

## Respond to all referee comments

### (1) Comment from Referee

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.

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 a 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 20 *nij* Must 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: -Additional papers should cited here in References. -p8, line 27; should be Gurnett - Helliwell (1995) seems to be not cited in the text.

(2) Author's response

**We would like to thank the Reviewer for the time he/she spent reading, positive response, and commenting our manuscript. We have prepared a point-by-point answer to his/her comments below. The responses are marked in bold and the modified parts are marked in yellow in the new marked version of the manuscript.**

Reviewer's Comments:

(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.

**Response:**

**Some minor corrections were made to edit the manuscript.**

Reviewer's Comments:

(2) Title: “into density ducts” is not good, and it is better to use “in density ducts”.

**Response:**

**The title of the manuscript was modified in accordance to the important suggestion of the Reviewer. The new title is "Excitation of chorus with small wave normal angles due to BPA mechanism in density ducts".**

Reviewer's Comments:

(3) Abstract, line 4 beam pulse amplifier (BPA) mechanism

**Response:**

**The text is corrected.**

Reviewer's Comments:

(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.

**Response:**

**We modified the text in accordance with reviewer's suggestion and referred to the review by Sazhin and Hayakawa (1992).**

Reviewer's Comments:

- 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.

**Response:**

**The list of references was extended, and the corresponding citation (Ishikawa et al, 1990) was added to the text of the manuscript.**

Reviewer's Comments:

(5) Line 16: in Bell et al. (2009).

**Response:**

**The text is corrected.**

Reviewer's Comments:

(6) Line 20 must be misspelling. Laird, 1992

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**The text is corrected.**

Reviewer's Comments:

(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)

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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.

**Response:**

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Reviewer's Comments:

(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.

**Response:**

**We agree with the distinguished reviewer. The concept of wave distribution function is a more general in comparison with the plane wave approximation. We mentioned this in the text.**

Reviewer's Comments:

(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.

**Response:**

**We added a couple of sentences about BPA concept.**

Reviewer's Comments:

(10) Page 3, line 6: The depleted duct (e.g. Helliwell, 1965)

**Response:**

**The citation is added.**

Reviewer's Comments:

(11) Line 7: enhanced duct (Helliwell, 1965; Karpman —

**Response:**

**The citation is added.**

Reviewer's Comments:

(12) Line 18: well-known form (Laird, 1992)

**Response:**

**The text is corrected.**

Reviewer's Comments:

(13) Line 21: Gendrin velocity

**Response:**

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**Response:**

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(15) Page 6, line 4: recall the formation process of chorus frequency-time spectrogram in the implementation of the BPA mechanism

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(17) Page 7, line 7: Actually the number of —

**Response:**

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Reviewer's Comments:

(18) Line 14: realization of the BPA mechanism

**Response:**

**The text is corrected.**

Reviewer's Comments:

(19) Line 26: the BPA mechanism

**Response:**

**The text is corrected.**

Reviewer's Comments:

(20) References: -Additional papers should cited here in References. -p8, line 27; should be Gurnett - Heliwell (1995) seems to be not cited in the text.

**Response:**

**The list of references was extended, and the corresponding citation (Lauben, D.S., Inan, U.S., Bell, T.F., and Gurnett, D.A.: Source characteristics of ELF/VLF chorus, J. Geophys. Res., 107, CiteD1429, doi:10.1029/2000JA003019, 2002.) was added to the text of the manuscript.**



(3) Author's changes in manuscript

Title

The text

"into density"

is replaced by

"in density"

Abstract line 1

The text

"mechanism (BPA)"

is replaced by

"(BPA) mechanism"

Page 1 line 1

The text

"in (Bell et al., 2009)"

is replaced by

"in Bell et al. (2009)"

Page 1 line 14

The text

"centered somewhat lower than half the minimum electron cyclotron frequency for the magnetic tube in question"

is replaced by

"somewhat lower than and just above half the minimum electron cyclotron frequency for the magnetic tube in question (see, e.g., a review by Sazhin and Hayakawa (1992))"

Page 1 line 20

The text

"Ishikawa **et al.**, 1990;"

is added.

Page 1 line 20

The text

"Laid"

is replaced by

"Laird"

Page 2 line 3

The text

"the experimental"

is replaced by

"the theoretical and experimental"

Page 2 line 4

The text

"Santolik et al., 2009"

is replaced by

"Muto et al., 1987; Hayakawa et al., 1990; Santolik et al., 2009"

Page 2 line 8

The text

"is based"

is replaced by

"(Taubenschuss et al., 2014) is based"

Page 2 line 11

The text

"formalism"

is replaced by

framework of a concept of wave distribution function (Muto et al., 1987; Hayakawa et al., 1990)

Page 2 line 16

The text

"not requiring significant anisotropy of the distribution function of energetic electrons"

is removed

Page 2 line 17

The text

"It has been shown that under suitable conditions a very effective amplification of short noise pulses can occur even in a stable plasma. Pulse amplification leads to the excitation of bursts of electromagnetic radiation having the same properties as would occur due to an instability resulting from a very high anisotropy in the distribution function of energetic electrons."

is added.

Page 3 line 6

The text

"(Helliwell, 1965)"

is added.

Page 3 line 7

The text

"(Helliwell, 1965)"

is added.

Page 4 line 4

The text

"electronic"

is replaced by

"electron"

Page 6 line 4

The text

"beam pulse amplifier"

is replaced by

"BPA"

Page 6 line 24

The text

"The mentioned frequencies are typical for low-band and upper-band chorus (Lauben et al., 2002)."

is added.

Page 7 line 7

The text

"Actually, that"

is replaced by

"Actually"

Page 7 line 14

The text

"beam pulse amplifier"

is replaced by

"BPA"

Page 7 line 26

The text

"beam pulse amplifier"

is replaced by

"BPA"

Page 8 line 18

The text

"Ishikawa, K., Hattori, K., and Hayakawa, M.: 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), E73, 149-154, 1990."

is added.

Page 8 line 22

The text

"Lauben, D.S., Inan, U.S., Bell, T.F., and Gurnett, D.A.: Source characteristics of ELF/VLF chorus, J. Geophys. Res., 107, CiteD1429, doi:10.1029/2000JA003019, 2002."

is added.

Page 8 line 30

The text

"Sazhin, S., and Hayakawa, M.: Magnetospheric chorus emissions, A review, Planet. Space Sci., 40, 681-697, doi:10.1016/0032-0633(92)90009-D, 1992.'

is added.

Page 9 line 15

The text

"Hayakawa, M., Shimakura, S., Parrot, M., Lefeuvre, F., and Hattori, K.: Direction finding of chorus emissions in the outer magnetosphere and their generation and propagation, Planet. Space Sci., 38, 135-143, doi:10.1016/0032-0633(90)90012-F, 1990."

is added

Page 9 line 26

The text

"Muto, H., Hayakawa, M., Parrot, M., and Lefeuvre, F.: 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, doi:10.1029/JA092iA07p07538, 1987."

is added