Radiation Characteristics Test of FOG Circuit Magnetic Field

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Abstract: Aiming at the magnetic field issue in the engineering application of fiber optic gyroscope (FOG), this paper explores the distribution law of magnetic field generated by the internal circuit of gyroscope and builds an electromagnetic field distribution scanning system to complete the test. The experimental results show that the overall radiation of FOG circuit magnetic field is low, and the front circuit radiation intensity is higher than that of bottom circuit. The front radiation is strongest at 8.76MHz, approximately 0.01mGs. It is of referential significance for the study of FOG magnetic sensitivity.

1. Introduction
Since the fiber optic gyroscope (FOG) came out in 1976, it has become a research hotspot in the field of domestic inertial instrument in recent years. FOG features all solid state structure without rotatable parts, large dynamic range, fast response speed, low power consumption, resistance to shock vibration, short start-up process, long service life and other advantages. It can be widely applied in military and civilian fields [1]. The operating principle of FOG is based on the Sagnac effect of optical path. The sensing component is a fiber optic ring. The fiber optic ring is not only sensitive to the non-reciprocal phase shift generated by Sagnac effect, but also sensitive to a variety of physical quantities. Therefore, the external environment is easy to produce a variety of nonreciprocal errors in FOG, and the error is superimposed on the Sagnac effect of FOG, which will lead to the change of the zero deviation of FOG output [2-4].

In the practical application of FOG, magnetic field is an inevitable interference source. So, it is of great significance to study the FOG magnetic field to avoid interference and ensure the precision of FOG. The magnetic fields faced by FOG include external magnetic field and internal magnetic field. External magnetic field includes earth magnetic field, power frequency interference and other environmental magnetic fields. Internal magnetic field is mainly generated by circuit boards, wires and photoelectric components [5-6]. The geomagnetic field belongs to the static and uniform magnetic field. This paper mainly analyzes the distribution law of the magnetic field generated by the internal circuit of gyroscope.

2. Test of the Radiation Magnetic Field of FOG Internal Circuit
2.1. Test Equipment
The test system consists of electromagnetic field scanner, spectrum analyzer, computer control and display software. The circuit board of FOG is scanned for electromagnetic field radiation characteristics, as shown in Figure 1. Electromagnetic field scanner adopts Sweden DETECTUS’ RX644EH electromagnetic field distribution scanner for thermal distribution, and spectrum analyzer...
adopts Agilent's E4440A spectrum analyzer to scan the circuit board of FOG for electromagnetic radiation characteristics. The scanning system can accurately measure the electromagnetic and thermal radiation of circuit board, cable and whole device to determine the intensity and location of component and radiation source. The measurement results can be presented in the form of two-dimensional or three-dimensional color graphics.

Figure 1. Electromagnetic Field Distribution Scanning System

2.2. Circuit Scanning
The main circuit of FOG is a double-sided circuit board, as shown in Figure 2 and 3. Electronic components and circuit board wiring are different on both sides. Hence, the radiation characteristics on both sides will be different. Therefore, the magnetic field radiation characteristics of circuit board are conducted scanning and test on both sides separately.

Figure 2. Front Circuit
Figure 3. Bottom Circuit

According to the size of circuit, the scanning range of scanner is 0~70mm on the horizontal axis and 0~70mm on the vertical axis. The probe height is 10mm higher than that of the circuit board. The probe movement step size is 5mm. The antenna ring of magnetic field probe is placed horizontally, and the sweep frequency range of spectrometer is set as 0~50MHz through software, the resolution bandwidth is 9kHz, video bandwidth is 30kHz and the scanning frequency is 5 times. The scan is conducted twice: pre-scan and precision scan. First, the whole circuit is pre-scanned to obtain the frequency points with high radiation intensity of circuit board. According to the results of pre-scanning, the frequency points with high radiation intensity are targeted and then the positioning and accurate scanning are conducted to obtain the distribution map of magnetic field radiation intensity of each part of circuit board with different frequencies.

According to the pre-scan results, the frequency points with large radiation are 8.761mhz,
35.047mhz, 17.524mhz, 43.808mhz and 26.285mhz. Of which, the fundamental frequencies with the strongest radiation are 8.761mhz, 35.047mhz, 17.524mhz, 43.808mhz and 26.285mhz, and they are the higher harmonics of the maximum radiation frequency point 8.7612mhz.

The distribution of magnetic field radiation intensity of partial accurate scanning is shown in Figure 4. By comparing the radiation intensity distribution diagram with Figure 2, it is found that the magnetic field radiation of front circuit is higher mainly in the vicinity of digital-to-analog converter DAC, FPGA chip, active crystal oscillator and PIN-FET detector (photoelectric converter).

![Figure 4. The Magnetic Field Radiation Intensity Distribution of Front Circuit at Different Frequencies](image)

(a) 8.761MHz  (b) 35.047MHz  (c) 17.524MHz

According to the test method of abovementioned front circuit, the radiation characteristics of FOG bottom circuit are tested. During the test, the setup of software and spectrometer and the placement of probe are exactly the same as that of front circuit. Firstly, the whole circuit is prescanned. According to the results of pre-scan, the frequency points with greater radiation are 8.761mhz, 17.524mhz, 26.285mhz and 35.047mhz. Among them, 17.524mhz, 26.285mhz and 35.047mhz are the higher harmonics of the maximum radiation frequency point 8.7612mhz. This indicates that the fundamental frequency with the strongest radiation is 8.761mhz, which is basically consistent with the pre-scan results of the front circuit. According to the results of the pre-scan, the accurate positioning scan is conducted. The radiation intensity distribution of partial magnetic field is shown in Figure 5. By comparing the radiation intensity distribution diagram with Figure 3, it is found that the area with strong magnetic field radiation in the bottom circuit is mainly near the PIN-FET detector (photoelectric converter)’s pin and individual capacitance.

![Figure 5. Distribution of Magnetic Field Radiation Intensity of Bottom Circuit at Different Frequencies](image)

(a)30.72MHz  (b) 44.239MHz  (c) 30MHz

3. Experimental Results

As the near-field probe of field distribution scanning system is not calibrated, only relative value of circuit board radiation intensity can be given. So, it is necessary to calibrate the field probe of the scanning equipment with other field intensity meters and standard radiation sources. Based on the
calibrated probe antenna coefficient and the values read by the scanner at time of circuit board measurement, the magnetic field intensity and magnetic induction intensity (air medium) radiated by the gyroscope circuit can be calculated, as shown in Table 1 and Table 2.

**Table 1. Magnetic Field Radiation Intensity of Front Circuit of Gyroscope**

| Frequency (MHz) | Spectrometer Readings (dBμV) | Magnetic Field Intensity (A/m) | Magnetic Induction Intensity (mGs) |
|-----------------|-------------------------------|-------------------------------|-----------------------------------|
| 2.098           | 0.7                           | 0.000146                      | 0.001838                          |
| 4.195           | -4.1                          | 0.000427                      | 0.00536                           |
| 8.76            | 8.8                           | 0.000796                      | 0.010004                          |
| 17.52           | 2.6                           | 0.000279                      | 0.003503                          |
| 26.28           | 0.9                           | 0.000177                      | 0.002225                          |
| 35.05           | 3.2                           | 0.000363                      | 0.004563                          |
| 43.8            | 0.9                           | 0.000165                      | 0.002078                          |

**Table 2. Magnetic Field Radiation Intensity of Bottom Circuit of Gyroscope**

| Frequency (MHz) | Spectrometer Readings (dBμV) | Magnetic Field Intensity (A/m) | Magnetic Induction Intensity (mGs) |
|-----------------|-------------------------------|-------------------------------|-----------------------------------|
| 2.098           | 0.8                           | 0.000148                      | 0.001859                          |
| 4.195           | -5.6                          | 0.000359                      | 0.00451                           |
| 8.76            | -0.5                          | 0.000306                      | 0.003847                          |
| 17.52           | -3.6                          | 0.000137                      | 0.001716                          |
| 26.28           | -10.7                         | 0.000047                      | 0.000585                          |
| 35.05           | -7.7                          | 0.000104                      | 0.001301                          |

From the tables, it can be found that the overall radiation of gyroscope circuit is low, while the radiation intensity of front circuit is greater than that of the bottom circuit, which indicates that the overall electric field radiation of bottom circuit is weak. The front radiation is strongest at 8.76MHz, approximately 0.01mgs. According to the above test results and for convenience of comparison, they can be summarized as the following table:

**Table 3. Scan and Calibration Results**

| Magnetic Field | Front Circuit | Bottom Circuit |
|----------------|---------------|----------------|
| Frequency Points with Larger Radiation | Strong → Weak: 8.761MHz, 4.195MHz, 35.047MHz, 26.28MHz, 17.524MHz, 43.80MHz, 2.098MHz | Strong → Weak: 4.195MHz, 8.761MHz, 2.098MHz, 17.52MHz, 35.05MHz, 26.28MHz |
| Generated position | DAC, FPGA chip, active crystal oscillator and PIN-FET detector | PIN-FET detector pins, individual capacitors |
| Strongest Frequency Point | 8.762MHz (Calibrated magnetic field intensity: 0.01mGs) |

**4. Conclusions**

Magnetic sensitivity is one of the research contents of FOG environmental adaptability. In this paper, the radiation characteristics of magnetic field generated by gyroscope signal detection circuit are studied. The experimental results show that the overall radiation of gyroscope circuit is low, the
radiation intensity of front circuit is higher than that of bottom circuit, and the front radiation is the strongest at 8.76MHz, approximately 0.01mGs. In addition, the driving circuit of light source is also one of the components of gyroscope circuit, and the radiation characteristic of generated magnetic field is the next research content.

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**Acknowledgments**

This work was financially supported by Natural Science Foundation of Hebei Province (F2016506014).

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