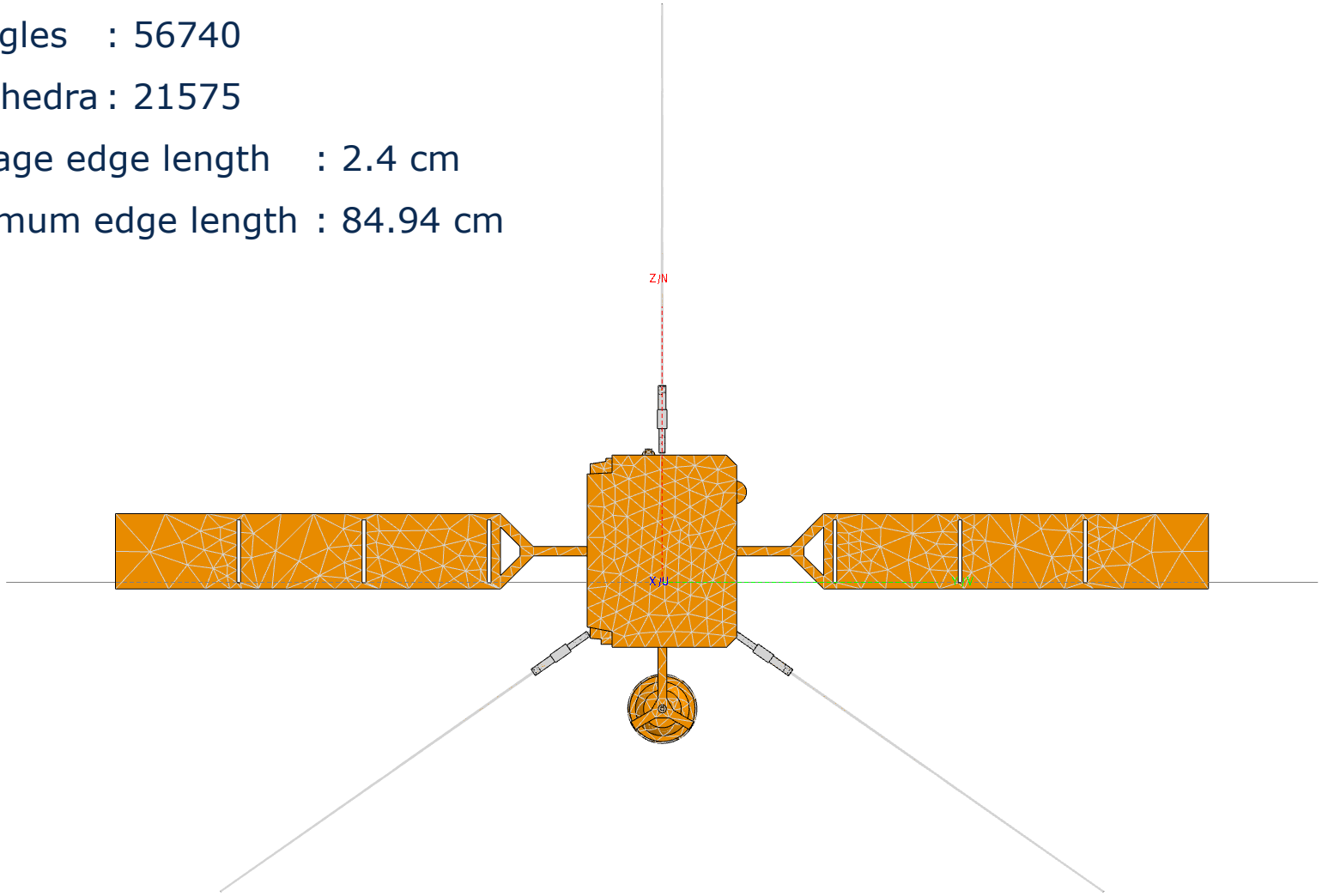
Mesh size

Triangles : 56740

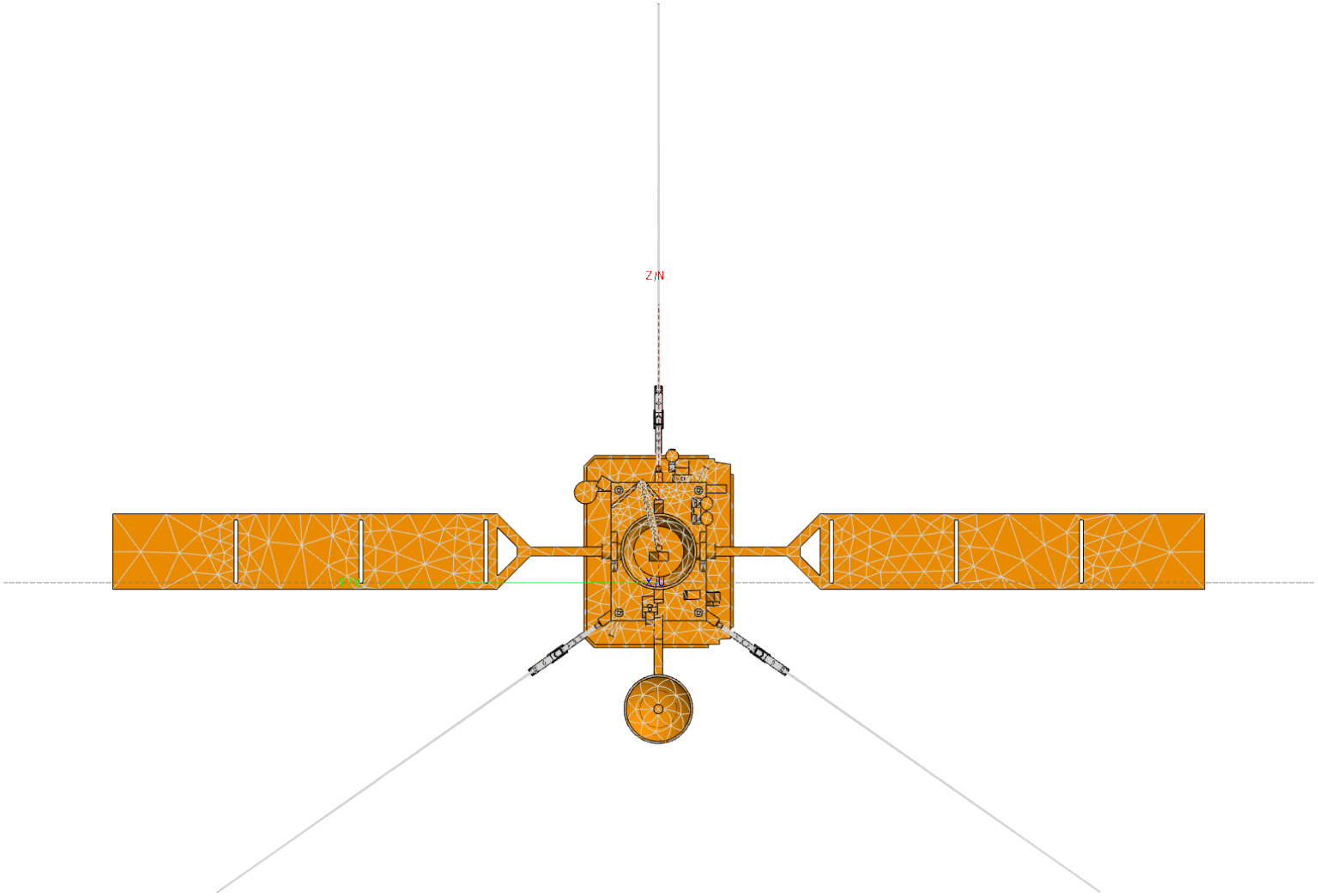
Tetrahedra : 21575

Average edge length : 2.4 cm

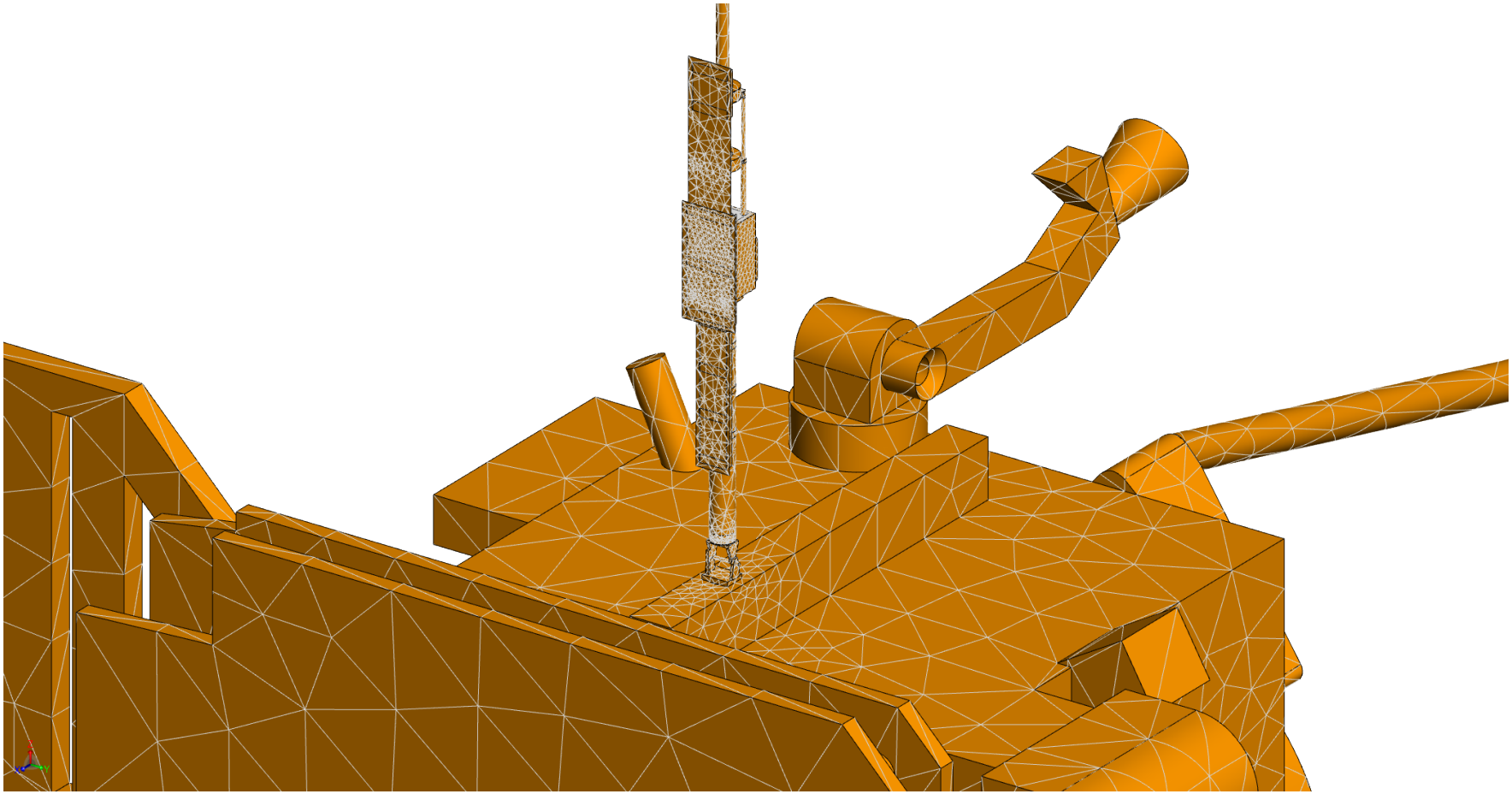
Maximum edge length : 84.94 cm



Mesh size



Mesh size



Antenna length for dipole

FEKO-Ergebnisse der effektive Längen für die geraden Einzelantenne auf unendlich ausgedehnter PEC-Ebene (wenn nicht anders angegeben) und bei f = 300 kHz. Der Polarisationswinkel γ der einfallenden Welle entspricht der geometrischen Ausrichtung der Antenne.

Konfiguration	**Effektive Länge in Metern, $\Gamma \cdot L_{eff}$**
Mit verlustbehafteten Isolator (PEEK) und Parallelschaltung aus 40 MΩ und 30 pF	3.045
Mit verlustlosen Isolator (PEEK) und Parallelschaltung aus 40 MΩ und 30 pF	3.045
Mit verlustlosen Isolator (PEEK) und 40 MΩ, aber ohne C	4.355
Ohne Isolatoren, mit 40 MΩ, ohne C	4.602
Ohne Isolatoren, mit 40 MΩ und 30 pF	3.153
Wire-Element mit 40 MΩ, ohne C	6.311
Wire-Element mit 40 MΩ und 30 pF	2.824
Wire-Element **auf original S/C (ANT 1)** mit 40 MΩ und 30 pF	1.699

References

Literature

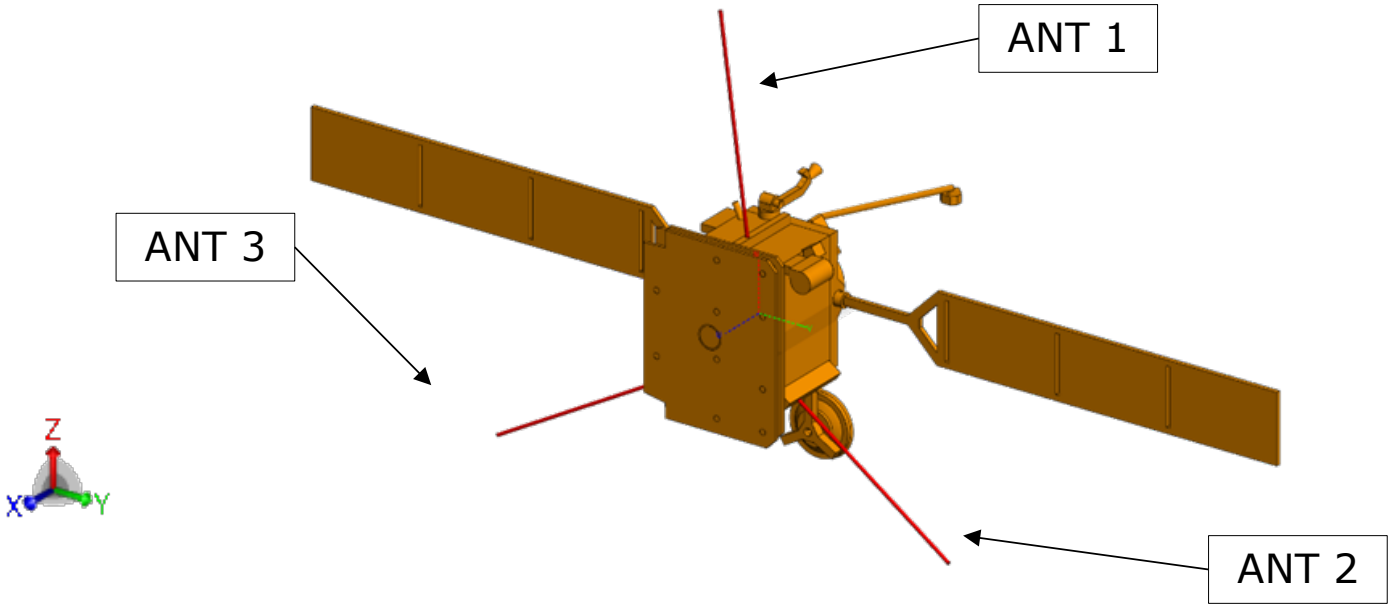
[1] Bale, S. D., R. Ullrich, K. Goetz, N. Alster, B. Cecconi, M. Dekkali, N. R. Lingner et al. "The electric antennas for the STEREO/WAVES experiment." In The STEREO Mission, pp. 529-547. Springer New York, 2008.

[2] M. Maksimovic “Inputs for RPW ANT simulation by the group of Dirk Plettemeier”, 23/02/2016

[3] M. Sampl, D. Plettemeier “Anechoic chamber measurements of spaceborne antennas (CM/ANT) - Final Report”, 30/09/2013

Tilt 0 deg - total maximum length

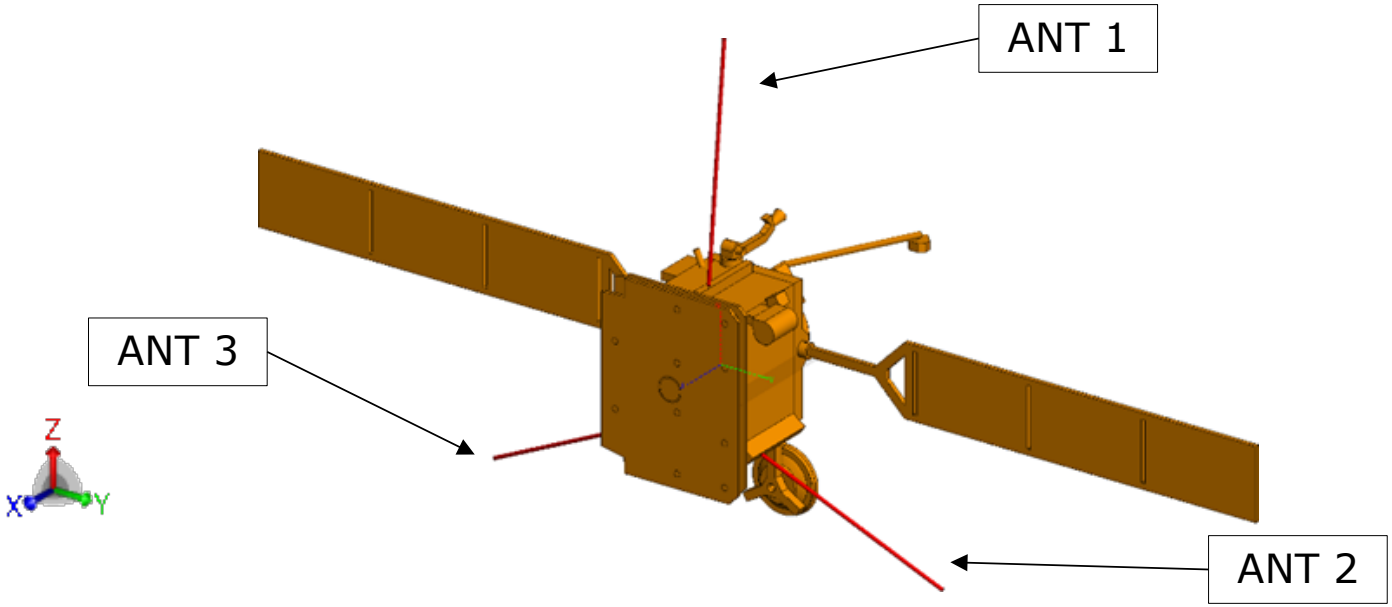
No PEEK-Insulators, no capacitance, only R=40 MΩ



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	3.95	81	0.8
Antenna 2	3.56	79.9	-116.7
Antenna 3	3.57	79.1	117.8

Tilt 10 deg - total maximum length

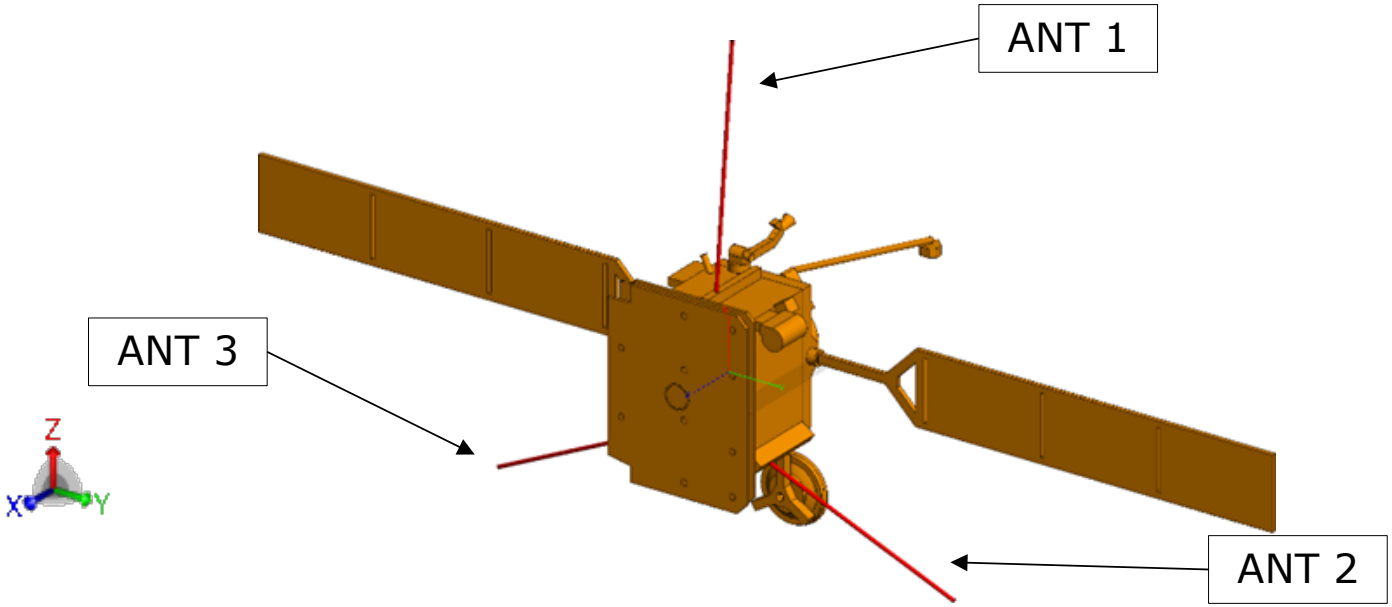
No PEEK-Insulators, no capacitance, only R=40 MΩ



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	3.92	88.3	1
Antenna 2	3.43	88.1	-116.2
Antenna 3	3.44	86.4	116.8

Tilt 20 deg - total maximum length

No PEEK-Insulators, no capacitance, only R=40 MΩ



	Effective length in m	ϑ in degree	φ in degree
Antenna 1	3.78	95	0.6
Antenna 2	3.29	95.9	-116.9
Antenna 3	3.29	93.7	115.7

OLD RESULTS

Effective antenna length for monopole configuration

Calculated parameters for monopole configuration with values for C_{stud} and C_{PA} from M. Maksimovic.

Parameter	ANT1	ANT2	ANT3
$C_{A,complete}$ in pF	66,576	67,625	65,434
$C_{A,cut}$ in pF	34,051	35,356	34,757
C_B in pF	32,53	32,27	30,68
C_{PA} in pF	25,00		
C_{stud} in pF	5,00		
C_{stray} in pF	62,5250	62,2690	60,6770
Γ in m	0,5157	0,5206	0,5189
$\Gamma \cdot L_{eff,MAX}$ in m	1,8440	1,6600	1,5990
$L_{eff,MAX}$ in m	3,5758	3,1885	3,0818
$\Gamma \cdot L_{eff,SUN}$ in m	1,8235	1,6350	1,5750
$L_{eff,SUN}$ in m	3,5360	3,1405	3,0355

Antenna length for dipole

Effective antenna length for dipole configuration

Calculated parameters for monopole configuration with values for C_{stud} and C_{PA} from M. Maksimovic.

Parameter	ANT1	ANT2	ANT3
$C_{A,complete}$ in pF	66,576	67,625	65,434
$C_{A,cut}$ in pF	34,051	35,356	34,757
C_B in pF	32,53	32,27	30,68
C_{PA} in pF	25,00		
C_{stud} in pF	5,00		
C_{stray} in pF	62,5250	62,2690	60,6770
Γ in m	0,5157	0,5206	0,5189
$\Gamma \cdot L_{eff,MAX}$ in m	3,1671	3,0416	2,3412
$L_{eff,MAX}$ in m	6,1414	5,8422	4,5123
$\Gamma \cdot L_{eff,SUN}$ in m	3,1670	3,0415	2,3412
$L_{eff,SUN}$ in m	6,1414	5,8421	4,5122