Sensor Fiber Optic Demodulation Methods

Article Overview

Fiber optic sensor demodulation extracts physical parameters from optical signals, with methods including intensity, spectral, and phase-based techniques, optimized for speed, accuracy, and multi-parameter sensing.

Overview of Fiber Optic Sensor Demodulation

Fiber optic sensors, particularly Fabry-Perot interferometers (FPIs), are widely used due to their high sensitivity, immunity to electromagnetic interference, compact size, and ability to operate in harsh environments . Demodulation is the process of converting the optical signal reflected or transmitted by the sensor into measurable physical quantities such as pressure, temperature, vibration, or acceleration . The choice of demodulation method directly affects the resolution, speed, dynamic range, and accuracy of the sensor system.

Common Demodulation Methods

o Intensity Demodulation This method relates the intensity of reflected light at one or multiple wavelengths to the cavity length of the Fabry-Perot sensor. It is simple and suitable for high-speed measurements but can be sensitive to noise and has limited measurement range .

o Spectral Demodulation Spectral methods analyze the interference spectrum of the sensor. Techniques like Fourier transform or coarse spectral sampling allow extraction of cavity length and phase information. Spectral demodulation can achieve high accuracy and is suitable for dynamic and static measurements .

o Phase Demodulation Phase-based methods extract the phase change of the interference signal, which corresponds to the physical parameter being measured. Advanced algorithms, including nonlinear differential equations and maximum likelihood estimation (MLE), improve accuracy and allow real-time high-speed demodulation . Phase demodulation is particularly effective for multi-cavity or multi-parameter sensors.

o Cross-Correlation and Non-Scanning Methods For sensors with multiple reflective surfaces, cross-correlation compares the sensor spectrum with a reference to find the maximum correlation, while non-scanning low-coherence interference methods detect optical path differences without mechanical scanning . These methods are suitable for multi-parameter and high-speed applications.

High-Speed and Real-Time Demodulation

Recent developments focus on real-time demodulation for transient signals. Techniques include:

o Coarse spectral sampling combined with FFT and MLE to achieve speeds up to 50-80 kHz while maintaining nanometer-level accuracy .

o Dense wavelength division multiplexing (DWDM) to split broadband spectra into multiple optical paths for parallel processing .

o FPGA-based digital signal processing for fast acquisition, transmission, and computation, enabling simultaneous measurement of multiple parameters .

System Design Considerations

A typical demodulation system includes:

o Transmitting module: emits light over a predetermined wavelength range.
o Fiber-optic Fabry-Perot sensor: reflects light with phase changes corresponding to the measured parameter.
o Light splitting and filter modules: separate the reflected light into multiple beams for analysis.
o Receiving module: converts optical signals into electrical signals.
o Processing module: applies algorithms (FFT, MLE, cross-correlation) to extract physical parameters . These systems are designed for high sensitivity, multi-parameter measurement, and robustness in extreme environments, making them suitable for aerospace, structural health monitoring, petroleum, and medical applications .

Key Takeaways

o Demodulation method selection depends on the sensor type, measurement speed, accuracy, and environmental conditions.
o Phase and spectral methods are preferred for high-precision and multi-parameter sensing.
o Real-time high-speed demodulation is achievable using coarse spectral sampling, FFT, MLE, and FPGA-based processing.
o Multi-cavity sensors require advanced methods like cross-correlation or non-scanning low-coherence interference to handle complex spectra. Fiber optic sensor demodulation continues to evolve, enabling faster, more accurate, and versatile sensing solutions across diverse industrial and scientific applications .

PDF | Demodulation methods are fundamental in the creation of high-performance interferometric fiber-optic

However, the per-formance and functionality of these sensors heavily rely on advancements in demodulation technology. The

This paper addresses the issue of low demodulation accuracy in interferometric signals caused by significant errors in

To address the challenges of parameter decoupling and low demodulation accuracy in fibre-optic interferometric dual-parameter

Then, the influencing factors of the common demodulation methods are described in detail, and the improvement methods proposed

This paper presents a method that integrates neural networks with arrayed waveguide gratings (AWGs) for

Interferometric optical fiber sensors based on wavelength demodulation play an important

Accurate demodulation of fiber-optic sensors is crucial for real-world engineering applications in monitoring and control. This paper

Fiber-optic interferometric sensors (FOISs) based on multiple-beam interference principle have been applied to many

The website is undergoing a system upgrade and is currently unavailable.

Abstract In response to the rapid demodulation requirements of optical fiber Fabry-Perot sensors for high-frequency

Sufan Yang, Chunxi Zhang, and Xiaxiao Wang Abstract Fiber-optic distributed acoustic sensors (DASs) can be used for various

To get rid of the dilemma between the speed and the resolution of optical fiber Fabry-Perot (F-P) magnetic field

This study proposes a high-frequency pneumatic system and demodulation method based on polydimethylsiloxane (PDMS) film

Accurate demodulation is essential for a deeper understanding of the physical processes in fiber optic sensing

This review highlights key breakthroughs in achieving high spatial resolution and high-speed interrogation through

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