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Cellular Base Stations' Antennas Heights in the Upper 6 GHz Band

To what extent will antennas of IMT base stations operating in 6425-7125 MHz be located above rooftops, potentially causing interference to existing wireless services in this band?

MARCH 2026

Executive summary

European mobile network operators have repeatedly indicated they will roll out services in the upper 6 GHz frequency band (6425-7125 MHz) using their existing grid of base stations operating in the 3.5 GHz band.

The DSA's analysis of the locations and heights of actual 3.5 GHz base stations shows that the vast majority of their antennas are located above nearby rooftops – a far higher proportion than those assumed in regional and international coexistence studies of international mobile telecommunications (IMT) in the upper 6 GHz band. This suggests the coexistence studies conducted to-date might have underestimated the potential for interference to incumbent services, such as fixed links or satellite uplinks which are currently operating in the upper 6 GHz band.

To provide a sample representative of deployments in Europe's urban areas, the analysis focused on actual 3.5 GHz base station deployments in the three largest cities in France. It found that between 73% and 96%[1] of 3.5 GHz antennas in Paris, Marseille and Lyon are located above surrounding building rooftops, when compared with buildings situated within 400 meters in the antenna's sector of operation. In Paris, for example, around 92% of 3.5 GHz antennas are above nearby rooftops, with a mean clearance of approximately 13 meters. In Marseille and Lyon, 95-96% of 3.5 GHz antennas are above local rooftops. In Marseille, the mean clearance is approximately 22 meters, reflecting its hilly topography and the frequent use of rooftop-mounted masts, while in Lyon the mean clearance is similar to that in Paris. These findings contrast with the assumptions used in CEPT and ITU studies of the potential for interference from IMT to existing services in the upper 6 GHz band. These studies generally considered that only 35% of urban base station antennas in the upper 6 GHz band would be located above rooftops.

The analysis conducted for this paper draws on the database of ANFR (France's national frequency agency) of licensed mobile base stations and open data building and terrain datasets.

1 Depending on the metric adopted.

Introduction and context

The European Commission[2] is evaluating regulatory frameworks for the shared use of the upper 6 GHz band between wireless access systems, including radio local area networks (WAS/RLANs), such as Wi-Fi, and international mobile telecommunications (IMT), as well as incumbent services, such as fixed services (FS) and satellite links. To that end, the European Commission tasked CEPT to study the feasibility of, and develop least restrictive harmonized technical conditions for, the potential shared use of the band by wireless broadband electronic communications services (WBB ECS) and by WAS/RLANs.

A key determinant of whether IMT services will interfere with other services is the degree of "clutter" (typically buildings) between the IMT base station antenna and incumbent services. For example, a nearby tall building could reduce the interference experienced by a wireless transmitter or receiver from a local IMT base station.

European mobile operators have repeatedly indicated they will roll out services in the upper 6 GHz band using their existing grid of base stations operating at 3.5 GHz (with a maximum e.i.r.p. of 82.6 dBm/100 MHz). To establish the likely impact of buildings on cellular signal propagation, the DSA analyzed actual 3.5 GHz base station deployments in three municipalities in France, with respect to their placement above or below surrounding building rooftops.

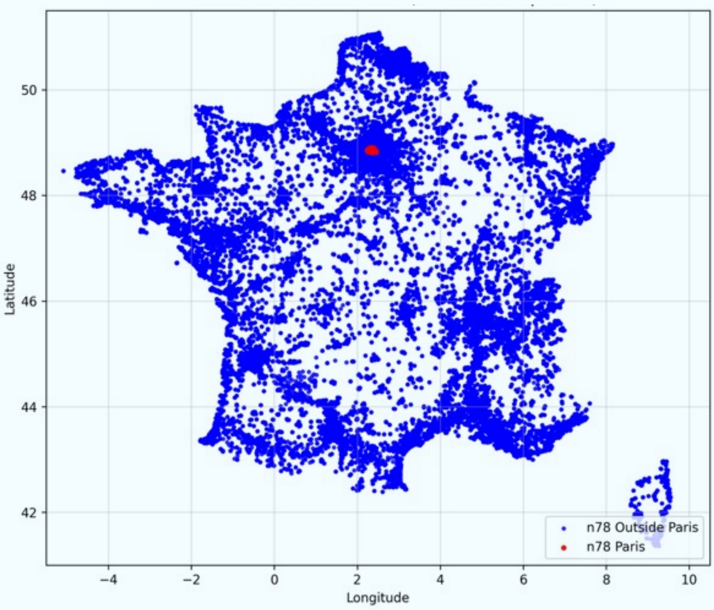
The aim of this analysis is to assess the proportion of base station antenna height being above or below rooftop based on actual IMT network deployment. The analysis focused on France because the necessary data is readily available. It draws on the official ANFR (France's national frequency agency) database of licensed mobile base stations and open data building and terrain datasets. The information about mobile station antennas was filtered to within the respective municipal boundary and by frequency and compared against the heights of surrounding buildings. This paper presents the results of this assessment, which suggest that coexistence studies developed to inform policymakers have over-estimated the extent to which clutter will mitigate interference between services sharing the upper 6 GHz band.

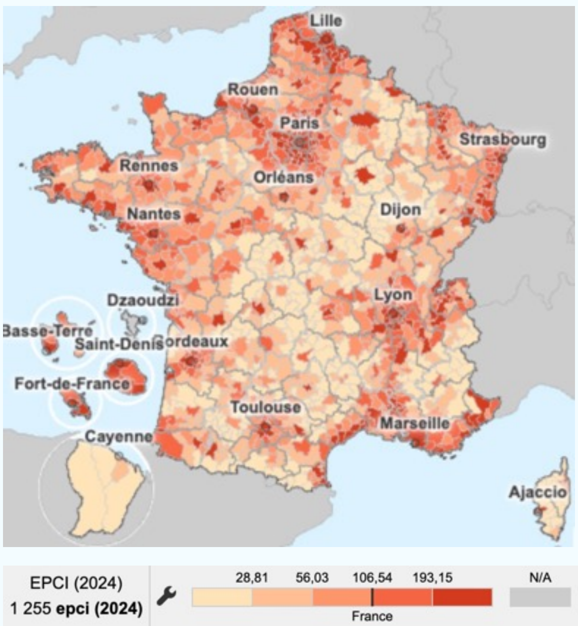
2 See https://cept.org/files/1412/Mandate%20to%20CEPT%20upper%206%20GHz%20band.pdf

The rollout of IMT in the 3.5 GHz band in France

In France, mobile network operators have rolled out IMT services in the 3400-3800 MHz band primarily in towns and cities. As shown in Figure 1, there is a strong correlation between the locations of the antennas deployed in mainland France and Corsica in this band, and population density, expressed in inhabitants per square kilometer.

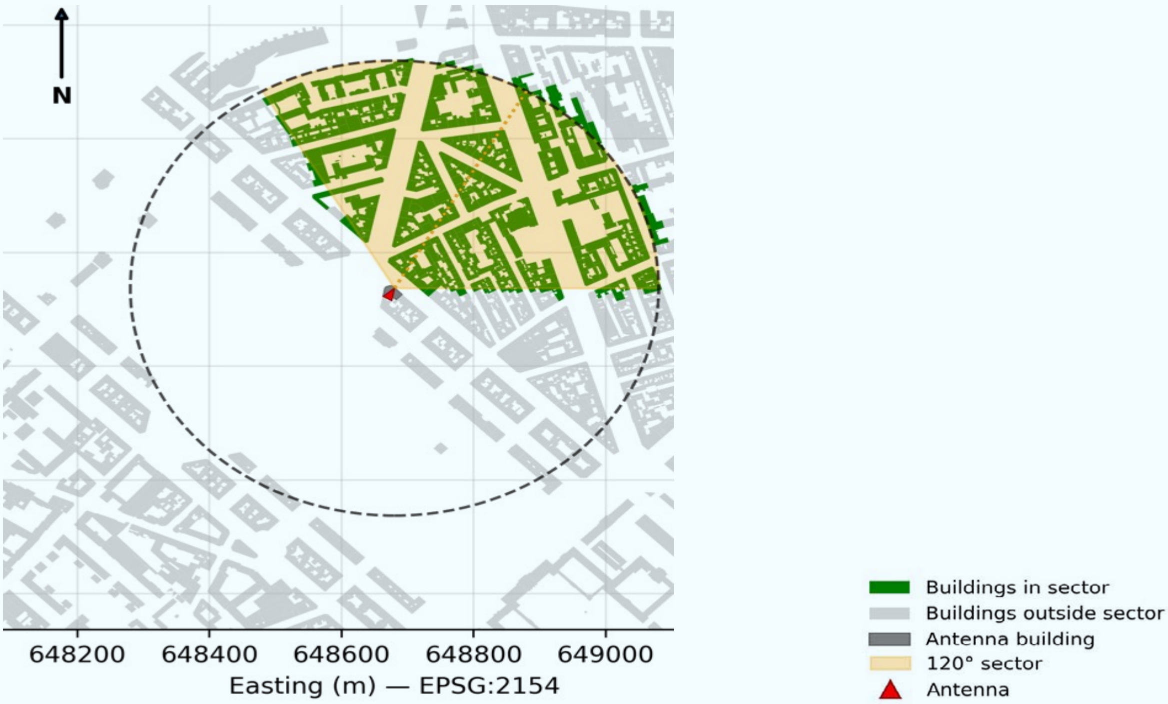
Figure 1: Top, the location of the 3400-3800 MHz antennas deployed in France. The blue dots represent the antennas outside Paris; the red dots represent those in Paris. Below, the population density as per EPCI (2024) – source.





The dataset extracted from the ANFR public database includes all the base stations above 5 W EIRP[3]. Using this source and applying the multi-city filtering process described in the annex of this paper, the analysis focused on the three largest French metropolitan areas: Paris, Marseille and Lyon.

Figure 2: Example of buildings considered within a 400-meter sector



A total of 7,169 antennas were identified within the municipal boundary of Paris, 2,370 in Marseille, and 1,371 in Lyon. To avoid edge effects near the administrative perimeter, antennas located within 400 meters of the boundary were excluded from the rooftop-comparison stage, leaving 6,039 antennas for Paris, 2,062 for Marseille, and 1,038 for Lyon in the core analysis.

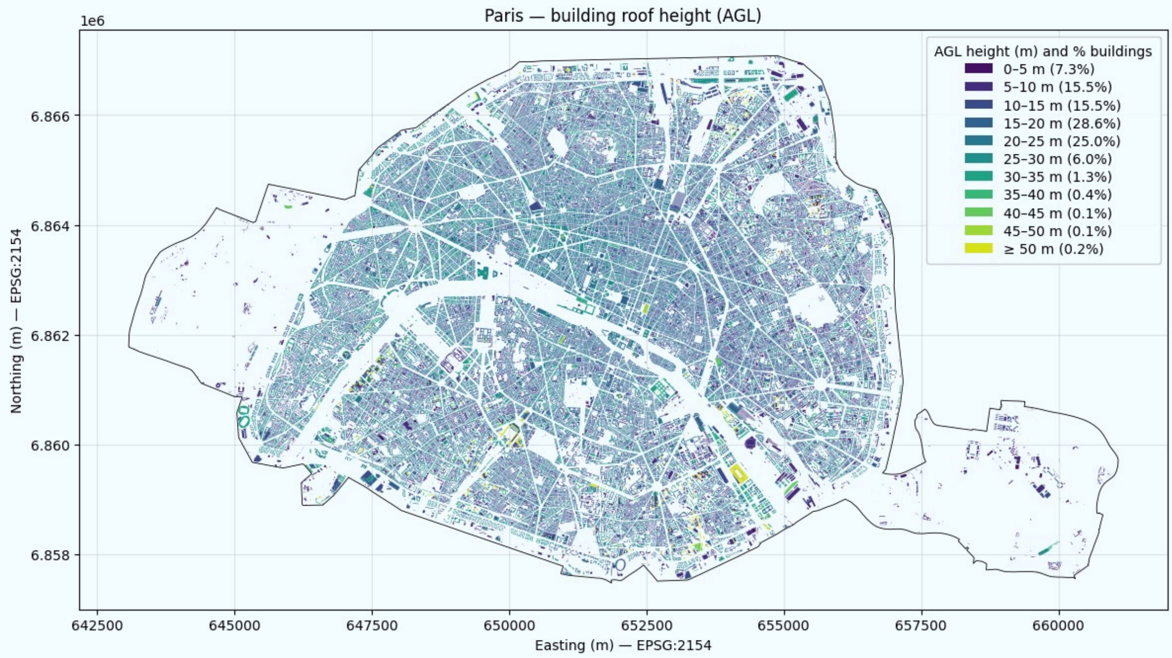
3 https://data.anfr.fr/visualisation/information/?id=donnees_sur_les_installations_radioelectriques_de_plus_de_5_wa

Comparing the height of antennas with that ofnearby buildings

For each base station site, information about antenna size and location were derived from the relevant tables, and the height of the radiating element was determined from the mid-point between the antenna's base and top. To convert to absolute elevation height, terrain altitude was obtained from RGE ALTI® 5 m[4], allowing computation of each antenna's mid-point above mean sea level (AMSL).

Building data were taken from the Base Nationale des Bâtiments[5], which provides, for every building polygon, both the mean rooftop elevation (AMSL) and the corresponding height above ground (AGL). These values were intersected with the antenna dataset to estimate, within the associated sector (400 meters), the elevation of the surrounding rooftops for each base-station site. Figure 3 shows the heights of the buildings (AGL) for the three municipalities. The 50-percentile antenna height AGL in Paris is 29-31 meters, in Marseille is 25-29 meters and in Lyon is 28-29 meters.

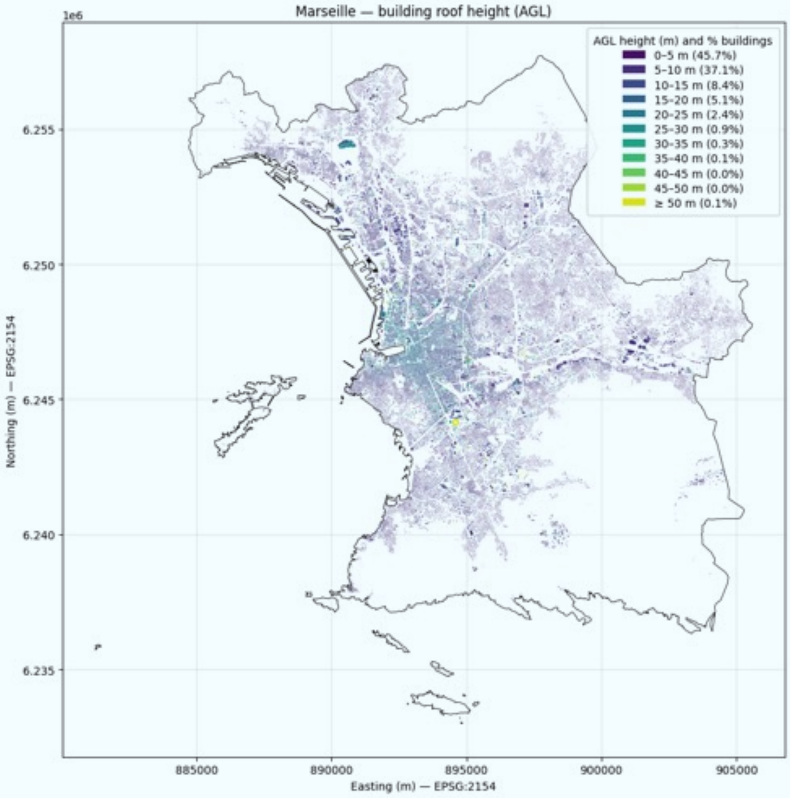
Figure 3: Building heights (AGL) for the three municipalities (continuted overleaf)

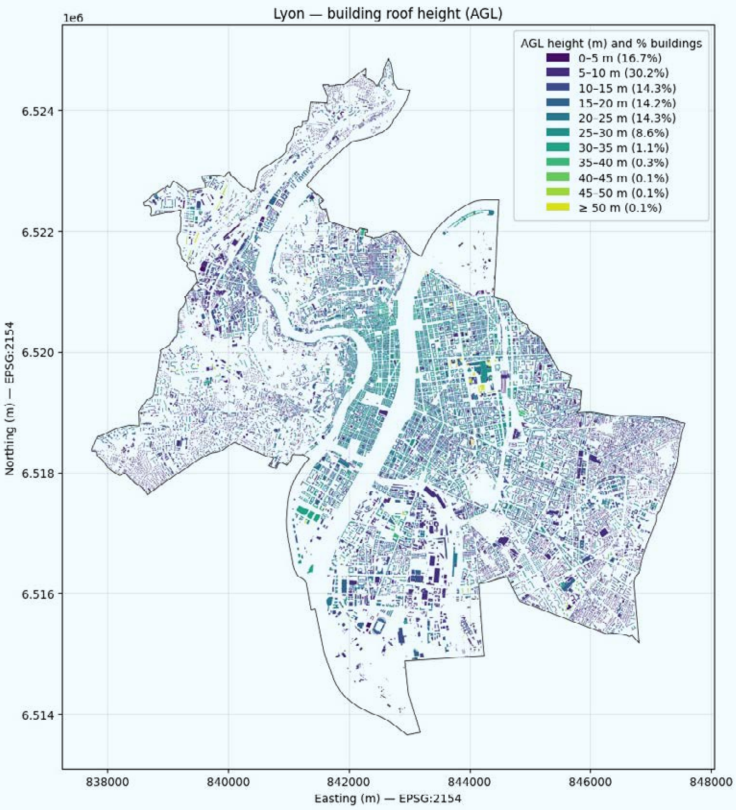


4 https://geoservices.ign.fr/rgealti

5 https://www.data.gouv.fr/datasets/base-de-donnees-nationale-des-batiments/

Figure 3: continued





The AGL distributions reveal that Paris has the highest median antenna height, around 30 meters, reflecting its predominantly rooftop-mounted macro-layer and limited natural relief. Lyon follows closely, with typical AGL values near 28 meters, while Marseille exhibits slightly lower AGL medians near 27 meters, consistent with operators leveraging terrain elevation in the city's hilly districts. The observed differences in AGL thus stem primarily from topography and building morphology rather than from distinct deployment strategies.

Statistics on building heights and 3.5 GHz antenna heights (AGL) for the three municipalities are summarized in Table 1.

Table 1: Mean and median heights (AGL) of buildings and 3.5 GHz antennas for the three municipalities

City	Mean building AGL height [meters]	Median building AGL height [meters]	Mean 3.5 GHz antenna AGL height [meters]	Median 3.5 GHz antenna AGL height [meters]
Paris	16.3	17.4	29.2	29.7
Marseille	6.9	5.3	28.2	26.5
Lyon	13.1	10.9	28.5	27.9

The calculation of the rooftop reference height was based on a cell size of 400-meter radius, which is the assumed radius of upper 6 GHz mobile cells in urban areas (see for example ECC 375 Report).

Table 2 shows the sensitivity of results to different definitions of the reference rooftop height (mean, median, 90th percentile (P90) and maximum), calculated within a 400-meter sector.

Table 2: Sensitivity of results based on the methodology used for the calculation of the reference rooftop height (AMSL)

Percentage of 3.5 GHz antennas above rooftops (400 meters)	Paris AMSL clutter = mean building height	Paris AMSL clutter = median building height	Paris AMSL clutter = P90 building height	Paris AMSL clutter = max building height
Paris	92.2%	92.7%	77.0%	25.5%
Marseille	95.5%	95.9%	76.5%	30.0%
Lyon	94.9%	96.2%	72.6%	16.8%

Across all three cities, the choice of rooftop reference affects the numerical results, but not the overall conclusion: the large majority of 3.5 GHz antennas are installed above the surrounding rooftops when realistic statistical definitions (mean or median rooftop height) are applied.

- In Paris, around 92% of antennas are above nearby rooftops, with a mean clearance of approximately 13 meters for both the mean and median references.
- Marseille exhibits slightly higher percentages (95-96% above) and greater mean clearances (≈ 22 meters), reflecting its hilly topography and the frequent use of rooftop-mounted masts.
- Lyon shows similar values (95-96% above, mean clearance ≈ 12-13 meters), confirming consistent deployment characteristics across urban France.

When the reference rooftop level is defined by the 90th percentile (P90) within each 400-meter sector, the share of antennas above surrounding rooftops decreases to 77% in Paris, 77% in Marseille, and 73% in Lyon, indicating that a limited subset of sites operates near the height of the tallest local structures.

By contrast, defining the reference as the maximum rooftop height leads to a sharp reduction in antennas considered “above rooftop” (26% in Paris, 30% in Marseille, 17% in Lyon) and results in negative mean differences. This outcome is expected: by definition, the “maximum” statistic is determined by the single tallest building in the search area, regardless of whether that structure is representative of the broader urban morphology or the dominant propagation path. As a result, this measure tends to overstate the effective rooftop level in dense environments, especially where isolated towers, high-rise blocks or landmark buildings are present. While methodologically useful as a conservative upper bound, the max-building approach does not reflect the conditions typically encountered by most base stations and is therefore less suitable as a baseline for coexistence and sharing studies.

Overall, these results confirm that, under realistic assumptions (mean or median rooftop references), between 92% and 96% of 3.5 GHz antennas in Paris, Marseille and Lyon are above the surrounding rooftops, with average clearances between 12 meters and 22 meters depending on city morphology and local terrain.

Applicability of the results

The ITU-R P.2108 recommendation[6] provides statistical models to account for the signal attenuation caused by buildings and vegetation (clutter) when one or both ends of a radio link are located within a cluttered environment.

The percentage of locations above or below clutter is a critical parameter used to determine how much “protection” or “interference” a specific site will experience.

ITU-R P.2108 does not specify how to calculate the percentage of locations above or below clutter, but it is an input parameter provided by study authors.

According to P.2108 Section 3.1, if the antenna height is greater or equal to the representative clutter height, the antenna is in Line-of-Sight or “Over-the-Rooftop” propagation regime, not in a “Clutter” regime, specified for terrestrial paths in Section 3.2.

6 Recommendation P.2108-1 (09/2021) – source.

To use the results presented in this analysis of three French cities in a coexistence study (e.g. for a Monte-Carlo simulation such as those presented in ECC Report 365), the percentages found should be treated as a weighting factor rather than a model parameter.

It is worth noting that the results of this analysis do not consider vegetation. In practice, if there are trees taller than the buildings, an antenna that is “above rooftops” might still be cluttered by foliage. This means that the results found by this analysis represent an upper bound for the “clear” antennas. If we included vegetation, the percentage of truly “uncluttered” antennas would likely decrease by few percentage points, potentially giving a bit more “protection” in the interference results.

Conclusions

A series of technical studies has attempted to assess the compatibility and coexistence between IMT and existing uses of the upper 6 GHz band and their potential evolution. Those Monte-Carlo studies generally assumed that only 35% of base station antenna in the upper 6 GHz band will be located above rooftops.

In ECC Report 375, which draws on these coexistence studies, CEPT reported considerably different values for the separation distances required to protect fixed services (FS) and radio astronomy services (RAS) from IMT interference depending on the percentage of IMT base stations assumed below clutter.

The analysis in this paper suggests that the above/below rooftop percentages announced and used in the sharing studies do not reflect actual deployment of IMT networks in the 3.5 GHz band. In fact, the results found indicate that higher percentages of stations are located above rooftops. Given the impact of these percentages on the clutter loss, this suggests that the assessed separation distances between incumbent services and cellular base stations operating in the upper 6 GHz band might need to be greater than those indicated in the studies that underestimated the percentage of base stations operating above rooftops. The analysis also suggests that deployment patterns are consistent across different urban settings, from topographically varied cities like Marseille to denser cities such as Paris and Lyon.

For future compatibility and sharing studies, it will be important to use simulation values which are representative of real deployments.

Methodology

The study considers 3400-3800 MHz (3.5 GHz) base stations registered in the ANFR public database (installations > 5 W) by the four largest mobile operators.

Each emitter is treated as an individual antenna sector, and its radiating element height is represented by the mid-point of the antenna.

The analysis was conducted separately for Paris, Marseille and Lyon.

Datasets and spatial references

The following official datasets were used:

- ANFR "Données sur les installations radioélectriques de plus de 5 W" (September 2025), including the tables describing emitters, antennas, supports, licensees and frequency bands.
- Municipal boundaries for Paris, Marseille and Lyon (GeoJSON format, official commune limits).
- Base Nationale des Bâtiments, providing building footprints with attributes for rooftop elevation above sea level (AMSL) and height above local ground (AGL).
- RGE ALTI 5 m digital elevation model, used to obtain terrain elevation (AMSL).

All datasets were converted to a common coordinate system (WGS 84) and harmonized before analysis, as needed.

Antenna data preparation

1. **Geolocation**: Antenna support coordinates (from ANFR) were converted from degrees–minutes–seconds to decimal degrees and validated for consistency.
2. **Data integration**: Information on the emitter, antenna, support, licensee, and operating frequency was combined into a single dataset per city.
3. **Frequency selection**: Only emitters operating in the 3400-3800 MHz range (3.5 GHz band) were retained.
4. **Municipal filter**: Emitters located inside the municipal boundary were included. Those lying within 400 m of the boundary were later excluded from the rooftop-height comparison, to ensure that the full 400 m analysis window remained inside the city.

Derivation of midpoint antenna height

For each emitter:

The base height of the antenna above ground (AER_NB_ALT_BAS) and its physical length (AER_NB_DIMENSION) were used to compute the mid-point height above ground (AGL) of the radiating element:

$$H_{mid,AGL} = AER_{NB_{ALT_{BAS}}} + 0.5 \times AER\_NB\_DIMENSION$$

The terrain elevation (AMSL) at the antenna's position was obtained from the RGE ALTI 5 m model.

The mid-point height above sea level (AMSL) was then derived as:

$$H_{mid,AMSL} = H_{terrain,AMSL} + H_{mid,AGL}$$

This mid-point value was used as the reference for all comparisons.

Comparison and aggregation

For each emitter, the difference between the antenna mid-point elevation and the corresponding reference rooftop elevation was computed.

This yielded, for every statistical definition:

- the difference in meters (positive = above surrounding rooftops), and
- a binary flag indicating whether the antenna was above or below surrounding rooftops.

City-level summaries were then generated, reporting:

- minimum, maximum, and mean differences,
- median difference, and
- percentage of antennas located above surrounding rooftops.

Statistical and visual analysis

- Descriptive statistics of antenna heights (AGL) were compiled for each operator and for all antennas combined, including percentiles (P10-P90).
- Cumulative distribution functions (CDFs) of antenna mid-point heights were plotted per operator and city.
- For context, the frequency spans actually used by each operator were illustrated as merged spectral intervals. These plots are not presented as a result because the information is too detailed and not needed for this analysis.
- Maps of antenna locations were produced, using consistent color schemes across all outputs. These plots are not presented as a result because the information is too detailed and not needed for this analysis.

Assumptions and quality control

- The antenna mid-point represents the effective radiating-element height.
- All comparisons use a 400 m search radius centered on the antenna location.
- The terrain elevation from RGE ALTI 5 m ensures terrain-aware AMSL estimates.
- The 3.5 GHz frequency range was applied as an overlap filter on the reported operating spans.
- If records presented missing coordinates or invalid height data, these were excluded.
- Reporting both AMSL and AGL clarifies the relative influence of terrain elevation and structural mounting height; AMSL serves as the principal basis for determining whether antennas are above surrounding rooftops.

Notes and limitations

- **Geographical representativeness**: The analysis covers three major French cities – Paris, Marseille and Lyon – representing distinct urban morphologies and terrain profiles.

  While the results are internally consistent and robust across these cities, further validation in other European contexts would be required before generalizing the findings.

- **Sector geometry and azimuth information**: When the ANFR dataset provides a valid azimuth and the antenna is marked as directional, the surrounding buildings are evaluated within a 120° sector centered on the azimuth direction, extending 400 m from the antenna site.

  Only buildings intersecting that sector are used to compute the rooftop height statistics, excluding the building on which the antenna itself is located.

  Where azimuth information is unavailable or the antenna is marked as non-directional, a circular 400 m area is used instead.

  This approach ensures that rooftop references are calculated consistently while reflecting the main orientation of each antenna sector where known.

- **Interpretation**: The results quantify the position of the radiating element mid-point relative to surrounding rooftops but do not account for factors such as mechanical tilt, vertical beamwidth, or local façade effects. Building heights are derived from official national datasets (BNB and RGE ALTI 5 m) whose nominal resolution and generalization may introduce small residual uncertainties, typically within a few meters.

Data sources

- ANFR base station database containing all licensed antennas in France (transmitting with e.i.r.p. ≥ 5 W)[7].
- Building dataset providing building footprints and measured heights[8].
- Administrative boundary dataset used to filter antennas to those physically located within the municipal boundary[9].
- RGE ALTI dataset from the French National Institute of Geographic and Forest Information (IGN) with a horizontal resolution of 5 m[10].

Data preparation

- The ANFR dataset (September 2025) was parsed to extract all antennas, with latitude/longitude coordinates reconstructed where necessary from DMS components in the support table.
- Antenna heights were calculated by adding the height of the base of the antenna to half the size of the antenna panel. This means, that the height used for the analysis corresponds to the height of the midpoint of the antenna.

7 Données sur les installations radioélectriques de plus de 5 watts – https://www.data.gouv.fr/datasets/donnees-sur-les-installations-radioelectriques-de-plus-de-5-watts-1/

8 "Base Nationale des Bâtiments" millesime 2024-10.a (26 February 2025) – https://www.data.gouv.fr/datasets/base-de-donnees-nationale-des-batiments/

9 Available at https://geo.api.gouv.fr/communes/INSEE_NUMBER?format=geojson&geometry=contour – "INSEE_NUMBER" is 75056 for Paris, 13055 for Marseille and 69123 for Lyon.

10 IGN RGE ALTI – https://geoservices.ign.fr/rgealti

- Deduplication was performed so that antennas sharing the same frequency band, location, azimuth, beamwidth, and height were counted once (to avoid multiple records for the same physical antenna installation).
- Boundary filter: antennas strictly inside the municipal boundaries of Paris, Marseille and Lyon were retained; others were excluded. An additional margin of 400 m was applied to ensure that building data was available for all the antennas considered. While this additional step reduced the number of antennas considered, it ensured more reliable statistics.
- Quality filters: (i) antennas were filtered based on whether their frequency operation was fully contained between 3400 and 3800 MHz (3.5 GHz), (ii) only antennas from the four main mobile operators were taken into account (extra check).

Surrounding buildings

Consistent with ITU-R P.2108, "clutter" denotes obstruction by nearby buildings or vegetation. In this study we consider buildings only and therefore we only took into account the rooftops within each antenna coverage. The reference rooftop height is calculated as follows:
Building heights: for each footprint, height was taken from the building dataset (both AGL and AMSL).
Analysis areas: around each antenna we formed either a sector with default beamwidth 120° or a circle (when the azimuth parameter was missing from the dataset), with radius 400 m (100 m and 600 m for sensitivity only). Buildings intersecting the area were included; the host building (if present) was excluded to avoid self-bias.

Reference rooftop height metric: The reference height was determined using three statistical measures: the mean building height within the selected area, the median building height, and the 90th percentile (P90) building height. As part of a sensitivity analysis, the maximum building height within the selected area was also considered.

Above/below rule: an antenna is "above rooftops" if its height, expressed from the height of the midpoint of the antenna panel, exceeds the reference rooftop height within the chosen radius.

Terrain-aware variant (AMSL): a terrain-corrected method was applied using a Digital Terrain Model (IGN RGE ALTI, 5 m). We obtained (a) antenna top elevation AMSL = DTM(site) + midpoint antenna height, and (b) rooftop elevation AMSL already included in the building dataset. The above/below rooftop decision was then made by comparing midpoint antenna AMSL height with the reference rooftop height AMSL in the analysis area.