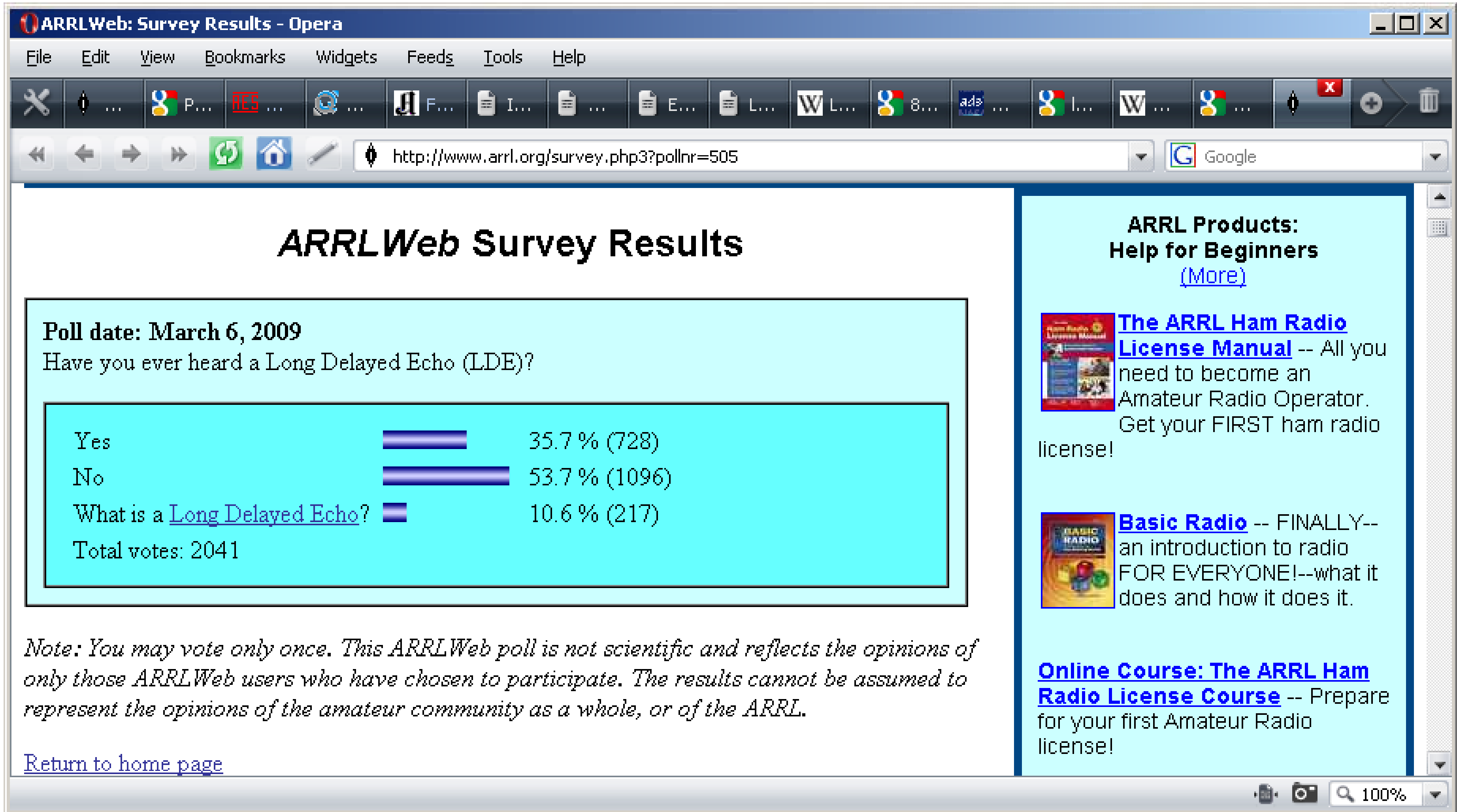
Long delayed radio echoes – 80 years with an unexplained phenomenon

Sverre Holm, F/LA3ZA,
University of Oslo

Long Delayed Echo

- LDE =
  - echo received after a second or so
  - or everything longer than 138 ms (round-trip time around the earth)
- First reported in Oslo, Norway 1927
- S. Holm, “Magnetospheric ducting as an explanation for delayed 3.5 MHz signals,” QST, March 2009.

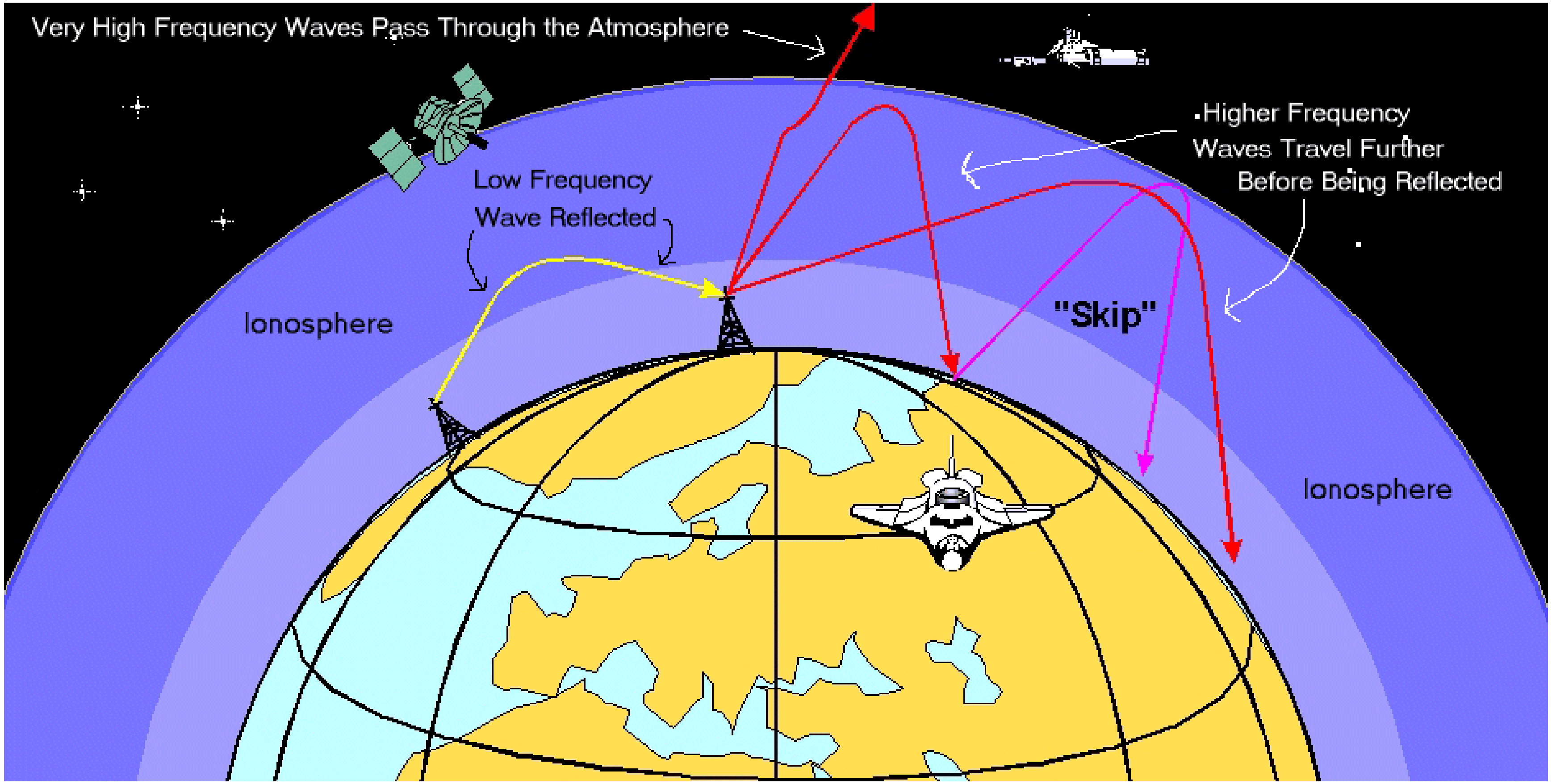
Have you ever heard a Long Delayed Echo?



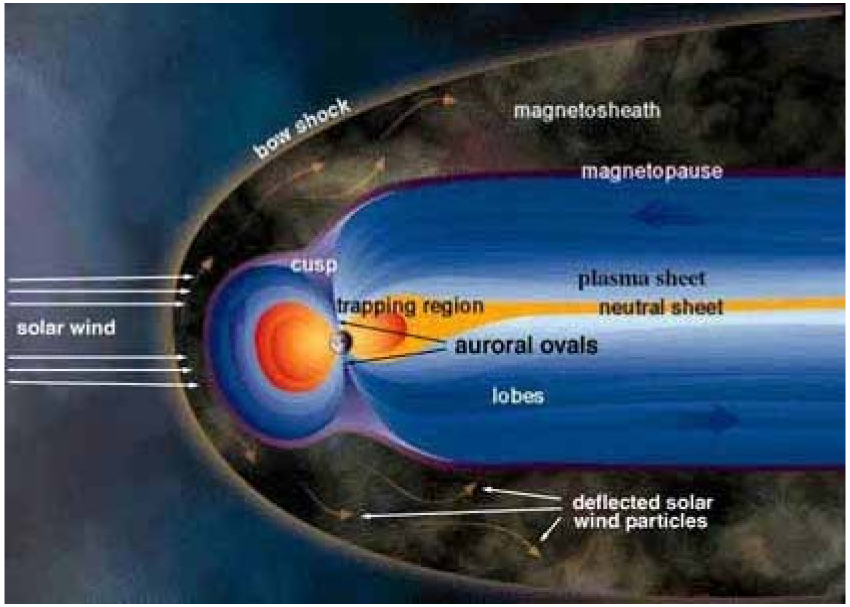
LDE

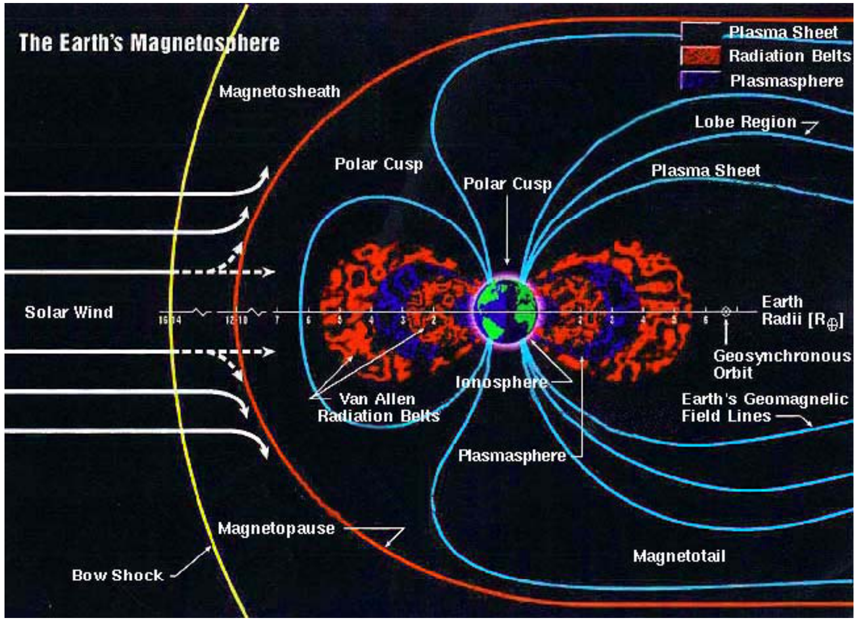
- History - Oslo in 1927-1928
- Echoes that can be explained
  - Magnetospheric Ducted Echoes
- Observations
- UFOs and alien space probes
- 4 most likely explanations

The ionosphere

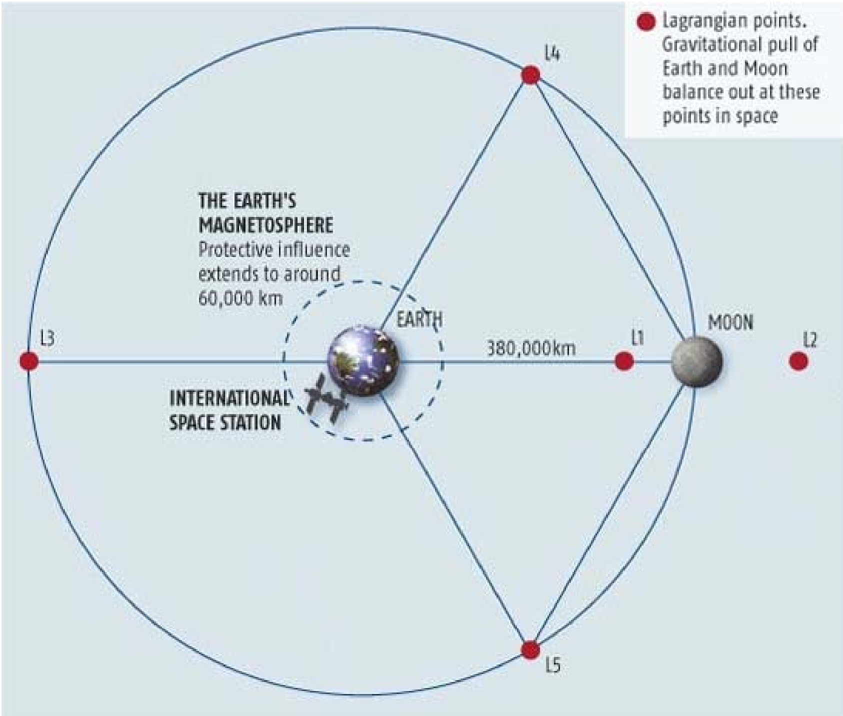


Magnetosphere





Moon – inner solar system



3 extra letters in Norwegian

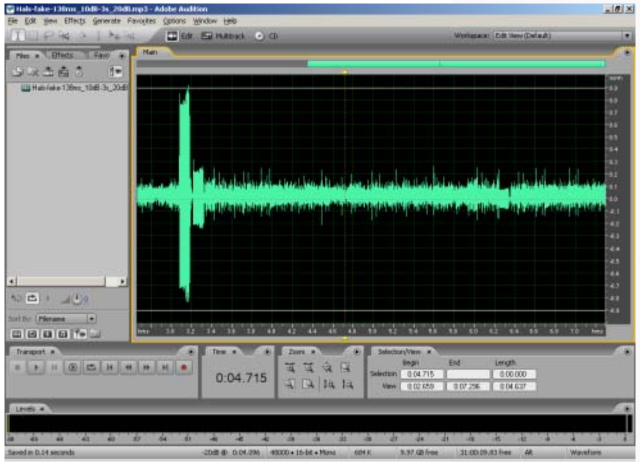
- æ
- å
- ø = ö = oe = œ (œil)
  - Jørgen Hals
  - Carl Størmer
  - Bygdøy (part of Oslo)

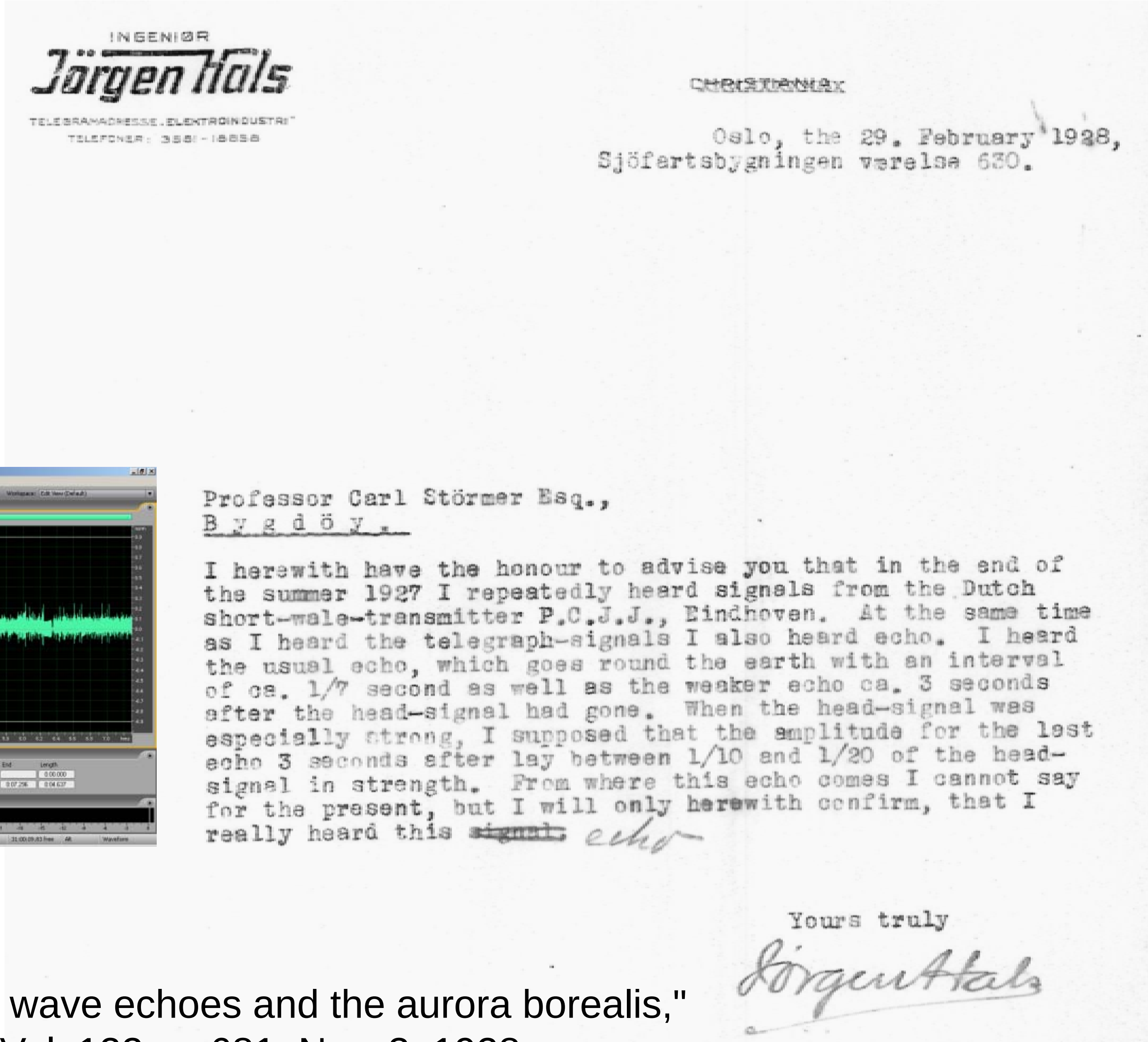
Shortwave in the 20's

- First trans-Atlantic signals <200 m received 11 Dec 1921
- First trans-Atlantic QSO 27 Nov 1923 , 110 m
- 1924: 80, 40, 20, 5 meter amateur bands
- First Worked All Continents April 1926
- First short wave broadcast, 11 March 1927, PCJJ (Philips) from NL to Indonesia

LDE: The beginning

- Prof. Størmer reported in 1928 how Jørgen Hals in Bygdøy in Oslo heard the Dutch transmitter PCJJ at 9.55 MHz with echoes 3 seconds after the main signal.





INGENIØR
Jörgen Hals

TELEGRAMADRESSE.ELEKTROINDUSTRI
TELEFONER: 3581 - 18858

~~CHRISTIANIA~~

Oslo, the 29. February 1928,
Sjöfertsbygningen værelse 630.

Professor Carl Störmer Esq.,
B y g d ö y .

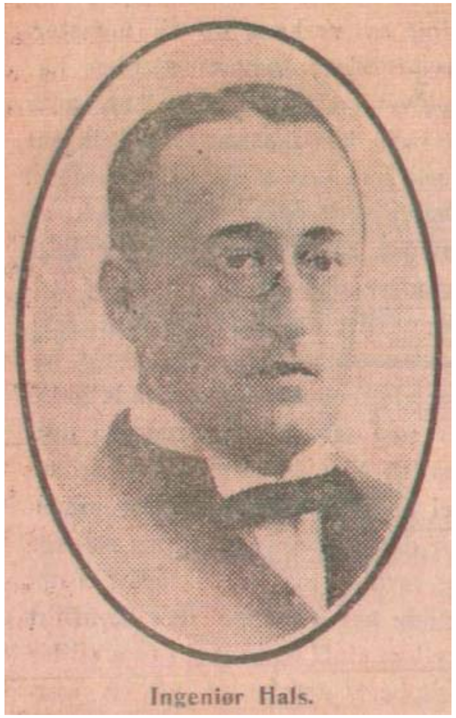
I herewith have the honour to advise you that in the end of the summer 1927 I repeatedly heard signals from the Dutch short-wale-transmitter P.C.J.J., Eindhoven. At the same time as I heard the telegraph-signals I also heard echo. I heard the usual echo, which goes round the earth with an interval of ca. 1/7 second as well as the weaker echo ca. 3 seconds after the head-signal had gone. When the head-signal was especially strong, I supposed that the amplitude for the last echo 3 seconds after lay between 1/10 and 1/20 of the head-signal in strength. From where this echo comes I cannot say for the present, but I will only herewith confirm, that I really heard this ~~signal~~ echo

Yours truly

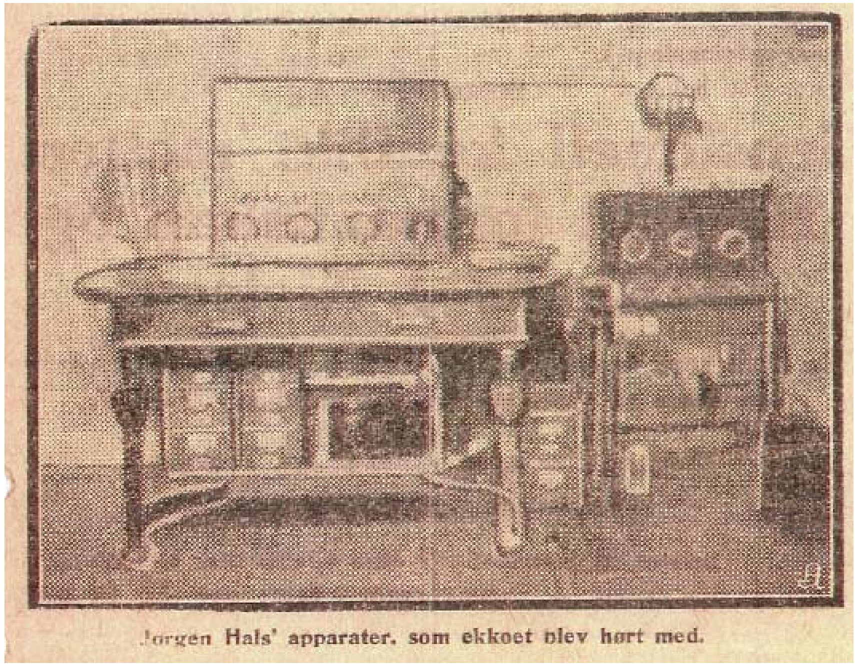
Jörgen Hals

C. Størmer, "Short wave echoes and the aurora borealis," Nature, No. 3079, Vol. 122, p. 681, Nov. 3, 1928.

Jørgen Hals – his radio equipment



Aftenposten 20. and 27 Nov 1928



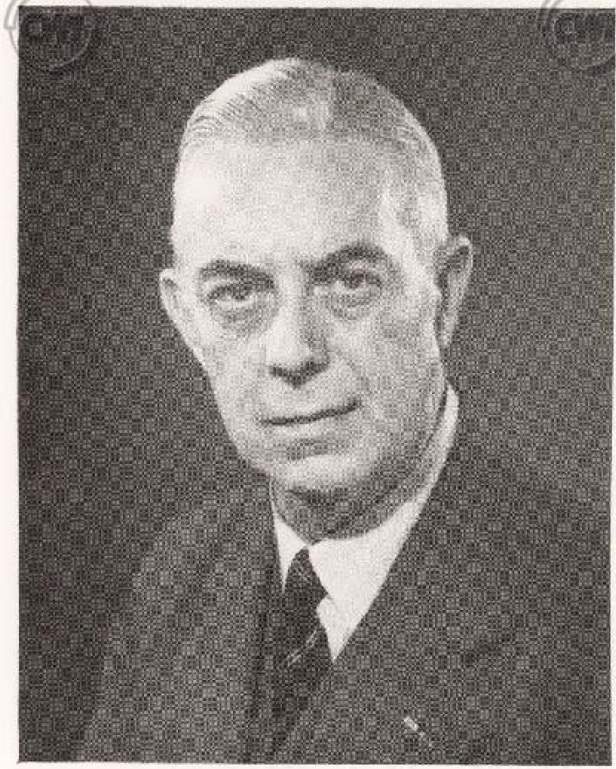
RX built by himself.
Notes, autumn 1928:
"The receiver is fixed on 31.4 meter and the reaction is pulled away just so far that the sound of the carrieng wave is audiable." (sic)

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

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 11 Oct 1928
  - Summer 1928: peak of solar cycle, SSN ~ 78



BALTHASAR VAN DER POL
(27 januari 1889—6 oktober 1959)

Simultaneous observation of echoes in NO and NL

- Echoes from PCJJ, Hilversum, λ=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

- B. v. d. Pol, "Short wave echoes and the aurora borealis," Nature, No. 3084, Vol. 122, pp. 878-879, Dec. 8, 1928.
- Measurement campaign: Inconclusive on why

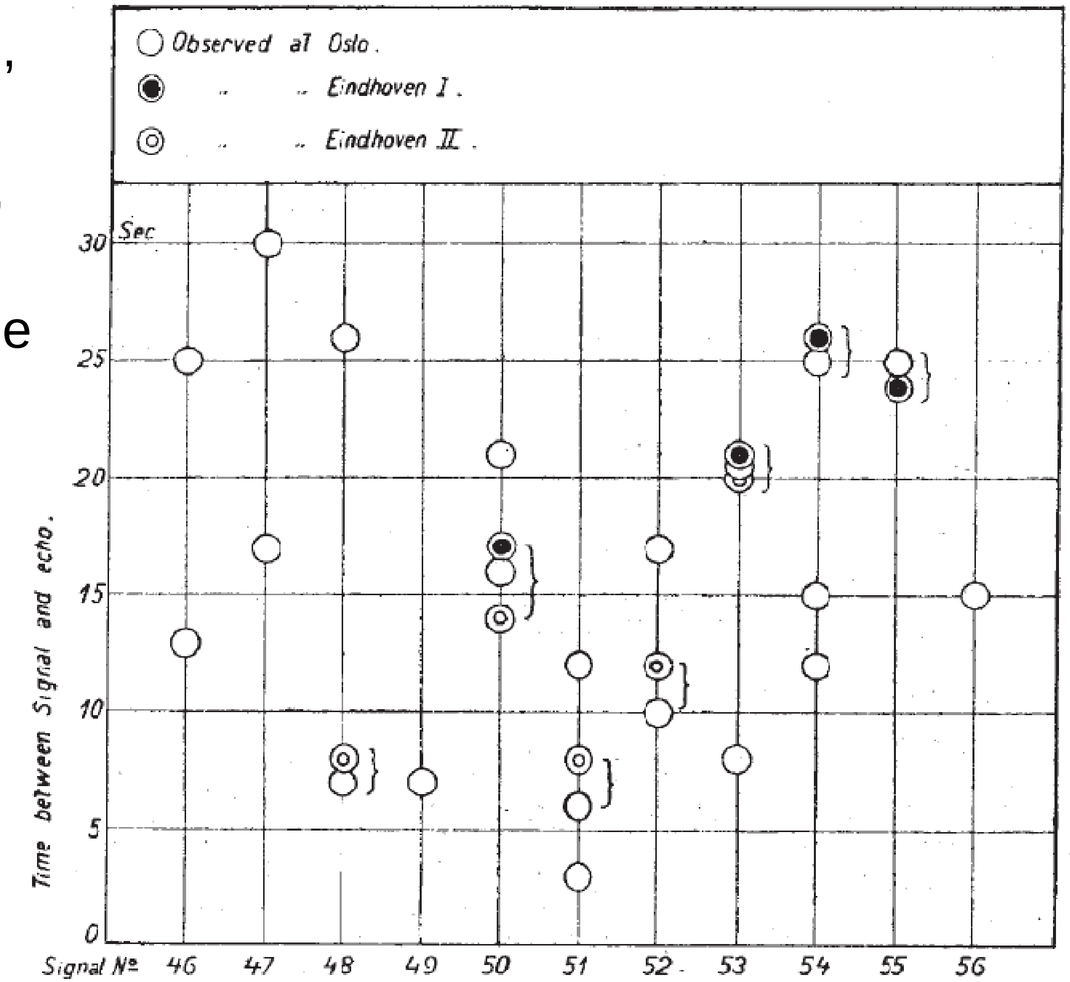


FIG. 1.

Others who listened

- Letter from v.d Pol to Størmer, 2 april 1929:
  - Prof. Karl Willy Wagner, Berlin
  - Monsieur Jouaust, Paris
  - Prof. E. V. Appleton, London (Nobel prize, 1947 – ionosphere).
- Also heard in Bodø (Northern Norway) and Spitzbergen (Svalbard)

1931 - 1934

- Experiments in France.
- 1934: World Radio Research League also conducted a series of experiments with transmitters in the UK (GSB) and in Switzerland, League of Nations (HBL)
  – Many observations of echoes
  – No new understanding of the phenomenon

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

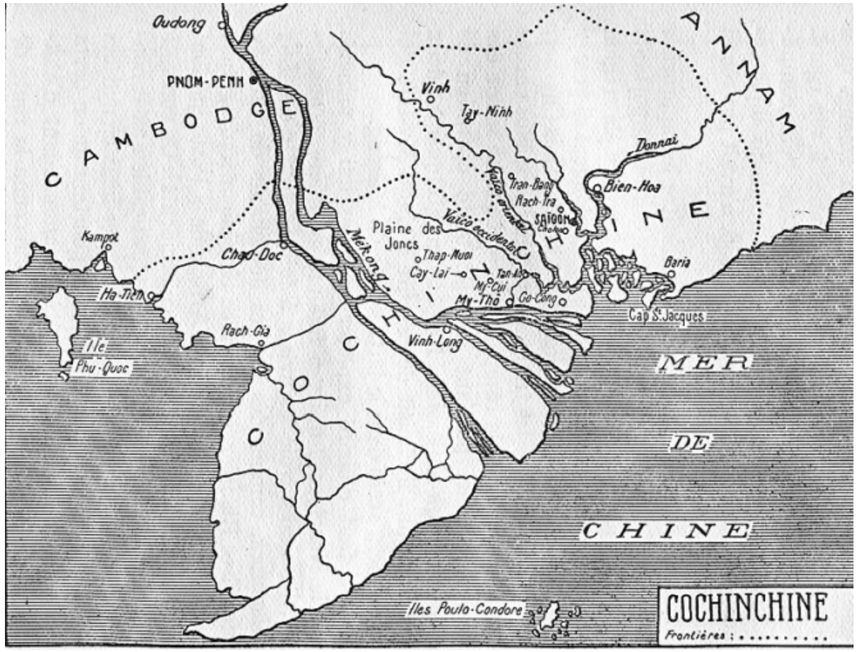
http://en.wikipedia.org/wiki/Carl_Størmer

Prof. Carl Størmer en Français

- C. Stormer, “Sur un écho d’ondes électro-magnétiques courtes arrivant plusieurs secondes après le signal émis, et son explication d’après la thèorie des aurores boréales,” Comptes Rendus Acad. Sci., Paris, 187, 5 Nov 1928, p. 811-812.
- Stormer, Carl "Sur les echos retardes." Comptes rendus des séances de l' Academie des Sciences, Vol. 189, p. 365-368, 26 Aug 1929, Errata p. 653.
- Stormer, Carl "Sur l'absence d'échos retardés pendant la totalité de l'éclipse du 9 mai en Indo-Chine," Comptes rendus des séances de l'Academie des Sciences, Vol. 190, p. 106-107, 13 janvier 1930

8 - 10 May 1929: Solar eclipse

- Station in Poulo Condore in Indochina, λ=25 m: 2000 echoes up to 30 sec
  - Strong echo in interval 20-30 sec
  - Weak echo in interval 0-10 sec
    - Was it the previous transmission, i.e. 30-40 sec?
- Galle & Tallon, Comptes Rendus, Paris, 6. jan 1930.



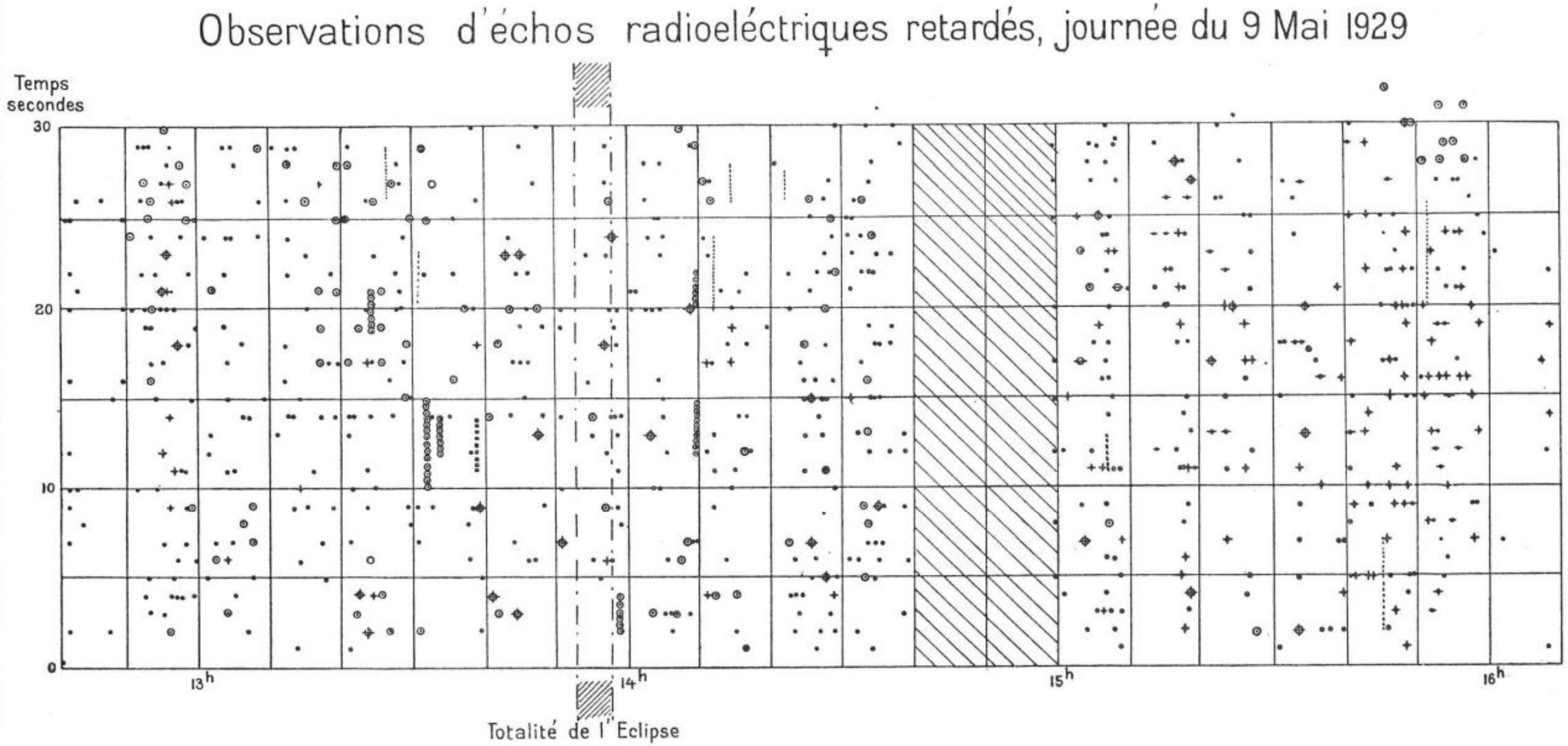


FIG. 3.—Part of diagram showing wireless echoes of long delay observed in Indo-China by Galle and Talon. Signals were sent every 30 seconds. The time is marked on the horizontal scale, and the echo-times vertically. Weak echoes are marked by small dots, strong echoes by large dots. For further details reference must be made to the detailed report, which is not yet published.

Muldrew 1979: "The data seem unbelievable"

1930-31 Correspondence with general Ferrié

- Letter from M. Jouaust on behalf of general Ferrié.
- Letters from Ferrié in Dec 1930
  – Mavel, Dakar experiments on 26-42 m, mostly 30 m
  – 5 observation stations.
  – Also experiments in Conakry, Mauretania
- Hals visited Ferrié in the summer of 1931

-

Le general Gustave Ferrie (1868-1932)

- Gustave Auguste Ferrié, né à Saint-Jean-de-Maurienne (Savoie) le 19 novembre 1868 et mort à Paris le 22 février 1932, est un ingénieur et général français, pionnier de la radiodiffusion. Il perfectionna la télégraphie sans fil (TSF), notamment en installant une antenne au sommet de la tour Eiffel.
- Pendant la Première Guerre mondiale, il développe la radio-télégraphie et devient ainsi l'un des artisans de la victoire de 1918. Il est élu membre de l'Académie des sciences en 1922.
- Grand Croix de la Légion d'honneur, il meurt à l'hôpital militaire du Val-de-Grâce à Paris en 1932.
- Un lycée professionnel dans le 10e arrondissement de Paris ainsi qu'un collège à Draguignan portent son nom. Une plaque commémorative1 en son honneur se trouve au pied de la tour Eiffel. Un prix « Général Ferrié » est remis à un chercheur dans le domaine des télécommunications.
- Le musée Ferrié (musée militaire), à Cesson-Sévigné (près de Rennes), présente l'évolution des techniques de communication.

http://fr.wikipedia.org/wiki/Gustave_Ferrié

NOVEMBER 23, 1934 WORLD-RADIO 731

THE DISCOVERY OF ECHOES OF LONG DELAY

By JØRGEN HALS

Introduction

It is a great pleasure to be able to introduce to 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.

Jørgen Hals

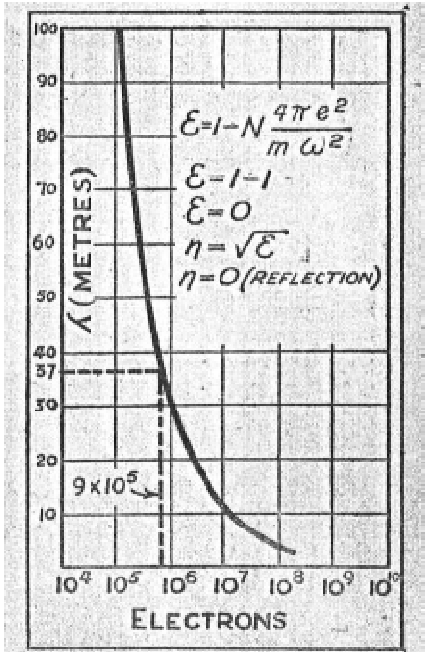


Fig. 2—Number of electrons necessary for reflection at various wavelengths

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)

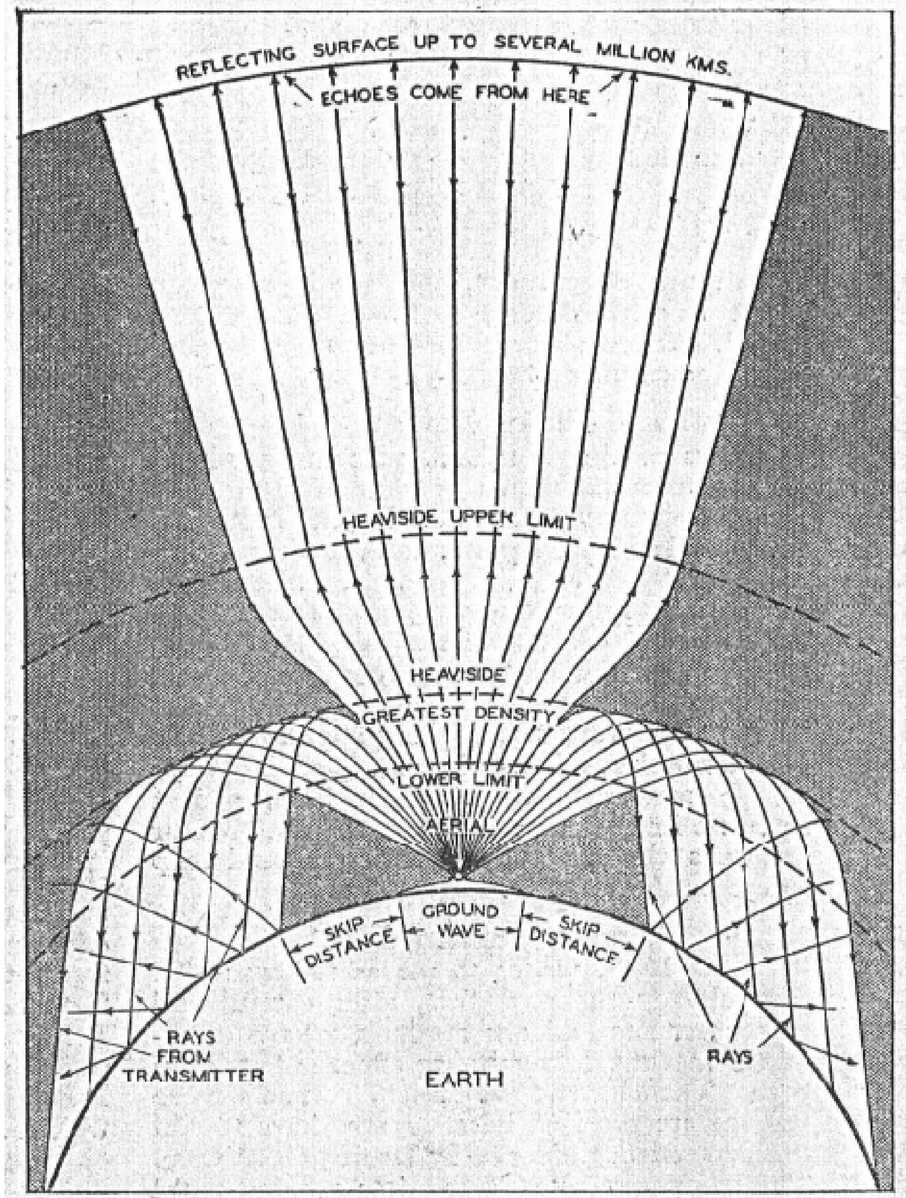


Fig. 1—Radiation of waves from an aerial

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,… 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

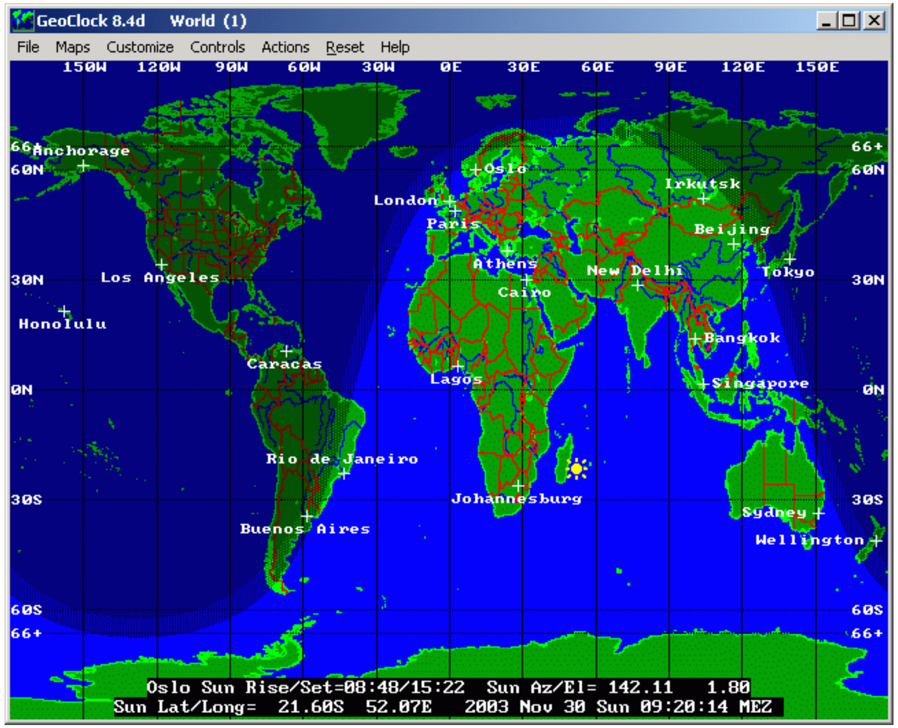
Ingeniør Jørgen Hals, Bygdøy, er død, nær 52 år gammel. Han

var opvokset i Aker og Oslo, og har utført en lang rekke arbeider på de forskjelligste områder. Således utførte han anlegg i elektrisitetsverk, valseverk, verksteder m. m. og hadde tekniske konsulentarbeider i bygningsbranchen, i maskin og varme og i den elektriske branche. Sine siste arbeider utførte han i Fridtjof Nansens pl. 8. Denne bygning er blitt den mest moderne i Oslo, samtidig som den representerer den dypeste fundamentering som hittil er utført her hjemme og visstnok også i hele Europa. Ingeniør Hals vakte i 1926 stor opsikt i videnskapelige kretser da han opdaget det meget omtalte radioekko fra verdensrummet. I 1935 påviste han månens innflydelse på Heaviside-laget. Hals var den eneste nordmann som deltok i den internasjonale kortbølgekongress (fysikk-avdelingen) i Wien 1937, hvor videnskapsmenn fra alle kanter av verden var representert.

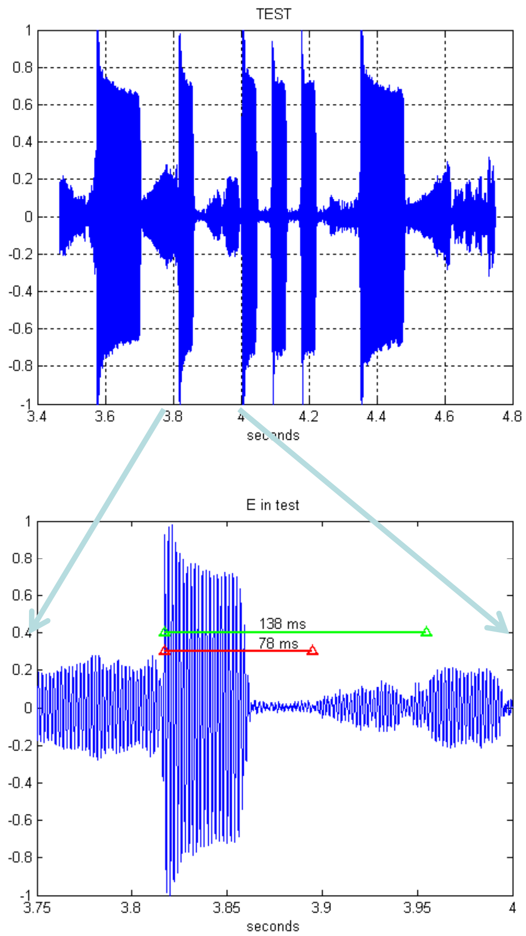
10-2-42

Short-wave signals travelling around the earth

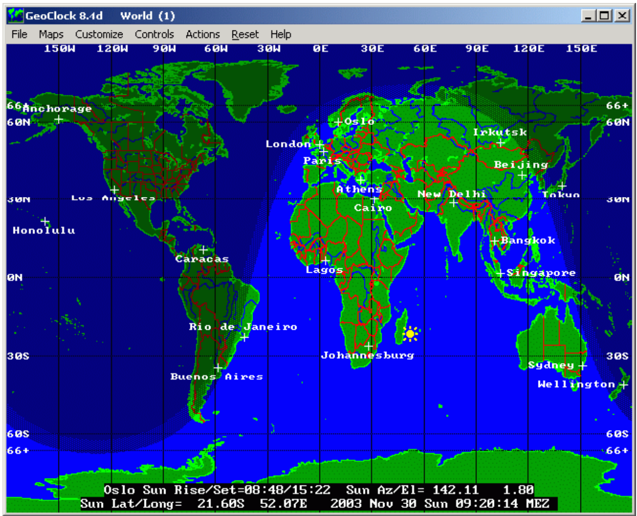
- Travel time around the earth: about 40.000/300.000 ≈ 0.138 sec
- JA3YBK recorded in Asker (near Oslo) by LA3ZA during CQ Worldwide contest on 30. Nov 2003, 08:20 UTC on 21004 kHz



Double-echo:
Travel both ways around the earth

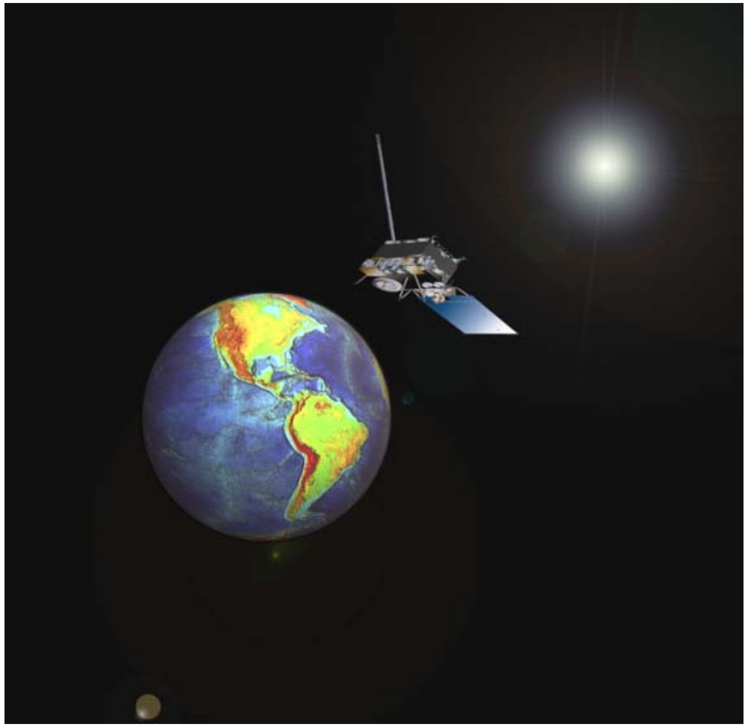


- Shortest distance Tokyo-Oslo: 8400 km ~ 30 ms
- Longest distance: 31600 km ~ 108 ms
- Difference: ~ 78 ms
- Around the earth: 138 ms



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, http://www.noaanews.noaa.gov/stories2006/s2561.htm



Less common delay: EME

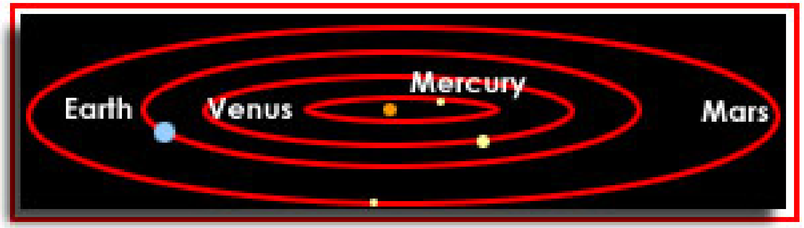
- Moon: 360000-406000 km = 2,4-2,7 sek,
- VHF, but also HF
- HF Active Auroral Research Program, 3.6 MW, Alaska

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



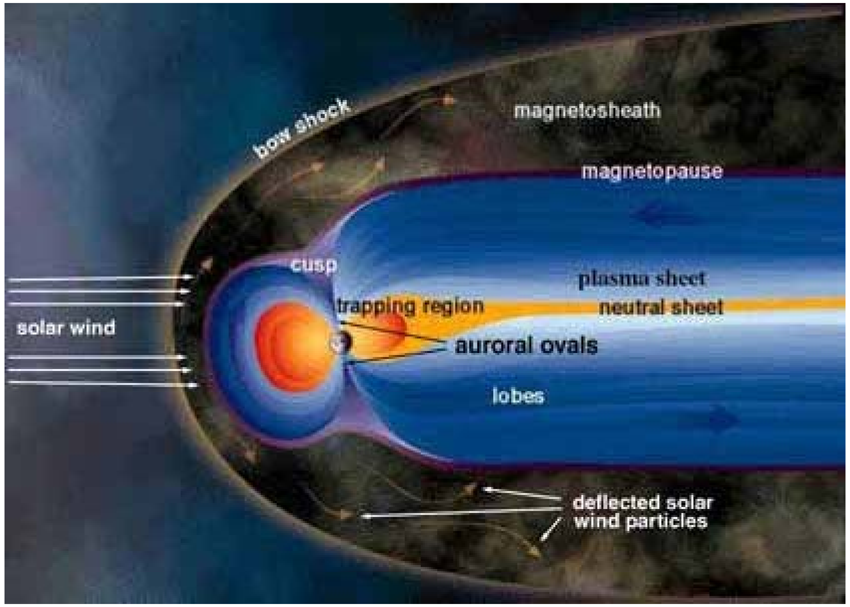
LDE: After WWII

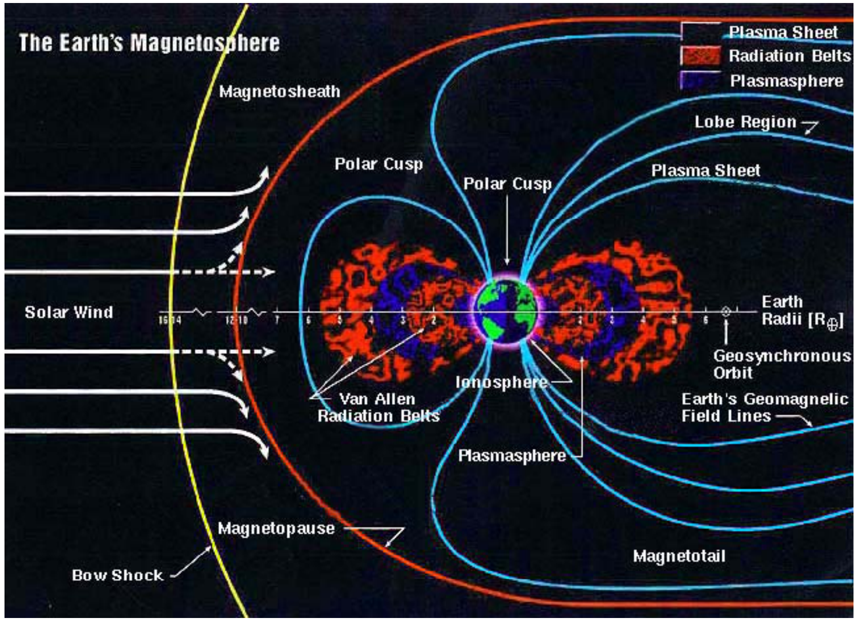
- After the war, measurements were done at Cambridge University [Budden and Yates, 1952], but no echoes were received and scientists were about to dismiss the phenomenon.

LDE: 60’s – 70’s

- But radio amateurs kept reporting echoes.
- A collection of these [Villard, Graf and Lomasney, 1969, 1970] led to the identification of medium delayed echoes (<0.4 seconds) which are caused by ducting along magnetospheric field lines and reflection from the conjugate hemisphere.

Magnetospheric Ducted Echoes Medium Delay Echoes



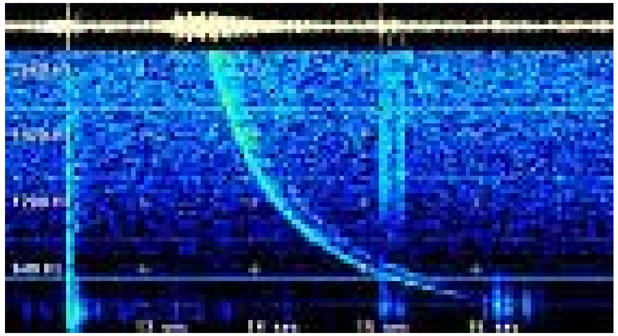


G3PLX, Northern England

- 26. Nov 2006, ~21 UTC (=local time), 1998 kHz.
- Delay 210-220 ms
- 100 Watt SSB, 50 m lw
- 59 echoes in 10 years
  - P. Martinez (G3PLX), Long Delayed Echoes, A Study of Magnetospheric Duct Echoes 1997-2007, Radcom, Oct 2007, pp. 60-63.

Whistler

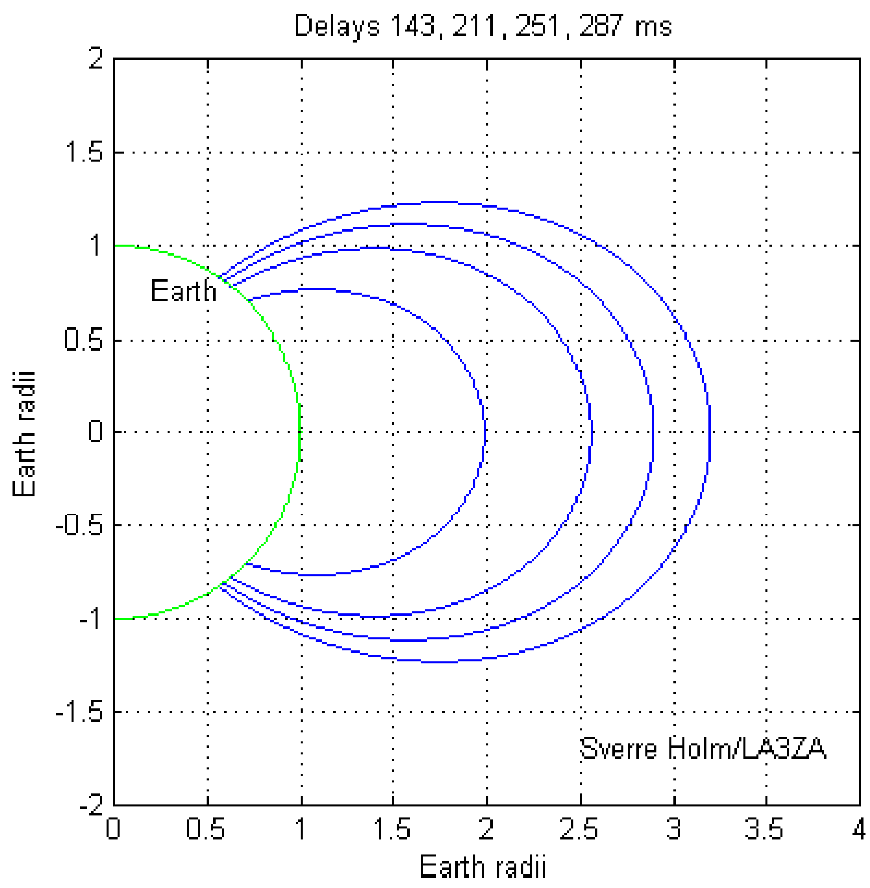
- VLF 1 - 10 kHz
- Starts as lightning on the opposite hemisphere
- Wavelengths in the 15 to 300 km range; the ducts are of comparable size and up
- Travels through magnetosphere
- HF and LF (slower) may have different travel paths-dispersion
- Duct does not need to be overhead as earth-ionosphere is a waveguide also



Ducts

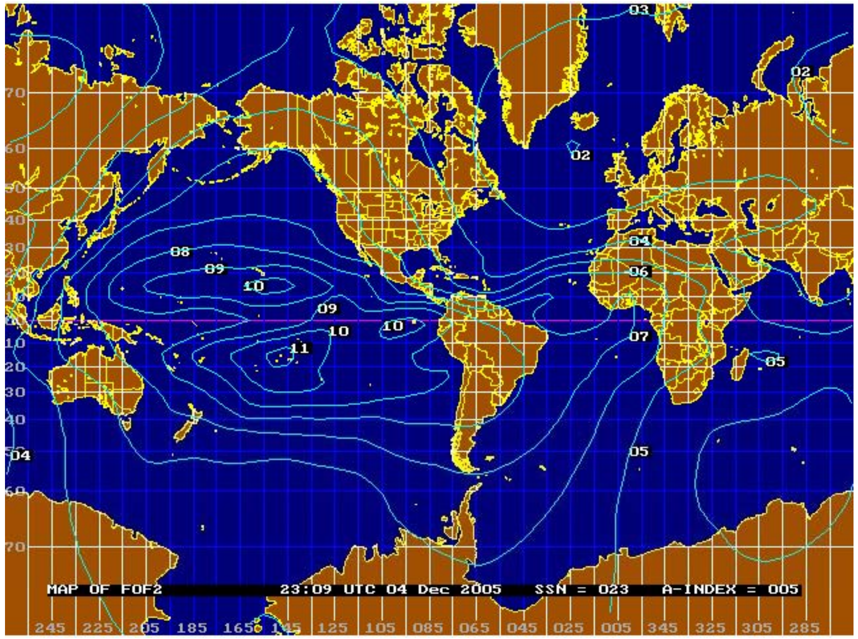
Nominal ducts and delays for

- GA (USA)
- Northern England
- Hobart (Tasmania)
- and the longest one for St. Petersburg (Russia)



Ionospheric trough

- F-region, in which electron densities are anomalously low
- http://amsglossary.allenpress.com/glossary/search?id=ionospheric-trough1
- 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 plamasphere, 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
- Fung, Green, Modeling of field-aligned guided echoes in the plasma-sphere, Journ. Geophys. Research. D. Atmospheres, 2005

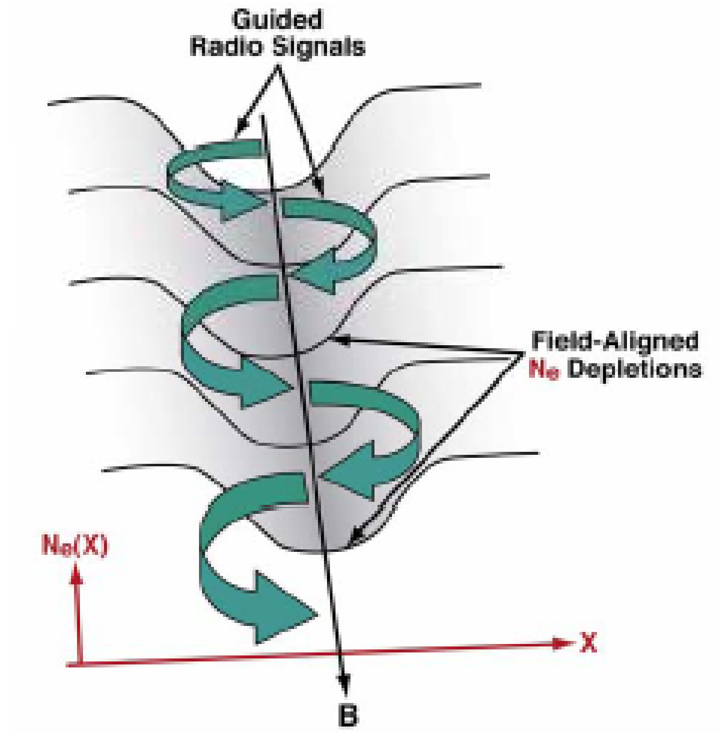


Figure 2. A schematic of ducting of a high-frequency ($f \gg f_{uh}$) electromagnetic wave (green arrows) by field-aligned electron density depletions.

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

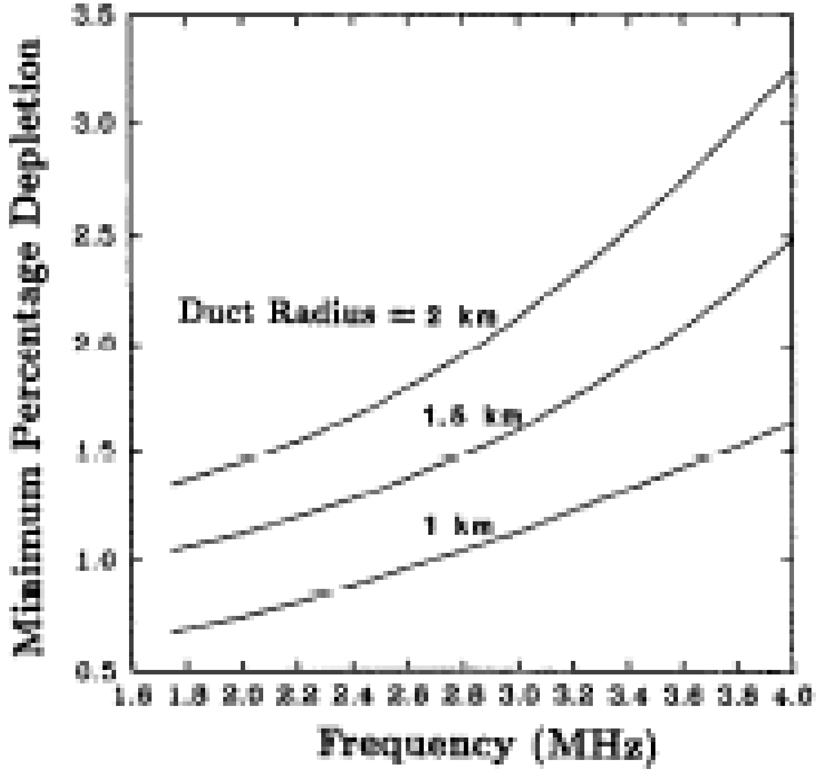
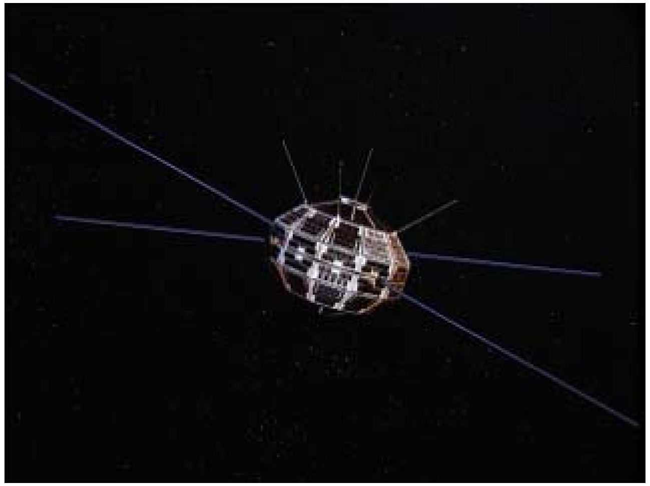


Fig. 5. Percentage depletions required to support a return signal.

Alouette

- 1962 Alouette I satellite
- Canada's entry into the Space Age
- Study the effects of the ionosphere on radio communications in the North from the
- Orbital altitude: ~1000 km.
- 145.70 kg
- Instruments:
  - ionospheric sounder,
  - a VLF receiver,
  - an energetic particle detector,
  - a cosmic noise experiment.
- Two dipole antennas: 45.7- and 22.8-m long



http://www.ieee.ca/millennium/
alouette/alouette_home.html

Villard et al QST 1980

- Must be near the mouth of the duct
- Best in Dec/Jan, 50% chance in Feb/Nov (Northern hemisphere)
- 1900 – 2400 local time, > one hour after sunset
- Antenna: upwards or in the direction of magnetic field
  - E.g. dipole oriented E-W
- Penetrate ionosphere
  - Given by f0F2/sinD < f, D magnetic dip angle
- Conjugate reflection
  - f0F2, other side > f
- Max delay 0,5 sec
- Frequency 1 to 4 MHz

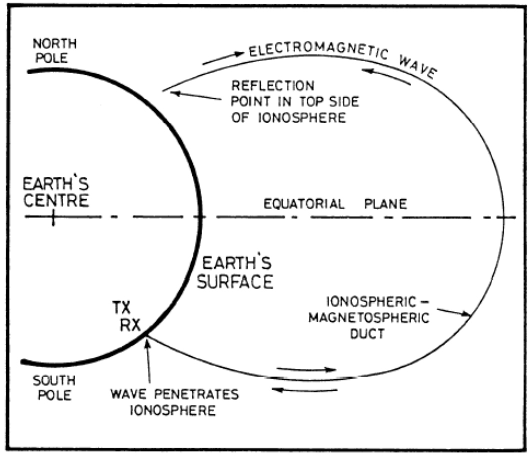


Figure 3 – Geometry of the propagation path.

Oswald Villard Jr (W6QYT)

- 1916 – 2004, professor at Stanford University for five decades
- 1959 efforts in over-the-horizon radar, which worked by reflecting high-frequency radar from the ionosphere
- A pioneer of Amateur Radio SSB (1947) and meteor-scatter techniques, Villard authored some two dozen QST articles between 1946 and 1994.

St. Petersburg 1985,1.8 MHz

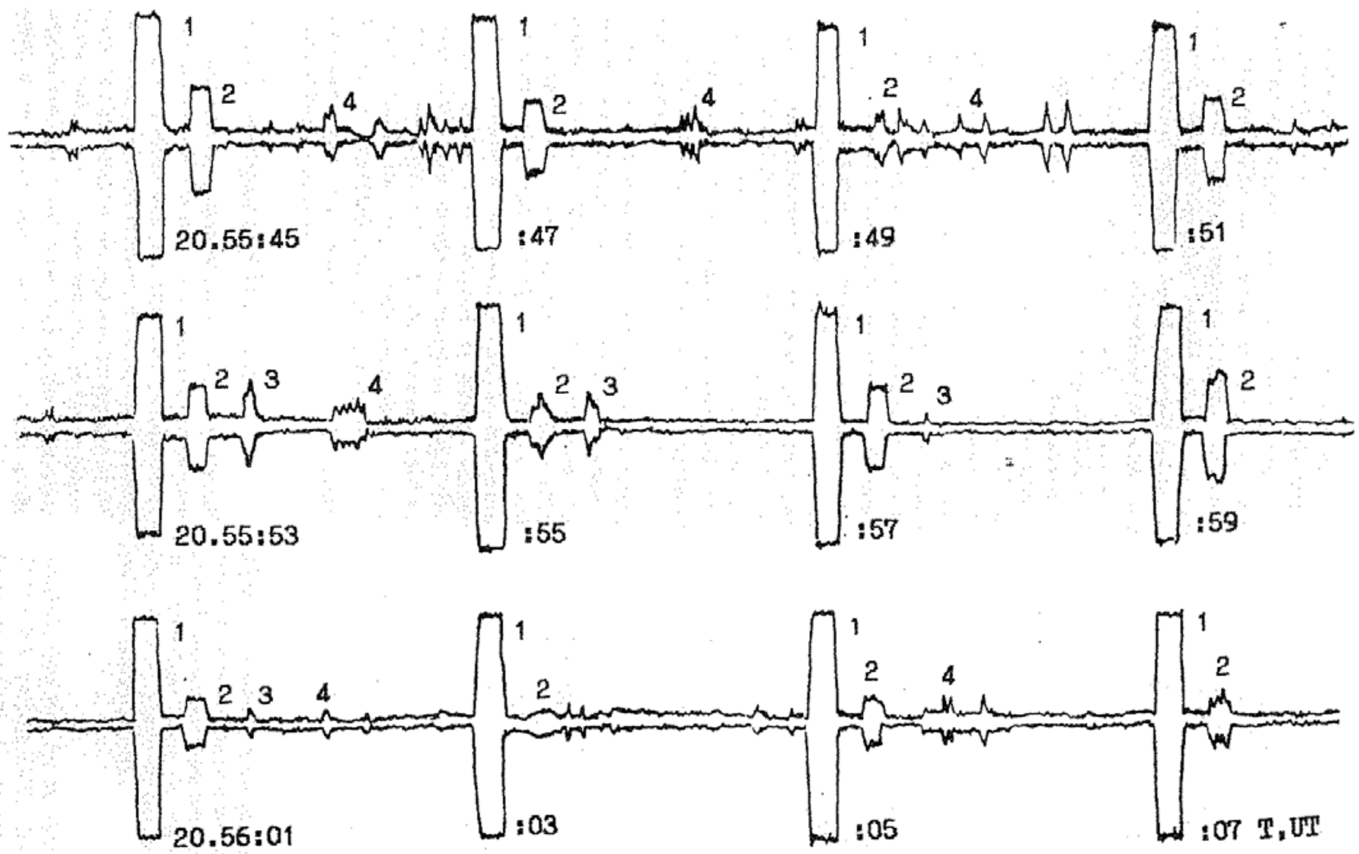


Figure 1. Example of oscillogram of magnetospheric echo signals on November 16, 1985: 1, impulse of transmitter; 2, echo signal with t_{gr} = 295 ms; 3, echo signal with $2t_{gr}$; 4, noise. The vertical scale is linearly proportional to relative signal strength.

Other observations

- AM broadcast band also: 1200 kHz.
- Blagoveshchensky: St Petersburg, 1985: 1.8 MHz, P=5 kW, avg. delay 290 ms
- Goldstone & Ellis: Tasmania, 1985-88, 1.91 MHz, P =17 kW, 260 – 270 ms
- Both the 1.8 and 3.5 MHz bands at the same time (W1TR mid 90's).
- W2PA, New York: 214-219 ms, 3.530 MHz in Feb 2008, duration 50 minutes.
- Seattle, WA, 1977, 22.30 – 00.30 local time, 75 m SSB, 225 +/- 5 ms

K4MOG, Atlanta, GA

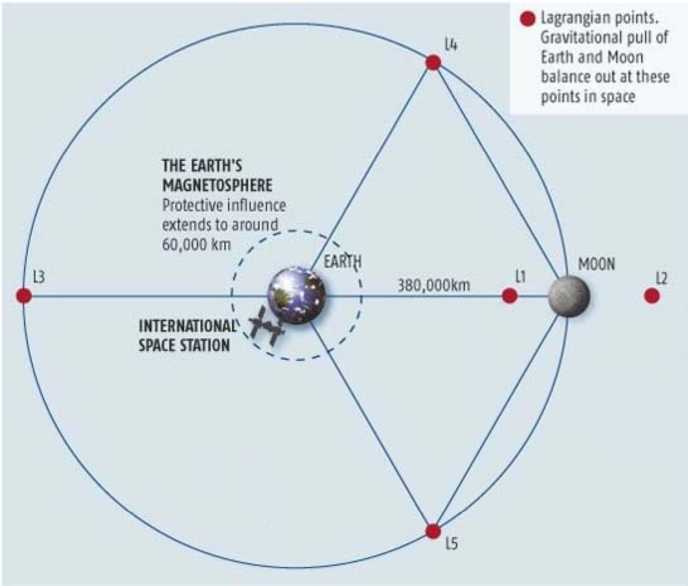
- 17. Feb 2006, 0345 UTC (2245 local time), 3.5 MHz, Echo 165-168 ms.
- Around-the-earth: 138 ms + tx/rx delay?
  - G. Greneker (K4MOG), “The Ultimate DX: An Around the Earth Path,” QST, June 2007.
- MDE: 143 ms +
  - S. Holm (LA3ZA), “Magnetospheric ducting as an explanation for delayed 3.5 MHz signals,” QST, March 2009.

LDE: After 60's

- The new optimism led to measurements at Stanford University and in Alaska [Crawford et al 1970], [Freyman 1981] and [Vidmar and Crawford, 1985].
- Some echoes were received, but there was little progress in explaining them.

A correlation of long-delay radio echoes and the moon's orbit

- Sassoon, G , Spaceflight. Vol. 16, pp. 258-264. July 1974
- Computed positions of moon + its two Trojan positions for each of 92 reports from Hals, Van der Pol, and Villard.
- Indicates a statistically-significant tendency for echoes when the trailing moon-equatorial position is above the observer's horizon.
- LDE caused by some phenomenon associated with this position?
- http://www.definity-systems.net/~apw/astro/orbit.html



Year	Call	Band	Delay	Mode	Echo
1932	W6ADP	28	18	CW	Own
50/51	W5LUU	7	5	CW	Own
1965	K6EV	14	3-4	SSB	Own
1967	W5VY	28	3	SSB	Own
1968	W5LFM	10	0.5	Time signal	ID
1968	W6KPC	28	1	SSB	Other
1969	W6OL	14	6-10	SSB	Other
1969	K6CAZ	2	2	SSB	Other/ own

Europe

- 1982, DL1BU, 28 MHz, several sec, own signal
- 1986, DJ4ZF+DL6QH, 14 MHz, RTTY: 40-50 characters @ 45.45 baud received – thought first it was a hoax
- 1982, YU1AW, 432 MHz, 2 sec after EME-echo

Russia/Soviet

- 1974 & 76, Alma-Ata, 3.5 MHz, > 10 sec
- 1978, Alma-Ata, 14 MHz, 20 sec, own
- 1975, Leningrad, 12.559 MHz, 2 sec, beacon
- 1980, Moskva, 28 MHz, 1-1.5 sec, other
- 1981, Moskva, 14 MHz, 0.5-1 sec, other
- 1981, Dushanbe, 28 MHz, 4 sec, own
- 1986, Fergana, 9.68 MHz, 2 sec, Sri Lanka

VE3HX

- 20 Dec 1989, 20:05 local time (EST)
- 28 MHz SSB, delay 2.9, 4.5, 5.5, 7.1, 8.1, and 9.5 sec
  - A. K. Goodacre, An unusual long-delay echo, Nature 347, 131, Sept 1990.

Delay of many hours?

- Long-Delayed Echoes: Reflections From an Ionosphere in Space? CQ 2005, Feb., p. 24 by Mac Obara TZ6JA ex JA8SLU
  - From a series of 3 articles by TZ6JA , 2004 in 59 magazine
  - Recording by JA7SN of his 80m signal delayed by ~50 minutes.
  - Several JA Topbanders reporting these echoes (JA1HQT, JA1CGM, JA8DNV and JA3ONB)

TABLE

1.8/3.5 TYPE LDEs RECORDS

2004 AUG

TYPE	MODE	STATION	DATE D·M·Y	TIME(LOCAL TIME) TRANSMISSION	RECEPTION	DELAY TIME	DISTANCE AU EARTH	SUN	POSSIBLE REFLECTOR
I	3·5 CW	UL7GW	14·12·72	20:05	20:05	10~15 sec	-	-	PLASMOID-GEOTAIL
II		W6WYW	11·10·01	20:00	20:30	30 min	1·8	2·8	MINOR PLANET
		JA7SN(1)	24·2·98	21:10	22:00	50	3.0	4.0	
III	3·5 CW	JA7SN(2)	26·12·93	22:05	16:02*	17h57min	65	66	EKBO N 3/10
		JA7SN(3)	16·1·98	21:50	21:40*	20:50	86	87	EKBO N 1/5
		JA1HQT	10·89 ~ 2·93	19:30 ~ 21:30	19:30* ~ 21:30*	24H ~ 25	86	87	
		JA1CGM							
		JA8DNV	27·12·02	21:00	23:10*	26:00	94	95	EKBO N 2/11
	1·8 CW	JA3ONB(1)	18·1·04	19:54	06:13**	34:19	124	125	EKBO
		JA3ONB(2)	-	-	06:25***	82:32	297	298	

* NEXT DAY
** 2 DAYS AFTER
*** 4 DAYS AFTER

EKBO: EDGE-WORTH KUIPER BELT OBJECT
N 3/10: MEAN MOTION RESONANCE BELT AFTER NEPTUNE

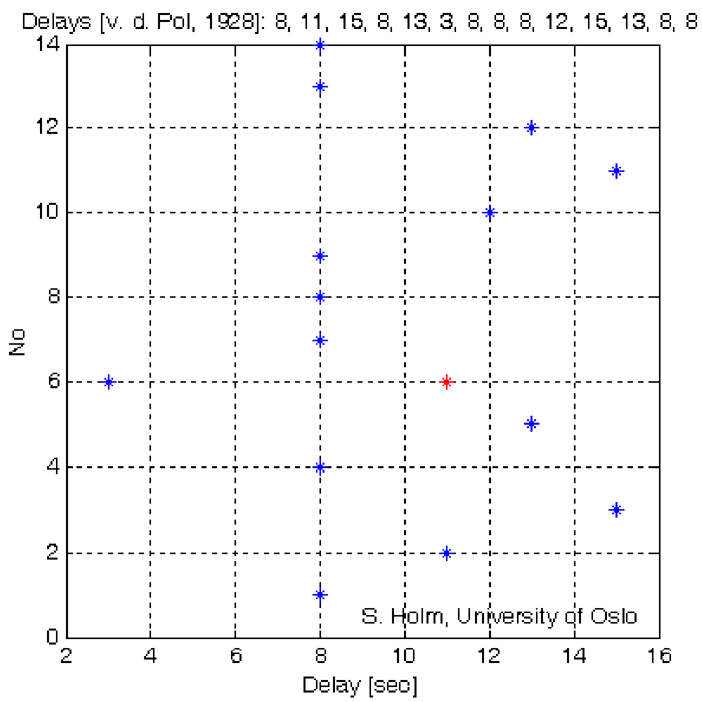
LDE: Status now

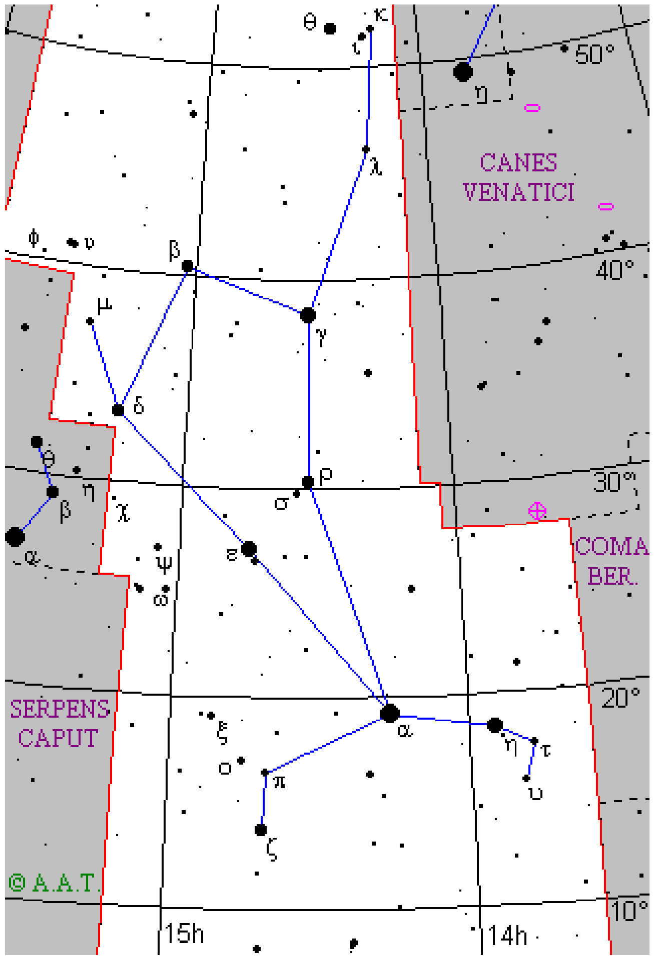
- The present status is that delays from a second and up at frequencies above 4 MHz and at VHF/UHF are unexplained and scientific interest has again fallen, although papers are still published e.g. [Ivanov-Kholodny et al, 2007].

An unmanned space probe?

- Bracewell, 1960: The probe could first listen for our signals - then repeat them
- To us, its signals would have the appearance of echoes having delays of seconds or minutes, such as were reported thirty years ago.
- Should we be surprised if the beginning of its message were a television image of a constellation?

Lunan, 1973:
Bootes 12600 years ago?





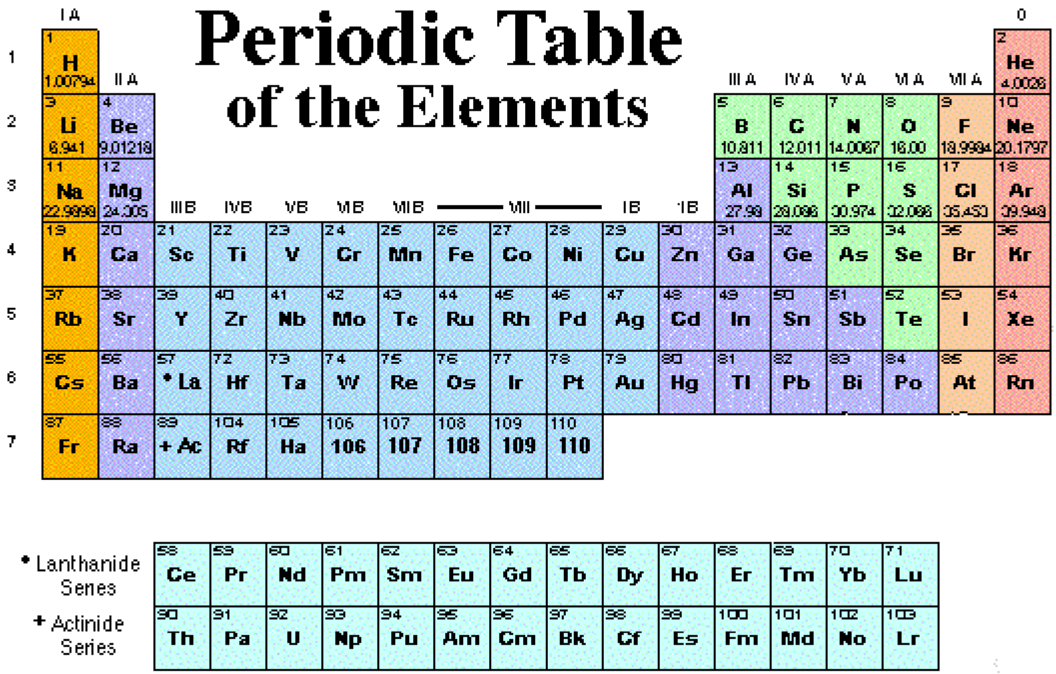
Delays recorded by van der Pol on 11 Oct. 1928, 20-21 local time in the Netherlands

How to make semiconductors?

Størmer and Hals echoes, 11. October 1928, 15.45-16.00 UTC:

1. 15,9,4,8,13,8,12,10,9,5,8,7,6 — P F Be O Al 0 Mg Ne F B O N C
2. 12,14,14,12,8 — Mg Si Si Mg O
3. 12,5,8 — Mg B O
4. 12,8,5,14,14,15,12,7, 5, 5,13,8, 8,8,13,9,10,7,14,6,9,5
   Mg O *B Si Si P* Mg N B B Al O O O Al F Ne *N Si C F B*
5. 9 — F

- Si + B + P =
  PN-junction in a diode
- Si + C + B + N + some F
  = LED



18 March 2009

Credible interpretations?

- Measurement round-off?
  - Størmer: *I noted in seconds the following intervals of time between signals and echo: ... The times noted by me can lay no claim to great accuracy, because I was not adequately prepared, but in any case they give a qualitative idea of the phenomenon.*
- One second unit?
- Probability of sequence?

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

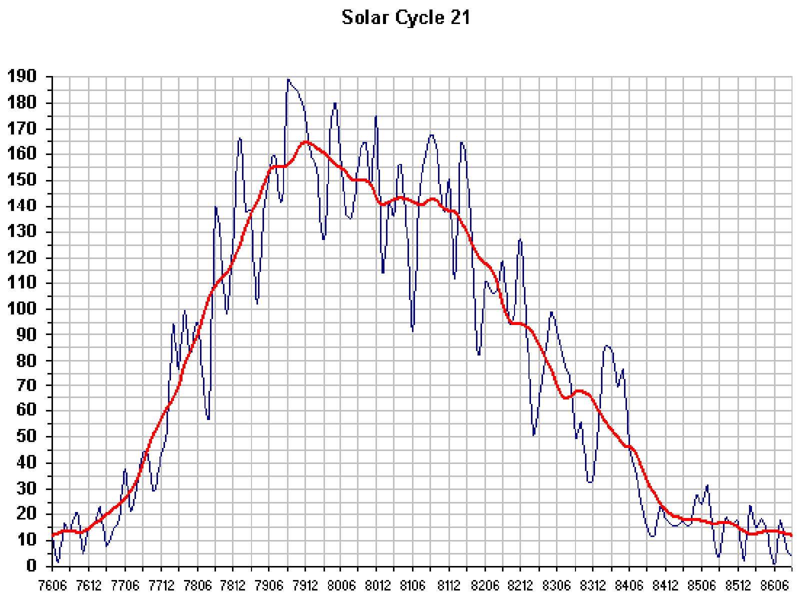
- Focusing and amplification effects in the ionosphere (100-400 km)
  - focusing at the antipodal points (the Appleton hypothesis, 1928).
- A signal is guided many times around the earth, for then to exit to the earth
- Delays up to 10 seconds for high HF
- Status: Unconfirmed
  - Not observed during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

28 MHz

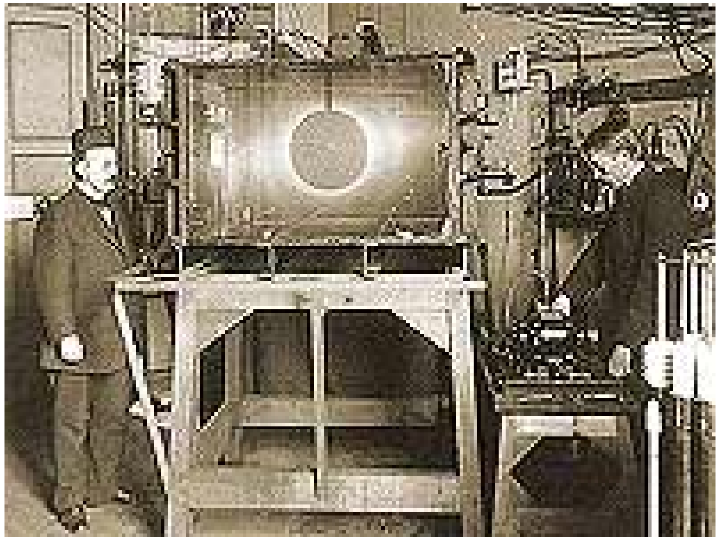
Goodacre, VE3HX, Nov 1978 - Jan. 1979 :

- Antenna towards West
- 28 MHz
- Delay up to 9 sec
- Statistiscal analysis: periodicity of 0.138 sec = around-the-earth (up to 65 rounds)

A. K. Goodacre, "Some observations of long-delay wireless echoes on the 28-MHz amateur band," Journ. Geophys. Res., Vol. 85, No. A5, pp. 2329-2334, May 1980.



2. Conversion to and from plasma waves in the ionosphere



Conversion in the vicinity of ionization and magnetic field inhomogeneities.

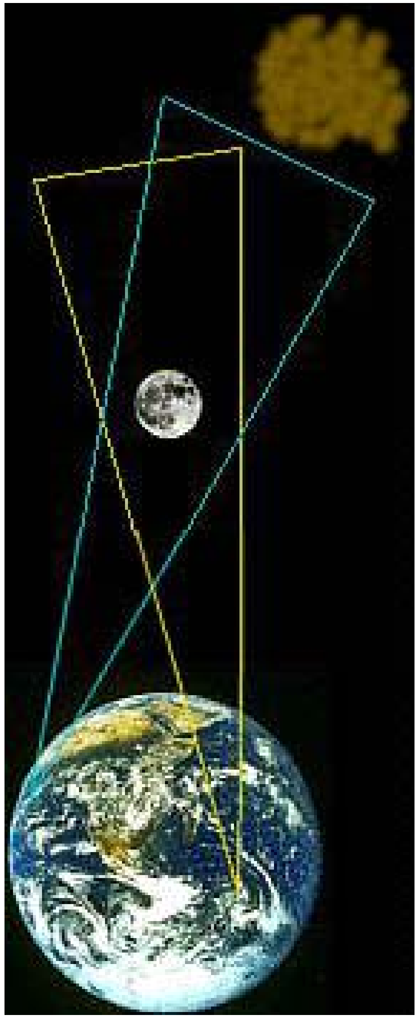
The Luxembourg effect

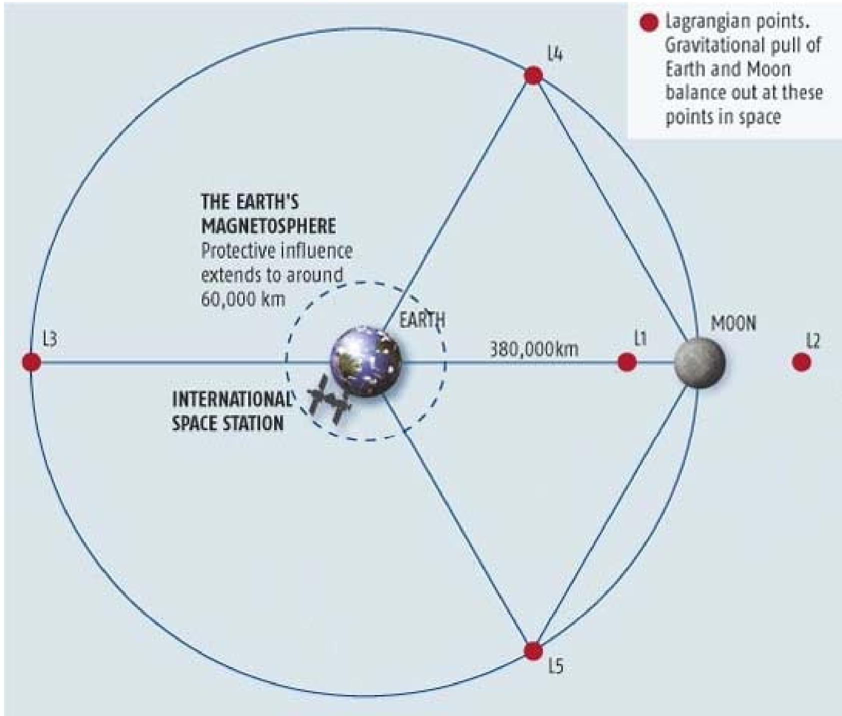
- 1933: Radio Luxembourg modulated Beromünster, CH, on 556 kHz, heard in Eindhoven, NL
- 1934: Explanation: Modification of the ionosphere of the strong RTL transmitter
- AM from RTL was transferred by non-linearity in the lower part of the ionosphere
- Active ionosphere modification with megaWatt - 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 km/s, may spread some tens of km
- Are then converted back to EM waves.
- Like a big memory, Δt < 10-20 sec
- Mid HF-frequencies, like those Hals observed
- Status: unconfirmed

3. Reflection from plasma clouds

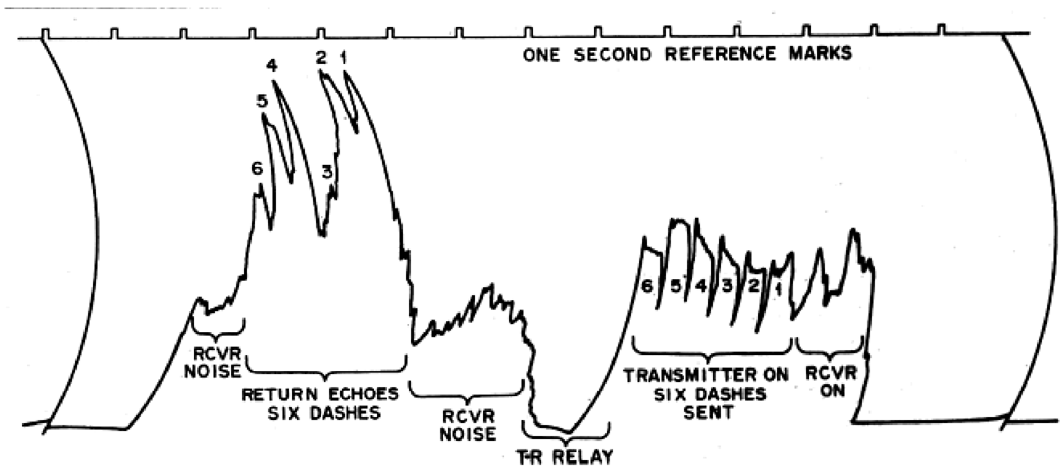




3. Reflection from plasma clouds

- Equilibrium points
- Clouds of ionized gas and particles can be stationary and give stable reflections
- Ex: The L2 Lagrange points is 61,500 km from the Moon => delay 0.4 sec ~ 2.8 - 3 s
- VHF- and UHF-signals.
- Status: unconfirmed

432 MHz



- K3PGP, 1 April, 1977
- During attempt at EME (earth-moon-earth) with ZE5JJ (Rhodesia)
- The curve must be read ‘backwards’: echo is 5.75 sec
- (2 x moon < 5.43)

1296 MHz

- Hans Rasmussen, OZ9CR
- EME
- Echoes delayed with 2,6+2=4,6 sec
- 1975

  – H. L. Rasmussen, "Ghost echoes on the Earth-Moon path," Nature, Vol. 257, p 36, Sept. 4, 1975.

4. Non-linear effects in addition to plasma wave conversion

MULDREW: GENERATION OF LONG-DELAY ECHOES

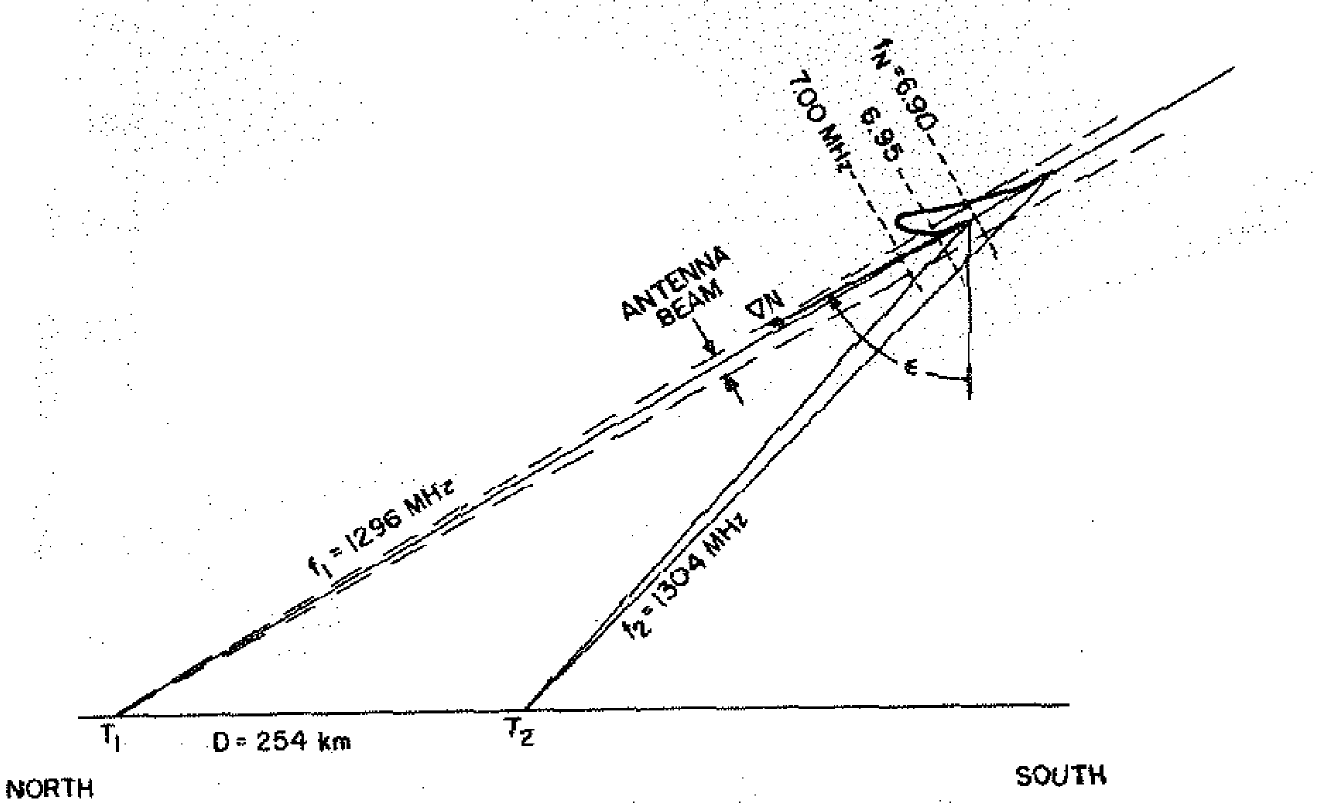


Fig. 2. Geometry for a particular solution which can explain the LDE results of Rasmussen.

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

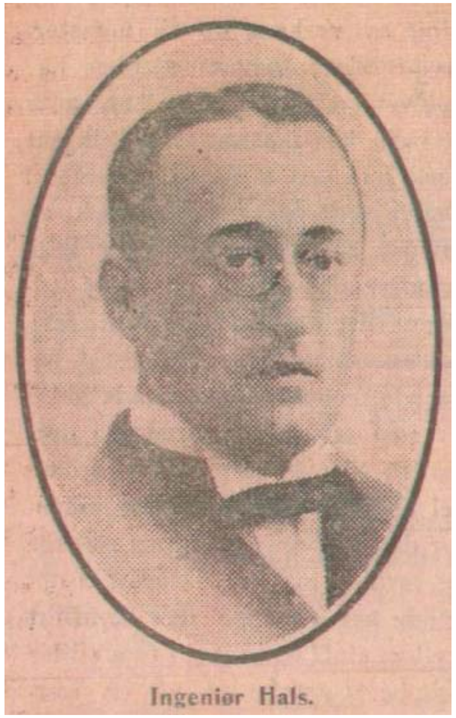
0. Magnetospheric ducting (**confirmed!)**
1. Travel many times around the world
2. Coupling to mechanical, low velocity, waves in the ionosphere
3. Reflection from distant plasma clouds
4. Non-linear mixing of two V/UHF signals plus coupling to mechanical waves

R. J. Vidmar and F. W. Crawford, "Long-delayed radio echoes: Mechanisms and observations," Journ. Geophys. Res., vol. 90, no. A2, pp 1523-1530, Feb. 1985.

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

Jørgen Hals, 1928



”From where this echo comes I cannot say for the present. I will only herewith confirm that I really heard this echo.