

Radar Impact Assessment

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August 2023

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ADMINISTRATION PAGE

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has assessed the potential impact of a building development, located in central Manchester, on the Secondary Surveillance (SSR) radar at Manchester Airport. This report has been commissioned to address Condition C9 of the planning permission. Specifically, this report investigates the likely technical requirement for mitigation as a basis for further engagement with NATS.

The development has a maximum height of 179.03 metres Above Ordnance Datum (AOD) and 143.48 metres above ground level (agl).

Predicted Impact

The modelling has revealed that development is predicted to be visible to the SSR based on bare earth terrain. The most significant structure along the radar line of sight profile appears to be the Great Northern Tower on Watson Street; however, the structure only provides screening for a small section of the building and therefore significant visibility of the building remains.

Despite the eastern and western façades being exposed to the radar, noticeable reflection effects are not predicted due to the convex surfaces and the presence of 'fins' which protrude out of the façades – see Section 6.3.3. These fins mean that the façades are not considered uniform reflectors that could cause noticeable reflection effects because the radar signal will be weakened and/or scattered before returning to the radar. The radar also has sophisticated mechanisms for minimising interference (see Section 5) and strong coverage in the radar's reflection zones, further reducing the likelihood of noticeable effects.

Overall, the radar internal processing is predicted to determine correctly that returns associated with reflected signals are false and the radar display is consequently not predicted to be affected by reflections. It is therefore recommended that Condition C9 is discharged without the requirement for implementing mitigation.

Next Steps

The decision ultimately lies with NATS, who safeguard the radar. Engagement with NATS at the earliest opportunity is recommended to establish their position regarding the requirement for mitigation.

If technical mitigation is required by NATS, it is recommended that a software-based fix is applied to the SSR. This requires coordinate data for the proposed development to be programmed into the radar system such that reflection effects can be minimised. This solution is commonly applied to SSR where visibility is deemed to be potentially significant.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 countries within Europe, Africa, America, Asia and Australasia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 BACKGROUND

1.1 Introduction

Pager Power has assessed the potential impact of a building development, located in central Manchester, on the Secondary Surveillance (SSR) radar at Manchester Airport. This report has been commissioned to address Condition C9 of the planning permission. Specifically, this report investigates the likely technical requirement for mitigation as a basis for further engagement with NATS.

Building developments have the potential to affect aviation operations in numerous ways. The most common impacts relate to building developments as physical obstructions both to aircraft and wireless signals used for radar and radio systems. This assessment pertains to the potential impact of the tower upon the SSR at Manchester Airport, located approximately 15.5km south of the development. Considerations of this assessment with respect to the SSR include:

- The radar's built-in capabilities to reject the effects of buildings.
- The likelihood of aircraft being displayed incorrectly on air traffic control displays due to the presence of the development.
- Practical proposals for mitigating any significant effects on the radar.

1.2 Planning Condition

The planning condition addressed in this report is presented below:

Planning condition Nr C9

No above ground construction of the tower podium (Phase 3 as defined by condition 51) shall take place unless and until a Radar Mitigation Scheme (RMS), (including a timetable for its implementation during construction), has been agreed with the Operator and approved in writing by Manchester City Council.

The Radar Mitigation Scheme (RMS) shall thereafter be implemented and operated in accordance with the approved details.

Reason: In the interests of aviation safety, pursuant to policies DM1 and SP1 of the Core Strategy.

2 DESCRIPTION OF DEVELOPMENT

2.1 Development Details

The Level 07 plan for the development is shown in Figure 1¹ below. The tower footprint is shown by the oval shaped section.

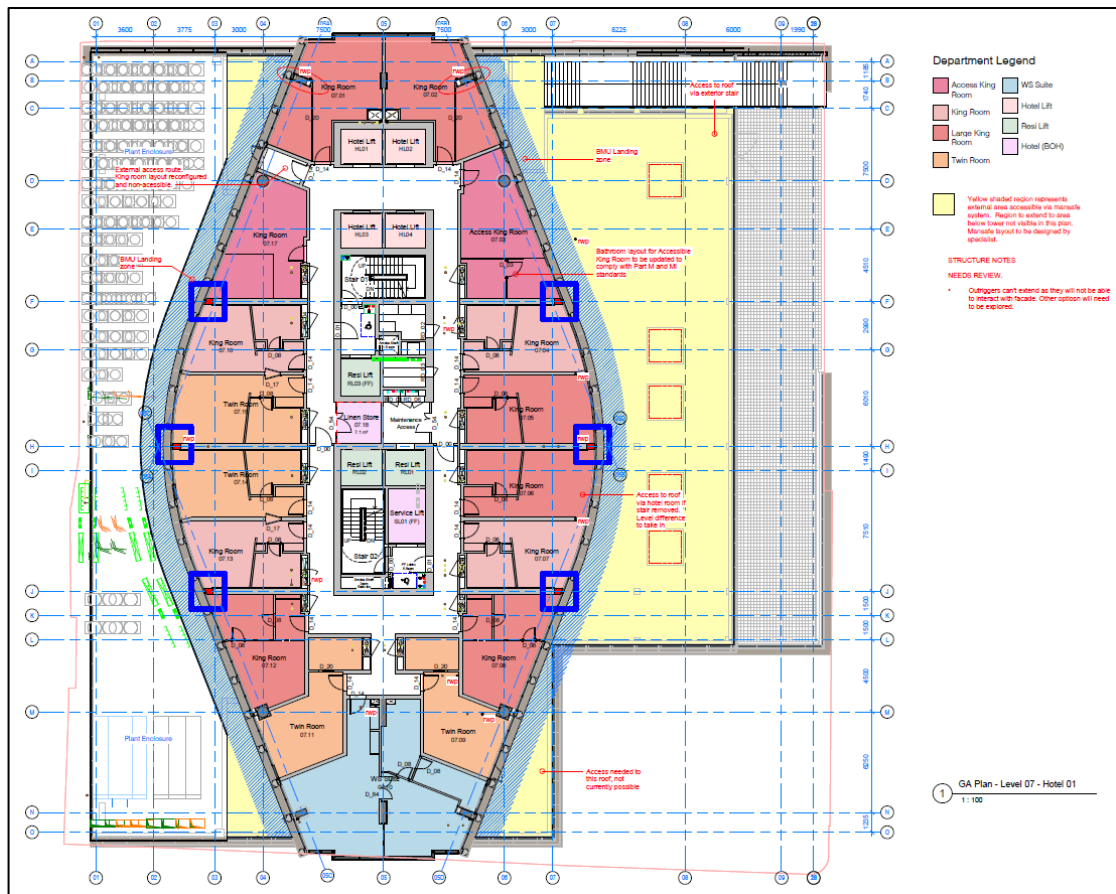


Figure 1 Development level 07 plan

Figures 2 to 4 on the following pages show drawings of the building elevations^{2,3,4}.

¹ 0643-HOD-ZZ-07-DR-A-20207 - Level 07 Plan (P9).

² 0643-HOD-ZZ-ZZ-DR-A-20300 - North Elevation (P6)

³ 0643-HOD-ZZ-ZZ-DR-A-20301 - East Elevation (P6)

⁴ 0643-HOD-ZZ-ZZ-DR-A-20307 - West Elevation - Podium (P6)



Figure 2 Development north elevation

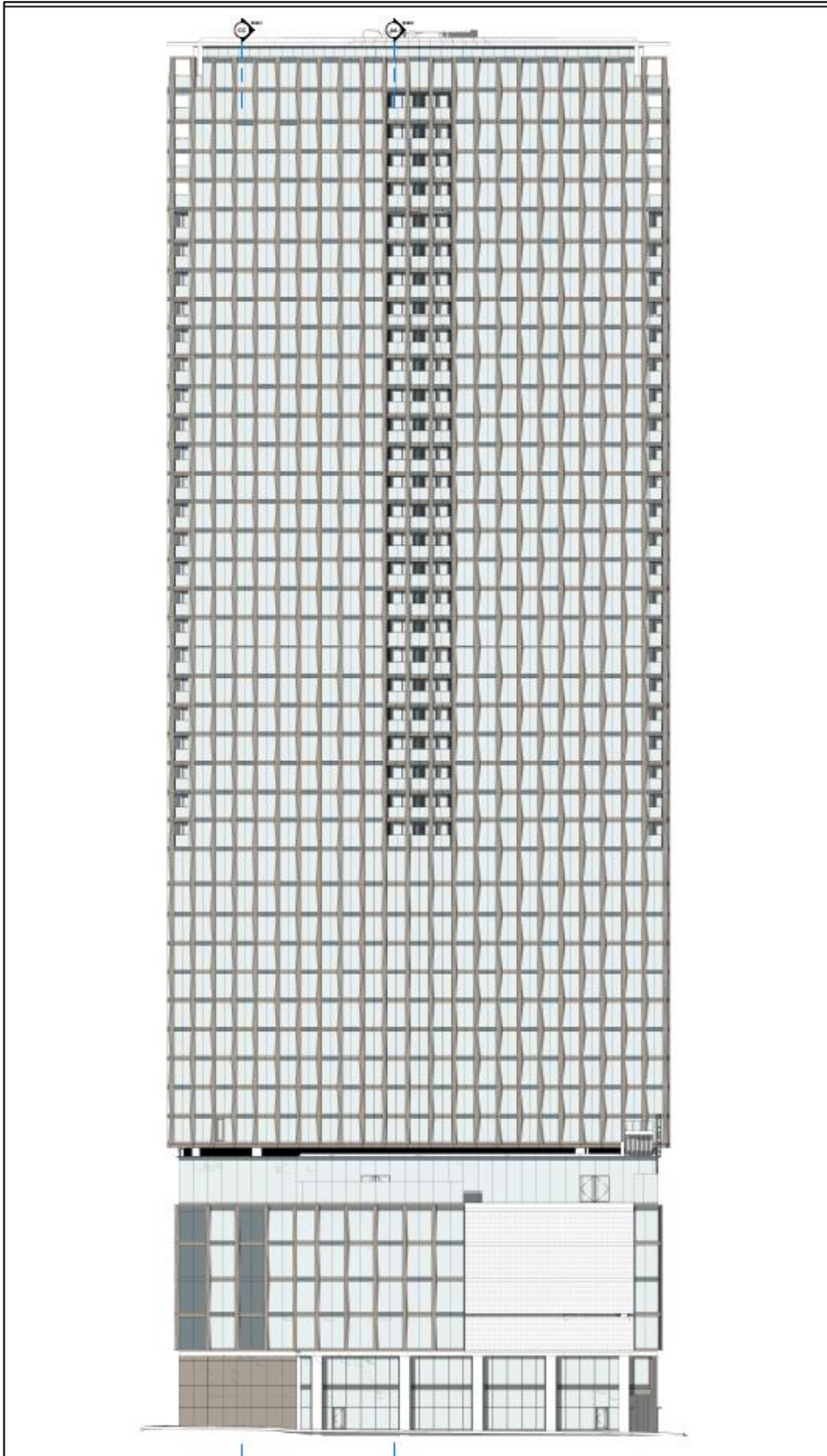


Figure 3 Development east elevation

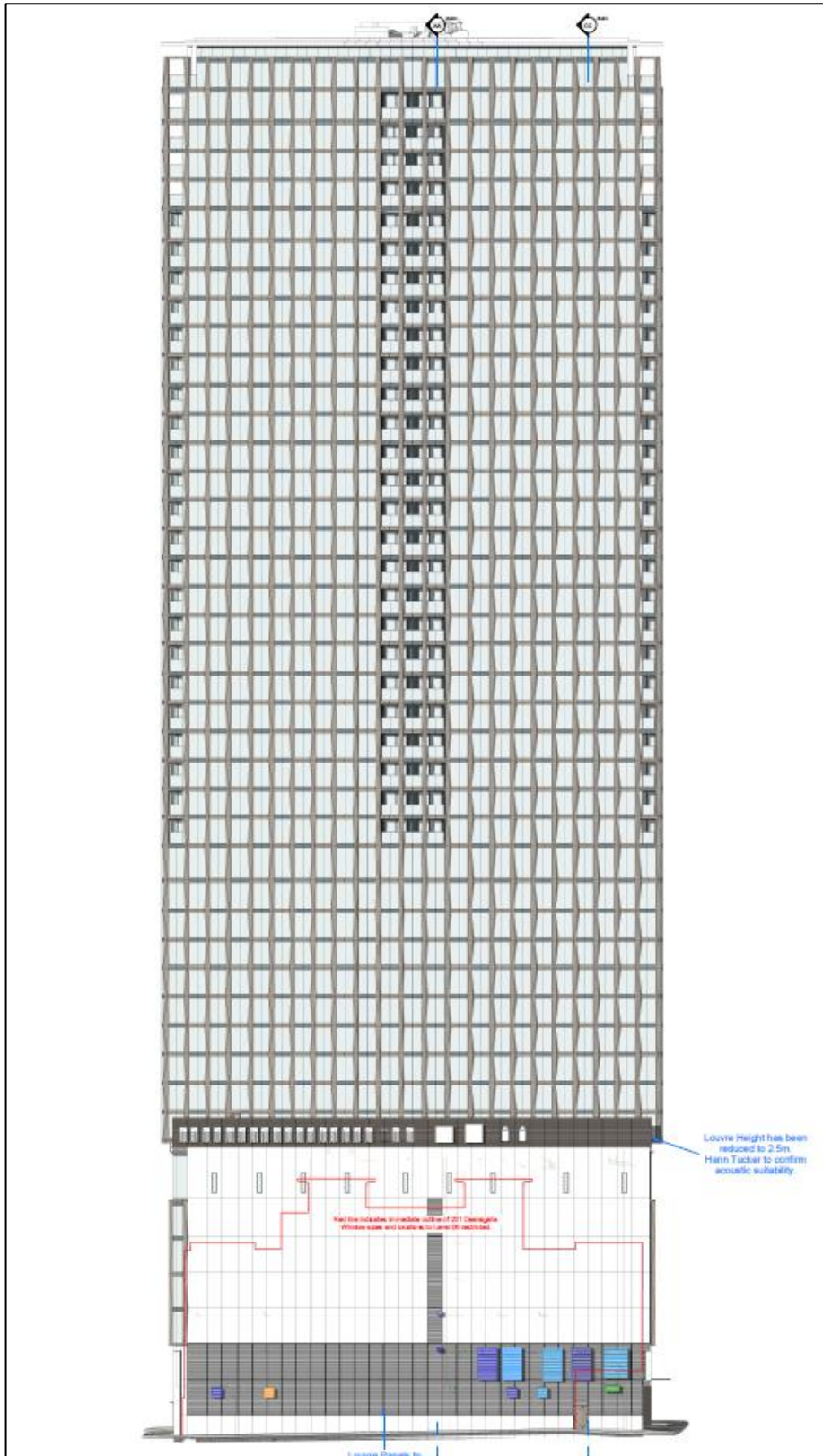


Figure 4 Development west elevation

2.2 Building Footprint and Height Details

The development footprint coordinates used for this assessment, along with the height and altitude details, are presented in Table 1 below.

ID	Easting	Northing	Max Height / Altitude
1	383639	398057	143.48m agl / 179.03m AOD
2	383648	398055	
3	383626	398033	
4	383652	398028	
5	383630	398006	
6	383639	398004	

Table 1 Footprint coordinate and height details

The tower footprint locations used for the radar line-of-sight assessment are shown in Figure 5 below.

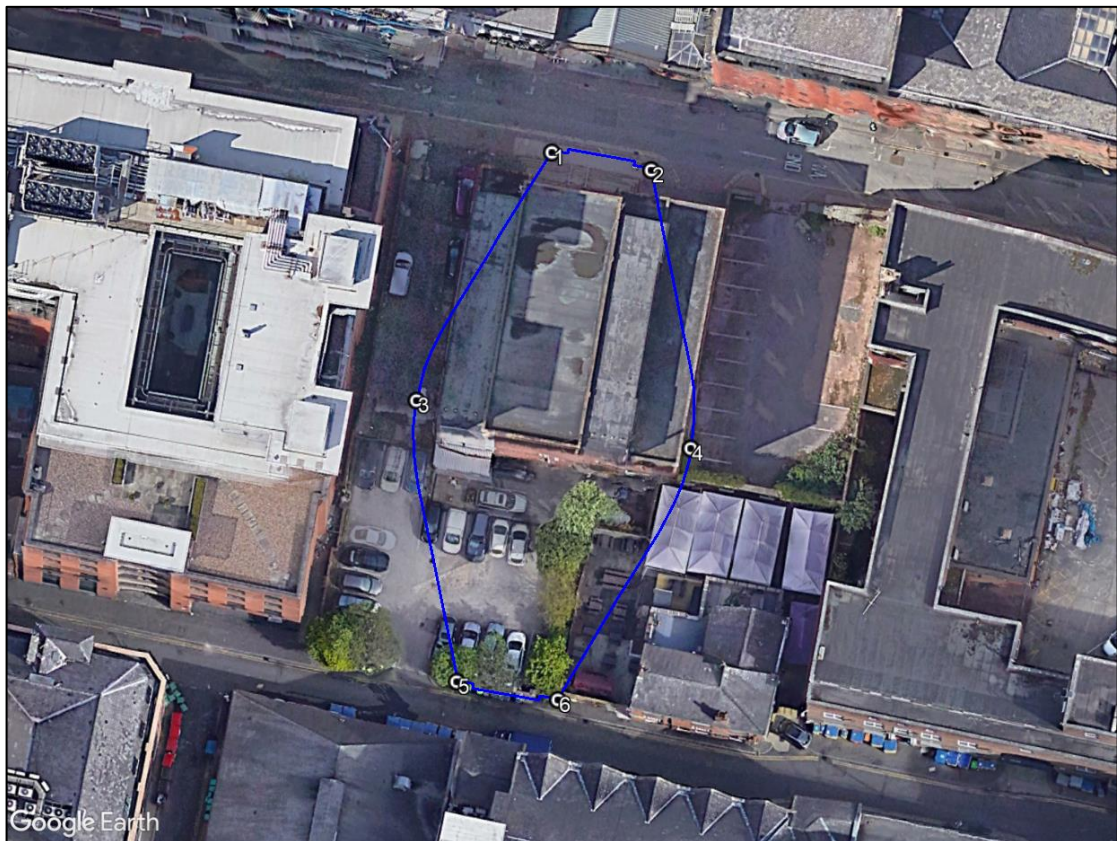


Figure 5 Tower footprint and assessed locations

2.3 3D Building Representation

A 3D aerial image of the development is shown in Figure 6 below.

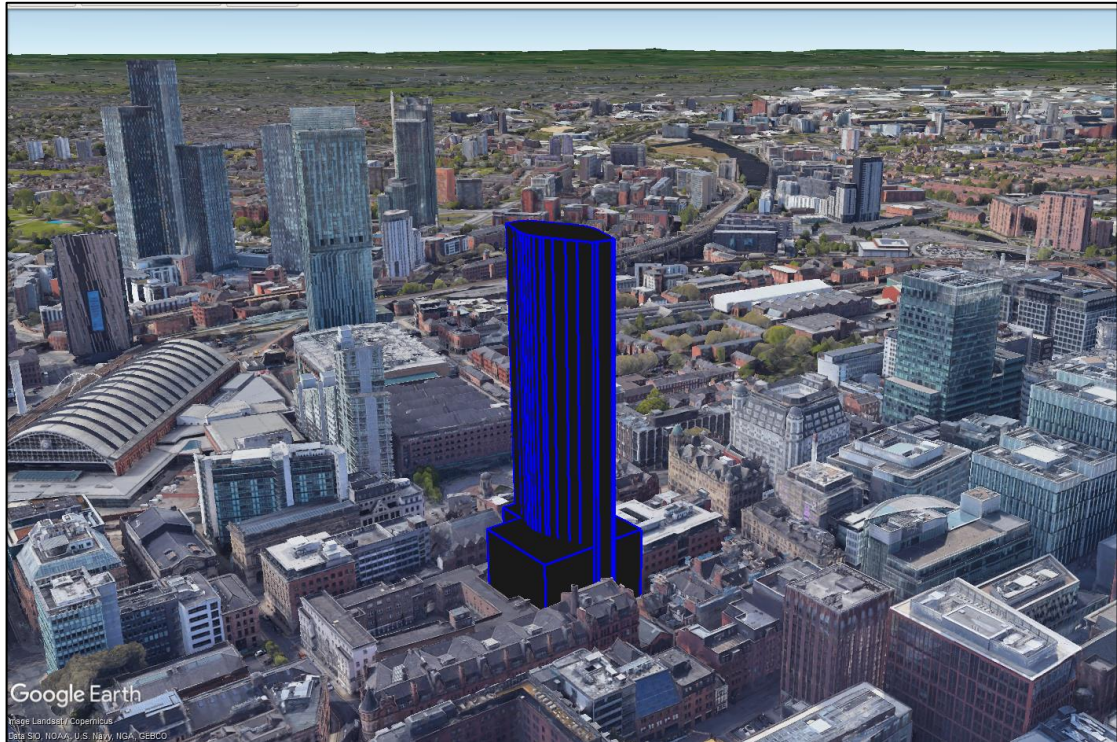


Figure 6 3D building representation

3 RADAR DATA AND INTERFERENCE MECHANISMS

3.1 Radar Details

Table 2 below provides the details for the assessed Manchester Airport SSR radar. All data has been provided by NATS.

Overall radar altitude above mean sea level	97 m
Distance between the development and radar	15.5 km
Average grid bearing from radar to development	8.5°

Table 2 Manchester Airport SSR radar location details

3.1.1 Radar Types and Usage

SSR broadcast interrogating radio signals that are detected by aircraft with on-board transponders. The transponder responds by broadcasting a radio reply which normally contains identification and altitude information. The SSR determines the aircraft's horizontal position from the direction the antenna is orientated, and the time taken to receive a response from the interrogation.

Both radar will be used by air traffic controllers to provide approach services to aircraft landing at and departing Manchester Airport. Both radar will also be used by air traffic controllers at national air traffic control centres to provide services to en-route aircraft.

The radar of significance with respect to the predicted impact is the SSR. The PSR is not expected to be significantly affected.

3.2 Interference Mechanisms

Buildings, structures and terrain can interfere with SSR. The level of interference normally depends on the size of the interfering structure and its distance from the radar. A larger structure closer to the radar is more likely to interfere than a smaller structure which is further away. The two predominant forms of interference are reflections and shadowing.

3.2.1 Reflections

Reflections from a structure can potentially result in genuine aircraft returns being plotted in the wrong place as a result of the structure reflecting signals in a specular (mirror-like) way. This means that an air traffic controller could mis-manage aircraft, leading to safety implications.

Both in-bound and out-bound signals are weakened due to reflections because they are reflected by a structure in both directions.

3.2.2 Shadowing

Radar signals are weakened by physical obstacles. The most significant signal blocking is often caused by terrain. Large obstructions within a radar's area of coverage can have a 'shadowing' effect, reducing the signal strength immediately behind them.

This effect is most pronounced immediately behind the structure and becomes less pronounced with distance. This is important because it means a structure's 'shadow' does not block radar coverage indefinitely, and the areas with the highest losses should be considered in an operational context.

Both in-bound and out-bound signals are weakened by shadowing because signals are attenuated by a structure in both directions.

3.3 SSR Capabilities

The radar is an SSR fitted with a Large Vertical Aperture (LVA) antenna. The radar is located to the south of Manchester Airport. It is a Mode S monopulse SSR supplied by Raytheon Systems Limited as part of a nationwide contract to upgrade NATS' national network of twenty sites.

The radar is understood to be a Condor 300 dual channel system with Mode S capabilities. This radar has a range of advanced built-in capabilities for increasing its reliability and performance. Specific features that reduce the radar's susceptibility to interference from buildings are listed in Table 3 below and on the following page.

Feature	Form of Interference	How Feature Reduces Interference	Additional Information
Integral Tracking Function	Reflections	More likely to determine return is genuine if it moves as an aircraft return is expected to.	Ensures good false target suppression.
Refined Algorithms	Reflections and Shadowing	Experience on many sites used to enhance performance.	Ensures good performance in complex environments.
Identification and rejection of false replies	Reflections	False returns are rejected	If two or more replies are identified from the same source all but the first is rejected.
Side Lobe Suppression	Reflections	False returns arising from antenna sidelobes are rejected	P1 and P2 pulses are used. This is an encoding system which enables sidelobe signals to be detected by comparing pulse sizes.
Sensitivity Time Control (STC)	Reflections	Removes reflections	Removes relatively low amplitude replies

Feature	Form of Interference	How Feature Reduces Interference	Additional Information
Minimum Detection Signal Level (MDS)	Shadowing	Maximises radar coverage whilst minimising noise detections	-
Dynamic Threshold	Shadowing	Weak signals stronger than any interference signals are detected.	-
Reply to Reply Correlation	Reflections	Multiple replies required for target processing	Single reply reports are rejected.
FRUIT ⁵ Rejection	Reflections	Track initiation only allowed if report contains two or more correlating replies in the same SSR mode	e.g. two or more Mode A replies
Track Processing	Reflections and Shadowing	Improvements are made in target location using history of target position.	Improvements made when confidence in location information is low
False Target Processing	Reflections	Advanced processing that applies a series of tests to identify and reject false returns	Techniques include: 1: Check whether Mode A code is unique 2: Check "known" reflection zones 3: Use geometric analysis for checking reflection zones 4: Self adaptive processing

Table 3 Radar features for reducing interference

⁵ FRUIT – False Replies Unsynchronized in Time

4 METHODOLOGY

4.1 Overview

The following section presents an overview of the assessment methodology and steps that have been followed.

4.2 Assessment Steps

The assessment steps were as follows:

- Establishing the radar's location and height.
- Establishing the radar's technical capabilities.
- Establishing building location, height, and orientation.
- Establishing building radar interference mechanisms.
- Establishing whether the development is shielded.
- Establishing building radar reflection zones.
- Establishing radar coverage in reflection zones.
- Establishing building radar shadow zones.
- Establishing radar signal weakening in shadow zones.
- Establishing terrain profile for radar reflection and shadow paths.
- Establishing shielding by buildings and vegetation for radar, reflection and shadow paths.
- Establishing the likelihood of an aircraft within identified reflection zones being displayed in an incorrect location.
- Establishing the likelihood of an aircraft in the identified shadowing zone not being displayed.
- Identifying mitigation options.

5 SSR INTERFERENCE MECHANISMS

5.1 Overview

SSR broadcast interrogating radio signals that are detected by most aircraft. Transponders onboard the aircraft respond and broadcast radio replies which normally contain identification and altitude information. An SSR then determines the aircraft's horizontal position from the orientation of the antenna at the time the signal was broadcast, and the time taken to receive a response from the interrogation. The result is subsequently displayed on the controller's radar screen. Altitude and identification data can be encoded within the response transmitted from the aircraft's transponder.

A simple diagram of the process is presented in Figure 7 below.

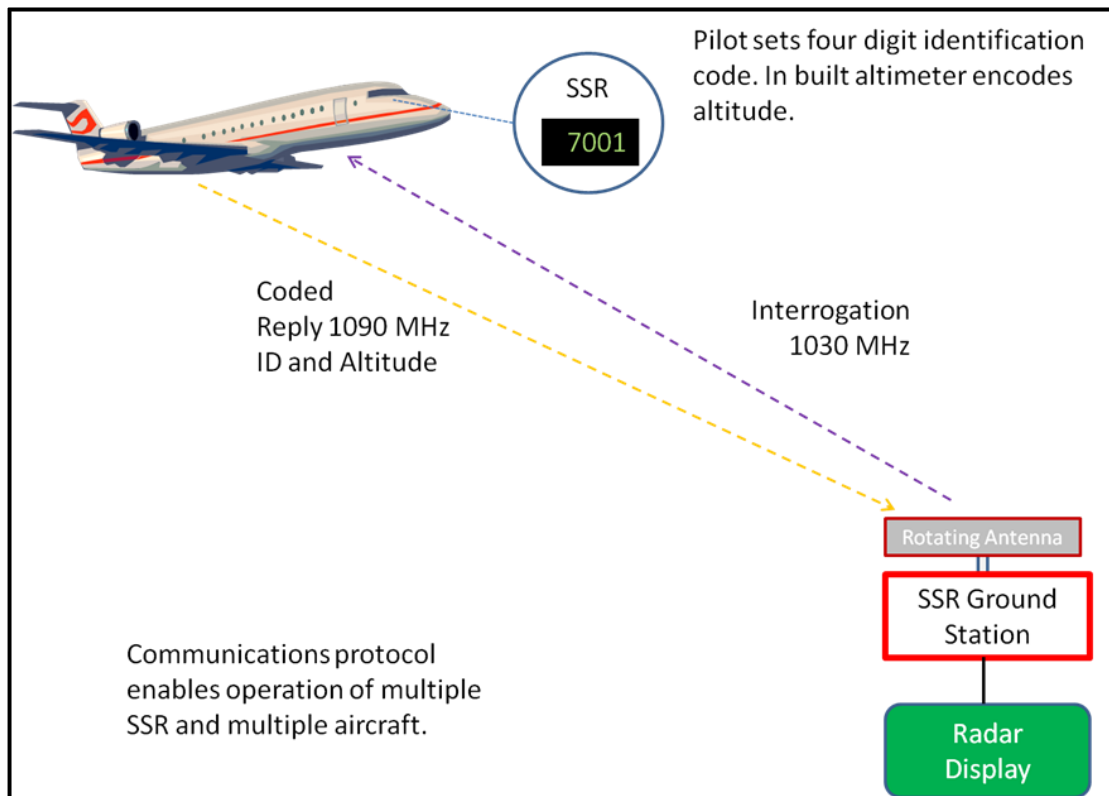


Figure 7 Principles of SSR Operation

If the transponder is not switched on, or does not exist, no detection will take place. All SSR and transponders operate to the same standards worldwide and all use the same frequencies. There is a complex coding protocol used to ensure that transmissions from multiple radar stations and aircraft do not get misinterpreted.

Buildings, structures and terrain can interfere with SSR. The level of interference normally depends on the size of the interfering structure and its distance from the radar. A larger structure

closer to the radar is more likely to interfere than a smaller structure which is further away. Two forms of interference have been considered. These are:

1. Shadowing – Either in-bound or out-bound signals are weakened because they are attenuated by a structure. The principle of shadowing is presented in Figure 8 below.

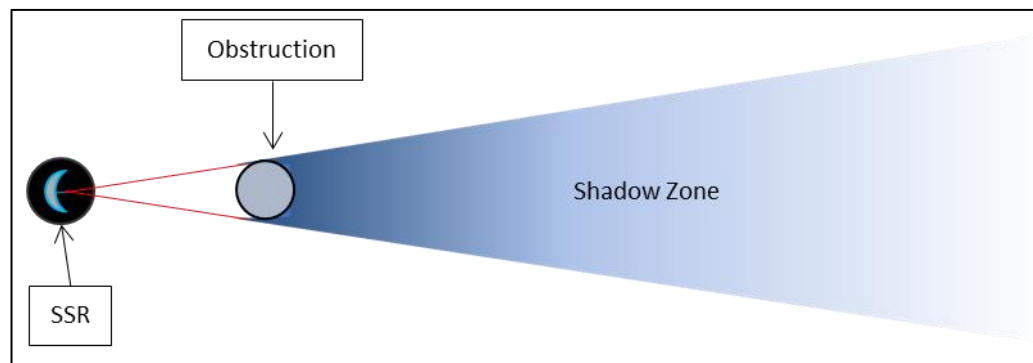


Figure 8 Principles of shadowing

2. Reflections – Either in-bound or out-bound signals are reflected off a structure. The principle of reflections is presented in Figure 9 below.

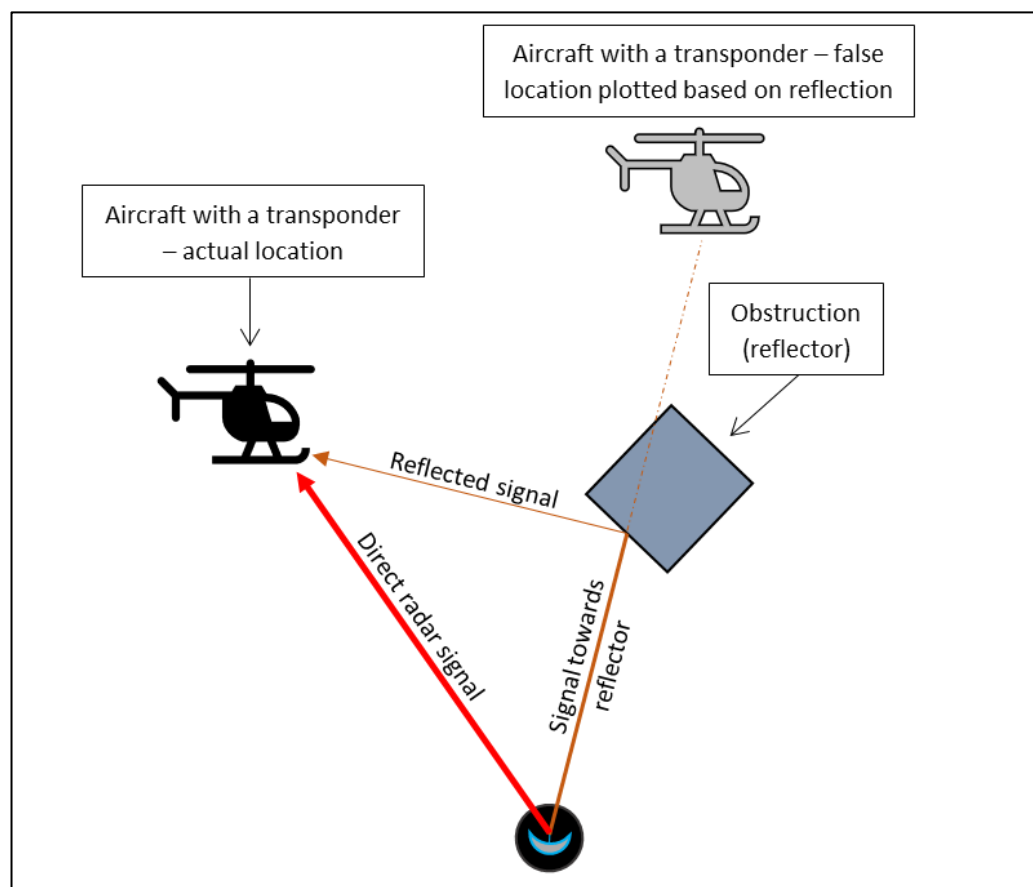


Figure 9 Principles of reflections

6 SSR IMPACT ASSESSMENT

6.1 Radar Line of Sight Analysis

The radar line of sight chart for the most visible corner of the development is shown in Figure 10 below. The charts show that, based on bare-earth terrain, the development will be in full radar line of sight to the SSR at Manchester Airport.

Information regarding the methodology or the additional line of sight charts can be provided upon request.

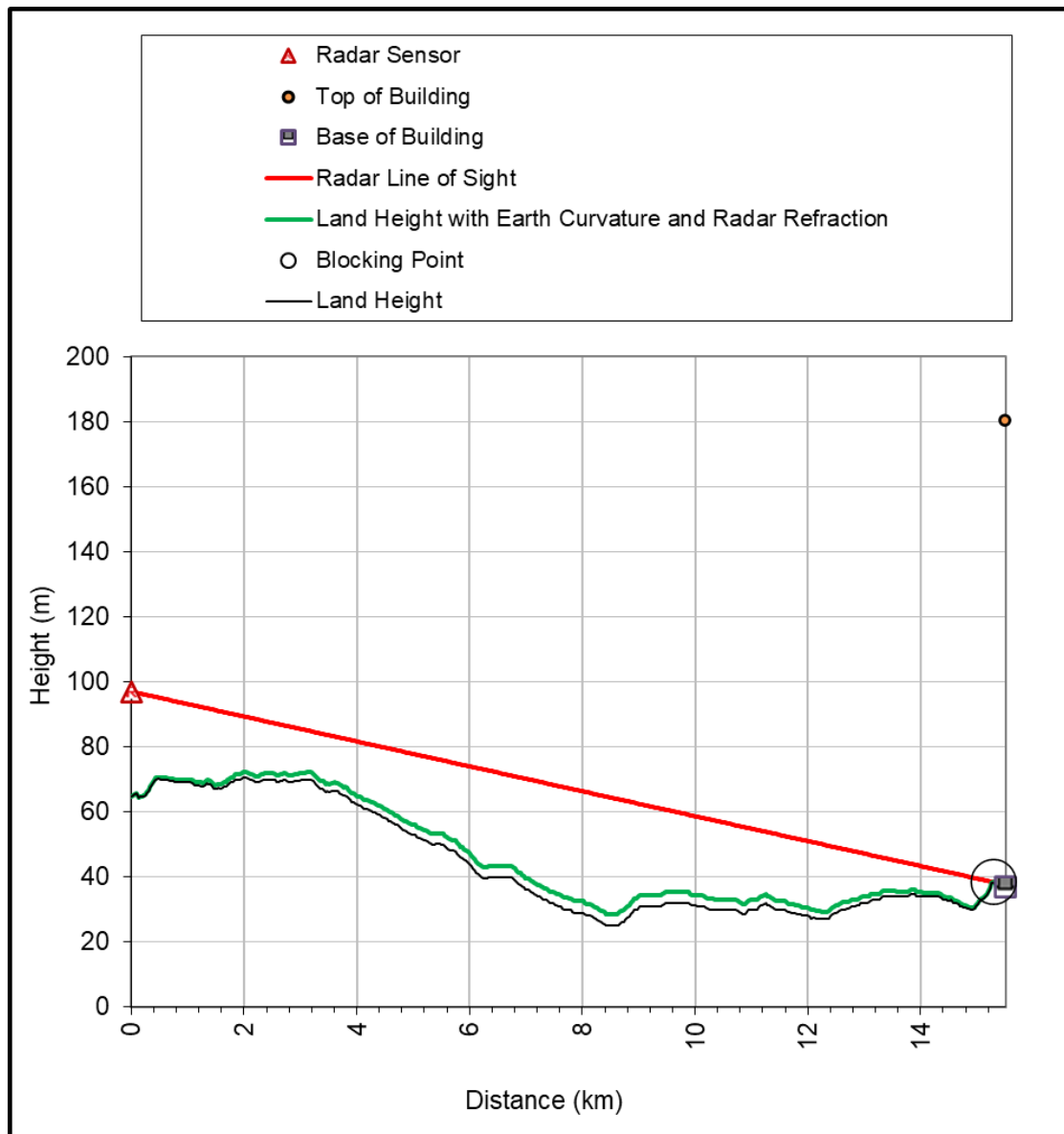


Figure 10 Radar line of sight chart - Corner 6

6.2 Additional Screening

The modelling described in the sections above accounts for the intervening terrain. It does not account for additional obstructions on the ground along the radar line of sight e.g., buildings or vegetation. The development has now been considered in the context of additional screening, which could reduce the effects of shadowing and reflections on the radar.

The most significant structure along the radar line of sight profile appears to be the Great Northern Tower on Watson Street; however, the structure only provides screening for a small section of the building and therefore significant visibility of the building remains.

6.3 Radar Impact - Reflections

The following subsections present the results of the reflection assessment for the building development. The reflection angles, elevations and distances have been determined initially by the line-of-sight assessment. Geometric calculations have then been undertaken to determine the angle, distance and elevation of any reflection.

6.3.1 Reflections Zones

Due to the development's orientation, reflections are only deemed possible from the western and eastern sides of the development. Although the southern façade will be exposed to radar signals, it is orientated directly back at the radar, eliminating the possibility of reflections.

Furthermore, the building is shaped such that the middle of the eastern and western façades are curved and do not constitute large uniform reflectors. Reflections from convex façade are not significant due to the beam being scattered in multiple directions rather than being a flat uniform, mirror-like reflection. This causes only weak reflections from aircraft to reach the radar and the radar has a range of advanced in-built systems to eliminate reflection effects.

A simplified version of the flat sections of the building has therefore been produced to appropriately assess the reflection effects. The assessed building reflectors are shown in Figure 11 on the following page.

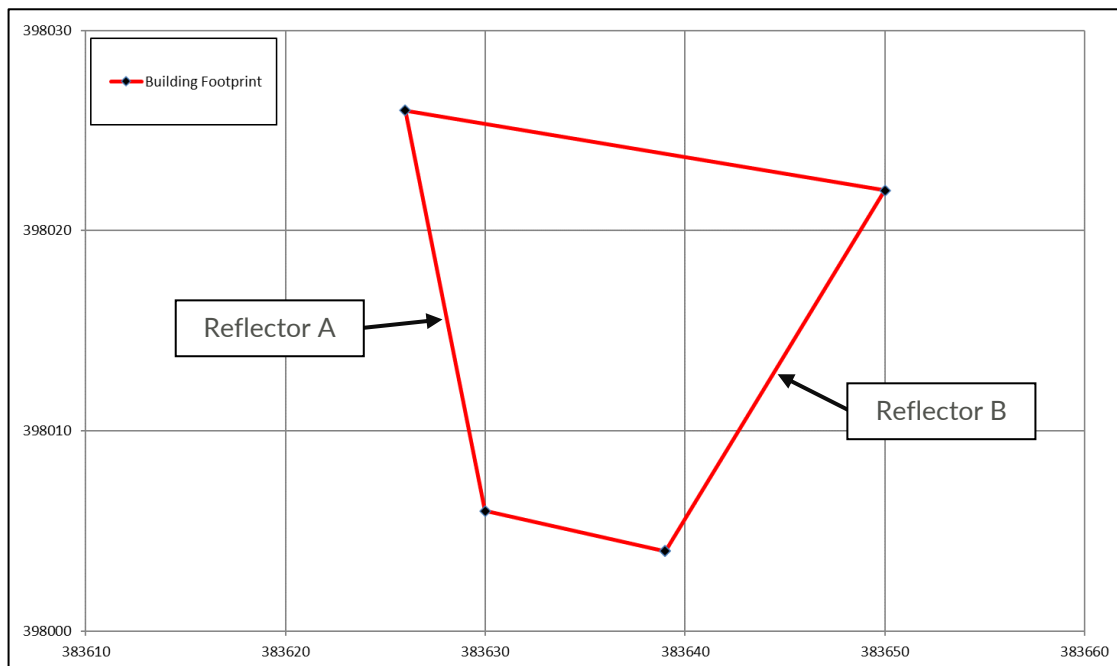


Figure 11 Building reflectors

The building reflectors relative to the tower footprint is shown in Figure 12 below.

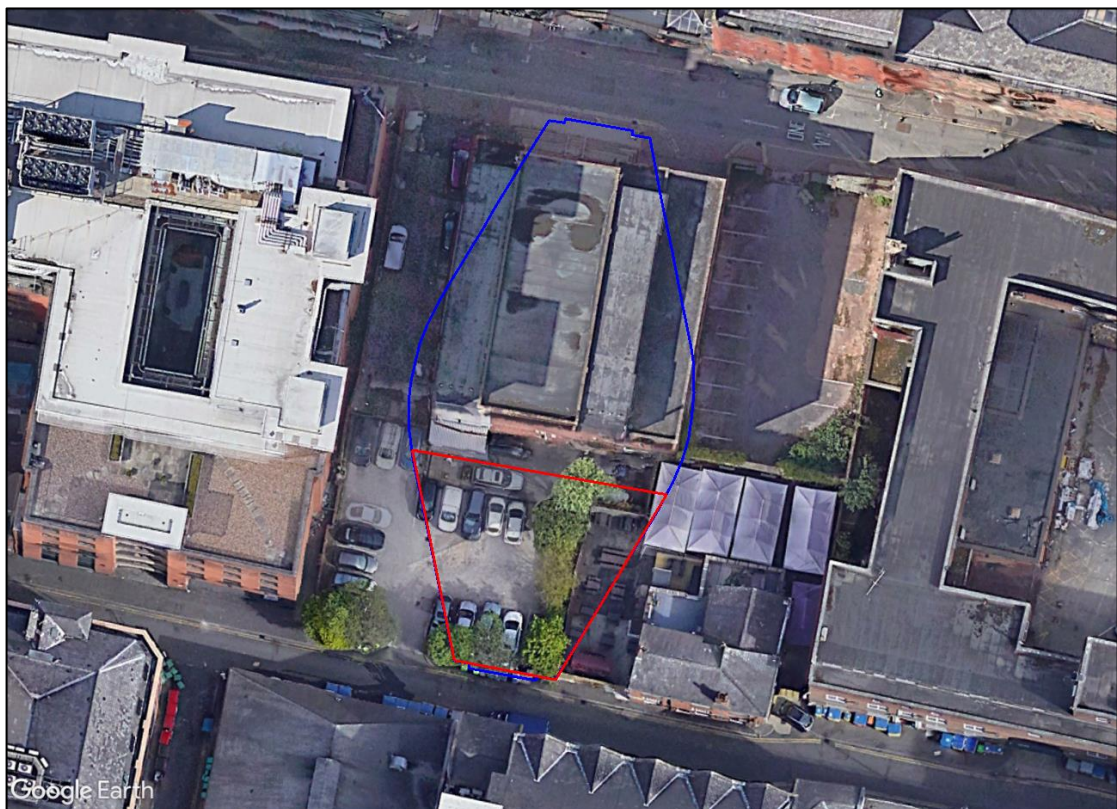


Figure 12 Building reflectors and tower footprint

The reflection zones and shadow zone for the development are presented in Figure 13 on the following page. The building location is shown as a red square icon and is not representative of its footprint. Figure 14 on page 26 then shows a zoomed chart image with the assessed footprint.

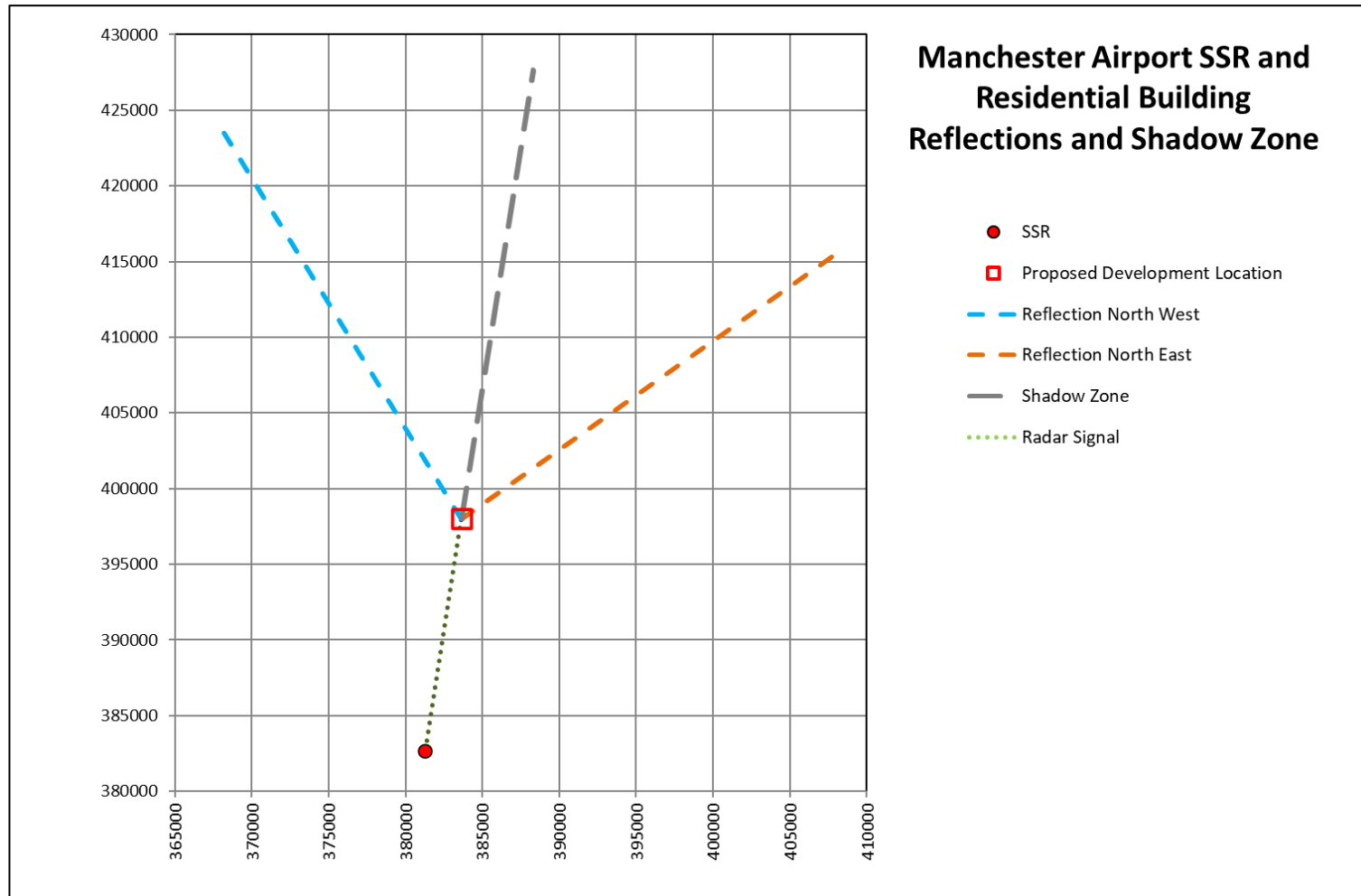


Figure 13 Building reflection zones and shadow zone – overview

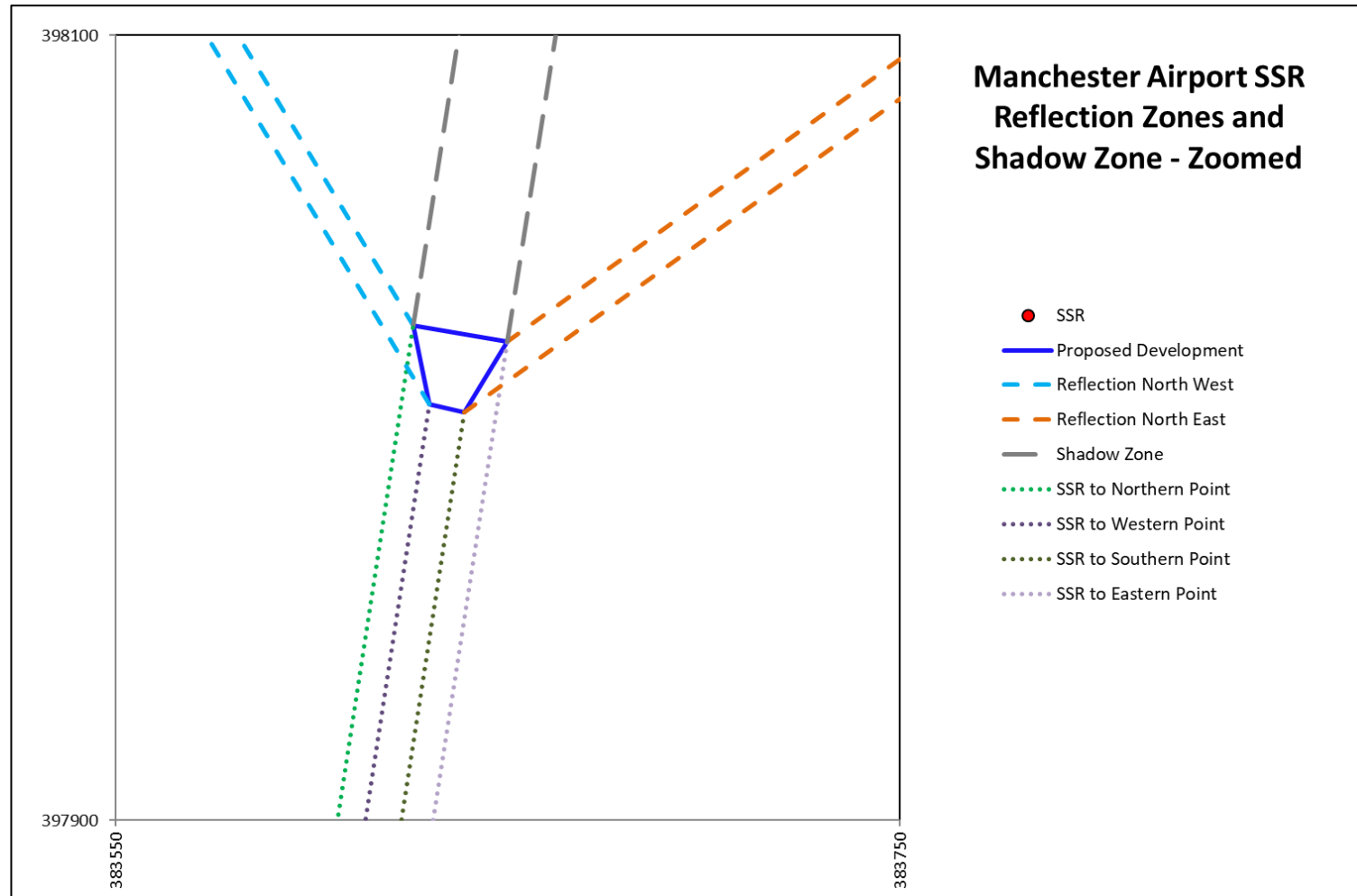


Figure 14 Building reflection zones and shadow zone – zoomed

6.3.2 Radar Coverage in Reflection Zones

Radar line of sight analysis has been undertaken to establish the radar coverage in the calculated reflection and shadow zones.

Figure 15 on the following page shows radar coverage above ground level at 1km intervals approximately centred on the development location. It can be seen that the SSR generally has coverage down to 20 metres above ground level in the reflection zones and shadow zone. This means that any aircraft detected via a reflection will most likely be detected directly by the SSR. It is therefore likely that the radar's internal processing will determine correctly that returns associated with reflected signals are false and the radar display is consequently unlikely to be affected by reflections.

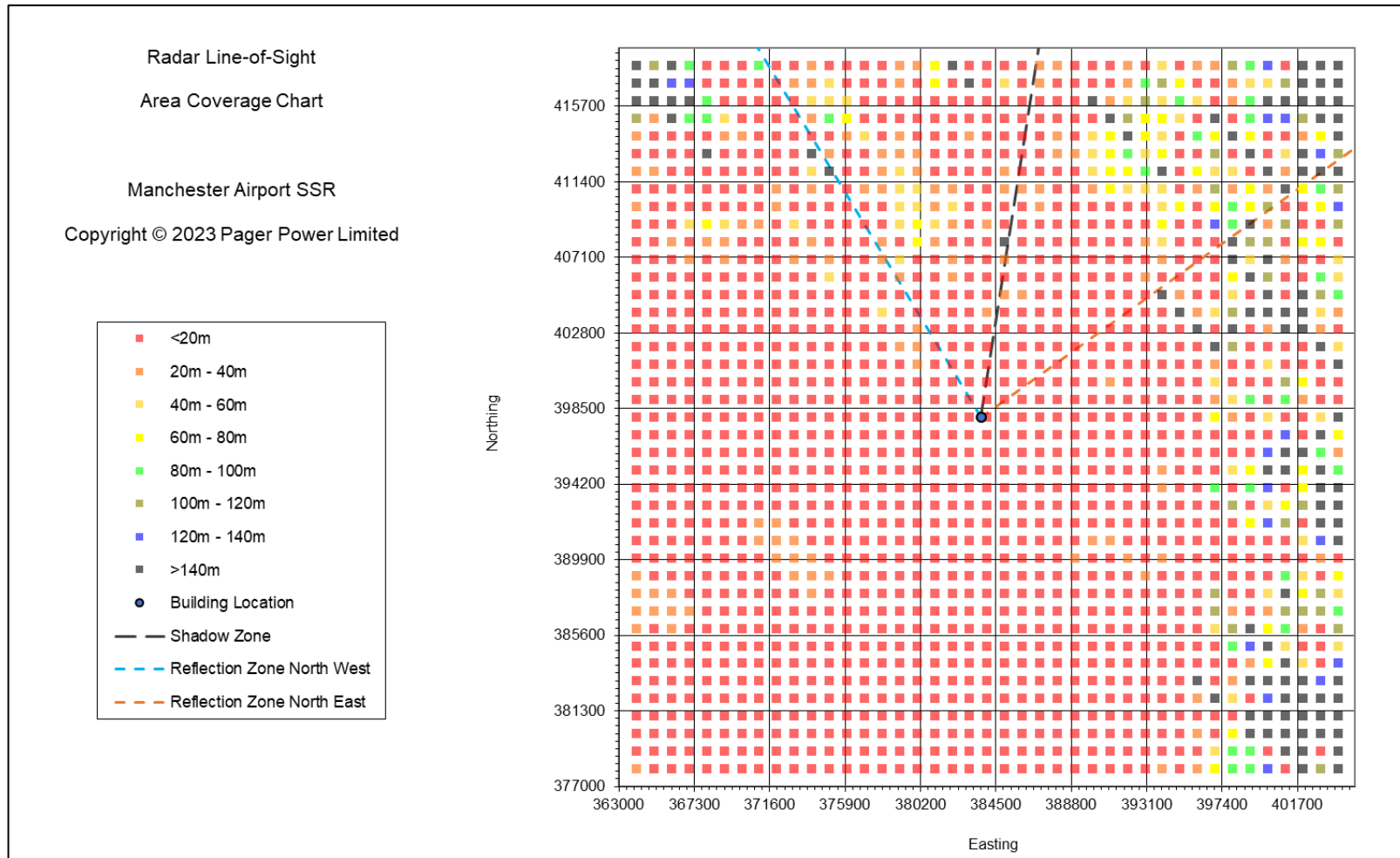


Figure 15 Chart showing radar coverage in reflection and shadow zones agl

6.3.3 Façade Design

The analysis undertaken in the previous sub-sections assumes that the façades are flat, which is the worst-case scenario for reflection effects because the façade results in mirror-like reflections. In practice, façades are often not flat and have architectural features that protrude from the façade, reducing the likelihood of reflection effects because the radar signal is dispersed by the different angles of the features.

The façade type across most of the eastern and western façades (as shown in Figures 3 and 4 on pages 11 and 12) is shown in Figure 16 below.

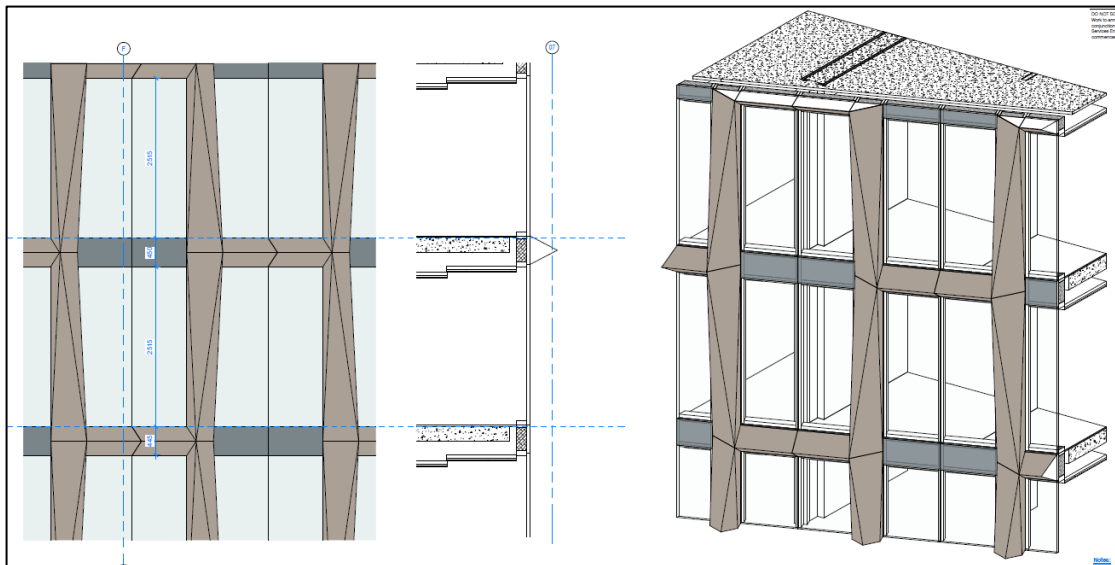


Figure 16 Façade design

The figure shows that 'fins' (brown sections) around each glass section protrude out of the façade. These fins mean that the façades are not considered flat reflectors that could cause noticeable reflection effects because the radar signal will be weakened and/or scattered away from the radar.

Overall, no significant impacts upon the SSR at Manchester Airport due to reflections are predicted on the basis of the relatively small area of the façade being in line of sight of a distance of 15km and the design of the façade meaning radar signals will not reflect in a uniform manner.

6.4 Radar Impact – Shadowing

A building's radar shadow extends beyond the building relative to the radar and on the same bearing. The shadow zone for the development is shown in Figures 13 and 14 on pages 25 and 26.

The shadow zone has a certain geometric width at the tower location and at 20 kilometres from the tower. The shadow zone also has an associated altitude at this distance. Table 4 on the following page presents this data.

Location	Width	Altitude (amsl)
Building	26.30 m	179.03 m
20 km from building	60.60 m	368.42 m

Table 4 *Shadow zone geometric data*

6.4.1 Shadow Zone Attenuation Losses

The calculated signal losses within the shadow zone have been calculated for an aircraft located at 2,400ft as per the Surveillance Minimum Altitude Chart (SMAC) for Manchester Airport, at various distances from the tower.

Table 5 below presents the full results of the calculations for each distance out to 20km. The attenuation loss calculations are presented in Appendix A.

Distance from SSR to Development (km)	Distance beyond Residential Building ⁶ (km)	Loss (dB)
15.5 km	0.5	0 dB No significant losses
	1	
	5	
	10	
	20	

Table 5 *Shadow zone attenuation losses*

An SSR signal integrating an aircraft within the vicinity of the building flying at 2,400ft, as per the SMAC, would not experience any significant interference from the development.

It is also understood that shadowing effects are less significant for NATS radar compared to the impact of reflections, based on previous analysis and consultation. This is particularly the case in central Manchester, where several buildings of a similar altitude to the development are located.

Overall, no significant impacts upon the SSR at Manchester Airport due to shadowing are predicted.

⁶ Relative to the SSR.

6.5 SSR Impact Conclusions

The modelling has revealed that development is predicted to be visible to the SSR based on bare earth terrain. The most significant structure along the radar line of sight profile appears to be the Great Northern Tower on Watson Street; however, the structure only provides screening for a small section of the building and therefore significant visibility of the building remains.

Despite the eastern and western façades being exposed to the radar, noticeable reflection effects are not predicted due to the convex surfaces and the presence of 'fins' which protrude out of the façades – see Section 6.3.3. These fins mean that the façades are not considered uniform reflectors that could cause noticeable reflection effects because the radar signal will be weakened and/or scattered away from the radar. The radar also has sophisticated mechanisms for minimising interference (see Section 5) and strong coverage in the radar's reflection zones, further reducing the likelihood of noticeable effects.

Overall, the radar internal processing is predicted to determine correctly that returns associated with reflected signals are false and the radar display is consequently not predicted to be affected by reflections. It is therefore recommended that Condition C9 is discharged without the requirement for implementing mitigation.

The decision ultimately lies with NATS, who safeguard the radar. If mitigation is required by NATS, the following section provides an overview of the expected process.

7 MITIGATION

7.1 Recommended Solution

The SSR system at Manchester Airport can accommodate a solution whereby known reflectors are programmed in, allowing the associated reflection effects to be minimised.

In order to do this, the location and bearing of the reflectors must be accurately quantified. This is so that the direction of reflections can be correctly calculated in order to facilitate the correction of associated errors.

7.2 Implementation

The solution itself must be applied by NATS, who safeguard the radar. The information likely to be required by NATS at the time of implementation is:

- Boundary coordinate data for the entire development.
- Height and elevation data for the entire development.
- Bearing of the façades that will be in radar line of sight to the radar.

Appendix A presents a template of the data that should be made available to NATS in order to facilitate the solution. The most accurate details that are available to the developer should be provided.

7.3 Process

The planning condition requires that the radar mitigation scheme is agreed with NATS and approved by the Local Planning Authority (LPA). The recommended steps, should mitigation be required, are:

- Engagement with NATS to establish their position regarding the requirement for mitigation and the recommended mitigation solution, if required.
- Agreement of a commercial contract and timescales for implementation (contract to be issued by NATS to the developer).
- Provision of the required technical information to NATS.
- Provision of the scheme to the LPA for formal approval.

APPENDIX A – SHADOW ATTENUATION LOSS CALCULATIONS

				Building AOD (m):	179.03	
				Elevation of radar (m):	97	
Frequency (GHz)	1.03			Elevation of aircraft (m):	731.52	
Wavelength (m)	0.291061					
					1	2
Distance from Antenna 1 to blocking point (m)					15500	15500
Distance from Antenna 2 to blocking point (m)					500	500
Height of blocking point (m)					-435.66125	13.84
			v		-51.88972057	1.648422
			J dB		-33.43975284	17.50831
			jv (Loss Factor)		0.021281996	7.506117
Shielding Loss			Jmin(v)		-33.4888677	
			Jav(v)		-33.43982267	

				Building AOD (m):	179.03	
				Elevation of radar (m):	97	
Frequency (GHz)	1.03			Elevation of aircraft (m):	731.52	
Wavelength (m)	0.291061					
					1	2
Distance from Antenna 1 to blocking point (m)					25055.21	25055.21
Distance from Antenna 2 to blocking point (m)					1000	1000
Height of blocking point (m)					-431.1370971	14.29
			v		-36.44491295	1.207963
			J dB		-30.37876402	15.20104
			jv (Loss Factor)		0.030273442	5.755091
Shielding Loss			Jmin(v)		-30.46966725	
			Jav(v)		-30.37900435	

				Building AOD (m):	179.03	
				Elevation of radar (m):	97	
Frequency (GHz)	1.03			Elevation of aircraft (m):	731.52	
Wavelength (m)	0.291061					
				1	2	3
Distance from Antenna 1 to blocking point (m)				25055.21	25055.21	25055.21
Distance from Antenna 2 to blocking point (m)				5000	5000	5000
Height of blocking point (m)				-349.9309305	17.73	17.73
			v	-14.20795091	0.719876	0.719876
			J dB	-22.24273653	11.98814	11.98814
			jv (Loss Factor)	0.077243719	3.97564	3.97564
Shielding Loss			Jmin(v)	-22.57386459		
			Jav(v)	-22.24601419		

				Building AOD (m):	179.03	
				Elevation of radar (m):	97	
Frequency (GHz)	1.03			Elevation of aircraft (m):	731.52	
Wavelength (m)	0.291061					
				1	2	3
Distance from Antenna 1 to blocking point (m)				25055.21	25055.21	25055.21
Distance from Antenna 2 to blocking point (m)				10000	10000	10000
Height of blocking point (m)				-274.4840953	22.04	22.04
			v	-8.510747512	0.68338	0.68338
			J dB	-17.85055683	11.71651	11.71651
			jv (Loss Factor)	0.128077298	3.853234	3.853234
Shielding Loss			Jmin(v)	-18.40959335		
			Jav(v)	-17.86014263		

				Building AOD (m):	179.03	
				Elevation of radar (m):	97	
Frequency (GHz)	1.03			Elevation of aircraft (m):	731.52	
Wavelength (m)	0.291061					
				1	2	3
Distance from Antenna 1 to blocking point (m)				25055.21	25055.21	25055.21
Distance from Antenna 2 to blocking point (m)				20000	20000	20000
Height of blocking point (m)				-173.8266807	30.3	30.3
			v	-4.320641012	0.753138	0.753138
			J dB	-12.1393491	12.23186	12.23186
			jv (Loss Factor)	0.247190938	4.088774	4.088774
Shielding Loss			Jmin(v)	-13.13077965		
			Jav(v)	-12.17097995		



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