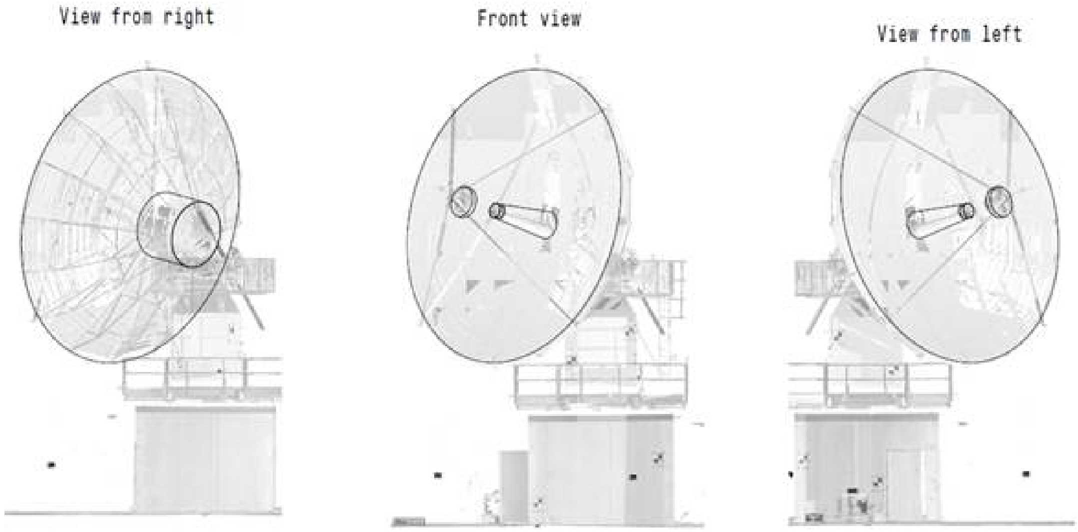
3D Laser Scanning

An ESA Microwave GmbH Service



3D Laser Scanning: A Dedicated Service by ESA Microwave GmbH

In this 3D laser scanning presentation, we describe the measurement process and the evaluation of the resultant data.
The process was developed by ESA Microwave GmbH for the measurement of ground station antennas. A 3D laser measuring device gives information relevant to the actual performance of each antenna.

3D laser scanning

3D laser scanning is today the most accurate and efficient method for the measurement of reflector geometry, offering several advantages over photogrammetry. A comparison of the two processes is given below:

Laser Scanning Setup

Photogrammetry

- A **cherry picker** or crane is needed and **at least two people** must be on site.
- The antenna must be taken **<u>out of service</u>** during process.
- **Several hundred adhesive targets must be applied by hand** onto the reflector.
- The **cost is quite high** and the process is **time consuming**.

As a result, **only a few hundred points will be measured**!

Challenge

Upgrading an existing antenna to **higher frequencies** also requires **higher resolution** from the reflector system.

The 3D laser precisely measures the current state of the existing antenna geometry at a resolution of ≤ 1 mm. This provides high-accuracy information about relevant performance parameters.

Your status

You have at your site one or several antennas that need evaluation.
Are you looking to upgrade to higher frequency band?
Would you like to refurbish your antennas and/or feeds?

Why ESA Microwave GmbH

The ESA Microwave GmbH team is highly experienced in the field of antenna development and retrofitting and we know what is important.

What we offer

ESA Microwave GmbH provides the following:

- Digitizing, scanning and measuring the antenna system.
- Acquisition of all data required for retrofitting in the antenna hub.
- Preparation of measurement data (alignment, registration and fine-tuning).
- Surface restoration based on digitised surfaces.
- Creation of a step file of the existing antenna's main and sub reflector.
- Calculation of intersections due to specified cuts on the surface.
- Feedback and calculation of data to determine the efficiency of the antenna.
- CAD area feedback and area comparison to determine (min-max) deviation.
- Subsequent calculations to determine the gain of the antenna.

Results

1. Data recording of the current state of the antenna. Analysis of structural changes that have occurred in recent years.

2. From the data we can clarify whether your existing antenna (no matter what manufacturer type, year of manufacture or size) can be upgraded, converted or even equipped with an ESA Microwave GmbH **dual-band or tri-band** feed system at your desired frequency.
   Examples: [C/Ku-Feed]
   [S/X/Ka-Feed]
   For further examples, please visit our website: www.esamicrowave.de

3. We deliver specifications and key data in order to know exactly what is possible and which values you can expect.

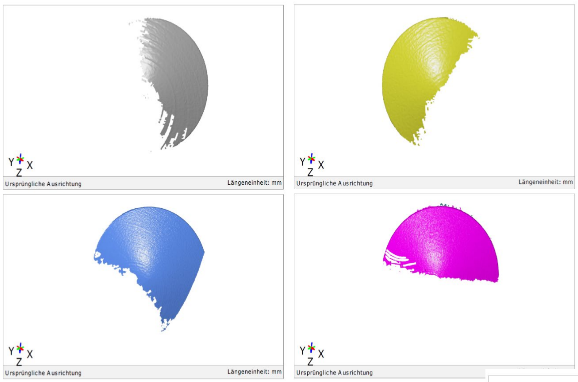
4. What gain-to-noise-temperature (G/T) performance can be achieved if your existing antenna is upgraded with a new feed system.

Technical Background

3D Laser-Scanning and Simulation

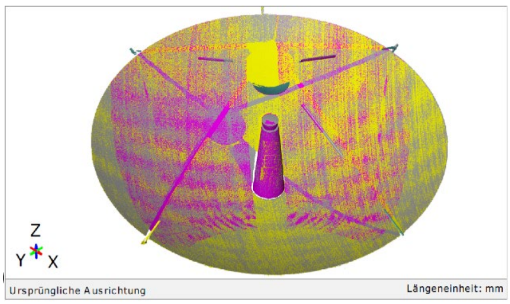
A few fixed points and targets are mounted on the antenna for the laser scanner.
This is a quick and easy process using magnets.
Your antenna will be laser-scanned from multiple angles.
About **60 million points** are measured on the antenna.
A point cloud is generated from this data and then used as a template for the CAD model.

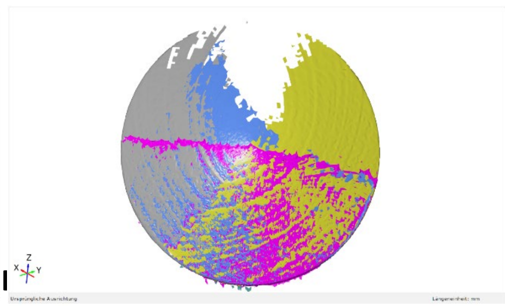
Single laser pictures of the sub and main reflector are calculated to create a total Image:



Calculated overall picture main reflector and sub reflector:

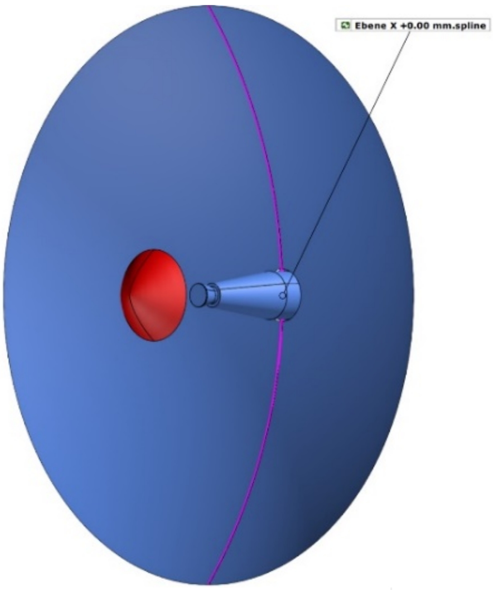
1.

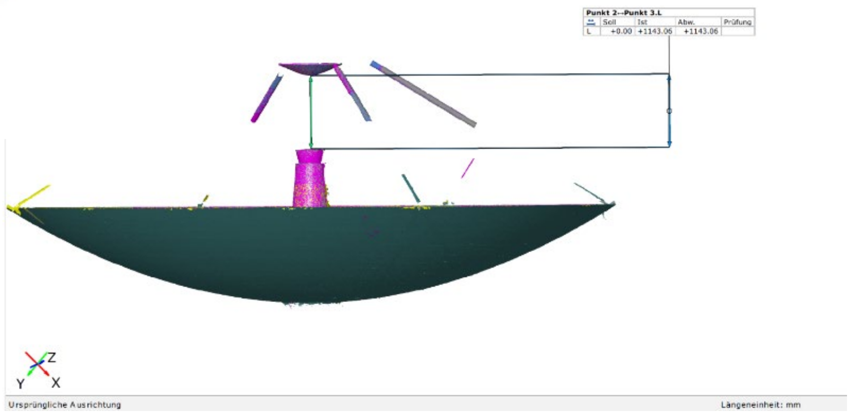




After creating the composite surfaces of the reflector, the scanned point cloud is transferred to a **design program developed by ESA Microwave GmbH** to create a changeable step file. The distances between the individual points are a few tenths of a millimetre.
The laser has a **specified tolerance of less than 1 mm**. The individual measurement points are now calculated from the images and analysed based on the targets attached to the measurement object before the measurement.

The more than 60 million measurement points (X,Y) based on a common coordinate system (centre of the main reflector) are generated in two STEP files (main/secondary reflector). The stroke is then measured and the entire antenna aligned with your axes. The X, Y and Z axes of the reflector result in subsequent calculations.
This results in a very precise dimensional copy of the object to be measured as a constructively usable source (STEP file).





2. Definition of the cutting positions

The reflector surfaces now represent the actual state of the antenna.
To calculate further parameters, several sections are defined on the surface and viewed more closely over the entire antenna. The top/down position of the reflector is adopted.

CAD drawing (top/down) of the customer's antenna:

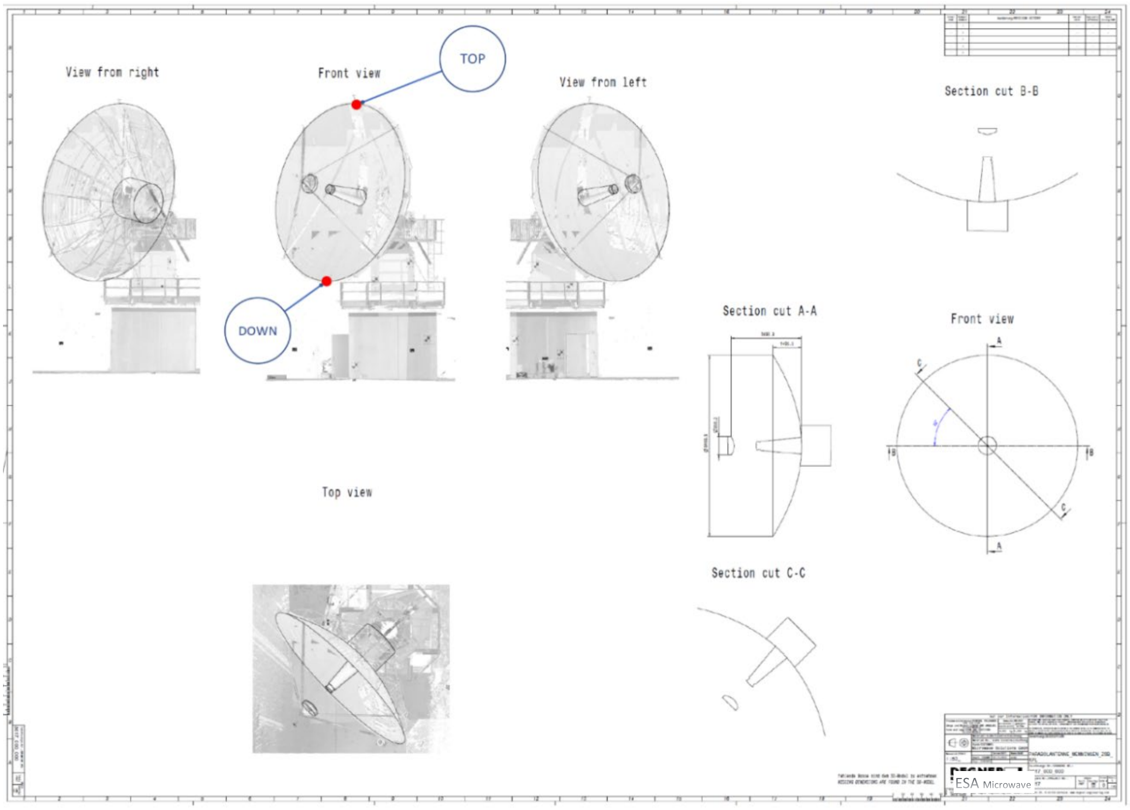


Illustration of the cutting positions/main reflector:

Picture above shows the small (non-shaded) area which was invisible during the laser measurement due to the viewing angle and the position of the reflector. This area is also evident on the sub reflector.

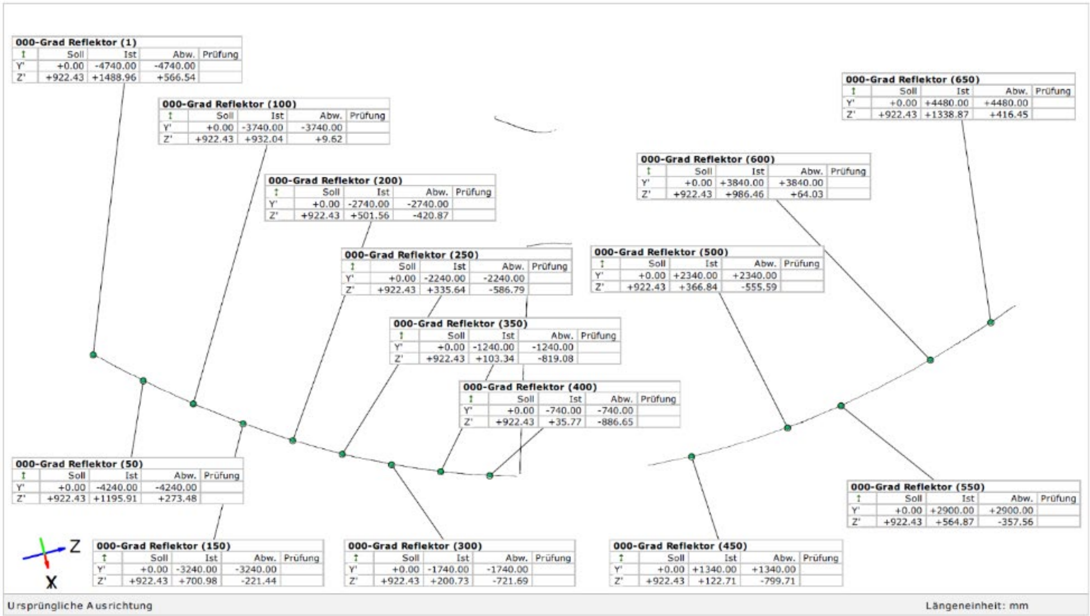
For reverse engineering, however, the lack of this data (below 2%) is negligible.

3. Calculation and feedback of surface geometries

The previously determined individual sections on the main reflector will now be considered more closely.
From all existing data, the parameterisation of the main reflector coordinates follows, for further simulations.

In the following example, the required parameters for calculating the antenna geometry data are generally listed. For an input in the GRASP reflector calculation program, these parameters are crucial coordinates.

Presentation of the section analysis 0° degree Single section. (Intervals of the points of intersection enlarged):



4. Nominal contour definition of the main reflector

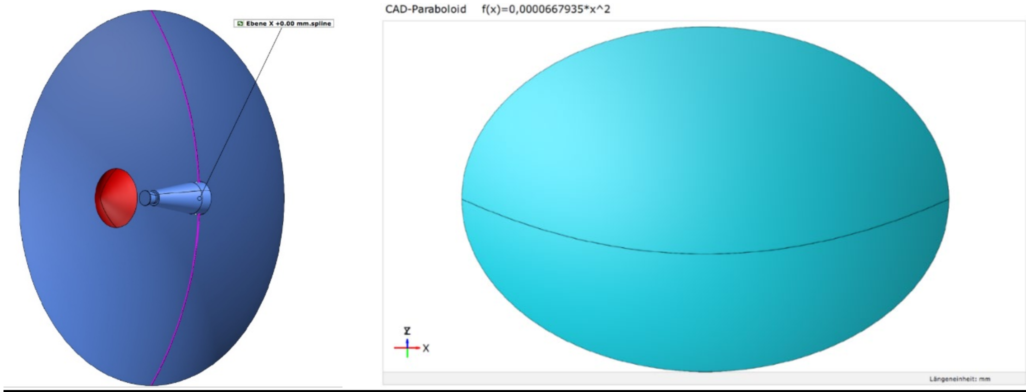
Since no values or specifications are known with respect to the nominal value of the antenna, this was modelled by an additional surface return.
Deviation from the measured surface geometries is usually compared to the specifications calculated and determined by the antenna manufacturer to determine the reference accuracy.

Since the target value is not indicated, a Best-Fit paraboloid is calculated based on individual sections and measured individual points, thus constructed as a CAD-paraboloid.

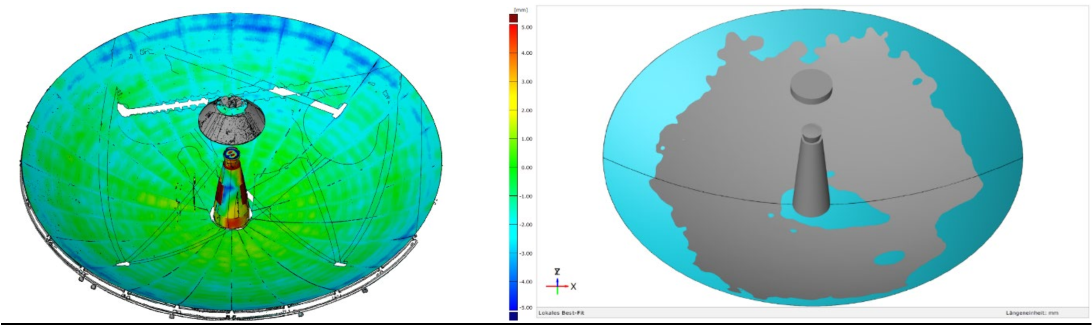
Comparison of the measured laser scanning surfaces and the Best-Fit CAD paraboloid constructed allows accurate minimum and maximum deviations of the measured antenna to be obtained.

The built-up paraboloid is simply a set-point hypothesis for quantifying differences. These discrepancies can then be used to specify an RMS value.

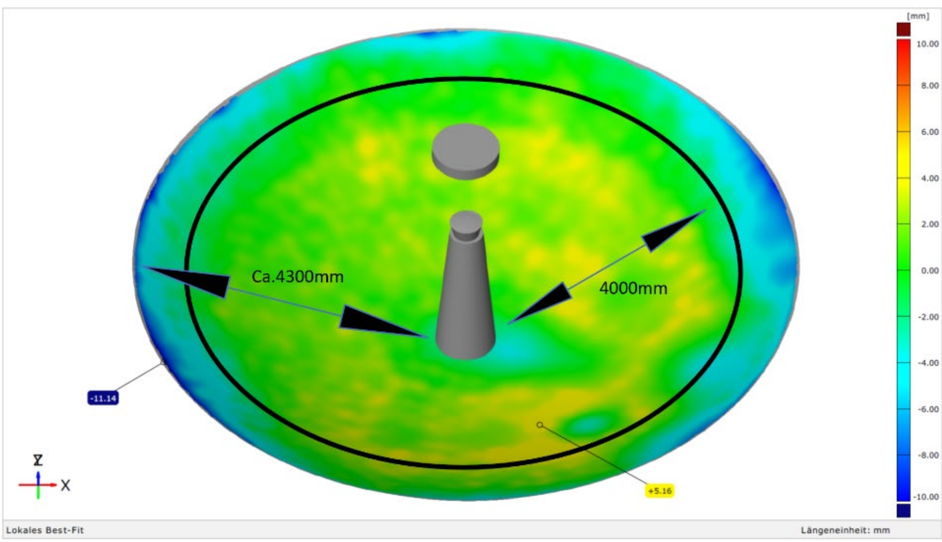
CAD paraboloid / assumption set point of the antenna:



Penetration of the CAD paraboloid compared to the measured surface of the reflector:



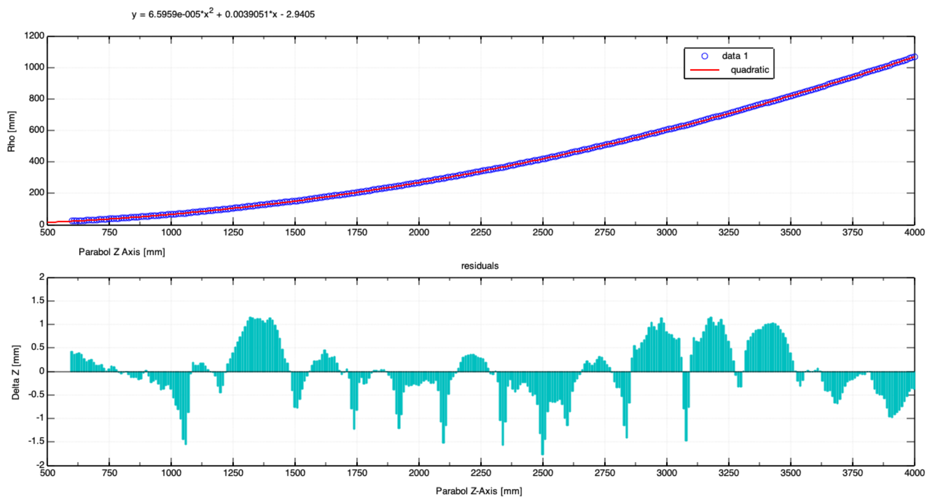
Area comparison and determination of deviation measurement data/set point:



The area comparison illustrates the gradation in the area of the scaling shown on the side. Marked and labelled by small dots are the two measuring points with the largest deviation in the Delta Min/Max range.
In order to obtain meaningful values as reference points for determining the deviation of the entire reflector, the reflector was subdivided and the previous individual sections (section 1, 2, 3, 4) were calculated with their thousands of individual points and their deviation from the nominal main reflector contour.
A distinction is made between the outer area of the antenna reflector and the inner area.

The inner surface of the antenna is more affected by the occupation of the radiation characteristics by gaps such as possible deformations of the reflector.

Main reflector: quadratic curve (Parabolic Reflector: F/D=0.3937) → F=3740mm
Data1: Average values from 8 Half-Cuts (Zmax=4000)



5. Calculation of the G/T of a customer's antenna

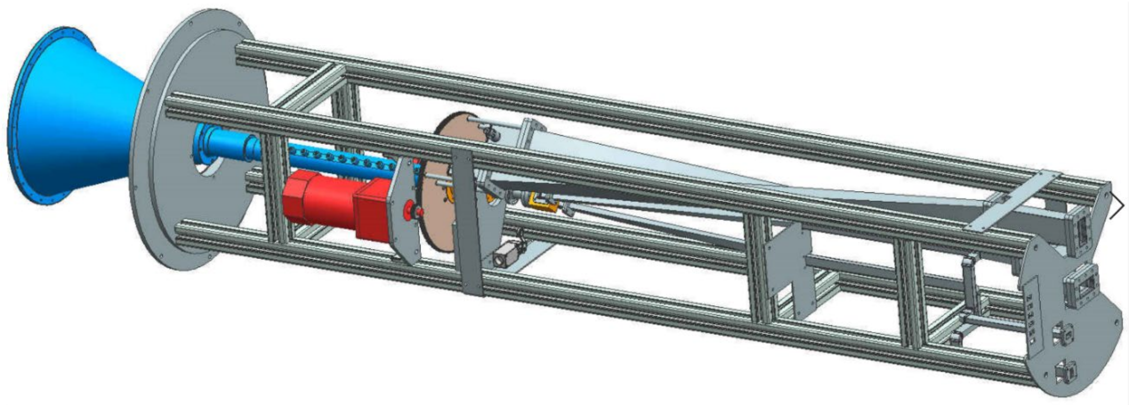
To calculate a meaningful and accurate G/T, the specifications and losses of the excitation system used must also be known.

In order to define the G/T value (worst case) for an antenna, as an obvious example, an already existing feed system from ESA Microwave GmbH will be included as a benchmark with its losses in the calculation. These parameters are mandatory for a reliable calculation.

Based on the dimensions of the tube, which are present due to the measurements, we additionally include the entire structure (excitation system, horn, waveguide) in our calculation and assume worst-case losses.

The specifications of these systems can be viewed on our website (www.esamicrowave.de) with the corresponding data sheets. It should be noted that the specified values of the data sheets always refer to the feed system without the individually optimised horn for the respective antenna and the subsequent waveguide design.
For comparison, we can calculate the G/T for you with two different systems but both have some similarities to the desired feed when retrofitting your antenna.

Example for a customised feed system in C band or Ku band:



"Figure of Merit" calculation for a Specific Earth Station Antenna
The Antenna System operates **for example in the C- and Ku-Band f**requency range.

The C-Band system is switchable either to circular polarisation RHCP/LHCP or to linear polarisation horizontal (H)/Vertical (V). Figure 1 shows a simplified block diagram of the dual polarised system and the system parameters needed for G/T calculation.

These Parameters are:

- Receive frequency
- Corresponding antenna gain
- Feed losses referred to the LNA Input
- LNA noise temperature
- Antenna elevation angle

<u>Additional Parameters will influence the "Figure of Merit":</u>

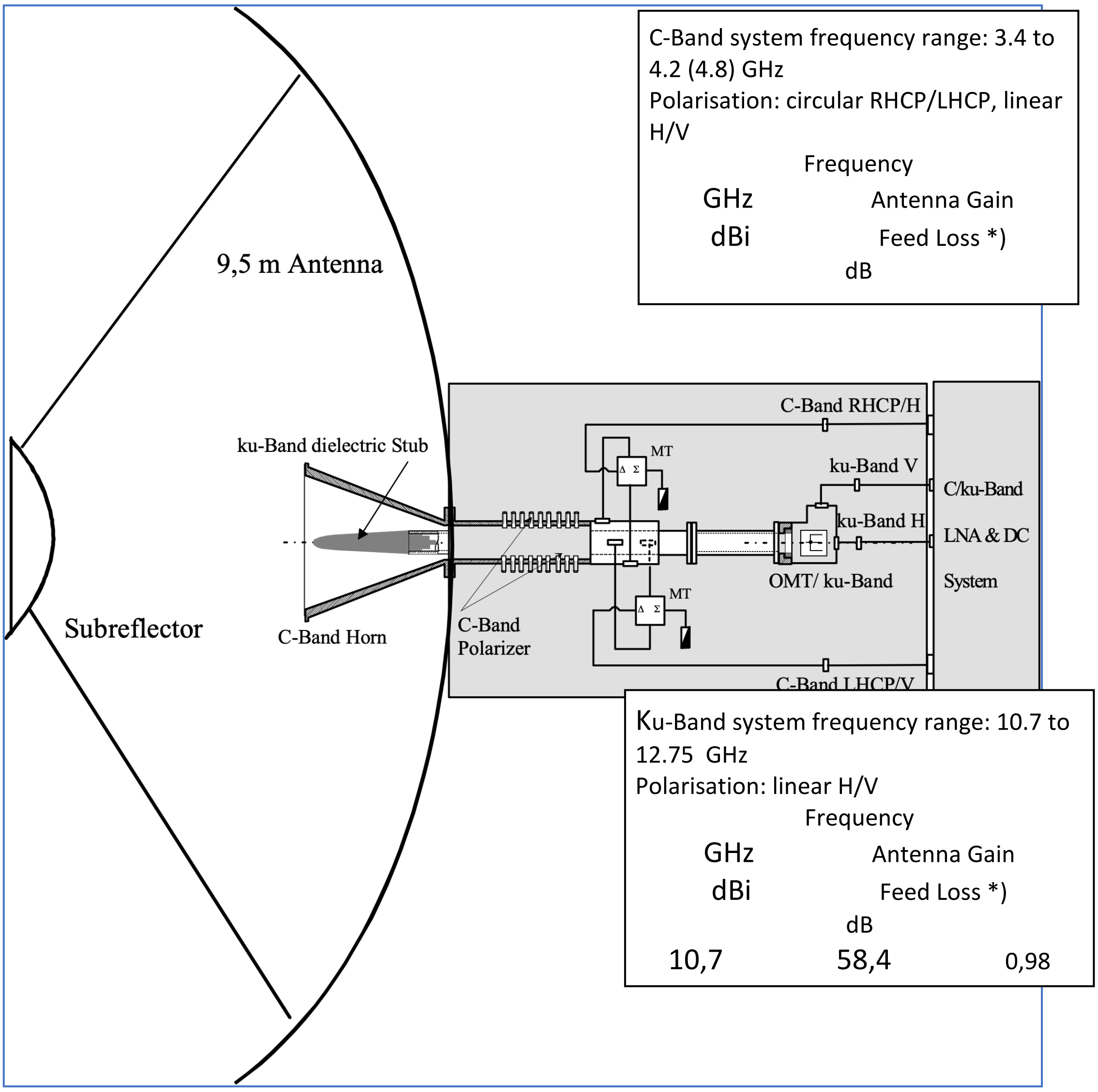
- Noise contribution due to reflector spillover
- Noise contribution due to reflector surface resistivity
- Reduction in antenna directivity due to reflector surface errors
- Gain reduction due to LNA return loss

At least ambient conditions:

- Mean physical temperature of the atmosphere
- Sky brightness temperature
- Atmospheric attenuation
- Cosmic microwave background temperature

For an existing operating antenna system, it is possible to verify some of the above mentioned parameters by precise measurements. When planning a system, some parameters have to be estimated: Return loss, antenna gain, LNA noise, spillover noise ...

Block Diagram showing a simplified example:



Example of a data sheet showing G/T calculations which we provide for a customer-specific antenna:

Constants

π	3,14159		
c/[m/s]	299800000		
T_0 [K] Ambient Noise	290,00		
T_{cmb} [K] Background Noise	2,73		
A, f/D~ 0,3	0,65		
ε_0 [As/Vm]	8,845200E-12		
σ_{Alu} [A/Vm]	3,54E+07		
e	2,7182818		
k Bolzmann [mWs/°K]	1,38E-20		
Input f/ GHz	12,75	12,75	GHz

Input Antenna Parameter D, η ,Feed Loss

	new Value	actual Value
D [m]	9,50	9,50
η [%]	68,00	68,00
A_{feed} [dB]	0,98	0,98

Input Surface Accuracy

	new Value	actual Value
Surf. Acc. ε_{MR} [mm RMS]	0,80	0,80
$_{MR}$ Main- $_{SR}$Subreflektor		
Surf. Acc. ε_{SR} [mm RMS]	0,60	0,60

Input Noise Atm. Noise, LNA Noise, Spill over Noise

	new Value	actual Value
T_{atm}* Atm. Noise [K] f{el}	22	22
T_{LNA} LNA Noise [K]	80	80
T_{SP} Spill over [K]+T_{gap}	8	8

Input Return Loss LNA , Impact of Subrelektor Struts

	new Value	actual Value
Return Loss-LNA [dB]	18,00	18,00
SR Struts Loss [db]	0,00	0,00
Panel Gap loss [dB]	0	0
Pointing error loss [dB]	0,1	0,1

*ITU -R P.372-10
T_{atm} = F {Elevation}

G_{Ant}	60,40	dBi
G_{LNA}	59,416	dBi

Antenna Gain ref. to LNA G_{LNA}

Surface accuracy Loss ΔG_R

ΔG_R	-0,806	dB

Sky Temperatur

T_{Sky}	24,52	K

TA_{Ant} Antenna Temperatur
$TA_{Ant} = T_{Sky} + T_n + T_{SP}$
T_n Surface resitivity

T_n	0,164	K
TA_{Ant}	32,69	K

T_{sys} System Temperatur
$T_{sys} = TA_{LNA} + T_{LNA}$

TA_{LNA}	84,53	K
T_{sys}	164,53	K

LNA RL Gewinnverlust ΔG_{RL}

ΔG_{RL}	-0,069	dB

Figure of Merit G/Tsys

G/T_{sys}	36,28	dB/K
Specified		dB/K
Noise at LNA input	-176,44	dBm/Hz

Calculate: AntGain Noise Fig of Merit