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Tailored exclusion zones for automotive radar around radio telescope sites

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Abstract

In this work, a novel methodology is presented for assessing the impact to the radio astronomy service (RAS) from automotive radars. The proposed approach concerns the calculation of aggregate contributions within hexagonal cells, providing an understanding of the most critical areas around a radio telescope. The methodology's applicability is demonstrated, highlighting its effectiveness in defining exclusion zones to safeguard RAS, particularly in areas where the surrounding topography does not provide adequate shielding.
Traffic conditions and clutter loss are taken into account to simulate a realistic scenario. The proposed methodology has proven effective in various scenarios, playing a crucial role in safeguarding radio astronomy services from emerging technologies.

1. Introduction

Compatibility studies are becoming increasingly refined as various radio spectrum users place growing demands on them. These studies could aid in formulating guidelines and regulations to ensure the consistency and harmonization of different telecommunication services. Radio Astronomy Service is by far the most sensitive telecommunication service as it utilizes the spectrum to measure extremely faint signals from the cosmos. Terrestrial applications sharing (or adjacent to) frequency bands allocated to RAS necessitate significant coordination to avoid harmful interference. Automotive radars, recently transitioned from temporary allocation on the 24 GHz band to a wide millimetre range 76 - 81 GHz, is a new challenge for RAS. Multiple radars surround the vehicle assisting the driver toward increasingly autonomous driving. Automotive radars belong to the so-called Advanced Driver Assistance Systems (ADAS) [1]. The applications range from safety-enhancing features such as Adaptive Cruise Control and Blind Spot Detection to assist functions like Parking Assistance.

The nature of these applications encourages the consideration of aggregated studies, involving multiple emitting devices active in the scenario under test. A single-entry study, where only one transmitter is considered emitting towards the radio telescope, is not a realistic scenario and may lead to unreliable outcomes.
Furthermore, the propagation path loss is strictly dependent on terrain characteristics surrounding the radio telescope, with some zones naturally shielded while others within the field of view of the radio telescope.
Typically, the separation distance between an active transmitter and a passive radio telescope is defined by establishing an exclusion zone radius around the radiotelescope site, which could unnecessarily encompass a broader area.
This work proposes a new method to precisely tailor an exclusion zone by defining the most sensitive zones to signals produced by automotive radars. The scenario under consideration is the 64-m Sardinia Radio Telescope (SRT) located in the Sardinia's Island, 35 km North of Cagliari, Italy. Comparison with other European radio telescopes, Effelsberg in Germany and IRAM-30M in Spain is performed as well.
The approach presented in this paper can be extended to other applications with similar features.

2. Methodology

The scenario under investigation is intricate, involving multiple layers of complexity such as varying traffic levels throughout the day and night, as well as the radar's pointing direction aligned with the street direction. Additionally, cars cannot be arbitrarily placed everywhere but must adhere to the street network.
To address these considerations, a Python simulation software tool, specifically pycraf [2], is employed to perform the compatibility study here proposed. The tested map size is a square box of 120 x 120 km. Leveraging the API of OpenStreetMap (OSM), the street network is provided. Figure 1 illustrates the road network and the deployment of cars around the SRT site, assuming the

conditions outlined in Table 1 that estimate fluctuations in traffic conditions [3] according to the road type.
Please note that the traffic conditions considered are moderate respect the actual traffic conditions [4]. However, due to the current limited use of vehicles equipped with radar, the above-mentioned scenario was selected.

Table 1: Vehicle densities according to the classification road by OSM

Road type	Vehicle density (vehicles/km)
Primary	3.6 ± 0.9
Secondary	0.6 ± 0.15
Tertiary	0.2 ± 0.05
Residential	0.1 ± 0.025
Other	0.1 ± 0.025

Furthermore, the clutter loss due to vegetation and buildings is considered [5]. The terrain classification is derived from the CORINE Land Cover data [6] and it is shown in Figure 2.

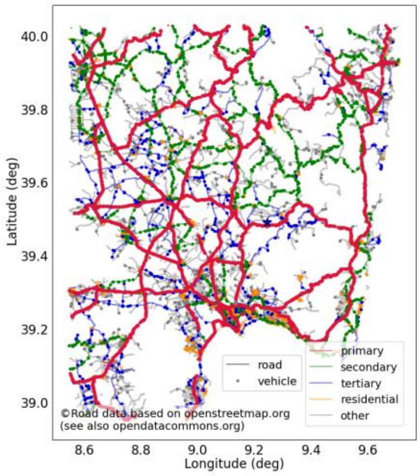

Figure 1: Road network around SRT obtained using API of OSM

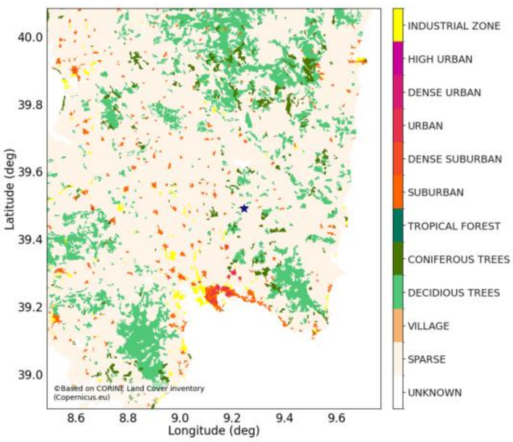

Figure 2: Clutter loss map around SRT from CORINE Land Cover data

3. Spectrum Usage

From the frequency management and spectrum engineering point of view, automotive radars fall under the category of short-range devices (SRD). The use of the spectrum by SRD is outlined in ERC Recommendation 70-03, which designates the 76-77 GHz frequency range for vehicular and infrastructure radar systems, and the 77-81 GHz range for the use of Automotive Short-Range Radars [7]. Automotive radar does not have dedicated bands listed in the ITU Radio Regulation. As a matter of fact, the automotive radars operate on a “non-interference and non-protected basis”, which means that they must non create interference to existing services, and they should not ask protection if other services cause interference to them.
On the other hand, RAS is designated as a primary service in the frequency bands from 76 GHz to 77.5 GHz and 79 to 81 GHz, while the range of 77.5-78 GHz is allocated with a secondary status. Additionally, the entire frequency range of 76-81 GHz is covered in footnote RR No. 5.149 due to the scientific significance associated with this frequency range.

4. System parameters

This section describes the parameters involved in the simulation. Coordinates of the observatory sites and the antenna diameter are shown in Table 2, while Table 3 summaries the key parameters essential for calculating the interference level reaching the RAS site.

Table 2: List of radio telescopes involved in this study

Observatory Name	Longitude (E) Latitude (N)	Antenna diameter
SRT (Italy)	09°14'42" 39°29'34"	64 m
Effelsberg (Germany)	06°53'01" 50°31'29"	100 m
IRAM 30M (Spain)	-03°23'34" 37°03'58"	30 m

Table 3: Radio astronomy station parameters

System Parameter	Value
Integration time	2000 s
Side lobe gain, Gr	0 dBi
Duty cycle	30 %
Threshold interference level ITU-R RA.769, Plim	-189 dBW
Antenna height, H_{rx}	D/2 m

Automotive radars are generally rated by operating range depending on the application they are designed for. The power limit of automotive radars is shown in Table 4 [8,9]. Focusing on the most impactful radars, the analysis is restricted to Long and Mid-range radar (LRR, MRR), with Short-range radar (SRR) considered negligible for this scope.

Table 4: Automotive radar power limits

Radar category	Modulation Bandwidth	Max EIRP - limit
LRR	Up to 1 GHz	40 dBm
MRR	Up to 2 GHz	37 dBm
SRR	Up to 4 GHz	30 dBm

One Long-range radar-oriented forward is examined, alongside with four Mid-range radars positioned in the corner directions. Long-range radar could be referred to the antenna patten of type A, while the Mid-range radars are conventionally labelled as type B [8,10]. Figure 3 illustrates the antenna pattern resulting from the combination of one type A and four type B radars.

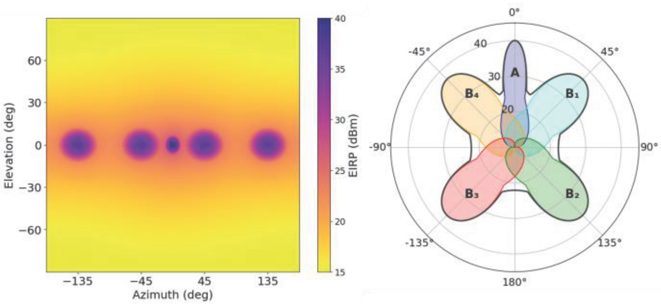

Figure 3: Radiation pattern of the antenna radar on the vehicle under test: one radar type A in the front direction, four radars type B in the corner directions. On the left the map of the radiation pattern in the full angular sphere; on the right the total antenna pattern for 0° elevation

5. Data analysis

The concept behind defining a tailored exclusion zone area around the victim site is to discretize the surrounding area into cells. The cell's shape is a regular hexagon, chosen to approximate a circle without losing empty space, which is a common approach in modelling cellular coverage. This representation is typically called hex binned map.
Figure 4 shows on the left the sum of vehicles inside each cell, averaged for 50 iterations and on the right the attenuation map as computed by averaging the attenuation loss between SRT and each point inside a hexagon cell, with hexagon's dimension of 10 km. The two maps give a representation of the most vulnerable areas both in terms of exposed directions and traffic conditions.
The power received at the radio telescope is calculated from each car, accounting for path loss, radiation pattern and clutter loss. For each cell, the aggregated received power is computed. This process is repeated multiple times, varying the location and the number of cars (following a Gaussian traffic model and according to the road classification, see Table 1).

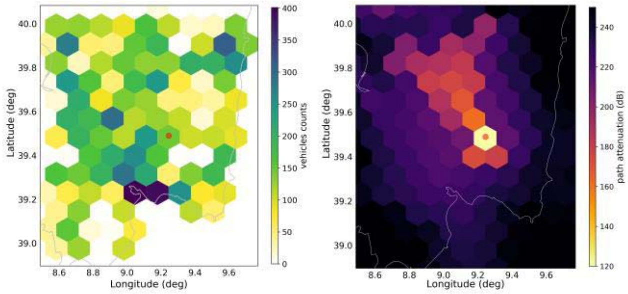

Figure 4: On the left, sum of the vehicles in the hex cell, and on the right the attenuation map with hex bin cells

A Monte Carlo approach is applied by averaging the results from 50 iterations to find a map that statistically approximate at the best the distribution of vehicles around the site.
In order to determine the total power received by the radio astronomical station, the cumulative sum of the cells is calculated. In other words, the cells are sorted from the weakest to the strongest received power and summed one by one. Knowing the threshold level beyond which the power received at the radio telescope cannot be exceeded (according to ITU Recommendation RA.769 [11]), it is possible to identify the noisier cells. When the cumulative sum exceeds the threshold, the remaining cells, with stronger power are designated as noisy cells as shown in the bar plot of Figure 5 for two different hex sizes. Figure 6 illustrates the power received at the SRT site using the described approach, with the highlighted cells representing the noisiest ones.

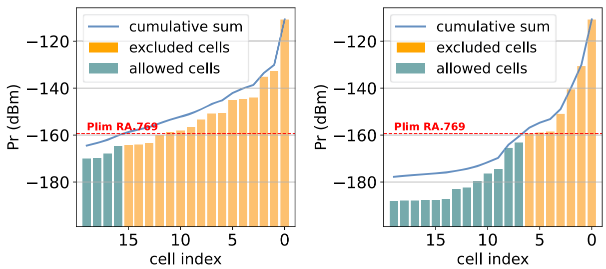

Figure 5: Bar plot of the 20 most critical cells with the cumulative sum. Left hex size = 4 km, right hex size = 10 km

Cars in such cells should turn off their radar to ensure successful operations of the radio telescope.
The same approach applied to SRT is replicated for Effelsberg and IRAM 30M. Figure 7 illustrates (with continuous lines) the exclusion zones as a function of hexagonal cell size.

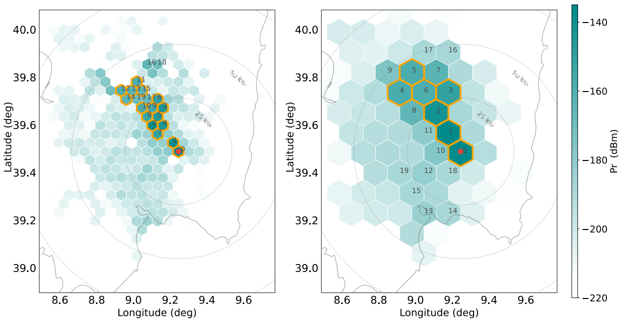

Figure 6: Received power at RAS station with highlighted critical cells. Left hex size = 4 km, right hex size = 10 km

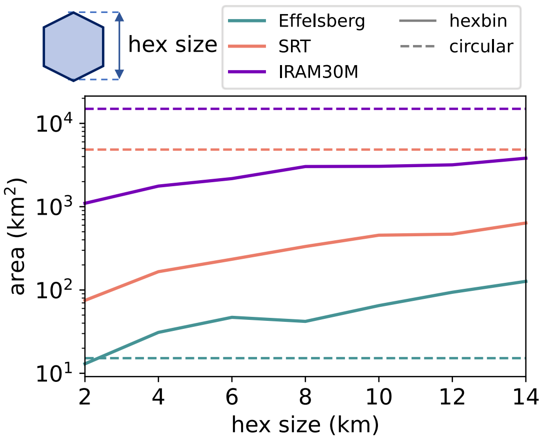

Figure 7: Comparison of exclusion zone area between circular and hex binned map

The results show an almost monotonic pattern, where the exclusion zone is smaller if smaller cell units are adopted, as it would be intuitively expected. The proposed methodology proves that the use of hex cells instead of a circular approach (dashed lines) [7] is very effective for sites such as SRT and IRAM 30M. The circular method involves establishing an exclusion zone with a circular shape centered on the radio telescope, defining a radius to exclude all nearby vehicles exceeding the acceptable threshold level. On the contrary, due to the presence of surrounding mountains, as in the case of Effelsberg, it is more appropriate to use the circular approach or choose for small cellular hex unit.

5. Conclusion

The proposed method provides an advantage in delineating the exclusion zone of capillary devices through the calculation of aggregate contributions. The area surrounding a radio telescope is discretized into regular hexagonal cells. The hex size plays an important role to calculate the exclusion zones to protect radio astronomy services, since the resulting area can vary ranging from multiple localized areas, for small hexagonal cells, to a larger area when larger cell elements are selected.

This approach is particularly effective for sites that are not perfectly shielded from the surrounding terrain, such as SRT and IRAM30M. However, for well-shielded sites, careful adjustment of the hex size is crucial to avoid the possibility of overestimating the required surface area when excessively large cells are chosen.

References

[1] European Road Safety Observatory “Road safety thematic report - Advanced driver assistance systems”, 2021, https://www.erso.eu

[2] B. Winkel “Python Package Index (PyPI): pycraf” https://pypi.org/project/pycraf/

[3] ECC Report 327, table 61: "Technical studies for the update of the Ultra-Wide Band (UWB) regulatory framework in the band 6.0 GHz to 8.5 GHz", 2021

[4] CEDR Report, “Pan-European Road Network Performance Report”, 2021

[5] Recommendation ITU-R P.452-16: “Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz”, 2015

[6] ©Corine Land Cover (CLC), https://www.copernicus.eu

[7] ECC Decision ECC/DEC/(04)03 “The frequency band 77-81 GHz to be designated for the use of Automotive Short Range Radars” 2019

[8] ECC Report 350 “Radiodetermination equipment for ground based vehicular applications in 77-81 GHz”, 2023

[9] ETSI TR 103 593 V1.1.1 “Short Range Devices; Transport and Traffic Telematics (TTT); Short. Range Radar equipment operating in the 77 GHz to 81 GHz”, 2020

[10] Recommendation ITU-R M.2057: “Systems characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems applications”, 2018

[11] Recommendation ITU-R RA.769-2: “Protection criteria used for radio astronomical measurements”, 2003