International Symposium DEMETER. Results of the DEMETER project
and of the recent advances in the seismo-electromagnetic effects and the ionospheric physic
CNES, Toulouse-Labege, 14-16 June 2006

Anomalistic wave propagation phenomena in whistler waveforms detected on wide-band VLF recordings of the DEMETER satellite

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The goal of this presentation

- To give a review of our investigations using the detailed records of the electromagnetic waveforms.
- To give a review of the interesting phenomena found in the DEMETER data.
- To give a review of the results of the application of the exact, new solutions of the Maxwell's equations opening a new way in the interpretation of the anomalistic-like e.m. phenomena.
- To present some new information about the e.m. signal and source activity of our planet.

The DEMETER satellite (CNES)

The parameters interesting for us:

- Launch: 29th June 2004, Baikonur
- Pre-operation phase: July-August 2004
- Regular operation: September 2004
- Orbit: LEO, height cca. 710 km

Inside the upper ionosphere!

- Instruments: ICE DC – 3.175 MHz
  IMSC few Hz – 17.4 kHz
- Modes: "survey" mode
  "burst" mode

Data used in this investigations

ICE and IMSC "burst" mode VLF data were used:

- Time and geographic region, "systematic" data processing:

  July 2004 – January 2005, (increasing);

  latitude = 30º – 53º N, longitude = 5º – 33º E.

- Time and geographic region, "scanning" data processing:

  July 2004 – January 2005, (increasing);

  tracking the "burst"-mode distribution on the globe,

  using large latitudinal coverage orbits (Alaska, Andes,

  New Zealand, Kamchatka etc.), i.e. sporadic global.

- Processed data mass:

  Overall **> 22 hours** recording time.

Identified anomalistic VLF phenomena

- The “Swallow-Tailed Whistler”, i.e. STW.
- The bifurcating or crossing whistlers, i.e. X-type whistlers.
- The oblique propagating, special whistler-groups.

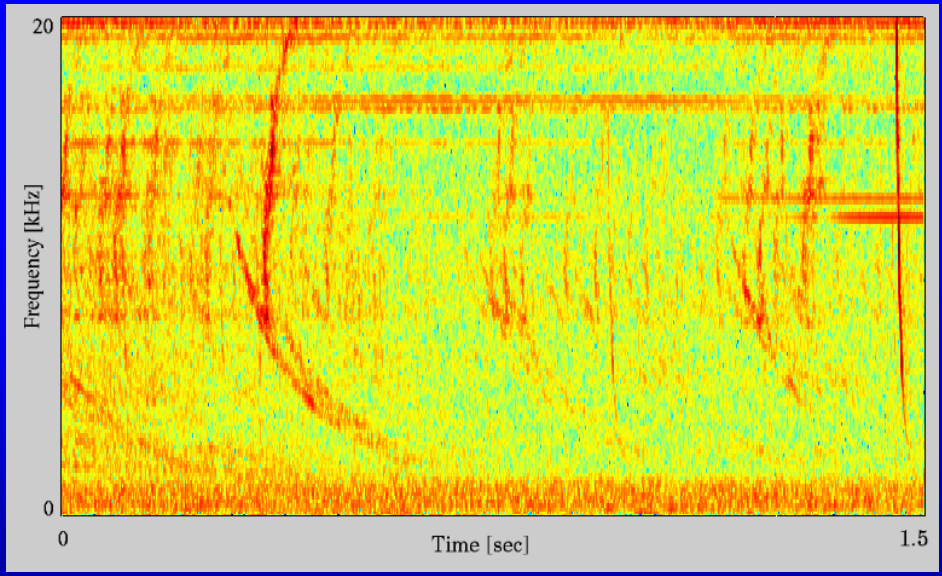
  (See in details on **poster**.)
- The “Spiky Whistler”, i.e. SpW.

  (See in details on **poster**.)
- Special combinations of the SpW character and the oblique propagating group structures.
- … and the next … $\Rightarrow$?

The “Swallow-Tailed Whistler”, i.e. STW.

The phenomenon:

- whistler-like “main-trace”,
- ‘v’-shaped or monotonously increasing “secondary trace”.



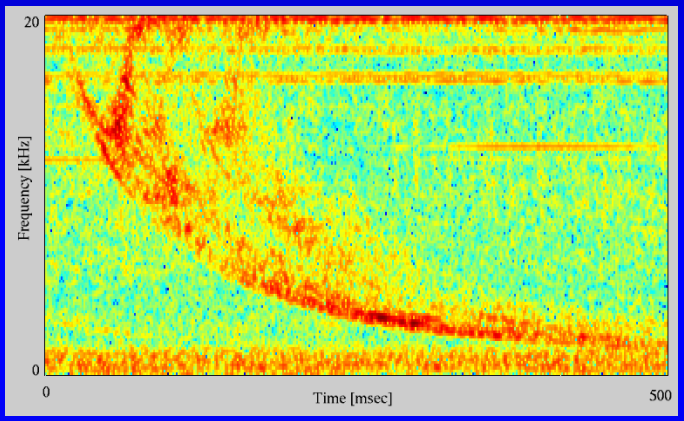
Data:

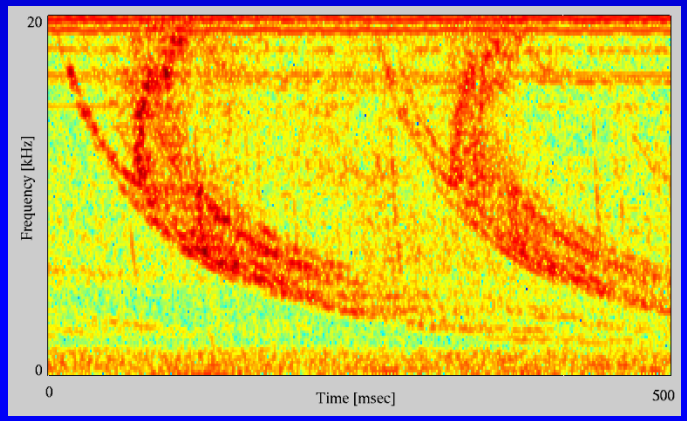
sensor: ICE E34
no. of orbit: 1547 up
time: 16.10.2004.
20:55:16 UT
local time: 21:42:28 LT
latitude: 43.2 N
longitude: 11.8 E
height: cca. 720 km

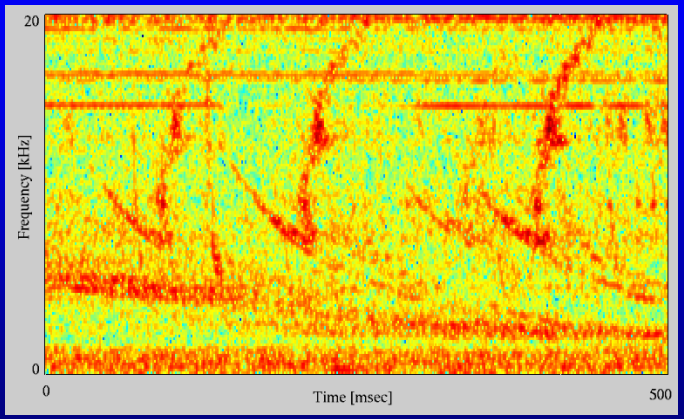
Starting Furcation Frequency (SFF) appear
and it is changing.

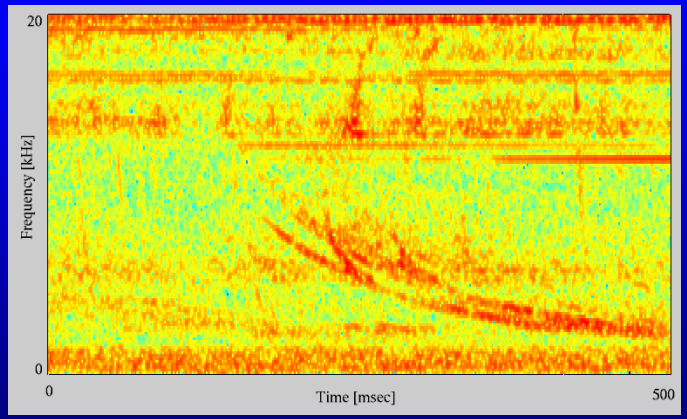
The “Swallow-Tailed Whistler”, i.e. STW.

Changing of SFF:









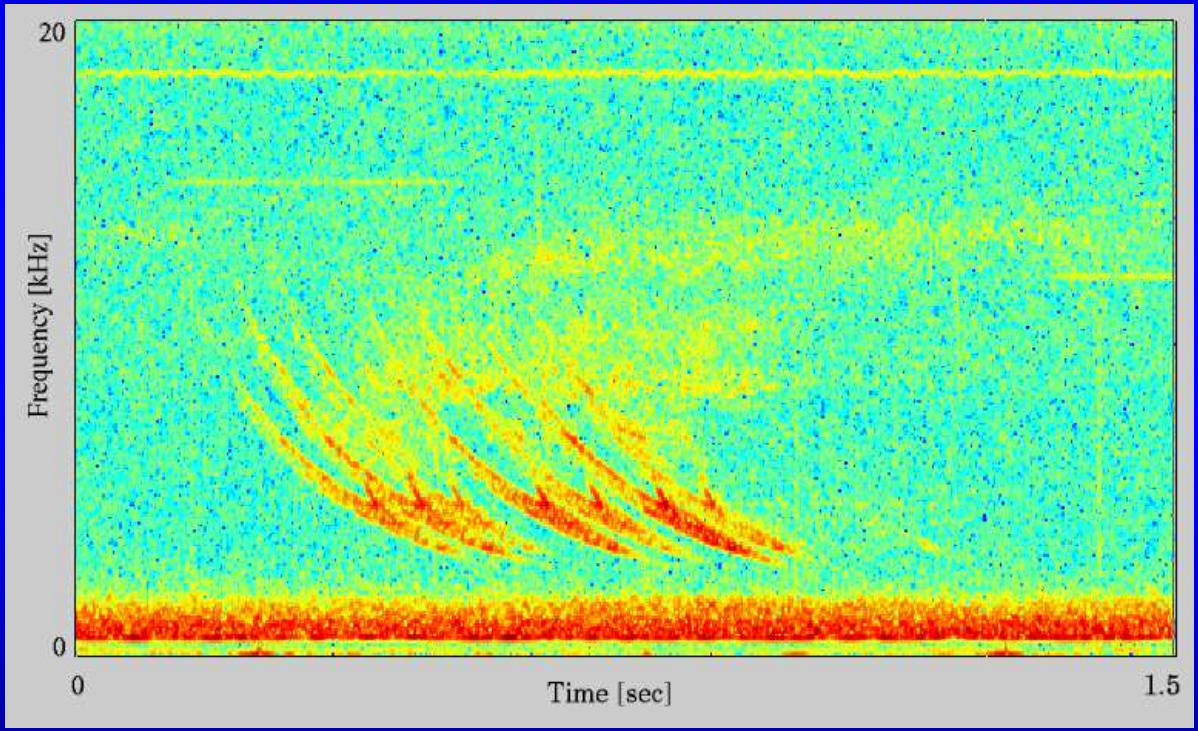
Data:

sensor: ICE E34
no. of orbit: 1547 up
time: 16.10.2004.
20:54:55.8 -
20:55:31.1 UT
local time: 21:44:07.8 -
21:51:31.1 LT
latitude: 41.9 - 44.0 N
longitude: 12.3 - 11.5 E
height: cca. 720 km

SFF decreases monotonously, the dispersion of the whole pattern slightly increases.

The “Swallow-Tailed Whistler”, i.e. STW.

Changing of SFF:



Data:

sensor: ICE E12
no. of orbit: 2355 down
time: 11.12.2004.
09:06:13 UT
local time: 10:56:13 LT
latitude: 51.3 N
longitude: 27.5 E
height: cca. 720 km

Very low SFF appears also, with higher dispersion.

The “Swallow-Tailed Whistler”, i.e. STW.

Discussion:

- Not a satellite-induced artifact.
- Not a whistler-triggered emission:

  - it is below the nose;

  - it has curvilinear structure in contradiction with known/observed emissions.

The “Swallow-Tailed Whistler”, i.e. STW.

Discussion:

- Not a satellite-induced artifact.
- Not a whistler-triggered emission:

  - it is below the nose;

  - it has curvilinear structure in contradiction with known/observed emissions.
- Not a magnetospherically reflected whistler (MR):

The “Swallow-Tailed Whistler”, i.e. STW.

Discussion:

- Not a satellite-induced artifact.
- Not a whistler-triggered emission:

  - it is below the nose;

  - it has curvilinear structure in contradiction with known/observed emissions.
- Not a magnetospherically reflected whistler (MR):

  - the dispersion of the “main” trace excludes the magnetospheric propagation, but it corresponds to conventional whistler dispersion at the given magnetic latitude, i.e. satellite position;

The “Swallow-Tailed Whistler”, i.e. STW.

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- Not a whistler-triggered emission:

  - it is below the nose;

  - it has curvilinear structure in contradiction with known/observed emissions.
- Not a magnetospherically reflected whistler (MR):

  - the dispersion of the “main” trace excludes the magnetospheric propagation;

  - the shape of STW differs from the normal MR-shapes;

The “Swallow-Tailed Whistler”, i.e. STW.

Discussion:

The shape of STW differs from the MR-shapes:

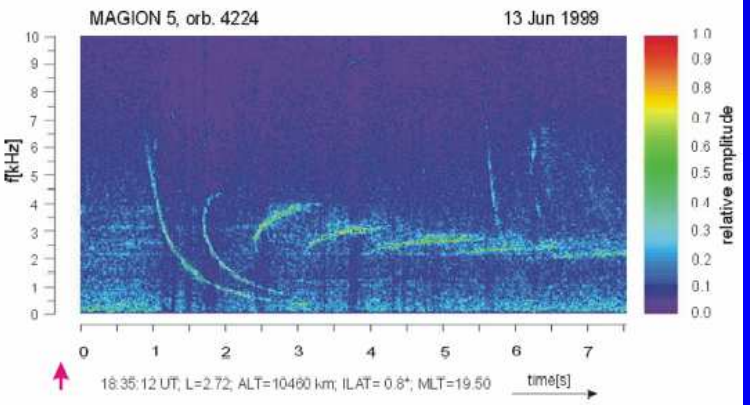


Fig. 6. MR whistler spectrogram observed by MAGION 5 on orbit 4224.

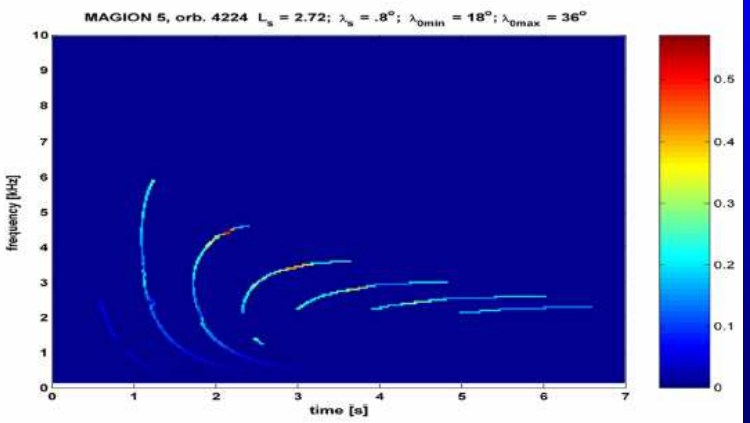


Fig. 7. Simulated spectrogram of MR whistler reproducing the real spectrogram taken by MAGION 5 on orbit 4224.

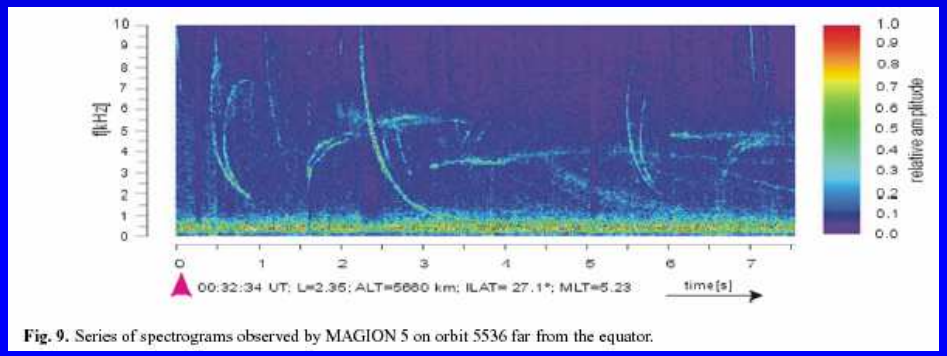


Fig. 9. Series of spectrograms observed by MAGION 5 on orbit 5536 far from the equator.

Annales Geophysicae (2004) 22: 3589–3606
SRef-ID: 1432-0576/ag/2004-22-3589

Annales Geophysicae

Characteristic properties of Nu whistlers as inferred from observations and numerical modelling

D. R. Shklyar[1], J. Chum[2], and F. Jiříček[2]

The “Swallow-Tailed Whistler”, i.e. STW.

Discussion:

- Not a satellite-induced artifact.
- Not a whistler-triggered emission:

  - it is below the nose;

  - it has curvilinear structure in contradiction with known/observed emissions.
- Not a magnetospherically reflected whistler (MR):

  - the dispersion of the “main” trace excludes the magnetospheric propagation;

  - the shape of STW differs from the normal MR-shapes;

  - the shape of STW differs from the ν-whistler’s shapes [1], which have no “leg”.

The “Swallow-Tailed Whistler”, i.e. STW.

Discussion:

- Not a satellite-induced artifact.
- Not a whistler-triggered emission:

  - it is below the nose;

  - it has curvilinear structure in contradiction with known/observed emissions.
- Not a magnetospherically reflected whistler (MR):

  - the dispersion of the “main” trace excludes the magnetospheric propagation;

  - the shape of STW differs from the normal MR-shapes;

  - the shape of STW differs from the ν-whistler’s shapes [1], which have no “leg”.
- Such kind of signal never was detected on ground based measurements.

The “Swallow-Tailed Whistler”, i.e. STW.

Conclusions:

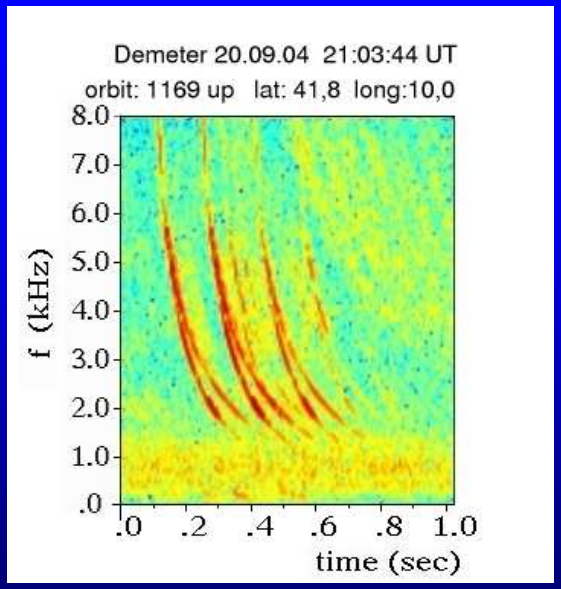
- New and anomalistic.
- One-hop (with low L-values) or fractional hop (uprising) UWB signals.
- One or two propagating UWB modes.
- SFF decreases monotonously.
- SFF values between 4-16 kHz.
- STWs appear in series lasting several tens of seconds.
- No seismic connection was found.

The “X-type or bifurcating whistler”.

The phenomenon:

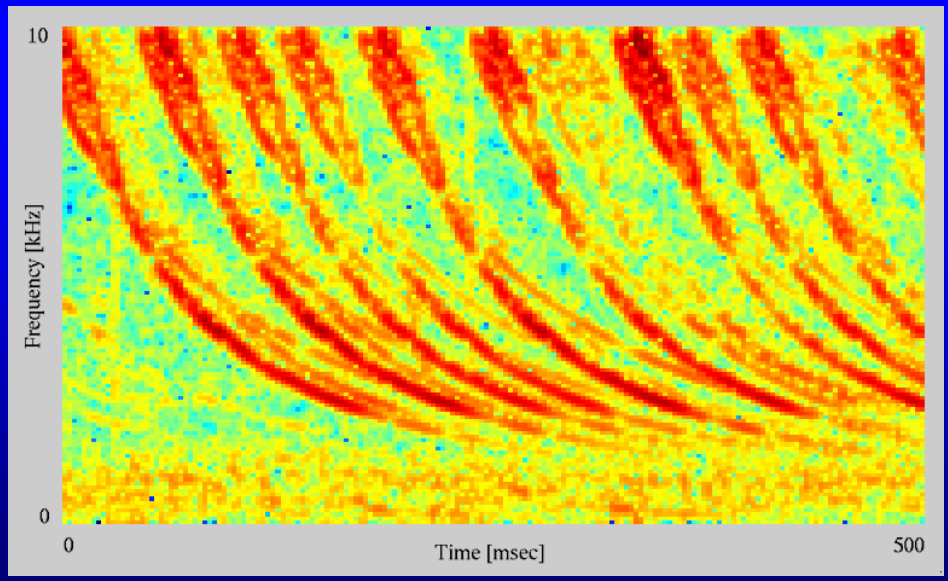
We have found a systematic bifurcation of the VLF signal and/or a systematic X-type FFT pattern with more propagating UWB modes.

20.09.2004. 21:03:44 UT, L=1.8



Bifurcation (‘splitting’)

20.09.2004. 21:03:21 UT, L=1.72



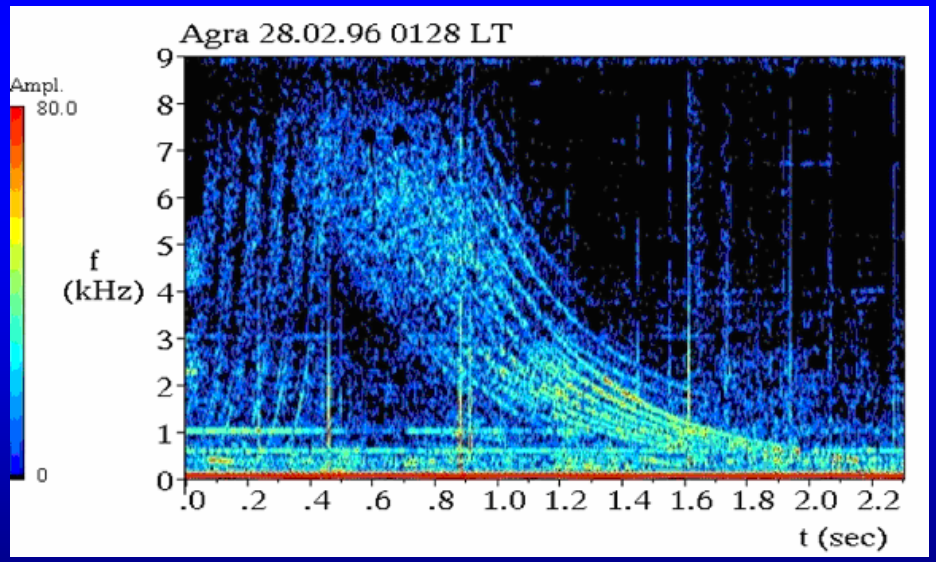
X-type pattern, with two or more modes

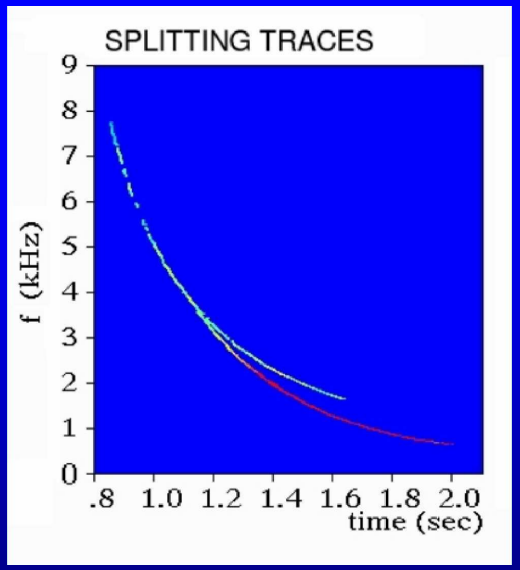
The “X-type or bifurcating whistler”.

The phenomenon:

Similar pattern was found on ground based recordings, measured by Birbal Singh (Phys.Dept. R.B.S. College, Bichpuri, Agra, India [2]).

(28.02.1996. 01:28 LT, geomagnetic latitude 17.02 N, L=1.15)





FFT of the original registration

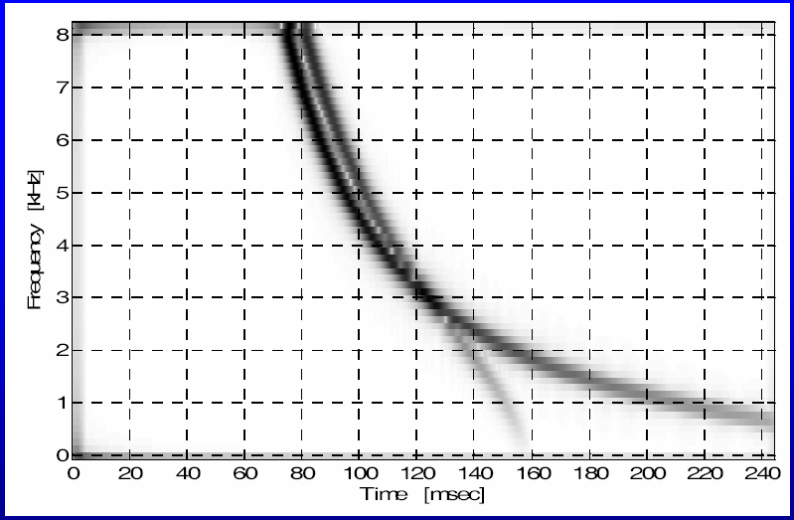
Fine structure of one trace – using matched filtering

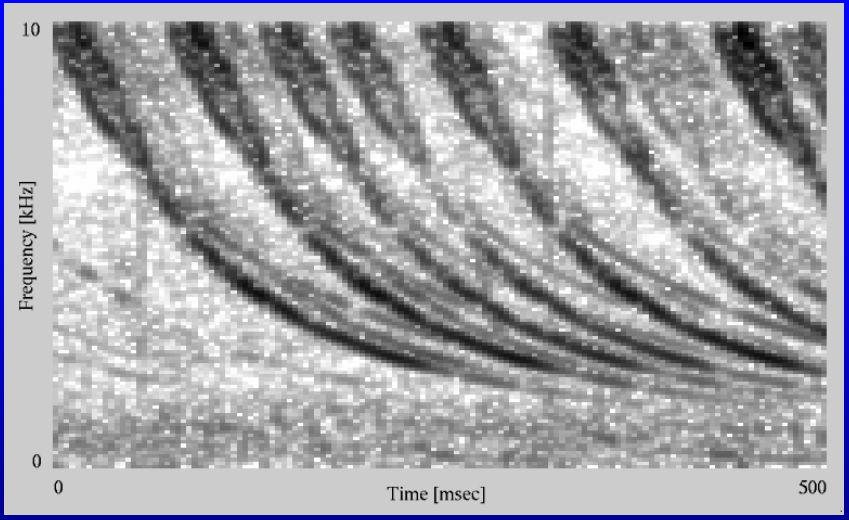
The “X-type or bifurcating whistler”.

First step in explanation:

The UWB signals ***propagating in a wave-guide filled with magnetized plasma*** have remarkable similarities with UWB signals measured by DEMETER and in Agra.

See more in details in [3].



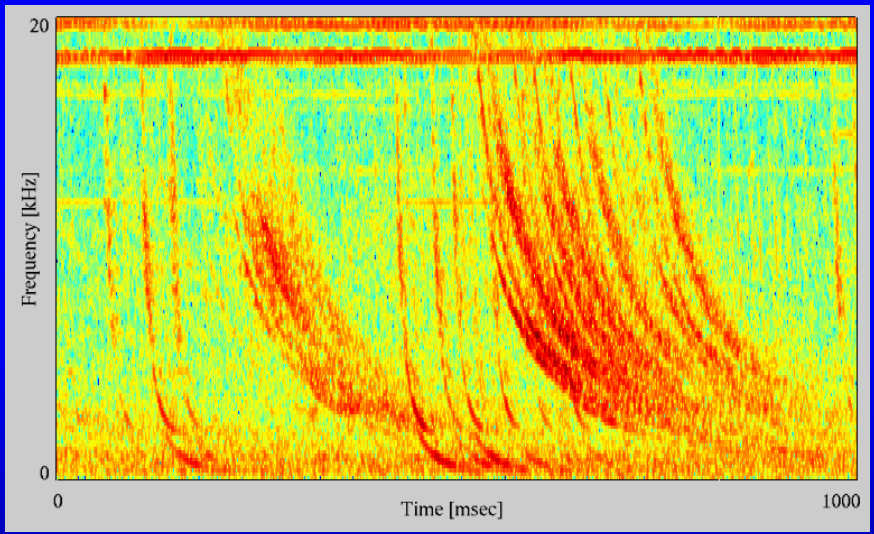


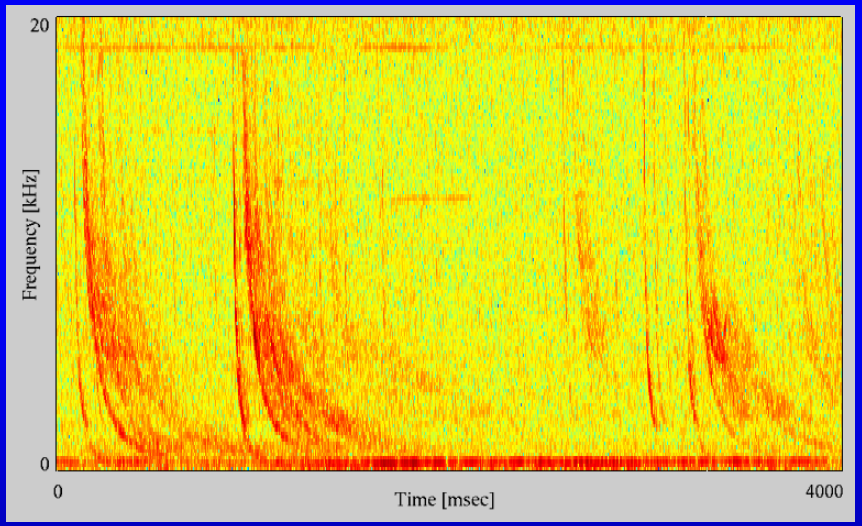
Two propagating UWB modes in a plasma-filled wave-guide. Measured by DEMETER

Oblique propagating whistler-groups.

The phenomenon:

Branch or pairs of whistlers forms systematically special groups.





Data: sensor: ICE E12, no. of orbit: 2812 up;
time: 11.01.2005. 20:27:45.1 UT,
local time: 21:54:57.1 LT;
lat: 30.5 N, long: 21.8 E, height: 699.0 km;

sensor: ICE 34, no. of orbit: 714 up;
time: 20.08.2004. 13:54:32.6 UT,
local time: 22:26:32.6 LT;
lat: 8.0 S, long: 128.0 E, height: 720.3 km.

Oblique propagating whistler-groups.

Discussion:

- The appearance of two typical values of the dispersion of fractional hop like whistlers was known earlier. ($D \leq 5\text{-}8\ s^{1/2}$ and $D \geq 12\text{-}22\ s^{1/2}$.)
- This special ‘bimodal’ group formation was unknown.
- The origin of the distinct dispersion and the cause of this formation was interpreted successfully,

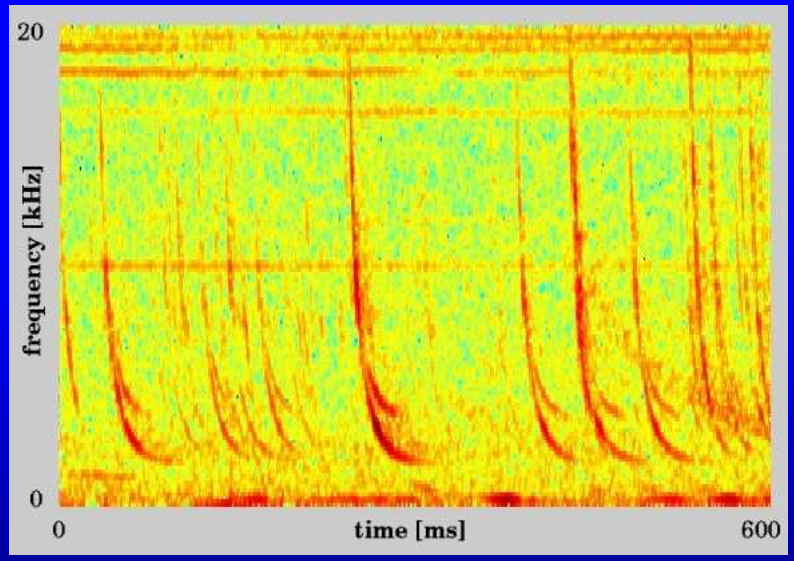
See more in details in [4].

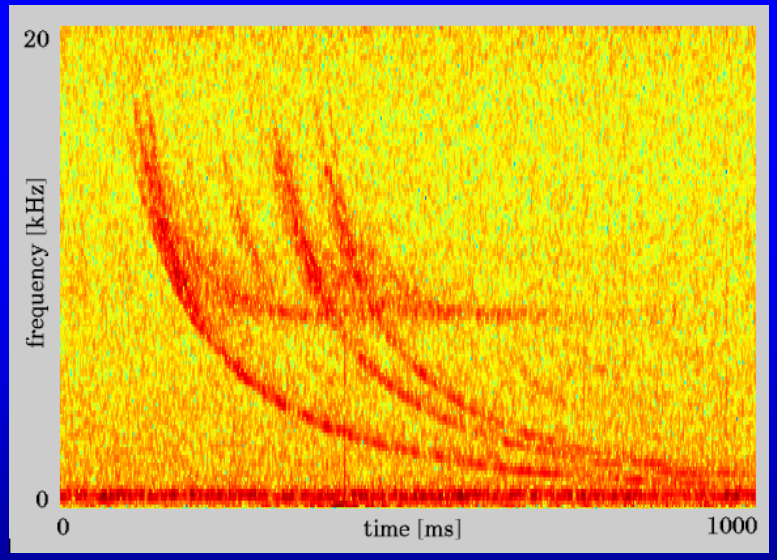
- The exact mechanism and boundary conditions of this characteristic, double out-coupling of the VLF UWB signals from the low atmosphere to the upper atmosphere is unknown yet.

The “Spiky Whistler”, i.e. SpW.

The phenomenon:

- Between the normal fractional hop (uprising) whistlers with the same dispersion fractional hop whistlers appear with more or less **spikes**.





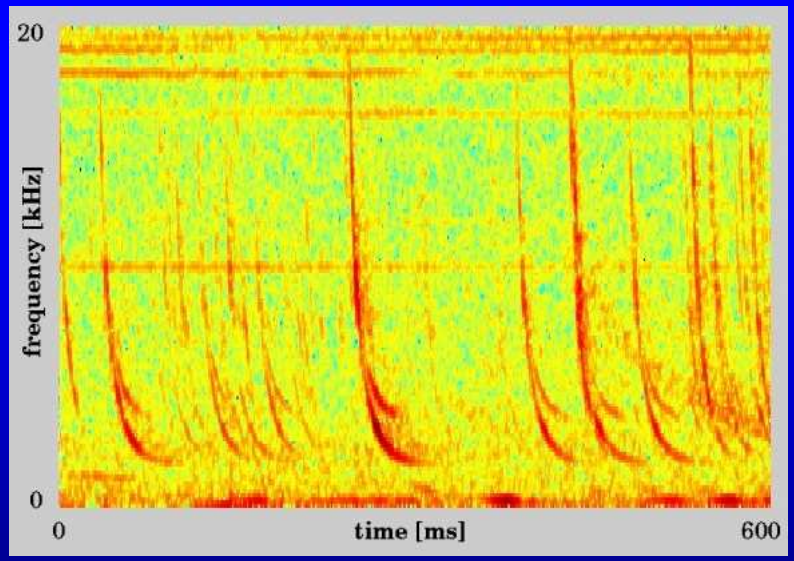
Data: sensor: ICE E34, no. of orbit: 1401 up;
time: 06.10.2004. 19:54:39.4 UT,
local time: 21:53:3.4 LT; L=1.36
lat: 39.1 N, long: 29.6 E, height: 707.8 km;

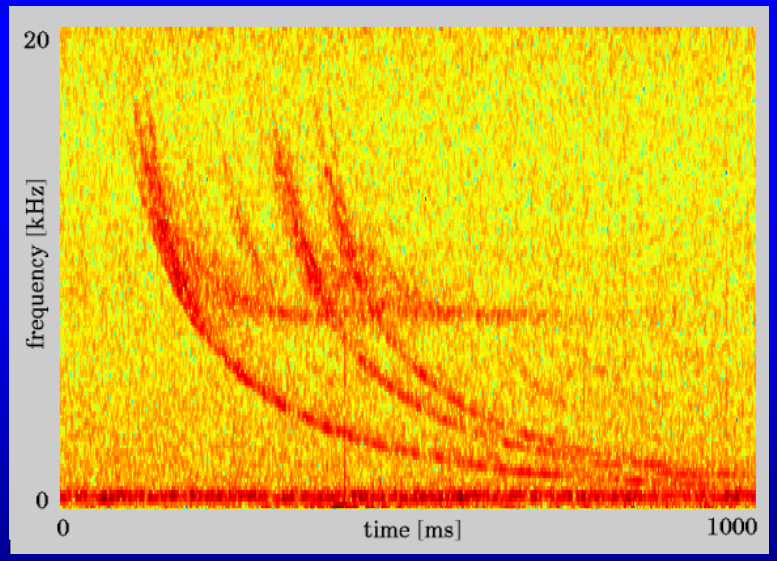
sensor: ICE 34, no. of orbit: 1558 down;
time: 17.10.2004. 14:16:46.4 UT,
local time: 9:35:10.4 LT; L=1.66
lat: 49.2 S, long: 70.4 W, height: 722.3 km.

The “Spiky Whistler”, i.e. SpW.

The phenomenon:

- Between the normal fractional hop (uprising) whistlers with the same dispersion fractional hop whistlers appear with more or less **spikes**.





- The occurrence number of these SpWs is smaller than the number of the normal fractional hop whistlers.

The “Spiky Whistler”, i.e. SpW.

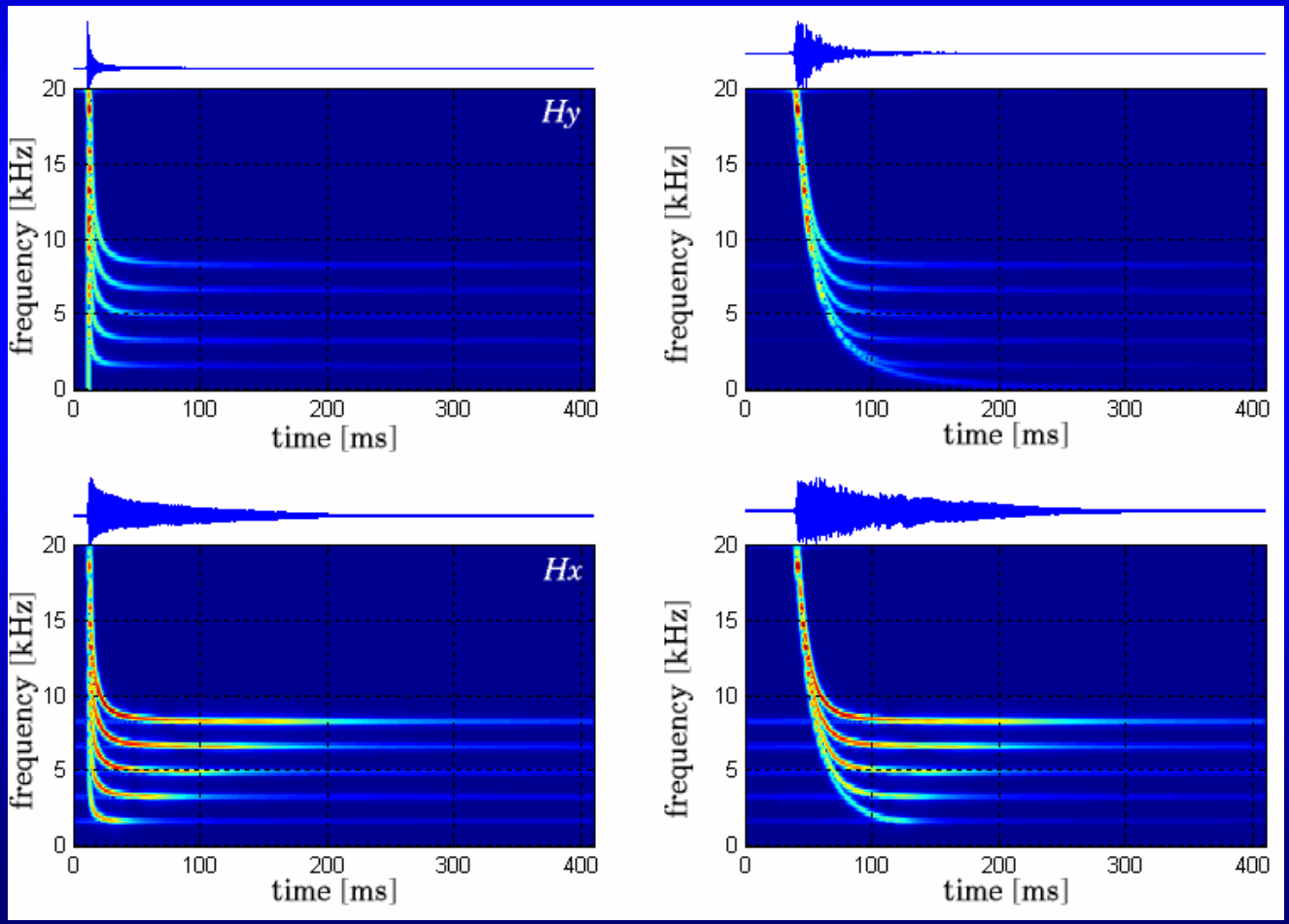
Discussion:

- The generation mechanism and the evolution of this signal structure was interpreted successfully using our theoretical results.

See more in details in [3].

The “Spiky Whistler”, i.e. SpW.

The generation mechanism and the evolution of these signals:

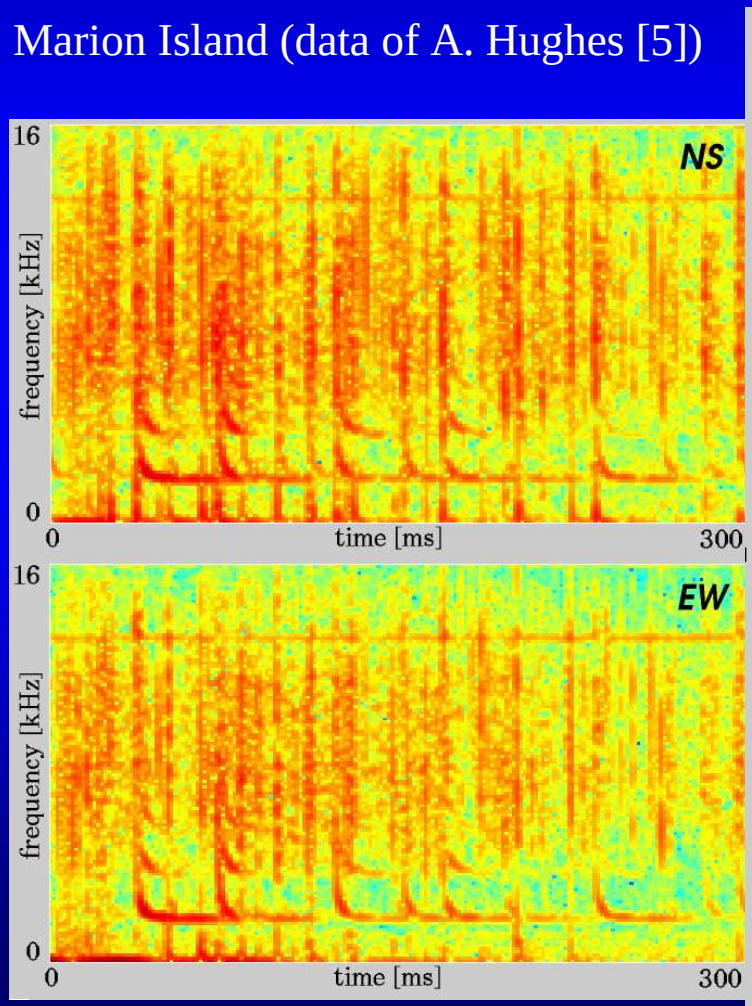


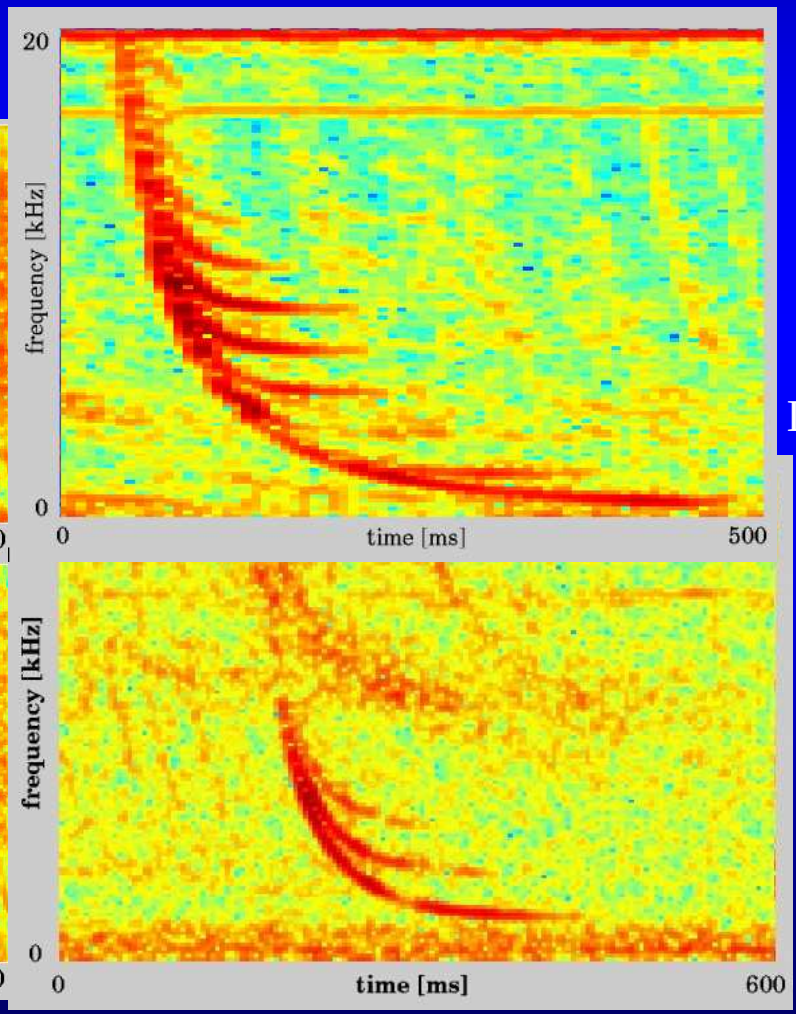
Full-wave UWB model

The “Spiky Whistler”, i.e. SpW.

The generation mechanism and the evolution of these signals:

Marion Island (data of A. Hughes [5])





DEMETER

The “Spiky Whistler”, i.e. SpW.

Discussion:

- The generation mechanism and the evolution of this signal structure was interpreted successfully using our theoretical results.

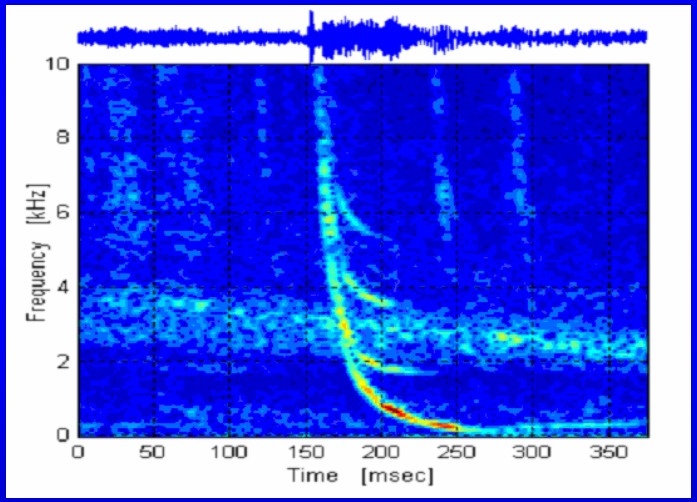
See more in details in [3].

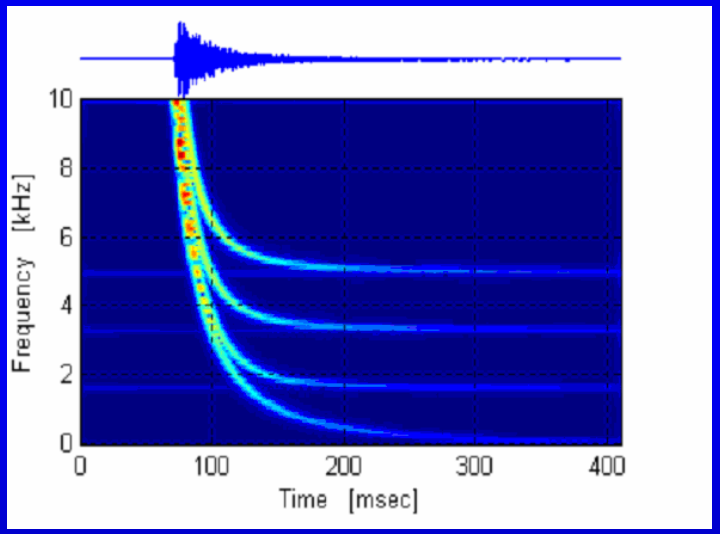
- The sources of SpWs are the CG lightnings.
- The sources of the normal non-SpWs are the CC lightnings.
- The ratio of the two type of whistlers are in good correlation with ground based observations. ***(See more in Lichtenberger at al. 2005 [6].)***

The “Spiky Whistler”, i.e. SpW.

Spiky Whistler measured by DEMETER and computed signal (time functions and their FFT spectrum) generated by tweeks:

The exact UWB solution of the problem is known.





Parameters determined by these data:

a) Height of the bottom boundary of the ionosphere.

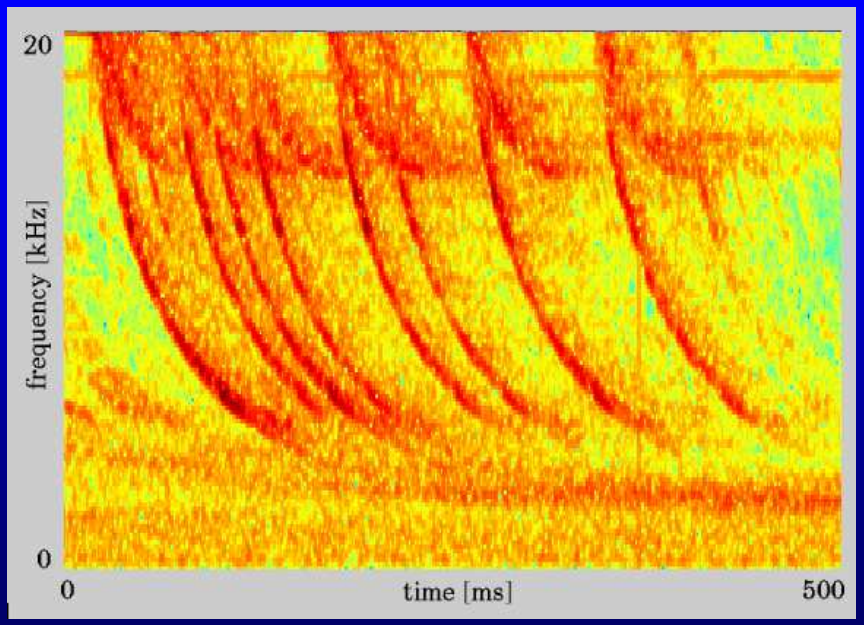
b) Electron density along the propagation path.

c) Direction and geometry of the propagation.

Special combinations of the SpW character and the oblique propagating group structures.

Signals and questions:

- In a lot of cases only some or a few guided wave modes are propagating to the satellite in the higher atmosphere, not the complete set of the modes.
- This is systematic in most cases.
- In this moment we do not know what is the cause of this ***selection*** between the guided modes propagating in the Earth-ionosphere wave-guide during the out-coupling and/or during the propagation in the ionosphere.



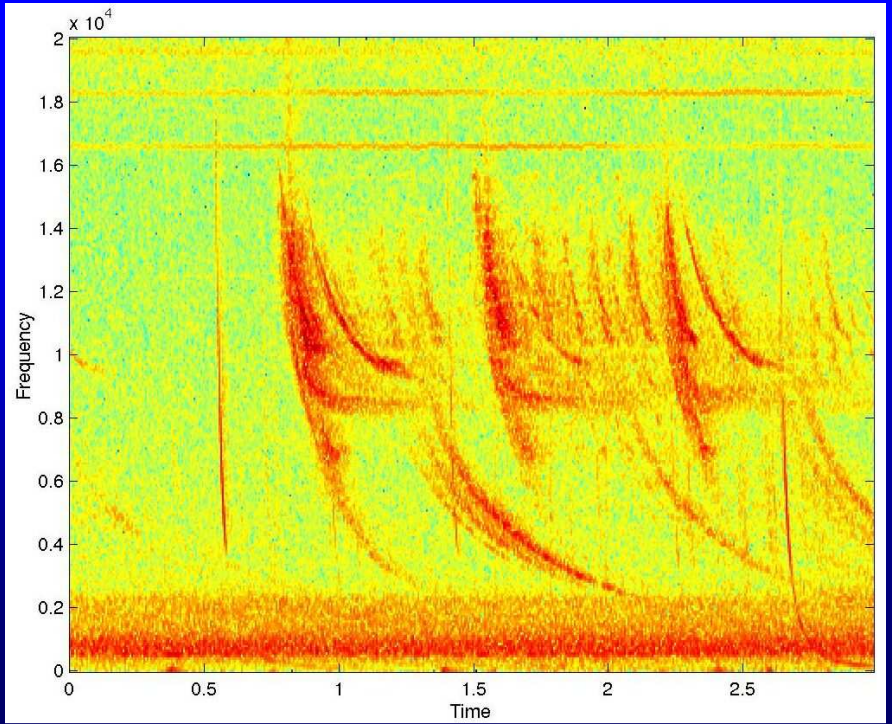
Data:

sensor: ICE E12
no. of orbit: 2623 up
time: 29.12.2004.
20:35:55 UT
local time: 21:49:55 LT
latitude: 36.3 N
longitude: 18.5 E
height: 701.4 km
L=1.51

Special combinations of the SpW character and the oblique propagating group structures.

Signals and questions:

- In some cases only a few guided wave modes are propagating to the satellite in the higher atmosphere, and the trapeze-like signal groups appear in one mode, however, do not appear in another mode.
- In the example propagate the basic, 4th, 5th and 6th modes;
  special group-events appear in the basic and 5th modes only.



- In this moment we do not know what is the cause of this ***selective*** phenomenon.
- However, now we have good questions about the out-coupling and about the special effects influencing the propagating UWB signals.

Summary

The main conclusions:

a) The UWB full-wave propagation models are good.

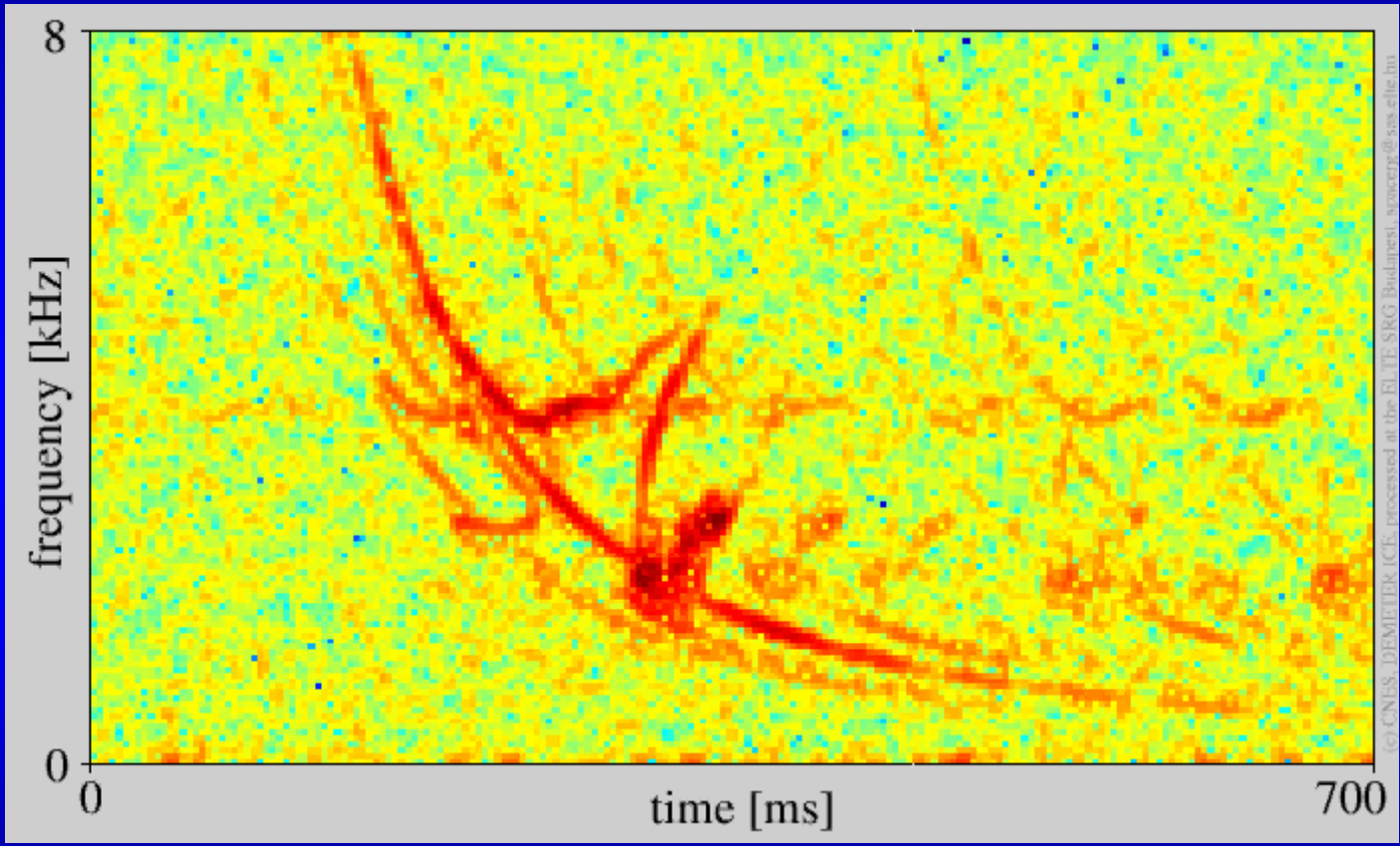
b) If the propagation of the whistlers, other VLF phenomena happens in wave-guides, then the guided modes will appear in the registered signals in every cases. Therefore the “duct-theory” need to be reviewed.

c) It is sure that basic ionospheric (magnetoionic) and out-coupling processes are unknown at this moment.

d) It is probable that we do not know several strange (‘anomalistic’) and important phenomenon.

e) No seismic relation was found in the presented anomalistic cases. The signals having seismic origins are different.

Summary



A probable effect of equatorial ionospheric turbulances.

Thank you for your attention !

References:

[1] Shklyar D.R., J. Chum and J Jiricek: Characteristic properties of Nu whistlers as inferred from observations and numerical modeling; Annales Geophysicae, 22, 3589-3606, 2004.

[2] Hamar D., O.E. Ferencz, J. Lichtenberger, B. Singh and R.P. Singh: Anomalistic phenomena in whistler waveforms: results of long propagation in Earth-ionosphere waveguide; URSI XXVIIIth Gen.Ass., New Delhi, India, COM-01354-2005.

[3] Ferencz O.E., Cs. Ferencz, J. Lichtenberger, D. Hamar, P. Steinbach, J.J. Berthelier, F. Lefeuvre and M. Parrot: Full-wave modeling of long subionospheric propagation and fractional-hop whistlers on electric field data of the DEMETER satellite; Int. Symp. DEMETER, Toulouse, France, P14, 2006.

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