CubeSat Antenna Vibration Control Using Piezoelectric Bender Considering System Requirements

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ABSTRACT

Vibration control of satellite antenna is a main concern to good quality data transmission and reduction of mechanical disturbance in attitude maneuvers. This paper is devoted to mathematical modeling and vibration control of cube-sat antenna. To do this aim, piezoelectric sensor and actuator is utilized and mathematical model of antenna by considering piezoelectric actuator as input parameter and antenna tip deflection as output parameter. By performing experimental tests, system unknown parameters as damping ratio and natural frequency are obtained based on FFT analysis and least square method. To control the antenna vibration, its mathematical model is obtained by considering piezoelectric voltage as an input and antenna tip deflection as an output. Herein, due to limitation on power subsystem, it is not possible to apply continues voltages and only 100 volt voltage is available which complicates the control task. Three different control algorithms are proposed to antenna control and compared together. The results show that the proposed control strategies are efficient and can reduce the control time from 10 to about 1 second. The appearing parameters in selected control algorithm are optimized using Genetic Algorithm (GA). The presented results in this paper are useful for design and control of antenna and also for accurate design of satellite control subsystem.

KEYWORDS

Satellite Antenna, Piezoelectric, Control Algorithm, Genetic algorithm

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1. Introduction

Todays, communication satellites play an important role in different technologies and people daily life. There are different subsystems in the satellite as structure, attitude control, thermal control, onboard computer and communication [1]. Satellites use different types of antenna to communicate with ground station (GS) and the antenna should be pointed to the GS to accurate transmit of data [2]. Different disturbance torques and forces in the spaces lead to satellite and antenna vibration which reduce the efficiency of data communication [3] which should be controlled to reliable data transmission mission. Piezoelectric actuators have been used in satellite for different aims [4-6].

In this paper, piezoelectric actuator will be utilized to control the vibration of satellite antenna. Herein, CubeSat antenna will be modeled as Clamped-Clamped beam with piezoelectric sensor and actuator. Although different studies were devoted to control of beam using piezoelectric [7,8], but they cannot be utilized to satellite antenna control due to limitation of available voltage levels in satellite. There are several voltage buses in the satellite and designed controller cannot apply continues voltage to piezoelectric which adds complexity to control process. This paper devoted to control of satellite antenna by considering above mentioned limitation of control voltage and this is the main novelty of this study.

2. Elements of the Extended Abstract

Figure 1 shows the antenna of cubeSat.

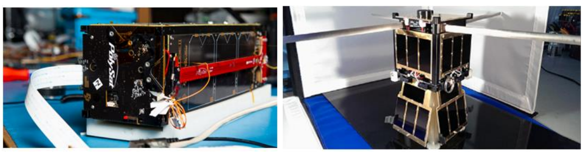

Figure 1. CubeSat antenna

In this paper, satellite antenna is modeled as clamped-clamped beam as shown in Figure 2.

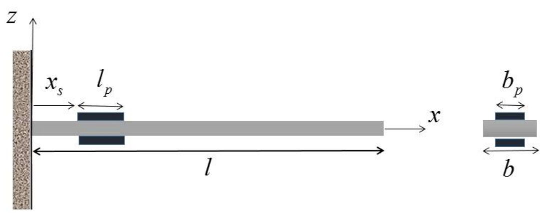

Figure 2. Clamped-Clamped beam with piezoelectric sensor and actuator

The equation of antenna motion can be written as forth-order partial differential equation which can be converted to ordinary differential equation using Galerkin method as Eq. (1).

$$\ddot{u} + 2\zeta\omega_n \dot{u} + \omega_n^2 u = k_p V_p(t) \tag{1}$$

In this equation, ω_n , ζ and k_p depends on antenna geometrical and physical parameters and V_p is the applied voltage to the piezoelectric actuator.

3. Control Algorithm

By applying the PID controller to this system as method 1, it is shown that the antenna vibration is controlled but it is not practical because of limitation of applied voltage to ± 100. To control the vibration of antenna following control algorithm is proposed as method 2:

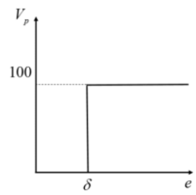

Figure 3. Control algorithm (method 1)

In this algorithm e is the beam end velocity error and δ is threshold. The last proposed algorithm is as follows:

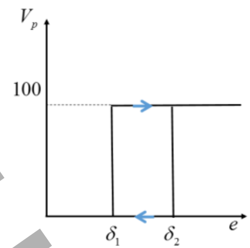

Figure 4. Control algorithm

This control algorithm can be written as following mathematical model:

$$V_p = \begin{cases} -100 & \dot{u} \geq \delta_2 \\ -100 & \delta_1 \leq \dot{u} \leq \delta_2 \ \& \ \ddot{u} \geq 0 \\ 0 & \delta_1 \leq \dot{u} \leq \delta_2 \ \& \ \ddot{u} \leq 0 \\ 0 & |\dot{u}| < \delta_1 \\ 0 & -\delta_2 \leq \dot{u} \leq -\delta_1 \ \& \ \ddot{u} \geq 0 \\ 100 & -\delta_2 \leq \dot{u} \leq -\delta_1 \ \& \ \ddot{u} \leq 0 \\ 100 & \dot{u} \leq -\delta_2 \end{cases} \tag{2}$$

In this algorithm e is the beam end velocity error and δ_1 and δ_2 are two thresholds which should be determined to reach the optimal solution. Because of importance of energy in satellite mission, objective function is defined as a linear combination of settling time and total energy consumption as follows:

$$f(\delta_1, \delta_2) = W_1 T_s + W_2 E \tag{3}$$

4. Discussion and Results

Figure 5 shows the vibration of antenna based on two proposed method. As seen in this figure the efficiency of method 3 is more than method 2.

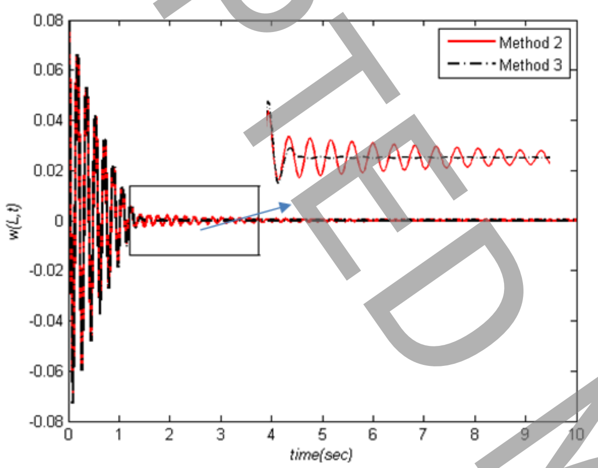

Figure 5. Antenna vibration based on two proposed method

Figure 6 compares the energy consumption of two proposed methods.

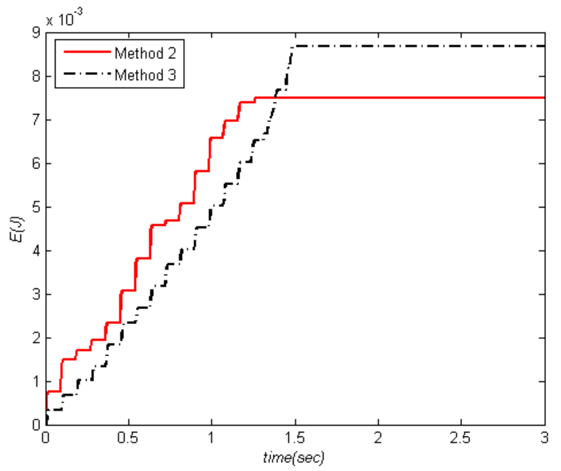

Figure 6. Energy consumption of two proposed methods

5. Conclusion

In this paper, control of cube sat antenna by considering the limitation of applied voltage to piezoelectric actuator is proposed based on different algorithms and the results are compared. The appearing parameters in control strategies are optimized using Genetic Algorithm. The results show that the proposed control strategies are efficient and can reduce the control time from 10 to about 1 second. The presented results in this paper are useful for design and control of antenna and also for accurate design of satellite control subsystem.

6. References

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