Long path echoes and Ionospheric ducts

Date: March 22, 2016 F.Egano, IK3XTV email:ik3xtv@gmail.com web: www.qsl.net/ik3xtv

Introduction

Australian scientist of the University of Sydney , Cleo Loi, has made the very interesting discovery of plasma tubes in Earth's magnetosphere. Using a radio telescope that allows watching the space in 3D, she has shown that the earth's atmosphere is integrated with these plasma ducts. It is a sensational discovery that could even change the theory of the structure of the magnetic fields.
The research was published under the title “Real-time imaging of density ducts between the plasmasphere and ionosphere” by Cleo Loi of The University of Sydney with the support of some members of the international consortium of the Murchison Widefield Array (MWA) radio telescope.
What could be the role of these structures in the HF radio propagation? I'm wondering if this discovery can have a connection with my research on the long path propagation and ionospheric ducting, which I ‘m briefly introducing in this article.

The Plasma tubes in the ionosphere

The complex plasma ducts are created by the atmosphere, when this is ionized by sunlight. These tubes are located in the ionosphere, which is a multilayered plasma environment of electronically charged particles. This plasma interacts with the earth's magnetic field, creating field-aligned ducts of plasma. These structures of plasma are at about 600 km above the Earth's surface, in the upper ionosphere and they appear to be continuing upwards into the plasmasphere (inner magnetosphere). It seems they are positioned in a striped pattern, some stripes at high plasma density and some other at low plasma density and they are supposed to move very slowly and parallel to the Earth's magnetic field. These structures are also important because they cause signal distortions that could affect trans-ionospheric communication (satellite and GPS) and even in EME (Moon bouncing), as I could notice in several studies about this type of propagation.

The Geometry of the Tubes

Some information about the geometry, which we can use to infer the length of the tubes.
They are roughly placed at 570 +/- 40 Km above the earth’s surface and the length of the magnetic field lines (according to some rough calculations) for this shell is about 14000 km for the portion above the surface of the Earth. If the ducts do indeed follow the magnetic field lines all the way around to the other hemisphere, then this is how long they would be, but the MWA observations alone cannot directly confirm this, since the array can only see a several-hundred km wide region of sky above Western Australia. The observations alone show that they are at least several hundreds km long, since this is the width of MWA field of view, and over this length scale it does look as though they are very well aligned with the geomagnetic field. Now given that they exist at altitudes where the field-aligned conductivity is nearly *infinite, it is very likely that they extend into the conjugate ionosphere. So by an educated guess I would say they are around 14000* km long. Could the tubes be misaligned with the magnetic field? To answer this question, I contacted Ms. Cleo Loi. Loi and collegues, they are about to push through some more observations of density ducts. What they see is that at the point of formation, the tubes are aligned with the field, but successively can become distorted. They think the distortion might be the result of neutral winds in the thermosphere that are dragging the feet of the ducts along and shearing the whole structure.

The Telescope

The Murchison Widefield Array (MWA) is a low-frequency radio telescope and it is located at the Murchison Radio-astronomy Observatory (MRO) in Western Australia. The MWA consists of 2048 dual-polarization dipole antennas optimized for the 80-300 MHz frequency range, arranged as 128 "tiles", each a 4x4 array of dipoles. The Collecting area is Approx. 2000 sq. meters and Spectral resolution of 40 kHz. The MWA will be operated remotely through an interface to a Monitor and Control software package resident on a dedicated computer located at the MWA site.

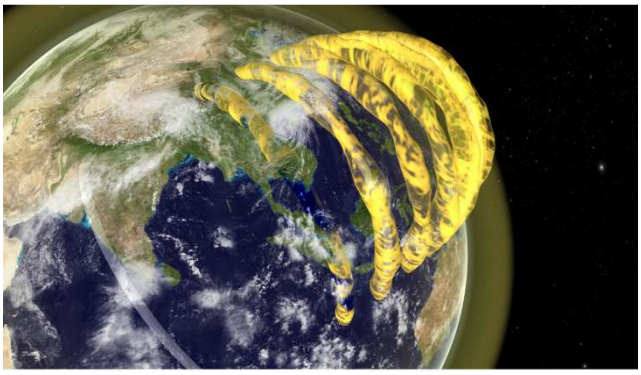

Fig.1a: Plasma tubes in the earth’s magnetosphere. Image credits: CAASTRO-Mats Björklund (Magipics)
Fig.1b: The wide field array consists of 128 antenna "tiles" over a seven-square-kilometer area at the Murchison Wide Field Array radio telescope in Western Australia used for this research. Ms Loi divided the array into two halves using the western half like a right eye and the eastern half like a left eye. Similar to the way humans use sight, she used triangulation to build a three-dimensional dynamic map of the plasma tubes over a large area. (Image credits: Wikipedia – Author: Natasha Hurley-Walker)

Some Long path echoes measures

I have performed several measures of echoes received by probable long path propagation. In this document I have reported just one case, as an example (Please see figure 2). But I have observed various cases, in which the delay of the echoes was ranging from 125 up to 140 ms (SDRE Short delayed radio echoes). The travel time around the earth is: 40,021 / 299.792,458= 0.133 sec. (Earth's circumference/speed of light). Official texts on the radio propagation state the propagation delay from long path in 138 ms since they take an additional 1400 km of path length in account due to reflections between the ground and the ionosphere. Personally,I think that this type of propagation is not conducted by the classics ionospheric jumps, but by a different mechanism of ionospheric low attenuation ducting.

The long path signal

In Figure 2, I have reported a very short extract from a recording CW transmission of YU5D received from IK2GRA. The first dash is the CW signal received short path (distance about 650 Km) from IK2GRA. The second dash, slightly overlapping the first, is the echo of the first dash, and it is received probably from the long path with a very low attenuation of about 3 dB. I have analyzed the audio track

deeply in details and I feel to make following speculation. It is possible that the signal of YU5D has made a further turn round the earth (within the ionospheric duct). That's why I can trace another signal echo, that might be called LP + 1 (Long Path +1), at about 270 ms from the main Short Path signal. This LP + 1 signal shows another 3 dB attenuation and it is evident among background noise.

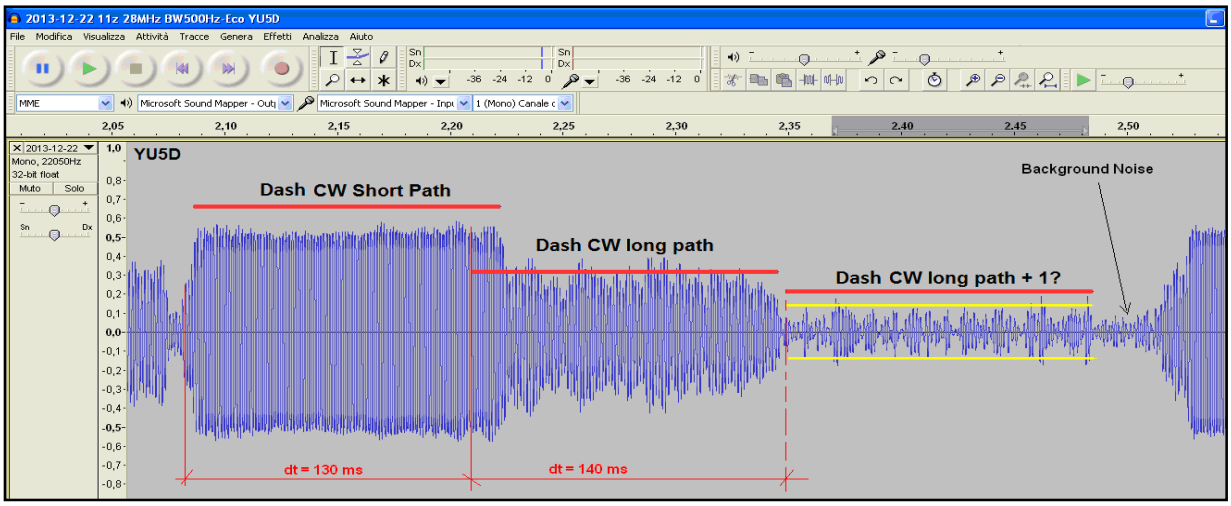

Fig.2: Reception of YU5D from IK2GRA. This is a sample recording of a 28 Mhz signal (cw dash), received via short path and the first echo is received via long path with a delay of 130 ms. The attenuation of the echo is very low, about 3 dB. The echo is partially covered by the short path signal. Probably there is also a second echo, I have called LP + 1, confused in the background noise, due to another round in the duct. The Short Path distance is about 650 Km and Long Path is about 39.400 Km. The audio measurement is made with the Audacity software. Recorded frequency: 28 mhz. Date: December 22, 2013. UTC Time: 11.00 . The solar indices:SFU 144 - Kp=1 (quiet)

Ionospheric Ducts

I am convinced that the HF propagation in the ionosphere does not always occur according to the classical model of ionospheric jumps, but in most cases there is a phenomenon of ionospheric ducting. The high plasma density of the duct is capable of trapping radio signals. Probably the radio wave follows a spiraling motion within these tubes with very low attenuation. Moreover, propagation should often occur towards transequatorial path, considering that the lines of force of the magnetic field are oriented from north to south. The circles cannot always pass through the center of the earth. It is also possible that the signal can make more than one revolution within the duct. The formation and the efficiency of the ducts seems to be much greater when the geomagnetic field is quiet.
The ducts form for certain frequencies, from long wave to short wave, the height of the ducts is variable and the delays are related to the frequency and height of the duct. I generally observed the event when the operating frequency was near the F2 critical frequency.
The existence of these Geo Magnetically-aligned structures with a density range of sizes exist in the near-Earth plasma environment, including 10 -100 km-wide ducting structures, is consistent, with studies conducted by Murchison Widefield Array and published in the Journal of Geophysical Research.

Attenuation

This is an important issue. All observations and recordings of echoes from long path show very low attenuation. In the case of Figure 2 YU5D: with short path of 650 km long path of 39400 Km. Their relationship is 60. According to the law of inverse square attenuation should be 10 * log60^2 = 35 dB. Instead it is 3 dB. From this report, it is clear that we can not be in case of free space propagation (attenuation function of the square of the distance) but in a duct propagation (type waveguide of the microwave).

Conclusion

It is not clear which processes can produce echo ducting conditions in the Ionosphere.
I think that further studies are needed to understand the impact that this discovery can have on HF radio propagation. The tubes of plasma may also explain the phenomenon still controversial of LDRE long delayed radio echoes.

Set up

The analysis of the audio recordings were made with Audacity, it is free open source, cross-platform software for recording and editing sounds. The configuration for reception is TX-RX Kenwood TS930S with Vertical multiband Antenna Hy Gain AV640. AGC setting=0 MP3 recording - program QARTest by IK3QAR + PC with sound card.

Collaboration

Special thanks to Cleo Loi, Australian astrophysicist graduate at the University of Sydney School of Physics. She is credited with proving the existence of plasma tubes inside the Earth's magnetosphere and extending into the plasmasphere.
She provided me with material and some additional information.
Thanks to Adolfo Brochetelli IK1DQW, for the cooperation. His experience as Officer (Radio telegraphist) of the Italian Navy has been of great help for me, and to Annibale Malagoli, IK2GRA and Loris Bonora, IK3PCZ for several audio recordings and reports.

References

- Cleo Loi, Australian astrophysicist graduate at the University of Sydney School of Physics.
- CAASTRO , ARC Centre of Excellence for All-sky Astrophysics- Australia
-Science Foundation for Physics - The University of Sydney
-The Murchinson widefield Array
-Density duct formation in the wake of a travelling ionospheric disturbance: Murchison Widefield Array observations (Journal of Geophysical Research)
-Wikipedia

Personal profile.
Flavio Egano, IK3XTV, Has Been an Amateur Radio operator since 1993 with a Class A license. He is an ARRL member and a member of ARI, the Italian Amateur Radio Association. For many years he Has Been Committed to radio propagation studies. He successfully completed and received a passing grade in a program of studies "Sensing Planet Earth", courses offered by Chalmers University of Technology, an online learning initiative through EDX. Flavio is an electronic engineering technician in Italy, and he works as a technical salesman for a multinational company. He lives with His Wife and Their daughter in Thiene (Vi) Italy