Rosenberger

Rosenberger Proximity Connector

RoProxCon-Hybrid Antenna

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1 Revision History

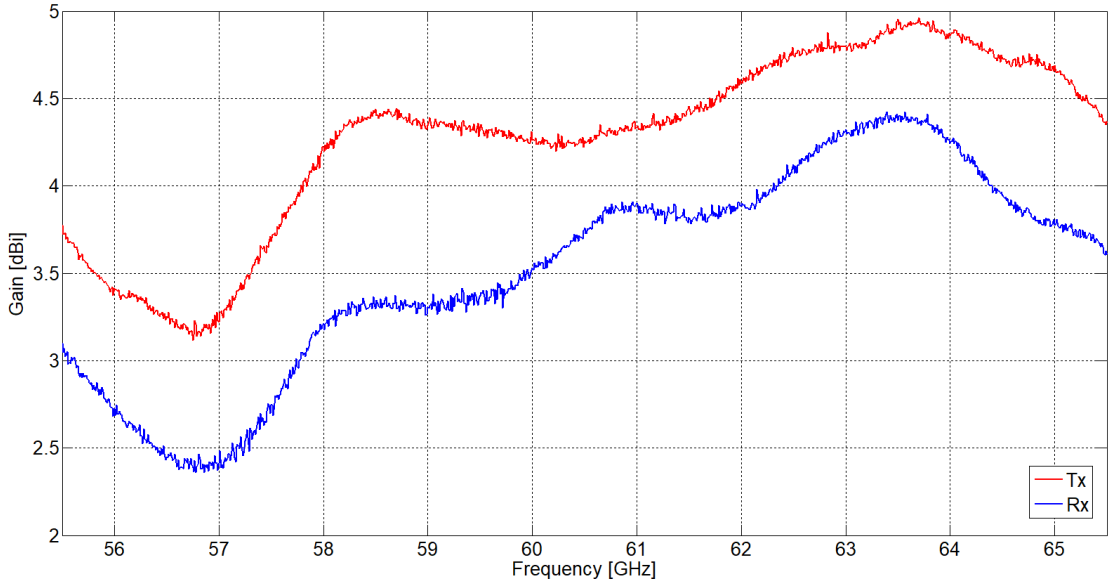
Date of this revision: 12.03.2025	Date of next revision *(date)*

Revision Number / Date	Author	Summary of Changes
V00.01 / 03.05.2023	Max Reuther	Date of antenna measurements
V01.00 / 18.06.2024	Max Reuther	Creation of RoProxCon Hybrid Antenna-Specification
V01.01 / 05.08.2024	Max Reuther	Description of measurement procedure added
V01.02 / 29.08.2024	Max Reuther	Summary table for broadside antenna gain and axial ratio added in section 2. Calibration dates and due dates of test equipment added in section 4.
V01.03 / 12.03.2025	Johannes Winkler	Removal of the chapter on the detailed description of the DUT for reasons of confidentiality

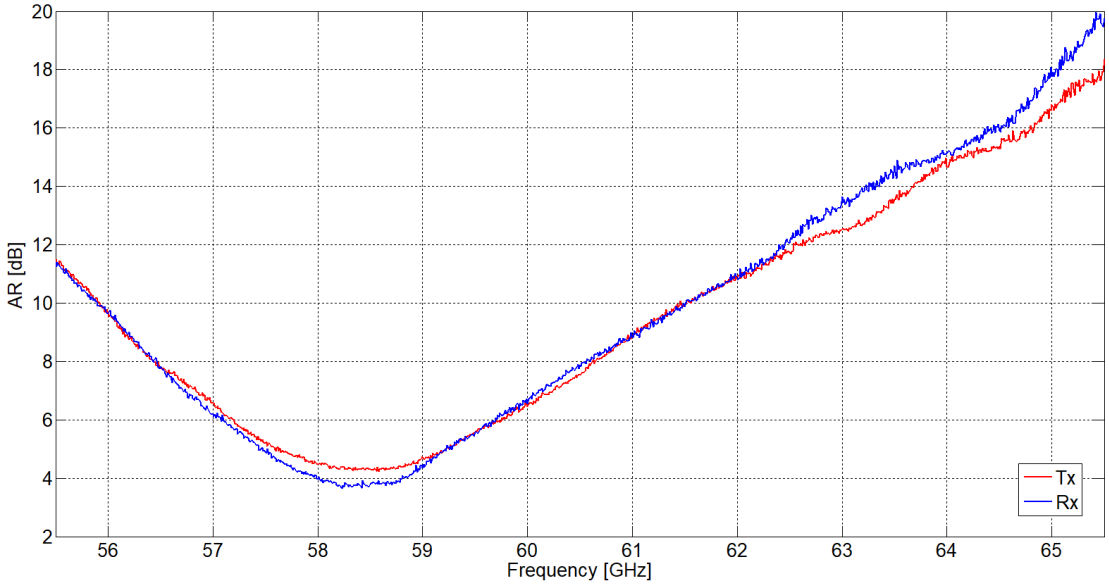
2 RoProxCon-Hybrid Antenna-Specification

Device/ Revision	MI1C804-901-01, MI1C804-902-01, MI1C804-901-02, MI1C804-902-02 / Rev. 200
Date of Measurement	May 3, 2023
Comment	The measured values include the effects/insertion loss of the antenna feeding network as well as of the RoProxCon Hybrid housing.

Broadside Gain (typical)



Broadside Axial Ratio (typical)



Summary Table of Tx- and Rx-Broadside Antenna Gain and Axial Ratio

Frequency [GHz]	Tx Broadside Gain (typ.) [dBi]	Rx Broadside Gain (typ.) [dBi]	Tx Broadside AR (typ.) [dB]	Rx Broadside AR (typ.) [dBi]
55,5	3,8	3,1	11,5	11,4
56,0	3,4	2,7	9,7	9,6
56,5	3,3	2,5	7,8	7,8
57,0	3,2	2,4	6,6	6,2
57,5	3,7	2,7	5,2	4,9
58,0	4,2	3,2	4,5	4,0
58,5	4,4	3,3	4,3	3,8
59,0	4,3	3,3	4,7	4,4
59,5	4,3	3,4	5,6	5,6
60,0	4,3	3,5	6,5	6,5
60,5	4,3	3,8	7,5	7,9
*60,6	4,3	3,8	8,0	8,0
61,0	4,3	3,9	8,8	8,8
61,5	4,5	3,8	10,0	9,9
62,0	4,6	3,9	10,8	10,9
62,5	4,7	4,1	11,7	12,1
63,0	4,8	4,3	12,6	13,6
63,5	5,0	4,4	13,6	14,7
64,0	4,9	4,2	14,7	15,1
64,5	4,7	3,9	15,4	15,9
65,0	4,7	3,8	16,8	17,8

*Carrier Frequency at 60.6 GHz

3 Description of Gain and Axial Ratio Measurement

3.1 Antenna Measurement Setup and Measurement Procedure

A block diagram of the deployed antenna measurement setup is shown in Figure 1, while a corresponding photograph of the setup is displayed in Figure 2.

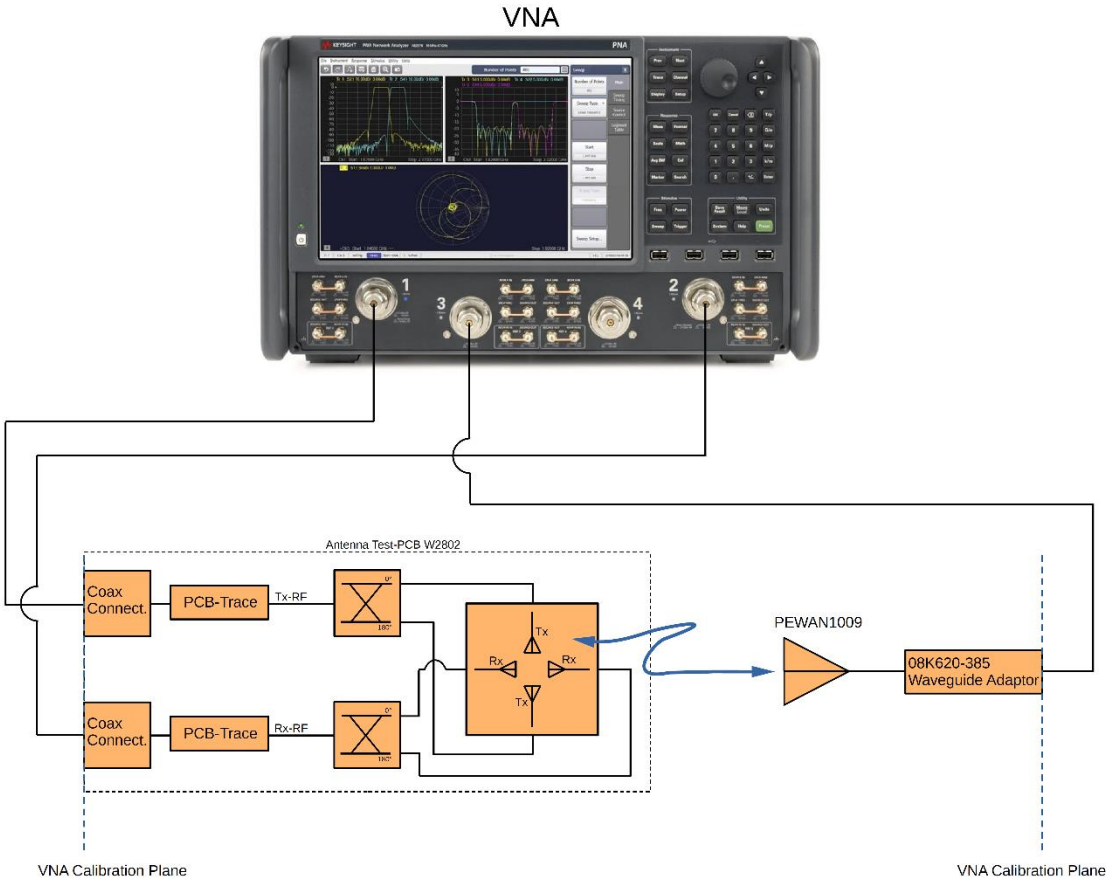


Figure 1: Antenna Measurement Setup.

Port 1 of the employed Keysight Performance Network Analyzer N5227B (PNA) is connected to the Tx-Port of PCB W2802, port 2 to the Rx-Port of PCB W2802, and Port 3 to the Pasternack standard gain horn antenna PEWAN1009 via the Rosenberger 08K620-385 WR-15-to-1.85mm waveguide adaptor. The PNA has a valid instrument calibration (see Section 4). Measurement calibration is performed in the coaxial 1.85mm-plane (see Figure 1) with aid of a Rosenberger RPC-1.85 calibration kit (Model 08CK010-150, Serial-No. GL001). The calibration kit has itself a valid factory calibration (see Section 4).
The insertion loss of the coaxial PCB connectors, the additional PCB traces on PCB W2802 compared to the PCB traces within the RoProxCon Hybrid, and the waveguide adaptor are determined in separate measurements, and are removed from the measurement.

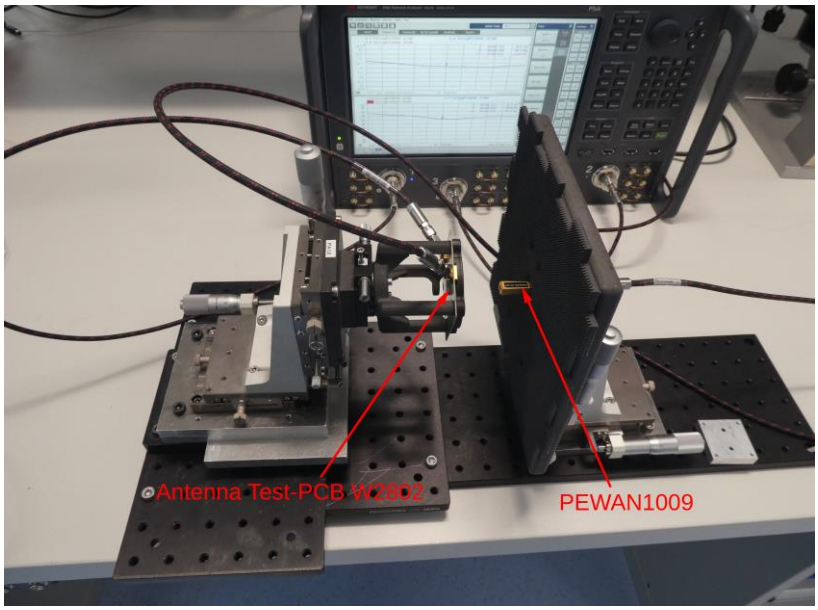


Figure 2: Photograph of Antenna Measurement Setup.

To this end, the additional PCB traces in the Tx- and Rx-signal path of PCB W2802 are designed to be of equal length. A thru standard utilizing the same coaxial connectors as PCB W2802 and having a PCB trace length equal to the sum of the additional PCB traces on PCB W2802 is manufactured. Half of the insertion loss [in dB] of the thru standard can then be accounted for as the insertion loss L_{thru} of each additional PCB trace together with the coaxial connector on PCB W2802. Figure 3 shows a photograph of the thru standard.

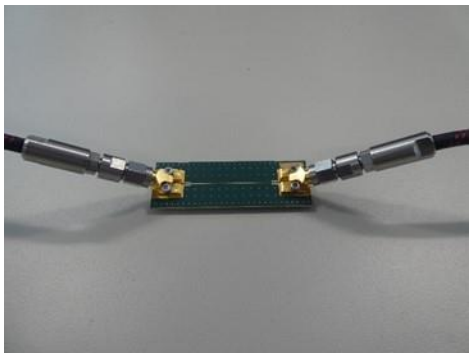


Figure 3: Thru Standard.

The insertion loss $L_{adaptor}$ of the 08K620-385 waveguide adaptor is determined in a back-to-back setup of two waveguide adaptors as shown as in Figure 4 and is equal to one half of the measured insertion loss (in dB) of the back-to-back setup.

Figure 4: Back-to-Back Setup of two 08K620-385 waveguide adaptors.

The broadside antenna gain G_{Tx} and G_{Rx} (in dB) of the Hybrid's Tx and Rx-antenna array can be determined through measurements of S_{31} and S_{23} according to Equations 1.1 and 1.2, respectively:

$$G_{\mathrm{Tx}} = \max_{\phi}|S_{31}| + 0.5 \cdot L_{\mathrm{thru}} + L_{\mathrm{adaptor}} + FSPL + \min_{\phi}(L_{\mathrm{Pol,Tx}}) - G_{\mathrm{Horn}} \quad (1.1)$$

$$G_{\mathrm{Rx}} = \max_{\phi}|S_{23}| + 0.5 \cdot L_{\mathrm{thru}} + L_{\mathrm{adaptor}} + FSPL + \min_{\phi} L_{\mathrm{Pol,Rx}} - G_{\mathrm{Horn}} \quad (1.2)$$

Since the antenna gains shall be referenced to the top side of the Hybrid's cover, the free space path loss *FSPL* [dB] can be determined from the signal frequency *f* [GHz] and the distance *d* [mm] between the aperture of the standard gain horn and the cover top side according to Equation (1.3):

$$FSPL = 20\log_{10}(f) + 20\log_{10}(d) - 27.56\ \mathrm{dB} \quad (1.3)$$

Both the gain and axial ratio measurements are taken at several distances, specifically between 30.0 mm and 33.0 mm in steps of 1.0 mm. The obtained results are averaged to reduce possible effects of multipath propagation.

The antenna gain G_{Horn} of the standard gain horn is given by the PEWAN1009 datasheet.

In Equations (1.1) and (1.2), $\max_{\phi}|S_{31}|$ and $\max_{\phi}|S_{23}|$ denote the maximum transmissions with respect to the azimuth angle ϕ, whereas $\min_{\phi}(L_{\mathrm{Pol,Tx}})$ and $\min_{\phi} L_{\mathrm{Pol,Rx}}$ are the minimum polarization losses with respect to ϕ, see Figure 5. The polarization losses $L_{Pol,Tx}$ and $L_{Pol,Rx}$ are derived by a preceding measurement of the axial ratio (*AR*) of the Hybrid's Tx- and Rx-antenna arrays, AR_{Tx} and AR_{Rx}, respectively. To this end, PCB W2802 is pivot-mounted in the azimuth ϕ, i.e., about the central longitudinal axis of the standard gain horn as depicted in Figure 5. During measurement, PCB W2802 is rotated about ϕ = -180° to +180° while the PNA collects the maximum and minimum transmissions ($\max_{\phi}|S_{31}|$, $\max_{\phi}|S_{23}|$ and $\min_{\phi}|S_{31}|$ and $\min_{\phi}|S_{23}|$) at each frequency point. The maximum and minimum transmission are stored in corresponding measurement traces (see Figure 6 for an example of an S_{31}-measurement). The transmit and receive antenna arrays' broadside axial ratio (in dB) can then be deduced from Equations 1.4 and 1.5, respectively:

$$AR_{\mathrm{Tx}} = \max_{\phi}(|S_{31}|) - \min_{\phi}(|S_{31}|) \quad (1.4)$$

$$AR_{\mathrm{Rx}} = \max_{\phi}(|S_{23}|) - \min_{\phi}(|S_{23}|) \quad (1.5)$$

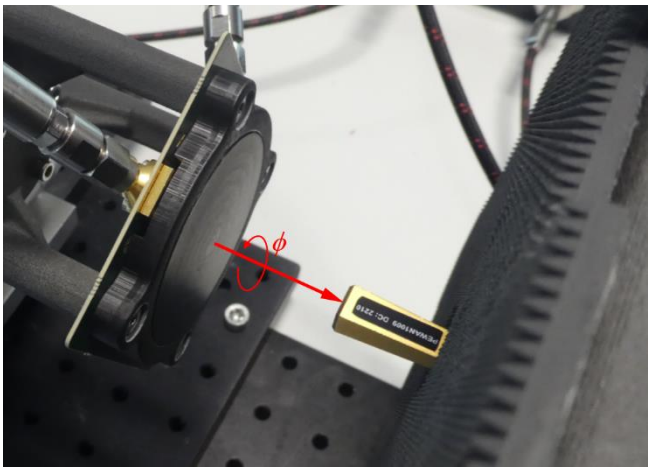


Figure 5: Pivot-mounting of PCB W2802.

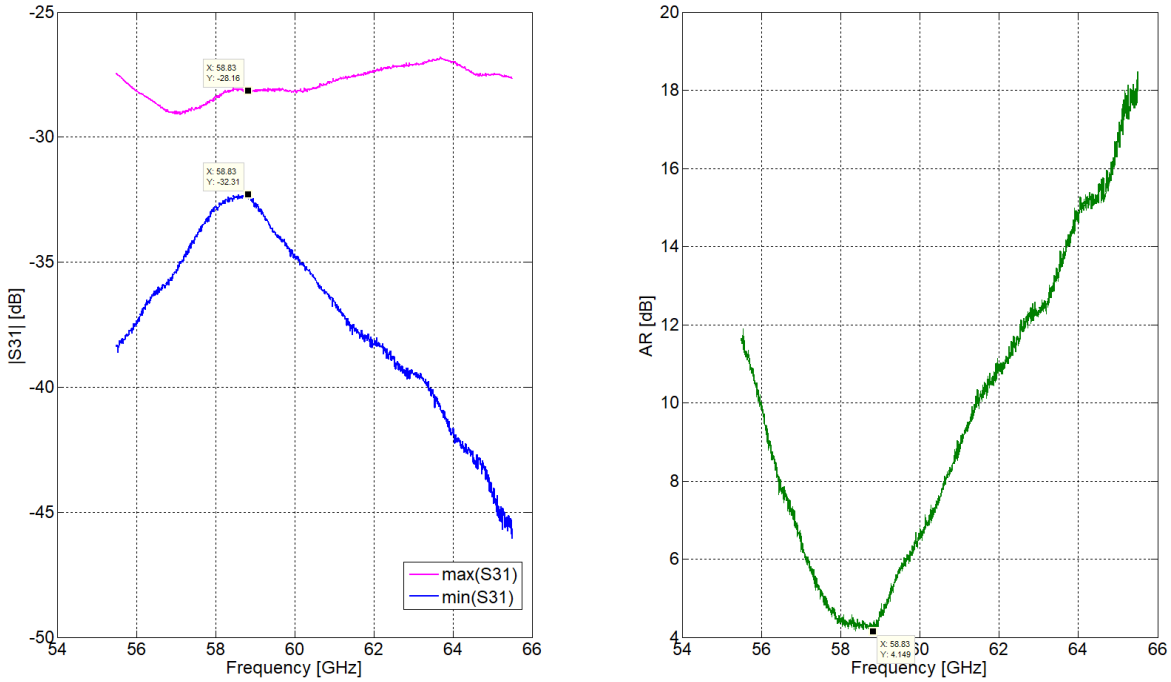


Figure 6: Max. and min. transmission w.r.t. ϕ over frequency (left) and axial ratio (right).

The minimum polarization losses (in dB) are given by Equations (1.6) and (1.7):

$$\min_{\phi}(L_{\mathrm{Pol,Tx}}) = -10\log_{10}\left(\frac{1}{2} - \frac{1}{2}\frac{\left(1 - AR_{\mathrm{Tx,lin}}\right)^2}{\left(1 + AR_{\mathrm{Tx,lin}}\right)^2}\right) \tag{1.6}$$

$$\min_{\phi}(L_{\mathrm{Pol,Rx}}) = -10\log_{10}\left(\frac{1}{2} - \frac{1}{2}\frac{\left(1 - AR_{\mathrm{Rx,lin}}\right)^2}{\left(1 + AR_{\mathrm{Rx,lin}}\right)^2}\right) \tag{1.7}$$

$AR_{\mathrm{Tx,lin}}$ and $AR_{\mathrm{Rx,lin}}$ are transmit and receive antenna arrays' broadside axial ratios converted into linear scale.

The broadside antenna gains G_{Tx} and G_{Rx} can now be determined with aid of Equations (1.1) and (1.2), respectively. The results are given in Section 2 together with the results of the axial ratio measurement.

4 List of Measurement Devices and Accessories

Item	Model	Serial Number	Calibration Certificate No.	Calibration Date	Calibration Due Date*
Keysight PNA 67GHz	N5227B	US61141146	1012456-1698277-1	June 7, 2021	June 7, 2023
Rosenberger RPC-1.85 Calibration Kit	08CK010-150	GL001	2203093	March 11, 2022	March 11, 2024
Pasternack Standard Gain Horn	PEWAN1009	-	-	-	-
Rosenberger Waveguide Adaptor	08K620-385	-	-	-	-
3x Rosenberger 1.85mm coaxial cable	LU5-502-1000	-	-	-	-

* Measurements were conducted on May 3, 2023.