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Precise 3-D Vessel Velocity Measurement for Docking and Anchoring

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ABSTRACT

The purpose of our study is to evaluate a possibility of adaptation on Velocity Information GPS (VI-GPS) for docking and anchoring in places that have the conventional Speed and Distance Measurement Equipment (SDME). One experiment to survey VI-GPS of static and dynamic performances was carried out on land, and 3-D velocities of a ferryboat on the sea. From these experimental results, it was shown that the VI-GPS has a good performance for a vessel with respect to static and dynamic characteristics.

KEY WORDS: SDME; precise velocity; VI-GPS; K-GPS

INTRODUCTION

Since the latter mid of 70's, Doppler docking SONAR measuring three axes velocities that are fore/aft movement and side movements at bow and stern over ground within very high accuracy or 1 cm/s is applied to maneuver very large vessels such as Very Large Crude Carrier (VLCC). On the other hand, the docking SDME have been also developed, that was usually installed on the dolphin alone and the docking velocities and distances at bow and stern were presented to ship and shore side. Recently, due to the sonic disturbance, this docking SDME on dolphin is developed with application of a laser instead of an underwater ultrasonic. It is frequent and effective for the VLCC to apply the velocity information to maneuver adequately and safely. Therefore, it was recommended that the two axes SDME should be fitted out more than 50,000 gross tonnages in 2000 International Convention for the Safety of Life at Sea (SOLAS), (Supervision, 2002), (IMO, 2000). On the other hand, for usual navigator of standard size vessels or less, there are a lot of benefits to use of its precise velocity. Sometimes the navigators caused the collision with dolphin or pier and affected his workload to heavy.

Two experiments were carried out to evaluate a possibility of adaptation on the GPS velocity information for docking maneuvering in place of the conventional SDME. One experiment was done on roof of building. One GPS antenna was fixed on land as a reference station, and another GPS antenna was equipped with 3-D movable body. In this experiment, two velocity of the movable body by Kinematic GPS (K-GPS) and VI-GPS (Hou, 2005), (Yoo, 2006) were compared statically, and a step response and accelerated motion were tested dynamically (Tatsumi, 2006), (Kouguchi, 2006). Another experiment was done on the sea. One GPS antenna as a reference station was fixed on the land, and another three GPS antennas were equipped with the ferryboat. In this experiment, two velocities of this ferryboat by K-GPS and VI-GPS were compared.

In this paper, two velocity measurement methods by K-GPS and VI-GPS are described at first. Secondly two experimental outlines and results are discussed. From the experimental results on land, the performance on static and dynamic velocity information by GPS showed that the random error is 1cm/s with the moving average time 1sec when the Position Dilution of Precision (PDOP) is less than 3. On the other hand, from the experimental results on the sea, the velocity information by VI-GPS for docking maneuvering is better than the velocity by conventional SDME and/or K-GPS.

VELOCITY MEASUREMENT BY GPS

The observation equation for the GPS carrier phase measurements is the following:

$$\Phi = \rho + c \cdot (dt - dT) + \lambda N - d_{ion} + d_{trop} + \varepsilon_{\Phi} \qquad (1)$$

where Φ is the carrier-phase observation; ρ is the geometric distance between a satellite and a receiver; c is the light speed in free space; dt and dT are the receiver and satellite clock error respectively; λ is wave length; N is integer; d_{ion} and d_{trop} are the ionospheric and the troposheric delay; ε_{Φ} is the receiver noise and multi-path error.

Kinematic GPS (K-GPS)

The kinematic GPS uses the double differences technique and the carrier phase observation equation is the following:

$$\Delta\nabla\Phi = \Delta\nabla\rho + \Delta\nabla d\rho + \Delta\nabla\lambda N - \Delta\nabla d_{ion} + \Delta\nabla d_{trop} + \varepsilon_{\Delta\nabla\Phi} \qquad (2)$$

where $\Delta\nabla$ is the double difference operator. The double differences