Fraunhofer IIS

Measured Performance of the EPAK Evo antenna

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1. Introduction:

This document describes the measurements performed on the EPAK Evo antenna at the Fraunhofer IIS Facility for Over-the-air Research and Testing FORTE in Ilmenau in the period from 08th till the 19th of February 2016.

The EPAK DSi6 antenna is designed and manufactured for maritime applications. It has a 60cm symmetric dish and is equipped with a 3-axis tracking unit, to be able to track in azimuth, elevation and skew. Figure 1 shows the DSi6 antenna as it is mounted on the motion emulator while being tested at FORTE.

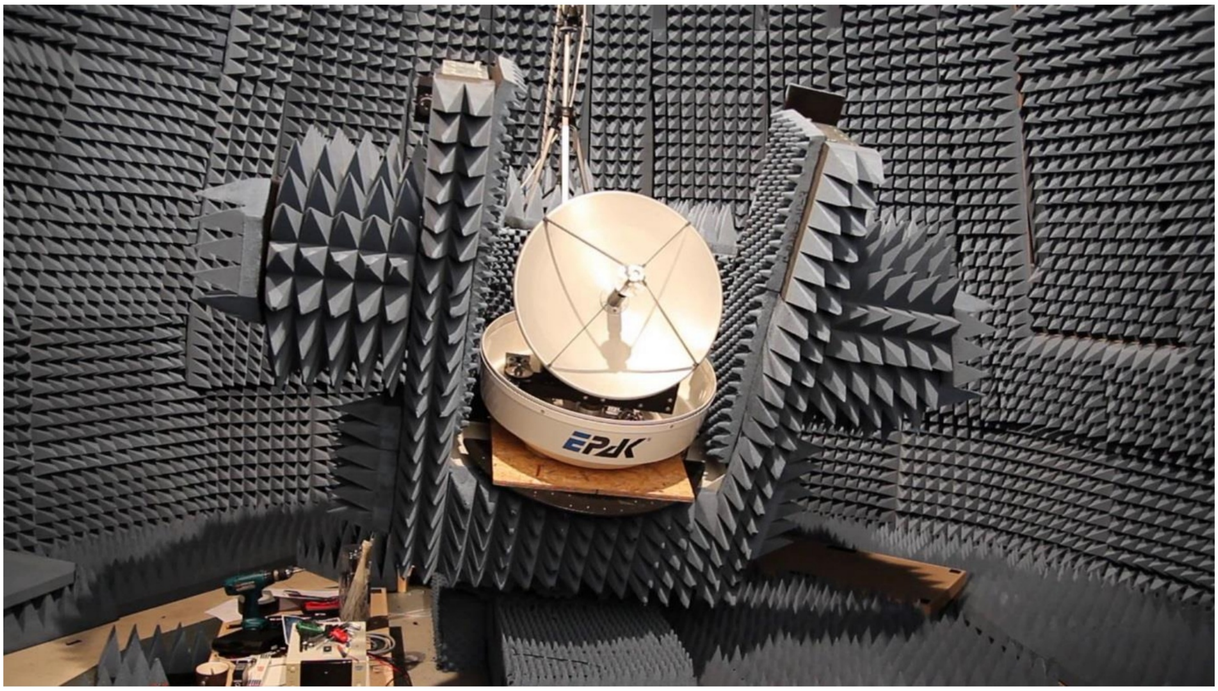
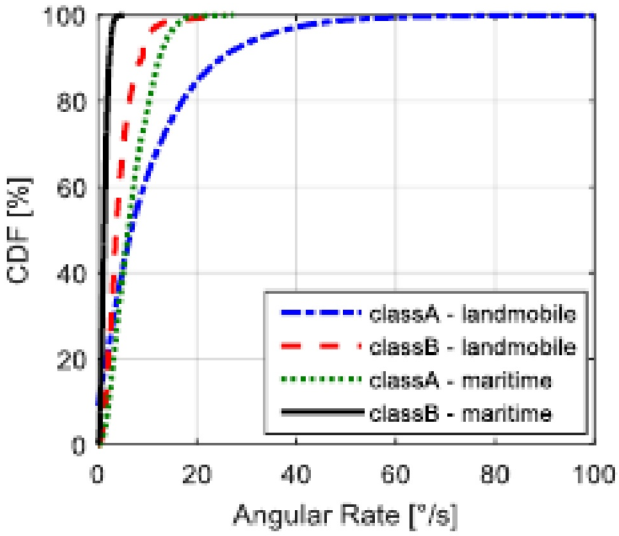


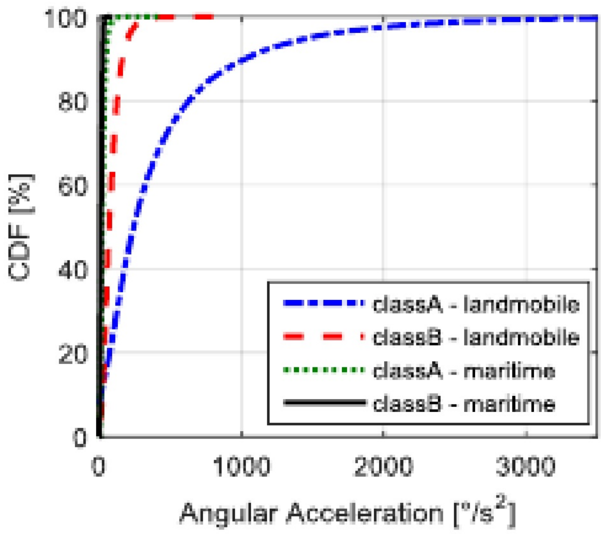
Figure 1 the Evo antenna from EPAK while being tested at FORTE

2. Objectives:

The objectives of the far-field range tests performed at FORTE were to measure the radiation patterns and gain of the antenna at different antenna elevations, frequencies, polarizations and Radome rotations.

FORTE is equipped with a 3-axis motion emulator which is used to replay realistic motion profiles. Fraunhofer IIS in collaboration with the Global VSAT Forum GVF and the European Space Agency ESA has developed two dynamic profiles for the land mobile and two for the maritime environments (cf. Figure 2). The profiles serve as standard to be referenced in SOTM tests and type approvals. For the maritime environment, one profile “class A” represents a standard for sea conditions which induce high angular dynamics (angular rates). The other profile “class B” represents a standard for sea conditions with lower motion dynamics. The angular velocity for the class A motion profile is less than 30°/s for 95% of the time for all axes (yaw, pitch and roll). The angular velocity for the class B motion profile is less than 10°/s for 95% of the time for all axes (yaw, pitch and roll).





The antenna was tested at FORTE using the maritime class A and class B profiles. Moreover, the land mobile classes as well as sinusoidal stimulated profiles were used to check the operational limits of the antenna. The time series and the Cumulative Distribution Function CDF for the different tested motion profiles are presented in Section 9.

3. Brief summary and test conclusions:

3.1. Tracking performance:

According to the Q99 of the de-pointing estimation, the antenna fulfills the de-pointing requirements specified by Eutelsat. In other words, for the maritime standard motion tracks, the antenna de-pointing does not exceed 0.4° for 99% of the time. If the Q100 is to be considered, the antenna is fulfilling the Eutelsat requirements only for the maritime class B motion track. Table 3 shows further details of the tracking capabilities and the Adjacent Satellite Interference ASI caused by the antenna.

3.2. Summary of Dynamic (Motion) Tests

Different motion tracks were replayed using the 3-axis motion emulator at FORTE and the tracking performance of the antenna was measured. Table 3 summarizes the results of the antenna dynamic tests.

A stationary measurement was also carried out to judge on the behavior of the tracking unit while having no motion. The standard land mobile and maritime motion profiles (cf. Figure 2) which are defined by Fraunhofer IIS in collaboration with the GVF and ESA were used.

In order to measure the limits of the tracking unit/algorithm, sinusoidal motion tracks were excited along the three axes (yaw, pitch and roll) simultaneously. Such sinusoidal excitations enable to judge at which angular rate and angular acceleration the antenna tracking breaks (if the limit is reached). Figure 290 shows that the tracking system proves to be working until angular rate (as vector norm for all axes) of about 50 °/s while Figure 292 shows that the tracking system proves to be working until angular acceleration (as vector norm for all axes) of about 150 $°/s^2$. The maximum vector norm angular rate of the motion track (in-phase sinusoidal stimulation along the three axes simultaneously) is 55 °/s while the maximum vector norm angular acceleration is 175 $°/s^2$

4. Additional Notes on Tracking Performance:

The results of the tracking performance tests are summarized in Table 1 where the worst case XPD, de-pointing, required EIRP reduction are listed.

In this section, a detailed analysis of each test is provided. Supporting figures show:

- **XPD** → the time series of the cross polarization discrimination measured using two cross polarized antennas on the antenna tower at FORTE.
- **De-pointing estimation** → the time series of the azimuth and elevation de-pointing estimation. A correlation based method is used for estimation where the Tx signal of the antenna is correlated with the pre-measured antenna Tx pattern to defined the antenna de-pointing over time. The method can be used to estimate de-pointing in azimuth and elevation. However, since for this antenna elevation de-pointing is not of interest, we show azimuth estimation only. It is adopted that the antenna is considered to be completely de-pointed and no estimation is plotted if the power level available at the tower (middle sensor) is more than 15 dB below the nominal power level at direct LOS. This is equivalent to saying that the antenna has more than 2° of de-pointing.
- **Adjacent satellite interference ASI** → using the pre-measured antenna Tx azimuth plane cut, the ASI at ±1.18°, ±2.36° and ±3.53° is measured. The minimum and maximum ASI levels for each satellite separation are summarized in Table 1.
- **Motion Emulator excitations** → time series for angular excitations of the motion emulator.
- **Probability Distribution Function PDF and Cumulative Density Function CDF of azimuth de-pointing estimation** → statistical measures to help in judging on the worst case de-pointing of the antenna.

All dynamic measurements were performed at uplink frequency=14.25GHz and downlink frequency=12.5GHz. All measurements were done using the polarization setting TxPol=H/RxPol=V.

Test #	Ref. page	Motion track	Max AngRate [°/s]	Pol [Tx/Rx]	Mute Fct.	Max. abs. az de-pointing in deg	Max. az de-pointing [Q99] in deg	Max. az de-pointing before 1st mute in deg	Worst XPD [dB]	EIRP reduction at worst de-pointing [dB]	ASI @ 1.18° [worst/best] in dB	ASI @ 2.36° [worst/best] in dB	ASI @ 3.53° [worst/best] in dB
1	123	Stationary	0	H/V	OFF	0.26	0.11	-	21.97	0.55	[2.7/7.7]	[20.8/31]	[18.4/23]
2	155	MaritimeB	4.92	H/V	OFF	0.31	0.2	-	20.52	0.94	[2.3/8.2]	[20/31]	[18/23]
3	147	MaritimeB	4.94	H/V	ON	0.31	0.19	-	20.34	0.94	[2.4/8.4]	[20/31]	[18.3/23]
4	179	Land-mobileB	26.48	H/V	ON	0.64	0.25	-	3.5	3.3	[-0.4/13]	[11/31]	[17/27]
5	195	Sine (in-phase)	54.37	H/V	ON	0.72	0.57	0.72	2.23	3.85	[-1/15]	[9/31]	[17/27]
6	187	Land-mobileB	26.51	H/V	OFF	0.75	0.27	-	15.4	4.05	[-1.4/15]	[8/31]	[17/27]
7	163	Land-mobileA	70.6	H/V	ON	1.88	1.52	1.8	-3	9.95	[-14/26]	[-14/31]	[-4/28]
8	139	MaritimeA	26.5	H/V	OFF	2.03	0.29	-	13.31	10.57	[-18.5/23.9]	[-20/31]	[-12/28]
9	131	MaritimeA	26.47	H/V	ON	2.03	0.31	-	12.16	10.57	[-18.5/24]	[-20/31]	[-12/28]
10	171	Land-mobileA	70.5	H/V	OFF	2.03	1.64	-	-21.1	10.57	[-18.7/27]	[-21/31]	[-12/28]
11	205	Sine (in-phase)	54.37	H/V	OFF	2.03	1.9	-	-22	10.57	[-18/27]	[-20/31]	[-12/28]

Table 1 tracking performance results sorted according to worst de-pointing. The worst cases are marked in red.

5. Traffic Tests:

A satellite modem from 'Romantis' was used with the EPAK Evo antenna in order to perform traffic tests. The Mute functionality of the antenna was switched ON during all traffic tests.

A simple point-to-point (Terminal-Satellite-Hub) scenario was assumed. LDPC was assumed for error correction and 16 PSK was used as a modulation scheme.

Four motion tracks where tested:

1. Stationary measurement, the antenna was hold standstill
2. Maritime Class A motion track defined by Fraunhofer IIS in collaboration with GVF and ESA
3. Maritime Class B motion track defined by Fraunhofer IIS in collaboration with GVF and ESA
4. Land mobile Class B motion track defined by Fraunhofer IIS in collaboration with GVF and ESA

The data rate normalized to the maximum value was used to judge on the traffic performance. A plot for the normalized data rate along with the azimuth de-pointing is provided for each test.

5.1. Stationary Measurement

Figure 3 shows that the terminal has no problem transmitting all traffic through during the whole period of the test.

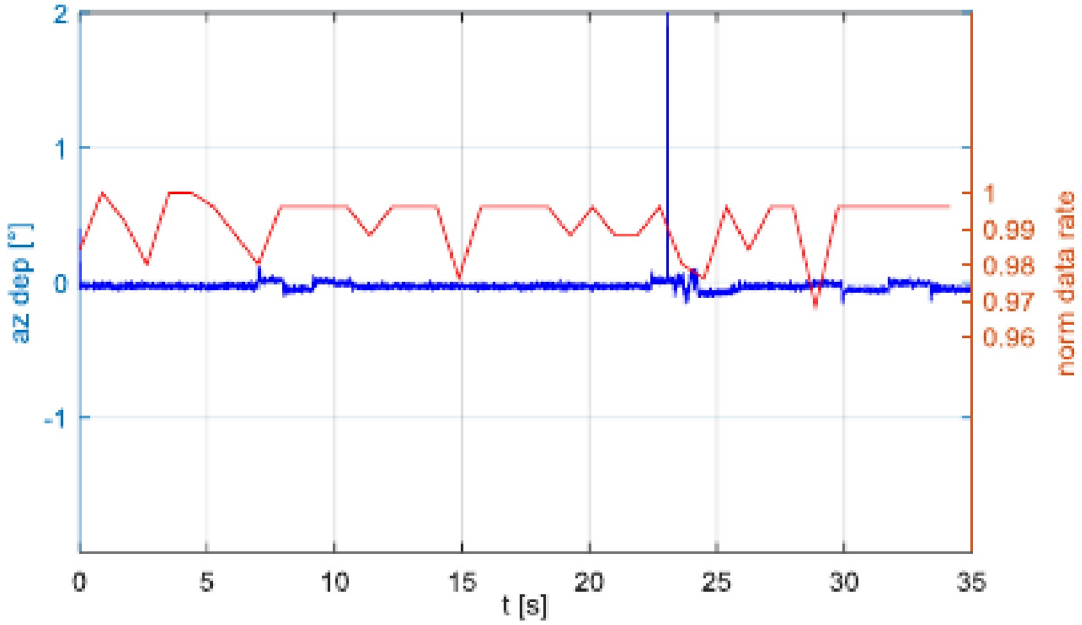


Figure 3 azimuth de-pointing and normalized data rate of a traffic test when the antenna is fixed stationary

Figure 4 shows the complementary cumulative density function (CCDF) of the normalized date rate. It can be seen that the data rate is always above 96% of its maximum value.

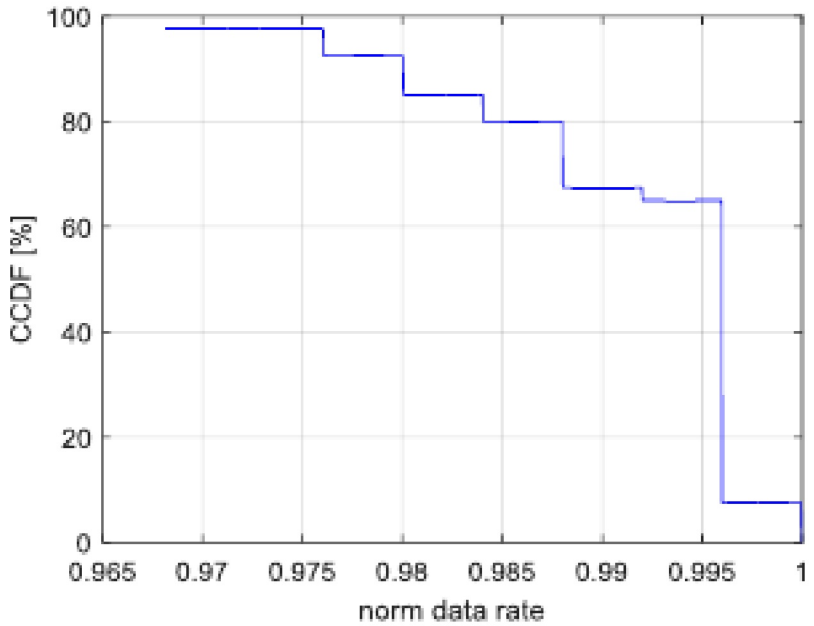


Figure 4 CCDF of normalized data rate

5.2. Maritime Class A

Figure 5 shows that the normalized data rate and the azimuth de-pointing are correlated.

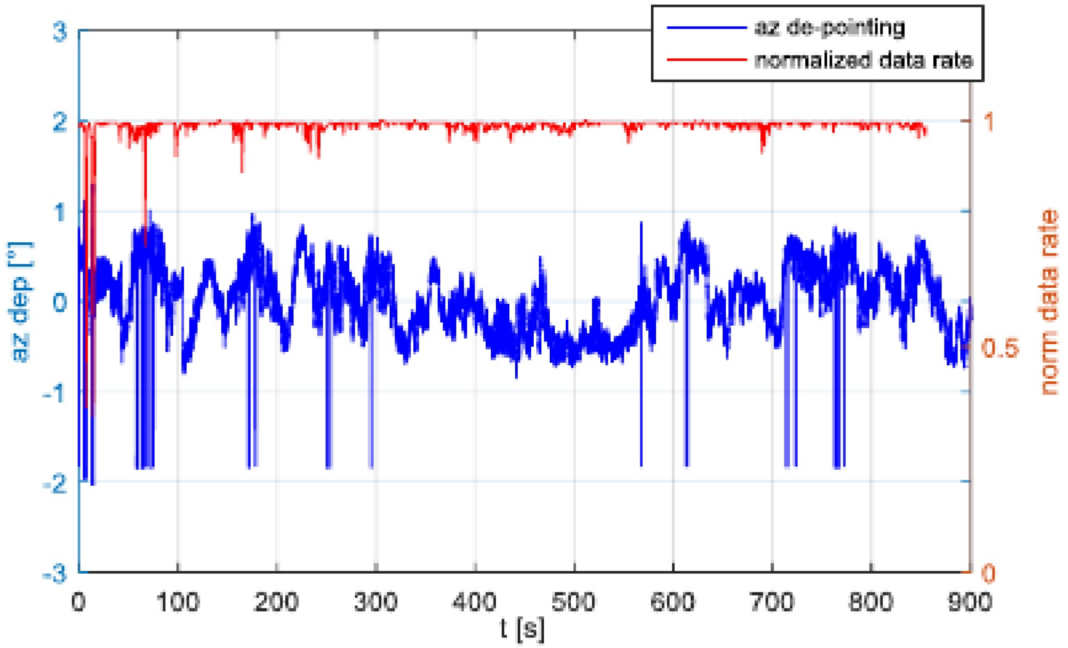


Figure 5 azimuth de-pointing and normalized data rate of a traffic test with the maritime class A motion track

Figure 6 shows the complementary cumulative density function (CCDF) of the normalized date rate. Figure 6 shows that the data rate is above 90% of its maximum value for 99% of all cases.

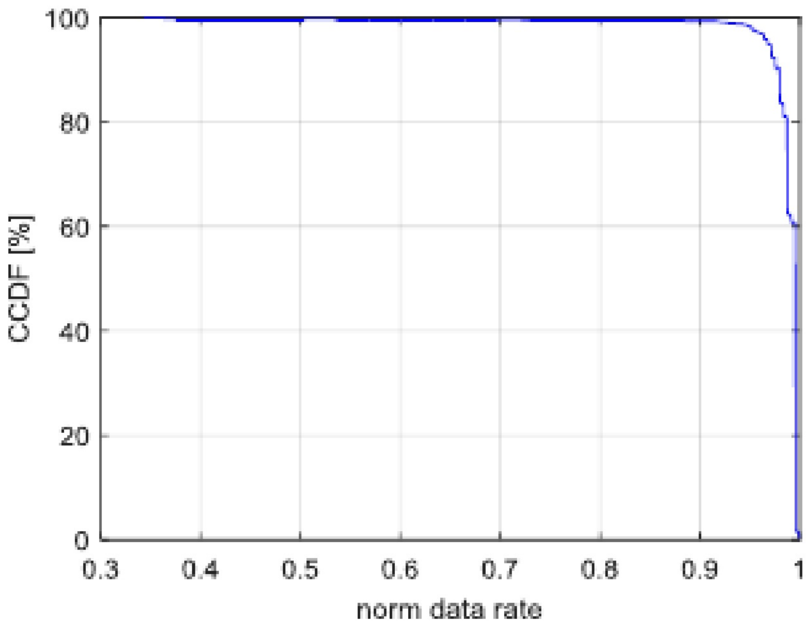


Figure 6 CCDF of normalized data rate

5.3. Maritime Class B

Figure 7 shows that the normalized data rate and the azimuth de-pointing are correlated.

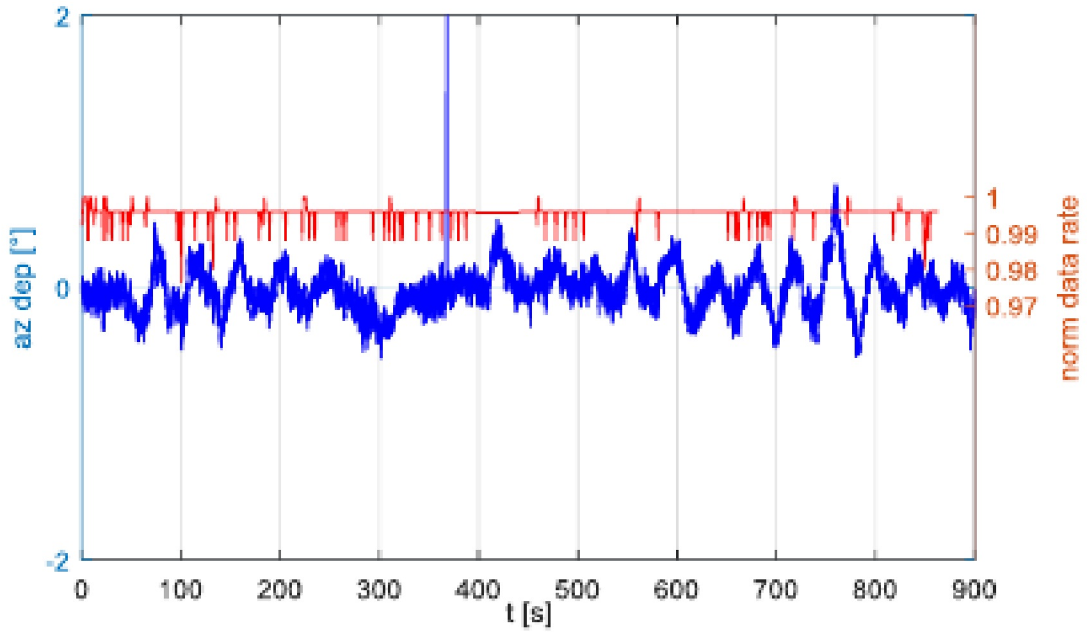


Figure 7 azimuth de-pointing and normalized data rate of a traffic test with the maritime class B motion track

Figure 8 shows the complementary cumulative density function (CCDF) of the normalized date rate. Figure 8 shows that the data rate is above 99% of its maximum value for more than 99% of all cases.

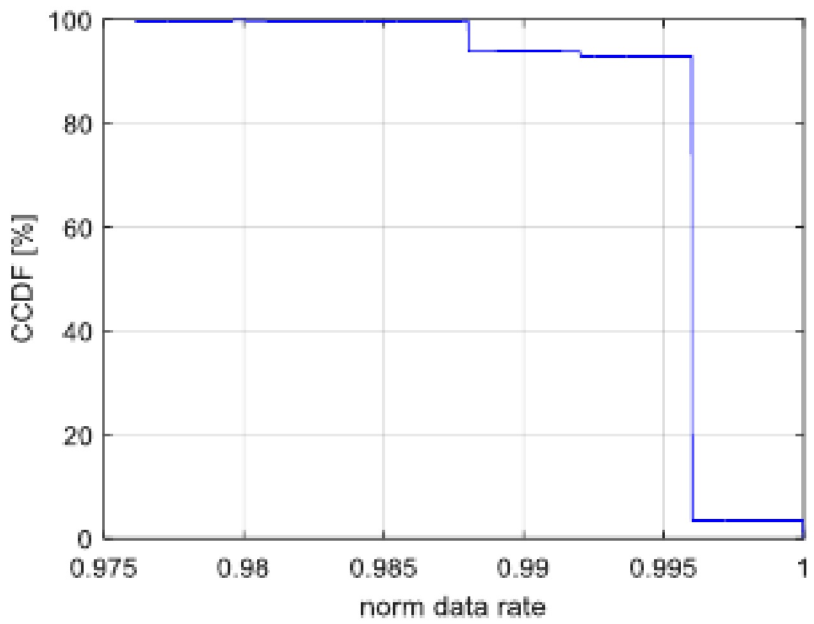


Figure 8 CCDF of normalized data rate

5.4. Land mobile Class B

Figure 9 shows that the normalized data rate and the azimuth de-pointing are correlated.

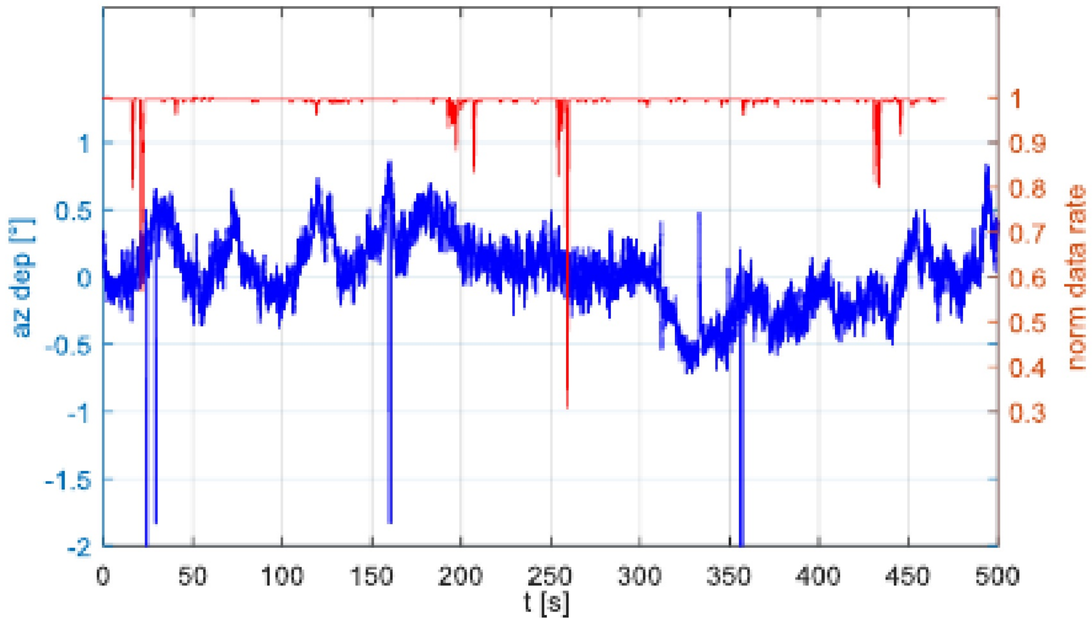


Figure 9 azimuth de-pointing and normalized data rate of a traffic test with the land mobile class B motion track.

Figure 10 shows the complementary cumulative density function (CCDF) of the normalized date rate. Figure 10 shows that the data rate is above 99% of its maximum value for more than 99% of all cases.

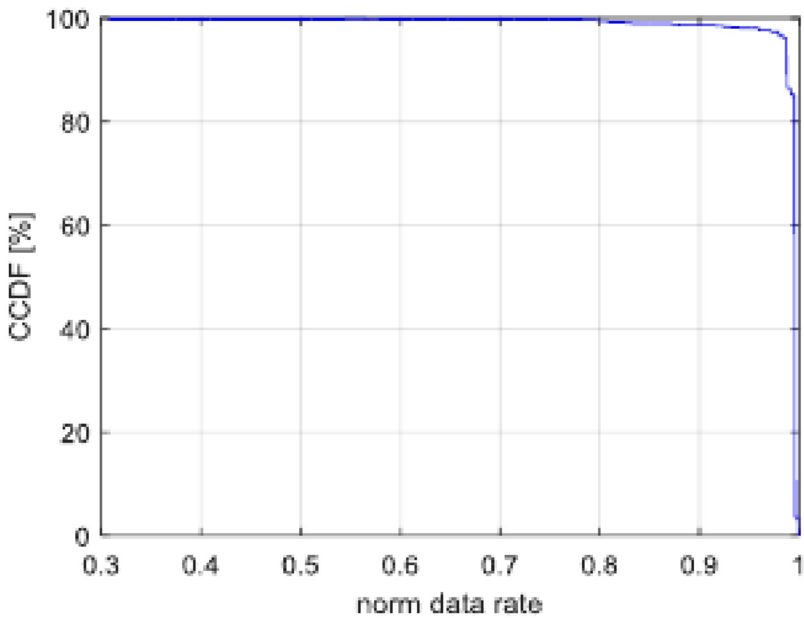


Figure 10 CCDF of normalized data rate

6. Summarized Tracking Performances

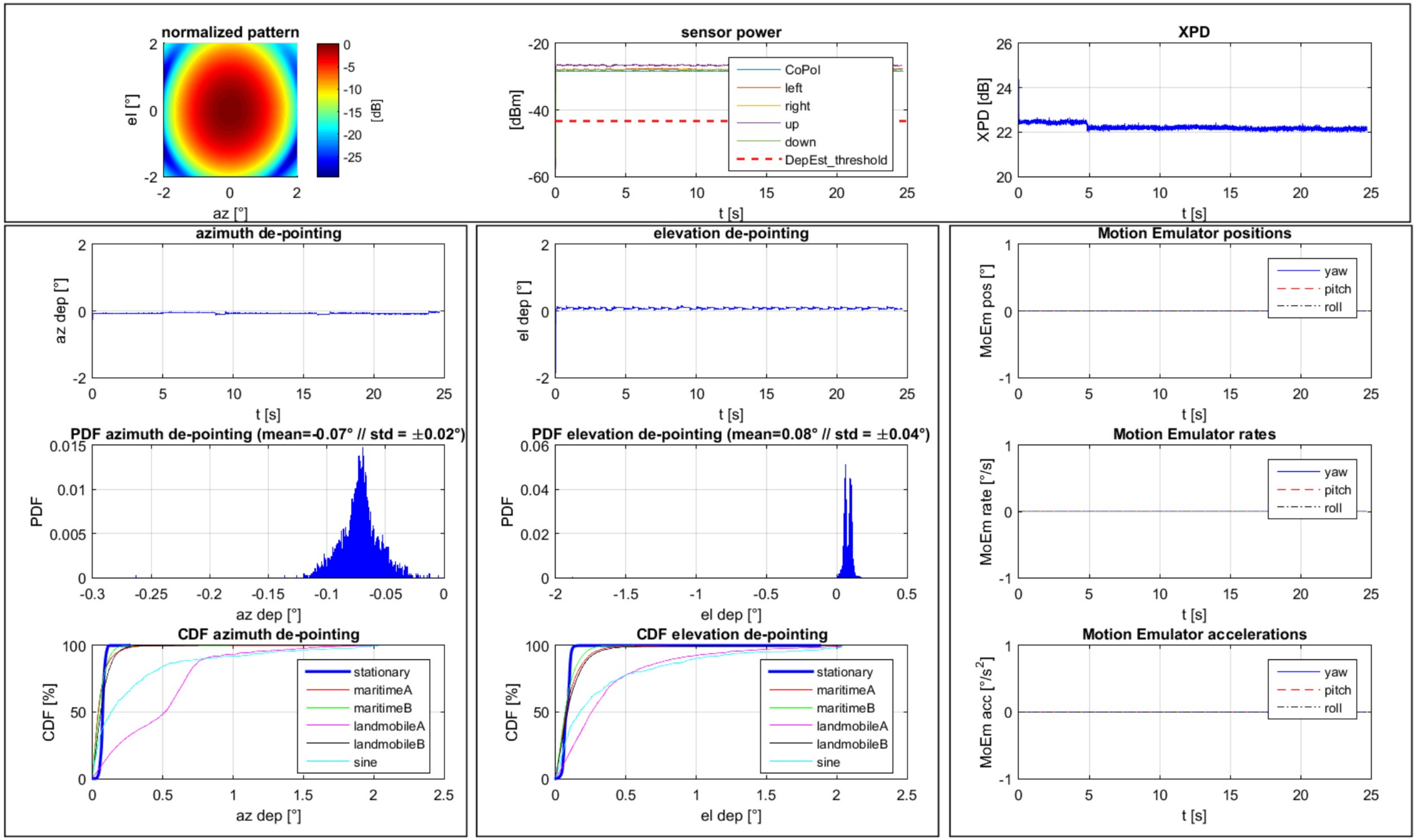


Figure 11 overview of pointing performance evaluation for stationary measurement

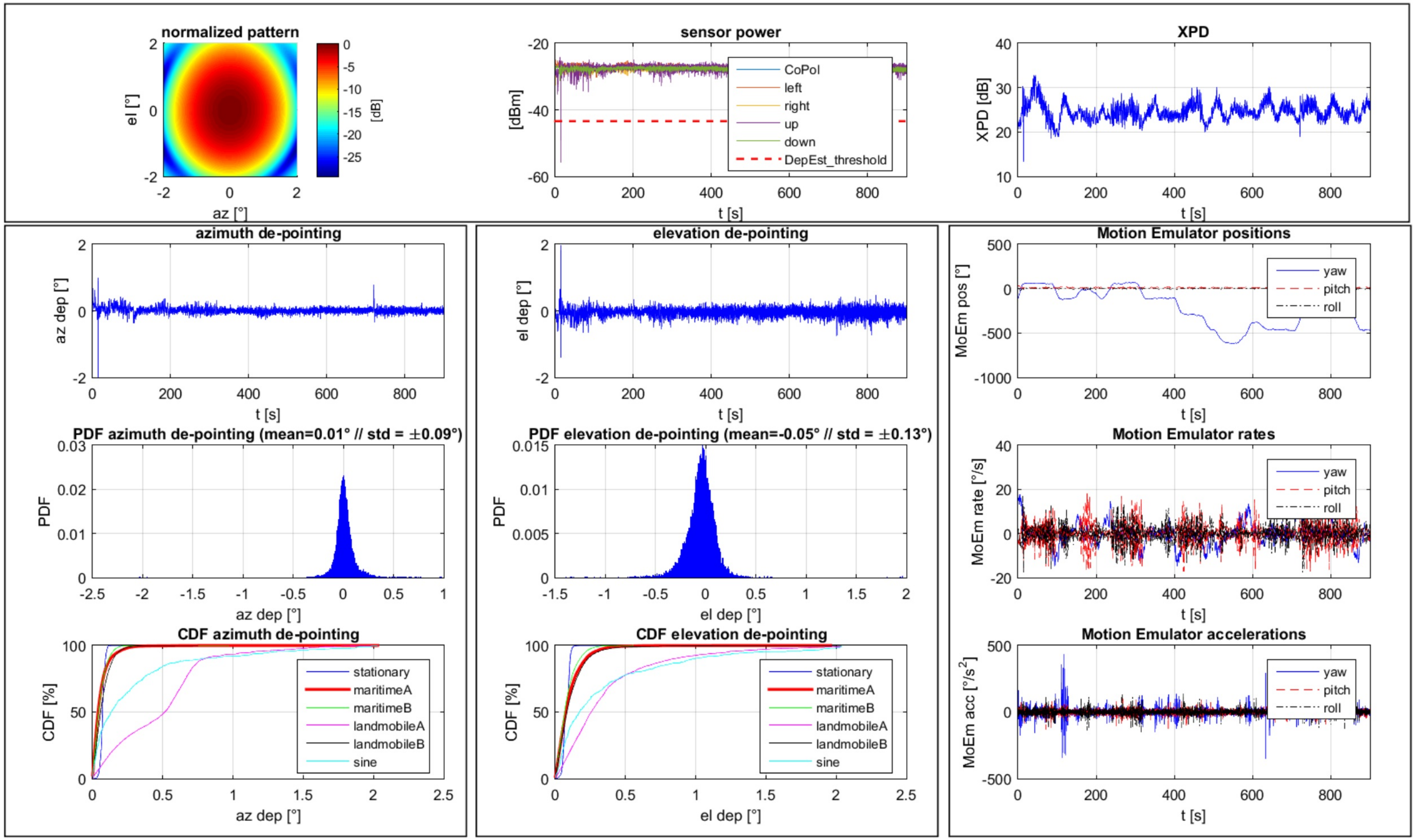


Figure 12 overview of pointing performance evaluation for maritime class A with Mute function OFF

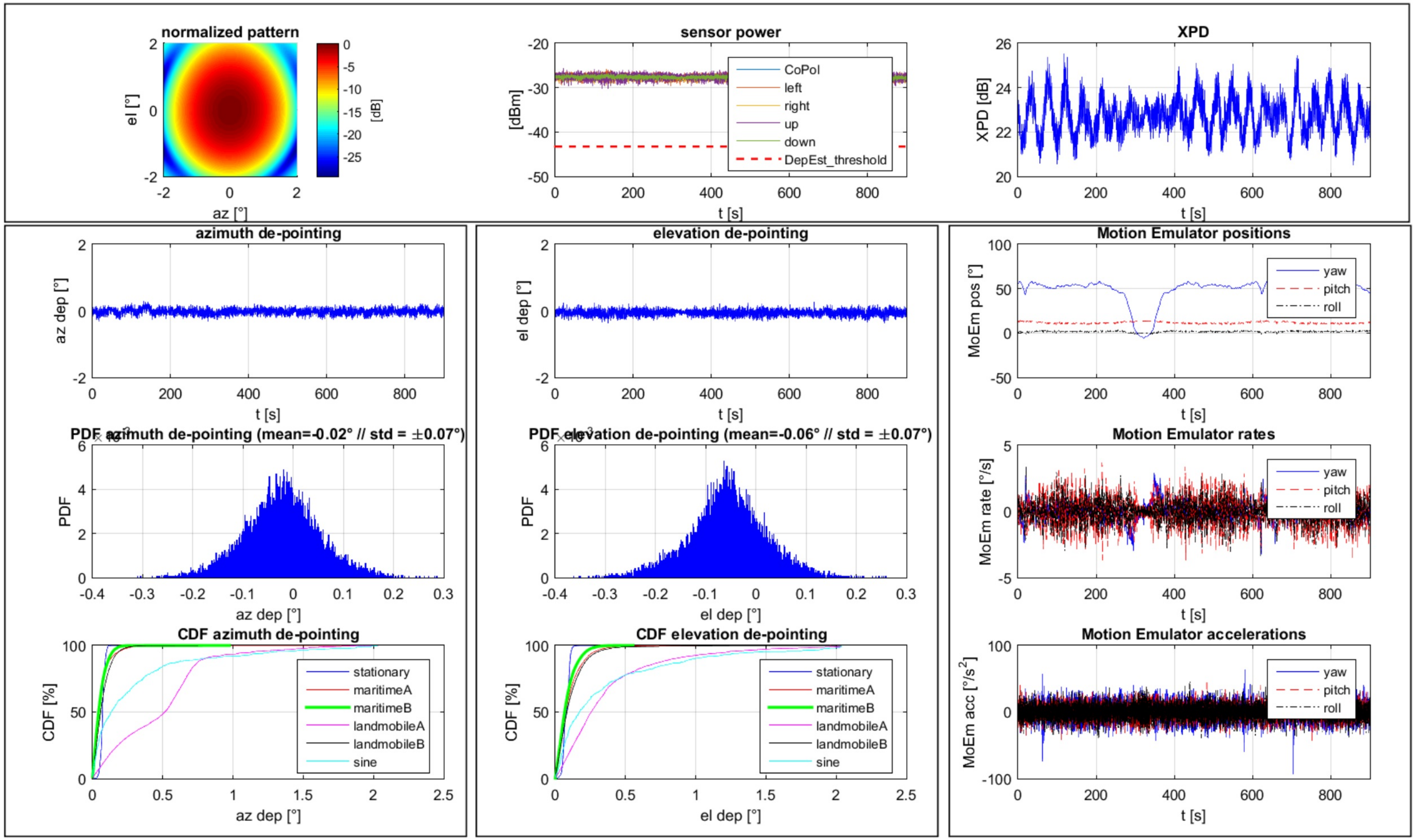


Figure 13 overview of pointing performance evaluation for maritime class B with Mute function OFF

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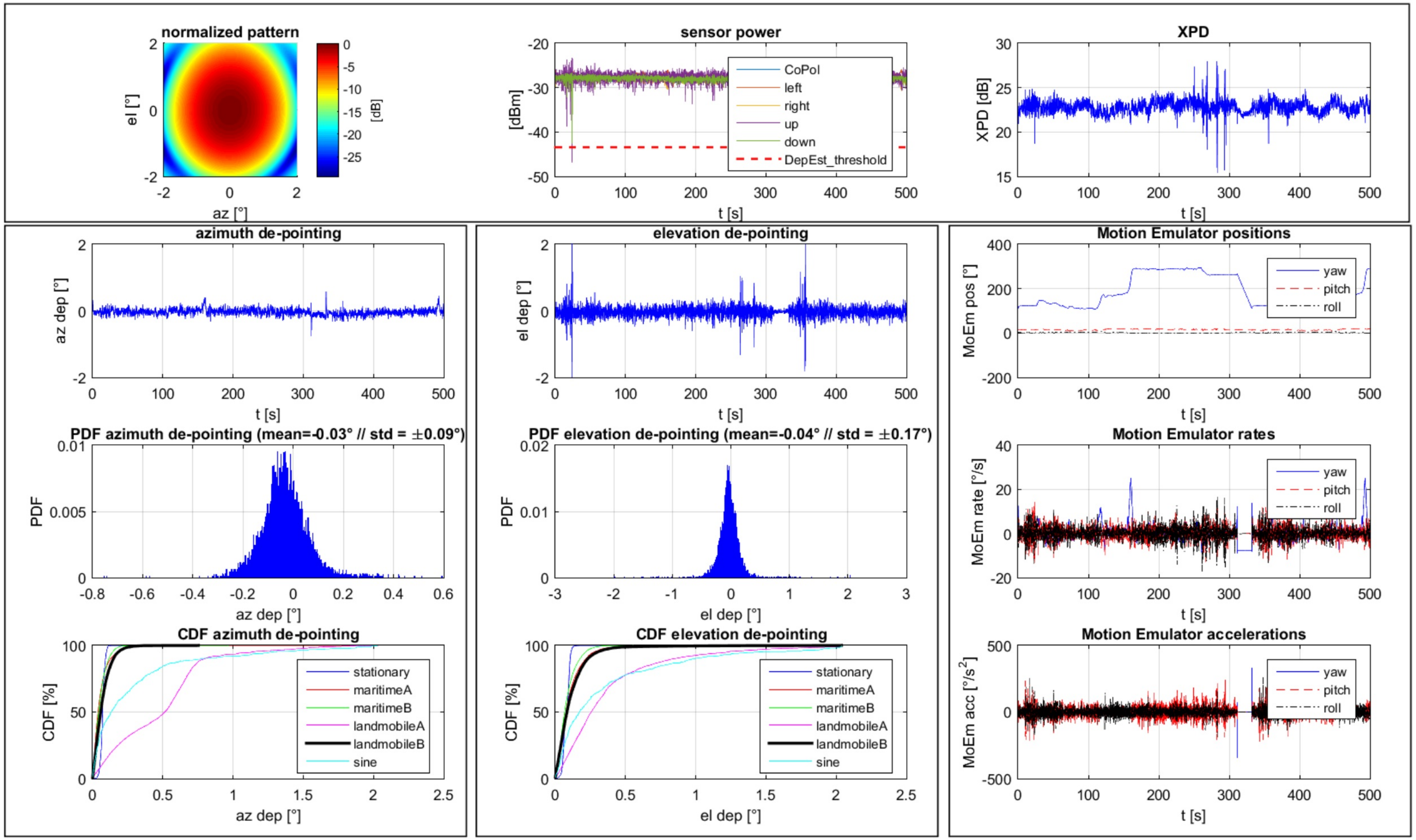

Figure 14 overview of pointing performance evaluation for land mobile class B with Mute function OFF