FREQUENCY RESPONSE OF MAGNETIC FLUX SHEATHS

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Abstract. When a sound wave is incident on a magnetic flux sheath, it causes fluctuations in the mean magnetic field of the sheath. We have calculated the space-average of the longitudinal component of these fluctuations and plotted this against the frequency of the incident sound wave. The main result is the presence of local maxima and minima in the response curve. If such maxima and minima could be detected in any actual observation then these would provide an estimate of the thickness of these magnetic structures.

1. Introduction

The coexistence of magnetic inhomogeneities and magneto-fluid waves in the solar atmosphere raises the question of their mutual interaction. Cram and Wilson (1975) provided some preliminary analysis on the basis of linear theory. From their results, it can be reasoned out that the forms of the perturbations of the various fluid-dynamical variables within the magnetic structures do depend on the frequency of the incident wave. In other words, for a given angle of incidence, there exists a definite frequency response of the magnetic structure, depending in turn upon the magnetic field intensity and the thickness of the structure. The aim of the present work is to (i) study how the shape of the response curve depends on a few of the above mentioned parameters, and (ii) suggest a possible way of estimating the thicknesses of very small magnetic structures. The particular fluid-dynamical variable chosen for this study was the mean value of the linearised magnetic fluctuations in the direction of the magnetic field. The space average of such fluctuations, when plotted against the frequency of the incident sound wave, showed local maxima and minima in the response curve. The separation between successive maxima contains information about the thickness of the magnetic structure.

At the centre of the solar disc, these fluctuations associated with the vertical structures in the solar atmosphere, will manifest themselves as changes in the longitudinal component of the magnetic field and can be detected with the present day magnetographs. The frequencies of maximum response, obtained from such observations, should enable us to estimate the thickness of the structures.

2. The Mean Magnetic Fluctuation in a Magnetic Flux Sheath

The zero order magnetic field in the structure is assumed to point in the y-direction and its intensity to vary along the x-direction. The profile of this variation is as represented in Figure 1. The details of the modes that can propagate in such a structure are given by Cram and Wilson. From their Equation (43), it follows that the
amplitude of the velocity component along the magnetic field is given by

\[
V = (Q_{r2} e^{ik_{x2}x} + Q_{t2} e^{-ik_{x2}x}) \left( \frac{C^2 - A^2}{C} \right) \cos \beta ,
\]

(1)

where \( Q_{r2} \) and \( Q_{t2} \) are the reflection and transmission coefficients, \( C \) is the phase velocity of the fast magnetosonic mode, \( A \) is the Alfvén velocity, \( \beta \) is the angle subtended by the transmitted ray to the interface and \( k_{x2} \) is the horizontal wave number. All these quantities are associated with the region of non-zero magnetic field and are calculated according to the formulae given by Cram and Wilson (1975). The amplitude of \( V \) is normalised to the incident wave amplitude, \( I(\alpha, \nu) \) where \( \nu \) is the frequency of incident sound wave. Thus \( V \) can be finally written as

\[
V = (Q_{r2} e^{ik_{x2}x} + Q_{t2} e^{-ik_{x2}x}) \left( \frac{C^2 - A^2}{C} \right) \cos \beta I(\alpha, \nu) .
\]

(2)

The linearised equation for the magnetic fluctuation \( b \) is

\[
\frac{\partial b}{\partial t} = \nabla \times (\mathbf{V} \times \mathbf{B}_0) ,
\]

(3)

where \( \mathbf{V} \) is the fluid velocity perturbation and \( \mathbf{B}_0 \) is the zero order magnetic field. We know that

\[
\mathbf{B}_0 = (0, B_0, 0) .
\]

(4)

For the perturbation of the field intensity we assume the form

\[
b = \hat{b} \exp i(\mathbf{k} \cdot \mathbf{r} - \omega t) .
\]

(5)

From the condition of phase-matching at the interface (Cram and Wilson, 1975), the