Automation in Construction 90 (2018) 156–165

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Reverse engineering techniques to optimize facility location of satellite ground stations on building roofs

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ARTICLE INFO

Keywords:
Antenna
Building roof
CAD software
Facility constraints
Ground station
Laser scanning
RealWorks software
Satellite FOV
Simulation
3D modeling

ABSTRACT

The development of small satellites, called CubeSats, at universities gave rise to another concept of ground station and its location site on building roofs. As a facility project, conditioned by urban regulations, the agreement between the ground station engineers and the facility managers is necessary in the site selection process. This paper proposes the application of reverse engineering techniques, such as the laser scanning, to provide them 3D spatial information by the 3D digital reconstruction of the scenario. The main result obtained in the case study at the Technical University of Madrid was the proposal of the re-designed ground station site increasing the antenna performance and considering the established facility constraints. In these building roofs scenarios, the virtual simulation process of telecommunications antennas sites based on the created 3D digital scenario is very useful to optimize the location before the installation process.

1. Introduction

Within urban areas, the need of antennas installations on rooftops is well known to support telecommunications systems such as police and emergency services, radio and television services, and satellite communications. This paper analyzes the particular case of the GS (Ground Station) scenario on building roofs and proposes a methodology for the optimal site selection of telecommunication antennas. These scenarios of antennas on rooftops have increased considerably in order to track small satellites built by students and research teams at universities and research centers. As a communications sensor with satellites for transmitting and receiving radio waves, the FOV (Field of view) is the most relevant factor in the antenna site selection. As a facility location within urban areas, the GS site selection must also meet the established building regulations. In these scenarios a site selection process which includes the analysis of the antenna mission requirements and the facility constraints on building roofs is becoming more necessary.

This paper analyzes this case scenario of GS facilities installed on building roofs associated to a new generation of small satellites, called CubeSats, which were initially developed in the late 90s by a number of organizations and universities in an attempt to accelerate construction opportunities of small and low cost space experimentation platforms [1]. The need to support their own satellite projects as an educational challenge conditioned this new scenario for the earth-based point of communication with these space platforms within the University facilities. This scenario is based on the GS installed on a building top floor to track the first Stanford's amateur satellite built in 1998 [2]. Since the first CubeSat program created by the California Polytechnic State University in the 90s [3], these scenarios have increased in relation to the development of these programs at universities and organizations all over the world. To date, more than 1700 Nanosats and Cubesats have been launched [4]. This has been possible thanks to the rapid speed in the development of these space platforms [5], its approach to space access [6] and their capabilities for science missions [7]. The QB50 project, a network of 50 CubeSats (see Fig. 1(a)) built by universities including their respective GSs [8], is a current sample of the GS locations increase on building roofs. The QBito (see Fig. 1(b)) is one of the QB50 CubeSats, which will be tracked from the GS installed on a building roof at the Technical University of Madrid (see Fig. 1(c)). This is the typical GS configuration consisting of four main components: outdoor components which include the antennas system and the rotor-positioner (see Fig. 1(d)), and indoor components which include the

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https://doi.org/10.1016/j.autcon.2018.02.019
Received 19 April 2016; Received in revised form 28 December 2017; Accepted 8 February 2018

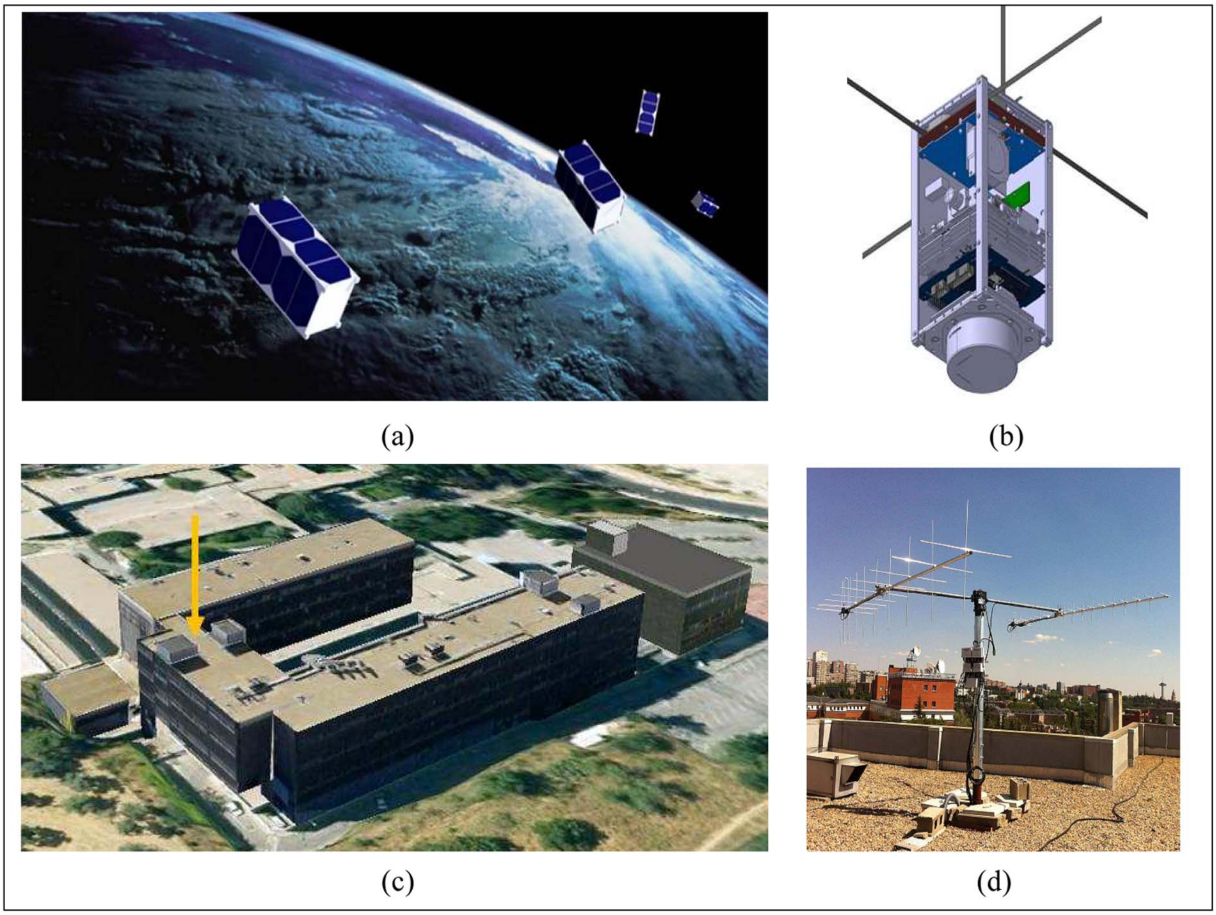

Fig. 1. Case study of the Ground Station scenario at the Technical University of Madrid (a) Artist rendition of the QB50 CubeSats in space [11]. (b) Virtual 3D model of the Qbito CubeSat [12]. (c) Location site at the ETSIT (Escuela Tecnica Superior de Ingenieros de Telecomunicacion) (Source: Google Earth program). (d) Typical antennas system.

transceiver and the modem normally installed on the floor just below [9,10].

The approach of this paper is the analysis of the GS location site regarding its influence in the antenna performance as a communications sensor, and in the installation project as a facility location conditioned by building regulations. First, the presence of nearby obstacles and high buildings surrounding the GS site reduces the satellite FOV in its AOS (Acquisition of Signal) and LOS (Loss of Signal) in certain azimuth directions along the horizon visible from the antenna site. Second, facility constraints must be considered in the GS project design, as these relate to technical specifications such as the antenna maximum height and the required fastening and anchor systems and, safety systems during the installation and for future works of facility maintenance. In this context, the research focuses in the RE (Reverse Engineering) process to carry on the scenario analysis.

RE processes which create digital realities that represent real-world scenarios enable extracting missing information from anything which is man-made, by going backwards through its development cycle and by analyzing its structure, function and operation [13]. This is possible by applying 3D digital surveying techniques such as the laser scanning technology which can capture huge numbers of points with high accuracy in a relatively short period of time, obtaining surface free-forms and generating high density point clouds. This is an innovative solution for modeling objects without the need of physical contact which enables the representation of their complex architecture, and a realistic interpretation [14]. The application of these new 3D survey methods can be adapted to different needs and highlight the possibility to carry out reliable engineering processes [15,16]. In addition, 3D digital model generation of urban scenarios is useful for accurate 3D mapping of other man-made structures [17], especially in works related to data capture from in-situ based views of indoor and outdoor structures of buildings without there being physical contact [18,19]. RE process based on laser scanning technology has been revolutionary in specific applications such as deformation monitoring, interfering design, construction archiving, as-built surveys, and BIM (Building Information Modeling) [20–24]. In addition, these processes allow a swift relationship between different professionals from different disciplines thanks to its capabilities of simulation, multi-view representation, real time visualization and, digital data extracting in any project stage.

The research aim is to develop a methodology based on RE techniques for the digital reconstruction of the GS scenario providing those professionals involved in the site selection process with accurate spatial information to be analyzed, from the current state of a given antenna site to the virtual simulation of site proposals. The methodology, mainly based on laser scanning technology, also combines the application of specific hardware and software solutions to recreate the GS scenario from both points of view, antenna performance and facility location. Solutions such as the total stations (surveying instrument) to capture the FOV from the antenna rotor center, the STK (System Tool Kit) simulation software [25] to test the antenna performance and the CAD (Computer-Aided Design) software to process specific 3D Data. The expected goal is selection of the optimal site by the agreement between the GS engineers and the facility manager taking into account the antenna mission requirements and the facility constraints, respectively. The proposed methodology for the optimal site selection of telecommunications antennas on building roofs and main results obtained in the case study at the Technical University of Madrid, are described.