

# A Study of Long Path Echoes

*Long term observations by IK3XTV suggest that long path echoes might propagate with low attenuation by ionospheric ducts.*

## Introduction

I've listened to many transmissions — both in telephony and telegraphy — that are characterized by a pronounced echo effect. Intrigued by this phenomenon, I enlisted the help of Annibale Malagoli, IK2GRA, and Loris Bonora, IK3PCZ, to make further measurements and to research the echo phenomenon on their transmissions. My papers (available online in Italian)<sup>1, 2</sup> report some experimental reception of echoes on the 15 m and 10 m HF bands, that I believe are due to multiple reception via short and long path. Under the right conditions, the signal can be received via both the short path and the long path. The resulting multipath generates a significant echo effect. The time it takes a radio wave to make a complete revolution of the Earth's circumference is  $40,021 / 299.792458 = 133$  ms. The literature on the radio propagation reports long-path propagation delay of as much as 138 ms, since they take into account a further 1400 km length of the route due to reflections between the Earth and the ionosphere (ionospheric jumps). In most cases we measured a consistent delay of 140 ms.

My belief is that this type of propagation is not via the classic ionospheric reflections, but by the mechanism of ionospheric low-attenuation ducting.

## The Long Path Signal

Figure 1 shows a very short extract from a recording of a CW signal transmitted by Upev Anton, YU5D, and received by Annibale Malagoli, IK2GRA. The first dash is the CW signal received via the short path distance of about 650 km. The second dash, slightly overlapping the first, is the echo of the first dash, that it is probably received from

the long path with a very low attenuation of about 3 dB more than the short path signal. I have analyzed the audio track in great detail and speculate that it is possible that the signal of YU5D has made a further circuit round the Earth within an ionospheric duct. I can also detect another signal echo, that might be called Long Path+1 (LP + 1), starting at about 270 ms from the main short path signal. This LP + 1 signal shows an additional 3 dB attenuation and it is evident above the background noise.

## The Equipment

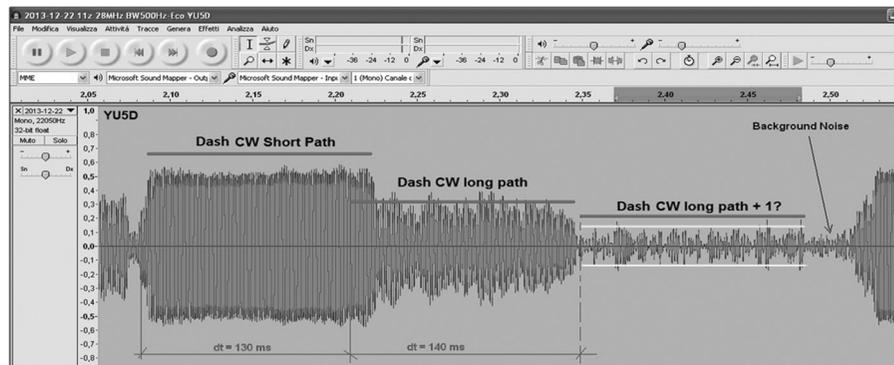
The station configuration for reception is a Kenwood TS930S transceiver with a Hy-Gain AV-640 vertical multiband antenna. The receiver AGC setting is zero. The MP3 software program was *QARTest* by IK3QAR recorded by a PC with a sound card. The receiving frequencies were in the 28 and 21 MHz bands.

Audio recordings were analyzed with *Audacity*, a free open-source cross-platform

software for recording and editing sounds. The transmissions were on a frequency in the 28 MHz band on December 22, 2013 at 11:00 UTC. The solar indices at the time were SFU 144 and Kp 1.

## Ionospheric Ducts

I am convinced that the HF propagation in the ionosphere does not always occur according to the classical model of ionospheric/ground reflections, but in some cases there is the phenomenon of ionospheric ducting. The high plasma density of the duct is capable of trapping radio signals. The radio waves may follow a spiraling motion within these ducts with very low attenuation. Moreover, propagation often occurs towards trans-equatorial paths, considering that the lines of force of Earth's magnetic field are oriented from north to south. It also appears 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.



**Figure 1 — Reception of YU5D by IK2GRA. This sample recording of a 28 MHz band CW dash signal was received via short path, and the first echo is received via long path with a delay of 130 ms.**

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 is consistent with studies<sup>3</sup> conducted using the Murchison Widefield Array and published by Shyeh Tjing [Cleo] Loi, an Australian astrophysicist at the University of Sydney School of Physics. Loi is credited with the first imaging of Earth magnetic field aligned density ducts inside the Earth's magnetosphere that extend into the plasmasphere.

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### Attenuation

Signal attenuation is an important issue. All observations and recordings of echoes from long path show very low attenuation. In the case of Figure 1, YU5D short path is 650 km, while the long path of 39,400 km,

a ratio of 60:1. According to inverse square law propagation, the attenuation difference should be  $20\log 60 = 35$  dB. Instead it is 3 dB. Clearly the propagation can not be free space propagation, but rather a duct mode propagation, similar to a microwave waveguide.

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### Conclusion and Acknowledgements

It is not clear what 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.

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### Notes

<sup>1</sup>[www.qsl.net/ik3xtv/ARCHIVIO/studio%20sugli%20echi%20long%20path.pdf](http://www.qsl.net/ik3xtv/ARCHIVIO/studio%20sugli%20echi%20long%20path.pdf).

<sup>2</sup>[www.qsl.net/ik3xtv/ARCHIVIO/studio%20sugli%20echi%20long%20path-%20sintesi.pdf](http://www.qsl.net/ik3xtv/ARCHIVIO/studio%20sugli%20echi%20long%20path-%20sintesi.pdf)

<sup>3</sup>Shyeh Tjing Loi, et al. [40 co-authors], "Real-time imaging of density ducts between the plasmasphere and ionosphere", *Geophysical Research Letters*, Vol. 42, Issue 10, pp 3708-3714, 25 May 2015.