Studies in Autonomic, Data-driven and Industrial Computing

João Manuel R. S. Tavares
Joel J. P. C. Rodrigues
Debajyoti Misra
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Data Science and Communication

Proceedings of ICTDsC 2023

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Preface

International Conference on Data Science and Communication (ICTDsC 2023) is organized by the Department of Electronics and Communication Engineering and Department of Engineering Sciences and Humanities, Siliguri Institute of Technology, Sukna, Siliguri, India, during March 23–24, 2024.

Data science and technologies like artificial intelligence, machine learning, deep learning are among the rapidly growing emerging technologies which are directly used for mankind. By using communication technologies together with data science, we can create whatever we dream. ICTDsC 2023 has given an opportunity to showcase the recent advancement of these field to technologists, scientists and other professionals in front of the globe.

The aim of the conference is to create a platform where researchers, engineers, academicians and industry professionals can come together to share their recent research works and discuss future trends in various areas of engineering. The conference has served as a meeting point for both newcomers and experienced individuals in the scientific and development communities. Its intentions are to encourage the exploration of emerging scopes, the exchange of new ideas and the establishment of collaborations between different research groups.

By organizing this conference, we have received immense response across the globe from countries like Australia, Georgia, Portugal, Malta, Tanzania, Bangladesh, Czech Republic, USA and almost all states of the India. We have received almost 200 research articles out of them our reviewer team selected best 59 research articles. We know that Springer Nature is the world's largest academic book publisher who has published these 59 research articles in their book series named autonomous and data driven and industrial computing.

The call for papers of the conference was divided into six parts as mentioned: Part I: Information Retrieval, Part II: Pattern Recognition, Part III: Computational Intelligence, Part IV: Data Science and Data Analytics, Part V: Network Security and Telecommunication, and Part VI: Smart Materials, Nano Materials.

The conference organizers ensured the quality of the presentations and the technical program by implementing a rigorous peer-review process. This process involved expert reviewers who assessed the submissions based on several criteria, including their contributions to the field, technical content, originality and clarity. By employing this robust review system, the organizers aimed to select the most valuable and relevant research works for presentation at the conference. The entire review process was conducted electronically, likely using an online submission and review platform. This modern approach streamlines the handling of submissions and facilitates efficient communication between authors, reviewers and the organizing committee. As a result of these meticulous efforts, the conference program featured high-impact presentations from distinguished guest speakers and researchers who had their papers accepted. By incorporating influential voices from the field, the conference could offer valuable insights and expertise to all attendees.

We would like to thank the Patrons, General Chairs, the members of the Technical Programme Committees, Advisory Committees and reviewers for their excellent and tireless work. We also want to thank Springer for the support and the authors for the success of the conference.

Porto, Portugal — João Manuel R. S. Tavares
Santa Rita do Sapucaí, Brazil — Joel J. P. C. Rodrigues
Siliguri, India — Dr. Debajyoti Misra
Siliguri, India — Dr. Debasmriti Bhattacherjee

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About the Editors

João Manuel R. S. Tavares graduated in Mechanical Engineering at the Universidade do Porto, Portugal in 1992. He also earned his M.Sc. degree and Ph.D. degree in Electrical and Computer Engineering from the Universidade do Porto in 1995 and 2001, and attained his Habilitation in Mechanical Engineering in 2015 from the same University. He is a senior researcher at the Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial (INEGI) and Full Professor at the Department of Mechanical Engineering (DEMec) of the Faculdade de Engenharia da Universidade do Porto (FEUP). He has been the Head of DEMec since June 2023.

João Tavares is co-editor of more than 80 books, co-author of more than 50 book chapters, 650 articles in international and national journals and conferences, and 3 international and 3 national patents. He has been a committee member of several international and national journals and conferences, is co-founder and co-editor of the book series "Lecture Notes in Computational Vision and Biomechanics" published by Springer, founder and Editor-in-Chief of the journal *Computer Methods in Biomechanics* and *Biomedical Engineering: Imaging and Visualization* published by Taylor & Francis, Editor-in-Chief of the journal *Computer Methods in Biomechanics and Biomedical Engineering* published by Taylor & Francis, and co-founder and co-chair of the international conference series: International Symposium on Computational Modeling of Objects Presented in Images, ECCOMAS Thematic Conference on Computational Vision and Medical Image Processing, International Conference on Computational and Experimental Biomedical Sciences and International Conference on Biodental Engineering. Additionally, he has been (co-)supervisor of several M.Sc. and Ph.D. thesis and supervisor of several post-doc projects, and has participated in many scientific projects both as researcher and as scientific coordinator. His main research areas include computational vision, medical imaging, biomechanics, scientific visualization, human-computer interaction and new product development.

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Part I
Information Retrieval

Chapter 1
Compensation Effect in the Collisional Turbulent Plasma

Giorgi Jandieri, Banmali Rawat, and Nika Tugushi

Abstract Considered is the indirect incidence of a radio wave with small amplitude on a collisional turbulent plasma's plane layer. The ray approximation is utilized to investigate the high-order statistical properties of dispersed radio waves. It discovered a specific path along which two asymmetric aspects of the issue (indirect wave incidence and plasma anisotropy) compensate one another. In this situation, the scattered waves' angular spectrum does not broaden or peak. The results of the numerical analysis of this spectrum's evaluation, which thickens the plasma layer, are consistent with those of the geometrical optics approximation.

Keywords Statistical moments · Turbulence · Magnetized plasma · Angular power spectrum · Compensation

1 Introduction

It is common knowledge that radio waves scattered in turbulent irregular media are subject to a significant amount of effect from absorption in random media. Radio waves scattered in turbulent irregular media are known to be significantly influenced by absorption in random media. The asymmetry of the problem is necessary for unexpected increase of oscillations in a medium with large-scale abnormalities. This asymmetry develops when radio waves are used to obliquely illuminate a medium containing anisotropic irregularities. The asymmetry of scattered radiation can also

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result from the asymmetry of the complex refractive index's imaginary portion. A turbulent collisional plasma, for instance, forms a finite angle with the radio waves' propagation in a certain direction in the presence of ambient magnetic field.

Many papers [1–4] are used to perform the analytical calculations and measurements made through experimentation of the statistical moments of a large number of radio waves that have become scattered because of the turbulent conditions of the atmosphere of the earth, particularly the ionosphere. It is common knowledge that the absorption that occurs as a result of collisions between plasma particles in turbulent plasma has a considerable impact on the statistical moments of the second order of waves that were scattered. The spatial power spectrum (SPS) of multiple scattered radiations as measured in space (in angular units) at small angles of wave incidence on a surface between vacuum and isotropic collisional turbulent plasma monotonically broadens with distance approaching a particular asymptotic value [5]. New phenomena arise increasing the incidence angle. Different spectral components of the SPS attenuate variously, and the width of the SPS anomalously broadens and is asymmetric in relation to its maximum. The SPS maximum is non-monotonically displaced from the interface's normal direction. These effects are a result of the problem's asymmetries. Similar asymmetry develops not only when the surface is illuminated in an angle; anisotropy may be a property of the medium itself.

As an example of a chaotically non-homogeneous absorptive medium, collisional turbulent magnetized plasma serves as a prime example. This paper uses the approximation pertaining to dispersion at low angles to investigate the angled reflection of a flat radio wave with a low magnitude on a collisional magnetized turbulent plasma's semi-infinite slab, with electron density fluctuations in [6–8]. The spectrum width varies non-monotonically with proximity to a plasma barrier. Strong absorption causes the SPS's width to increase and surpass that of the plasma without collisions. In the collisional turbulent magnetized plasma, the broadening of the SPS and the displacement of its maximum of scattered radio waves were examined for power-law spectral function. Using the complex ray (-optics) approximation, the Gaussian correlation function of irregularities in electron density is shown in [7–9]. "Compensation Effect" in the polar terrestrial ionosphere was considered in [10] taking into account Hall's, Pedersen, and longitudinal conductivities fluctuations.

In the present work, evaluation of the angular spectrum (the enlargement of the SPS of several scattered radio waves and the shift in its maximum) in a collisional turbulent magnetized plasma is investigated on the bases of the ray approximation. Compensation conditions are found; i.e., the directions along which anisotropic factors (inclined onset of a wave at the vacuum-plasma surface and anisotropy of plasma produced by collisions) mutually compensate each other. Numerical simulations are carried out for the power-law spectrum.

2 Electromagnetic Waves Propagation in a Homogeneous Absorptive Plasma Layer

It allows a plane radio wave to illuminate a semi-infinite layer of the collision magnetized plasma as it travels through the vacuum from where it originated. The XY plane contains the vector that represents the electric field. Within plasma, the Z-axis points in a direction that is normal to the boundary between these two media. If Z-axis coincides with the ambient magnetic field $\mathbf{B_0}$. A homogeneous collision magnetized plasma has certain components that make up its dielectric permittivity tensor. These components are [3]

$$\varepsilon_{yy} = \varepsilon_{xx} = \varepsilon_{\perp} - isg, \varepsilon_{xy} = -\varepsilon_{yx} = -i\text{æ} + 2s\text{æ}/(1-u),$$
$$\varepsilon_{zz} = -isv + \varepsilon_{||}, \varepsilon_{zx} = \varepsilon_{xz} = \varepsilon_{zy} = \varepsilon_{yz} = 0, \tag{1}$$

where $\varepsilon_{\perp} = (1-v)\cdot(1-u)^{-1}$, $\text{æ} = \sqrt{u}\cdot v/(1-u)$, $\varepsilon_{||} = 1-v$, $g = v(u+1)\cdot(1-u)^{-2}$; $v(\mathbf{r}) = \omega_p^2(\mathbf{r})/\omega^2$ and $u = (eH_0/m_e c\omega)^2$ are non-dimensional magneto-ionic plasma parameters, $\omega_p(\mathbf{r}) = \left[4\pi n_e(\mathbf{r})e^2/m_e\right]^{1/2}$ is the plasma frequency. $n_e(\mathbf{r}) = n_0 + n_1(\mathbf{r})$ is the electron density, n_0 is a constant term, $n_1(\mathbf{r})$ is a random function of position describing electron density fluctuations, $n_1 << n_0$; e and m_e are the magnitude of an electron's charge and its mass. Complex refractive index of the collision magnetized plasma is [5]

$$N^2 = 1 - \frac{2v(h-v)}{2h(h-v) - u\sin^2\theta \pm \sqrt{u^2\sin^4\theta + 4u(h-v)^2\cos^2\theta}}, \tag{2}$$

where $h = 1 - is$, $s = \nu_{\text{eff}}/\omega$ is the frequency at which electrons collide with other particles of plasma; the sine with the upper sign represents the ordinary wave, the sine with the lower sign belongs to the extraordinary wave, and θ is a refraction slant among the refractive wave $\mathbf{k}$ and the magnetic field that comes from the outside $\mathbf{B_0}$. In a negligible approximation (without accounting for electron density changes), wave vector components have real values: $k_{0x} = k_0 \sin\theta_i$, $k_{z1} = k_0 \cos\theta_i$, and θ_i is an incident angle of wave on a plasma slab. Refractive wave in plasma becomes complex $k_{z2} = \sqrt{k_0^2 N^2 - k_{0x}^2}$, $k_0 = \omega_0/c$.

2.1 *Second-Order Statistical Moments of the Phase Fluctuations*

Electron density fluctuations in a turbulent magnetized plasma lead to the amplitude and phase fluctuations of a refractive wave. They are completely arbitrary functions of the coordinates in space. Using the geometrical optics approximation, the eikonal equation can be approximated in a small-angle approximation as follows:

$k^2 = k_0^2 N^2$, where $\mathbf{k}(\mathbf{r}) = -\nabla\varphi$ is the local complex wave vector. This equation yields [9]

$$(\mathbf{k}\cdot\nabla\mathbf{k}) - \frac{1}{2}k_0^2\frac{\partial N^2}{\partial\mathbf{k}_\perp}\nabla\mathbf{k} = \frac{1}{2}k_0^2\frac{\partial N^2}{\partial n}\nabla n, \tag{3}$$

where $\mathbf{k}_\perp = \mathbf{k}_\perp(\mathbf{k}_x, \mathbf{k}_y)$.

Apply the phase properties of the wave in series $\mathbf{k} = \mathbf{k_0} + \mathbf{k_1}(r) + \cdots$.
$\varphi = \varphi_0 + \varphi_1 + \cdots$, we obtain [9]

$$k_{0z}\frac{\partial\varphi_1}{\partial z} + \left[k_{0x} - \frac{1}{2}k_0^2\frac{\partial N_0^2}{\partial k_{0x}}\right]\frac{\partial\varphi_1}{\partial x} = -\frac{1}{2}k_0^2\frac{\partial N_0^2}{\partial n_0}n_1. \tag{4}$$

Integrating Eq. (4) along the complex characteristics taking into account that

$$\frac{\partial k_{z2}}{\partial k_{0x}} = -\frac{1}{k_{z2}}\left(k_{0x} - \frac{1}{2}\,k_0^2\,\frac{\partial\,N^2}{\partial\,k_{0x}}\right) \equiv \beta + i\gamma \tag{5}$$

and for brevity the index "0" will omit everywhere. Utilizing the limit condition
$\varphi_1(z = 0) = 0$ for the phase fluctuations, we obtain

$$\varphi_1(x, y, L) = \frac{\alpha}{k_{z2}}\int_{-\infty}^{\infty}\mathrm{d}k_x\int_{-\infty}^{\infty}\mathrm{d}k_y\,\exp(ik_x x + ik_y y)\int_0^L \mathrm{d}\xi\, n_1(k_x, k_y, \xi)\cdot$$
$$\cdot\exp\left\{-ik_x\left(\frac{\partial k_{z2}}{\partial k_x}\right)_0(L-\xi)\right\}, \tag{6}$$

where L refers to the thickness of a plasma layer and $\alpha \equiv -\frac{1}{2}k_0^2\frac{\partial\,N_0^2}{\partial\,n_0}$. Distance satisfies the condition $(L/\xi\, l_{||}) << 1$. The resulting formulas are therefore applicable to waves traveling arbitrary distances in a turbulent magnetized plasma.

3 Statistical Moments of the Phase Fluctuations

Equation (6) enables us to determine the transverse correlation function of the phase fluctuations when we take into account that the observation points, ρ_x and ρ_y, are far apart. With minor manipulation, we obtain

$$W_\varphi(\rho_x, \rho_y, L) = 2\pi\frac{\alpha^2}{k_{0z}^2}\int_{-\infty}^{\infty}\mathrm{d}k_x\int_{-\infty}^{\infty}\mathrm{d}k_y\,V_n(k_x, k_y, \beta k_y)\frac{1}{2\gamma k_y}$$
$$\left[1 - \exp(-2\gamma k_y L)\right]\exp(ik_x\rho_x + ik_y\rho_y). \tag{7}$$

At strong fluctuation of the phase $\langle \varphi_1 \varphi_1^* \rangle >> 1$, the complex field's correlation function can be expressed as [4–8]

$$W_E(\rho_x, \rho_y, L) = E_0^2 \exp\left[ik_{0y}\rho_y - 2(\mathrm{Im}k_{z2})L\right]$$
$$\exp\left(\frac{\partial W_\varphi}{\partial \rho_x}\rho_x + \frac{1}{2}\frac{\partial^2 W_\varphi}{\partial \rho_x^2}\rho_x^2 + \frac{1}{2}\frac{\partial^2 W_\varphi}{\partial \rho_y^2}\rho_y^2\right). \quad (8)$$

A sequence of derivatives based on the correlation function of the phase is determined at point: $\rho_x = \rho_y = 0$.

The information of the SPS, which is of the utmost significance, can be acquired through the Fourier transformation, which is performed on the correlation function (8). When there are significant changes in the phase, it takes on a Gaussian form.

$$S(k_x, k_y, L) = S_0 \exp\left\{-\frac{(k_y - \Delta k_y)^2}{2\langle k_y^2 \rangle} - \frac{k_x^2}{2\langle k_x^2 \rangle}\right\}, \quad (9)$$

where Δk_y identifies the movement in the maximum value of the SPS as a result of the incoming radiation being generated by abnormalities in the electron density; $\langle k_x^2 \rangle$ and $\langle k_y^2 \rangle$ describe the width of this spectrum in the XOZ, orthogonal to the main planes, and YOZ planes, respectively; S_0 is the maximum value of the SPS. The obtained formulas can be obtained applying formula (7) by differentiation:

$$\Delta k_y = \frac{1}{i}\frac{\partial W_\varphi}{\partial \rho_y}, \langle k_y^2 \rangle = -\frac{\partial^2 W_\varphi}{\partial \rho_y^2}, \langle k_x^2 \rangle = -\frac{\partial^2 W_\varphi}{\partial \rho_x^2}, \quad (10)$$

all derivatives taken at the moment of $\rho_x = \rho_y = 0$.

Substituting Eq. (7) into (10), we obtain

$$\Delta k_y = \frac{2\pi}{\gamma}\frac{\alpha^2}{k_{z2}^2}\int_{-\infty}^{\infty} \mathrm{d}k_x \int_{-\infty}^{\infty} \mathrm{d}k_y V_n(k_x, k_y, \beta k_y)\left[1 - \exp(-2\gamma k_y L)\right], \quad (11)$$

$$\langle k_y^2 \rangle = \frac{\pi}{\gamma}\frac{\alpha^2}{k_{z2}^2}\int_{-\infty}^{\infty} \mathrm{d}k_x \int_{-\infty}^{\infty} \mathrm{d}k_y k_y V_n(k_x, k_y, \beta k_y)\cdot$$
$$\left[1 - \exp(-2\gamma k_y L)\right], \quad (12)$$

$$\langle k_x^2 \rangle = \frac{\pi}{\gamma}\frac{\alpha^2}{k_{z2}^2}\int_{-\infty}^{\infty} \mathrm{d}k_x \int_{-\infty}^{\infty} \mathrm{d}k_y \frac{k_x^2}{k_y} V_n(k_x, k_y, \beta k_y) \cdot \quad (13)$$
$$\left[1 - \exp(-2\gamma k_y L)\right].$$

The results indicate that an irregular expansion and shift of the spectral maximum occur if imaginary parts of the derivative are present. $\partial k_{z2}/\partial k_{0x}$ is not equal zero, even though this phrase includes both oblique wave incidence and irregularities in the electron density. Particularly a) at oblique incidence of wave on the isotropic absorptive plasma $\partial k_{z2}/\partial k_{0x} = - k_{0x}/k_{z2}$ and in this case $\gamma = 0$; b) at wave's oblique incidence on a slab of magnetized plasma, we can apply formula (7). Taking into account that $\partial N^2/\partial k_x \sim \partial N^2/\partial\theta$, we can apply directly formula (2) differentiating by angle θ. These effects are particularly pronounced if $\gamma\, k_y\, L > 1$ as k_y determines the width of the spatial spectrum V_n. Investigation shows that exists the preferable direction determining by the equation $\gamma = \mathrm{Im}\ (\partial k_{zp}/\partial k_{0y}) = 0$ at which neither displacement nor the anomalous broadening not take place, as a result of the collision's turbulent plasma's anisotropy and oblique radio wave incidence compensating for one another. This is the direction referred to as compensation. When waves propagate at a different angle, the SPS will widen. This is the non-conductive collision magnetized plasma's "Compensation Effect" (polar ionosphere).

4 Numerical Calculations

Satellite and remote sensing measurements demonstrate that in F-region of the terrestrial ionosphere electron density irregularities have the power-law spectrum. Corresponding correlation function with a power-law index p has been proposed in [11–13]

$$W_n(\mathbf{k}) = \frac{\sigma_n^2}{(2\pi)^{3/2}} \frac{r_0^3 (k_0 r_0)^{(p-3)/2}}{\left(r_0\sqrt{k^2 + k_0^2}\right)^{p/2}} \frac{K_{p/2}(r_0\sqrt{k^2 + k_0^2})}{K_{(p-3)/2}(k_0 r_0)},$$

where σ_n^2 quantity characterizes the level of irregularities, $K_\nu(x)$ is McDonald function, r_0 and $L_0 = 2\pi/k_0$ are the inner and outer scales of turbulence, respectively; $k_0 r_0 << 1$. In the interval $k_0 r_0 << k\, r_0 << 1$, it is possible to express the spatial spectrum as

$$W_n(\mathbf{k}) = \frac{\sigma_n^2}{(2\pi)^{3/2}} \frac{\Gamma(p/2)}{\Gamma[(p-3)/2]} \frac{k_0^{p-3}}{(k^2 + k_0^2)^{p/2}}.$$

In analytical and numerical calculations, we use new spectral function of electron density irregularities combining both anisotropic Gaussian and power-law spectral functions:

$$W_n(\mathbf{k}) = \frac{\sigma_n^2}{8\pi^{5/2}} \frac{A_p l_{||}^3}{\chi^2\left[1 + l_\perp^2(k_x^2 + k_y^2) + l_{||}^2 k_z^2\right]^{p/2}}, \\ \exp\left(-\frac{k_x^2 l_\perp^2}{4} - p_1\frac{k_y^2 l_{||}^2}{4} - p_2\frac{k_z^2 l_{||}^2}{4} + p_3 k_y k_z l_{||}^2\right), \tag{14}$$

where $p_1 = (\sin^2\gamma_0 + \chi^2\cos^2\gamma_0)^{-1}\left[1 + (\chi^2 - 1)^2\sin^2\gamma_0\cos^2\gamma_0/\chi^2\right]$, $p_2 = (\sin^2\gamma_0 + \chi^2\cos^2\gamma_0)/\chi^2$, $p_3 = (\chi^2 - 1)\sin\gamma_0\cos\gamma_0/2\chi^2$, $A_p = \Gamma(p/2)\Gamma[(5-p)/2]\sin[(p-3)\pi/2]$, k_x, k_y, and k_z are the components of the wave vector $\mathbf{k}$, $\chi = l_{||}/l_\perp$ is the anisotropy coefficient—the proportion of plasma irregularity's transverse and longitudinal distinctive linear diameters, and γ_0 is the angle that lengthy plasmonic structures make when seen in relation to magnetic lines of force. Because of diffusion effects in both the field align and field perpendicular directions, the shape of electron density irregularities takes on a spheroidal form. This is the cause of the irregularities.

Plasma parameters: $u = 1.25$, $\mathrm{v} = 0.2$, $s = 0.02$. Dip angle between the external magnetic field and Z-axis is 20°. In all figures, curve 1 corresponds to the compensation direction (refraction angle $\theta \approx 16°$), curve 2 corresponds to the angle $\theta \approx 30^\circ$, and curve 3 is devoted to the normal incidence of wave on a surface between vacuum and a magnetized plasma.

Figure 1 represents the dependence of the SPS versus distance propagating by the wave in the magnetized collision plasma layer. Numerical simulations show that shift of maximum of the SPS is absent (curve 2); beyond this direction, the mean angular spectrum tends to this direction in proportion to the layer thickness. At small layer, depth L exponent under integrals (11)–(13) can be decomposed into a series. In this case, the variance linearly depends on distance $\langle k_x^2\rangle \sim L$, which is confirmed by numerical experiments.

The curves of a second statistical moment (variance in the incident plane) are plots on Fig. 2. This dependence is very similar to the case of normal incidence of a plane wave on the surface between vacuum and the isotropic medium [5]. Two asymmetric

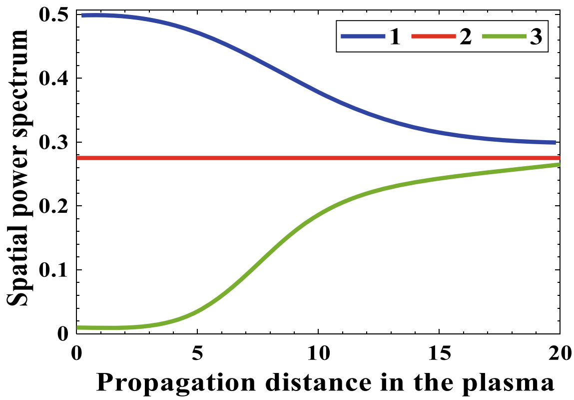

Fig. 1 Spatial power spectrum versus distance propagating by radio wave in the plasma layer

factors of the task (medium anisotropy and inclined incidence of wave on a surface) compensate each other and the SPS not broadens. In other two directions (curves 2 and 3), the effect of some asymmetry reasons prevails and the non-monotonic dependence of dispersion on the thickness of the layer and the effect of anomalous broadening takes place.

Figure 3 depicts the dependence of the third central moment (asymmetric coefficient) as a function of distance propagating by wave in the turbulent plasma layer. As expected, the SPS is symmetrical with respect to the compensation direction.

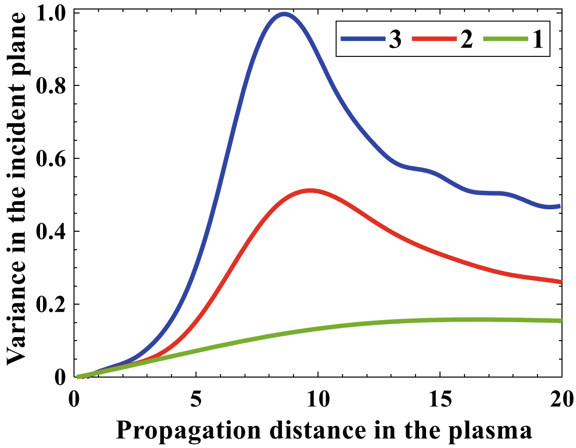

Fig. 2 Second central moment as a function of a plasma slab thickness

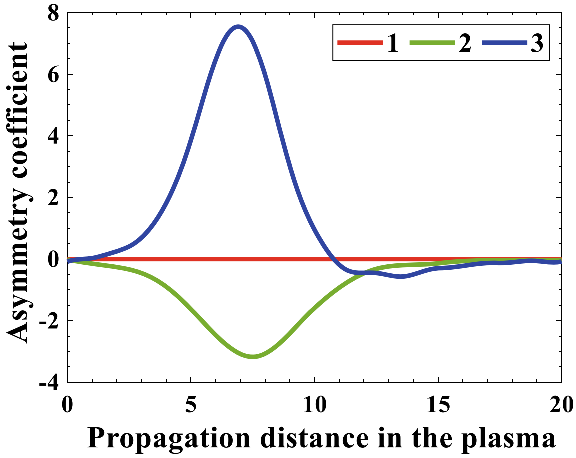

Fig. 3 Third central moment as a function of propagation distance of radio waves in plasma layer

5 Summary/Conclusion

In a collisional magnetized plasma, statistical properties of scattered radio waves are obtained by applying a small-angle approximation and geometrical optics approximation. Power spectrum in space, a spatial representation of the spectrum of variations in electron density, the dip angle of a magnetic flux from the outside, and the angle of an incident wave on the interface between vacuum and magnetized plasma all influence multiply scattered radiation. Due to these factors' independence from one another, their combined action can either amplify or mitigate the effects associated with the transformation of the angular spectrum of power. Each of these factors, acting alone, causes distortion of the power spectrum in space of waves that are scattered. The most interesting, in our opinion, is the conclusion that in a certain direction, the effects of these factors are mutually compensated and that along it, the radiation spreads as it would on an isotropic medium with a normal incidence. The "Compensation Effect" has been numerically confirmed, according to the geometrical method's ray approximation. Numerical calculations confirm the obtained results and are valid for different parameters and other spectral functions applying geometrical optics approximation [8]. The results will be helpful for longwave and shortwave communication systems, remote sensing, and the geomorphology of ionospheric irregularities at all scales.

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Chapter 2
Portable Device-Based Stress Level Estimation Using Biological Rhythms

Imam Hossain, Md. Golam Rashed, Dipankar Das, Md. Julkarnain, Vaskar Deka, and Partha Pratim Debnath

Abstract Stress creates a major health-related issue in our society, because many health-related problems, such as a lot of economic losses, social disruptions, and human mental problems, are the consequences of it. In general, humans experience stress, especially those who are involved in work in developed capitalist countries and under huge mental workloads continuously and endless technological development. Stressors come across in our daily life (for instance, the difference of opinion among family members or hard work deadlines) and may play a vital role in personal health and well-being. In this study, we introduce a model of health awareness system that incorporates two assessment strategies: questionnaire asking method and physical

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measurement method, to determine the stress level using the android application-enabled portable device. The questionnaire asking method is useful for detecting psychological and behavioral scores of the stress level. These questionnaires were fixed based on the score of the subjective measure by surveying twenty (20) psychological questions related to the stressor. To estimate the stress level more precisely, we also used the measurement analysis method which includes the physical health-related fitness tests. The application has been developed using android studio IDE and smartphones. By identifying ongoing stress situations using the application, the users can modify physical or behavioral lifestyles to successfully avoid them. It is revealed that such an application can be applied effectively in research experiences and advances the research on stress level estimation.

Keywords Stress measurement · Biological rhythms · Portable devices · Physical symptoms · Android platform · Smartphone

1 Introduction and Motivation

Stress is an issue that everyone experiences in today's modern life [1]. A more comprehensive definition describes stress as the psychological or physiological response to internal or external stressors [2]. Stress has a lot of negative consequences which reduce our work efficiency that can be appeared from the environment, workstation, social situation, job issue, family matter, business place, universities or internal illness of medical situation, etc., and many people suffer from it in all ages and all sectors. Human mental stress can be a cause of many unwanted psychological conditions: depression and anxiety and have influences on our physical conditions: high blood pressure, uncontrolled diabetes, body temperature, pulse rate fluctuation or respiration rate, etc. However, there is no specific method available to measure the long-term stress [3]. Thus, in this study, we propose an android application-enabled stress measurement and consultation approach that combines two measurement strategies: questionnaire asking method and physical measurement method.

The stress diagnosis system is an ancient process in several countries which are used when a person reaches a critical situation. In recent years, finding ways to accurately measure the stress level of a human is an active research area, because it is the maiden step in identifying and effectively reducing stress level, as a consequence minimizing the adverse mental and physical effects of stress [4]. In literature, there are several methods of measuring stress levels, ranging from conducting multi-item questionnaires [5, 6], analyzing speech [7, 8], and analyzing cortisol levels in saliva [9, 10]. Although the origin of such methods to measure stress dates back to the early part of the twentieth century, the acceptance of stress estimation through technologies as valid and reliable was begun in the early part of the twenty-first century. With the grace of cutting-edge technologies, currently, several sensing technologies are incorporated in the smartphone [11], smartwatch [12], and other wearable devices [13] to measure stress levels effectively. Although some of the existing methods propose effective ways to measure stress levels, however, most of them are often annoying, invasive, expensive, harassing ways for general people, somewhat unreliable as a measure of stress level, or susceptible to recall bias.

In the new era, the health awareness system comes back to an intelligent way to diagnosis stress levels using the android application on a smartphone like portable device, whereas persons can be conscious of the stress to stay at home. In this study, we have presented an android application for smartphone like portable device using questionnaires and measurement methods that are used to detect and reduce the stress level of human being. The main objective of this research is to detect early-stage stress levels and prevent harmful long-term consequences. Here, we are aimed to determine two types of stresses: physical stress that measures the physical illness of the person (for instance, diabetes, blood pressure, heart rate problem, headache, etc.) and psychological or mental stress that identifies the effective risk assessment for workplace stress and work pressure, organizational stress, and behaviors such as, sleeping too much or less, taking alcohol, and drugs. The novelty of this research is that we have developed a health awareness system which is composed of questionnaire method, and measurement method using an android-based application for rising awareness of users as opposed to the conventional system is provided in a traditional way for a specific questionnaire method.

The remaining of this research paper is organized as follows: Sect. 2 describes the proposed health awareness system which involved a questionnaire and measurement method also states the tables of physical symptoms of measuring factor. Section 3 reveals the working model of the android applications system of stress level estimation. Section 4 describes the result and discussion. Section 5 demonstrates the conclusion and future scopes of research work. Finally, the list of references is presented at the end of this paper.

2 Proposed Health Awareness System

In this research work, we proposed a health awareness system for determining stress levels which is illustrated in Fig. 1. This system is effectively usable on portable device-based smartphones. Smartphone users can easily determine their stress levels using the proposed health awareness system. To determine the stress level, we introduced and incorporated two distinct methods, namely the questionnaire method and the measurement method. The stress level is determined by using either any one of the stress scores obtained from the individual method or by combining the stress score from the individual method. After determining the stress level, the proposed health awareness system autonomously conveys suggestions and/or refers relevant consultant to the concerned system user. In the questionnaire method, the psychological symptoms-related questions are used to determine the biological stress score.

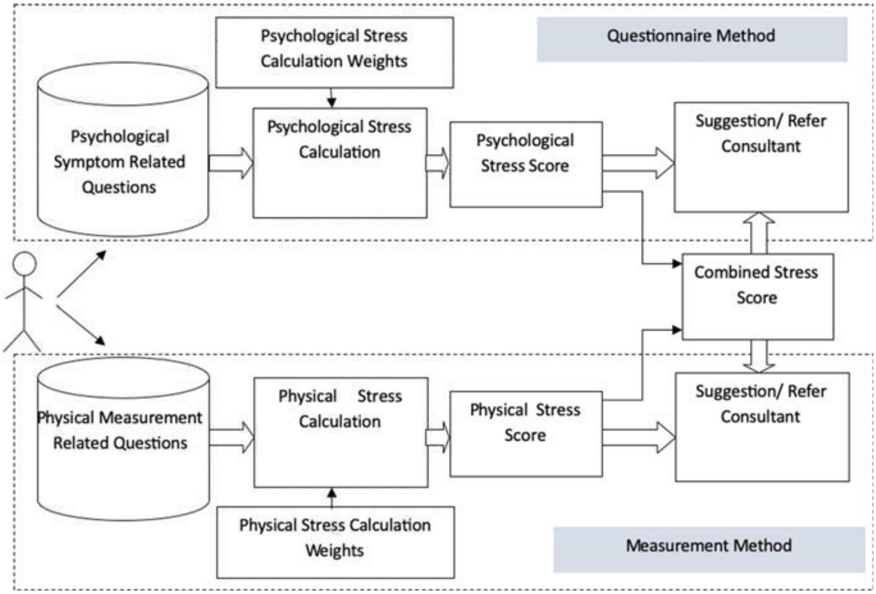

Fig. 1 Health awareness system model for stress level estimation

On the other hand, in the measurement-based method, physical measurement-related diagnosis outputs are used to calculate the physical stress score. Each of the methods is described in detail in the following subsections.

2.1 Questionnaire Method in Detecting Stress Level

In estimating the stress level of a person, initially, we are intended to face that person to some predefined symptom-related questions. In this study, we have considered 20 (twenty) such psychological symptom-related questions as stated in Table 1. The partial responses to these questions are not sufficient to determine someone's stress level. However, we believe that the responses to all of these questions initially assist the proposed system to determine his/her stress level. None of the single questions in this questionnaire method proves any stress she/he is experiencing; however by looking at the results of groups of questions, it may be possible to define what areas of life stress affects the most.

After taking the response of each of the questions from the user, questionnaire method of our system will calculate the psychological stress score by using a simple equation as follows: