DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

PhD Public Defence

Title: Attitude Stabilization System for Marine Satellite Tracking Antenna

Location: AAU Esbjerg Campus, Room C1.119

Time: Thursday 26 April at 13.00

PhD defendant: Yunlong Wang

Supervisor: Associate Professor Mohsen Soltani

Moderator: Associate Professor Mette Hedegaard Thomsen

Opponents:
Associate Professor John-Josef Leth, Department of Electronic Systems, Aalborg University (Chairman)
Associate Professor Trung Dung Ngo, University of Prince Edward Island, Canada
Data Scientist Xiao-Zhi Gao, GIM Oy, Finland

All are welcome. The defence will be in English.

After the public defence there will be an informal reception in the vestibule (C2) at Esbjerg Campus.

DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

Abstract:

Marine Satellite Tracking Antenna (MSTA) is an important shipboard device for establishing communication between ships and the geostationary satellites. The attitude stabilization system is an important subsystem of MSTA, which is responsible for keeping the antenna dish tracking the geostationary satellite with high precision, in the existence of sever ship dynamics. For the Ka-band MSTA, the latest technology of MSTA, the design and implementation of the attitude stabilization system is very challenging. According to the performance requirements of the Ka-band MSTA product, the Root Mean Square (RMS) value of the tracking angle error should be less than 0.2 deg. Besides the high performance requirements, the cost of each component in the system also has to be considered, because the Ka-band MSTA under researching will be a commercial product of SpaceCom A/S. Trying to design an attitude stabilization system that can meet both of the two challenging requirements, high performance and low cost, is the task of this PhD project.

The attitude stabilization system of Ka-band MSTA mainly consists of the attitude sensor and attitude controller, the procedure of design and implementation of them are stated in this thesis. Many researching works have been done in this thesis about the theories and algorithms of attitude sensor. The classical Kalman filter, nonlinear attitude estimator based on LaSalle's invariance set theorem, multiplicative extended Kalman filter (MEKF), and virtual horizontal reference (VHR) attitude estimator, etc, are designed and implemented as the sensor fusion algorithm. In terms of the hardware design of attitude sensor, four versions of attitude sensor boards are designed and manufactured. The new version is always the improvement results of the old version, with the use of better electronic components and Microelectromechanical Systems (MEMS) sensors. After many times of improvements, the latest version of attitude sensor board can satisfy the requirements of the attitude stabilization system. Regarding the attitude controller board, it is also improved in terms of control algorithm and hardware. With respect to the control algorithm, the Model Predictive Controller (MPC) is explored firstly to handle the constraints in the attitude stabilization system, arising from stepper motors. The designed MPC algorithm can satisfy the system performance requirement in simulation environment, but not in real test system. After analysis, it found that the poor performance of MPC is caused by the low accuracy model of MSTA. Instead of improving the model accuracy, the robust control method is employed to copy with the problem of model uncertainly. The H-infinity loop shaping method, one of the popular robust control method, is applied as the attitude stabilization controller. From the hardware testing results, it can be found that the performance of the one-axis attitude stabilization system have satisfied the requirements of Ka-band MSTA.

The research about ship attitude prediction is also carried out by using Input Delay Neural Network (IDNN). It is believed that the performance of the attitude stabilization system can be increased if the ship motion can be predicted. Moreover, a data-driven optimization method is proposed based on a self-made test bench, the purpose of which is to optimize the algorithm parameters and also to minimize the cost of system components.