

Chapter 5 – Active/Passive Hybrid Temperature Compensation and Signal Demodulation

5.1 Concept of Active/Passive Hybrid Compensation and Demodulation

The output of a sensor usually contains the components of external disturbance (i.e. temperature change, vibration etc.). In this section, a new method is proposed to reduce these unwanted effects. In the new scheme, the sensor is operated in the ‘quadrature operation’ nonlinear region of the magnetostriction curve as shown in Figure 5.1.

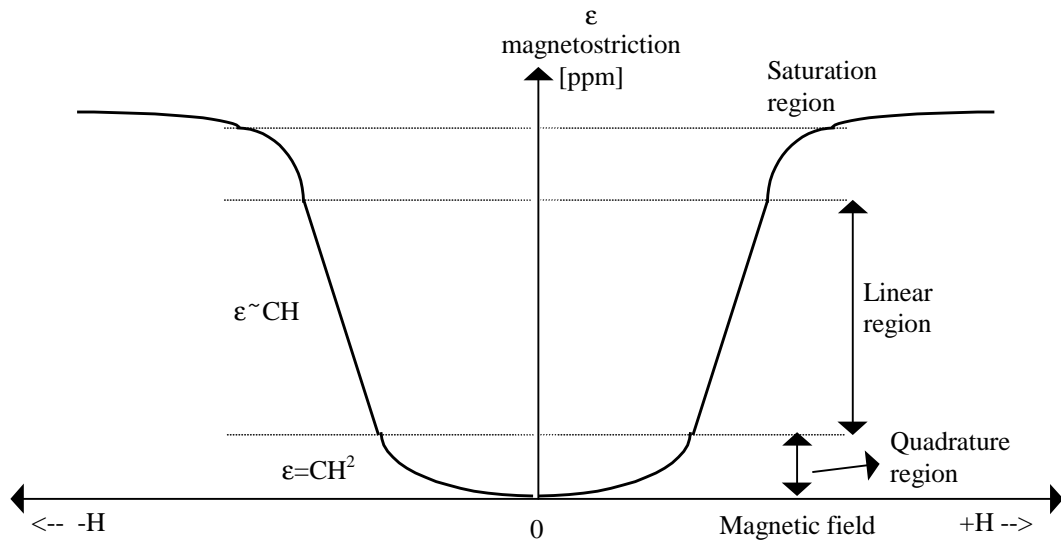


Figure 5.1 Operating regions of the sensor.

Let the DC magnetic field to be measured be H_{dc} and the amplitude of the dither magnetic field at an angular frequency of ω be H_{ac} . Thus the total magnetic field imposed on the sensor gage H is given as

$$H = H_{dc} + H_{ac} \cos(\omega t) \quad (5.1)$$

The magnetostriction of the sensor gage is given as

$$\varepsilon = C.H^2 \quad (5.2)$$

where C is the magnetostrictive coefficient in that operating range. The phase change in the output of the sensor is

$$\Delta\varphi = n.k.\Delta L = n.k.2.\Delta l = 1.\frac{2\pi}{\lambda} 2.\Delta l \quad (5.3)$$

where λ is the wavelength of the source. $n=1$ for air, and Δl is the airgap change. Since the output of the sensor is given by $V = \frac{V_p}{2}(1 + \cos \varphi)$, for small exturbances the output voltage V becomes

$$dV = -\frac{V_p}{2} \sin \varphi .d\varphi \quad (5.4)$$

Δl in Equation (5.3) can be expressed as

$$\Delta l = \Delta l_H + \Delta l_T = \varepsilon.l_0 + CTE.l_0.\Delta T \quad (5.5)$$

where l_0 is the gage length, ε is the strain due to external magnetic field, CTE is the coefficient of thermal expansion of the Metglas material and ΔT is the change in ambient temperature. Substituting Equations (5.2), (5.3) and (5.5) in Equation (5.4), we have

$$\Delta V = -\frac{V_p}{2} \sin\left(\frac{4\pi}{\lambda}(l + l_0.CH^2 + l_0.CTE.\Delta T)\right) \frac{4\pi}{\lambda} l_0 (CH^2 + CTE.\Delta T). \quad (5.6)$$

From Equation (5.1) we get

$$H^2 = H_{dc}^2 + \frac{H_{ac}^2}{2} + \frac{H_{ac}^2}{2} \cos(2\omega t) + 2H_{dc}H_{ac} \cos(\omega t) \quad (5.7)$$

Substituting Equation (5.7) in Equation (5.6) we get

$$\Delta V = -\frac{V_p}{2} \sin\left(\frac{4\pi}{\lambda} \left(l + l_0 C \left(H_{dc}^2 + \frac{H_{ac}^2}{2} + \frac{H_{ac}^2}{2} \cos(2\omega t) + 2H_{dc} H_{ac} \cos(\omega t) \right) + l_0 \cdot CTE \cdot \Delta T \right) \times \frac{4\pi}{\lambda} l_0 \left(C \left(H_{dc}^2 + \frac{H_{ac}^2}{2} + \frac{H_{ac}^2}{2} \cos(2\omega t) + 2H_{dc} H_{ac} \cos(\omega t) \right) + CTE \cdot \Delta T \right) \right) \quad (5.8)$$

Thus the output voltage contains the frequency terms ω , 2ω and all the frequency components added by the Bessel function. If the operating point of sensor is maintained i.e., $\sin\phi = \text{constant}$, the temperature involved term can be eliminated. The term in the first parenthesis explains the effect of temperature variation and H_{dc} on the operating point. Since the output contains frequency components at ω ,

$$\Delta V_{\omega} = A \sin\phi \cdot 2CH_{dc} H_{ac}, \quad (5.9)$$

and the component at 2ω is given by

$$\Delta V_{2\omega} = A \sin\phi \frac{H_{ac}^2}{2} C. \quad (5.10)$$

Thus we have

$$\frac{\Delta V \big|_{\omega}}{\Delta V \big|_{2\omega}} = \frac{4H_{dc}}{H_{ac}} \quad (5.11)$$

Hence Equation (5.11) can be used to eliminate the effect of fluctuation in the operating point due to temperature variations and other possible disturbances. The normalized output has a linear relationship with H_{dc} , which is the magnetic field of interest. By using this scheme, it is theoretically possible to get an extremely accurate measurement of the external magnetic field.