Comparative Assessment of Ramp and Biasing Signal Amplitude Variations of Digital Closed-Loop Fiber Optic Gyroscope

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Abstract: *Fiber optic gyroscope is a rotation sensor working on the principle of Sagnac effect. Fiber optic gyroscopes are used in inertial navigation system, aircraft, guidance, etc. FOG has to be operated in closed loop condition to achieve inertial grade performance. In the closed-loop operation, the ramp signal is used as a feedback signal to nullify the rotation induced sagnac phase shift. The peak to peak voltage of ramp is equal to V2π voltage of IOC (Integrated Optic Chip). A biasing signal is also applied to IOC for intensity modulation. If the variations in the ramp and biasing signal are occurred, then it introduces variations in the gyro performance. The gyro performance is evaluated in terms of bias, scale-factor and linearity.*

Keywords: FOG, closed loop fiber optic gyroscope, DPEC (Digital Phase Estimator Card).

1. Introduction

Earlier Inertial Navigation Systems (INS) based on mechanical gyroscopes were heavy, complex and of limited bandwidth, dynamic range and reliability. Their reaction time was large and the instrument was difficult to maintain. Optical gyroscopes such as Ring Laser Gyros (RLG) and Fiber Optic Gyros (FOG) are far more superior to their conventional counterparts because of low reaction time, no `g' sensitivity drift, wide dynamic range, high accuracy and reliability which is the need for modern inertial navigation systems. These problems lead to very low production rate and hence the high cost. However RLG is a complex technology challenge as it needs very good quality optical components. It also has a problem of dead zone because of coupling between backscattered light with counter rotating beams.

FOG based on Integrated Optic Chip (IOC), temperature controlled super luminescent diode (SLD) and polarization maintaining (PM) fiber along with digital signal processing can give compact, passive, all solid state gyro as a better alternative to mechanical gyros.

2. Principle

Sagnac first demonstrated the optical gyroscope principle in 1913. Optical gyroscopes implemented so far use Sagnac effect, which states that an optical path difference induced by counter propagating beams in a rotating frame is proportional to the absolute rotation.

$$\Delta\phi_s = \frac{2\pi L D \Omega}{\lambda c}$$

Where D is the diameter of the sensor coil, L is the length of the optical fiber, λ is light wavelength and c is the speed of light in vacuum.
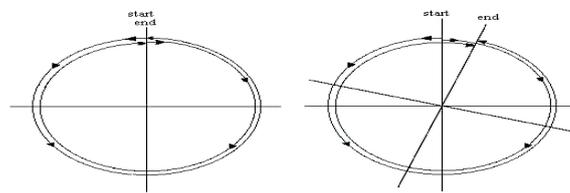
Figure 1: Sagnac effect

3. Block Diagram
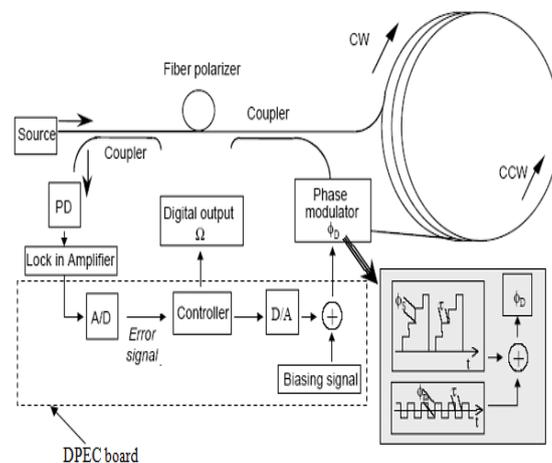
Figure 2: Block Diagram

The lock-in amplifier output is sampled and quantized yielding the eeror signal, which is maintained close to zero by the digital feedback. The sampling frequency corresponds to the inverse of the radiation transit time τ, for the required synchronization of the ramp and the biasing signal. Starting from the error signal, the controller drives the phase modulator so that it generates phase steps of amplitude equal to the Sagnac phase shift and duration τ. The digital to analog converter automatically creates the ramp reset, by means of its overflow. The reset step corresponds to a phase variation of 2π radian, in order to get always correct Sagnac phase shift. In this configuration, there is phase stability during signal recovering.

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The filtering and amplification process is done in controller. If the filtering and amplification are properly adjusted then the feedback loop will adjust the feedback phase shift so that it is always nearly equal and opposite in sign to the Sagnac phase for all constant input rotation rates.

$$\phi_f = -\Delta\phi_s$$

Equation implies that the total phase shift (i.e., the sum of the feedback and the sagnac phase shifts) around the fiber sensing loop is nearly equal zero. Such fiber gyros are also called phase nulling gyros. The output of the CLFOG is now the electrical signal applied to the feedback element.

4. Working Methodology

4.1 Comparison of ramp and biasing signal effects:

There are many effects which affect the performance of gyroscope. In this paper we are presenting about scale factor, linearity and % error.

4.1.1 Procedure

Step 1: Biasing signal amplitude is fixed and ramp signal amplitude variations are done
Step 2: Ramp signal amplitude is fixed and biasing signal amplitude variations are done.
Step 3: Both ramp and biasing signal amplitude variations are done simultaneously.

4.2 DPEC Board

The DPEC (Digital Phase Estimator Card) accepts the rotation induced modulated Sagnac phase error data output of CLFOG system and digitizes for further signal processing. It integrates the demodulated Sagnac phase error to generate stair case feedback phase nullifying signal again. It forms closed loop functionality with an integral controller. It provides feedback phase nullifying signal and bias to the modulator (IOC) of the FOG. The DPEC board transfers the phase integrator output to the host by compensating the temperature induces bias errors, upon the request of synchronization pulses.

4.3. RS232/RS422 Interface

This interface is used for communicating with PC application software, which was implemented on UART.

5. Results

The scale factor plot for ramp variations is done. The scale factor change is more as the error is increasing.
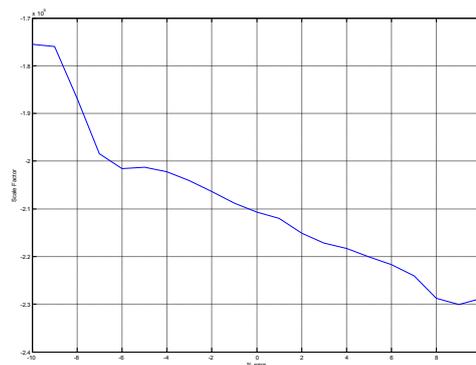
Figure 3: Scale factor for ramp signal variations
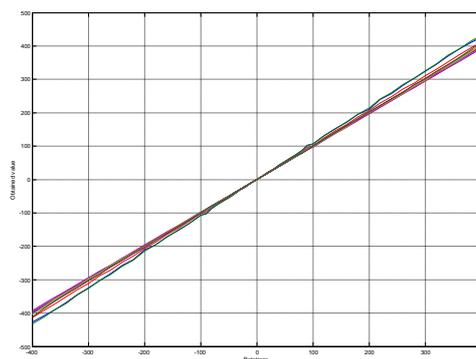
Figure 4: Linearity for ramp signal variations
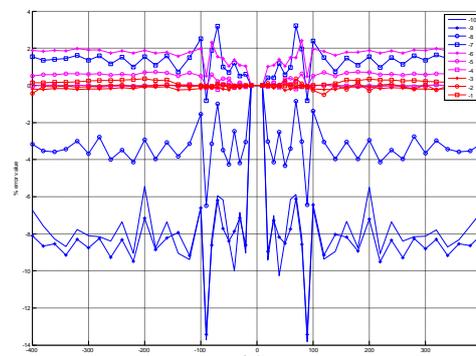
Figure 5: % of error for ramp signal variations
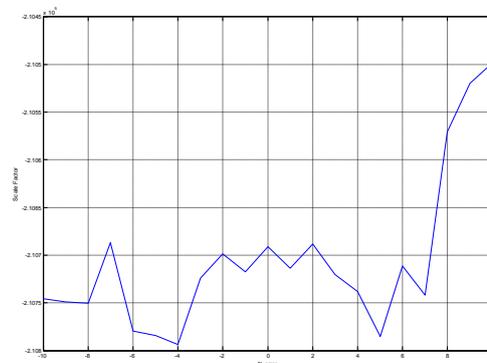
Figure 6: Scale factor for biasing signal variations
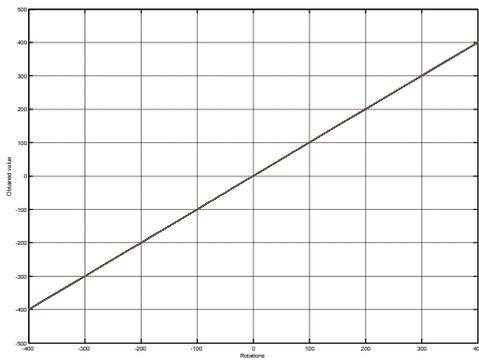
Figure 7: Linearity for biasing signal variations

Figure 8: % of error for biasing signal variations
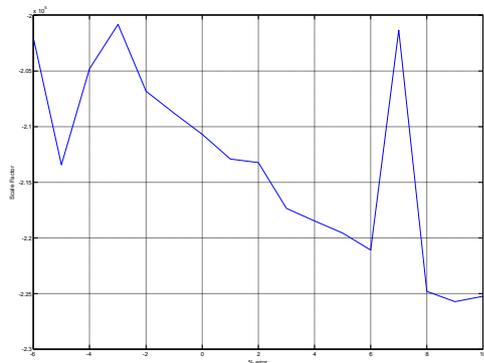
Figure 9: Scale factor for ramp and biasing signal variations
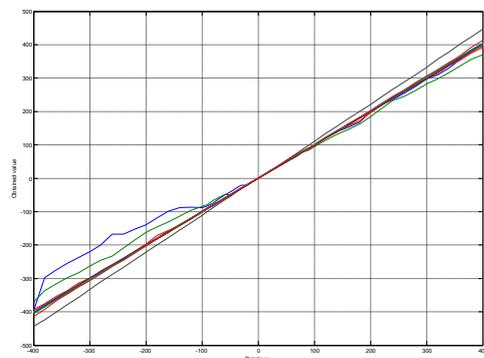
Figure 10: Scale factor for ramp and biasing signal variations

Figure11: % of error for ramp and biasing signal variations

6. Conclusion

If the variation in the gyro parameters is occurred, then it introduces variations in gyro performance. The scale factor change is less when ramp amplitude is kept constant and square amplitude is varying. If both ramp and biasing signal amplitude are changed then at particular points the rotation are not sensed. The perfect linearity is occurred when ramp amplitude is kept fixed.

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