A 5G SIGNAL COVERAGE PROPOSAL FOR ADVANCED AIR MOBILITY

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ABSTRACT

The advent of the fifth generation (5G) of mobile networks has drawn attention to the consolidation of new use cases for Advanced Air Mobility (AAM). Thus, the 5G millimeter wave (mmWave) is paving the way to revolutionize the AAM telecommunication system by providing data at high rates and in a faster and ultra-reliable manner. However, the current trade-off between 5G in high bands (i.e., 24 GHz-40 GHz) and increased signal propagation loss makes the development of a compatible network architecture for Unmanned Traffic Management (UTM) a complex task. In this context, the main contribution of this paper is to propose a 5G signal coverage map that meets the telecommunication requirements imposed by UAV operations. First, this work investigates an appropriate communication technology for AAM advanced systems. Then, a Signal-to-Interference-plus-Noise Ratio (SINR) map is simulated to propose an antenna array architecture around the Aeronautics Institute of Technology (ITA). Finally, this architecture is evaluated in four different scenarios to maximize 5G radio frequency by changing antenna parameters. Simulations demonstrate that the proposed 5G antenna organizing scheme can be used to hold AAM operations efficiently and consequently improve airspace capacity.

Keywords: Advanced Air Mobility, Unmanned Traffic Management, 5G Coverage.

1. INTRODUCTION

The advancement of electronics and computer science experienced in the 21st century meant that a variety of new studies could explore the consolidation of Urban Air Mobility (UAM) operations. Another modal that encompasses UAM is called Advanced Air Mobility (AAM), which comprises, in addition to air taxi services using Vertical Take-Off and Landing (VTOL) aircrafts, delivery operations with Unmanned Air Vehicles (UAVs) (Chin et al., 2021). Thus, it is essential to understand the strict communication requirements that must exist between vehicles in order to specify AAM scenarios. In this way, the Vehicle-to-Everything (V2X) integration requires a stable and continuous network connection. As a result, several international authorities began to investigate how existent Air Traffic Management (ATM) models can integrate the future operations of an Unmanned Traffic Management (UTM) system.

In future scenarios, where airspace becomes a more limited resource to hold simultaneous operations in different ecosystems, multiple communication problems are expected due to a complex ATM. The different levels of autonomy foreseen for the AAM allied to the swarm of different types of UAVs and VTOLs sharing interposing routes requires greater cooperation and harmony between manned and unmanned airspaces (Shrestha et al., 2021). Thereby, the current UTM system requires an efficient and reliable network communication, capable of transmitting data at high delivery rates and speeds. Thus, with more aircraft to coordinate, operators must create dynamic workflows that can be controlled through a network. However, current 4th generation (4G) of mobile networks fail to meet the demands for a robust telecommunication system required by AAM (e.g., high data rate, high reliability, high coverage and low latency) (Cheng et al., 2018), which makes the development and implementation of robust systems difficult. To this integration continues to evolve and allow more devices to be connected to the network, in particular, the network on which the devices are inserted must also evolve (Bernardo et al., 2022). To overcome these problems, 5G technology has been used to facilitate both wireless broadcast and point-to-point transmissions, being an important component of Unmanned Aerial Systems (UAS) (Hosseini et al., 2019). Thereby, the recent study advances and industry interest in the application of new technologies for the transport sector are the motivation for this work. It is worth mentioning the interest of the research in knowing what is the best 5G network architecture that should be built to embed AAM applications. The main contribution of this work is to provide this 5G signal architecture based on the restrictions imposed by the UTM system.

In this paper, we provide an overview of the maturity level of the UTM sector to integrate high-tech mobile networks by describing basic concepts and challenges. In addition, a 5G antenna array architecture capable of supporting future AAM operations around the Aeronautics Institute of Technology (ITA) is presented. The 5G network signal coverage provided by this architecture is mapped to a future scenario in which there is high demand for data transmission at high frequency, to mitigate communication problems that may arise due to high airflow demand. A brief discussion of how 5G can be used to increase airspace capacity is also provided. The architecture type proposed in this paper allows the development of solutions to solve airspace capacity problems and provide better UTM communication. For the scenario studied, 5G technology is expected to facilitate the flight dynamics of autonomous vehicles by self-coordinating and readjusting their operations under the telecommunication infrastructure presented in this work.

The remainder of this paper is organized as follows: Section 2 details the related work. Section 3 describes the 5G network planning (e.g., network layout, design, and propagation models), while Section 4 describes the simulation coverage results. Finally, Section 5 presents the conclusions and future work.

2. BACKGROUND

This section aims to present the theoretical basis of computer networks in urban mobility regarding 5G advancement and applications.

2.1. 5G Technical Requirements

The network evolution can be seen in a work that began in the 80s, in the introduction of mobile network technology with 1G. Used in the first cell phones, the transmission in the 1G network worked in an analog way, using radio signals to encode the audio, and the technology was limited to providing voice services between devices (Gawas, 2015). With the current arrival of 5G networks, there is connection support for much more devices on the network with significantly faster speeds. The 5G technology can offer a wider spectrum to attend to ever-growing demands at the highest transmission rates and lowest latencies. The key performance indicators for 5G include the user-experienced data rate, connection density, end-to-end delay, traffic volume density, mobility, and peak date rate (Jiang & Liu, 2017). These indicators provide a sense of how 5G communication infrastructure should be architected to meet these constraint scenarios and solve new challenges in mobile networks.

In addition, to better understand 5G architectures and requirements for deployment, the International Telecommunication Union (ITU) created an initiative called International Mobile Telecommunications for 2020 and Beyond (IMT-2020), which consists of recommendations (e.g., 5G radio regulations, operational aspects, performance, and test specifications) for 5G deployment. ITU has released the vision recommendation (Series, 2015) and defined the values for each key capabilities of 5G shown in Table 1.

Table 1 5G key capabilities and values from ITU-R. Source: Series, 2015

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Key capabilities	Values
Peak data rate	20 Gbps
User experienced data rate	0.1-1 Gbps
Latency	1 ms over-the-air
Connection density	10^6users/km^2
Area traffic capacity	10 Mbit/s/m^2

It is therefore worth emphasizing the need to understand what type of structure makes up the 5G architecture. To the AAM demands, society must reach a new level in communication technologies, being able to transmit signals in new frequency bands. These frequency bands, called millimeters waves (mmWave), are considered a key technology for 5G wireless communications (Huang et al., 2017). The mmWave systems have frequency ranges between 20 and 300 GHz (Khan et al., 2021) where a total of around 250 GHz bandwidths are available (Bogale et al., 2017). However, this frequency spectrum causes the signal propagation loss to be high, which significantly reduces the range of 5G signal coverage. Those issues inherent to mmWave communication can be bypassed through the configuration and optimal arrangement of antennas for signal propagation.

The UTM systems must be optimally coordinated and based on efficient trajectories, in addition to the need for them to be endowed with accurate avoid-collision systems. Intending to better understand this technology and applications for these scenarios, Li et al. (2018) conducts an extensive literature review on 5G technology and future trends for UAV communication. Furthermore, it is worth mentioning a very important study area for the consolidation of the use of mobile networks, which consists of mapping and positioning 5G antennas efficiently.

Having seen the 5G key capabilities presented, is expected a sturdy telecommunication system to support AAM operations. This system must be designed to provide low-cost solutions, minimize traffic congestion faced by terrestrial infrastructure and create new economic opportunities for the consolidation of a V2X model. Some recent applications designed for V2X based on state-of-the-art in mmWave communication networks will be presented in the next section.

2.2. 5G Networks Applied to V2X scenarios

In a futuristic urban mobility perspective with the AAM deployment, remote control is more consistent with the use of wireless networks. For the context of urban mobility, wireless communication technologies applied to small areas are not suitable for the wide range of devices connected on the network, what prompts the study of the best network architectures to be used in forthcoming scenarios.

Chin et al. (2021) tested different optimal congestion management algorithms to supply satisfactory operations in an AAM scope. They developed a robust protocol based on decentralize information to avoid gridlocks in the system and increase airspace capacity in a congested volume scenario. They reached at an efficient solution that has relevance to the problem of coordination and control of traffic, what is much expected by network technologies with the increasing deployment of connected autonomous vehicles.

Rodriguez et al. (2021) presented a framework to optimize 5G-integrated autonomous mobile robots. Using a 5G emulator and a wireless multi-access gateway they could focus on its overall 5G control and edge-cloud operation. As a result, it was possible to see that this 5G operation was superior in terms of control-loop reliability compared to a Wi-Fi 6 architecture, what shows the 5G potential and reliably to operate autonomous mobile robots.

In addition to the aforementioned challenges related to V2X communication through 5G, which is also faced by AAM, the mobile network technology must deal, due to its current structure, with several external problems. Challenges related to signal attenuation on rainy days (Drozdy et al., 2016), the difficulty in penetrating the signal in obstacles, (e.g., vehicles, constructions, and signal diffraction) can affect negatively the quality of transmission. Because of such the problems exposed, the advanced architecture that is thought for the AAM deployment must be smart enough to ensure operation safety. In this way, the interest in optimizing this architecture increases as seen in recent studies on Ultra-Reliable Low-Latency Communications (URLLC), which are paving the way for UAVs remote control. Thus, due to the increase of connected UAVs in URLLC modes, it is expected for the next few years overhead in airspace capacity. The dense UAV transport systems emerge as an increasingly important task to understand the current telecommunication infrastructure.

In this work, an antenna mapping infrastructure was simulated to provide a 5G coverage signal around ITA. From the point of view of a typical AAM scenario, the mapping proposed in this paper can be used to accurately plan the cell site locations to provide uniform 5G coverage. Previous works attempted to use 5G frameworks to compute network metrics that guarantee a feasible operation of autonomous vehicles. This work, on the other hand, uses the 5G radio signal considering the interference between the antennas to identify the best cell site arrangement. Besides that, it was considered appropriate cell site parameters (e.g., bandwidth, carrier frequency, transmit power) for each transmitter, according to what is seen in the literature as efficient for scenarios involving UAVs. Finally, all planned cell positions are deployed using a signal simulation around ITA map to analyse the proposed placement of the antennas.

3. METHODOLOGY

The 5G network requires full coverage for reliable data transmission so that it is available at any time for an AAM application. For this, there must be an optimal network coverage plan that takes into account all the 5G technical requirements and can deliver transmission quality to the end user. Network coverage refers to the entire area around the base station (i.e., cell site), where the air vehicle can request any service on the network and successfully connect to the cell site to receive the response to its request. In turn, the cell radius is defined as the maximum distance a UAV can connect with a 5G cell without losing communication. Thus, it is possible to estimate, for a predetermined area, the number of cells needed to perform the signal coverage. For this 5G coverage mapping simulation, it was considered an inter-site (ISD) distance of 100 meters shown in Fig. 1, since it is leading with a high frequency band, designed for a small coverage.

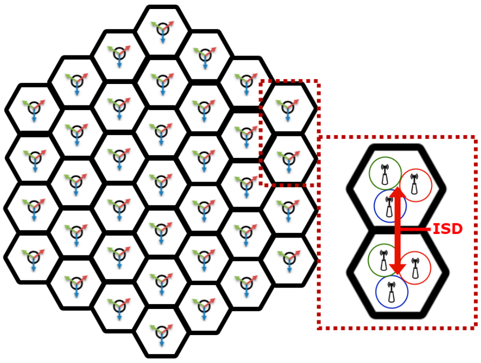


Figure 1 5G network layout with 37 cell sites, each with three sectors.

In higher frequency bands, it can be seen the increase of free space propagation loss, which will limit the individual cell site radius to 100 meters for the high-frequency band compared to several kilometers in 4G (Ahamed & Faruque, 2021). A UAV, during its flight, can receive more than one dominant signal from nearby cells if the ISD is not maintained (i.e., out-of-cell interference), which degrades the network performance and, consequently, the optimally of the air vehicle flight, which can lead to collision problems with other UAVs. As soon as the AAM telecommunication infrastructure operator deploys several 5G cells in a region, it must find the best antenna array parameters that maximize the signal coverage.

This paper assumes a future scenario based on the urban environment with high demand for data and transmission speed. This type of scenario is called a dense urban-Enhanced Mobile Broadband (emBB) (Hassani-Alaoui & El Abbadi, 2019). More specifically, a scenario with high user density and traffic loads around ITA. The area was chosen due to the great interest in the maturation of technology, being a public university institution linked to the Brazilian Air Force (FAB). In addition, ITA covers an area of great economic impact in the state of São Paulo and is located within the Aerospace Department of Science and Technology (DCTA) campus. DCTA also encompasses São José dos Campos International Airport (ICAO: SBSJ), giving the area a periodicity in air traffic demand. The test environment is based on the guidelines defined in the ITU-RM report (Series, 2017) to evaluate 5G radio technologies, which suggests regular scheme antenna positioning taking the form of a hexagon. The layout consists of 31 sites, each with 3 cells, placed in a hexagonal layout to cover the ITA area, as shown in Fig. 2.

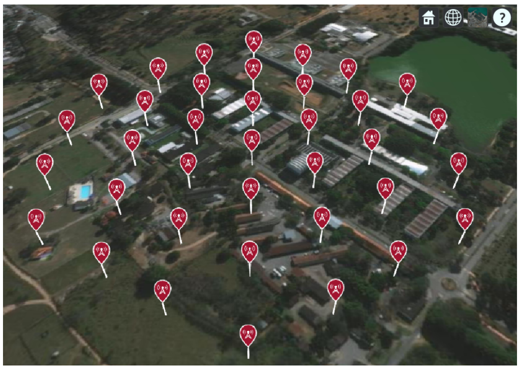
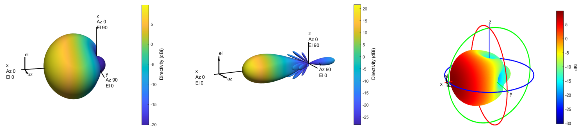


Figure 2 Antenna mapping model around ITA campus.

In this way, each cell site is composed of three 5G signal transmitters (i.e., sectors), so that each transmitter can be represented by a single antenna element or by an antenna array containing n antenna elements. Since the 5G mobile network works with very high-frequency bands, a large number of antennas can be integrated into a single array. Therefore, an array can be defined as two or more connected antennas that transmit the signal together as a single antenna element. Figures 3a, 3b and 3c shows the 3D radiation pattern of a 5G antenna with a single element, with 8-by-8 antenna elements and considering a patch antenna model as the array element provided by MATLAB.



(a) Single element. (b) 8-by-8 array. (c) Patch antenna.

Figure 3 Comparison of the 3D radiation pattern of different 5G antennas.

In general, the single element antenna delivers a low gain radio waveband, while the propagation pattern of an antenna array delivers a narrower and more direct waveband, consequently with higher gain, which is indicated for this AAM scenario of long-distance communication between UAVs. Configure the best antenna placement for 5G signal maximization it is considered to be a very complicated task, as positioning needs to induce as little interference damage as possible in existing mobile network systems.

Considering a level of technology maturation where the transmitted 5G waveform has already been generated and affected by the propagation channel, it is interesting to evaluate how to optimally arrange the antennas to map the 5G signal for AAM use cases. To coverage largest area with optimal cost, solutions can be created to maximize the signal from the network antennas in a certain directions. One of these techniques, called beamforming, use the processor in conjunction with an array of sensors to provide a versatile form of spatial filtering (Van Veen & Buckley, 1988). Being able to cancel noise and interference, this technique allows different access points to be arranged in a way to maximize the coverage area. In scenarios where there is a blockage, an antenna is able to pass the request of a UAV promptly to another antenna closer within the same cluster. In this paper, the beamforming technique was adopted to maximize the signal gain by the antennas.

In order to create and compare different 5G antenna placements, it was used a product to simulate, analyze and test 5G communication systems. The 5G Toolbox is an open-source tool available at MATLAB. The framework used the Phased Array System Toolbox to create hexagonal cell network as well as the custom antenna array. Through this tool, it was possible to construct a 5G urban macro-cell test environment to ensure the ubiquitous coverage area required for AAM operations and visualize the Signal-to-Interference-plus-Noise Ratio (SINR) on a map for different antennas, assuming that the UAVs will be arranged uniformly and randomly above the sites and hexagonal cells. SINR is a term considered for expressing the measure of a signal quantity combined with noise and interference, serving as an essential parameter to understand the quality of an incoming signal in radio frequency systems (Panigrahi et al., 2020).

This paper follows the guidelines of IMT-2020 for the 5G network planning and coverage simulation (Series, 2017), but some of the parameters needed to be manually adapted to better fit in UAS use cases. For example, it used a 100 m ISD that is smaller than the 300 meters presented, a carrier frequency of 28GHz instead of 4GHz, and a transmit power of 43 dBm, considered suitable parameters for URLLC scenarios for UAVs (Khan et al., 2020). The signal radiated by the transmitter spreads across the atmospheric air and propagates from the antenna to the receiver (i.e., VTOL, UAV). The amount of signal attenuation depends on several factors (Ahamed & Faruque, 2021), such as carrier frequency, cell site location, antenna height, and distance between transmitter and receiver.

Table 2 shows parameters used in the simulator to ensure network efficiency around the ITA. For all four scenarios, were used in the simulation 3 sectors of signal propagation, a 15° downtilt angle, and transmitter antennas of 25 meters.

Table 2 Parameters used in simulation.

Parameters	Value
Number of cell sites	31
ISD	100 m
Bandwidth	250 MHz
Carrier frequency	28 GHz
Total transmit power	43 dBm

Thus, to evaluate the defined parameters, four scenarios were used, which will be described below.

- **Scenario #1: SINR map for single antenna element**. The first scenario could be used for an architecture that does not require continuous coverage for data traffic, with lower cost and a free propagation scenario (e.g., 5G network application in the academic environment for small tests and simulations to remote control of Small Unmanned Aerial Vehicles (SUAVs). For each location on the map within the range of the transmitter sites, the signal source is the cell with the greatest signal strength, and all other cells are sources of interference.
- **Scenario #2: SINR map for 8-by-8 antenna array**. The second scenario applies mechanical downtilt, which consists of physically adjusting the antenna mounting brackets to obtain an accurate measurement around each transmitter to better visualize the signal propagation. In this scenario, a rectangular antenna array can provide greater directionality and peak SINR values than when using a single antenna element.
- **Scenario #3: SINR map using close-in propagation model**. The third scenario deals with situations where there is a need for strict network requirements for the UTM system control. This model produces an SINR map that shows reduced interference effects compared to the free space propagation model used in the other scenarios. The close-in propagation model is a path loss for different 5G use cases.
- **Scenario #4: SINR map for 16-by-16 antenna array**. The fourth scenario seeks to

extend the analysis by using a 16-by-16 antenna array. This type of architecture allows the analysis of the feasibility of specific signal coverage for AAM that fully meets the network availability, reliability, and data rate. This scenario is expanded to test how the number of transmitters per cell, the antenna downtilt angles, and the antenna height can affect the quality of the radio frequency signal.

The free space propagation loss is much higher when dealing with high-frequency bands like 5G. In this way, the mmWave network architecture must consider noise and interference in signal mapping. The signal maps generated with the simulator will be displayed in the next section.

4. RESULTS AND DISCUSSION

In this paper, a signal map is generated to estimate 5G network coverage using the free space propagation model. In this section, the results of the 5G network coverage simulation will be presented, where the ITA will be considered as an implementation area. The simulated network coverage and the SINR are presented together with Google Maps for better geolocation of the studied area since the simulator considers the region topography (i.e., altitude).

In the first case, Fig. 4a shows a visualization of the SINR area coverage map with colored communication using a single antenna element and a free space propagation model. The SINR map uses a scale ranging from -5 to 20 dB, where warmer colors indicate greater signal strength. Each one of the 31 sites has three transmitters corresponding to each cell. Thus, the antenna angle of the transmitters is positioned in an appropriate direction offset by 120º each. Since SINR is used to estimate the quality of the network connections, areas with an SINR value less than or equal to 0db represent no signal presence, while blank space areas within the network indicate areas where the SINR is below the default threshold of -5 dB. These areas do not have the minimum required SINR, creating a coverage gap for the UAVs. Due to the lack of signal strength, it is not a viable architecture for AAM-dense operations.

To increase the directional gain and the peak SINR value, it was used in a second case an 8 x 8 rectangular antenna array. Figure 4b shows this scenario in an extended coverage area map, where the configuration allows a gain in an oriented wave range.

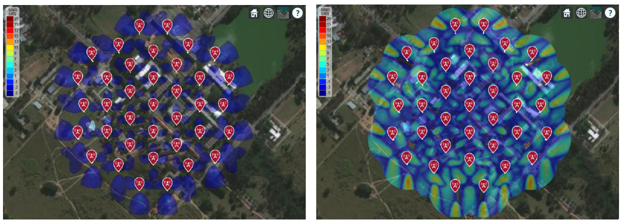
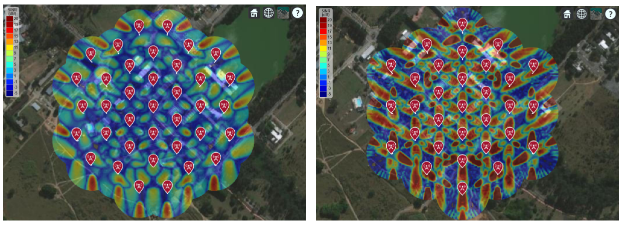

(a) Scenario #1. **(b) Scenario #2.**

Figure 4 Comparison of the SINR maps for the first two scenarios.

As shown, there are less blank spaces in the map, which indicates results with higher SINR values due to less interference. A high gain can be observed as the number of antenna elements increases. As the gain grows with the size of the antenna array, the SINR value will also increase, improving the overall performance of the network. However, this type of architecture is also not the best for AAM operations, as there are still several areas that do not have radio frequency coverage for the 5G network.

More over, it was simulated a test scenario using the close-in propagation model described by Sun et al. (2016). As can be seen by Series (2017), the antenna element needs to provide a maximum gain of 9.5 dBi and a front-to-back ratio of approximately 30 dB (i.e., narrowed beam). In order to evaluate the improvement of the signal coverage, in this scenario the equation-based antenna element definition was replaced by a real antenna model through Antenna Toolbox in MATLAB. It was possible to see the same gain provide by the antenna element, although with a lower front-to-back ratio. The SINR map using close-in propagation model is shown in Fig. 5a.

However, better coverage can be seen by adding a 16-by-16 array antenna for each transmitter as shown in Fig. 5b. The gain provided by this antenna configuration shows that as the number of elements in the array grows, higher SINR values can be seen, which is required by the 5G network.

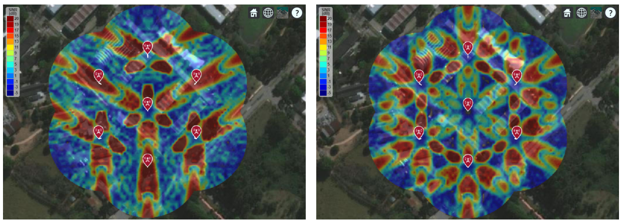


(a) Scenario #3. **(b) Scenario #4.**

Figure 5 Comparison of the SINR maps for the last two scenarios.

Thus, for better signal coverage to meet AAM expectations, 5G network requires higher SINR values. One observed way to achieve the desired coverage is to increase the array antenna size for each cell site. As much as the architecture using 16-by-16 array significantly improves the signal, one can observe a gain directed through a narrow beam of radiation. As seen in the SINR map for scenario #4, some areas still suffer signal variation, which can significantly impact the performance of autonomous flight operations.

In order to further improve the signal coverage, the number of sectors (i.e., transmitters) per cell site can be increased. As the 16-by-16 matrix configuration propagates the signal in a very narrow and highly directed format, the use of six sectors can be applied instead of three. Figure 6a shows the SINR map of a 16-by-16 array with three sectors, while Fig. 6b deals with a cell architecture of six sectors. All antenna configuration parameters remain the same as those presented for the previous scenarios. However, for better signal visualization, the number of cell sites adopted is 7 instead of 31.

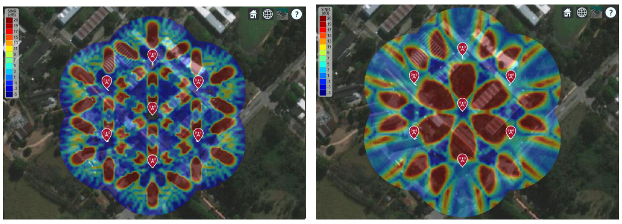


(a) 16-by-16 array with 3 sectors. **(b) 16-by-16 array with 6 sectors.**

Figure 6 Signal strength and coverage when varying sectors.

The average level of signal coverage increases as more sectors are added to each cell. Still, coverage is not evenly distributed over most areas, which means that some places do not have adequate radio frequency propagation for AAM. To further optimize the 5G signal coverage, the scenario was tested with six sectors and different antenna inclination angles.

The antenna downtilt method is one of the most effective for controlling the radiation beam (Molisch, 2012). Figure 7a shows signal coverage for a 16-by-16 array architecture and six sectors offset by 60° each and 25° mechanical downtilt, while Fig. 7b presents the SINR map for a 5° mechanical downtilt angle on the antenna brackets.

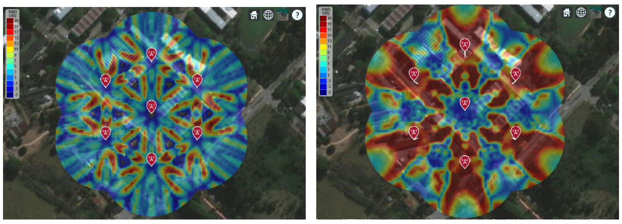


(a) 25° antenna downtilt angle. **(b) 5° antenna downtilt angle.**

Figure 7 Signal strength and coverage when varying antenna downtilt angle.

It is possible to verify that a 5° angle promotes better radio frequency coverage than a 25°, with signal in areas close to the central antenna above 15dB, which is very good for a 5G network coverage.

Also, the transmitter antenna height directly impacts the signal coverage. Figure 8a presents, under the same parameters as the previous scenario shown in Fig. 7b, the SINR map for an architecture that uses 10 meters antennas. As a comparison criterion, Fig. 8b shows the radio frequency coverage for 40 meters antennas.



(a) 10 meter antennas. **(b) 40 meter antennas.**

Figure 8 Signal strength and coverage when varying antenna height.

The RF signal is better for higher antennas, as can be seen by comparing Fig. 8a with Fig. 8b. In a scenario with the dense movement of autonomous flying vehicles, this type of setup makes the most sense as the signal will be propagated mostly high up, where AAM operations take place most of the time.

In short, the cell layout architecture to support operations involving remotely controlled UAV flights is more efficient when it contains more spaced sectors, to spread the signal evenly. As such AAM operations involve a URLLC network and high frequencies, it is essential to evaluate better antenna parameters matching such as those presented here. The downtilt angle of the antenna brackets, the antenna's height, and the optimal number of sectors per cell are essential requirements for system development, which must be treated carefully through studies and tests. By using Google Maps terrain profile data, the results depend on the terrain data maintenance and updating. The results presented can be used as a comparison criterion for future deployment of 5G antennas around ITA. The main discussions about the challenges of implementing a 5G signal coverage for AAM, as well as the conclusions obtained from this work, can be seen in the next section.

5. CONCLUSION

The present work allowed us to evaluate a 5G signal coverage that meets the future demands of AAM. For the upcoming fifth-generation networks' usefulness in this type of transport mode, there is an urgent of design a radio frequency coverage architecture capable of supporting URLLC traffic. In this sense, the high-frequency bands of 5G (i.e., mmWave) are well suited for application in several use cases that involve data traffic between AAM applications (e.g., UAVs, SUAVs, VTOLs) and with a ground infrastructure. The simulation framework presented in this work allowed the spatial evaluation of mmWave availability by generating beamforming signals and providing high signal gain and coverage. The overall goal was to provide an architecture based on the network characteristics that an AAM communication system must have to work optimally. To achieve this goal, we performed tests with beamformed mmWave in four scenarios explored in this paper. Through the SINR maps generated for the area around ITA, the designer of a future 5G network architecture can evaluate the best antenna arrangement that mitigates the propagation loss and sensitivity to blockage, which are mmWave characteristics.

This paper presents a 5G coverage planning applicable to different parameters, such as the transmitter design (i.e., single element, array), network layout (i.e., number of cells, ISD, number of sectors), propagation modeling, and antenna layout (i.e., downtilt angle, height). The results show that the better spaced the transmitters are for each cell site, the better the radio frequency coverage of the 5G spectrum. Understanding the communication infrastructure, its relationship with the environment, and the amount of AAM operations that must take place is the first step towards achieving the desired scenario in a futuristic mobility model. For future work, we plan to simulate and statistically analyze the airspace capacity covered by the different infrastructure scenarios presented. With this analysis, it will be possible to compare different UAV routes that maximize the SINR value through optimal 4D trajectories and minimize overlaps for AAM operations security.

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