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Original research article

Research on short-range azimuth detection accuracy based on magnetic dipole model

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ABSTRACT

In order to achieve the target azimuth detection, this paper uses magnetic measurement azimuth on the basis of laser ranging. A rotary scanning magnetic dipole model was established and the target-azimuth solution was achieved using a periodic-phase detection algorithm. Combining magnetic dipole model and target azimuth solution method, the influence of the distance between the sensor and the magnetic core, the rotation scanning detection period, the signal detection threshold and the standard deviation of the probability density of noise signal on the statistic distribution of azimuth measurement are analyzed. The accuracy of azimuth detection is studied by numerical simulation and measurement experiment.

1. Introduction

The proximity azimuth measurement technology is the key to achieve target detection and precise guidance [1–3]. Due to the limitation of environment, space and power consumption, it is difficult to realize the short-range azimuth measurement by using the traditional measurement methods for small moving bodies and unmanned aerial vehicles (UUVs) [4–8].

The laser has the advantages of high precision and good directivity [9,10]. It has been widely used in detection, ranging and imaging [11,12]. For laser azimuth detection, laser imaging is a common method [13–15]. This method can achieve higher resolution azimuth measurement, but due to the use of area detector, the detection unit is numerous and the imaging algorithm is complicated. In addition to the laser imaging, there is a multi-window azimuth detection method [11]. This method can achieve the target omnidirectional detection, but large number of optical windows and detectors result in large volume and low system stability [15].

In this paper, a short-range azimuth measurement system is presented. The target is scanned by single laser beam which is driven by motor; at the same time, the rotating alternating magnetic field is detected by using micro-magnetic sensor, corresponding to the laser echo time, the target azimuth information is solved.

2. System description and theory

2.1. System description

Fig. 1 shows L-M short-range azimuth measurement system. This system mainly includes laser proximity detection module, magnetic azimuth solution module and azimuth solution module.

The information transfer case of the laser proximity detection system shown in Fig. 2. Target distance and azimuth information are measured by the laser receiver module and azimuth measurement module, finally, signal processing circuit comprehensive and

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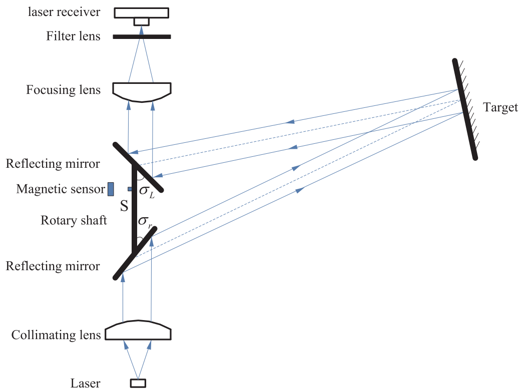

Fig. 1. The setup of the Laser proximity azimuth detection system.

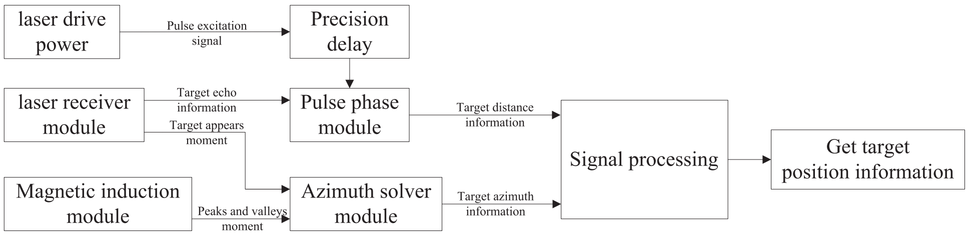

Fig. 2. Schematic diagram of system signal transfer.

solve the distance and azimuth.

This system has the advantages of small size, high real-time performance, and low power consumption, so it is more efficient and reasonable than the traditional methods described above.

2.2. Magnetic dipoles model

The target azimuth dynamic detection is achieved by the rotation of the scanning method, the mathematical model of rotation scanning cycle magnetic signal is established as follows. First of all, to establish a rectangular coordinate system, set the center of the trajectory of the magnetic core as the origin, when the magnetic core and the sensor are in the right direction, it is stipulated that the direction of the central connecting line is the x-axis. The material of cylindrical core is NdFeB, it is counterclockwise scanning, the track is a circle of radius r and the speed is ω, the N, S pole respectively located on both ends, and the axis is located in the xoy plane. Using the HMC1021 magnetic sensor to detect the magnetic core in the Y-axis direction, the magnetic core rotation periodic signal is obtained. At the same time, defining the moving coordinate system $o_m x_m y_m$ of the magnetic core, the origin is the center of the magnetic core, setting the central axis as the y_m axis, making the magnetization direction is the positive direction of the y_m axis. Assuming that the magnetic core and Y-axis Angle are θ, the coordinates of the sensor are as follows:

$$\begin{cases} x_m = L\sin\theta \\ y_m = L\cos\theta - r \end{cases} \tag{1}$$

The magnetic field distribution of the permanent magnet core in the above model can be described by the magnetic dipoles (MD) model. The magnetic source is regarded as a magnetic dipole, therefore, for a cylindrical permanent magnet core, the magnetic induction B at any position outside can be expressed as:

$$\vec{B}(\vec{m}, \vec{r}) = \frac{\mu_0}{4\pi r^5}[3(\vec{r}\cdot\vec{m})\vec{r} - r^2\vec{m}] \tag{2}$$

Where $\vec{m}$ is the magnetic dipole moment, set as (0, m), m is the size of the magnetic dipole moment, $\vec{r}$ is the vector between field sources. Each axial component of magnetic induction in follower coordinate system can be derived as:

$$\begin{cases} B_{xm} = \frac{3m\mu_0}{4\pi r^5}L\sin\theta(L\cos\theta - r) \\ B_{ym} = \frac{m\mu_0}{4\pi r^5}[2(L\cos\theta - r)^2 - L^2\sin^2\theta] \end{cases} \tag{3}$$

By the transformation of the coordinate system, the magnetic field components of the magnetic core in the y-axis direction is: