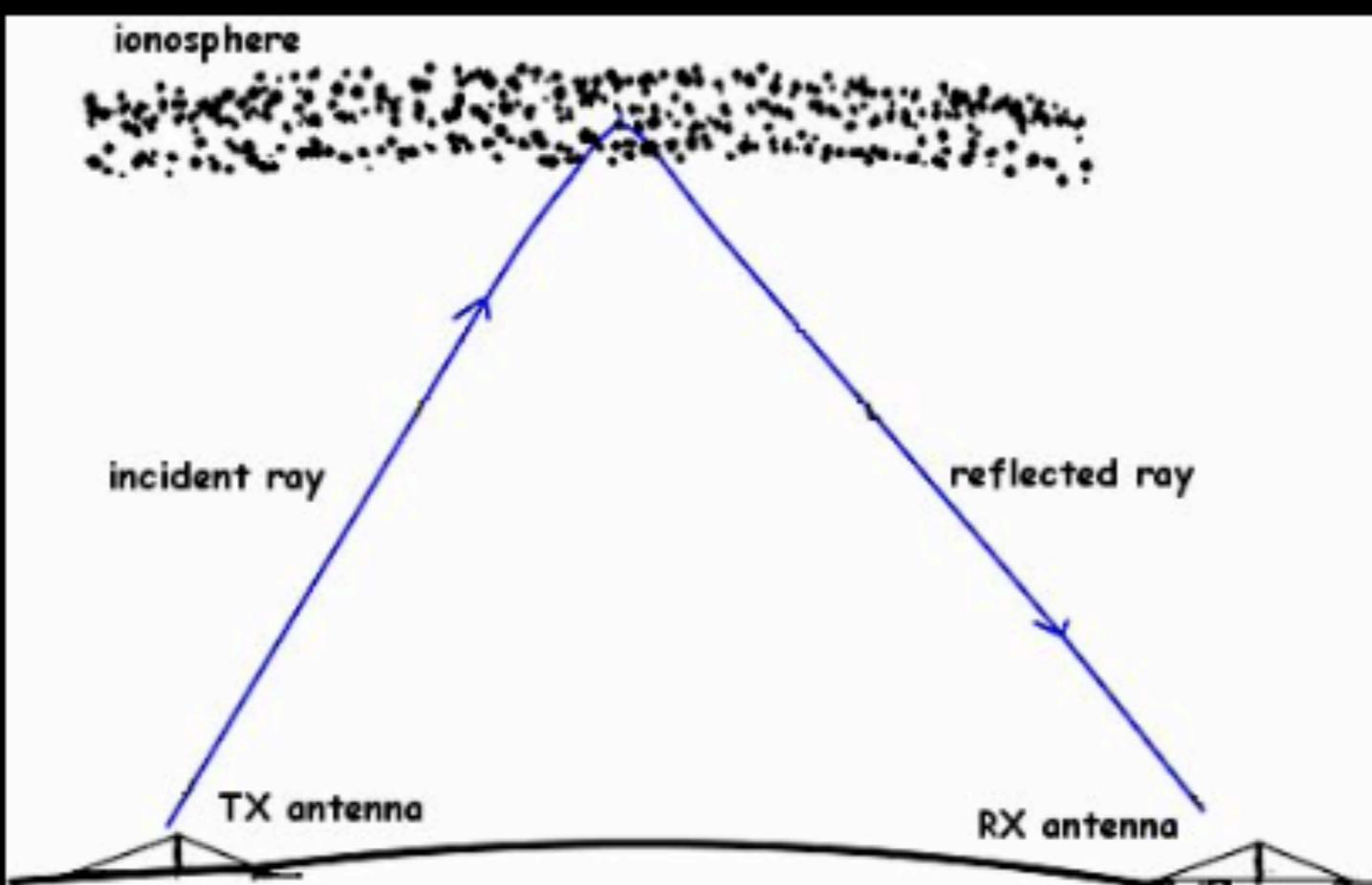


Ham Radio and the Discovery of the Ionosphere

Original Author: Chen-Pang Yeang, University of Toronto

26 June, 2022

Radio Amateurs in the Discovery of the Ionosphere



- Rethink the meaning of experimentation.
- How did citizen science complement professional science?

Wireless Technology & Radio Propagation Studies



Heinrich Hertz



4

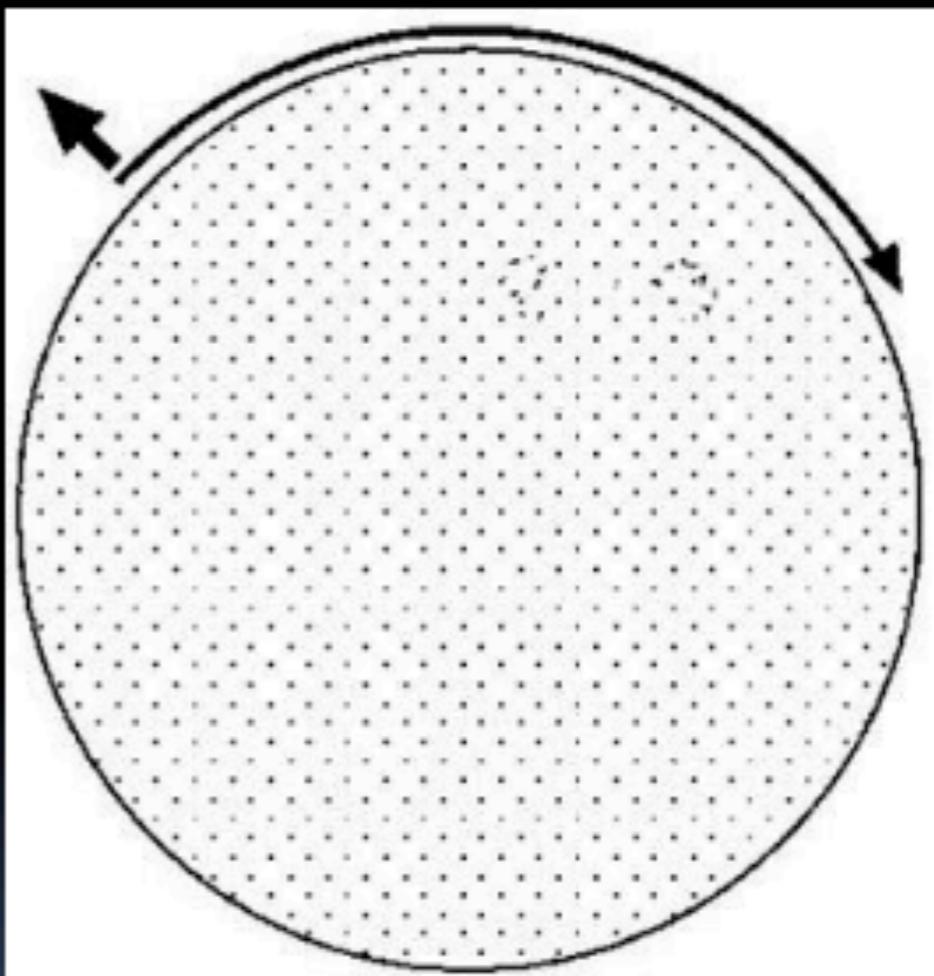
Experimental demonstration
of electric waves (1887)

Surface Diffraction Theory

Hector Macdonald (1903):



Radio waves diffracted along
the earth's surface.

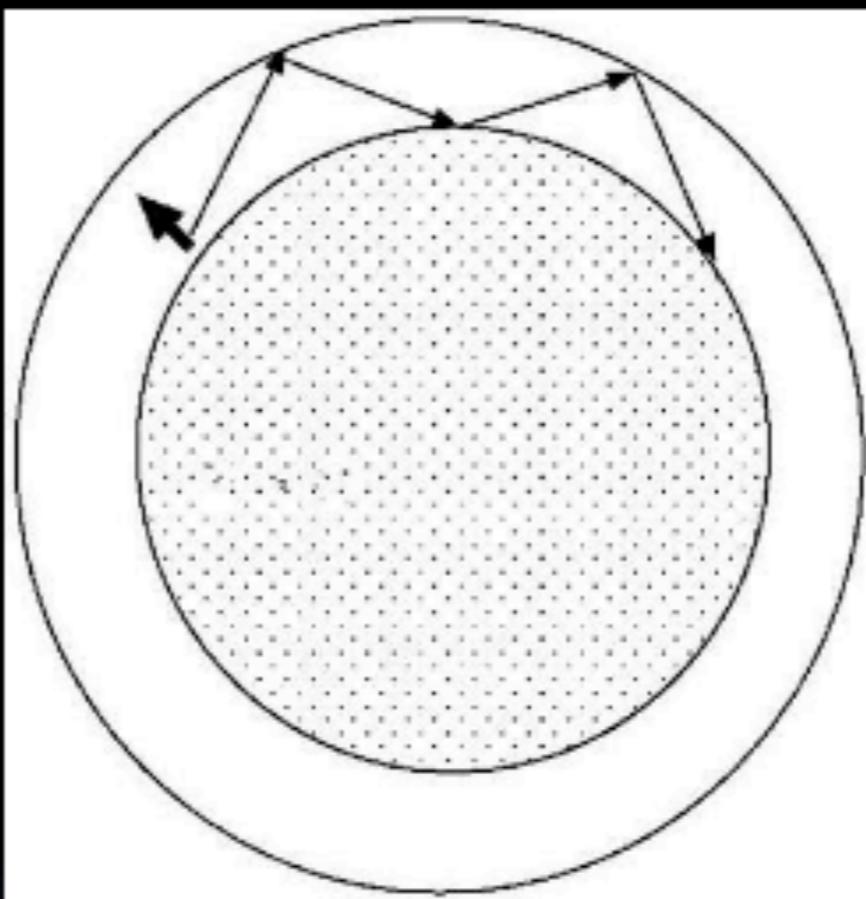


Atmospheric Reflection Theory (1902)

Oliver Heaviside (London)



Arthur Kennelly (Boston)



- Existence of an upper conducting layer.
- Waves bounce between the ⁶ earth and the layer.
- A qualitative theory to explain propagation phenomena.

Austin-Cohen Formula

$$I_r = A \frac{I_s h_1 h_2}{\lambda d} \exp \left[-\frac{\alpha d}{\sqrt{\lambda}} \right]$$

I_r : received current intensity

d : distance

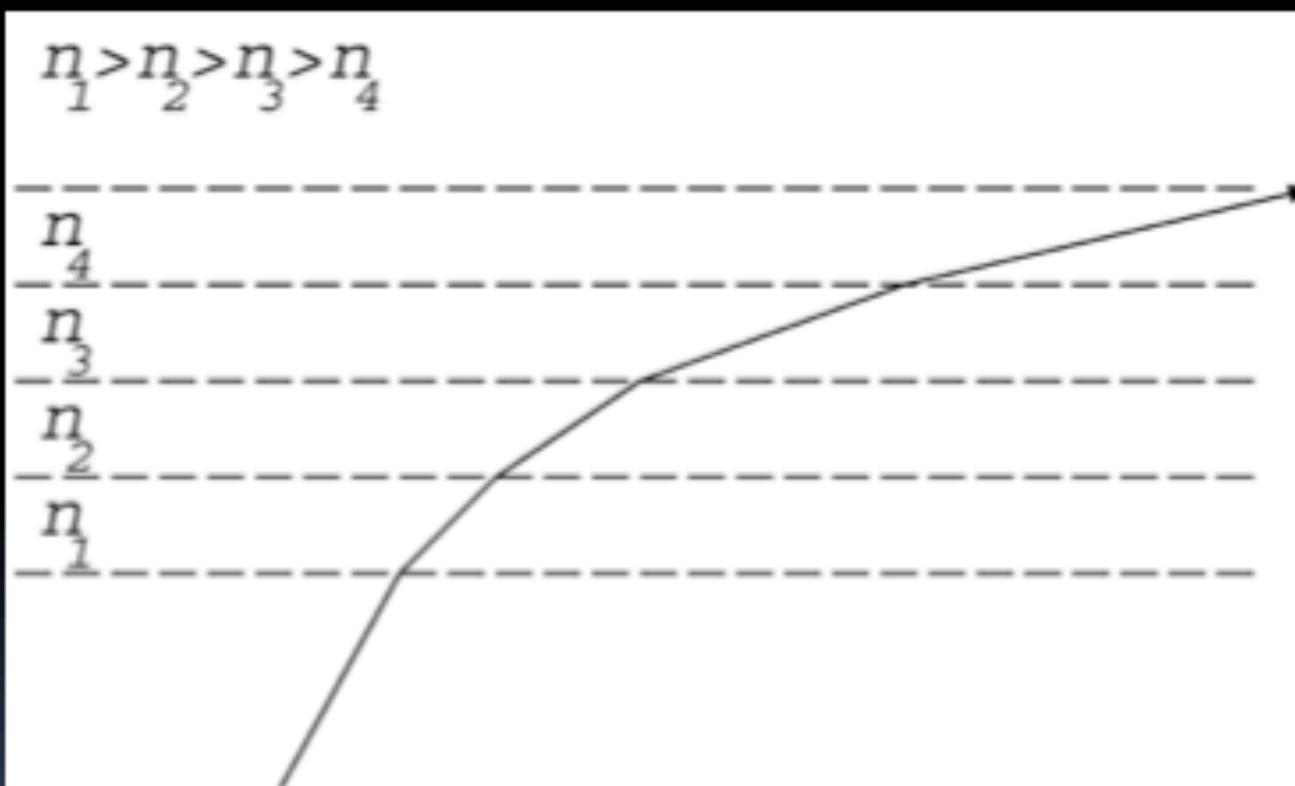
λ : wavelength

But...

- Reflection theory could not produce quantitative predictions
- Diffraction theory predicted more severe decay with distance.

Ionic Refraction Theory (1912-24)

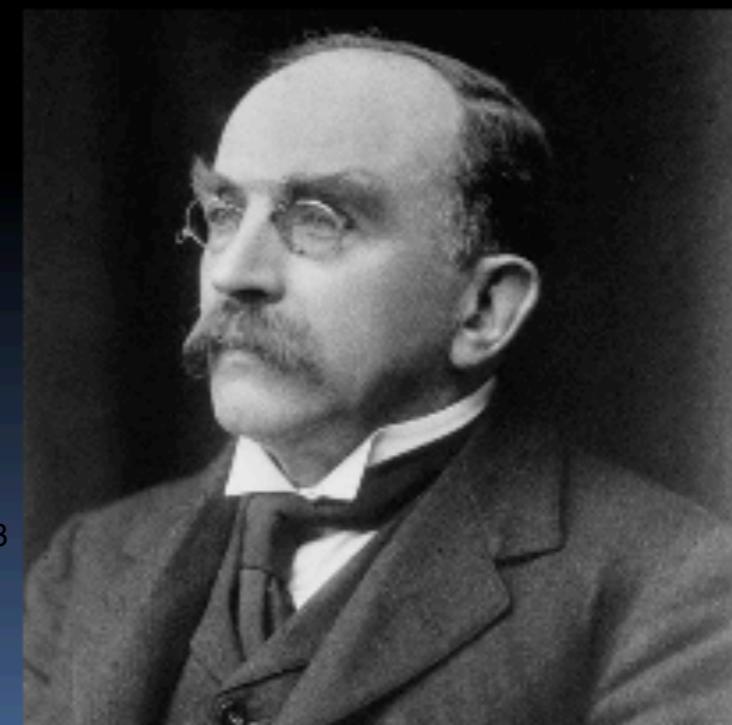
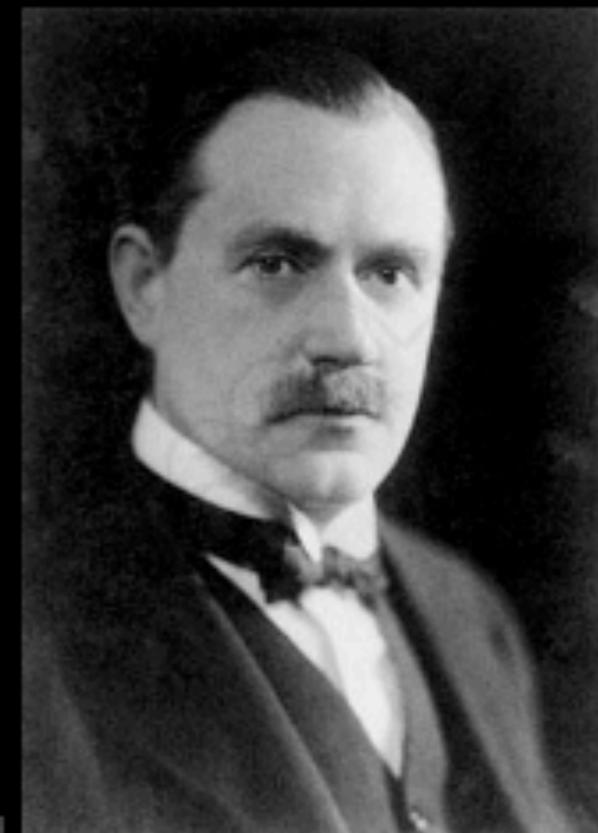
- Waves refracted in the layer.
- The upper layer comprises ionized air.
- Refractive index decreases with height.



8

But where was evidence?

William Henry Eccles
(London)



Joseph Larmor
(Cambridge)

Ham Radio & Collective Experimentation

House Calendar No. 243.
S. 6412.

(H. R. 141.)

IN THE HOUSE OF REPRESENTATIVES

May 6, 1912.

Referred to the Committee on Merchant Marine and Fisheries.

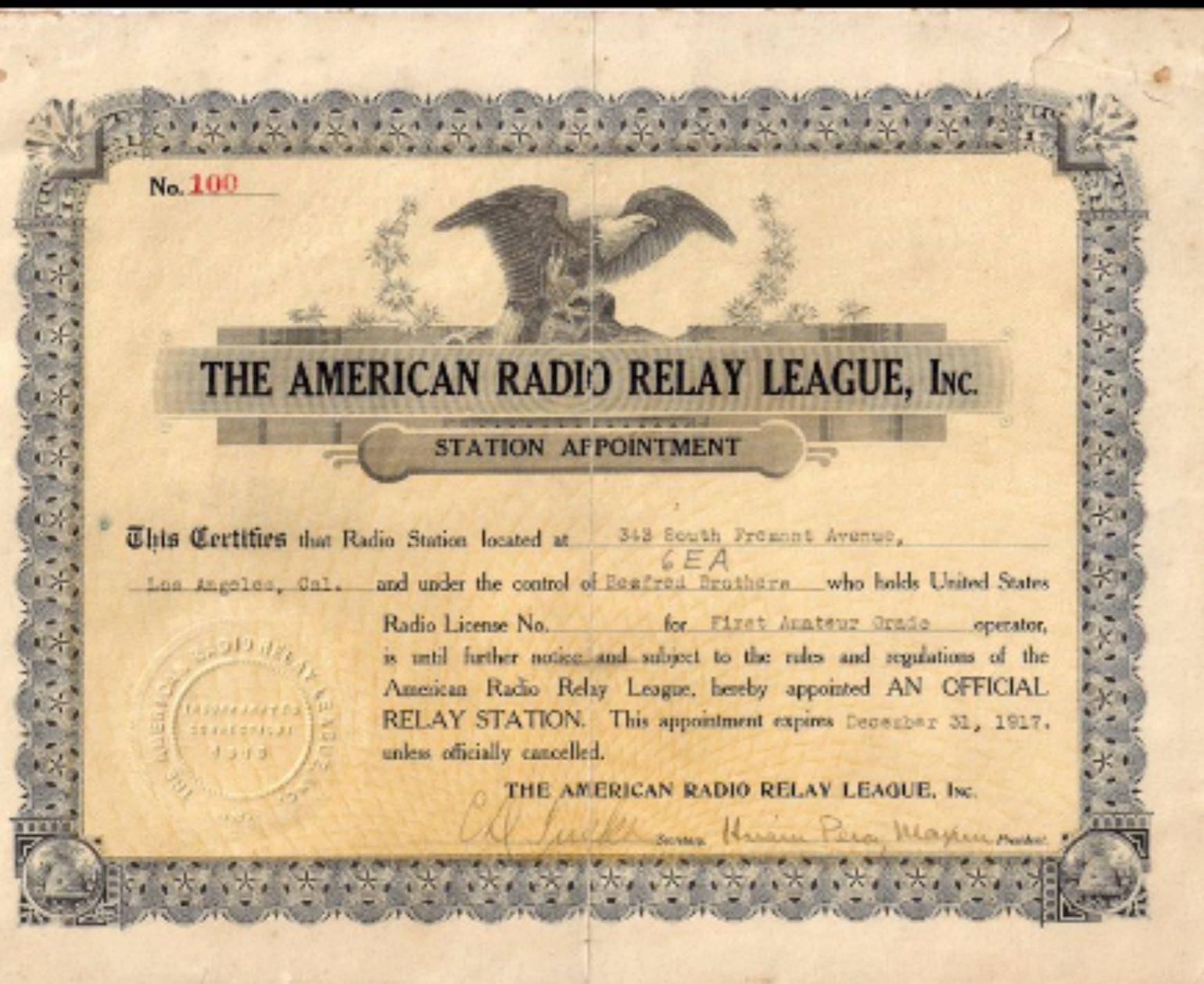
May 10, 1912.

Adopted by the House Calendars committee to be joint.

AN ACT

- To regulate radio communication.
Be it enacted by the Senate and House of Representatives
of the United States of America in Congress assembled,
That a general commission of investigation within the penalties
of law of the United States shall be set up of experts and experi-
enced men for radio telecommunication, or a similar or equivalent
commission among the several States, or such foreign nations
as the government of the United States may be here-
after cause to visit, or to establish, or to re-establish, or
to re-investigate, or to re-examine, or to
re-investigate or re-examine the effect of which extends beyond
the ~~territorial~~ jurisdiction of the State or Territory in which

- US Radio Act 1912 restricted amateur access to wavelengths shorter than 200 m.
- American ham societies used experimentation to legitimate their lobbying for the amateur right to spectrum.



Hiram Percy Maxim

In World War I, amateurs served in militaries and gained knowledge about new radio technology

September, 1917 Q S T 21

A Regenerative Audion Connection

By E. Kraus

DURING the past winter it has been my good fortune to continue an amateur work of the regeneration type that has proven to be extremely sensitive, highly selective, and capable of giving great results without the usual difficulties resulting to go out of tune in the diagnosis of the operator.

In view of the enormous number of operators now using the audion, it is highly probable that this circuit has not yet been used, but has not been used. However, I have found that it is very easy to construct, operate, and maintain by experience alone.

Starting from the fact that the audion has a very stable and linear voltage-current characteristic, it will cause a very considerable change in the strength of the plate current if it is connected in series with the plate circuit of the detector. This causes the plate current of the detector through the pentode stage to decrease with still further amplification. The most obvious way of accomplishing this purpose is to connect an inductor in series with the plate and control the bias of the detector.

A REGENERATIVE CONNECTION

E. Kraus, A.C.

acter of the plate need adjusted to produce the required effect. Accordingly, a variable condenser was connected across the plates. At one stage of the work,

Receiving.

audion detector were obtained which were easily comparable with the theory of the time. The detector is still used while many ships could be read all over the oceans. The tuning coils had very sharp cut-offs to be used with maximum efficiency.

Trials of various types of detector capacitors and screen coils have been made out. For the most satisfactory results have been secured with the two methods described.

The basic plan of Fig. 1 is to connect the detector and the working elements of the triode of the 2A6 double triode in parallel to use a 3-point method, special provision being made to make the bias short. The working is continuing the same like separate lengths of wire which would be either length of approximately four loops. The take is a carbon board and is placed to prevent shorting, but the winding is extremely tight so that the current may be cut off from "leakage" losses.

The main secondary "B" is 2.12 turns in diameter and contains two sections of shielding. Each section is one half long and is wound with No. 22 double insulation wire. The primary "A" is 1.5

June, 1916

Q S T .

8

Q S T

November, 1922

increase the capacity in a greater ratio than the inductance decreases, so the velocity of the currents on a practical wire is always somewhat less than the velocity of light. On short wave-lengths, however, the velocity approaches very close to the velocity of light, generally between the limits of 80% and 98% of the velocity of light for 200 meters, depending upon the size and number of wires.

In order to make the antenna unidirectional, it is necessary to stop the reflections at the end farthest from the receiver end. This is accomplished very simply by placing a non-inductive resistance between the antenna and ground at the far end. If this resistance is made equal to the "Surge Impedance" of the wire, it absorbs all of the energy and prevents any of it from being reflected back to

the feed-back signal because it is preferable to have zero voltage. Diagrams of the two types are shown at Fig. 2 and Fig. 3.

For the reception of undamped signals of long wave lengths, where the capacity load back of the inductive feed-back can be used with success. For the benefit of

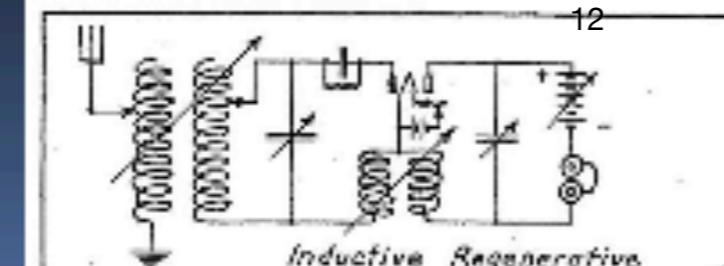
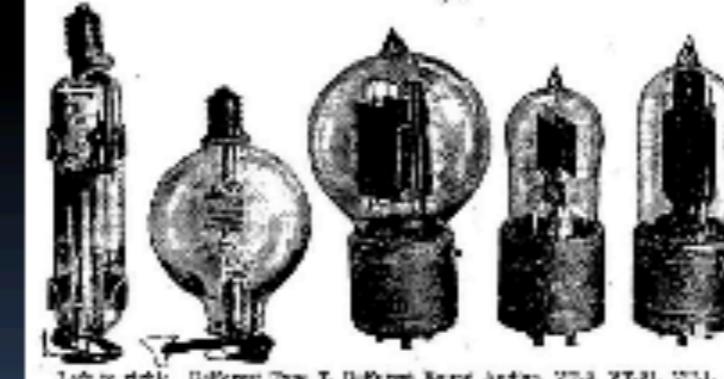
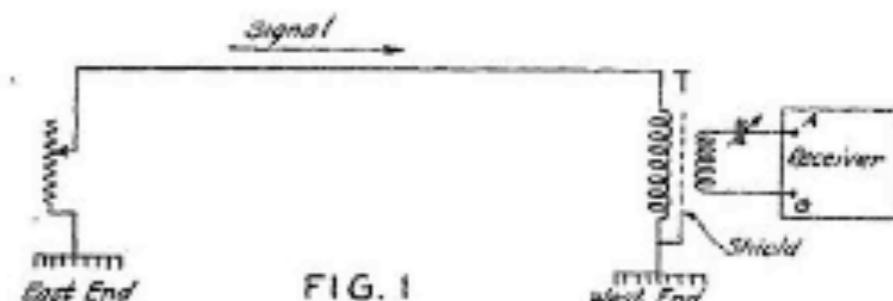
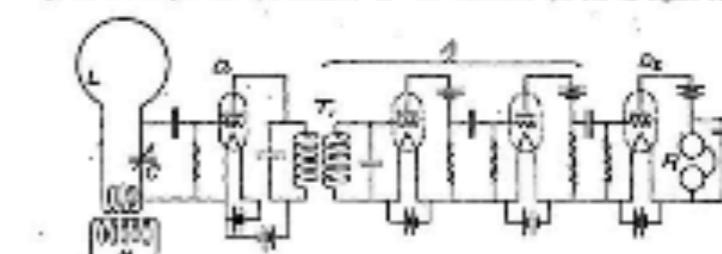


Fig. 2

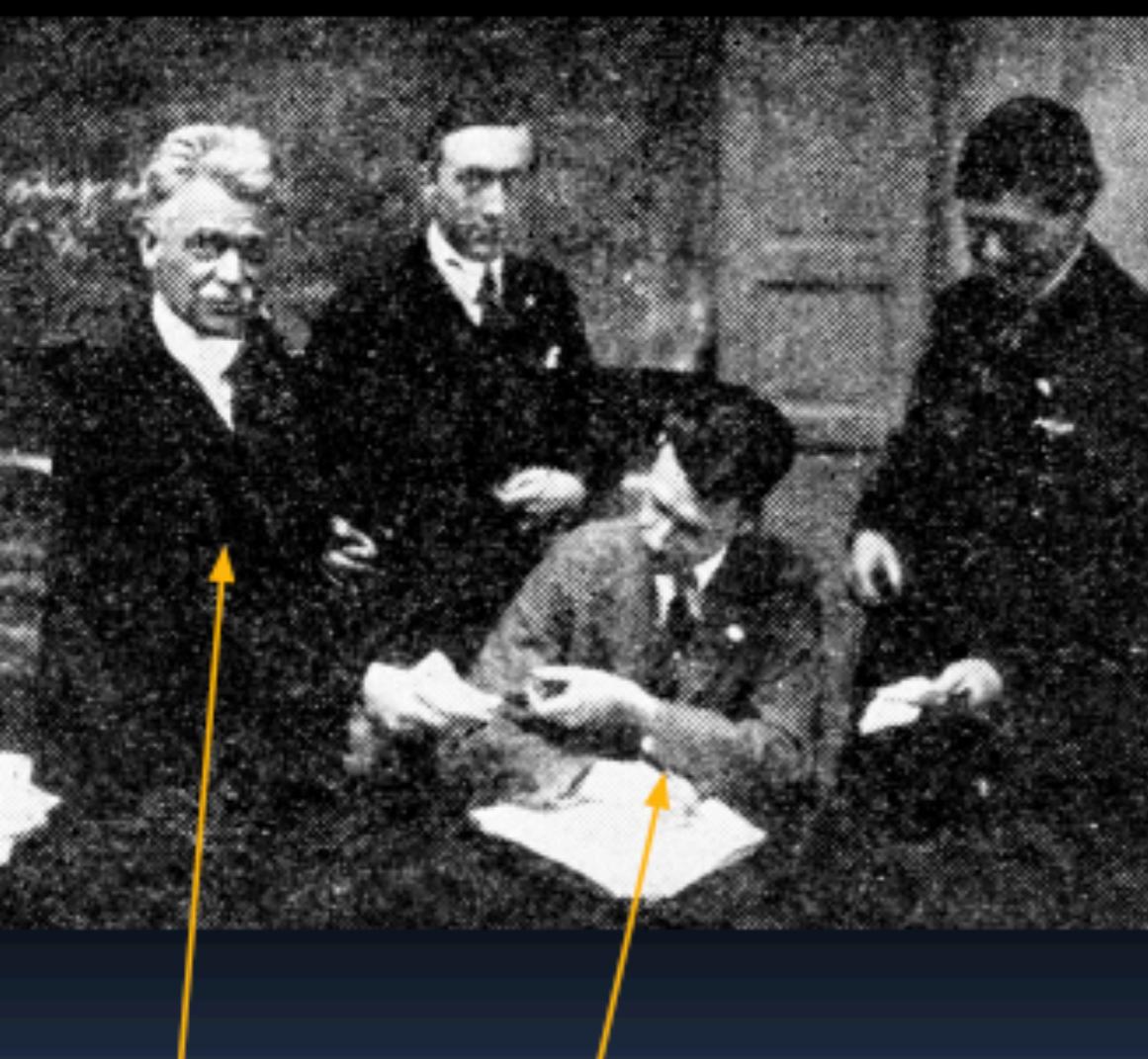


The Signal Circuit A, B, C, which solves the problem by means of an oscillator. This oscillator consists in raising the frequency of the incoming signal to some pre-determined resonable frequency which can be easily selected, passing this current through an amplifier and then detector or rectifier. The amplified current. The transformation of the original high frequency to the predetermined value is best accomplished by means of the heterodyne and multiplication, and the feedback processes involved will be understood by reference to the diagram of Fig. 1. Since L O represents the usual tuned receiver circuit, loop or otherwise, if a regenerative heterodyne and D, a rectifier. A



modulation on the carrier by the oscillator of the amplifier is of a frequency above modulator. While this frequency is only 10,000 cycles and while it is therefore well within the range of practical frequencies, its amplitude depends on the ratio between 10,000,000 and 10,000,000 cycles per second and hence in any attempt to increase it by multiplying the given difference due to fluctuation would be increased as in increasing the original high frequency to resonance. However, the stability to use the heterodyne on the second oscillation is not of great importance because the amplitude of the signal is to be varied in large and hence the difference can be as signal strength.

Meeting at Washington, DC, 2 April 1920



Maxim & Kenneth Warner
ARRL

John H. Dellinger
National Bureau
of Standards



Albert H. Taylor
Naval Research
Laboratory

Coordinated Mass Experiment

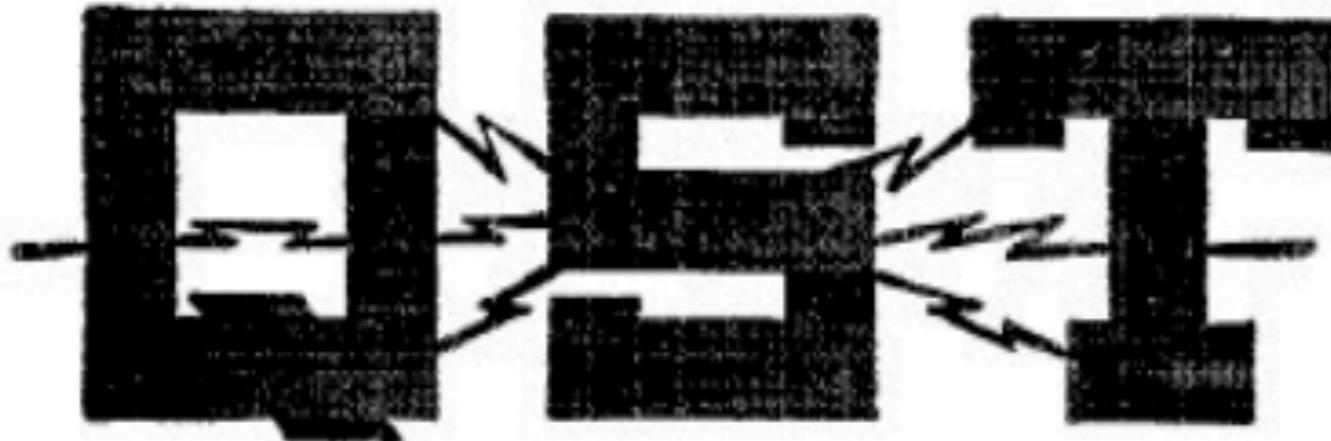
- June-August and October 1920, January and April 1921
- New England, New York, Virginia, Illinois, Indiana, Ohio.
- 17 ham transmitting stations (wavelengths 200, 250, 375 m).
- 150 ham receiving stations.
- Called for general participation in *QST*.
- Published trial schedule in advance.

Standard Procedure & Data Format



- Standardized formats of experimental reports.
- Taught ham operators how to ignore recognizing correct messages and focus on intensity variation.

- ARRL-NBS fading trials generated thousands of records.
- The data's scientific significance was unclear.
- But the campaign laid out a model for ham's mass experiments.



A Magazine Devoted Exclusively to the Radio Amateur

Transatlantic Tests Successful

OH, Mr. Printer, how many exclamation points have you got? Trot 'em all out, as we're going to need them badly, because WE GOT ACROSS!!!!!!

As we prepare the copy for this issue

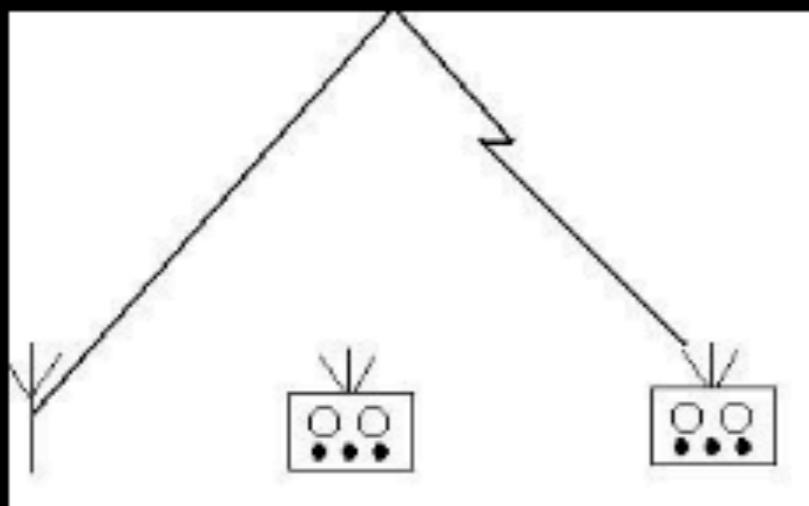
Newmarket, and on his spark at that, but Mr. Coursey's report may show more of our cousins in the Dominion.

Station 1BCG at Greenwich, Conn., was reported on two consecutive nights and indications are that it had the greatest size.

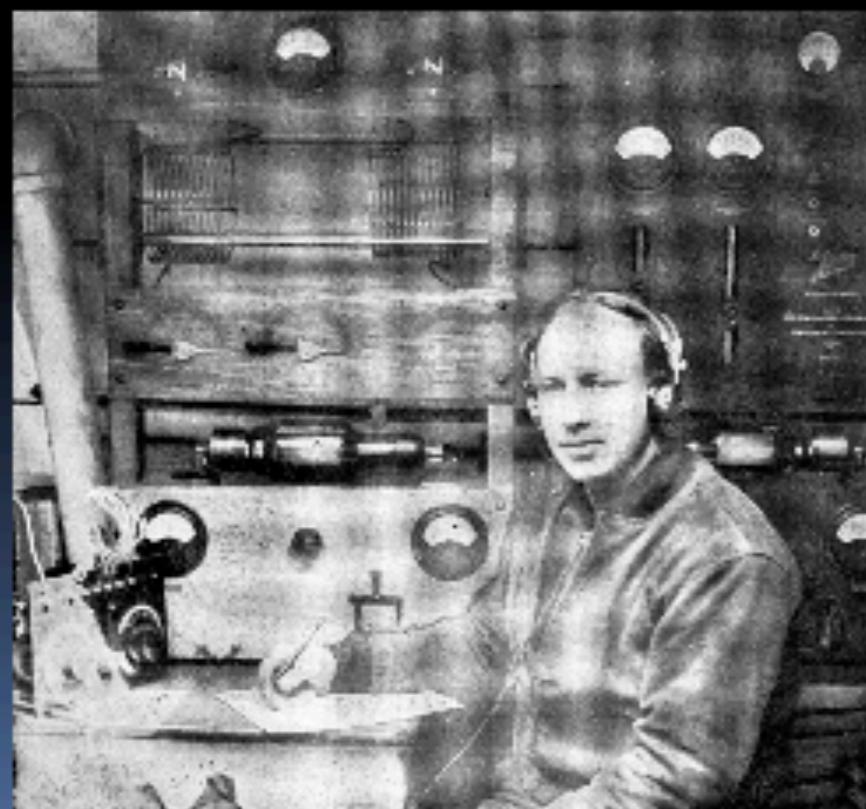
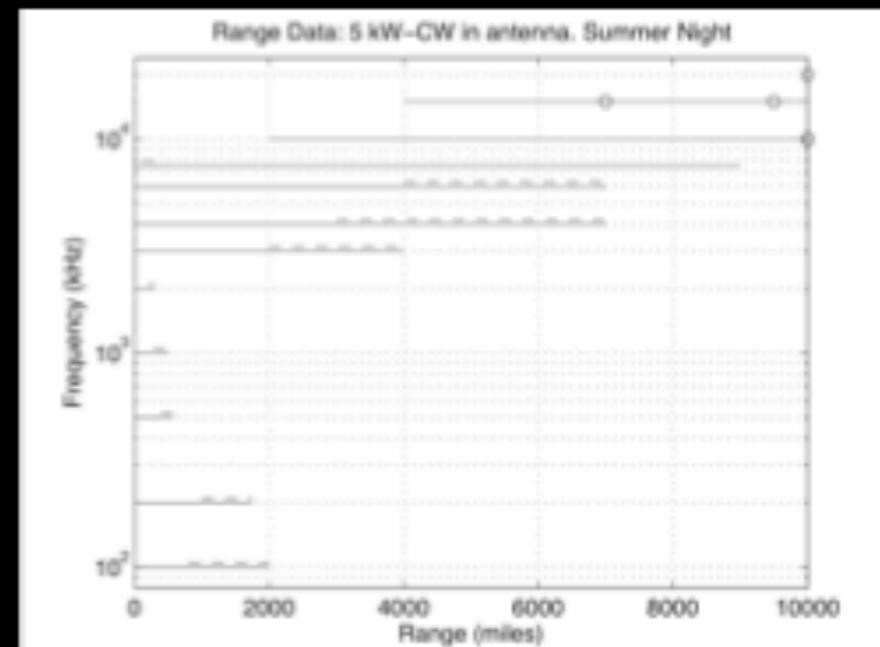
- Ham radio operators' transatlantic trials showed the plausibility of long-distance propagation for wavelengths shorter than 200 m.
- Contradiction to the Austin-Cohen formula and received atmospheric reflection theory.
- Need to probe further into the atmospheric layers.
- Collective mass experimentation, with distinct forms of mobilizing participation, operational protocols, and establishing credibility.

New Phenomena at Short Wavelengths

Skip distance



Non-monotonic change
of range with frequency



Albert H. Taylor

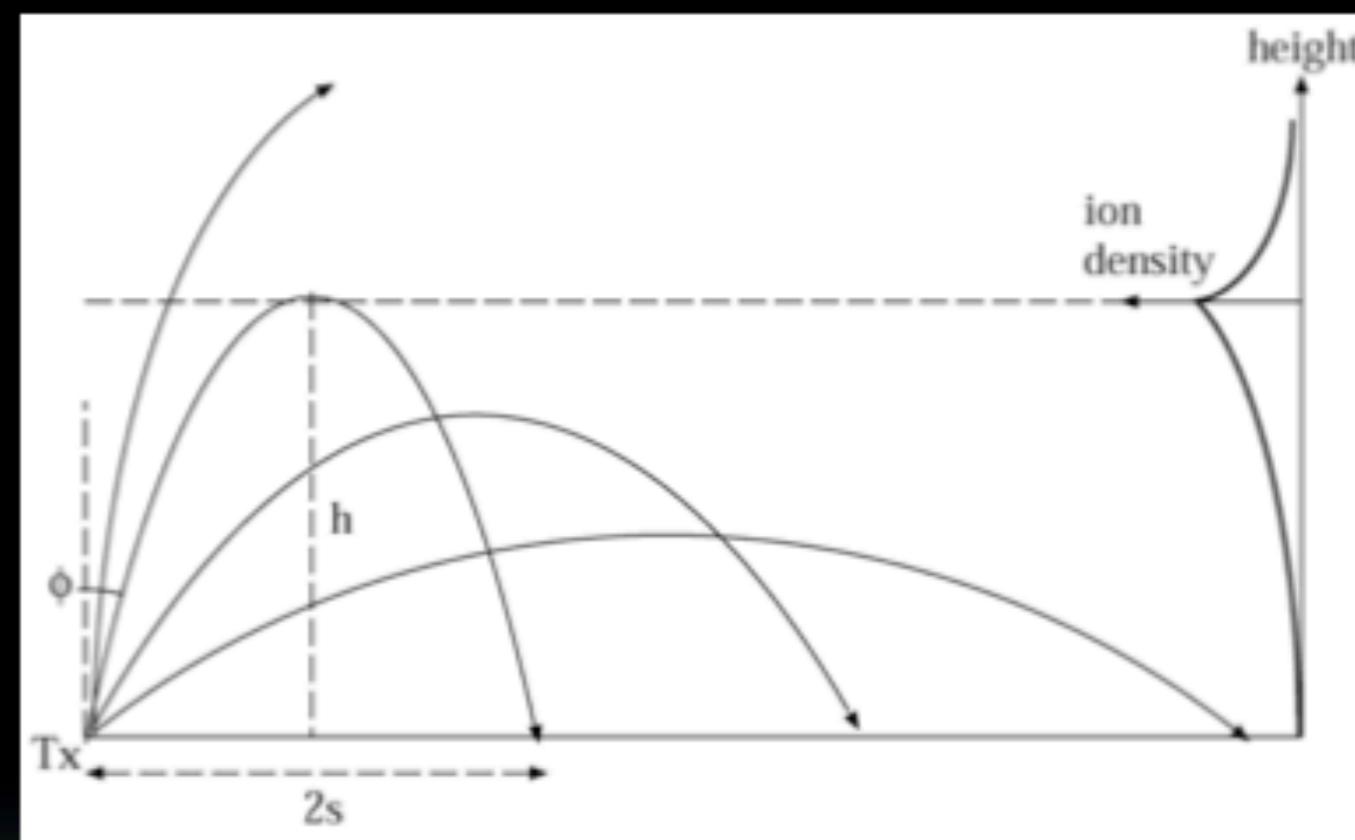


Ionic Refractive Theory to Explain Skip Zone (1926)

At large angle of elevation,
finite ionic layer has insufficient
refractive power to bring back
radio rays

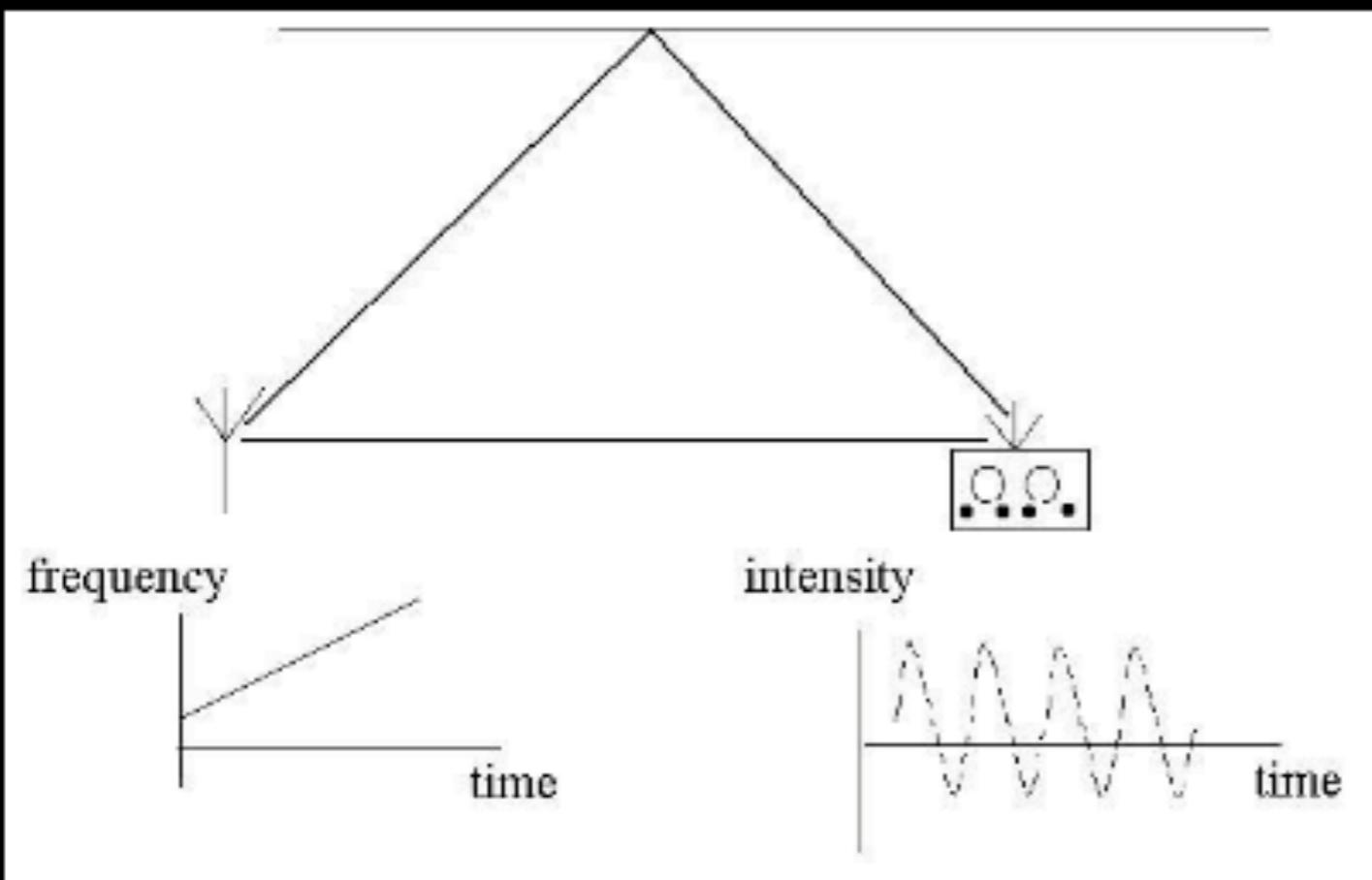
Radio rays “escape” away

No signal within skip zone



The point of escape depends on radio frequency, maximum electron density, layer height.

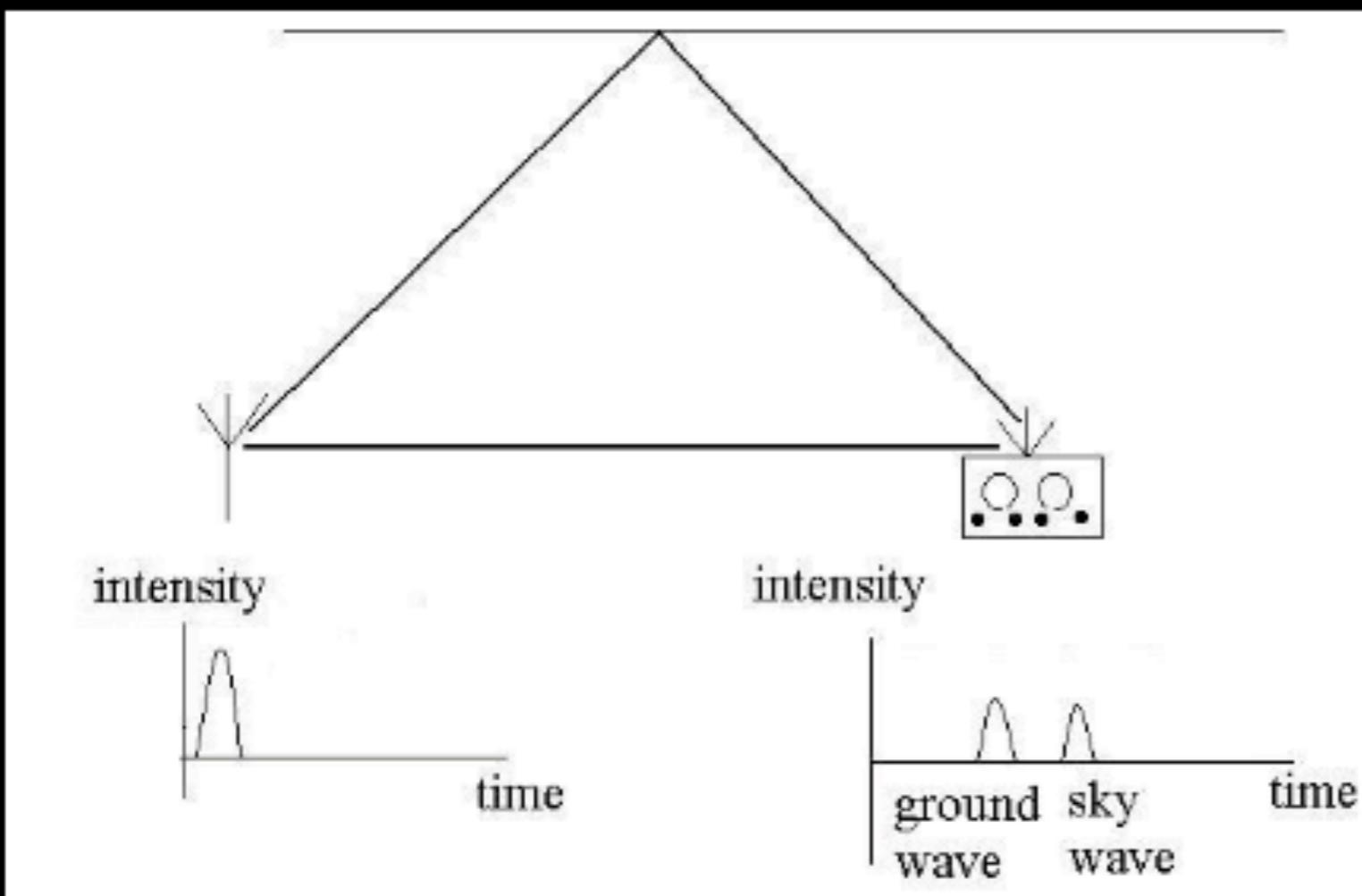
Direct Evidence for the Ionosphere (1924)



Edward Appleton
(Cavendish Lab)

Find the layer's height from the number of peaks

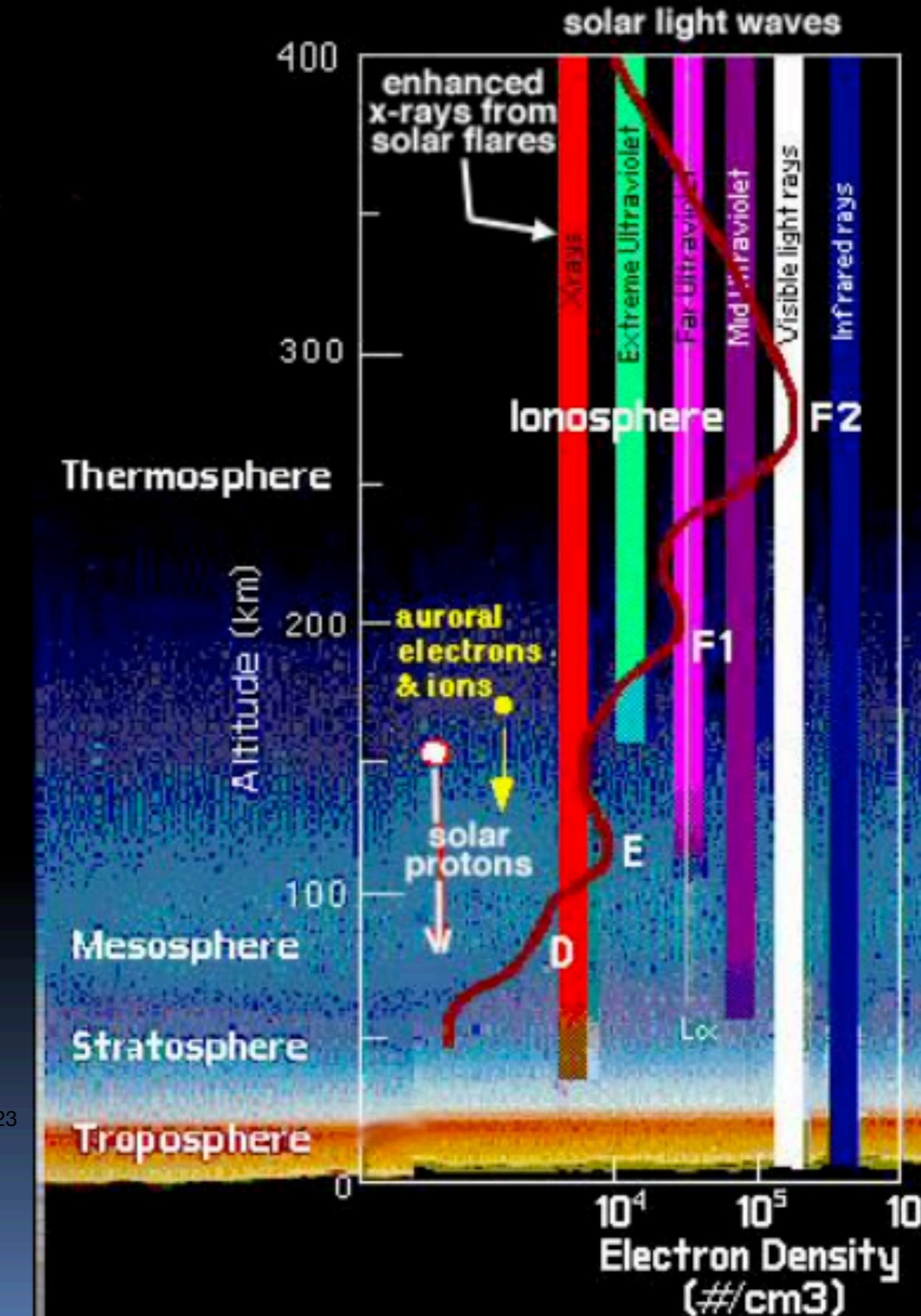
Direct Evidence for the Ionosphere (1925)



Gregory Breit & Merle Tuve
Carnegie Institution

Find the layer's (virtual) height from the pulse delay

Radio Ontology of the Ionosphere



Conclusion: Ham Radio and Radio Propagation Experiments

- Ham radio played a crucial part in discovering ionosphere.
- Thought and acted outside the box of professional scientists and engineers: long-distance transmission under short wavelengths was possible.
- Facilitating a new form of experimentation:
 - mass participation
 - network of coordination through media, amateur societies
 - standardized protocols
 - building credibility
- Values of hobbyist science at the age of over-specialization.