International Journal of Recent advances in Physics (IJRAP) Vol.2, No.3, August 2013

Stability Of Magnetostatic Surface Waves In A Semiconductor-Ferrite-Left-Handed Material Waveguide Structure

Majdi Hamada[1], Ali Hamed El-Astal[1] and Mohammed Shabat[2]

[1]Department of Physics, Al-Aqsa University, Gaza, P.O. Box 4051
Gaza Strip, Palestinian Authority
hamada@alaqsa.edu.ps
a_elastal@alaqsa.edu.ps
[2]Islamic University of Gaza, P O Box 108, Gaza Strip, Palestinian Authority
shabatm@gmail.com

ABSTRACT

Recently increasing works have been devoted to study and fabricate new artificial materials called metamaterials or left handed materials. These materials have unusual behavior as they have simultaneously both negative permittivity and permeability.

In this paper, we investigate the effect of left handed materials and the conductivity of semiconductor material on the dispersion characteristics of left-handed-ferrite-semiconductor waveguide structure, and then we discuss the stability of magnetostatic surface waves in the mentioned three waveguide structures by perturbation method.

Keywords

Metamaterials, Solitons, Surface waves, Semiconductor, Left handed materials.

1. INTRODUCTION

A great deal of important development has been made in the studies of magnetic and magneto static solitons in gyro-magnetic materials. This was stimulated by the great achievement in the theoretical research and practical application of optical solitons in fibers. The basic nonlinear soliton-like effects, arising during the propagation of a magneto-static spin wave (MSW), in a simple ferromagnetic emerged from the pioneering experimental work of Kalinikos [1] and De. Gasperis et al [2]. As a consequence, the experimental evidence for bright spin wave soliton is secure [3]. Only dark MSSW solitons on a single ferromagnetic thin film have been observed experimentally [3]. Theoretical analysis shows that it is possible for magneto-static surface waves in ferromagnetic films to develop into solitons within 10 cm propagation distance [4]. In a simple ferromagnetic waveguide with vacuum cladding and substrate, no magneto-static solitons can be generated in any possible directions. They analyzed the forward and backward volume waves in YIG films and showed that the forward magneto-static volume waves within their low frequency range could develop into solitons [5], and an increase of the incident power would lead to multiple peak structures[6]. Boyle et. al. made use of Lighthill criterion to analyze the possibilities of magneto-static soliton formation and propagation. Their theoretical results well explained the experimental phenomena [7].

The multilayer structures provide a much greater range of possibilities for controlling the characteristics of MSW solitons. A. S. Kindyak et al. [8] carried out a theoretical analysis of the nonlinear properties of MSSW in a layered structure containing ferromagnet and semiconductor thin films. They gave a criteria for the existence of bright surface spin wave envelop solitons. They confirmed that soliton propagation in quite different regions of MSW spectrum is possible. Such solitons require certain materials to exist and basic waveguide structures can be fabricated such as wave guides containing YIG-GaAs and YIG-InSb.

Yu Liming et al. [9] studied the characteristics of magneto-static surface waves (MSSW) in a ferromagnetic film attached to a semiconductor cladding with carriers and showed the existence of magneto-static solitons in the film. They indicated that under the influence of drifting carriers, and within some frequency ranges, MSSW can develop into magneto-static solitons, with the group velocity and phase velocity opposite under some conditions, and the velocity magnitude is related to the carrier density.

Recently negative refraction in left-handed materials (LHMs) has attracted much interest, offering a rich ground for both theoretical and experimental research. More than three decades ago, the theory of the propagation of electromagnetic waves in such media was developed by Veselago [9]. Pendry et. al. [10,11] proposed the essential ideas, which led to the fabrication of the first LHM. This research group demonstrated theoretically that, in the microwave region, a lattice of metallic split-ring resonators (SRRs) with characteristic features in the millimeter range behaves as an active medium with negative permeability μ_L [10]. Furthermore, a network of thin metallic wires behaves as a quasi-metal with a negative permittivity ε at microwave frequencies [11-12]. Smith et. al. [14] fabricated, by combining these two structures, a metamaterial which, within a certain frequency range, has both ε and μ negative, i.e. a LHM. Although some of the properties of LHM are still not fully understood [14-18], they offer a rich ground for both theoretical and experimental research. Thus surface polariton of a LHM [19], scattering properties of LHM spheres [20] or cylinders [21], or the properties of electromagnetic wave propagation in LHM [22] have been studied theoretically, whereas their transmission properties have been investigated experimentally [13,23].

According to the interested characteristics of LHM, mentioned above and elsewhere [25-28], in this article we include a LHM and semiconductor layers in our investigated layered structure. Hence we study the characteristics of MSSW in a Semiconductor-Ferrite-LHM Structure as shown in figure 1, and find the possibility of magneto-static solitons.

2. BASIC CONCEPT

In figure1 magneto-static wave propagates along the Y axis, and an external magnetic field is applied along the +Z or –Z axis. The figure shows a waveguide structure consists of a ferrite layer II with thickness d, a semiconductor cladding III and a LHM substrate I. We neglected the exchange field in region II. In region III, there exists one kind of carrier with unchangeable density and the collision frequency of the carriers is far from the exciting and diffusing frequencies. The static electronic field drives the carrier excursion along the wave propagation direction.

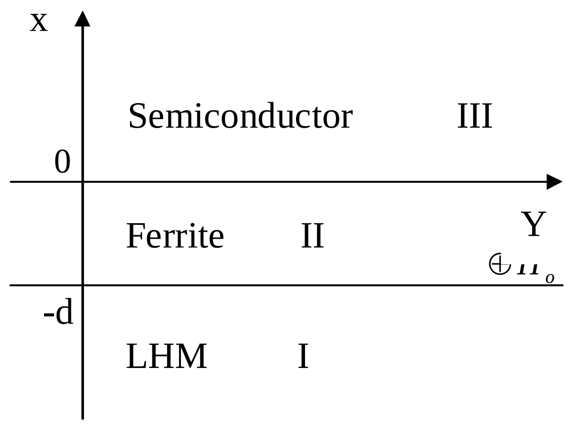


Figure 1. Diagram of the Magneto-static surface waveguide composed of Semiconductor-Ferrite-Left-Handed Material Structure.

The effective magnetic permeability of the left handed material is characterized by μ_L and ε_L as:

$$\mu_L = 1 - \frac{F\,\omega^2}{\omega^2 - \omega_r^2}$$

Here F = $\pi r^2 / a^2$ is the fill factor, a is the lattice constant, r is the inner radius of the ring, and ω_r is the resonant frequency.

$$\varepsilon_L = \frac{\omega_{pL}{}^2}{\omega^2}$$

ω_{pL} is the plasma frequency in the LHM layer and it is defined in GHz ranges.

Note that for μ_l and ε_L the losses are neglected, and the values of parameters ω_r and ω_{pL} and F are chosen to fit approximately to the experimental data [29-30].

2.2 Ferrite Layer II (-d ≤ x ≤ 0)

The ferrite layer is characterized by the magnetic permeability tensor [μ] as:

$$[\,\mu\,] = \begin{bmatrix} \mu_{11} & i\mu_{12} & 0 \\ -i\mu_{21} & \mu_{11} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mu_{11} = 1 + \frac{\omega_o\,\omega_m}{\omega_o^2 - \omega^2}, \qquad \mu_{12} = \frac{\omega\,\omega_m}{\omega_o^2 - \omega^2}$$

$\omega_0 = \mu_o H_0$, $\omega_m = \mu_o M_0$, H_0 is the applied magnetic field and M_0 is the applied magnetization.

2.3 Semiconductor Layer III (x ≥ 0)

The semiconductor layer is characterized by:

$$[\varepsilon] = \begin{bmatrix} \varepsilon_{11} & -i\varepsilon_{12} & 0 \\ i\varepsilon_{21} & \varepsilon_{22} & 0 \\ 0 & 0 & \varepsilon_{33} \end{bmatrix}$$

$$\varepsilon_{33} = 1 - \frac{\omega_p^2(\omega - k\upsilon_0)}{\omega^2(\omega - k\upsilon_0 - i\nu_c)}, \qquad \omega_p^2 = \frac{ne^2}{m\varepsilon_0\varepsilon_s}$$

ω_p; is the plasma frequency in the semiconductor layer, υ_0; the drift velocity of carriers, ν_c; collision (angular) frequency, m; effective mass of carrier, n; carrier density, e; electric charge of carrier, ε_s; effective dielectric constant of lattice. The dielectric susceptibility tensor [ε] is the effective representation of the carrier motion in the semiconductor. The component ε_{33}, which is required in our analysis, is given in the above expression in terms of frequency and wave number.

Under these assumption, applying the Maxwell equations to the above three regions respectively, and following the notations and approach of [27,28], one can easily obtain the dispersion relation of magneto-static surface waves (MSSW) in the ferromagnetic film as:

$$e^{-2kd} = \frac{[1+\gamma_3(\mu_{11}+\mu_{12}s)][\mu_L+\mu_{11}-\mu_{12}s]}{[1-\gamma_3(\mu_{11}-\mu_{12}s][\mu_L-\mu_{11}-\mu_{12}s]} \tag{1}$$

where k = $\beta + i\alpha$ is complex wave number, where α is the factor of amplification, s = ± 1 refer H_o being applied in the +Z or –Z direction.

$$\gamma_3 = \sqrt{1 - \frac{\omega^2\mu_o\varepsilon_o\varepsilon_s}{k^2} + \frac{\omega_p^2\varepsilon_o\varepsilon_s(\omega - k\nu_o)}{k^2(\omega - k\nu_o - i\nu_c)}} \tag{2}$$

Since $k^2 >> \omega^2\mu_0\varepsilon_0\varepsilon_e$ $and\, \nu_c >> \omega, k\nu_0$ in the magneto-static and collision dominant approximation, equation (2) turns into the following equation:

$$\gamma_3 = \sqrt{1 + i\frac{\sigma\mu_o}{k^2}(\omega - k\nu_o)} \tag{3}$$

Where

$\sigma = \dfrac{ne^2}{m\nu_c}$ is the conductivity.

In the case when $\mu_1 = 1$ the left handed behaves as air and the dispersion relation becomes as:

$$e^{-2kd} = \frac{\left[1+\gamma_3(\mu_{11}+\mu_{12}\,s)\right]\left[1+\mu_{11}-\mu_{12}\,s\right]}{\left[1-\gamma_3(\mu_{11}-\ \mu_{12}\,s\right]\left[1-\mu_{11}-\mu_{12}\,s\right]} \tag{4}$$

which is similar to equation (32) into [31].

We set $\mu_o H_0 = 0.0156T$, $\mu_o M_0 = 0.0278T$, the drift velocity of carriers $v_o = 5\times10^5\ m/s$.

The dispersion relation (1) has been solved in the frequency region interval $\omega_o + \omega_{m\backslash 2}$ to $[\omega_o\,(\omega_o + \ \omega_m)]^{\frac{1}{2}}$.

Magneto-static surface wave can be generated with dispersion curves having a positive and negative ingredient which indicates that we have a forward waves at lower frequencies and a backward wave at higher frequencies for s = +1, while for s = -1, we have only a forward waves, as shown in figures 2,3.

In figure 2 the dispersion curves are not sensitive for the conductivity (σ), while in figure 3 the dispersion curves are sensitive for the change of the fill factor F. The fill factor is responsible for the design of the LHM.

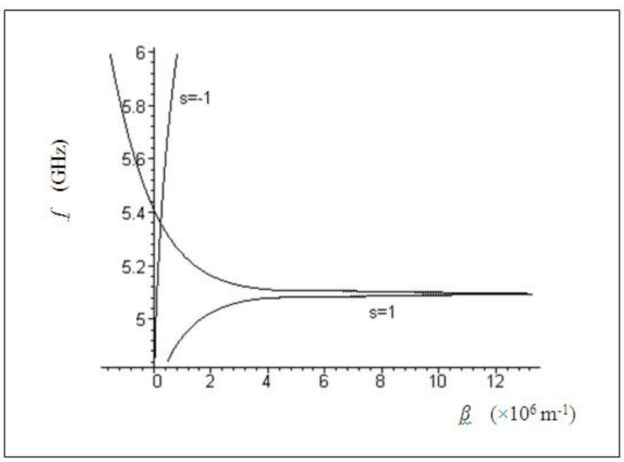


Figure 2. The Computed wave index β [Re(k)] versus operating frequency (f) for different values of conductivity (σ): solid line σ = 3×10^2 (1/Ωm), dotted line σ = 9×10^2 (1/Ωm), $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o = 5\times10^5$ m/s , d = 4×10^{-7} m.

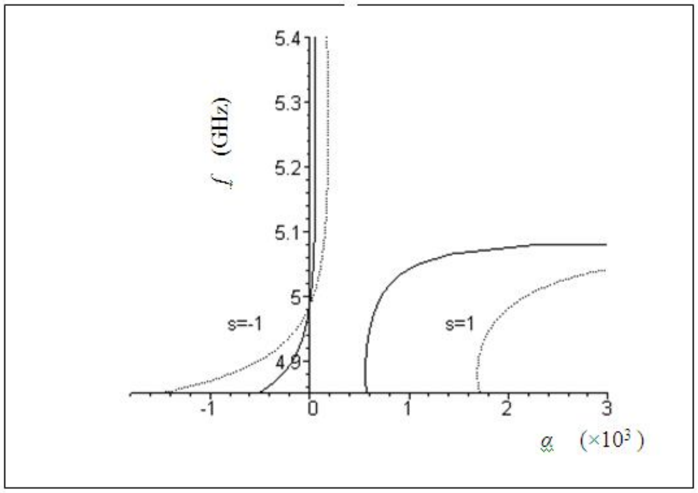


Figure 3. Computed the attenuation α [Im(k)] versus operating frequency (f) for different values of conductivity (σ): solid line $\sigma = 3\times10^{2}$ (1/Ωm), dotted line $\sigma = 9\times10^{2}$ (1/Ωm), $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o=5\times10^{5}$ m/s , $d=4\times10^{-7}$m.

The frequency characteristics of the attenuation factor α have been plotted as show in figures 4,5. The frequency attenuation curves in figure 5 have been plotted for different values of conductivity, while these curves have been presented for different values of the drift velocity of carriers. It has been noticed that for s = -1, the attenuation factor increases to a certain level then it becomes constant. In the other hand, for s = +1, the attenuation factor increases rapidly, which is attributed to the coupling between the forward and backward waves.

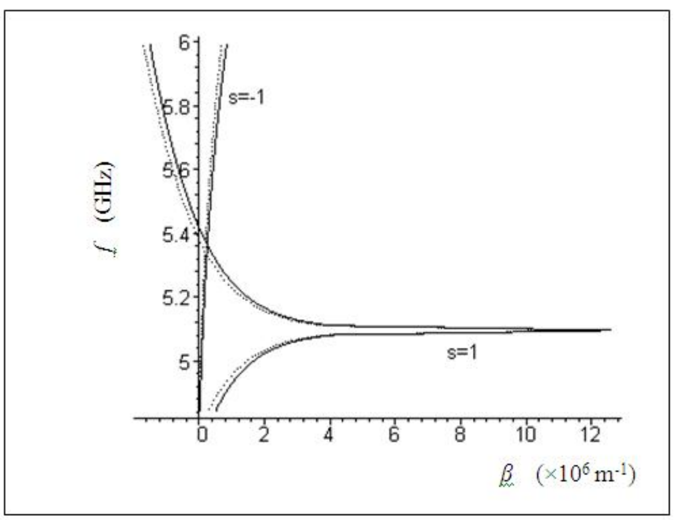


Figure 4. The Computed wave index β [Re(k)] versus operating frequency (f) for different values of the fill factor (F): solid line F = 0.55, dotted line F = 0.6, $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o=5\times10^{5}$ m/s , $d=4\times10^{-7}$ m, $\sigma = 5\times10^{2}$ (1/Ωm).

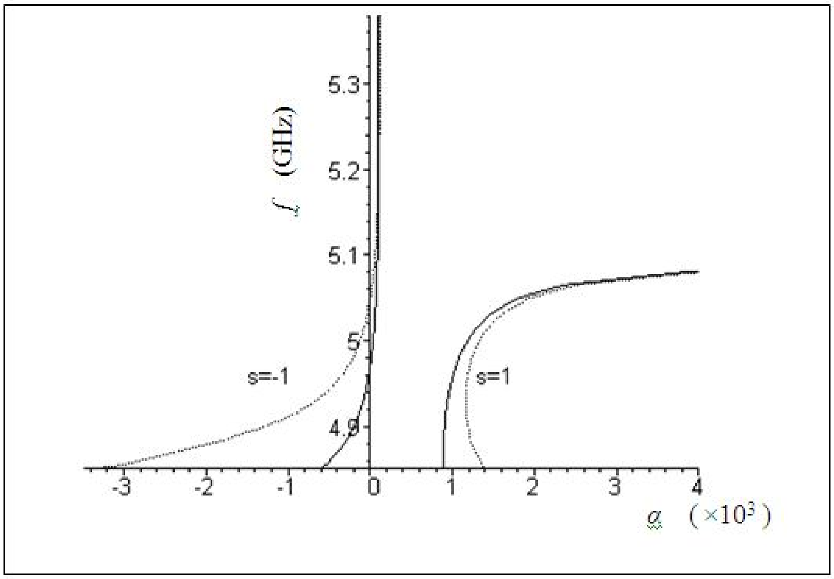


Figure 5. Computed the attenuation α [Im(k)] versus operating frequency (f) for different values of the fill factor (F) solid line F = 0.55, dotted line F = 0.6, $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o = 5\times10^5$ m/s , $d = 4\times10^{-7}$ m, $\sigma = 5\times10^2$ (1/Ωm).

3 POSSIBILITY OF THE EXISTENCE OF MAGNETOSTATIC SURFACE ENVELOP SOLITONS

During the propagation of MSSW, the role of nonlinearity is manifested as a dependence of the frequency and phase velocity on the wave amplitude. Assuming that the amplitude A is a slowly varying function, the dispersion relation equation for the MSSWs may be formally written in the form: $G(\omega, k, |A|^2) = 0$. Since the nonlinearity is assumed to be weak, the deviation of the frequency ω from ω_0 *to* $\omega_o + \Omega, \Omega << \omega_o$ and the changes in k compared with the wave vector k_o of the linear equation will be small. After expanding $k(\omega)$ about k_o (ω_o) as a series in terms of $(\omega - \omega_o)$, we obtain the nonlinear Schrodinger equation:

$$i\frac{dA}{dy} - \frac{\beta_2}{2}\frac{d^2A}{dt^2} + \gamma|A|^2 A = 0, \tag{5}$$

where $\beta_2 = d^2\omega / dk^2$ is the group velocity dispersion, and $\gamma = (d\omega / d|A|^2)_{|A|} = 0$ is the nonlinear coefficient, whereA is the dimensionless amplitude of a MSSW pulse.
A necessary condition for formation of an envelope soliton is that the Lighthill criterion $\beta_2\gamma < 0$ is satisfied.
The criterion means the balance between the chrips produced by group velocity dispersion and nonlinearity respectively.

The group velocity dispersion, $(\partial^2 \omega / \partial k^2)$, and the coefficient of the nonlinear frequency shift, $\partial\omega / \partial|A|^2$ can be found most readily by exploiting partial differentiation of the dispersion equation G = 0. First of all, the linear dispersion equation is explicitly, $G(\omega(k), k) = 0$.
So that the total differential of *G*, with respect to *k*, is

$$\frac{dG}{dk} = \frac{\partial G}{\partial k} + \frac{\partial G}{d\omega}\left(\frac{d\omega}{dk}\right) = 0 \tag{6}$$

The group velocity is, therefore,

$$\frac{d\omega}{dk} = -\frac{\partial G / \partial k}{\partial G / \partial \omega} = -\frac{G_k}{G_\omega} \tag{7}$$

The second total derivative is

$$\frac{d^2G}{dk^2} = \frac{d}{dk}\left(\frac{\partial G}{\partial k}\right) + \frac{d}{dk}\left(\frac{\partial G}{\partial \omega}\right)\frac{d\omega}{dk} + \frac{\partial G}{\partial \omega}\frac{d^2\omega}{dk^2} \tag{8}$$

in which

$$\begin{aligned}\frac{d}{dk}\left(\frac{\partial G}{\partial k}\right) &= \frac{\partial^2 G}{\partial k^2} + \frac{\partial^2 G}{\partial k \partial \omega}\left(\frac{d\omega}{dk}\right) \\ &= G_{kk} + G_{k\omega}\frac{d\omega}{dk}\end{aligned} \tag{9a}$$

$$\begin{aligned}\frac{d}{dk}\left(\frac{\partial G}{\partial \omega}\right) &= \frac{\partial^2 G}{\partial k \partial \omega} + \frac{\partial^2 G}{\partial \omega^2}\left(\frac{d\omega}{dk}\right) \\ &= G_{k\omega} + G_{\omega\omega}\frac{d\omega}{dk}\end{aligned} \tag{9b}$$

Equations (7)-(9) yield

$$\beta_2 = \left(\frac{d^2\omega}{dk^2}\right) = -\frac{1}{G\omega}\left\{ G_{kk} - 2G_{k\omega}\frac{G_k}{G\omega} + G_{\omega\omega}\frac{G_k^2}{G_\omega^2} \right\} \tag{10}$$

The nonlinear coefficients $(\partial k / \partial |A|^2)$ can be found with the method used by Zvezdin and Popkoy [32] and then by A.D. Boardman [4]. Setting the uniaxial axis coincident with Z-axis, then for small deviations of the magnetization from the equilibrium state, the Z component of the magnetization becomes

$$M_z \cong M_0 \left(1 - \frac{|M_x|^2 + |M_y|^2}{2M_0^2} \right) \tag{11}$$

where M_0 is the saturation magnetization and M_i are the components of the variable magnetization (i = x, y, z). Then, in the limit kd<<1, we have $M_z \cong M_0 - M_0|A|^2$ and $\omega_m \cong \omega_m (1 - |A|^2)$ [32-33]. Substituting the value of ω_m into our dispersion relation and calculating the derivative with respect to $|A|^2$, we obtain $G(\omega, k, |A|^2) = 0$.

Since this is the case, $$\frac{dG}{d|A|^2} = \frac{\partial G}{\partial \omega}\frac{d\omega}{d|A|^2} + \frac{\partial G}{\partial |A|^2} = 0 \tag{12}$$

So that

$$\gamma = \frac{d\omega}{d|A|^2} = -\frac{\partial G / \partial |A|^2}{(\partial G / \partial \omega)} = -\frac{G_{|A|^2}}{G\omega} \tag{13}$$

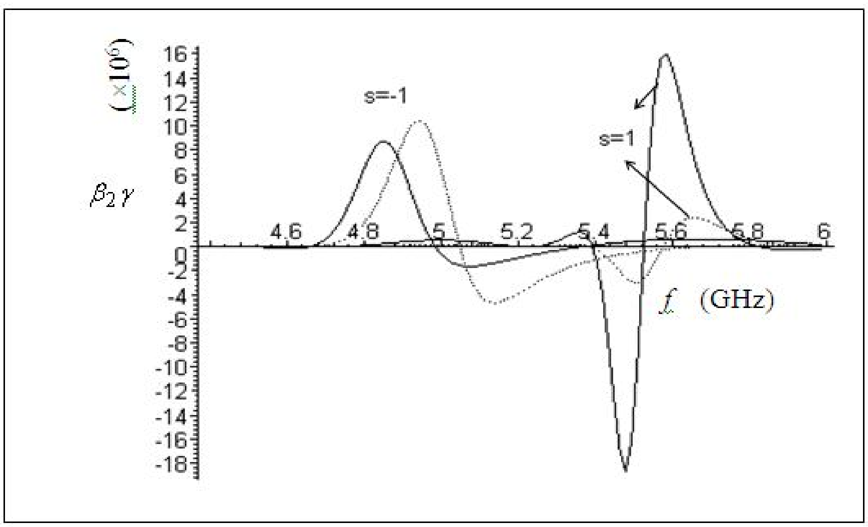
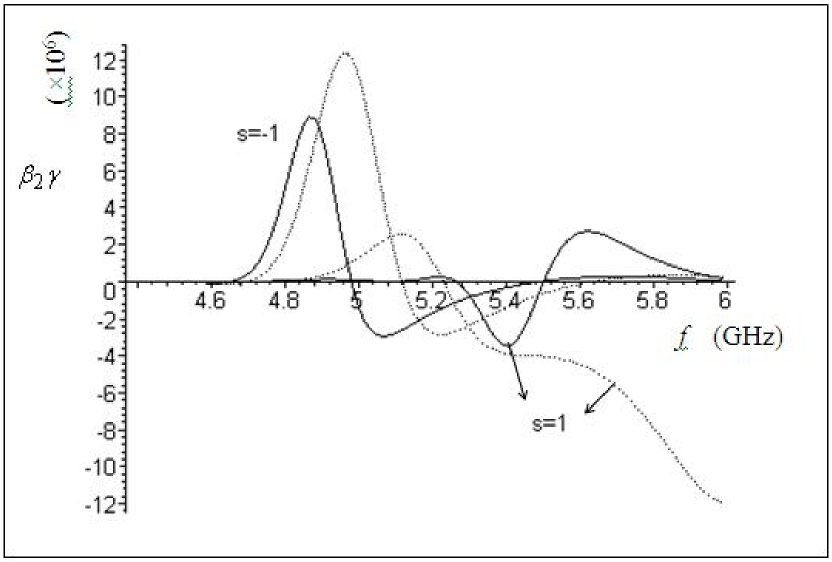


Figure 6. Product of group velocity dispersion(β_2) and nonlinear coefficient (γ) as a function of frequency for different values of conductivity (σ): solid line $\sigma = 3\times10^2$ ($1/\Omega$m), dotted line $\sigma = 9\times10^2$ ($1/\Omega$m), $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o = 5\times10^5$ m/s , d=4×10^{-7}m, β =1000 (m^{-1}).



.

Figure 7. Product of group velocity dispersion (β_2) and nonlinear coefficient (γ) as a function of frequency for different values the fill factor (F) solid line F = 0.55, dotted line F = 0.6, $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o=5\times10^5$ m/s , d = 5×10^{-7}m, σ = 3×10^2 (1/Ωm) , β =1000 (m^{-1}).

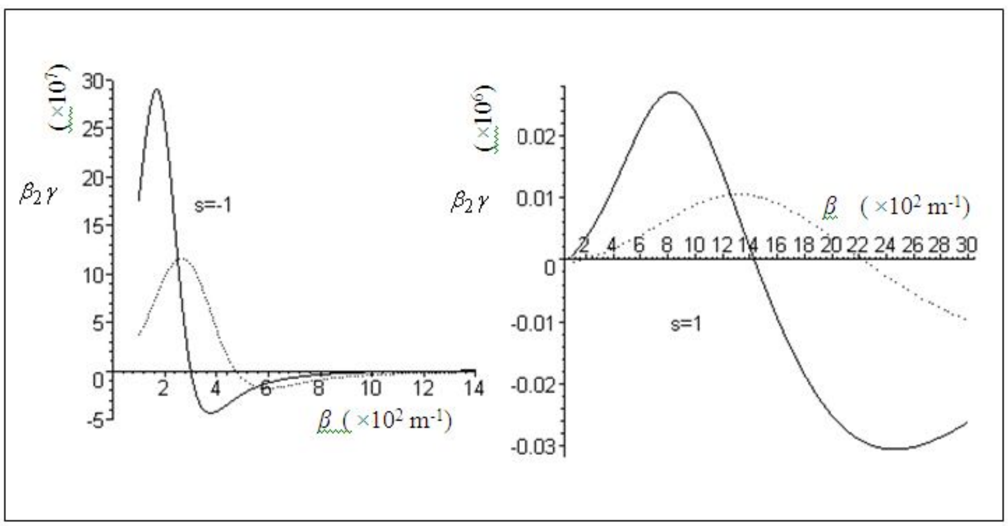


Figure 8. Product of group velocity dispersion (β_2) and nonlinear coefficient (γ) as a function of frequency for different values of conductivity (σ): solid line σ = 2×10^2 (1/Ωm), dotted line σ = 5×10^2 (1/Ωm), $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o = 5\times10^5$ m/s , d = 5×10^{-7} m, f =5.2 (GHz).

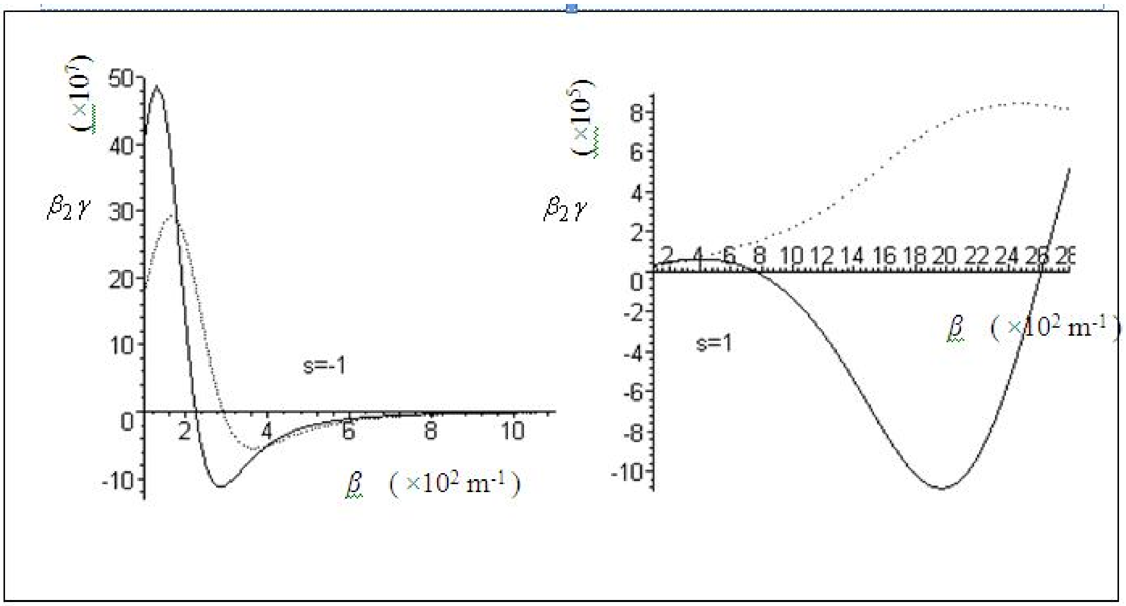


Figure 9. Product of group velocity dispersion (β_2) and nonlinear coefficient(γ) as a function of frequency for different values of the fill factor (F): solid line F = 0.54, dotted line F = 0.55, $\mu_o H_o = 0.0156$ T, $\mu_o M_o = 0.0278$ T, the drift velocity of carrier $v_o = 5\times10^5$ m/s , $d=5\times10^{-7}$m, $\sigma = 3\times10^2$ (1/Ωm), f = 5.2 (GHz).

It has been noticed from figures 6-9 that the magneto-static surface waves in ferromagnetic-LHM can develop into magneto-static bright envelop solitons for both s = ± 1.

In figure 6, the Brighthill criterion ($\beta_2\gamma$) has been plotted versus the frequency for different values of conductivity (σ). Figure 6 shows the bright envelop solitons occur at lower frequencies for s = -1, while they are noticed at higher frequencies for s = +1.

The same above results are also obtained when we plot the Brighthill criterion versus frequency for different values of the fill factor (F), as shown in figure 7.

The Brighthill criterion ($\beta_2\gamma$) shown in figures 6,7 has been plotted versus β and are presented in figures 8,9 where the wave index β values have been taken from the solution of the dispersion relation as shown in figures 2,3. Figures 8,9 show that the bright envelop solitons occur at lower values of β, i.e. with fast magneto-static waves at s = -1. In the other hand when s = +1, the solitons are noticed at low values of velocities of magneto-static waves.

By increasing the fill factor F when s = +1, we no longer find the solitons, as shown in figure 9.

4 CONCLUSION

In this paper, the propagation of electromagnetic waves in a layered structure consisting of ferrite film bounded by a semiconductor cover and a metamaterial substrate was analyzes and discussed. The stability of magnetostatic surface waves through mentioned three waveguide structures has been obtained by implementing the perturbation method and the lighthill criteria has also been checked to find out the possibility of existence of magnetostatic envelope solitons.

ACKNOWLEDGEMENTS

One of the authors (M.M.Shabat) acknowledges financial support from the Alexander von Humboldt, germany for a study visit to Germany, and the hospitality of Prof.H.Roskos, at the Wolfgang Goethe-Universität, Frankfurt.

REFERENCES

1. B. A. Kalinikos, N. G. Kovshikov, A. N. Slavin, JETF Lett. 38 (1983) 413.
2. P. De Gasperis, R. Marcelli, Phys. Rev. Lett. 59 (1987) 481.
3. M. Chen, M. A. Tsankov, J. M. Nash, C. E. Patton, Phys. Rev. Lett. 70 (1993) 1707).
4. A. D. Boardman, Qi Wang, S. A. Nikitov, et al., IEEE Trans. Magn, 30 (1), (1994) 14.
5. A. Tsankov Mincho, Chen Ming, Carl E. Patton , J. Appl. Phys. , 76 (7), (1994) 4274.
6. M. Chen., A. Tsankov Mincho, Jon M. Nash, et. al, Phys. Rev., B49 (18), (1994) 12773.
7. J. W. Boyle, S. A. Nikitov, A. D. Boardman, et. al., Phys. Rev., 53 (1996) 12173.
8. A. S. Kindyak, A. D. Boardman, and V. V. Kindyak, Journal of Magnetism and Magnetic Materials 253 (2002) 8.
9. Yu Liming and Wang Qi, Journal of Shanghai University, 3 (1) (1999).
10. V. G. Veselago, Usp. Fiz. Nauk 92 (1964) 517.
11. J. B. Pendry, Microwave Theory Tech. 47, (1999) 2075.
12. J. B. Pendry, A. J. Holden, W. J. Stewart, I. Youngs, Phys. Rev. Lett. 76, (1996) 4773.
13. R. M. Walser, A. P. Valanju, P. M. Valanju, Phys. Rev. Lett. 87 (2001) 119701.
14. D. R. Smith, W. J. Padilla, D. C. Vier, S. C. Nemat-Nasser, S. Schultz, Phys. Rev. Lett. 84 (2000) 4184.
15. J. B. Pendry, Phys. Rev. Lett. 85, (2000) 3966.
16. D. R. Smith, D. Schurig, J. B. Pendry, Appl. Phys. Lett. 81, (2002) 2713.
17. J. Pacheco, T. M. Grzegorczyk, B. I. Wu, Y. Zhang, J. A. Kong, Phys. Rev. Lett. 89 (2002) 257401.
18. N. Garcia, M. Nieto-Vesperinas, Phys. Rev. Lett. 88, (2002)207403.
19. P. M. Valanju, R. M. Walser, A. P. Valanju, Phys. Rev. Lett. 88 (2002) 187401.
20. R. Rupin, Phys. Lett. A 227 (2000) 61.
21. R. Rupin, Solid State Commun. 116 (2000)411.
22. V. Kuzmail, A. A. Maradudin, Phys. Rev. B 66 (2002) 045116.
23. R. W. Ziolkowski, E. Heyman, Phys. Rev. E 64 (2001) 056625.
24. F. J. Rachford, D. L. Smith, P. F. Loschialpo, D. W. Forester, Phys. Rev. E 66 (2202) 036613.
25. M. S. Hamada, A. H. El-Astal, M. M. Shabat, Int. J. Modern Physics B21 (2007), 1817.
26. M. Hamada, M. M. Shabat, D. Jager, Proc. Of SPIE 5445 (2003) 184.
27. M. S. Hamada, A. H. El-Astal, M. M. Shabat, Int. J. Microwave and Optical Tech. 2(2) (2007), 112.
28. H. M. Mousa, M. M. Shabat, Int. J. Modern Physics B 21(6), (2007), 895.
29. I. V. Shadrivov, A. A. Sukhorukov, Y. S. Kivshar, A. A. Zharov, A. D. Boardman, P. Egan, Phys. Rev.: E 69, (2004) 016617.
30. R. Ruppin, J. Phys: Condens. Matter: 13 (2001) 1811.
31. I. Awai, K. Ohtsuki, J. Ikenoue, Japanese J. Appl. Phys. 15(7), (1976) 1297.
32. A. K. Zvezdin, A. D. Popkov, Zh. Eksp. Teor. Fiz. 84, (1983) 606.
33. A. D. Boardman, S. A. Nikitov, N. A. Waby, Phys. Rev. B, (1993) 13602.

Authors

Prof. Ali Hamed El-Astal was born in 1964, Gaza, Palestinian Territories. In 1986 he got his B.Sc in Physics & Maths from UAE University. In 1991 he obtained the M.Sc. in optoelectronics and optical information processing from the Queen's University of Belfast,UK. In 1995 he was awarded the Ph.D. in

laser physics and spectroscopy also from the Queen's University of Belfast,UK. In 1996 he was appointed as an assistant professor in physics at department of physics, Al-Aqsa University, Gaza, Palestine. In 2008 he was promoted as a full professor in laser physics at Al-Aqsa University. He worked as a dean of postgraduate studies and scientific research within the periods 2003-2004 and 2006-2010. From November 2010 he has worded as Al-Aqsa Vice president. He published various refereed papers on laser physics and other related topics and participated in many conferences.

Dr. Majdi Hamada was born in 1963 in Gaza, Palestinian Territories. He got his B.Sc in physic in 1987 from Islamic University, Gaza Strip. He earned his M.Sc in Applied optics from the University of Salford, U.K. in 1991 and his Ph.D degree from Ain Shams University, Egypt in 2003. He has joined the physics department at Al-Aqsa University, Gaza as an assistant professor 1993. He promoted as an associate professor in 2008. He was a head of physics department in the period (2004-2005). He participated in several conferences and workshops. His research interests are: nonlinear wave optic – magnetostatic surface waves, superconductors and metamaterial application.

Mohammad M. Shabat, was born in Beit Hanoun, Gaza Strip, Palestine in 1960. He received his B.Sc. in Physics from Al-Aazhar University, Cairo, Egypt in 1984 and the Ph.D. degree from the University of Salford, U.K., in 1990. He was a Research Fellow at the University of Manchester Institute of Science and Technology, UK, from 1989 to 1992. In April 1992, he joined the Physics Department at the Islamic University of Gaza (IUG) as an Assistant Professor of physics. He became an Associate Professor in 1996 and a Professor of Physics in 2000. In the period 2001-2005, he was the Vice President for Administrative Affairs at IUG. He was awarded the Shoman Prize for a Young Arab Scientist (Jordan) in 1995, and the Humboldt Research Fellowships in 1998-99 at the Center of Semiconductor Technology and Opto-electronics, Duisburg-Essen University, Germany.

He was a visiting scientist at Bochum University, Germany, in 1994; at the Institute National Polytechnic de Grenoble, (INPG), France, in 1995; at Salford University, U.K, in 1997; ICTP, Trieste, Italy, in 1996,1997 and 1998, 2000, 2001, 2003, 2004; and Duisburg-Essen University, Germany, in1998, 1999 and 2002, 2003, 2004 and 2006. From 2006-2008. Prof.Shabat was a visiting Professor in Max Planck Institute for the Physics of Complex Systems, Dresden, Germany. Professor Shabat has received "Galileo Galilei" Award of the International Commission of Optics (affiliated to ICSU and IUPAP) in 2006. Prof.Shabat has recently received ICPSR**,** ISSESCO Prize in Science and Technology, Islamic Educational, Scientific and Cultural Organization (ISESCO**)**, 2010**.** He is currently the Vice President for the Academic Affairs at the IUG. More recently, Professor Shabat became Distinguished Professor.

He published more than 200 papers in international journals in Material Science, Optical Science, physics, mathematics and education and presented many papers at local and international conferences. His research interests include newly artificial materials called Metamaterials or Left-handed materials, Nanomaterials, Super-lattices, Nonlinear optical sensor, opto-electronics, magnetostatic surface waves, numerical techniques, mesoscopic systems, energy, applied mathematics, Nanotechnology and physics education.
He supervised more than 20 postgraduate students (M.Sc and PhD) in mathematics and physics. Recently he has established a Palestinian Optical Society (POS). He is an external examiner for BSc examinations, Msc dissertation and PhD theses in physics and mathematics at Palestinian and Egyptian universities.