Ham Radio and the Discovery of the Ionosphere

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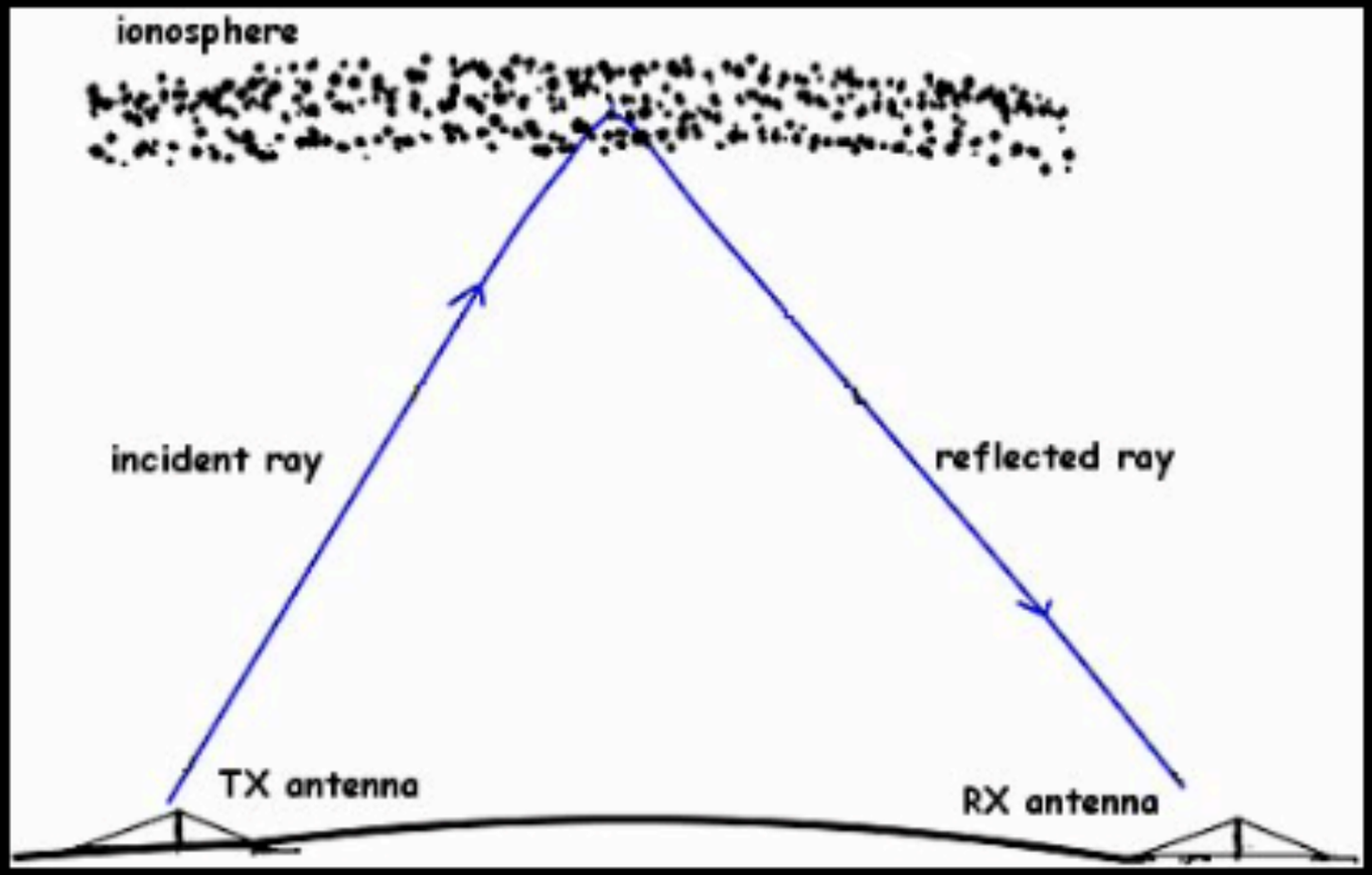
26 June, 2022

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

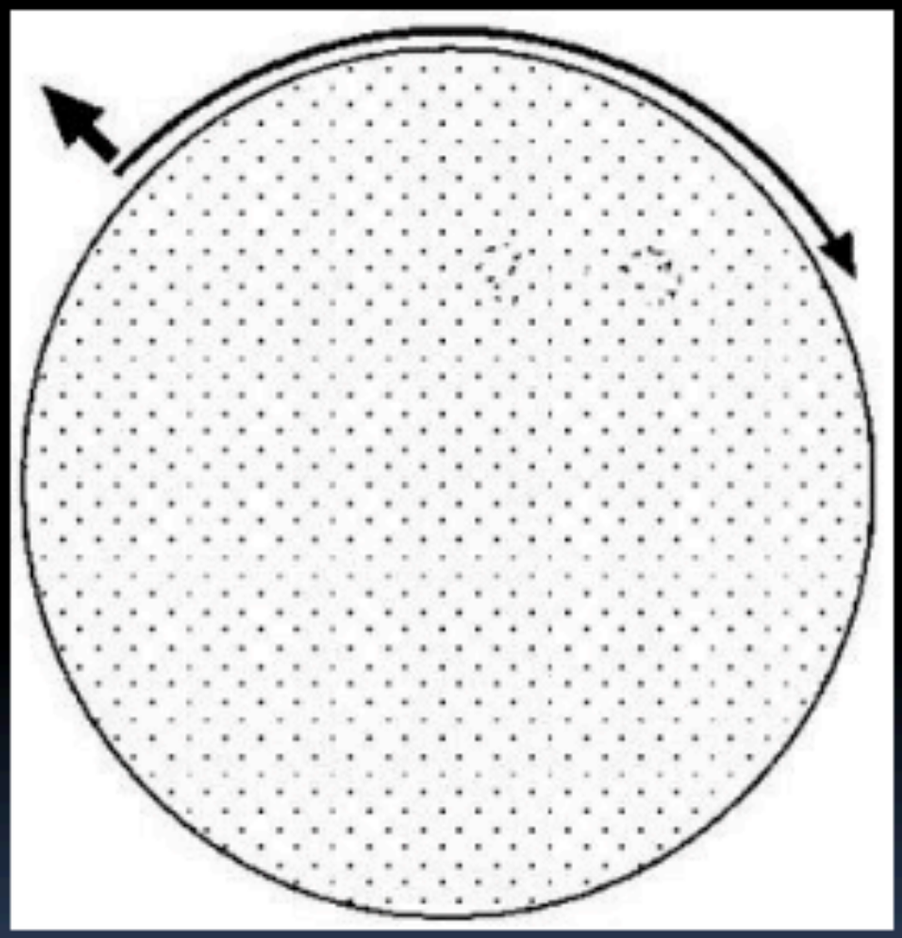
Heinrich Hertz

Experimental demonstration of electric waves (1887)

Surface Diffraction Theory

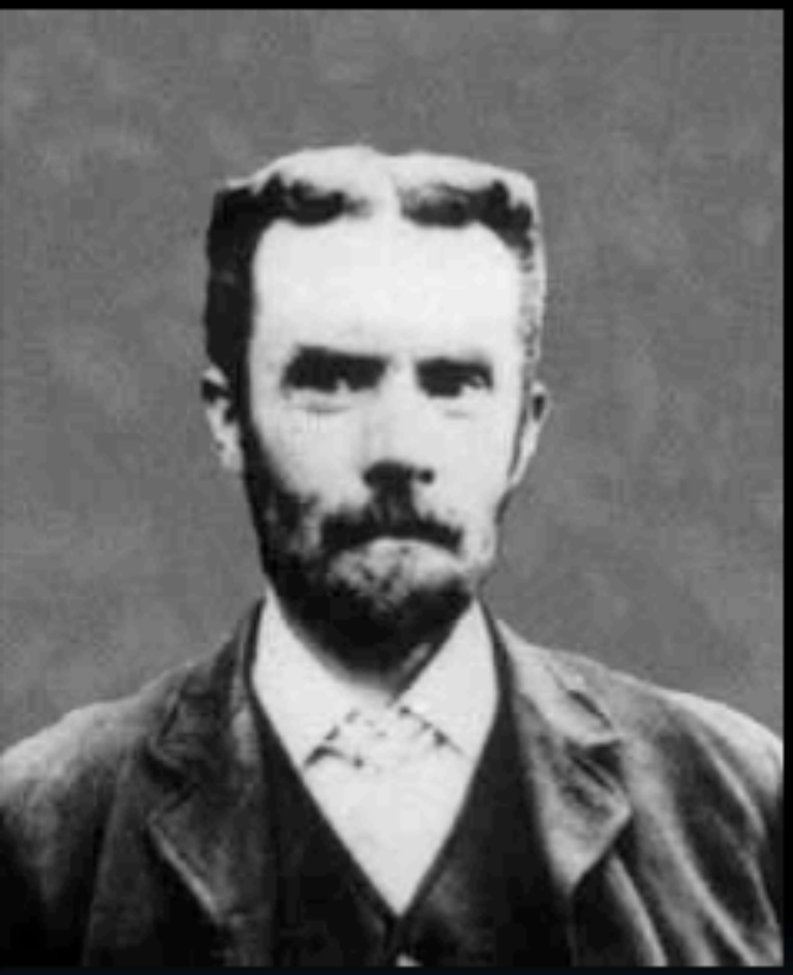
Hector Macdonald (1903):

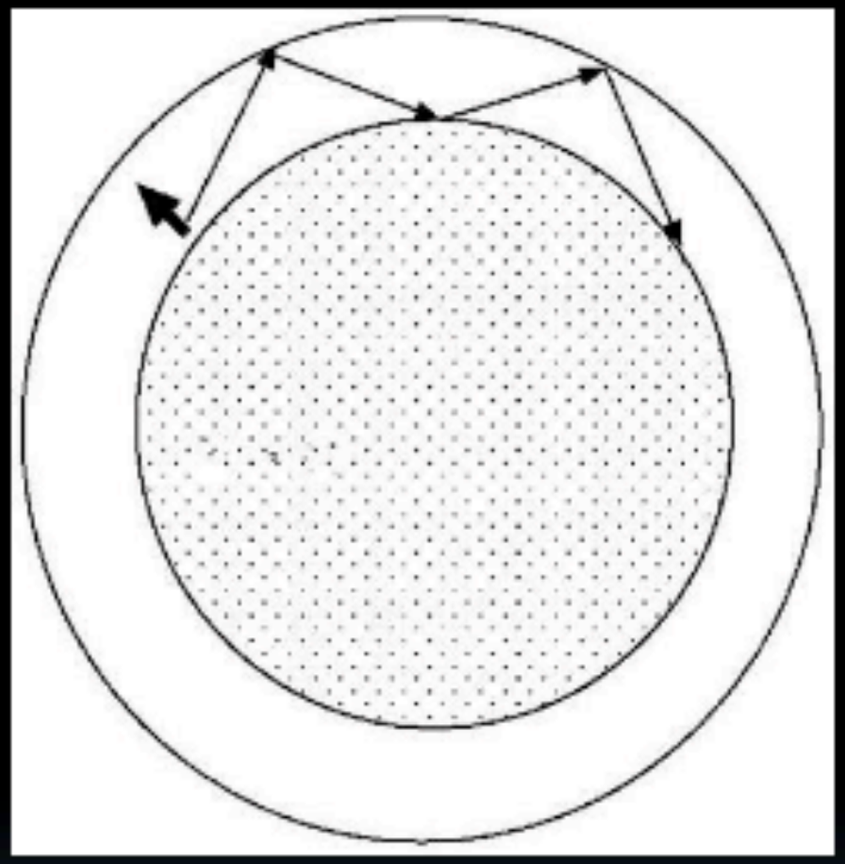
Radio waves diffracted along the earth's surface.



Atmospheric Reflection Theory (1902)

Oliver Heaviside (London)





Arthur Kennelly (Boston)

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

Austin-Cohen Formula

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

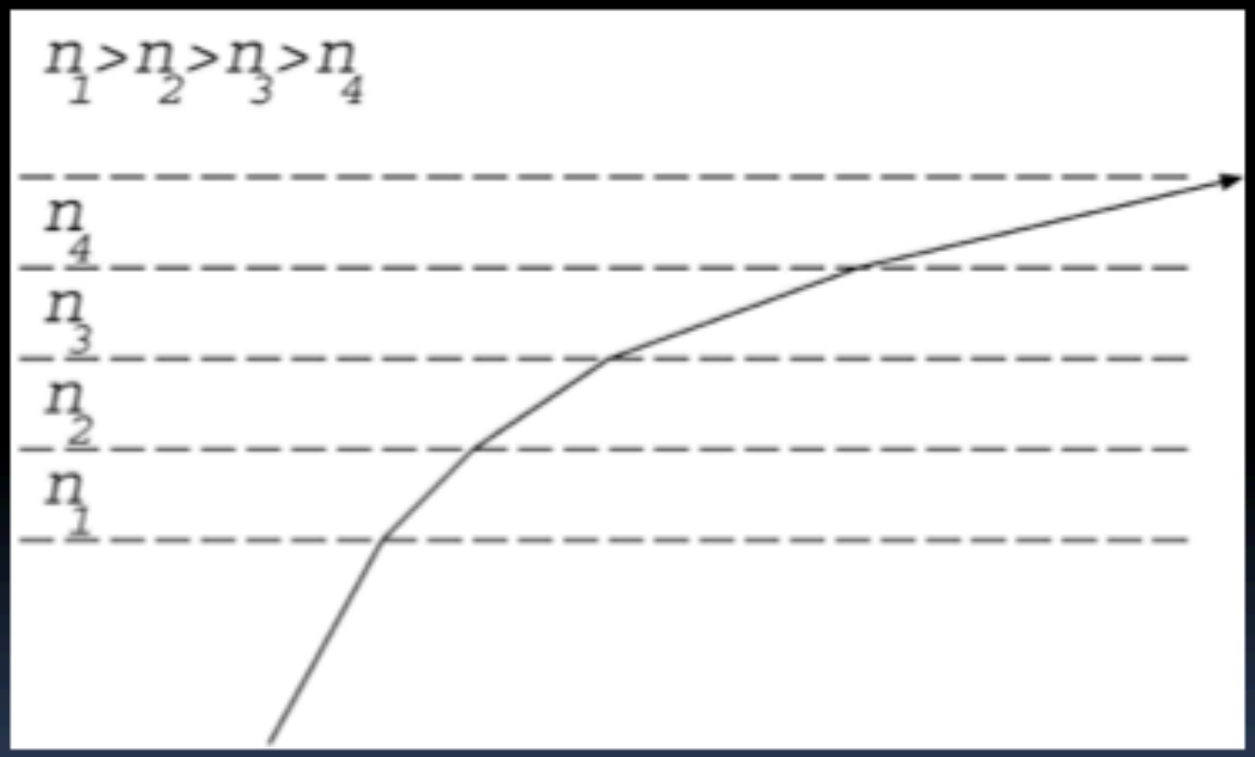
I_r: received current intensity
d: distance
λ: wavelength

But…

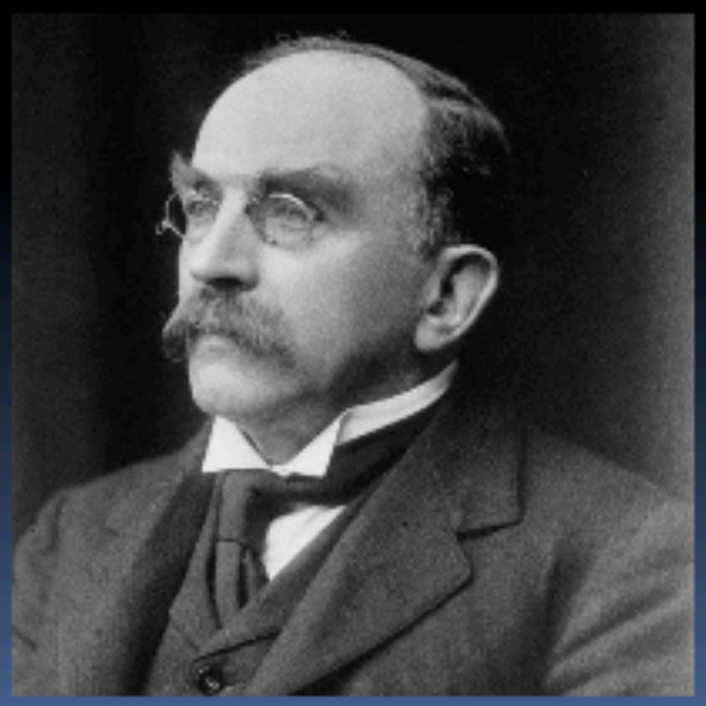
- Reflection theory could not produce quantitative predictions
- Diffraction theory predicted more severe decay with distance.

Ionic Refraction Theory (1912-24)

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



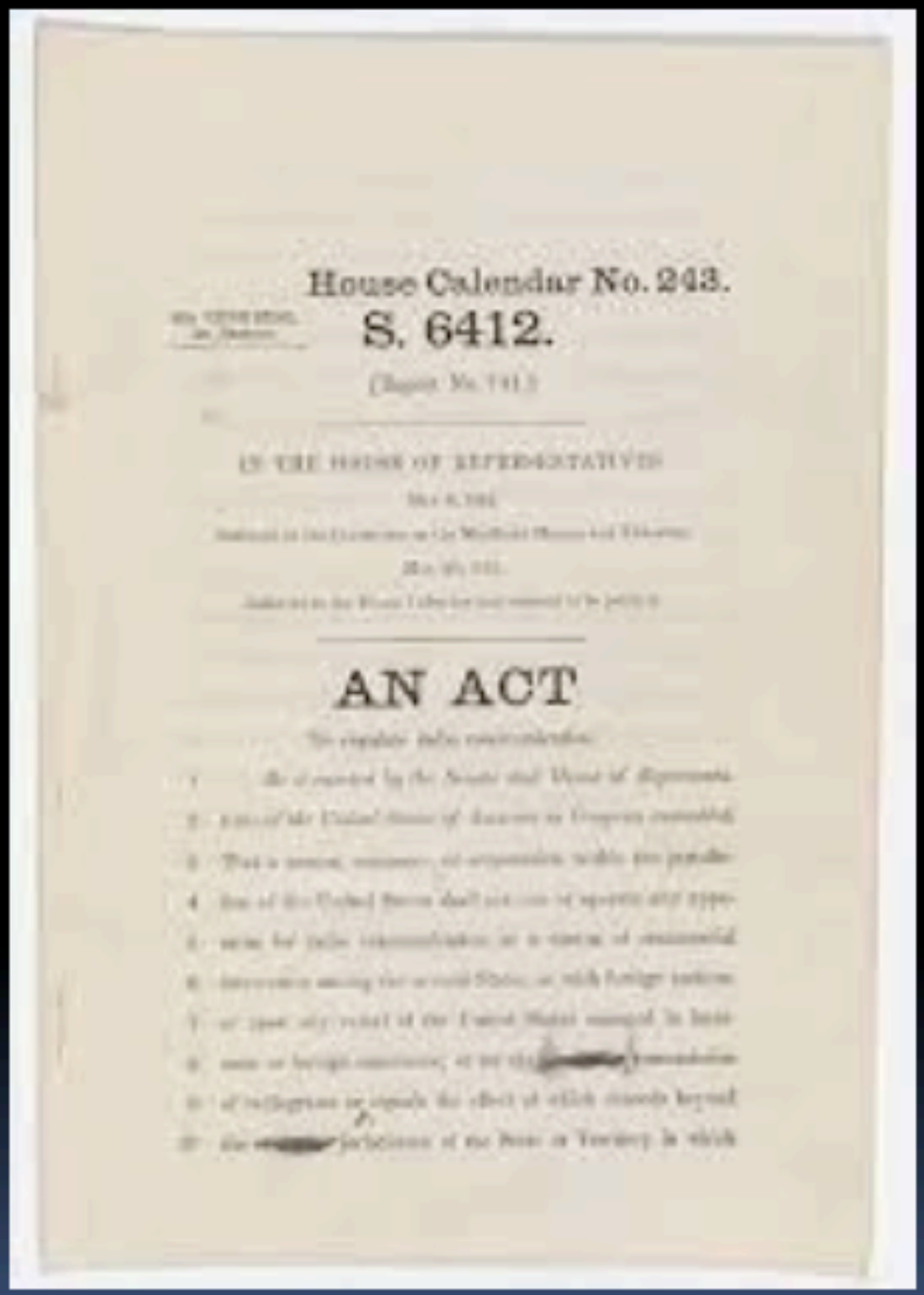
William Henry Eccles (London)



Joseph Larmor (Cambridge)

But where was evidence?

Ham Radio & Collective Experimentation



House Calendar No. 243.

S. 6412.

(Report No. 141.)

IN THE HOUSE OF REPRESENTATIVES

AN ACT

- 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.

No. 100

THE AMERICAN RADIO RELAY LEAGUE, Inc.

STATION APPOINTMENT

This Certifies that Radio Station located at 348 South Fremont Avenue,
Los Angeles, Cal. 6EA and under the control of Benfred Brothers who holds United States
Radio License No. for First Amateur Grade operator,
is until further notice and subject to the rules and regulations of the
American Radio Relay League, hereby appointed AN OFFICIAL
RELAY STATION. This appointment expires December 31, 1917,
unless officially cancelled.

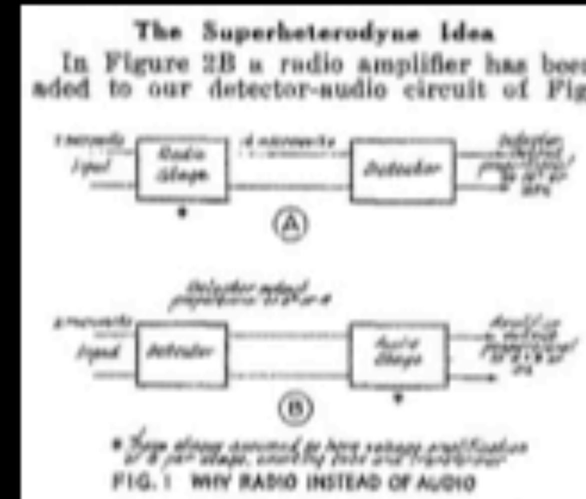
THE AMERICAN RADIO RELAY LEAGUE, Inc.

C. D. Tuttle Secretary. Hiram Percy Maxim President.

Hiram Percy Maxim

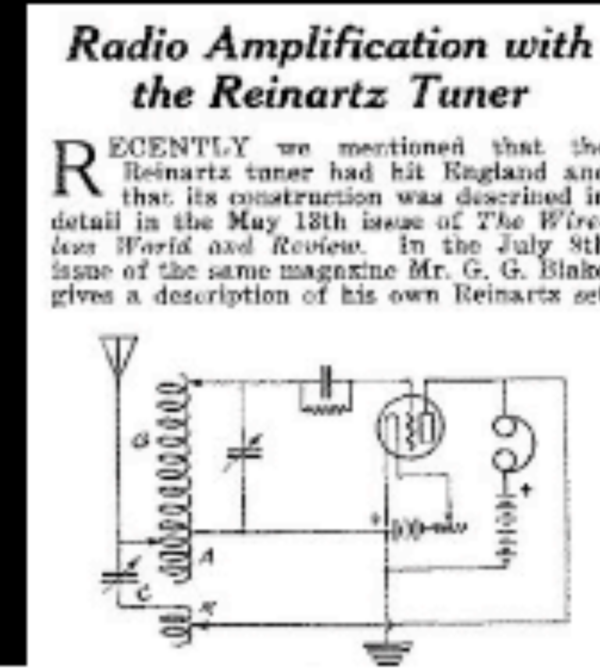
American Radio Relay League established at Hartford, CT in 1914

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



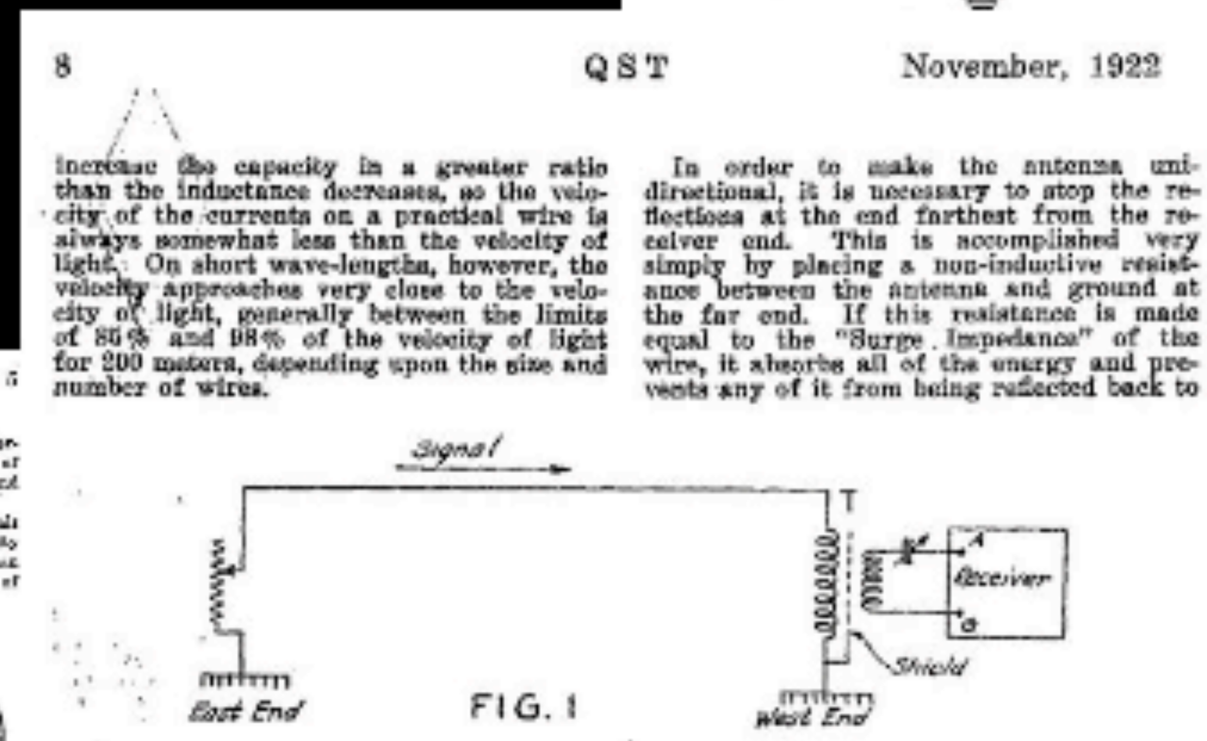
The Superheterodyne Idea

In Figure 2B a radio amplifier has been aded to our detector-audio circuit of Fig.



Radio Amplification with the Reinartz Tuner

RECENTLY we mentioned that the Reinartz tuner had hit England and that its construction was described in detail in the May 13th issue of *The Wireless World and Review*. In the July 8th issue of the same magazine Mr. G. G. Blake gives a description of his own Reinartz set

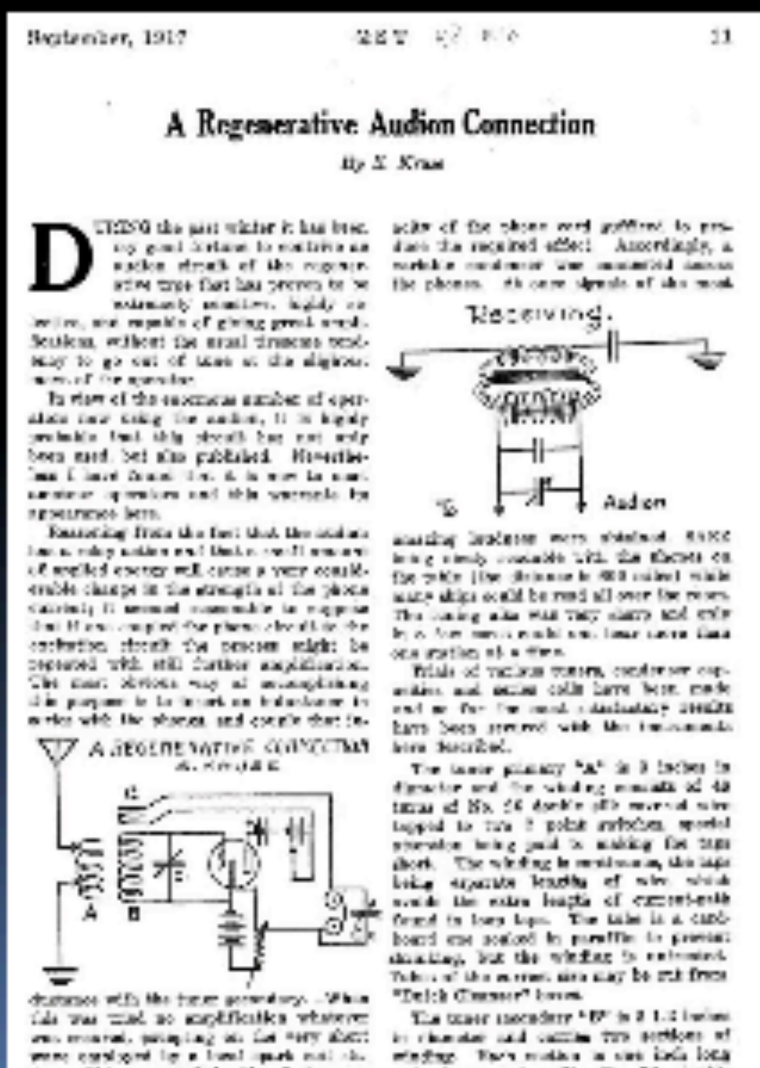


8 QST November, 1922

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 85% and 98% of the velocity of light for 200 meters, depending upon the size and number of wires.

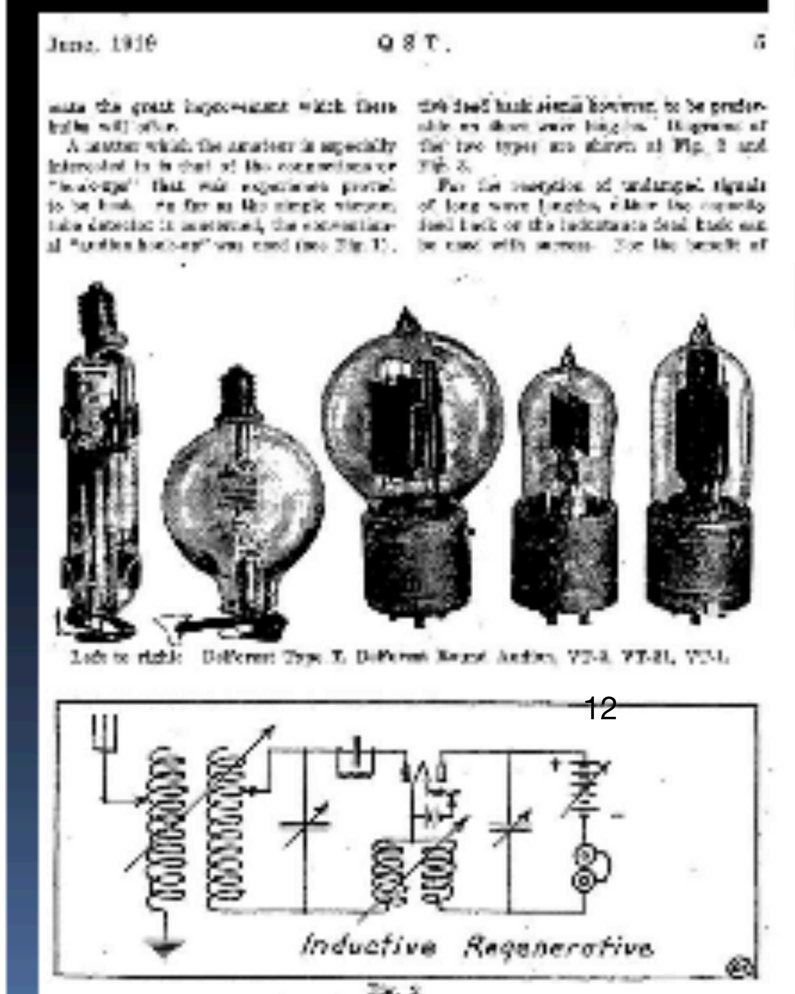
In order to make the antenna unidirectional, it is necessary to stop the reflections at the end farthest from the receiver end. This is accomplished very simply by placing a non-inductive resistance between the antenna and ground at the far end. If this resistance is made equal to the "Surge Impedance"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

FIG. 1



September, 1917

A Regenerative Audion Connection



June, 1919 QST. 5

Left to right: DeForest Type T, DeForest Round Audion, VT-2, VT-21, VT-1.

Fig. 2

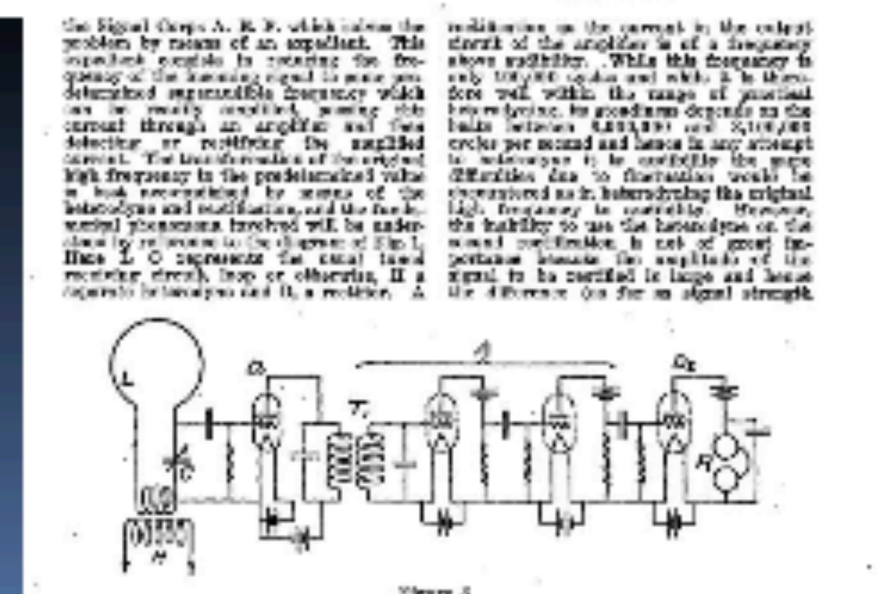


Figure 3

12

Meeting at Washington, DC, 2 April 1920

Maxim & Kenneth Warner
ARRL

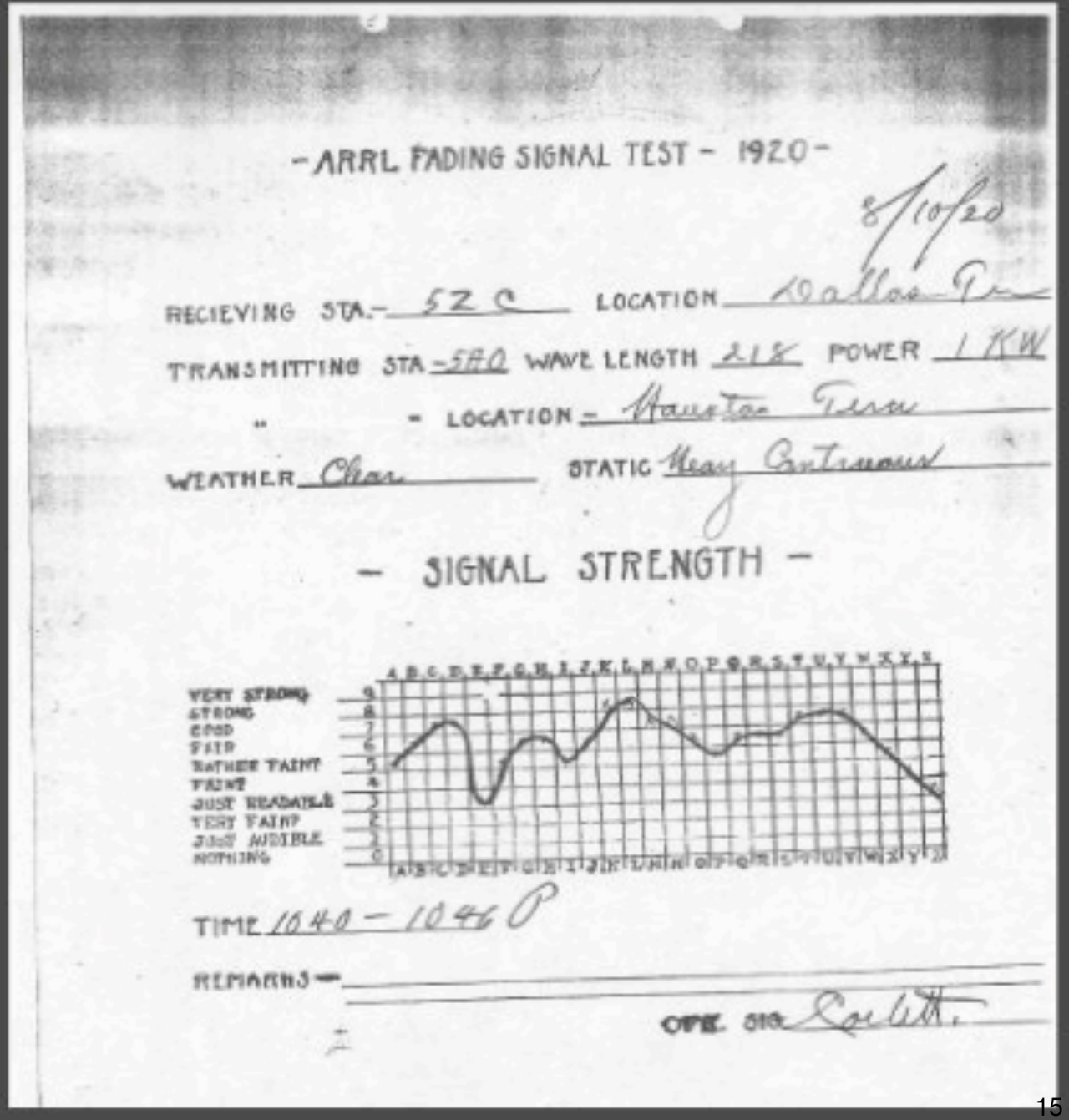
John H. Dellinger
National Bureau
of Standards

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



-ARRL FADING SIGNAL TEST - 1920-

8/10/20

RECIEVING STA.- 5ZC LOCATION Dallas Tex

TRANSMITTING STA -5AO WAVE LENGTH 215 POWER 1 KW

" - LOCATION - Houston Texas

WEATHER Clear STATIC Heavy Continuous

- SIGNAL STRENGTH -

VERY STRONG 9
STRONG 8
GOOD 7
FAIR 6
RATHER FAINT 5
FAINT 4
JUST READABLE 3
VERY FAINT 2
JUST AUDIBLE 1
NOTHING 0

TIME 1040 - 1046 P

REMARKS -

OPR. SIG Corbett.

- 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.

QST

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

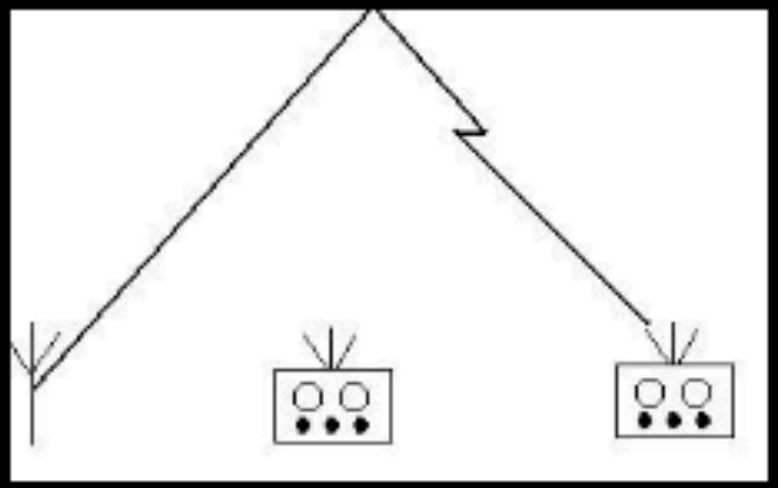
Newmarket, and on his spark at that, but Mr. Coursey's report may show more of our cousins in the Dominion.

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

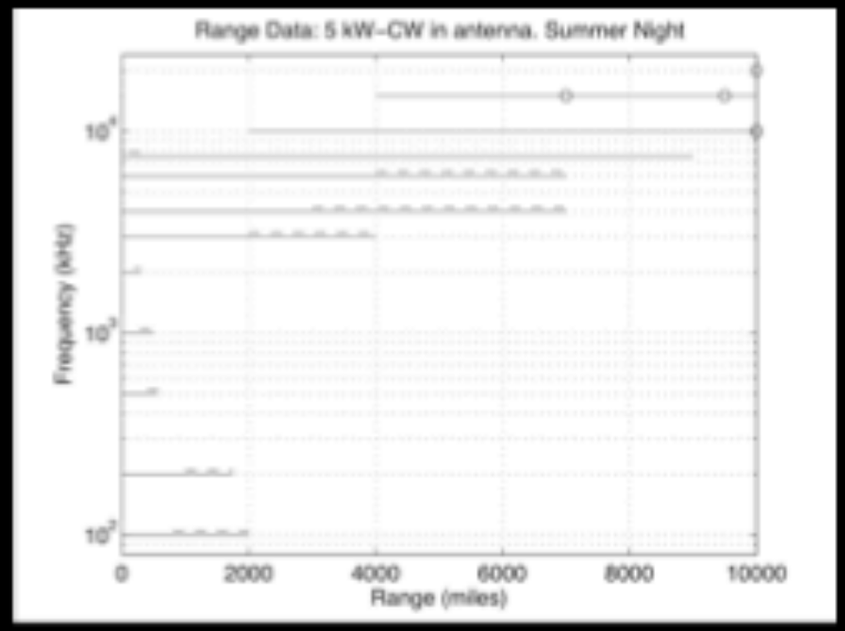
- Ham radio operators' transatlantic trials showed the plausibility of long-distance propagation for wavelengths shorter than 200 m.
- Contradiction to the Austin-Cohen formula and received atmospheric reflection theory.
- Need to probe further into the atmospheric layers.
- Collective mass experimentation,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

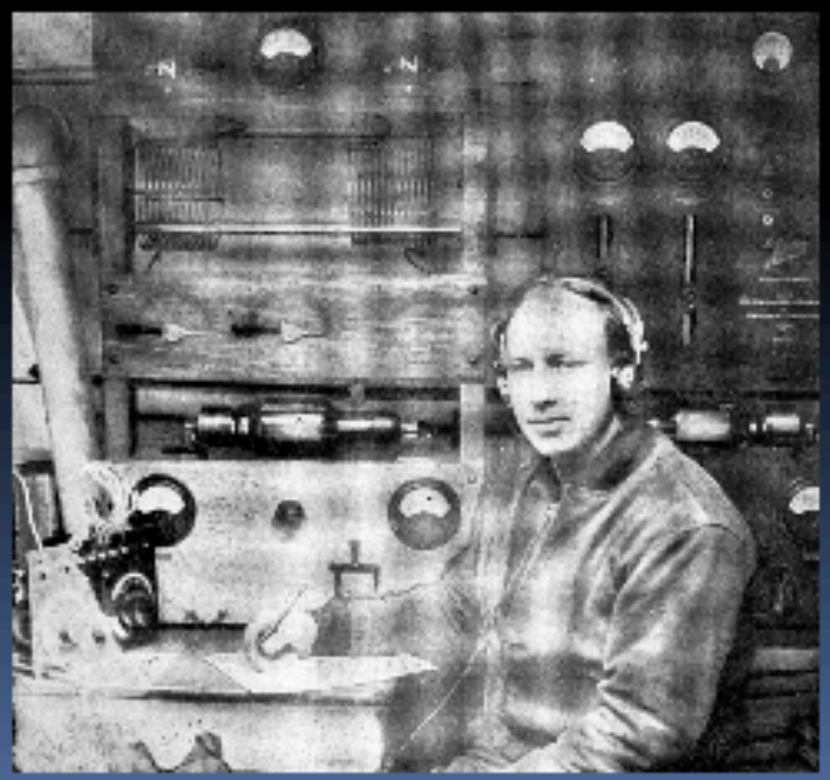
New Phenomena at Short Wavelengths

Skip distance



Non-monotonic change of range with frequency





John Reinartz 1QP

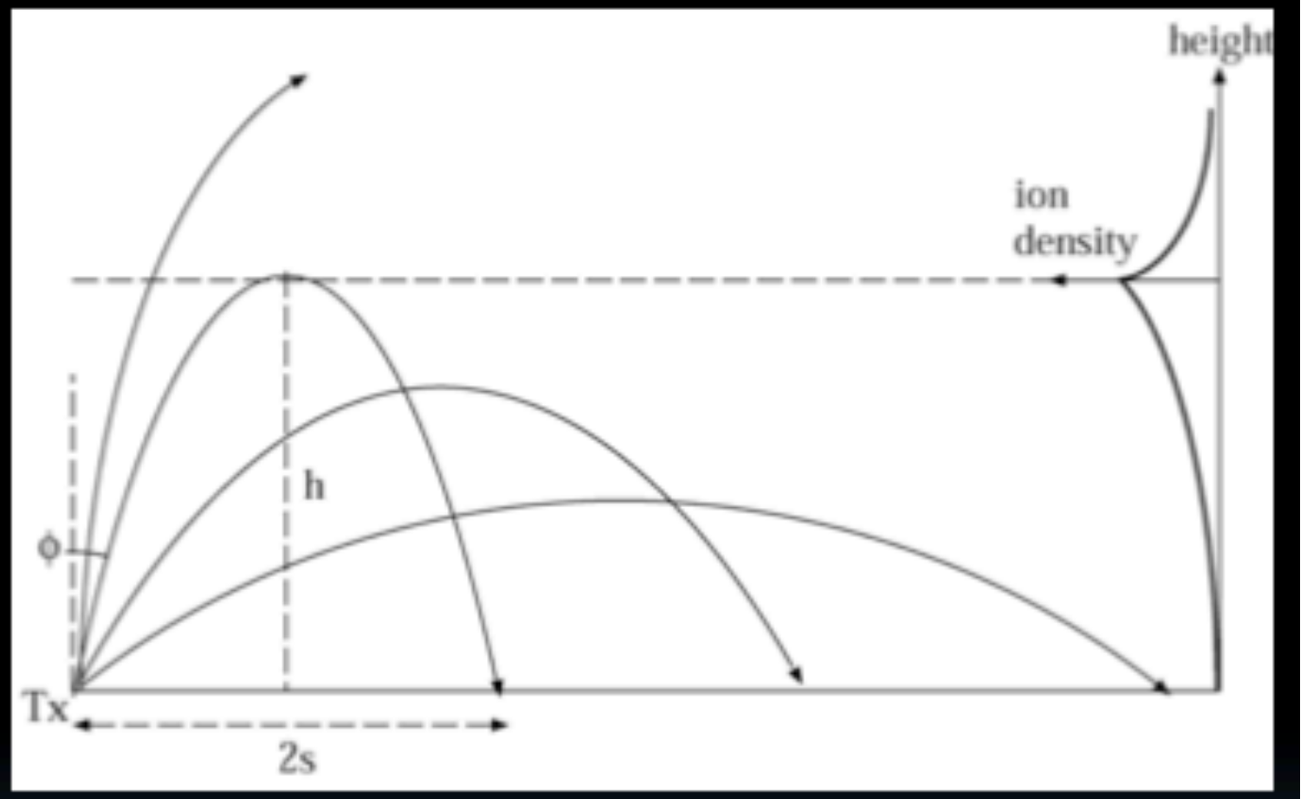
Albert H. Taylor

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

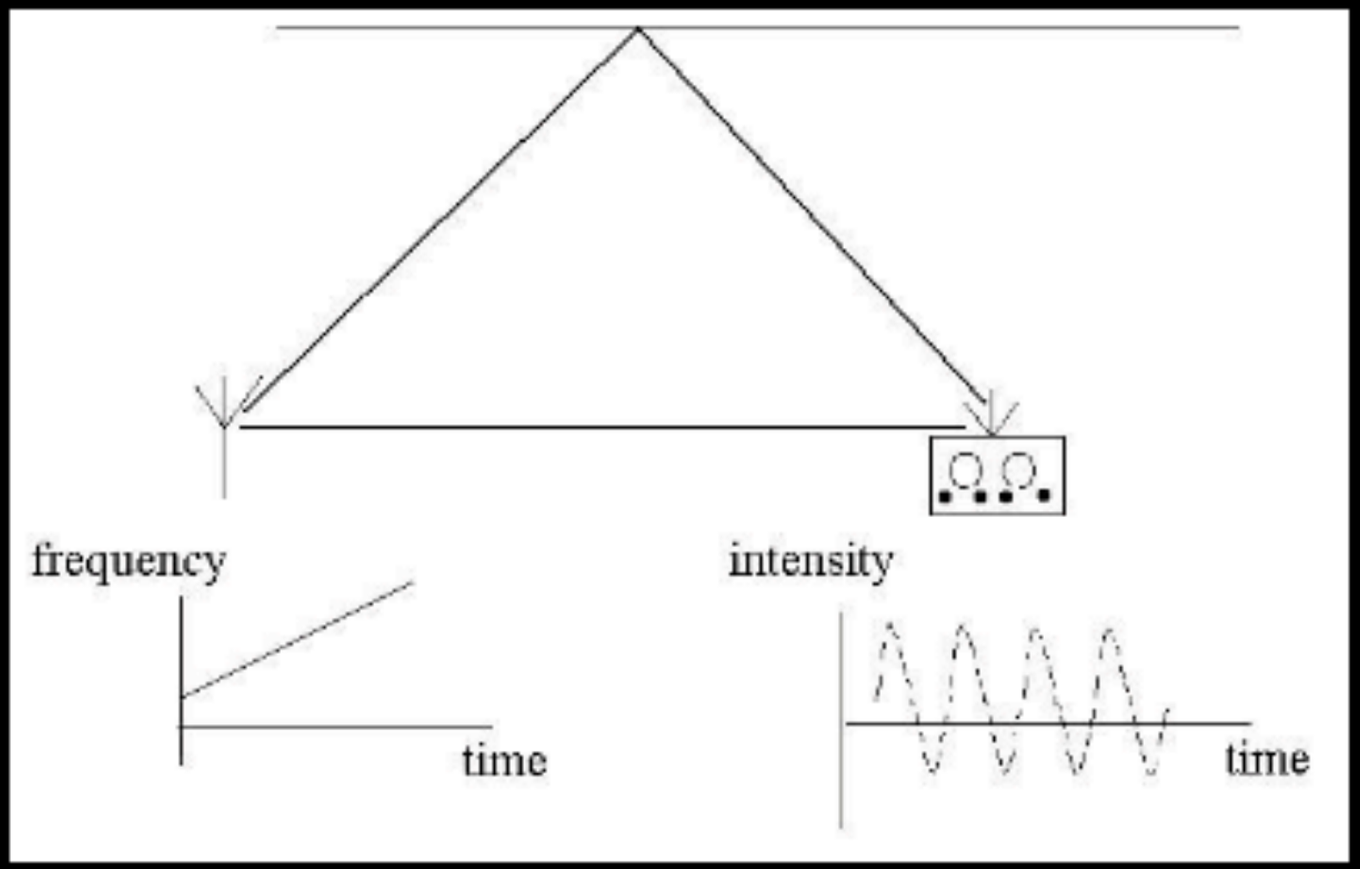
Radio rays "escape" away

No signal within skip zone



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

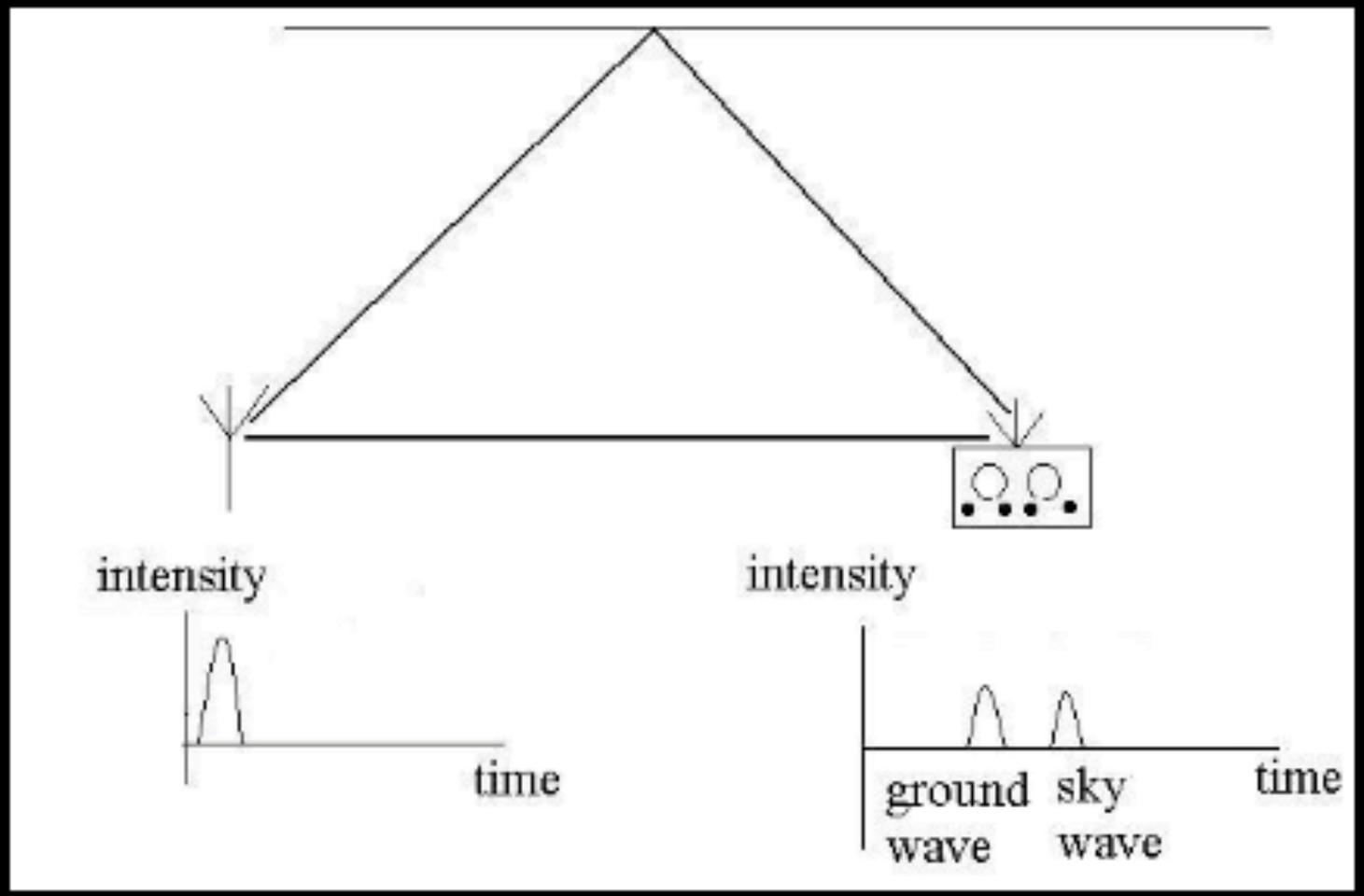
Direct Evidence for the Ionosphere (1924)



Edward Appleton
(Cavendish Lab)

Find the layer's height from the number of peaks

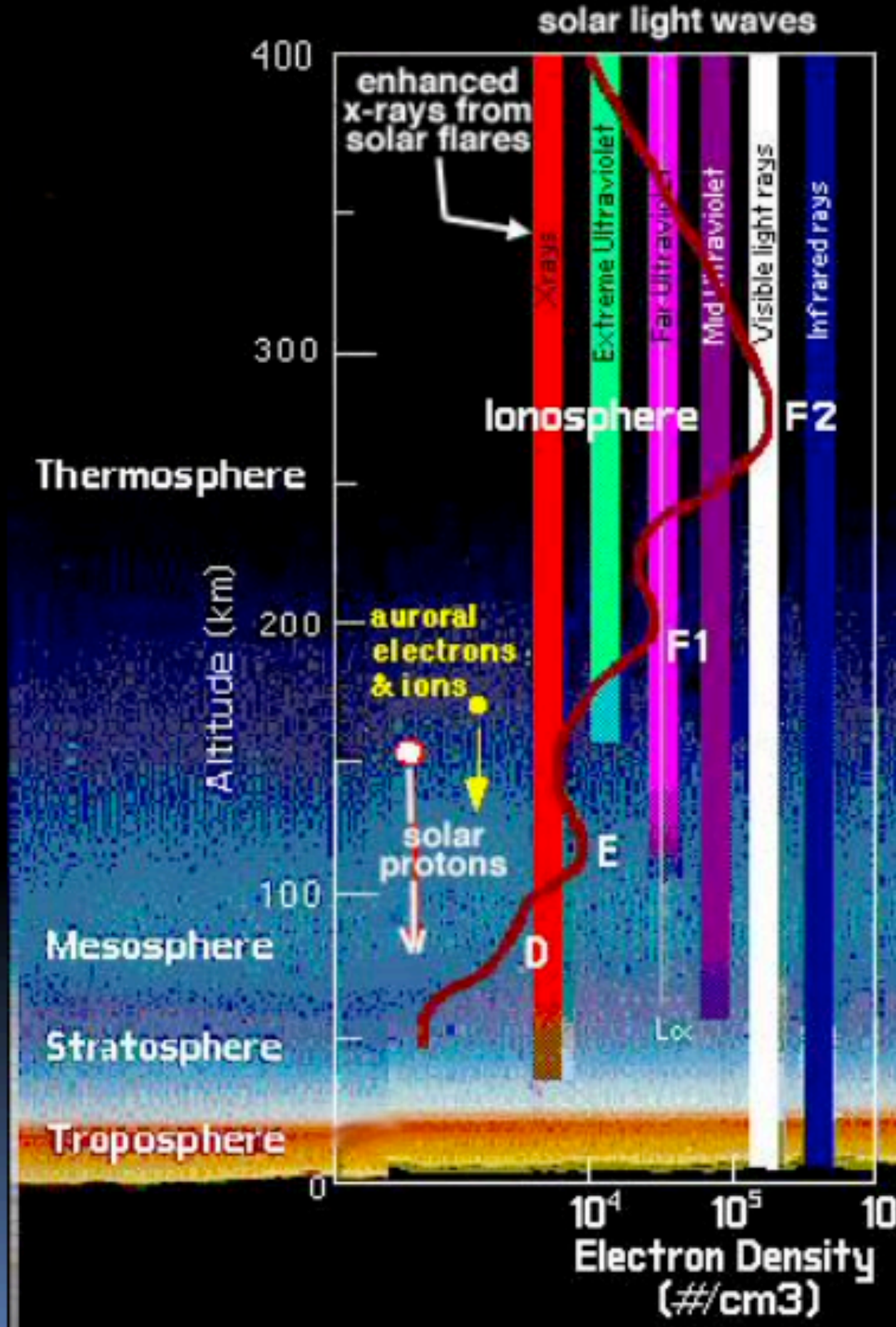
Direct Evidence for the Ionosphere (1925)



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.