BEFORE THE INDEPENDENT HEARINGS COMMISSIONER APPOINTED BY THE INVERCARGILL CITY COUNCIL

UNDER	the Resource Management Act 1991
IN THE MATTER	of Part 8 of the Act
BY	**SPACE OPERATIONS NEW ZEALAND LIMITED** Requestor

STATEMENT OF EVIDENCE OF GRAHAM HULSTON

Dated: 15 September 2026

Todd Walker

Solicitor acting
R E M Hill
PO Box 124 Queenstown 9348
P: 03 441 2743
rosie.hill@toddwalker.com

Statement of evidence of Graham Hulston

Introduction

[1] My name is Graham Hulston. I hold the qualifications of Bachelor of Electrical Engineering (1986) and Postgraduate Certificate in Engineering (2011) from Canterbury University. I also hold a New Zealand Certificate in Telecommunications-Radio (1982). I am an Accredited Radio Engineer (ARE) with the Radio Spectrum Management (RSM) group within the Ministry of Business, Innovation, and Employment (MBIE)

[2] For 30 years I worked for Kordia Limited, a company which provides radio and other telecommunications related engineering consultancy services as a radio engineer. For the last 17 years I have been self-employed providing radio engineering consultancy to mainly Government Departments, Utilities, NZ Police and FENZ. I have over 40 years of experience in the design and troubleshooting of radio links.

[3] I have not been involved in the preparation of the notice of requirement; however, I have been engaged by Space Operations New Zealand Limited (**Requestor / Space Ops NZ**) to provide independent technical evidence.

Code of Conduct

[4] Although this is not an Environment Court hearing, I have read the Environment Court Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2023 and agree to comply with it. I confirm that the opinions expressed in this statement are within my area of expertise except where I state that I have relied on the evidence of other persons. I have not omitted to consider materials or facts known to me that might alter or detract from the opinions I have expressed.

Scope of evidence

[5] I have been instructed by Space Operations New Zealand Limited (**Space Ops / Requestor**) to provide evidence on Space Ops' notice of requirement for a designation in respect of airspace and land surrounding the Awarua Satellite Ground Station (**Ground Station**)

surrounding Lot 1 Deposited Plan 483454 and Lot 1 DP 524692 held in Record of Title 837915, located at 781 Colyer Road, and Lot 2 DP 524692 held in Record of Title 1134415, located at 721 Colyer Road (together, the **Site**).

[6] My evidence principally addresses effects of diffraction associated with physical intrusion into a radio path, referred to as the horizon mask component of the notice of requirement in the evidence of Mr Dunn. The significance of any physical intrusion into a radio path will depend on the combined effect of these mechanisms in the circumstances of the particular proposal. As such, it is not possible to comprehensively address all hypothetical obstructions in my evidence. The purpose of my evidence is to provide a technical understanding of the effects of such obstructions on the Space Ops NZ's operations and established Ground Station.

[7] The evidence of Mr McNeill also outlines the operations undertaken at the Ground Station and gives examples of spacecraft and launch-vehicle communications occurring at low elevation angles. I rely on his evidence as to those operational activities.

[8] My evidence is limited to addressing the engineering consequences of introducing an obstruction into radio paths from a technical perspective.

Overview of radio communications

<u>What is radio?</u>

[9] In this evidence, the term "radio" is used in its strict technical sense, to refer to any method of communication that employs radio frequency electromagnetic waves to send and receive information between locations. The applications of radio are nowadays very numerous, including fixed and mobile communications such as:

(a) Sound broadcasting and Television broadcasting;

(b) Accessing the internet

(c) Others such as radio meteorology, radio astronomy, and radio navigation, etc.

[10] Radio communication services use radio signals to relay information from a transmitter to a distant receiver. The essential elements of a radio system are a transmitter and antenna (also termed an aerial) at the sending location, and an antenna and receiver at the receiving location. If two-way communications are required, each location will have both a transmit and receive system.

[11] Radio signals are sent from a transmit antenna as an electromagnetic radio wave to the receiver. As a radio wave "propagates" (i.e. travels) further from its source, it becomes weaker. If it encounters an obstacle it will suffer "diffraction loss" (described below) and become weaker still. At times the radio wave can be subject to anomalous atmospheric refraction effects, causing yet further loss. Radio wave "scattering" may also occur which can result in delayed "echo" signals.

[12] The radio wave is picked up by the receive antenna, along with echoes, interference from other radio sources, and electrical background noise. The receiver then recovers and reconstructs the original information, which in a well designed system, will be free from the impacts of echoes, interference, and noise for all but a very small percentage of time.

[13] Radio waves are transmitted at various frequencies, which are measured in "Hertz". In this evidence all frequencies are expressed in millions of Hertz, termed mega-Hertz (MHz).

[14] A radio transmission actually occupies a small band of frequencies, referred to as its "spectrum". As a general rule, to avoid mutual interference between radio transmissions, each transmission in the same geographical area should occupy unique spectrum. Whilst there are exceptions to this rule, it illustrates the need for careful management and conservation of the total spectrum available to allow as many radio services as possible to operate in the same geographical area.

<u>Radio communication services provided by Space Ops NZ at Awarua Ground Station</u>

[15] The prime purpose of the site is to transmit and receive radio signals to and from satellites orbiting above the earth. The orbits are classed as geosynchronous (**GSO**) or non-geosynchronous (**NGSO**). For a GSO

satellite the position of satellite remains stationary with respect to the surface of earth so antenna points always in the same direction to any given satellite. For a NGSO where the satellite moves relative to the surface of the earth, the antenna must track the movement of it across the sky to remain in communication. NGSO satellites typically orbit 400 to 800km above the earth.

[16] The most important and critical type of communication is that used for tracking, telemetry and control (**TT&C**) of the satellite. Without this, the satellite is "space junk". The main focus at Awarua is TT&C with NGSO satellites and the key frequency bands used are 400.15 to 402MHz, 449.75-450.25MHz, 2025 -2110MHz and 2200 – 2290MHz.

[17] The period of time that an earth station can communicate with a NGSO satellite is short (minutes not hours) as the satellite appears above and then disappears below the horizon during a pass. To maximise the communication time during this brief pass it necessary to track the satellite as soon as it appears above and drops below the horizon. Under the Radio Licence Certification Rules (PIB 38) issued by Radio Spectrum Management (**RSM**), it states in section 5.10; "Earth station antennas shall not transmit at elevation angles of less than 3° measured from the horizontal plane to the direction of maximum radiation".

Diffraction of radio signals

[18] As a radio signal is radiated from an antenna it spreads out, and the strength of radio signal weakens with distance and if there are obstacles in the way between the transmitter and receiver then the signal is further weakened. To ensure that the received signal is loud enough to be understood, sensitive radio receivers are used along with directional antennas to concentrate the radio signal in a narrow beam. Even with these measures the signal is still weak and there is little margin for additional signal loss caused by obstacles on the surface of the earth. This additional loss is caused by a physical property of electromagnetic radiation called diffraction and affects to a lesser or greater degree all frequencies from very low (1kHz) to very high (e.g. gamma radiation 10^{24} Hz).

[19] When calculating the obstruction loss caused by diffraction, the concept of Fresnel zones is used to assess how the obstruction will affect the radio signal. The Fresnel zone is a function describing the radius around the line-of-sight radio path at any point along the path that should be obstruction-free so that there is no diffraction of the signal.

[20] For any radio path with a given frequency an ellipsoid can be drawn between the transmitter and the receiver. The radius of the cross section varies with distance with it zero at the ends and maximum at the middle of the ellipsoid. If any obstacle protrudes into the ellipsoid then diffraction will occur, weakening the signal. The goal of radio path engineering is to minimise the risk of this occurring particularly for sensitive earth to space paths.

[21] The Fresnel zone is dependent on the length of the radio path, the distance along the radio path the obstruction may occur, and the frequency of the radio signal.

[22] Depending on the reliability required of a radio path, radio engineers often choose a clearance of 60% of the First Fresnel Zone (0.6 First Fresnel clearance) rather than 100%, which may be harder to achieve and affording only little improved reliability to the radio path.

[23] The application of Fresnel zone clearance to determining an appropriate horizon mask is discussed in the evidence of Mr Robin McNeill.[1]

[24] **Appendix A** illustrates the Fresnel ellipsoid and cross section. **Appendix B** illustrates the cases where the radio path is (1) above and (2) beside the obstacle.

[25] Fresnel zones are a useful tool in demonstrating the effect of obstacles / obstructions on radio signals and whether there is sufficient clear space for the radio path for communication to operate reliably. The notice of requirement does not address Fresnel zone clearance, but instead only requires a line-of-sight 5° elevation mask. This represents a concession by Space Ops because allowing for Fresnel zone clearance would require a more restrictive horizon mask than that proposed in the notice

---

1 From [38].

of requirement. However, including Fresnel zone clearance in the determination would likely be impractical to implement as the simple trigonometry required to calculate a 5° elevation mask would be replaced by a formula that would not be easily intuited.

Conclusion

[26] There is a significant risk that obstacles within the path of the satellite communication will cause diffraction and reduce communication reliability to and from satellites. Given the possible types of obstacles surrounding the Ground Station and potential development within the Rural and Industrial 4 Zones, the proposed horizon mask is an appropriate screening mechanism. I defer to the evidence of Mr McNeill in determining what an appropriate angle elevation would be in order to meet the operational requirements of Space Ops NZ.

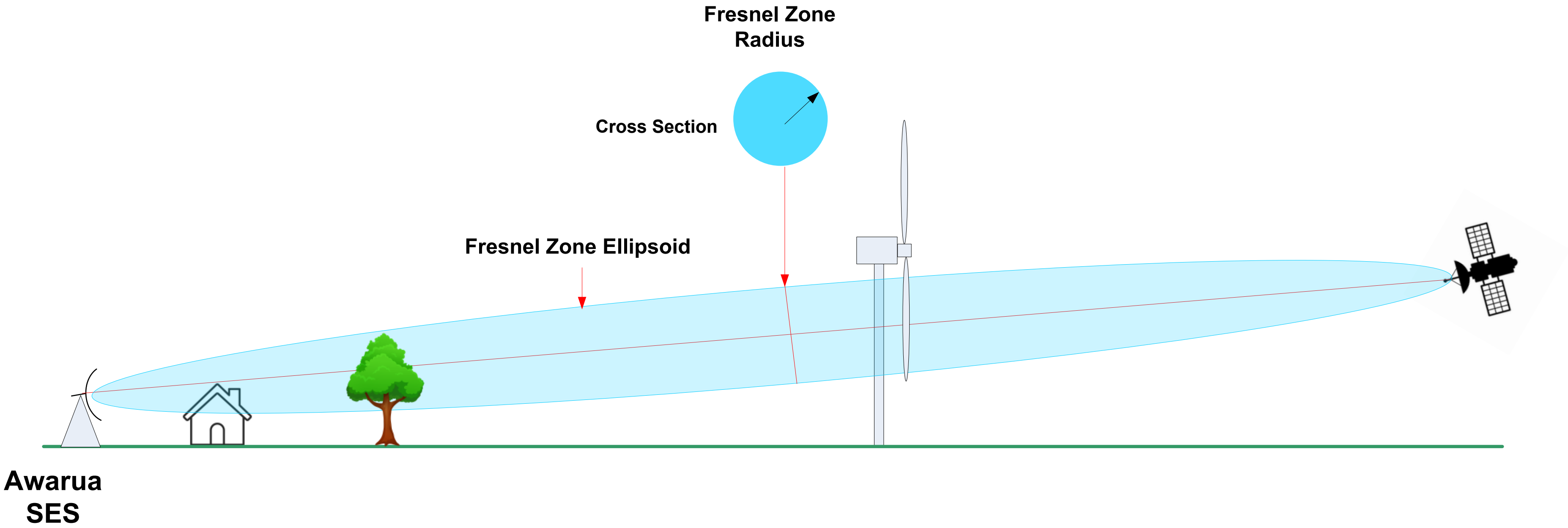
[27] The significance of any penetration depends upon the specific characteristics of the obstruction / obstacle and the affected radio paths.

[28] Depending on a number of factors, some intrusion into the Fresnel zone may be tolerated but this will have to analysed for each satellite being communicated with from the Ground Station. For this reason, I support the inclusion of the technical assessment section under the proposed Condition 2 (Option A): Penetration of Horizon Mask in the notice of requirement. I also agree with the proposed criteria list in the technical assessment.

Dated: 15 September 2026

Graham Hulston

Appendix A: Fresnel Zone Ellipsoid



Appendix B: Fresnel Zone Clearance

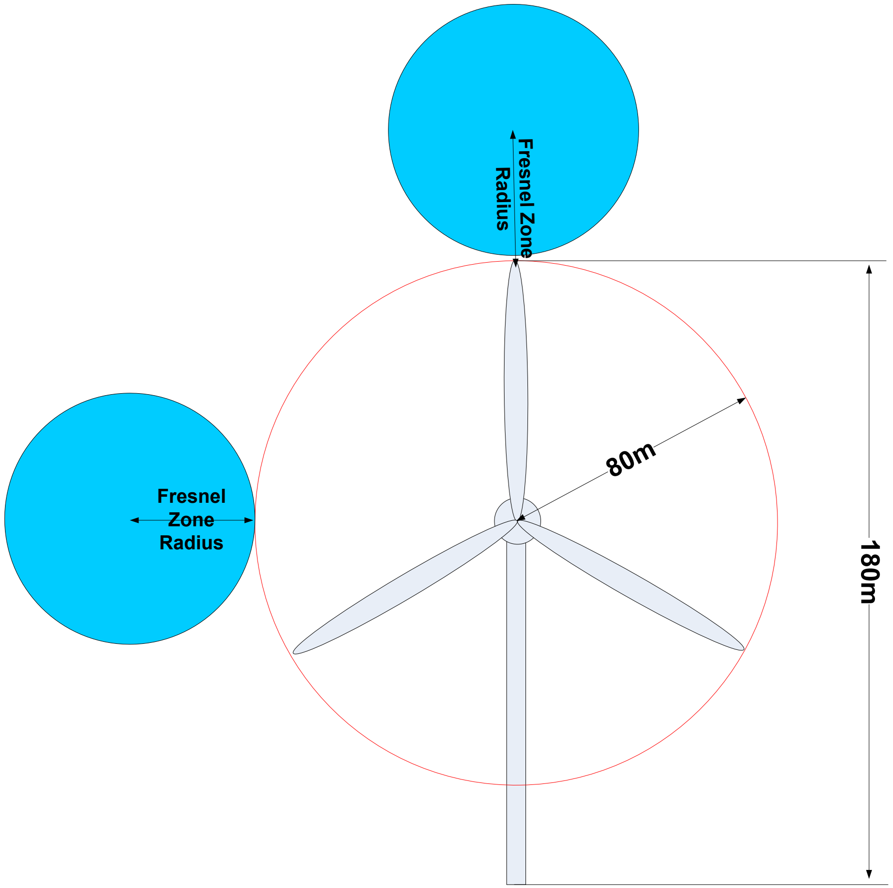


Diagram showing the cross-section of two line-of-sight microwave radio paths and their associated Fresnel zones (shaded blue) in relation to an obstacle 180 metres high. Each radio signal is of the same frequency and the same distance from the transmitter. Each of the line-of-sight paths just clear the obstacle and so there will be no diffraction loss.