AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Onboard GPS Satellite Transparent Antennas

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

by

Mostafa Mahmoud Rabie Hanafy

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering, Misr International University, 2013

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Cairo - (2018)

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Examiners' Committee

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Date: 11 July 2018

Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract (Thesis Summary)

The main objective in this Thesis is to design, simulate, fabricate, lab measure and result analysis of a microstrip transparent antenna for Cubesat satellites to communicate with the MEO orbit GPS constellation and to fulfill the following specification requirements:

Frequency: GPS L1 band (1.575 GHz) and then transformed to GPS L2 band (1.227 GHz), Bandwidth (BW) > 50 MHz, Circular Polarization with Axial Ratio (AR) ≤ 3 dB, Radiation Pattern: Gain (G) > 5 dBi , 3dB beamwidth > 60°, Small reflection coefficient (Return loss) ≤ -10 dB, Power handling Capability > 2W, 1 port 50 ohm SMA female standard connector, Small size and low weight, Low profile, Percentage of Transparency (PT) > 60%.

In this thesis an introduction to the history of Cubesats and its required antennas, also the motivations, problem statement, project phases and report organization are introduced in Chapter 1. Literature survey about Cubesats, there different types of antennas, transparent antenna techniques, GPS and its antenna requirements are introduced in Chapter 2.

Three transparent GPS microstrip antenna designs are introduced in this thesis.

In Chapter 3, two antennas are designed using transparent substrates (Quartz and Pyrex Glass), to show a variety of different substrates that can be used in the transparent antenna design. The two antennas are designed to operate at the GPS L1 band (f_r = 1.575 GHz) and then frequency transformed to operate at the GPS L2 band (f_r = 1.227 GHz). These antennas are simulated using Computer Simulation Technology, CST. The L1 band Quartz MSA achieves Return Loss (S11) of -15.7 dB, bandwidth, BW of 64.7 MHz (4.12 % of f_r), gain of 6.052 dBi, efficiency, e_0 of 96.45 %, Axial Ratio of 3.5 dB and Percentage of Transparency (PT) of 61 %. The L1 band Pyrex Glass MSA achieves Return Loss (S11) of -18.3 dB, bandwidth, BW of 107 MHz (6.8 % of f_r), gain of 4.7 dBi, efficiency, e_0 of 98 %, Axial Ratio of 2.9 dB and Percentage of

Transparency (PT) of 90 %. The L2 band Quartz MSA achieves Return Loss (S11) of -15.8 dB, bandwidth, BW of 48 MHz (3.91 % of f_r), gain of 5.733 dBi, efficiency, e_0 of 96.57 %, Axial Ratio of 3.9 dB and Percentage of Transparency (PT) of 61 %. The L2 band Pyrex Glass MSA achieves Return Loss (S11) of -16.333 dB, bandwidth, BW of 73 MHz (5.94 % of f_r), gain of 4.45 dBi, efficiency, e_0 of 95.97 %, Axial Ratio of 3.3 dB and Percentage of Transparency (PT) of 90 %.

In Chapter 4, the third antenna is designed using a nontransparent substrate (Rogers RT/duroid 5880), however achieving transparency. The third design gives the flexibility of choosing any type of substrates, without losing the transparency of the antenna. In other words a transparent antenna can be designed without any material limitations. This antenna is designed to operate at the GPS L1 band (f_r = 1.575 GHz) and then frequency transformed to operate at the GPS L2 band (f_r = 1.227 GHz). The antenna is simulated using Computer Simulation Technology, CST. The L1 band Rogers RT/duroid 5880 MSA achieves Return Loss (S11) of -45.83 dB, bandwidth, BW of 60 MHz (3.82 % of f_r), gain of 6.687 dBi, efficiency, e_0 of 97.5 %, Axial Ratio of 3 dB and Percentage of Transparency (PT) of 71.5 %. The L2 band Rogers RT/duroid 5880 MSA achieves Return Loss (S11) of -25.64 dB, bandwidth, BW of 40.8 MHz (3.33 % of f_r), gain of 6.15 dBi, efficiency, e_0 of 95.04 %, Axial Ratio of 2.9 dB and Percentage of Transparency (PT) of 71.5 %. Temperature analysis is performed on the three antennas designed in this thesis at operating frequency (f_r = 1.575 GHz), to test their performance in the outer space. The parameters of the three L1 band antennas designed in this thesis as well as the parameters of their three transformed L2 band versions are analyzed and compared, using a Performance Indicator (PI) and a Performance Metric (PM). The Rogers RT/duroid 5880 L1 band antenna is then fabricated at the National Telecommunications Institute, NTI. Lab measurements of the fabricated antenna are performed using Vector Network Analyzer (VNA) and further parameter measurements are performed using the Anechoic Chamber at the

Microwave and Antenna Research Lab, Ain Shams University. The fabricated MSA achieves Return Loss (S11) of -15 dB at f_r = 1.48 GHz with percentage of error of about 6 % in resonance frequency (f_r), bandwidth, BW of 60 MHz, gain of 5.65 dBi, efficiency, e_0 of 75 % and Percentage of Transparency (PT) of 71.5 %. Antenna parameters obtained from lab measurements are compared with that obtained from simulations and the results are analyzed.

Finally the conclusions and future work are introduced in Chapter 5.

Key words: Microstrip Antenna, Circular Polarization, Global Positioning System (GPS), Transparent Antenna, Cube satellites, Cubesats.

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