Defensie

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Sectie Infra

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ONDERWERP: Hoogstraten – Project tot het oprichten van 6 windturbines

Refertes:
1. Uw email van 08 juli 2021
2. Ons dossier 3D/3829
3. Uw réf: WT 2579
4. Circulaire GDF-03 – Richtlijnen betreffende de bebakening van hindernissen voor de luchtvaart

Dit advies blijft geldig voor een termijn van 2 jaar voor zover onze huidige criteria niet worden aangepast.

Geachte,

Hiermee komen wij terug op uw email van 08 juli 2021.

Gelieve hieronder het advies van Defensie i.v.m. luchtvaart, en radar aspecten te willen vinden.

LUCHTVAART

Op grondgebied van **categorie E** is dag- en nachtbebakening van het ganse project vereist vanaf dat het obstakel een totale hoogte bereikt van ≥150m boven het grondniveau. De bebakening dient conform te zijn met de normen welke zijn vastgelegd middels de CIR GDF 03 van de FOD Mobiliteit en Vervoer.

De maximale bouwhoogtes en de vereisten voor bebakening gelden ook voor eventuele bliksemafleiders en voor obstakels van tijdelijke aard zoals werfkranen.

RADAR

Het project bevindt zich verder ook in de LOS (Line Of Sight) van de Radarsystemen van **Bevekom**. Gezien de specifieke locatie van het project dient een simple engineering study conform EUROCONTROL-GUID-130 aan te tonen dat er geen negatieve impact is op de correcte werking van de naderingsradar van **Bevekom**. Als dit niet strikt wordt nageleefd, dient ons advies t.o.v. het windpark als ongunstig te worden beschouwd.

De engineering study moet rekening houden met de bestaande (gebouwde en/of vergunde) windturbines in de omgeving van de nieuwe windturbines.

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DGMR - Divisie CIS & Infra
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De studie dient bij een gespecialiseerde firma en op kosten van de aanvrager besteld te worden. Ze dient voorgelegd te worden aan onze diensten ter evaluatie van de conformiteit en interpretatie van de conclusies.

Om elk tijdverlies uit te sluiten dienen de gevraagde gegevens, met vermelding van het nummer 3D/3829, de juiste positie in Lambert 72-coördinaten en de totale hoogte van de obstakels, naar het volledig hieronder vermelde adres te worden overgezonden.

Defensie kan bijgevolg **geen definitief advies** uiten voor wat de inplanting van de in het onderwerp vermelde windturbines betreft. Een definitief advies zal pas kunnen gegeven worden van zodra de resultaten van bovenvermelde engineering studie gekend zijn.

Huidig advies wordt u overgemaakt zonder enige nadelige erkentenis en met behoud van alle rechten in hoofde van de Belgische Staat.

In het bijzonder kunnen uit dit advies geen rechten geput worden en behoudt de Belgische Staat zich het recht voor haar positie gedurende het verdere verloop van dit dossier te wijzigen.

Met de meeste hoogachting,

De Chef van de Sectie Infrastructuur
In opdracht

14/07/2021

X

Signed by: Vincent De Smet (Authentication)

Vincent DE SMET, ir
Kapitein-commandant
Bureelchef Domaniale Expertise

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Uw bericht van :	Uw kenmerk :	Ons kenmerk :	Ons dossier nr.	Bijlage(n) :	Brussel de:
7/07/2021	-	LA/A-POR/WWO/21-1171	WT2579	Advies Defensie	27/10/2021

Geachte heer,

Naar aanleiding van uw brief van 7 Juli 2021, deel ik u mee dat het Directoraat-generaal Luchtvaart, na consultatie van Skeyes en Defensie, momenteel, bij gebrek aan definitief advies van Defensie, geen positief advies kan geven voor het oprichten van 6 windturbines te Hoogstraten / Wuustwezel / Brecht met een hoogte van 230m AGL (boven het natuurlijk grondniveau).

Aangezien de betrokken windturbines gelegen zijn in de LOS (Line Of Sight) van de radarsystemen van Bevekom, vraagt Defensie dat u, overeenkomstig haar radarbeleid, een "simple engineering study" indient. Meer informatie kan u terugvinden in het advies van Defensie in bijlage.

De Lambertcoördinaten van de betreffende windturbines zijn:

	X:	Y:
T1:	173971.0	233282.0
T2:	173550.0	232582.0
T3:	172438.0	231162.0
T4:	171596.0	230326.0
T5:	171144.0	229620.0
T6:	170740.0	229080.0

Dit project is binnen een zone categorie E>150 gelegen.

De volledige inhoud van dit advies dient te worden meegedeeld aan de bouwheer. De aanvrager dient het Directoraat-generaal Luchtvaart schriftelijk op de hoogte te brengen van het gevolg dat aan zijn advies werd gegeven.

Wij vestigen er uw aandacht op dat, als de werken zouden uitgevoerd worden zonder rekening te houden met bovenvermelde opmerkingen, het Directoraat-generaal Luchtvaart in dat geval alle verantwoordelijkheid afwijst in geval van eventuele problemen in verband met luchtvaartgebonden activiteiten. Het Directoraat-generaal Luchtvaart houdt zich tevens het recht voor om deze voorschriften te laten naleven met alle juridische middelen die hem ter beschikking staan.

Hoogachtend,

Voor de Directeur-generaal,

Serge Delfosse
Diensthoofd

Kopie:

Skeyes (DGI/PA/U/Wind 2464/IUR-2021-0857)
Defensie (MITS : 21-50134744, dossier 3D/3829)

Nota *: U beschikt over 60 dagen na ontvangst van deze administratieve beslissing om een beroep in te dienen bij de Raad van State op grond van artikel 14 van de gecoördineerde wetten op de Raad van State. Dit beroep moet per aangetekende brief (Wetenschapsstraat 33 - 1040 Brussel) of via het digitale uitwisselingsplatform voor procedurestukken "e-ProAdmin"(http://eproadmin.raadvst-consetat.be) ingediend worden bij de Raad van State met een uiteenzetting van de feiten en de rechtsmiddelen.*

Windproject Hoogstraten-Wuustwezel (uitbreiding E19 Oost)

Aspiravi NV

Simple Engineering Assessment RADAR

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Version Control

Date	Status	Authority	Signature
02 Nov 21 v0.1	Draft	Vermeulen Reinhard Service Technician	
03 Nov 21 v1.0	Review and approval	Robrecht Rosseel, ir. Technical Lead	
08 Nov 21 v1.1	Updates	Domien De Ruyck ir. Managing Director	

Contents

1. List of Abbreviations

LoS .... Line of Sight

BAF .... Belgian Air Force

MoD .... Ministry of Defence

SEA .... Simple Engineering Assessment

SRTM .... Shuttle Radar Topography Mission

AGL .... Above Ground Level

AMSL .... Above Mean Sea level

RADAR ..... Radio Detection and Ranging

WT .... Wind Turbine

MTI .... Moving Target Indication

MTD .... Moving Target Detector

STC .... Sensitivity Time Control

CFAR .... Constant False Alarm Rate

ASR .... Airfield Surveillance Radar

PSR .... Primary Surveillance Radar

SSR .... Secondary Surveillance Radar

Pd .... Probability of Detection

RCS .... Radar Cross Section

dBsm .... Decibel Per Square Meter [$10 \log_{10} (\frac{RCS}{m^2})$]

VCC .... Vertical Clutter Canceller

RF .... Radio Frequency

RAG .... Range-Azimuth Gating

2. Introduction

Wind development located within line of sight of radar systems (LoS) can cause clutter and interference resulting in significant performance degradation. As wind turbines continue to be installed (more and bigger), and as advances in wind energy technology enable wind farms to be deployed in new regions of the country, the probability for wind development to present conflicts with radar missions related to air traffic control, weather forecasting, homeland security, and national defense is also likely to increase, as is the potential severity of those conflicts.

2.1 Wind turbine project

The project on behalf of **Aspiravi** concerns the following proposed wind turbines located near **Hoogstraten** and **Wuustwezel**, all coordinates are in Lambert72, the dimensions in this table are the maximum dimensions for this project (worst case scenario from radar point of view):

Turbine	**X**	**Y**	**Tip Height**	**Hub Height**
WT1	174038	233290	230m	149m
WT2	173552	232612	230m	149m

Table 2.1: Turbines under test

The turbines under test are visualised in the picture below.

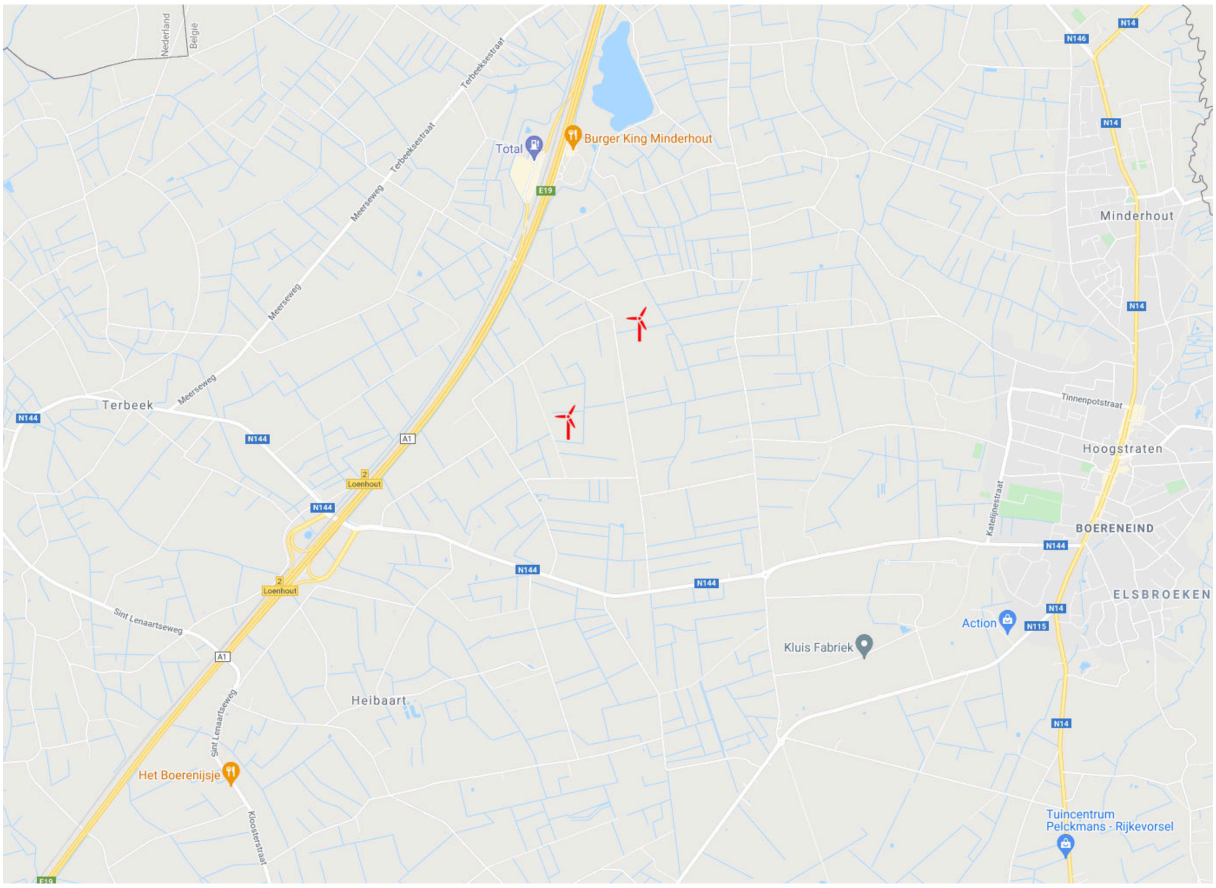

Figure 2.1: Geographic presentation of the turbines under test.

The turbines in table 2.1 will be studied taking into account a possible cumulative effect from wind turbines already installed or permitted near the turbines under test.

Taking into account the location and height of the turbines, a SEA for the Beauvechain radar is required. An overview of the distance for the turbines to the radar is given in table 2.2.

	Beauvechain
WT1	73.3 km
WT2	72.6 km

Table 2.2: Distance between the turbines under test and the Beauvechain radar.

2.2 Radar specifications

The radar specifications that are taken into account are listed below [5], see table 2.3. The parameters have been provided or confirmed by the Belgian Ministry of Defence. The technical details have been omitted due to reasons of confidentiality.

ASR Beauvechain technical specifications
MTI
MTD
Median filter
Soft STC
VCC
CFAR
Range - Azimuth cell
Rotation speed
Instrumented range
Beam Width
Pulse compression
Wavelength

Table 2.3: ASR Beauvechain technical specifications.

3. Scope

3.1 Eurocontrol requirements

Given that the project lies beyond 15km of the radar under assessment and in radar line of sight, MoD asks to perform a ”Simple Assessment” (zone 3 in the figure below). This assessment, as detailed in section 4.3 of the EUROCONTROL [1] document, should be sufficient to enable the surveillance data provider to assess the situation.

Zone	Zone 1	Zone 2	Zone 3	Zone 4
Description	0 - 500 m	500 m - 15 km and in radar line of sight	Further than 15 km but within maximum instrumented range **and in** radar line of sight	Anywhere within maximum instrumented range but **not in** radar line of sight or outside the maximum instrumented range.
Assessment Requirements	**Safeguarding**	**Detailed assessment**	**Simple assessment**	**No assessment**

Since the wind project lies beyond 16km no Secondary Surveillance Radar (SSR) assessment is required.

The scope for this project **Aspiravi - Hoogstraten-Wuustwezel** is thus as follows:

Impact	Reference [1]	Radar
		Beauvechain
PSR probability of detection	4.3.1	✓
PSR false target reports	4.3.2	✓
PSR processing overload	4.3.3	✓

Figure 3.1: Scope of the study.

The general way of executing the SEA has been confirmed by MoD without remarks [7].

3.2 Obstacles in the vicinity

In this assessment we take into account surrounding obstacles such as other wind turbines to evaluate the combined impact. For this we use an approximate 10 km radius. In this project 53 other turbines have been identified, for more details see appendix A. These turbines represent the worst case global effect with information coming from the IE Services database and Geopunt [8]. The positioning of these turbines can be seen in the figure below. The black turbines represent the obstacles surrounding the turbines under test, which are symbolised by the red turbines.

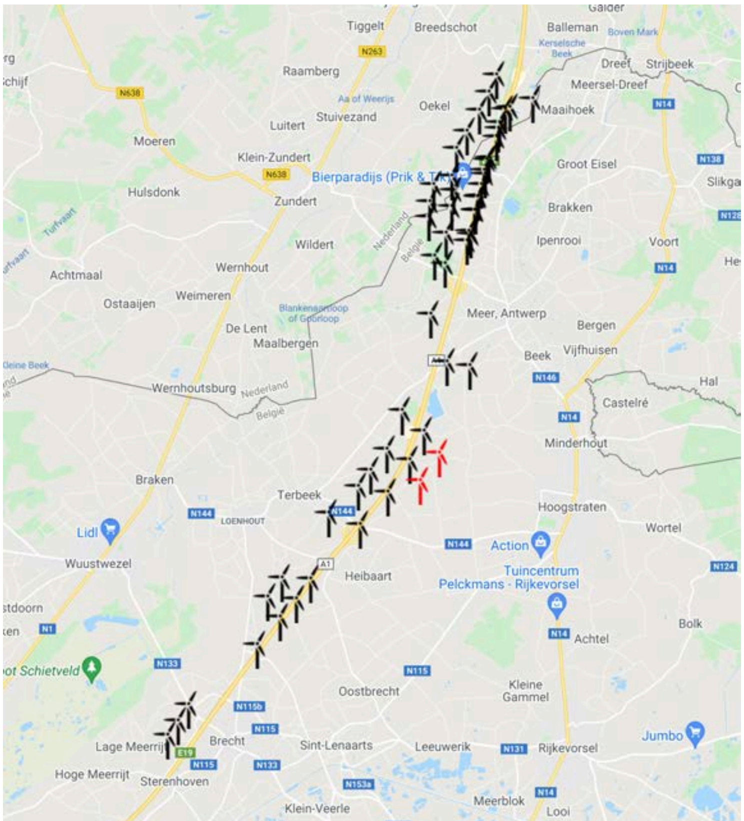

Figure 3.2: Obstacles around the turbines under test.

4. Simple Engineering Assessment TA-10 Beauvechain

A PSR simple engineering assessment is defined in the EUROCONTROL document to consist out of 3 parts, see also chapter 3 of this document:

- PSR probability of detection
- PSR false target reports
- PSR processing overload

Each of these items will be discussed in detail below. A geographic overview of the turbines under test and the defined obstacles is given below, figure 4.1. In red we see the new turbines, in black the existing turbines and the black radar at the bottom of the figure represents the Beauvechain Airport Surveillance radar (ASR).

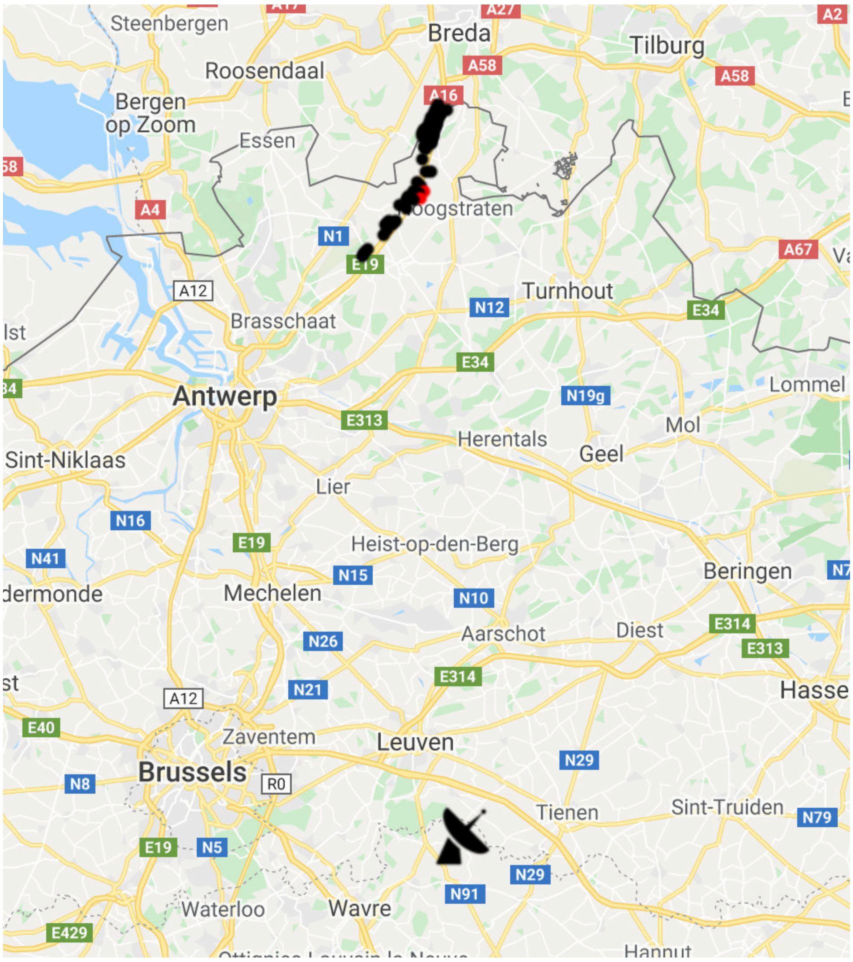

Figure 4.1: General overview relative to the Beauvechain radar.

4.1 PSR Probability of detection

Shadow regions behind the turbines

When a turbine lies directly between the transmitting and receiving antenna, the strength of the signal reaching the receiver is lower than it would otherwise be. For a radar system, this is the case for every obstacle that is within line of sight. The shadow region gives an indication of the severity of this effect. For the calculations we took into account the 4/3 earth model.

Shadow Height

First we look into the shadow height. We compare the shadow height of the turbines with the shadow generated by the terrain (SRTM [6]), a schematic representation is given in figure 4.2. These calculations are based on screening with an optical model for the propagation of the electromagnetic rays.

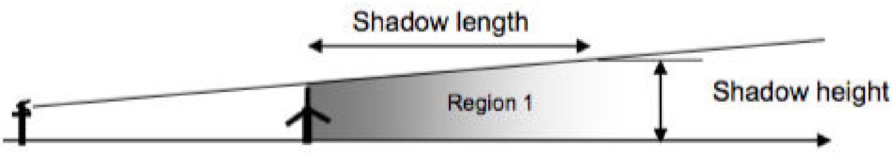

Figure 4.2: Schematic representation of the shadow height

The closer the turbine to the radar system, the bigger the expected impact. For the turbines under test (table 2.1) we obtain the following results; figure 4.3.

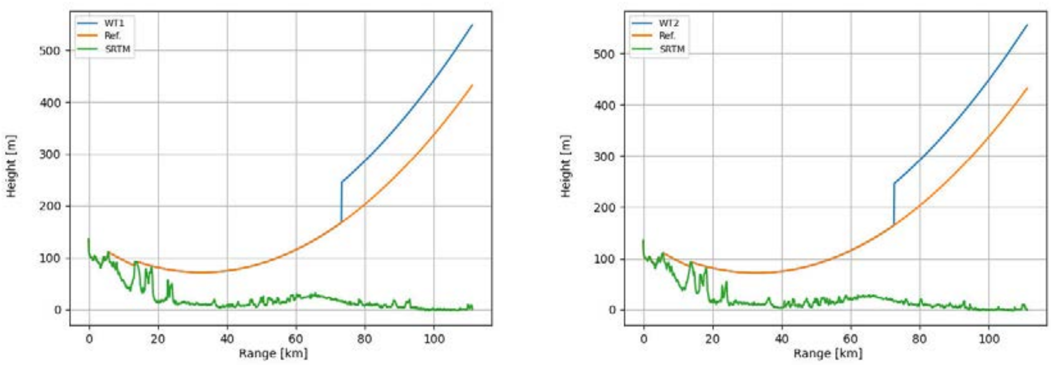

Figure 4.3: Shadow height Beauvechain radar, full instrumental range.

	Terrain shadow	Turbine shadow	Difference
WT1	432	548	116
WT2	432	556	123

Table 4.1: Shadow height comparison.

Partial conclusion: We notice that the wind turbines under test generate an additional shadow in the vertical dimension. At full instrumental range (60NM) this difference is 120m or a 28% increase compared with the current terrain shadow. This calculation gives us the worst case scenario, in reality this additional effect will be much smaller due to building obstructions and specific wave effects. The shadow zone is a region where the electromagnetic field is weaker when compared to a zone without obstructions (free space), so this zone is not completely dark.

Shadow Width

Similar as the shadow height we can calculate the shadow width which occurs due to the blocking of the radar signal in the azimuthal plane. The "signal blocking" is caused by destructive interference behind the turbines due to forward scattering effects.

A schematic overview is given in the figure below:

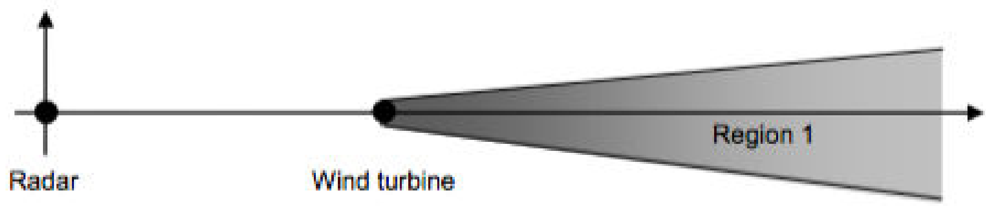

Figure 4.4: Schematic representation of the shadow width.

The shadow width depends on the addition of the signal in phase and anti-phase. If we calculate this for the three first *Fresnel zones* where destructive interference occurs (n = 1, 3 or 5) we obtain the results in figure 4.5.

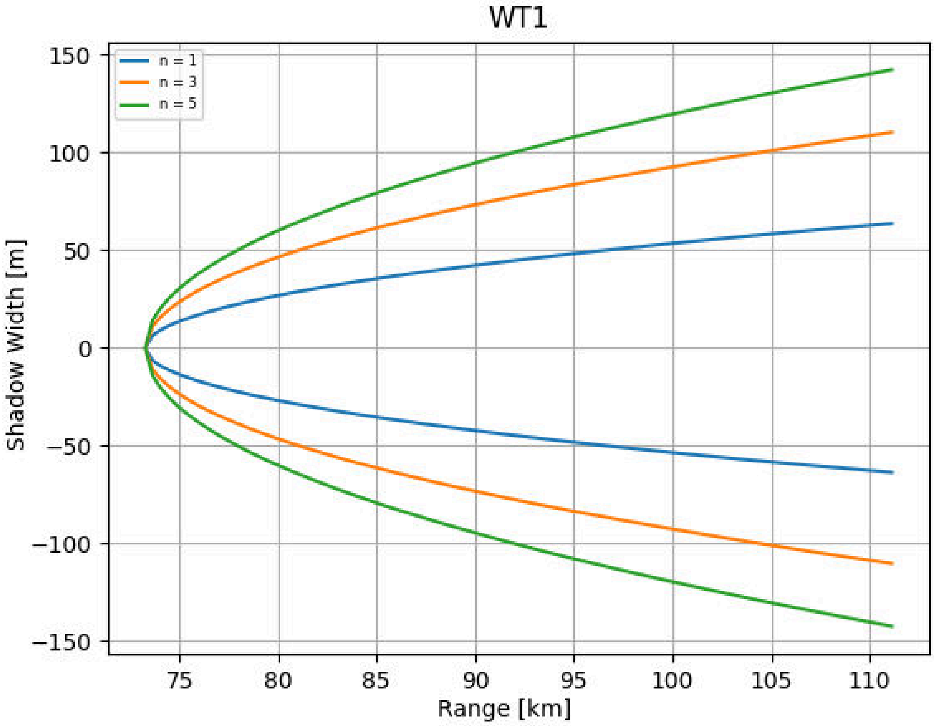

Figure 4.5: Actual representation of the shadow width for different Fresnel zones.

Partial conclusion: We notice that the wind turbines under test generate an additional shadow width zone. In reality, the shadow zone will not extend until the full instrumental range but will only occur the first kilometers behind the turbines. The additional shadow width zone will combine with the shadow zones of the existing/permitted turbines. In the shadow width region, the effects are caused by destructive interference between the radar signal and the forward scattered signal coming from the wind turbines. Due to the weaker signal coming from forward scattering of the turbines only a reduction in power will be measured in these zones, not a complete loss of signal. This effect will be the strongest in the first Fresnel zone (n=1) and will be almost undetectable in the 3rd relevant Fresnel zone (n=5). Due to the large difference in intensity between the forward scatter and the direct waves, the effect will only be noticeable close to the turbines.

Raised threshold above and around the turbines

The possible large reflections of the wind turbines raise the detector threshold of the radar, which lowers the probability of detection of a target. The size of the region depends on the CFAR algorithm installed, as specified in section 2.2.

Given the size of a range cell, we calculate that a wind turbine can potentially influence the radar threshold ±930 meters from its position. Combined with the beam width and distance to the turbines under test we obtain the following impacted zones, see figure 4.6.

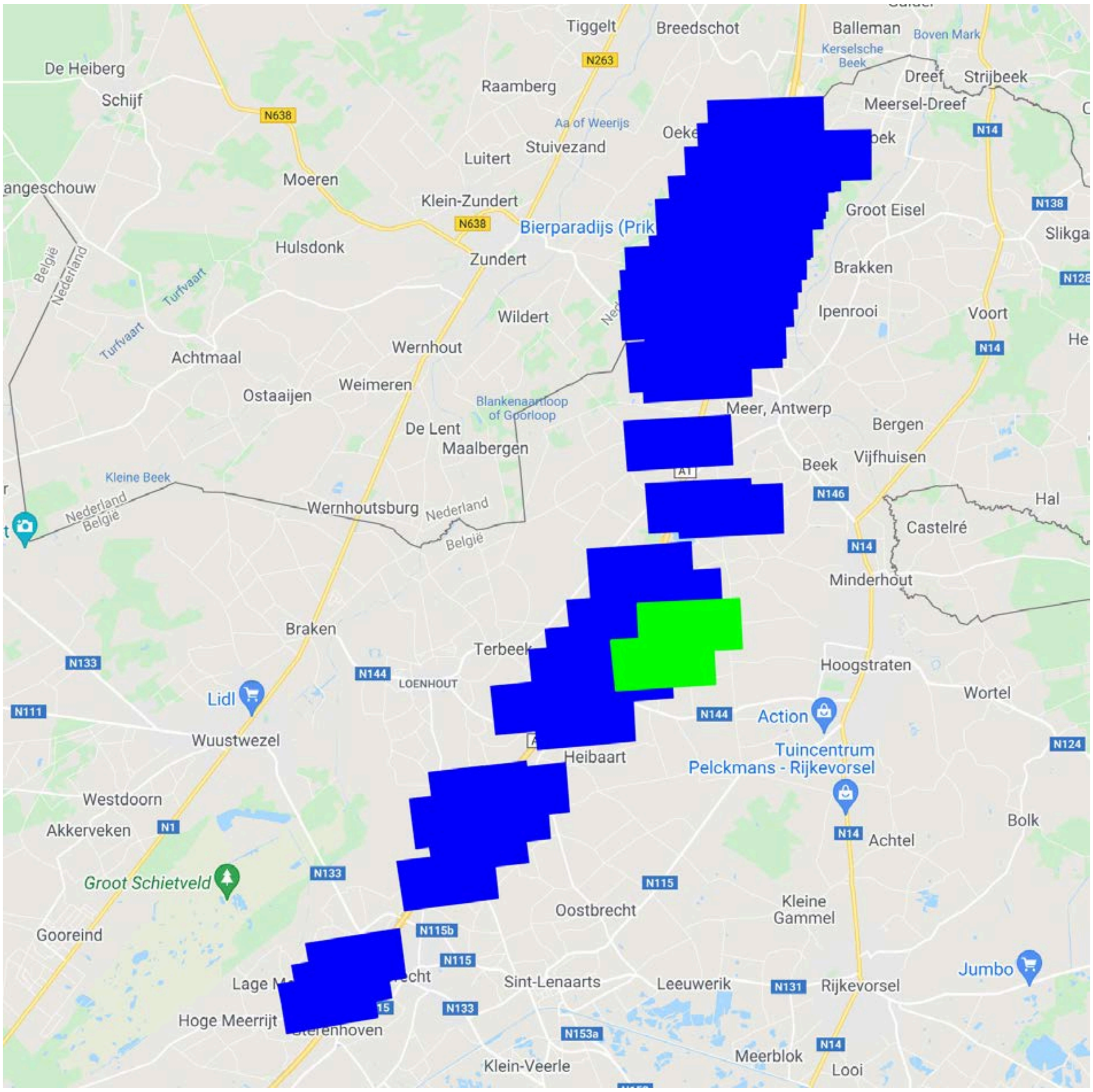

Figure 4.6: Schematic representation of the Beauvechain radar CFAR zones.

The green area is the CFAR region of the turbines under test. The blue area is the CFAR region of the existing or permitted turbines. If we compare the blue and the green area we can see a netto increase of the CFAR impacted region, the calculations are given in table 4.2. There is an overlap between the CFAR zones of the turbines under test and also an overlap with the existing and permitted turbines, a cumulative effect of about 3 dB will be present in the zones with the most severe overlap.

CFAR Area calculation	
Area before	40.52 km^2
Area after	41.53 km^2
Difference	1.01 km^2
Difference	2.50 %

Table 4.2: CFAR area increase.

For the RCS of the turbines under test different values have been used. In real life this will also be the case, depending on the wind direction and blade speed of the turbines. Even within one complete blade revolution this RCS value can vary by a factor of 10,000. A simplified statistic overview is given in the table below, 4.3 [4].

Monostatic RCS S-band			
Maximum	Mean	Median	Minimum
37 dBsm	27 dBsm	27 dBsm	0 dBsm

Table 4.3: Stochastic representation of monostatic RCS turbines, S-band.

For this study we analysed the impact on the raised threshold above and around the turbines for RCS values of 10, 15, 20, 25, 30 and 35 dBsm to simulate all possible scenarios. Next we calculated the impact on a target right above the turbines (worst case) at different altitudes. The target size is simulated as 0 dBsm ($1m^2$).

If the reflected power of the target remains above the detection threshold, it can still be seen by the radar system. In these calculations we processed the impact of MTI/MTD and the beam pattern. A schematic overview of our test setup can be seen below:

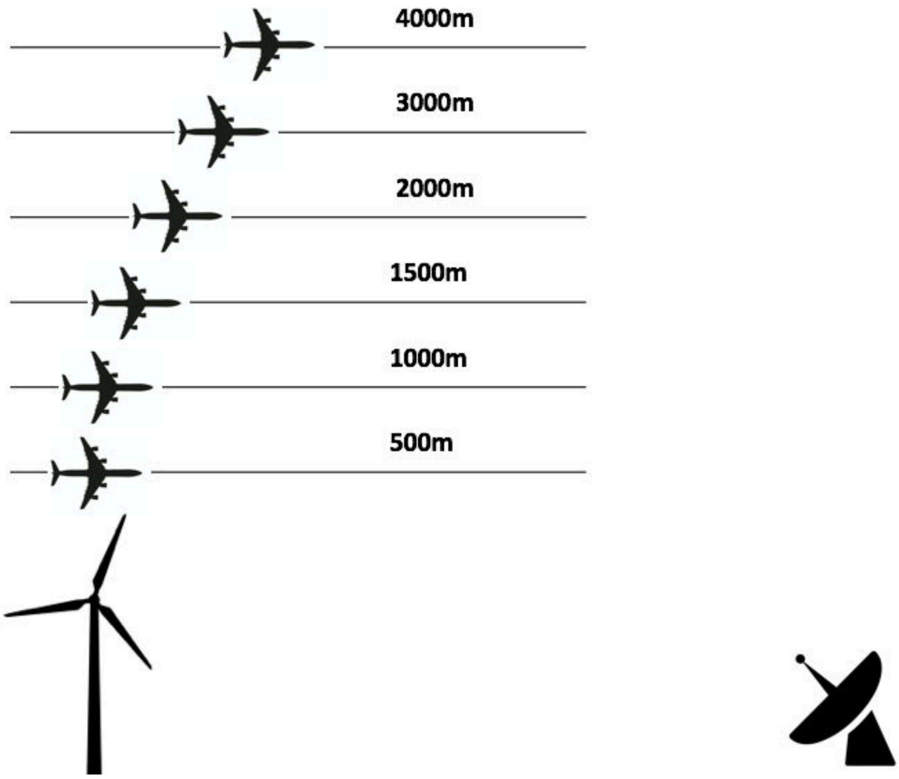

Figure 4.7: Schematic representation of the CFAR test setup.

To present the case for the Beauvechain radar we display the results for a WT RCS of 15 and 20 dBsm. For the complete results, see annex B.

WT	**Beam**	**Reference**	**500m**	**1000m**	**1500m**	**2000m**	**3000m**	**4000m**
WT1	1.0	-123.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-133.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-123.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-133.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

Table 4.4: Detection of a 0 dBsm target at different altitudes (RCS_{WT}= 15dBsm).

WT	**Beam**	**Reference**	**500m**	**1000m**	**1500m**	**2000m**	**3000m**	**4000m**
WT1	1.0	-118.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-128.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-118.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-128.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

Table 4.5: Detection of a 0 dBsm target at different altitudes (RCS_{WT}= 20dBsm).

The 'Reference' column in the tables above state the value of the reflected power coming from the turbines after applying all mitigations (and CFAR) present in the radar. The overflying targets can only be detected if the returned power is larger than this reference value.

We notice for a turbine with a RCS of 15dBsm (table 4.4) that overflying targets with a RCS of 0dBsm will be seen from an approximate altitude of 500m AMSL when flying above or near the wind turbine. When the WT has a reflection of 20dBsm (table 4.5) the small airplane will only be visible for the radar from 2000m AMSL.

To give an idea about the expected RCS of the turbines under test we have performed a simplified RCS calculation. In this calculation we have only taken into account the part of the turbines that is visible for the radar system. As detailed simulations have shown, the turbine masts are the dominant contributors to the monostatic RCS, regardless of the orientation of the rotor [9].

The mast has been simulated as a frustum and we calculated its monostatic RCS in relation to the different relevant EM incident angles. The result is displayed below, figure 4.8. Because of the similarity between the turbines only the graph of the first turbine has been displayed.

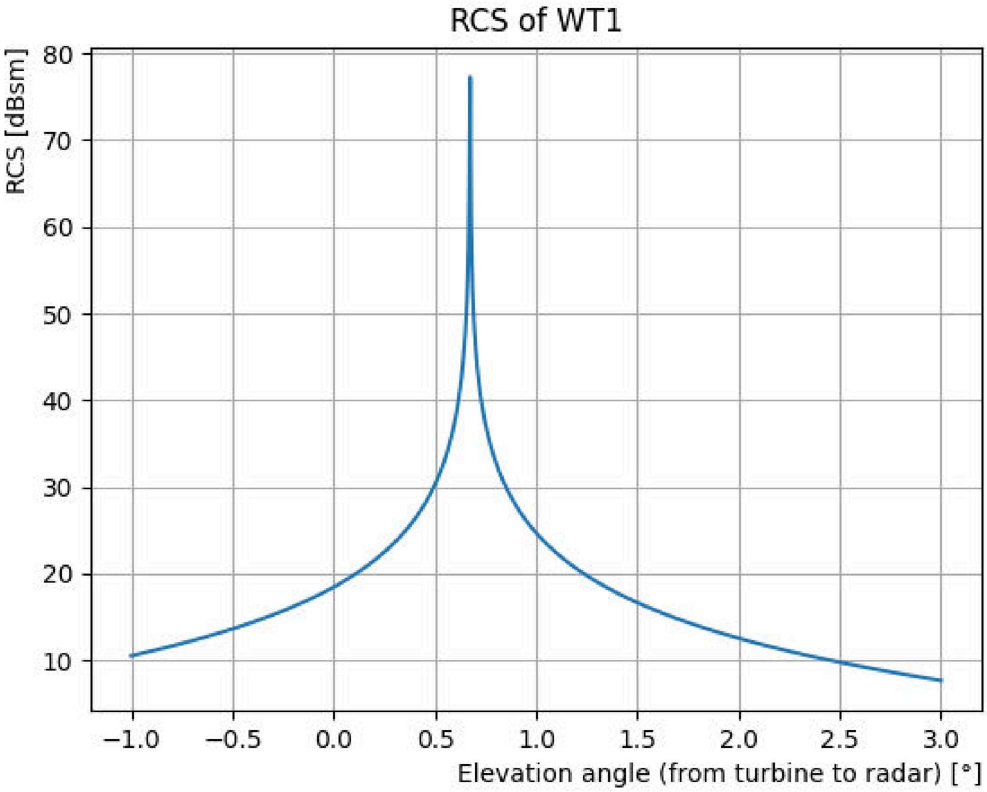

Figure 4.8: Monostatic RCS of a turbine under test at different elevation angles.

	Elevation Angle [°]	**RCS S-band [dBsm]**
WT1	0.224	21.9
WT2	0.221	21.9

Table 4.6: Overview monostatic RCS simulation of the turbine under test.

In this case, only a part of the mast and the rotor will be visible for the radar. The RCS contribution of the mast can be estimated around 21.9Bsm. When adding the RCS contribution of the rotor, the expected RCS for a single turbine is 23dBsm. Taking into account the cumulative effect, the total impact on the CFAR algorithm will be 26dBsm.

Partial conclusion: As the radar of Beauvechain has no automatic mitigations installed, the impact of wind turbines on the CFAR could be considerable (depending on the turbine RCS). For a turbine reflectivity of 15dBsm the small objects flying above will be visible as from 500m AMSL. A RCS of 20dBsm will reduce the visibility for the smallest targets. The expected RCS impact on the CFAR algorithm is 26dBsm. This is the worst case scenario with cumulative effects from other turbines. The smallest targets will be hard to detect, regular aircraft will have a larger RCS and will be easier to detect, but not during all scans.

Impact on signal processing

The impact on the signal processing will be a general rise of data to be processed, with the current technology used in radar systems this impact will be negligible.

4.2 PSR false target reports

Modern surveillance radars are equipped with multiple mechanisms to obtain detections of flying targets only. To suppress reflections at non-moving objects (stator), adaptive cluttermaps are maintained within each doppler bin.

A flying target will be detected if its reflection exceeds the risen CFAR threshold in its range-azimuth cell. This has been discussed in section 4.1. Since the RCS of the turbines under test will vary over time (even within a single rotation), false targets will be present if no mitigations are applied.

4.3 PSR processing overload

The extra video processing as a result of the wind turbines under test is negligible in comparison with the radar technology used, see also section 4.1, impact on the signal processing.

4.4 Practical analysis

The technology of the Beauvechain radar makes it possible to export the clutter maps of the system. The turbines are located at 39.2 NM - 39.6 NM from the radar at an azimuth of 356.3° - 356.7°. The clutter map for the low beam in the region of the project is visualised in figure 4.9.

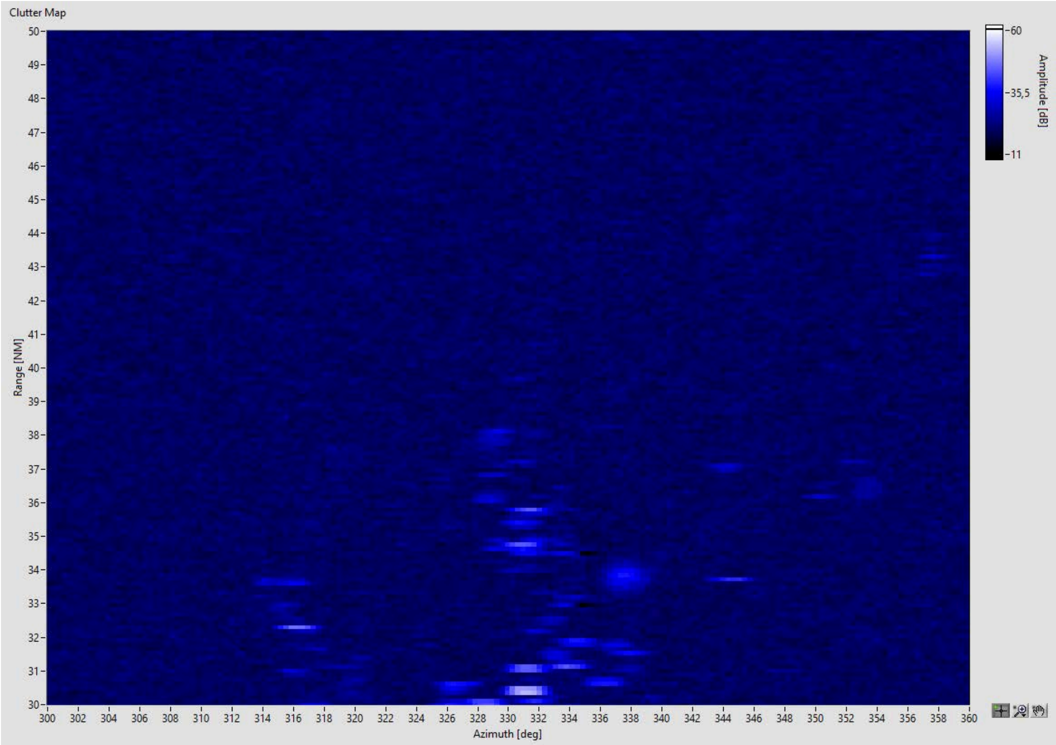

Figure 4.9: Clutter map of the Beauvechain radar (low beam - Doppler bin 0).

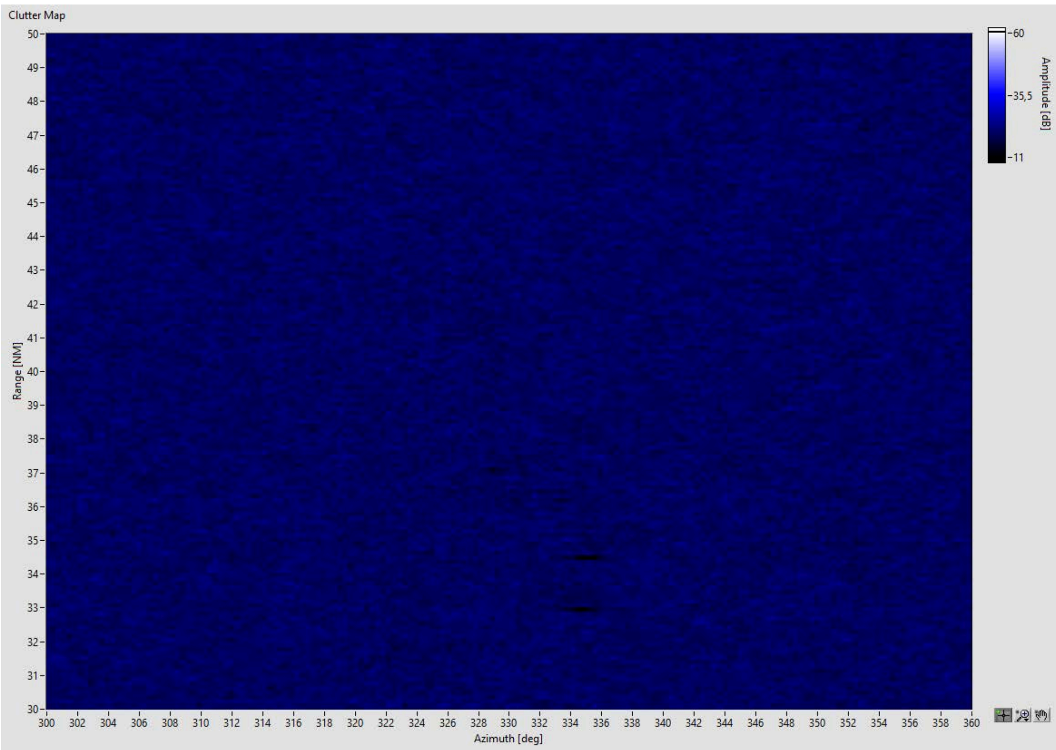

Figure 4.10: Clutter map of the Beauvechain radar (low beam - Doppler bin 4).

A lot of clutter is present in Doppler bin 0 of the low beam of the Beauvechain radar. The impact of these zones on the system is important for the possible generation of false plots and the detection performance. In higher doppler bins (Fig. 4.10), the high peaks are no longer noticeable. The black rectangles represent the RAG zones that are already applied in the signal processing. This is a part of the wind farm mitigation possibilities. Near the turbines under test, some small RAG zones are present, these are not visible on the image due to their small size. Due to the negative effects, most of the existing turbines have mitigations applied on them. Only the smaller existing turbines are not mitigated. The clutter levels of the high beam are visible in Figures 4.11 and 4.12.

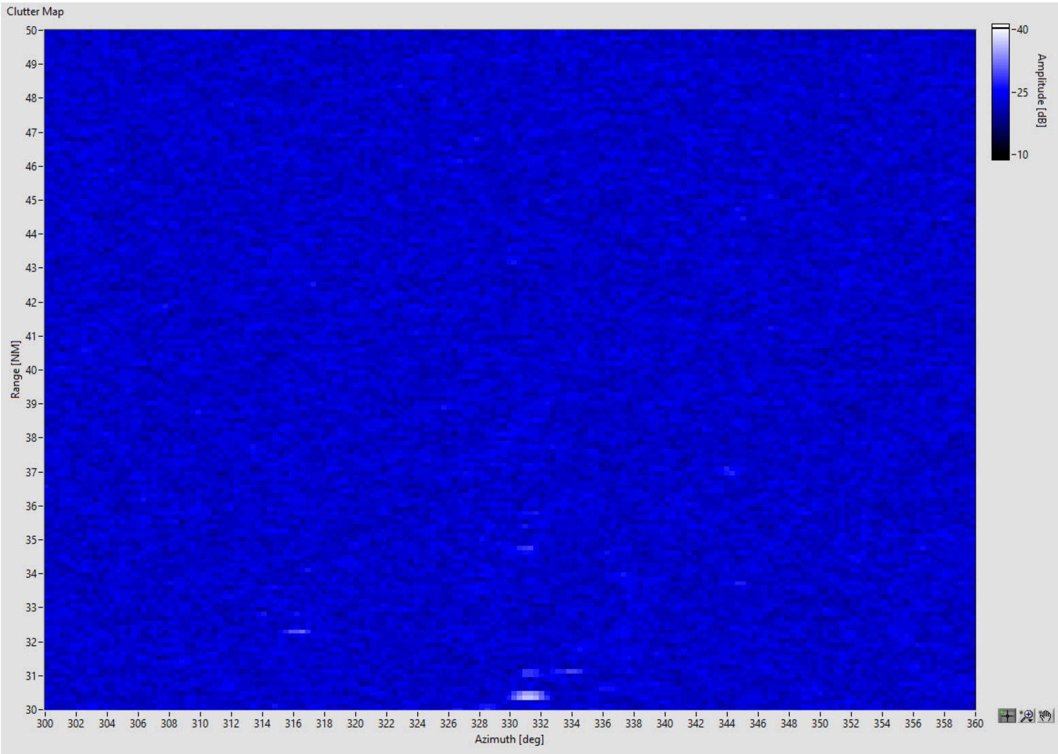

Figure 4.11: Clutter map of the Beauvechain radar (high beam - Doppler bin 0).

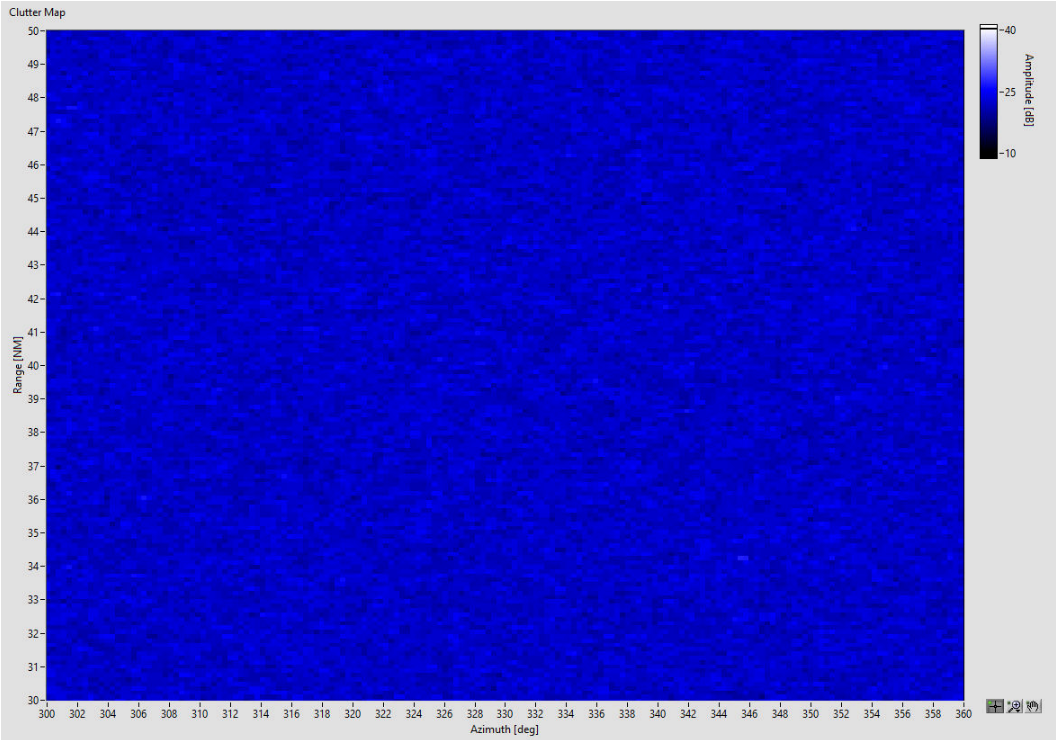

Figure 4.12: Clutter map of the Beauvechain radar (high beam - Doppler bin 4).

In the region of this project, wind projects have been installed with an impact on the radar performance. The turbines with the largest dimensions (still smaller than the ones in this project) are mitigated with the RAG/VCC mitigations. There is a small raise of the clutter map noticable in the low beam due to the smaller existing turbines.

4.5 Mitigations

Section 4.1 and 4.4 show that there will be an impact on the detection near and above the turbines under test. Next to this, false plots (Section 4.2 will be present. In order to be sure, an **after installation report** needs to be drafted in which the return video signal from the turbines under test are measured in their own clutter environment and compared with the different signal processing thresholds.

5. Conclusion

Beauvechain

Shadow width and height effects are present for the Beauvechain radar, these can impact the PSR probability of detection. However, due to the existing turbines at similar distances, these effects are already present without significant consequences on the operationality of the radar.

The shadow height will limit itself to the part of the turbines under test which is higher than the surrounding obstacles. The relative raise of the shadow height (28%) will be limited. The shadow width zone is limited in width and only a reduction in intensity will be noticeable, this zone is not completely dark. The new shadow zone will merge with the shadow zones of the existing turbines.

A considerable impact will occur on the CFAR processing due to the fact that no automatic windmill mitigation is installed. Small targets will be easily detected for RCS values of the wind turbines up to 15dBsm, from 20dBsm and higher, the smallest targets will be harder or impossible to detect. Small targets close to the turbines under test may be invisible during some scans, depending on the RCS value of the target. The expected cumulative RCS impact on the CFAR algorithm is 26dBsm.

PSR false target reports are to be expected depending on the orientation of the turbine rotors. No PSR processing overload is to be expected.

From both the theoretical and practical analysis, an impact is expected in the region of the turbines. This impact will limit the performance of the Bevekom radar in the area around the turbines. In order to reduce or eliminate the negative effects of the turbines under test, the VCC and RAG maps need to be investigated and/or altered after the installation. This investigation can be performed by an **after installation report** in which the turbines under test are measured in their own clutter environment and compared with the different signal processing thresholds.

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Appendices

A. Turbines in the vicinity

Turbine	Lambert X	Lambert Y	Height
Z1	172726	233387	155m
Z2	170476	229641	150m
Z3	167251	226206	153m
Z4	172056	231503	150m
Z5	172320	232847	155m
Z6	174357	239842	200m
Z7	175420	241192	118m
Z8	174706	238586	150m
Z9	173661	233852	150m
Z10	175190	240603	118m
Z11	176329	242134	150m
Z12	174208	235556	197m
Z13	167775	226966	153m
Z14	170054	229186	150m
Z15	173306	233130	150m
Z16	175046	239996	118m
Z17	172000	232453	155m
Z18	174758	238820	150m
Z19	174890	239349	118m
Z20	167509	226576	153m
Z21	175630	241875	118m
Z22	170104	230165	193m
Z23	174308	239429	200m
Z24	175510	241528	118m
Z25	173102	234339	180m
Z26	169738	229666	193m
Z27	173810	236739	200m
Z28	174186	238764	215m
Z29	175757	241918	215m
Z30	175469	241388	215m
Z31	175238	240661	215m
Z32	175137	240243	215m
Z33	175129	240356	118m
Z34	174980	239703	215m
Z35	174903	239357	215m
Z36	174786	238746	215m
Z37	170824	230144	150m

Turbine	**Lambert X**	**Lambert Y**	**Height**
Z38	172750	232322	150m
Z39	171280	231786	155m
Z40	174967	239675	118m
Z41	174317	240212	200m
Z42	175427	242728	150m
Z43	175240	242303	150m
Z44	174985	241850	150m
Z45	174692	241327	150m
Z46	174433	240881	150m
Z47	173853	239996	150m
Z48	173772	239561	150m
Z49	173746	239180	150m
Z50	174150	238017	150m
Z51	173881	238201	150m
Z52	174786	235465	150m
Z53	169500	228492	150m

B. Impact on the CFAR

This chapter gives the estimated returned power of a reference target of 0dBsm and compares this to the incident power coming from the wind turbine after all of the data processing (CFAR, VCC, MTD, ...) This makes it possible to check from which altitudes a small aircraft can be detected.

B.1 Beauvechain

B.1.1 WT RCS 10 dBsm

WT	Beam	Threshold	500m	1000m	1500m	2000m	3000m	4000m
WT1	1.0	-128.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-138.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-128.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-138.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

B.1.2 WT RCS 15 dBsm

WT	Beam	Threshold	500m	1000m	1500m	2000m	3000m	4000m
WT1	1.0	-123.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-133.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-123.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-133.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

B.1.3 WT RCS 20 dBsm

WT	Beam	Threshold	500m	1000m	1500m	2000m	3000m	4000m
WT1	1.0	-118.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-128.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-118.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-128.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

B.1.4 WT RCS 25 dBsm

WT	Beam	Threshold	500m	1000m	1500m	2000m	3000m	4000m
WT1	1.0	-113.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-123.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-113.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-123.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

B.1.5 WT RCS 30 dBsm

WT	Beam	Threshold	500m	1000m	1500m	2000m	3000m	4000m
WT1	1.0	-108.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-118.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-108.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-118.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9

B.1.6 WT RCS 35 dBsm

WT	Beam	Reference	500m	1000m	1500m	2000m	3000m	4000m
WT1	1.0	-103.0[dBw]	-121.2	-121.5	-121.7	-121.9	-122.7	-124.0
WT1	2.0	-113.0[dBw]	-130.1	-129.3	-128.5	-127.8	-126.2	-125.0
WT2	1.0	-103.0[dBw]	-121.1	-121.3	-121.6	-121.8	-122.6	-123.9
WT2	2.0	-113.0[dBw]	-129.9	-129.1	-128.4	-127.6	-126.1	-124.9