Long delayed radio echoes – the illusive secret of the ionosphere

Sverre Holm
LA3ZA
What has happened to these signals? Where have they been?

- Larry Horlick, VO1FOG, Newfoundland:
  - ~290 ms,
  - 3.5 MHz SSB,
  - 25.01.2019, 22:50 local

- Poul-Erik Karlshøj, OZ4UN, 2009, Copenhagen:
  - 260 ms, 3.5 MHz CW, 10.1.2009
  - ~20:00 local

Ja det er godt nok mærkeligt … nu er det der igen
Yes it's weird enough … now it's there again
First observation, Oslo, Norway, 1927, Jørgen Hals

Aftenposten 20. and 27 Nov 1928

Huk aveny 7b, Bygdøy, Oslo, Norway,
Oslo kommune, byarkivet, fotodatabasen
• http://www.byarkivet.oslo.kommune.no/
• A-20027/Uh/0001/294, from 1950
I had expected a letter in Norwegian …

Simultaneous observations, 3-30 sec

- Echoes from PCJJ, Hilversum, 9.54 MHz, 24 Oct 1928, 16-17 UTC
- Heard in Oslo, NO and Eindhoven, NL
- Convinced most sceptics that the effect was real
- Measurement campaign: Inconclusive on why

5 mechanisms – only 1 is understood

1. Around the world
2. Distant plasma clouds
3. Mechanical waves in ionosphere
4. Non-linearity and mechanical waves
5. Ducting in the magnetosphere

- Wikipedia: Long delayed echo
- The Five Most Likely Explanations for Long Delayed Echoes
  Vidmar and Crawford, "Long-delayed radio echoes: Mechanisms and
- 15 Possible Explanations for Long Delayed Echoes
  Shlionskiy, "Radio echos with multisecond delays," Telecomm.and Radio Eng.,
  1989
5. Ducting in the magnetosphere

- ~143 ms: GA, 2006, 3.5 MHz
  - Or round-the-world echo?

- 210-223 (~211) + 438 ms: G3PLX: 2, 2.4, 2.7, 3.5, 3.9 MHz, 59 instances

- 260-270 (~251) ms: Tasmania, 1985/86, 1.91 MHz

- 284-305 (~287) + 590 ms: St Petersburg, RU, 1984/85, 1.8 MHz
Nonvertical Propagation and Delayed-Echo Generation Observed by the Topside Sounders

D. B. Muldrew

Abstract—Knowledge of the topside ionosphere resulting from studies of nonvertical propagation, such as scatter from ionization irregularities and miniroughs, hemispherically conjugate echoes, combination modes, multiple-hop propagation, unusual 2-wave propagation, and whistler-mode propagation, is reviewed. From these studies there appear to be two major types of magnetic field-aligned ionization irregularities: a thick type and a thin type. The thick type has a thickness of tens or hundreds of kilometers and occurs both near the auroral zone and at latitudes corresponding to the equatorial anomaly. The thin type has a thickness of a few hundred meters and may extend thousands of kilometers along a field line. At high latitudes the thin type has a tubular cross section, may have an electron density either greater or less than the ambient, and may result from fluxes of energetic particles; at low latitudes the thin type has an electron density deviation of the order of 1 percent or less. The thin type of ionization irregularity supports propagation which is responsible, at some distance from the satellite, for two different delayed-echo phenomena. In the vicinity of the satellite electrostatic waves with near-zero group velocity are probably responsible for the \( f_r \) and \( f_s \) resonance spikes and also for the newly discovered \( f_r \) resonance spikes which occur at nonzero and noninfinite values of the wavenumber. A novel spike, called the “floating spike,” is believed to result from propagating electrostatic waves.
The Magnetospheric Echo Box — A Type of Long-Delayed Echo Explained

Radio amateurs have helped unlock the mystery of LDE signals that have puzzled scientists for over five decades. Continued observations, however, are still needed.

By O. G. Viliard, Jr.*, W6OJT, D. B. Muidrew,** and F. W. Washam, Jr.,*** K7DG

QST, Oct. 1980

Peter Martinez, G3PLX, Radcom, Oct. 2007

• The most detailed report there is
• Just made available on RSGB Propagation: Long-Delayed Echoes
The ultimate DX: An around the earth path

During the morning of February 17, 2006, at approximately 0345 UTC, while calling CQ on 3.524 MHz, I heard a fading echo effect. The echo on my CW signal was strong and delayed so long that I stopped sending to determine if some other station was on my frequency. There was no other station on my frequency and the echo appeared to be from my own transmission. Several tests were performed to ensure there was no digital signal processing (DSP) mode circulating the signal in the transceiver’s DSP processor. The effect lasted approximately 30 minutes, which allowed enough time to record the signal using a sound card recording system. Analysis indicates that the signal was most likely characterizing the delay properties of my Ten-Tec Orion receiver.\(^1\) The delay time of a signal from the antenna to audio output is about 14 ms. In his work, K4MOG used a Yaesu FT1000MP-MKV transceiver, which also has DSP filtering. His observation of excess delay compared to an earth circumference may be the result of receiver delay time. — 73, Martin Ewing, AA6, 28 Wood Rd, Branford, CT 06405; aafe@arrl.net

**Figure 1** — Keying sidetone followed by change-over switch time and then delayed echo.

MagnetoSpheric ducting as an explanation for delayed 3.5 MHz signals

Gene Greneker, K4MOG, gave an interesting and well-documented account entitled “The Ultimate DX: An Around the Earth Path” in the Technical Correspondence column, in the June 2007 issue of QST. Over a 30 minute period he heard his own signal coming back on 3.524 MHz at a delay of 165 to 168 ms. He explained it as a signal traveling around the earth, possibly along some ionospheric duct, in order to account for the additional delay compared to the usual 138 ms. This is plausible not the least due to its southern location, the expected delay at K4MOG’s location in Georgia is only about 0.15 seconds (see Figure 4 of the Oct 1980 QST article by O. G. Villard, W6QVT and others\(^2\)).

The delay, however, depends on geomagnetic latitude — the latitude relative to the magnetic North pole. This position shifts with time, and in 2006 his location was at 44.8° North relative to the geomagnetic North pole (http://modelweb.gsfc.nasa.gov/models/cgm/cgm.html). This gives a delay of 143 ms. 9 ms less than in 1980 when the midnight local time. K4MOG received his echoes at 0345 UTC, or 2245 local time.

The antenna should radiate well in the direction of the magnetic field, as for instance a horizontal dipole oriented East-West would do. K4MOG used a 7 MHz double Zepp oriented North-South at a height of 70 feet (21 meters). Since it was used at half the design frequency, his antenna is probably not omnidirectional, as evidenced by his experience with DX both to Europe and to Antarctica. Its height of about ½ λ should also ensure substantial radiation upwards.

Also, the likelihood for ducting increases near a solar minimum, as indeed 2006 was.\(^3\)

Finally, the value for the critical frequency, foF2, at two nearby sites, English Air Force Base in Florida and Dyess Air Force Base in Texas, show values as low as 3.1 and 2.8 MHz respectively at the time (http://smi.acarauml.edu/ehdfbase/), indicating that a vertical signal at 3.5 MHz could have passed through the ionosphere and thus entered a magnetospheric duct.

— 73, Sverre Holm, LA3ZA, Delvteien 1, NO-1383 Asker, Norway, la3za@arrl.no
QST, Nov 2009, OZ4UN, Poul-Erik Karlshøj

Observation of Long Delayed Echoes on 80 Meters

Poul-Erik Karlshøj, OZ4UN

I had an extraordinary experience on the evening of January 16, 2009, on 80 meters. While in a contact with EA2II on 3512 kHz at 1845 UTC I noticed what I at first thought was another station transmitting on my frequency. But I soon realized that it was the echoes of my own signal.

My Setup
I was using an Elecraft K2 transceiver with 100 W output to an 80 meter circumference loop antenna. The loop is supported by trees in an east-west vertical plane with an irregular somewhat triangular shape. It is fed in the midpoint of the lower wire, that is, the loop is horizontally polarized. The antenna apex

237 milliseconds

Figure 1 — This oscillograph shows two dits each followed by an echo delayed 237 ms.
Field-aligned duct or trough

- Related to hemispheric asymmetry of the winds in the ionospheric dynamo region
- Electron density diminished by about 1%
- Diameter 1-2 km, from F-layer of one hemisphere to the other
  - A waveguide if $f < 10 \lambda$
  - Works up to $\sim$5 MHz
- 40+ dB stronger than free space propagation
  - Platt & Dyson, J Atmos. & Terr. Phys., 1989


19.03.2021
LA3ZA - Long delayed radio echoes
Approximate estimate of delay

- Geomagnetic latitude, $\theta_{GM}$, from position, year:
  - http://wdc.kugi.kyoto-u.ac.jp/igrf/gggm/
  - https://omniweb.gsfc.nasa.gov/vitmo/cgm.html

- How far away the field line extends in earth radii: $L = \cos^{-2} \theta_{GM}$

- Path of magnetic field line:
  $$r = L \cos^2 \theta, \ \theta = 0 \ldots \pm \theta_{GM}$$

- Integrate path to find delay
- Accurate to +/- 5-10 ms
Measurement of AF delay will overestimate RF delay

K3 TX: Sidetone – RF: 15 ms
K3 RX: RF – tone: up to 35 ms

Elecraft K3: by 15+35 = 50 ms (50 Hz bw)
Elecraft K2: by 4+8 = 12 ms (no DSP)
### Observations, sorted by delay

<table>
<thead>
<tr>
<th>Call Sign</th>
<th>Delay (ms)</th>
<th>Frequency (MHz)</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>W6FB, K6YT, KM6I, N6ZFO, North CA</td>
<td>~126</td>
<td>3.5</td>
<td>7.11.2015</td>
<td>2300</td>
</tr>
<tr>
<td>K4MOG, GA</td>
<td>~143</td>
<td>3.5</td>
<td>17.02.2006</td>
<td>2245</td>
</tr>
<tr>
<td>G3ZRJ, also heard by GW3OQK 100km</td>
<td>~200</td>
<td>3.5</td>
<td>01.01.2012</td>
<td>2118-2152</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 &amp; 3.9</td>
<td>26.11.2006</td>
<td>21</td>
</tr>
<tr>
<td>G3PLX</td>
<td>210-220</td>
<td>2 &amp; 3.9</td>
<td>16.02.2008</td>
<td>2222</td>
</tr>
<tr>
<td>W2PA, NY</td>
<td>214-219</td>
<td>3.5</td>
<td>25.01.2019</td>
<td>1945-2045</td>
</tr>
<tr>
<td>OZ4UN</td>
<td>~237</td>
<td>3.5</td>
<td>10.1.2009</td>
<td>1985-1988</td>
</tr>
<tr>
<td>Tasmania</td>
<td>260-270</td>
<td>1.8</td>
<td>2050</td>
<td></td>
</tr>
<tr>
<td>VO1FOG, Newfoundland</td>
<td>~290</td>
<td>3.5 SSB</td>
<td>25.01.2019</td>
<td>2250</td>
</tr>
<tr>
<td>St.Petersburg</td>
<td>284-305</td>
<td>1.8</td>
<td>16.11.1985</td>
<td>2055</td>
</tr>
</tbody>
</table>

All times are local. ~ means predicted delay.
Conditions for it to happen

- 1-4 MHz
- Winter. Northern hemisphere: best Dec/Jan, also: Feb/Nov
- 19-24 local time
- More likely during years of low solar activity
- Antenna: radiates up or in direction of magnetic field
- Not too far from duct’s entry point
- Signal has to exit the ionosphere, i.e., low F2 critical frequency
- Must reflect at ionosphere on opposite hemisphere, high \( f_0F_2 \)

Long Delayed Echoes

• From 1927 until today: up to 30 sec
• From 1.8 to 1296 MHz
• Tests in Norway, Netherlands, France, USA, UK, Soviet Union, …
• Most observations from radio amateurs
• Understood: Magnetospheric duct, 1-4 MHz, < 0.5 sec
  – G3PLX, 2007: I am tempted to suggest that magnetospheric ducts may never be more than a rare scientific curiosity.
• Jørgen Hals, 1928: ”From where this echo comes I cannot say for the present, but I will only herewith confirm, that I really heard this echo”
Read more

• The Five Most Likely Explanations for Long Delayed Echoes:
  – https://www.mn.uio.no/fysikk/english/people/aca/sverre/articles/lde.html

• 15 Possible Explanations for Long Delayed Echoes
  – https://www.mn.uio.no/fysikk/english/people/aca/sverre/articles/shlionsky15.html

• Wikipedia: Long Delayed Echo, refers to my two pages above

Thanks:
• National Library, Oslo:
  – Anne Melgård, Nina Korbu
• University Library, Univ Oslo:
  – Knut Hegna
• Radio amateurs who have contacted me over the years with examples of echoes