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Interactive comment on "Excitation of chorus with small wave normal angles due to BPA mechanism into density ducts" *by* Peter A. Bespalov and Olga N. Savina

Anonymous Referee #1

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Referee report on the paper, "Excitation of chorus with small wave normal angles due to BPA mechanism in density ducts" by P. A. Bespalov and D. N. Savina

I have read the above paper with interests, and I have come to the conclusion that this paper can be acceptable for publication in Angeo, but only after the authors will make the revisions listed below.

General remark: The idea of wave-particle interactions in a confined area such as whistler ducts is very acceptable, and this is theoretically investigated in this paper. Fundamentally it can be acceptable for publication, but only after the authors will make the appropriate revisions.

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Discussion paper

Specific remarks: (1) English The English of this paper is not good enough to be accepted in an international journal like Angeo. I strongly request the authors to polish their English with the help of an native English speaker. This will definitely enhance the quality of the paper. (2) Title: “into density ducts” is not good, and it is better to use “in density ducts”. (3) Abstract, line 4 beam pulse amplifier (BPA) mechanism (4) Introduction, line 14 Something is wrong, and I can suggest the following change. -somewhat lower than and just above half the minimum — - in question (see a review by Sazhin and Hayakawa (1992)).

Sazhin, S., and M. Hayakawa, Magnetospheric chorus emissions: A review, Planet. Space Sci., vol.40, 681-697, 1992.

- Line 20; I can suggest one more paper, which is published in a not so popular journal. (Karpman and Kaufman, 1984; Ishikawa et al., 1990; Laird, 1992; ——) if you are interested in.

Ishikawa, K., K. Hattori, and M. Hayakawa, A study of ray focusing of whistler-mode waves in the outer magnetosphere, Trans. of the IEICE (Institute of Electronics, Information and Communication Engineers of Japan), Vol. E73, 149-154, 1990. You will see it as an attachment. (5) Line 16: in Bell et al. (2009). (6) Line 20ïijŽMust be misspelling. Laird, 1992 (7) I am very unhappy with the first paragraph of p.2. Because you have cited only the recent papers on direction finding of chorus emissions, and it seems that you are not aware of earlier work before 1990. Previous papers should be properly described in the paper.

Page 2, line 4: (Muto et al., 1987; Hayakawa et al., 1990; Santolik et al., 2009)

Muto, H., M. Hayakawa, M. Parrot, and F. Lefeuvre, Direction finding of half- gyrofrequency VLF emissions in the off-equatorial region of the magnetosphere and their generation and propagation, J. Geophys. Res., 92, 7538-7550, 1987. Hayakawa, M., S. Shimakura, M. Parrot, F. Lefeuvre, and K. Hattori, Direction finding of chorus emissions in the outer magnetosphere and their generation and propagation, Planet. Space

Sci., 38, 135-143, 1990.

(8) The authors mention that the direction finding by Taubenschuss et al. (2014) is based on the assumption of a single wave. However, the earlier DF works by Muto et al. and Hayakawa et al. are much more general, because they used the wave distribution function. So, how about including the following sentences on line 9 (after the sentence of in a cold homogeneous plasma). We here compare the THEMIS results with earlier analyses based on a more general concept of wave distribution function. For the lower band chorus, the earlier work by Hayakawa et al. (1990) is very consistent with the THEMIS result. While, there is some discrepancy between Muto et al. (1987) 's result and THEMIS result for the upper band chorus. (9) Line 17: - beam pulse amplifier (BPA) mechanism of — - BPA concept appears firstly here in this paper, and you had better mention something about this BPA here. (10) Page 3, line 6: The depleted duct (e.g. Helliwell, 1965) (11) Line 7: enhanced duct (Helliwell, 1965; Karpman — (12) Line 18: well-known form (Laird, 1992) (13) Line 21: Gendrin velocity (14) Page 4, line 4: electron cyclotron (15) Page 6, line 4: recall the formation process of chorus frequency-time spectrogram in the implementation of the BPA mechanism (16) Line 9: classify the duct solutions (17) Page 7, line 7: Actually the number of —- (18) Line 14: realization of the BPA mechanism (19) Line 26: the BPA mechanism (20) References: -Addional papers should cited here in References. -p8, line 27; should be Gurnett -Heliwell (1995) seems to be not cited in the text.

Please also note the supplement to this comment:
https://www.ann-geophys-discuss.net/angeo-2019-83/angeo-2019-83-RC1-supplement.pdf

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2019-83, 2019.

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No. 131

PAPER

A Study of Ray Focussing of Whistler-Mode Waves in the Outer Magnetosphere

Kiyohiko ISHIKAWA†, *Nonmember,* Katsumi HATTORI† *and* Masashi HAYAKAWA†, *Members*

SUMMARY The purpose of this paper is to investigate the ray focussing of whistler-mode waves in the outer magnetosphere which results in an enhanced wave-particle interactions. The critical frequency in a homogeneous plasma is first studied, at which the refractive index surface of whistler-mode waves indicates a zero curvature at a longitudinal wave normal angle. This critical frequency is also found to be consistent with the zero diffraction coefficient in the full-wave theory for a slightly inhomogeneous plasma. The two-dimensional ray-tracing computations for varying the frequency and initial wave normal direction in an inhomogeneous realistic model of the outer magnetosphere, have yielded that although the critical frequency for the homogeneous case has its importance even in the inhomogeneous plasma, the strongest ray focussing seems to occur at a frequency slightly below the above critical frequency, and hence that an enhanced gyroresonance wave-particle interaction is anticipated at this frequency.

1. Introduction

Gyroresonance wave-particle interaction is important in studying not only the generation of VLF/ELF emissions in the magnetosphere, but also the structure and stability of the magnetospheric energetic particles (e. g., Helliwell and Crystal[(1)]). In order to enhance efficiently the phase-bunching of incoming gyroresonant electrons by counter-propagating waves, the focussing of radiation along the magnetic field lines is highly required[(1),(2)]. Hence, it is of great significance to investigate the propagation of whistler-mode waves near the equator in a wide frequency range with normalized frequency from 0.1 to 0.7 in the outer magnetospere, with respect to paying a particular attention to the efficient wave-particle interactions. There is ample experimental and theoretical evidence of wave refraction in the plasmasphere, but little study is done on the topic of wave refraction in the outer magnetosphere (see Muto and Hayakawa[(3)], and the references therein). In Sect. 2 we discuss the propagation of whistler-mode waves in a homogeneous magnetospheric plasma based on the study of refractive index surface and then a full wave study. Then, Sect. 3 deals with the whistler-mode wave propagation in an inhomogeneous, realistic magnetosphere by means of the two-dimensional ray-tracing computations.

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2. Propagation in a Homogeneous Magnetosphere

The propagation of whistler-mode waves in a homogeneous plasma can be studied with the aid of refractive index surfaces. For dense plasmas such that the electron plasma frequency f_p is much larger than the electron gyrofrequency $f_H (f_p \gg f_H)$, we have plotted the change in morphology of the whistler-mode refractive index surface above and below the critical frequency of $f_H/2$. Figure 1 illustrates this situation, and Fig. 1 (a) refers to the frequency below the critical frequency and Fig. 1 (b) above the critical frequency. As seen from the figure, the surface below the critical frequency is convex at small wave normal angles, while above the critical frequency we find the surface simply concave. Hence, we

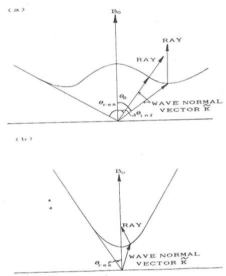

Fig. 1 Change in morphology of whistler-mode refractive index surface (a) below and (b) above the critical frequency. The relationship of ray and wave normal directions is indicated. Three characteristic angles, θ_{inf}, θ_g and θ_{res} are illustrated, which are defined in the text.

Fig. 1.

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