ANDRZEJ FELSKI
Polish Naval Academy

EXPLOITATIVE PROPERTIES OF DIFFERENT TYPES OF SATELLITE COMPASSES

ABSTRACT

Satellite compass is the specific, multiantenna receiver of the satellite navigation system which, apart from the standard functions, like position, time, Course and Velocity etc. enable to measure the angles of the orientation of the ship's hull. The most popular solution is two--antenna solution, which gives opportunity to measure two angles: heading and pitch or roll. However, three antenna solutions are accessible as well (www.furuno.co.jp). In this option the device can measure full information about space orientation of the object. Discussed devices has common name 'compass' although they are still not officially confirmed in this role and according IMO's resolutions they can be used only as auxiliary source of information and is classified as Heading Transmitting Devices (MSC.116).

The origin of satellite compasses we can find in interferometry used in astronomy since sixties, however the present solutions in fact are adopted from Real Time Kinematic variant of GPS technology (Felski 1999). Nonetheless products accessible on the shelf are very diverse in construction, electronics and software so in practice of their exploitation very different proprieties could be observed.

In the report the practical experiences with the use of two different types of satellite compasses are presented, as well as the analysis of observed errors. It turned out that the behavior of satellite compass is not comparable to any gyro or magnetic compasses which are in fact something natural. In fact signal from satellite compass has three kinds of errors: first one is small noise with amplitude of same arc-minutes which is natural in any electronic devices, the second one is long-term changes which are seems be dependent on satellite constellation configuration and finally short, big changes correlated with transition period when new configuration of satellites is catches-on. According to the observations very important are solutions assumed in electronics and software, because observations confirm that two different constructions characterize themselves with very different proprieties.

Keywords:
GPS, Satellite compass, errors.

INTRODUCTION

For last few years the application of so-called satellite compasses on ships has become more and more popular. In fact these are specific, multiantenna receivers of the satellite navigation system and probably this is the reason why this new kind of equipment seems be familiar for seamen, in contrary to other new devices, which are not so easy adopted.

Satellite compass, apart from the standard functions offered by GPS receiver, enable to measure the angles of the orientation of the ship's hull, which means in fact the heading and roll or pitch. However at present they are not approved as the compass, but this device has minor price and his exploitation is very ease, without any maintenance needs. Because of that it can be find on the board of many ships more and more often. This refers especially small ships. According to common opinion there are systems designed as a low-cost alternative to conventional spinning-mass and fiber-optic gyrocompasses for application on workboats, commercial fishing vessels, large yachts, naval patrol boats, and small merchant ships, which are not required to carry a gyrocompass.

Interesting and surprising is the use of such devises in the army for tanks and other turreted vehicles, anti-tank Guided Missile Systems, Remotely Controlled Weapon Stations and Mobile Sat-Com for its maturity, inexpensiveness and combat--proving system offered by Israel Azimuth Technologies Ltd company (azimuth.co.il).

Although the origin of this equipment is Very Long Base Integration (VLBI) technique well-known from the astronomy in fact now it is the special case of RTK (Moving Base RTK). Both antennas: base (primary) and rover (secondary) are situated in strong relation to some axis of the ship. As we are not interested in very accurate determination of the position of antennas, basis among both antennas is constant and is situated in constant position to the hull of the ship the differences between each antennas and satellites gives the ability to determine the angles in two axes (on the figure 1 there are axes X and Z).

In fact, satellite compasses' producers do not describe in details design of his products. It causes certain doubts, which appear at the study of the comportment of satellite compasses. Of course the navigator on the ship is interested first of all in accuracy of measurement, at the foundation that the service is accessible and continuous. Thereby producers usually define the accuracy of heading determination with the value of the mean error, what is agreeable with IMO resolutions. In short, they assure that errors are less than one degree. Indeed, according to author's investigation presented during European Navigation Conference GNSS 2009 Conference in Naples and IAIN Congress in Stockholm the question of the accuracy of this devices is complicated. Accuracy of this kind of compasses during long term is in fact about one degree, but some of them periodically have very big errors what does not permit to use them as the sensor for autopilot for example.

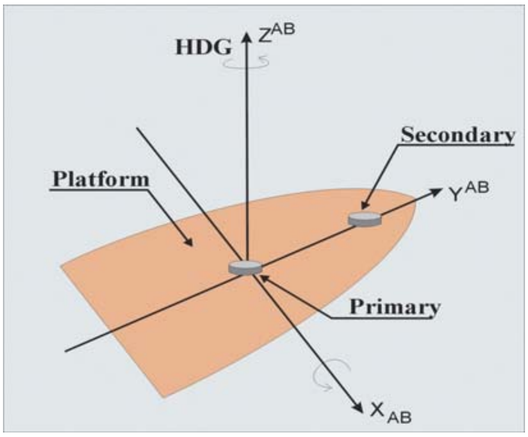


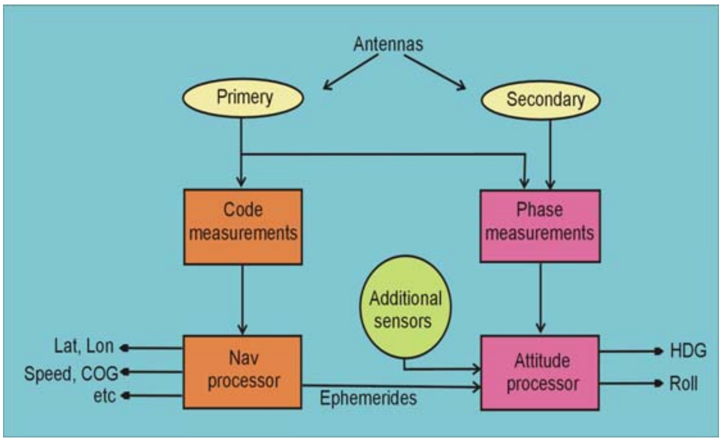
Fig. 1. The idea of measurements in the satellite compass

At the moment satellite compass can serve as a Heading Transmitting Device only, which means, that it can not replace gyrocompass on the standard ship. HDT should transmit stable heading reference information for radar, autopilot, chart plotter, sonar, automatic identification system, voyage data recorder, communication or TV antennas and the similar devices.

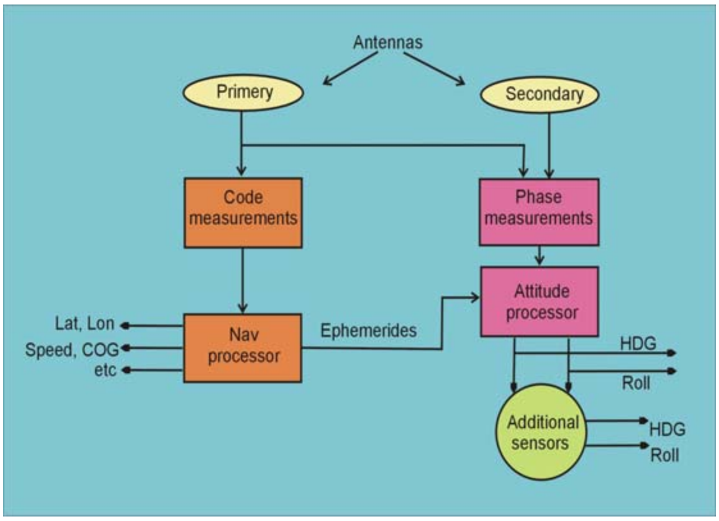
DIFFERENCES IN COMPASSES DESIGN

Reported investigation has been conducted with two different devices. Two compasses: Navistar made by Sperry and Crescent V100 of Hemisphere has been examined. Both, but also other satellite compasses offered on the market are the combination of the multiantenna receiver and additional sensors. In this function magnetic sensors or gyroscopes and accelerometers are apply. Additional sensors play a special role in case of disturbances in satellite signals propagation. Any way besides the kind of the sensor is used the important is its place in the electric diagram of the compass.

Satellite compass can be described as the code measurement receiver which works with so cold primary antenna and second additional chain for phase measurements, which works with both antennas. The phase measurement is the source of information about the angles of ship's body orientation. In one kind of solution additional sensors are included as augmentation equipment for the attitude determination in case of radio disturbances. In the second one additional sensors are in fact the source of attitude information, but they are still corrected by phase measurements channel, although pure information from phase measurements could be received also.



First solution



Second solution

Fig. 2. Two types of satellite compass designs

From above presented sketches we can lead out the conclusion that code measurement channel works independently to the attitude channel, so known character of errors in position determination is not connected with heading or pitch measurements. This is confirmed in the previous author's experiments.

It is commonly known that GPS receivers has some transition periods where new constellation of satellites is catches on or in the case of reflections of the signal (multipath). Gyro sensors or magnetic ones (fluxgate type) output signal is much more stable and this is clearly visible during experiments with both types of compasses.

On figure 3 a typical example of more than 80000 measurements by means of two types of compasses is presented. This registration was performed at intervals of one second, so it lasts more then 20 hours. On this figure several cases of big errors of needle type could be observed in the registration by means of the first type of compass. The second one has in fact free of them.

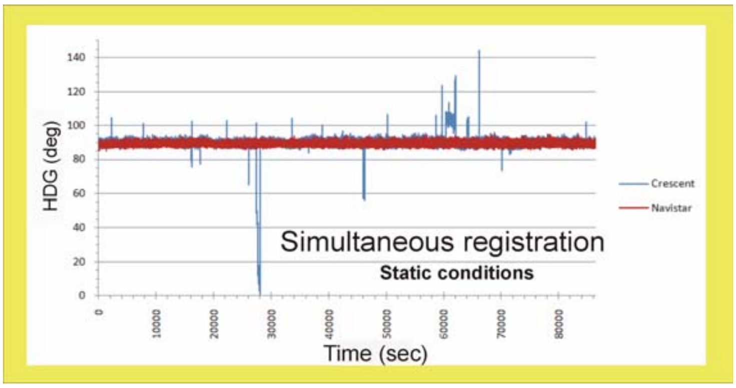


Fig. 3. Comparison of heading plots made with two different devices in the static condition

Both compasses have been examined in dynamic conditions: on railway-trolley which constitutes very repeatable conditions for experiments and during sea tests on the cutter as a part of master thesis prepared by P. Kasjaniuk under author's supervision. Similar errors as in static conditions have been observed during measurements made on the railway-trolley. The experiment has been executed several times on the straight section of railways (see fig. 4) with partially shadowed sky.

Fig. 4. Railways experiments [Kasjaniuk, 2010]

Some results of the first type of compass are presented on the figure 5. It is worthy to notice that errors are no correlated, which mean no influence of environment. Periods of experiments has been no related to satellite constellation so we can account observed errors influenced by constellation.

Example of both compasses behaviors in dynamic condition is presented on the figure 7. There are results of tests made on the small hydrographic cutter presented on the figure 6. On the figure 7 an example of zig-zag maneuvers of the cutter equipped with both types of compasses is presented.

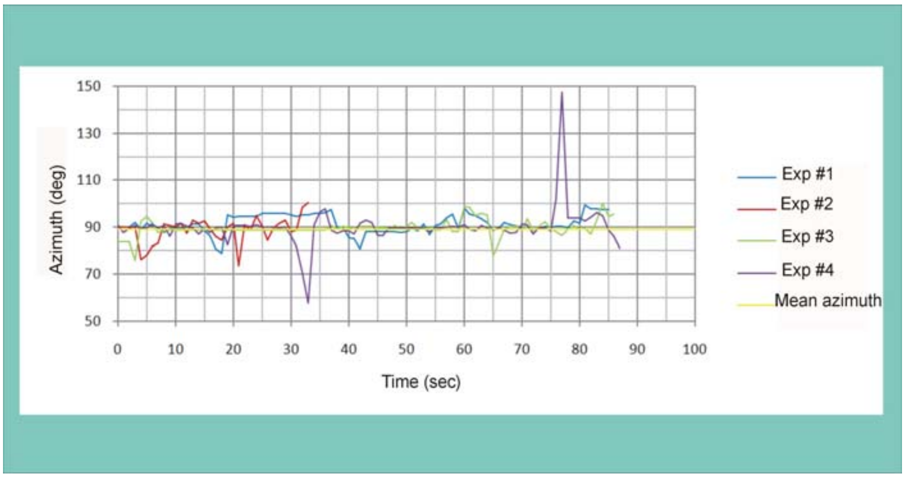


Fig. 5. Examples of rides on tests track

Fig. 6. Cutter used for measurements

It is noticeable that Crescent has bigger oscillations after the turn and has some latency, which is probably caused by filter. In fact helmsman did not steer on the constant heading during this period, but in gives us opportunity to observe behavior of both compasses. Crescent is late with relation to ship's heading changes and it has his own oscillation bigger than Navistar.

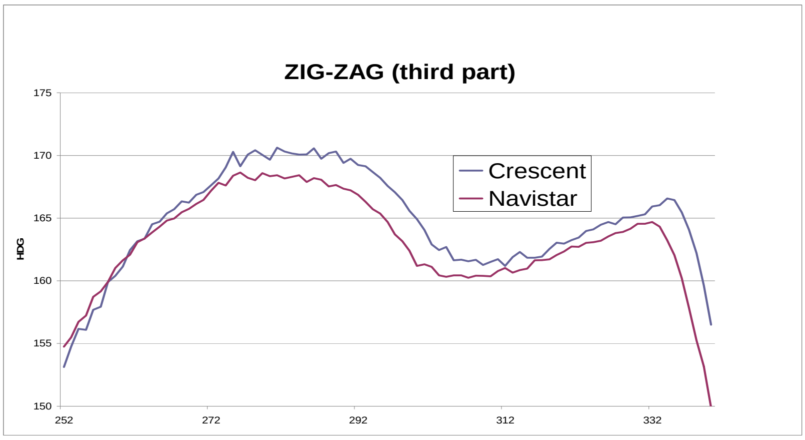


Fig. 7. The example of heading determined on zig-zag maneuver

Very similar picture in the different experiments has been observed as well static as dynamic. The second type of satellite compass is free of aperiodical big errors of heading (needle type) but it has smaller errors in general also. In static conditions it is three times smaller when one degree which is the average error of the Crescent.

CONCLUSIONS

The mass-introduction to the practice of satellite compasses, which in the author's opinion will take place in the nearest future, requires the recognition of the specificity of these devices. Analyzing the presented experiments author arrive at a conclusion that design of hardware of this compasses plays primary role in quality of measurements. Compasses of first type (according the fig. 3) have its own specificity, which can lead to large temporary errors. Indeed such errors can be greater than 10 deg; however they do not appear in a period longer than one minute. It seems that partially the reason of these errors have a relation with the place of the installation of the antenna, what means that special care at the choice of the place of its installation should be kept, but in the same situation compasses of second types are free of such errors. So concluding presented considerations we can ascertain that choosing the satellite compass for the ship the second type of construction ought to be preferred.

According to the observations the second type of errors of satellite compasses could be specified also. It is very low frequency errors with period of hundreds of minutes. No kinds of errors are supposed to be related to known characteristic of quality of observations in satellite measurements like, for example, HDOP, number of visible satellite or elevation.

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