Long delayed radio echoes – 80 years with an unexplained phenomenon

Sverre Holm
Long Delayed Echo

• LDE =
  • echo received after a second or so
  • or everything longer than 138 ms (round-trip time around the earth)
    • An LDE which is well understood: Earth-Moon-Earth

• First reported in Oslo, Norway 1927

  • S. Holm, Mystiske forsinkede radiosignaler i Oslo, Forskning.no, March 2004
  • S. Holm, “Magnetospheric ducting as an explanation for delayed 3.5 MHz signals,” QST, March 2009.
Shortwave in the 20’s

• 3-30 MHz or 100-10 m wavelength

• First trans-Atlantic signals <200 m received 11 Dec 1921

• 1924: 80, 40, 20, 5 meter amateur bands

• First short wave broadcast, 11 March 1927, PCJJ (Philips) from NL to Indonesia
LDE:

I had expected a letter in Norwegian ...
Huk aveny 7b, Bygdøy, 1927

Oslo kommune, byarkivet, fotodatabasen
- http://www.byarkivet.oslo.kommune.no/
- A-20027/Uh/0001/294
- Bilde fra 1950
LDE: 1928 - 1930

• Regular 30 kW test transmissions from the Netherlands and at times from Indonesia (15.94 m).
  • B. van der Pol, early 1928-Jan 1930
  • Largest effort ever undertaken for LDE study?
  • Hals and Størmer both heard echoes in the fall of 1928
Summer 1928: peak of solar cycle

NOAA
Logical extension of range of radio...

- 4 Dec 1928, Newspaper, Dagens Nyheder og Nation....”
  - Echoes of 3-17 sec (expects several minutes) – logical progression in range of radio waves:
    - Local
    - Across the Atlantic
    - Around the earth 1 and 2-3 times

- P O Pedersen (1874-1941), Danish engineer and physicist, collaborated with Valdemar Poulsen
Convincing: Simultaneous observation of echoes, NO and NL

- Echoes from PCJJ, Hilversum, $\lambda = 31.44$ m, 9.54 MHz
- Heard in Oslo and Eindhoven, 24 Oct 1928, 16-17 UTC
- Convinced most sceptics at the time that the effect was real

- Measurement campaign: Inconclusive on why
Carl Størmer

Fredrik Carl Mülertz Størmer (September 3, 1874 – August 13, 1957) was a Norwegian mathematician and physicist, known both for his work in number theory and for studying the movement of charged particles in the magnetosphere and the formation of aurorae.

He then studied with Picard, Poincaré, Painlevé, Jordan, Darboux, and Goursat at the Sorbonne in Paris from 1898 to 1900.

He visited Göttingen in 1902, and returned to Oslo in 1903, where he was appointed as a professor of mathematics, a position he held for 43 years.

Størmer was a foreign member of the Royal Society and a corresponding member of the French Academy of Sciences. He was given honorary degrees by Oxford University (in 1947), the University of Copenhagen, and the Sorbonne, and in 1922 the French Academy awarded him their Janssen Medal. In 1971, the crater Störmer on the far side of the Moon was named after him.
THE DISCOVERY OF ECHOES OF LONG DELAY

By JØRGEN HALS

Introduction

It is a great pleasure to be able to introduce the readers of WORLD-RADIO and members of the World Radio Research League the original notes of Mr. Jørgen Hals, the discoverer of echoes of long delay. These notes are published in this country for the first time.

Mr. Jørgen Hals is a Norwegian civil engineer and a keen student of radio. His discovery gave him an international reputation. His work is universally recognised, and his results are always quoted whenever wireless echoes are mentioned.

It is necessary to state that at the time when these notes were written nothing was known definitely about the Appleton Layer. The first announcement of its existence was made on September 3, 1927, in an article in Nature entitled: “The existence of more than one ionised layer in the atmosphere.” I have this on Professor Appleton’s authority.

RALPH STRANGER.
J. Hals (1934), drawn before the discovery of the Appleton layer

- Heaviside-Kennely = E-layer (90–150 km)
- Appleton layer = F-layer (150–800 km)

May 2016
**Størmer’s hypothesis**

- Reflection from a toroidal surface formed by streams of charged particles from the sun.
  - Distance several ten’s times the earth's radius
  - Predicts seasonal behavior with best reflection during spring and fall equinoxes.
  - Størmer's original hypothesis from 1928 which he also elaborated on in his book from 1955

- Later confirmed: [the Van Allen radiation belt](#), but the distance is only 4-5 earth radii, i.e. 0.2 seconds round-trip time.
Obituary 10 Feb 1942

- Deceased, almost 52 years old
- Engineer, contractor: buildings, power plants, factories
- 1926 (sic): Much remarked in scientific circles when he discovered the much publicized radio echo from space
- 1935: Pointed out the moon’s influence on the Heaviside layer (?)
  - Appleton: He found that the height of the ionospheric layers was affected by the Moon as well as the Sun. [Link](http://www.radio-electronics.com/info/radio_history/gtnames/edward-victor-appleton.php)
- 1937: ... participated in the int. short wave conference (physics section) in Vienna
- Morgenbladet 10 Feb 1942
5 mechanisms – only 1 is understood

1. Ducting in the magnetosphere and ionospheric reflection
2. Travel many times around the world
3. Mode conversion w/ coupling to mechanical waves in ionosphere
4. Reflection from distant plasma clouds
5. Non-linearity in addition to mode conversion

Magnetospheric ducting

7. Nov 2015: 3.5 MHz, several heard it, California
3. Feb 2016, 3.5 MHz, 2 Suffolk and Devon, UK

http://la3za.blogspot.no/search/label/MDE

3. Feb 2016, 3.6 MHz, Suffolk
5W, 1W and 100mW
• J. Hals: "From where this echo comes I cannot say for the present, but I will only herewith confirm, that I really heard this echo”

• World-Radio, 1934: His work is universally recognised, and his results are always quoted whenever wireless echoes are mentioned

Read more

- Wikipedia: Long Delayed Echo, refers to my two pages below
  - https://en.wikipedia.org/wiki/Long_delayed_echo
- The Five Most Likely Explanations for Long Delayed Echoes:
  - http://heim.ifi.uio.no/~sverre/DE/
- 15 Possible Explanations for Long Delayed Echoes
  - http://heim.ifi.uio.no/~sverre/DE/Shlionskiy15.htm

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- Nasjonalbiblioteket:
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- Universitetsbiblioteket, Oslo:
  - Knut Hegna
- Radio amateurs who have contacted me over the years with examples of echoes due to ducting in the magnetosphere
Jørgen Hals – his radio equipment

Aftenposten 20. and 27 Nov 1928

Receiver built by himself.
Notes, autumn 1928:
“The receiver is fixed on 31.4 meter and the reaction is pulled away just so far that the sound of the carrier wave is audiable.” (sic)
The ionosphere
Magnetosphere
Moon – inner solar system

THE EARTH’S MAGNETOSPHERE
Protective influence extends to around 60,000 km

L1

L2

L3

L4

L5

International Space Station

Lagrangian points, Gravitational pull of Earth and Moon balance out at these points in space

May 2016
Jørgen Hals

• Had some ideas about the presence of echoes at 35 m and 3 seconds
  • Talked to prof. Størmer in Dec 1927
  • Theories about echoes from the moon and near equinoxes which may have affected the time of his listening
• Had listened through the winter 1926/27
• First echo 14 April 1927 from his own transmitter
  • license to transmit?
  • Sounded like steam escaping from a boiler
Common delay: satellite

- Satellite hops:
  - Geostationary orbit
  - to/from TV news studio to another continent
  - telephone call
  - \(~4*36,000/300,000 = 4*0,12\ sek = 0,48\ sek\)
  - NASA,
Less common delay: EME

- Moon:
  360000-406000 km = 2.4-2.7 sek,
- VHF, but also HF
- HF Active Auroral Research Program, 3.6 MW, Alaska

K7AGE (YouTube)
- best echoes 4:20
- 9:55: amplitude display
- 13:15: 6979.25 -> 7407.5 kHz.
- EA6VLQ EME 2m
Not so common delays

- **Venus:**
  - 38,2-261 mill km,
  - > 4 min 15 sec

- **Mars:**
  - 55,7–401.3 mill km,
  - > 6 min 11 sec (10-17 min for Spirit)
  - Aug 1924: Mars-earth at their closest
    - US radio stations were asked to observe a radio pause for 5 min every hour
Magnetospheric Ducted Echoes
Medium Delay Echoes

May 2016
G3PLX, Northern England

• Delay 210-220 ms
• 100 Watt SSB, 50 m lw
• 59 echoes in 10 years
Ducts

Nominal ducts and delays for
• GA (USA)
• Northern England
• Hobart (Tasmania)
• and the longest one for St. Petersburg (Russia)

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Ionospheric trough

- F-region, in which electron densities are anomalously low
- Hedin et al 2001:
  - It is frequently observed in the nighttime sector, just equatorward of the auroral zone.
  - This trough is often referred to as the “main ionospheric trough” or “mid-latitude trough” to distinguish from troughs in other locations.
  - The polar edge of the trough is co-located with the auroral zone. The equatorward boundary is less distinct, consisting of a gradually increasing amount of electrons, towards the plasmasphere, which could be called the normal ionosphere.
Duct properties

• It is not clear what processes can produce echo-guiding conditions in the plasmasphere that can extend from hemisphere to hemisphere


Figure 2. A schematic of ducting of a high-frequency \( (f \gg f_{ch}) \) electromagnetic wave (green arrows) by field-aligned electron density depletions.
Duct size vs frequency

- Most ducts have a depletion of 1% or less
- Received power 40 dB or so more than in free space propagation
- Platt, Dyson, MF and HF propagation characteristics of ionospheric ducts, Journ. Atmospheric and Terrestrial Physics, 1989

Fig. 5. Percentage depletions required to support a return signal.
LDE: Most likely hypotheses

1. Travel many times around the world
2. Coupling to mechanical, low velocity, waves in the ionosphere
3. Reflection from distant plasma clouds
4. Non-linear mixing of two VHF/UHF signals plus coupling to mechanical waves

[Vidmar and Crawford, 1985]
1. Signals travelling many times around the earth
1. Signals travelling many times around the earth

- Focusing and amplification effects in the ionosphere (100-400 km)
  - focusing at the antipodal points (the Appleton hypothesis, 1928).
- A signal is guided many times around the earth, for then to exit to the earth
- Delays up to 10 seconds for high HF
- Status: Unconfirmed
  - Not observed during round-the-world experiments, e.g. WW II
2. Conversion to and from plasma waves in the ionosphere

Conversion in the vicinity of ionization and magnetic field inhomogeneities.

May 2016
The Luxembourg effect

• 1933: Radio Luxembourg modulated Beromünster, CH, on 556 kHz, heard in Eindhoven, NL

• 1934: Explanation:
  Modification of the ionosphere of the strong RTL transmitter

• AM from RTL was transferred by non-linearity in the lower part of the ionosphere

• Active ionosphere modification with megaWatt - e.g. Eiscat Tromsø
2. Conversion to and from plasma waves in the ionosphere

- On the top of the ionosphere: conversion to mechanical plasma waves
- \( v = 1 \text{ km/s} \), may spread some tens of km
- Are then converted back to EM waves.
- Like a big memory, \( \Delta t < 10\text{-}20 \text{ sec} \)
- Mid HF-frequencies, like those Hals observed
- Status: unconfirmed
3. Reflection from plasma clouds
3. Reflection from plasma clouds

• Equilibrium points
• Clouds of ionized gas and particles can be stationary and give stable reflections
• Ex: The L2 Lagrange points is 61,500 km behind Moon => delay 0.4 sec ~ 2.8 - 3 s
• VHF- and UHF-signals
• Status: unconfirmed
4. Non-linear effects in addition to plasma wave conversion

Fig. 2. Geometry for a particular solution which can explain the LDE results of Rasmussen.
4. Non-linear effects in addition to plasma wave conversion

- The existence of an unknown transmitter on almost the same frequency as your own
- Non-linearity in the ionosphere => difference frequency which couples to plasma waves
- Is delayed and is then coupled back via the unknown signal to the original frequency.
- Can explain the observations of several radio amateurs who have received delayed echoes during EME attempts
- Status: unconfirmed
Conclusion: Observations

• Many observations from 1927 until today
• Frequencies from 1.8 to 1296 MHz
• Tests done in USA, England, Soviet
• Most observations from radio amateurs
• Unpredictable!
• Not everything can be understood!
Conclusion: Most likely models

0. Magnetospheric ducting (confirmed!)
1. Travel many times around the world
2. Coupling to mechanical, low velocity, waves in the ionosphere
3. Reflection from distant plasma clouds
4. Non-linear mixing of two V/UHF signals plus coupling to mechanical waves

Research

• Use of Internet
  • Ionospheric and geomagnetic indicators in near real time
  • Real-time exchange of data between stations
• Predict magnetospheric ducts
  • Better models
  • Use reception of whistlers to tell when magnetospheric delays can occur?
• HAARP and other large facilities