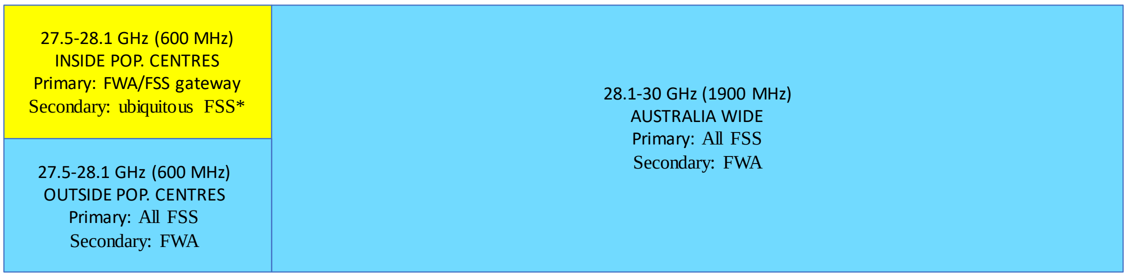
1 Introduction

Recent spectrum planning decisions by the Australian Communications and Media Authority (ACMA) have introduced new arrangements in the 27.5-29.5 GHz band, *inter alia*. The new arrangements are summarised in the image below.



As indicated in this diagram, the most prominent feature of ACMA's spectrum planning decision is the shared nature of the band, i.e. fixed-satellite services (FSS) and fixed wireless access (FWA) are expected to share throughout the 27.5-29.5 GHz band. Although the nature of the sharing changes with geography, e.g. whether a service is inside or outside a metropolitan area, there is a clear expectation for sharing to occur cooperatively, with no part of the spectrum denied to either service anywhere in Australia.

nbn is Australia's largest satellite incumbent with large investment in the 27.5-29.5 GHz band (among others), known in the satellite industry as the Ka-Band, and all satellite upgrade paths are critically dependent on this band. **nbn** is also Australia's largest provider of terrestrial wireless broadband services and, although not currently operating in any band >3.6 GHz, is has acquired 28.5-29.5 GHz to enable an upgrade path. As such, **nbn** is heavily interested in a sharing outcome which is suitable for both services.

This document presents an impact assessment of **nbn**'s SkyMuster satellite service on planned FWA networks operating in the same frequency and geography.

2 System characteristics

The system characteristics of both the satellite and terrestrial services is shown in Tables 1 and 2 respectively. The Earth station characteristics shown in Table 1 are representative of the user segment of the **nbn** SkyMuster satellite service. They are derived from real world data and are a true-to-life representation of Australia's most extensive – and in 27.5-29.5 GHz, the only – deployment of very small aperture terminals (VSAT).

Parameter	**Value**	**Units**
Frequency	28	GHz
Earth station transmit power – clear sky	-73.5	dBW/Hz
Earth station emission bandwidth	12	MHz
Earth station elevation	40	degrees
Earth station antenna gain to horizon	-20	dBi
Earth station transmit duty cycle	1	%

Parameter	Value	Units
Cross-polar discrimination (circular-to-linear)	3	dB

Table 1. Earth station emission characteristics

The terrestrial system characteristics are shown in Table 2 and are assumed to be an FWA implementation of IMT-2020-like applications.

Parameter	Base (BS)	User (UE)	Units
Frequency	28		GHz
Noise temperature	290		K
Noise figure	12		dB
Margin	7	10	dB
Activity factor	80	25	%
TDD ratio	20	80	%
Bandwidth	200	67	MHz
Probability of bandwidth overlap with Earth station	100	33	%
Antenna gain	23	17	dBi
Antenna pattern	Recommendation ITU-R M.2101		

Table 2. FWA characteristics

3 Interference calculation methodologies

To determine the interference potential from Earth stations into FWA employing IMT-2020-type characteristics, two approaches are presented. Both use statistical methods which randomise variables such as location and antenna pointing. The first method is time-invariant and calculates interference margin as a function of distance separating transmitter and receiver. The other calculates a time percentage probability of excess interference as a function of distance between transmitter and receiver.

3.1 Margin vs distance

As indicated above, the first calculation of interference potential aims to determine the interference margin as a function of distance between the transmitting Earth station and receiving FWA station. This is done according to the following:

- VSATs are uniformly randomly distributed across a 200m x 200m grid
- FWA station is assumed to be at the centre of this grid
- Azimuth angle to each VSAT is determined, along with distance and free space loss at 28 GHz
- For each simulation point, a uniformly randomly distributed value for azimuth pointing of the FWA station is determined and compared with azimuth to VSAT to determine an offset angle
- Gain at calculated offset is calculated according to Recommendation ITU-R M.2101

- using 4x16 elements for BS
- using 4x4 elements for UE

- Off-axis emission level from a VSAT is calculated as $I_{offaxis} = P_d + G_{offaxis} + 10\log BW_{VSAT} - XPD$ where:
  - P_d is power spectral density
  - $G_{offaxis}$ is the off-axis gain towards the horizon
  - BW_{VSAT} is emission bandwidth
  - XPD is cross-polar discrimination
- Interference threshold for the FWA station is $I_{thr} = -228.6 + 10 * \log T + NF + \frac{I}{N} + 10\log BW_{FWA}$ where:
  - T is noise temperature
  - NF is noise figure
  - I/N is $10\log(10^{0.1*M} - 1)$ where M is margin
  - BW_{FWA} is receiver bandwidth
- Free space loss and FWA antenna gain in the direction of the VSAT is applied to $I_{offaxis}$ to determine received power at the FWA station
- Received power at the FWA station is compared with I_{thr} and a margin calculated
- Margin is plotted as a function of distance for each simulation point
- This approach is similar to that used in Section 4 of Report ITU-R S.2463, which concerns a different band but which otherwise studies a very similar sharing scenario

This method is a relatively straightforward application of the system characteristics given in Tables 1 and 2. Apart from randomly varying the position of the Earth station, the only other variable is the pointing angle, and therefore off-axis gain, of the FWA station.

Also worth noting is the method for calculating the I/N ratio, which necessarily differs from that used in fixed-fixed sharing studies. Particularly, since a FWA base station receives on only a 20% duty cycle, and Earth station transmit duty cycles are 1%, interference can only ever be a short term phenomenon, if it occurs at all. As such, the long-term I/N threshold[1] used for static sharing between terrestrial services is an inappropriate measure to apply to short-term inter-service sharing scenarios. Rather, this study uses the same method applied in every other assessment of short-term interference, namely, to allow system margins to be temporarily consumed by a short-term interferer. This approach, and the equation given above (using margin to determine I/N) is taken directly from Appendix 7 of the ITU Radio Regulations.

3.2 Time percentage as a function of distance

The second calculation methodology considers the time variations inherent in each of the transmitting and receiving stations, according to the following:

- VSAT is placed sequentially at each point in a 150m x 150 m grid with a 10 m spacing
- FWA station is assumed to be at the centre of the grid
- Distance, free space loss at 28 GHz, and the azimuth angle from FWA station to VSAT are determined for each grid location
- A time series analysis is performed at each grid point
- FWA receive and Earth station transmit times are uniformly randomly distributed across 100,000 time samples, using the duty cycle for each service
- For each time sample, if VSAT is transmitting when FWA station is receiving
  - A uniform random azimuth pointing angle is calculated for the FWA station
  - This pointing angle is compared to the azimuth to the VSAT and an offset is determined

[1] The I/N ratio assumed in the development of the apparatus licensing framework for terrestrial services in 27.5-29.5 GHz is aimed at helping to determine device boundaries, effectively demarcating adjacent property claims. As such, the application of the I/N threshold in this situation primarily serves a legal, not technical purpose, and should have no bearing on sharing between satellite and terrestrial services.

- The FWA station receive antenna gain at that offset is determined in the same way as the "margin vs distance" analysis above
  - FWA receive gain and free space loss are applied to $I_{offaxis}$ to determine received power at the FWA station
  - Received power at the FWA station is compared with a threshold
  - If received power is above the threshold an interference event is recorded
- For each grid point, the percentage of time points, at which an interference event is recorded, is determined, and scaled by the probability of bandwidth overlap.
- Time percentage of interference events for each grid point is plotted on the 150m x 150m grid

4 Results

The results of this sharing study are presented in Figures 1 and 2 below, which display a graph using both interference calculation methodologies, for FWA base and user stations respectively.

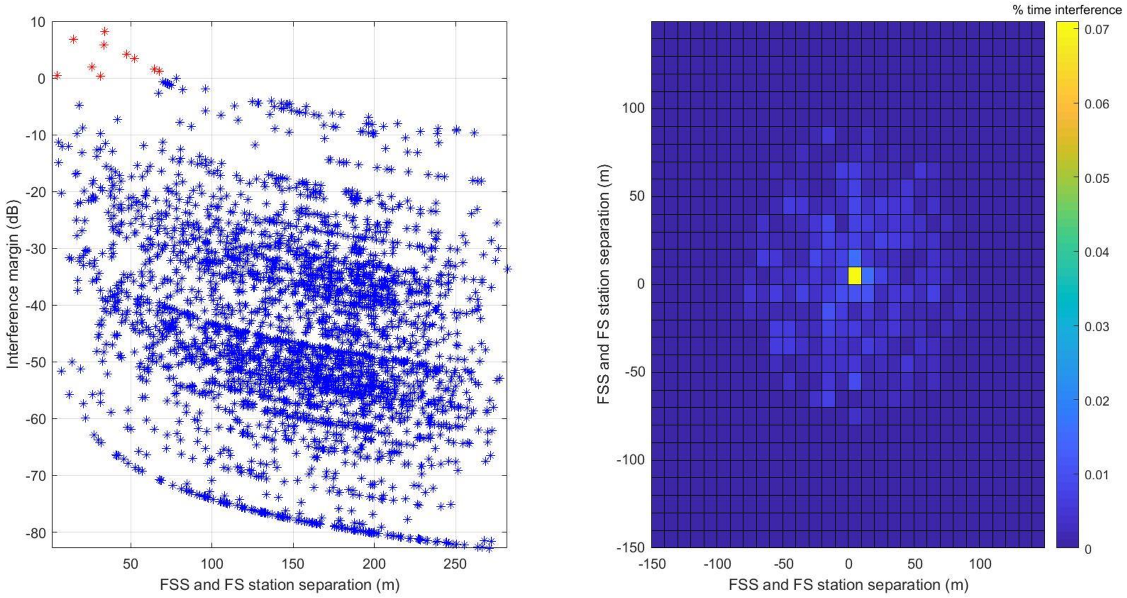


Figure 1. Interference assessment FSS-FWA BS

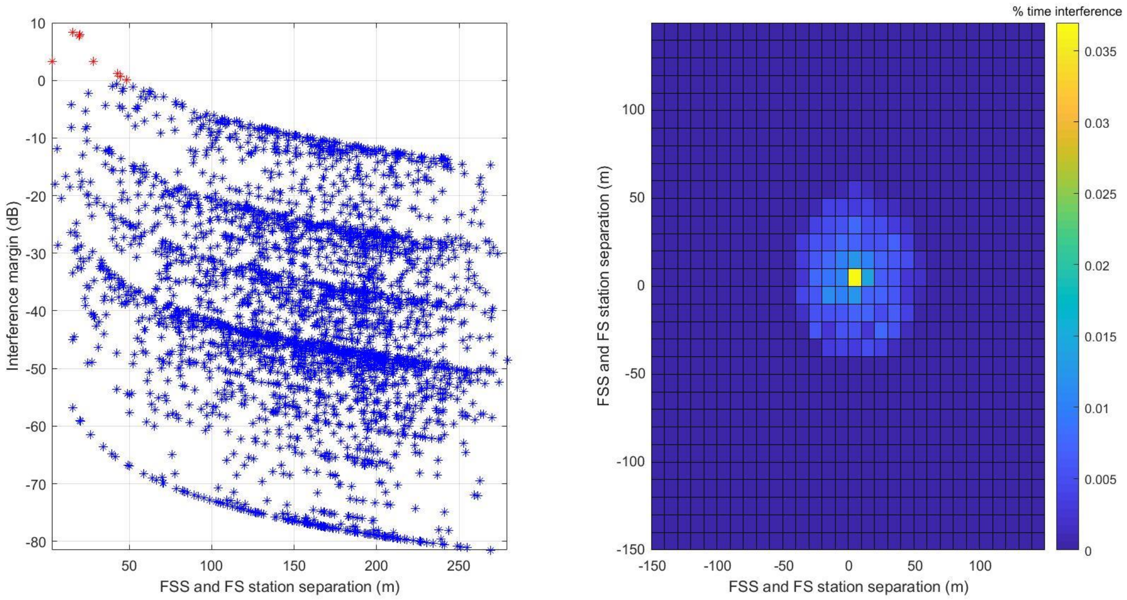


Figure 2. Interference assessment FSS-FWA UE

As shown in Figures 1 and 2, interference is not expected for any separation distance greater than about 100m (BS) and 50m (UE). Within these distances, the right panel of each figure shows an interference probability not exceeding 0.1% (BS) or 0.05% (UE) of time. Significantly, there does not appear to be a minimum separation distance within which the two systems are necessarily incompatible.

Not considered in this analysis are several factors which would reduce the interference potential even further, such as clutter, terrain, various fading mechanisms, site management, or atmospheric absorption. A full consideration of all these factors would certainly show an insignificant residual risk of interference but is left out of this analysis for simplicity, given the already extremely low likelihood of interference, even when the potential for interference is not being actively managed.

5 Conclusions

This document presents the results of a sharing study between transmitting Earth stations with real-world characteristics relevant to the current Australian operating environment, and receiving FWA stations with IMT-2020 characteristics. Results show that, without applying any active mitigation techniques, there is a negligible potential for interference. These results support the conclusion that successful sharing between satellite and terrestrial services can be expected, without any requirement for frequency or geographic separation.