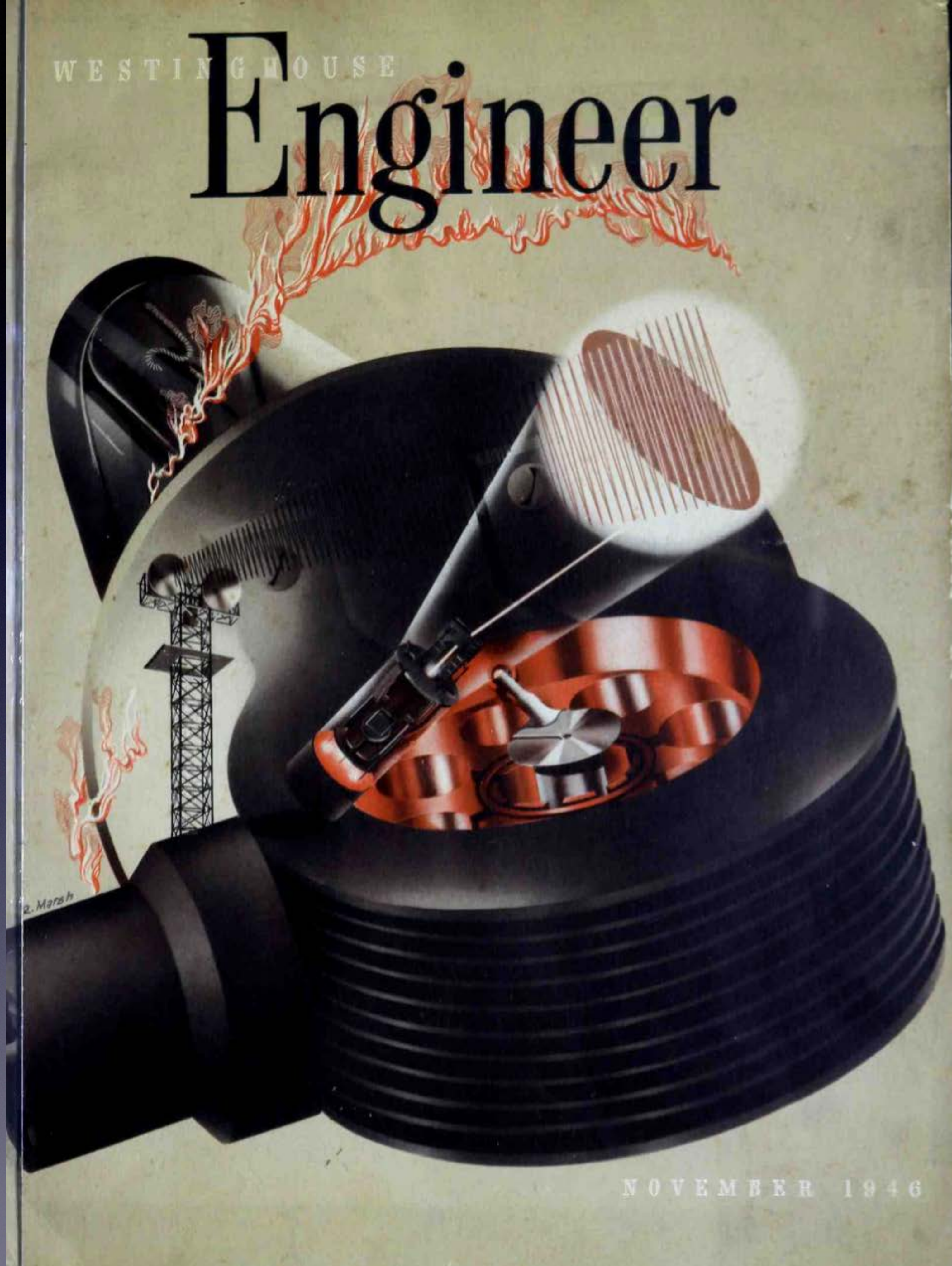


Towards a New Frontier in Radio Science:

Amateur - Professional Connections for Geospace Research

P. J. Erickson
MIT Haystack Observatory
Westford, MA USA
pje@haystack.mit.edu

HamSCI Meeting
NJ Institute of Technology
23 February 2018

MIT
HAYSTACK
OBSERVATORY

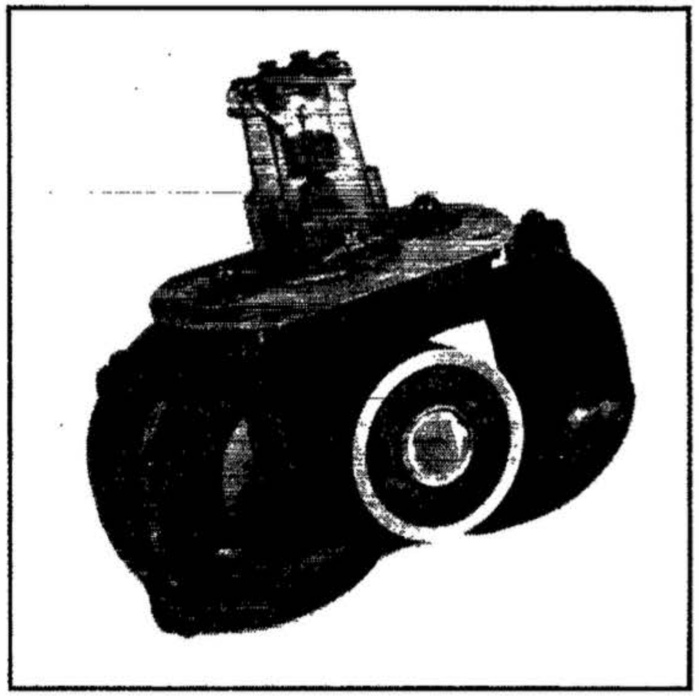
Centimeter-Wave Magnetrons

The Tubes That Made Microwave Radar Possible

BY HENRY F. ARGENTO*

ALTHOUGH radar has emerged from the war as a startling new discovery, its principles are not as new as they might appear to be at first hand. Radar was known and developed simultaneously in America, England, France and Germany during the early 1930s. Like every other electronic device, its development and improvement was predicated on the development and availability of tubes. The heart of any electronic device is a tube, whether it be a radio set, a radar, or an electronic counting device.

Very early radars were low-frequency devices which used enormous dual antennas and large, bulky transmitters and receivers. It was known at the time that radars capable of greater resolution and accuracy, as well as much smaller and lighter in weight, could be developed if tubes could be made available to generate power at the superhigh frequencies. Accordingly, the British Admiralty assigned the problem of developing a generator of microwaves to a research group at the University of Birmingham. The Birmingham group developed a practical form of cavity magnetron which, along with other developments, opened the possibility of obtaining satisfactory power output at extremely short wave lengths. In the latter part of 1940, a British technical mis-



This type of package magnetron uses direct coupling from one of the magnetron cavities to a section of wave guide. The glass window on this section of guide acts as a matching transformer into the external wave guide. The glass boot around the heater leads is cut away to provide for forced cooling of the heater leads and seal.

of energy to reach its objective and to be reflected

Profound Thanks:

Dr. Bill Liles, NQ6Z
Dr. Ethan Miller, K8GU - Johns Hopkins APL
Ward Silver, N0AX - ARRL
Carl Luetzelschwab, K9LA
Prof. Nathaniel Frissell, W2NAF - NJIT
Dr. Terry Bullett, KD0ZWU - NOAA
Prof. J. M. Ruohoniemi, Virginia Tech
John Ackermann, N8UR
Rich Moseson, W2VU

José Nunes, CT1BOH

Will Rogers, KD4FOV - MIT Haystack
Skip Youngberg, K1NKR
Joe Dzekevich, K1YOW

Nashoba Valley Amateur Radio Club (NVARC)
American Radio Relay League

NSF NASA

MIT HAYSTACK OBSERVATORY

HamSCI Meeting NJ Institute of Technology
23 February 2018

Early Influences

Radio Vaticana

Voice of America

Hallicrafters SX-110 (1962)

6SG7 RF Amp, 6SA7 Converter, 6SG7 1st IF Amp, 6SK7 2nd IF Amp, 6SC7 Audio Amp/BFO, 6K6GT Audio Output, 6H6 Detector/ANL/AVC and 5Y3GT Rectifier.

P. J. Terni (right)
October 21, 1957
Millerton, NY

Harlem Valley RR
NY Central

Railway Express Agent
Stanley Skillen (left)

Operator and 2nd “trik” agent
Charles Reiss (middle)

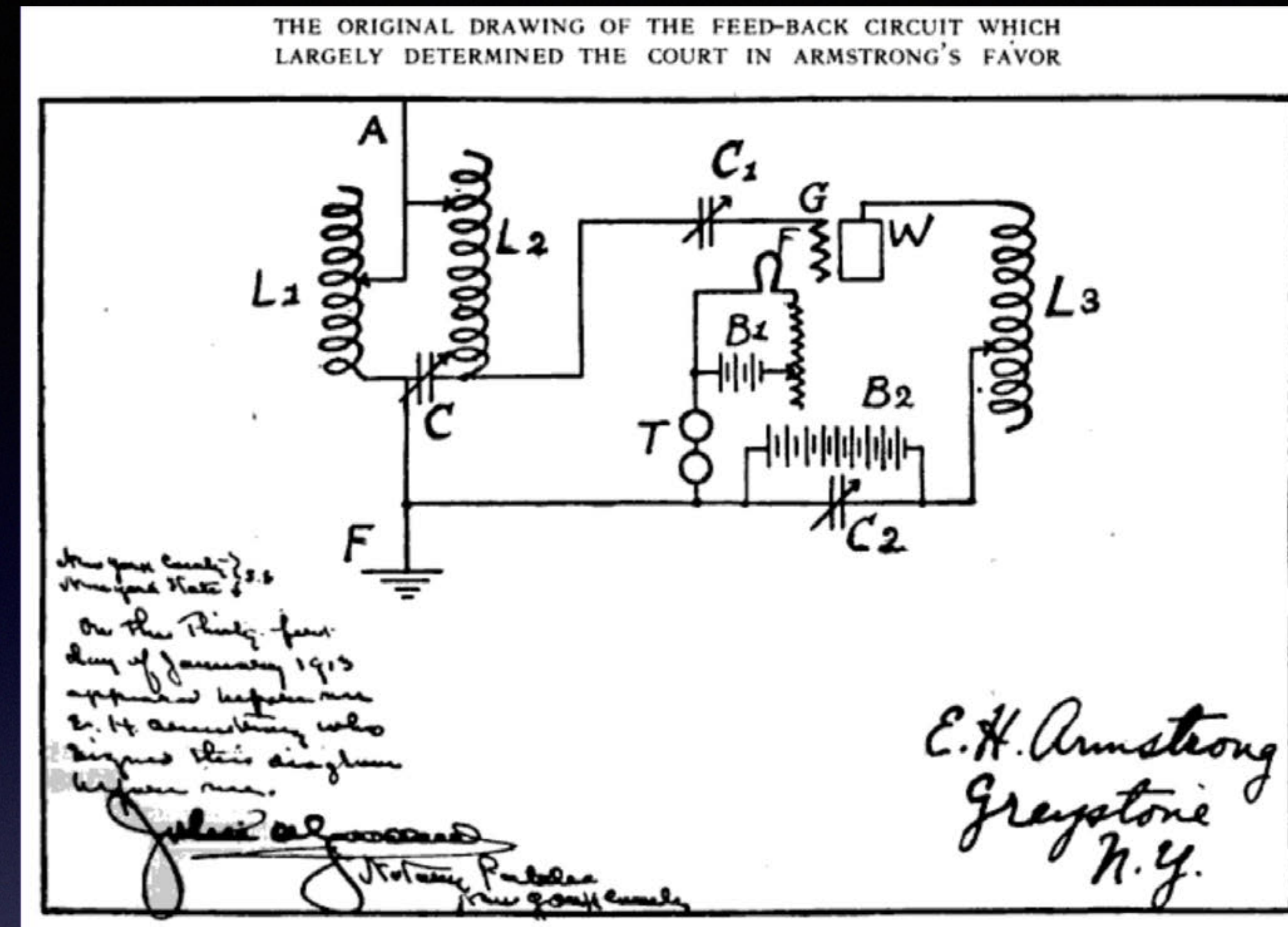
Pioneers of Plasma Physics: Irving Langmuir (1881 - 1957)

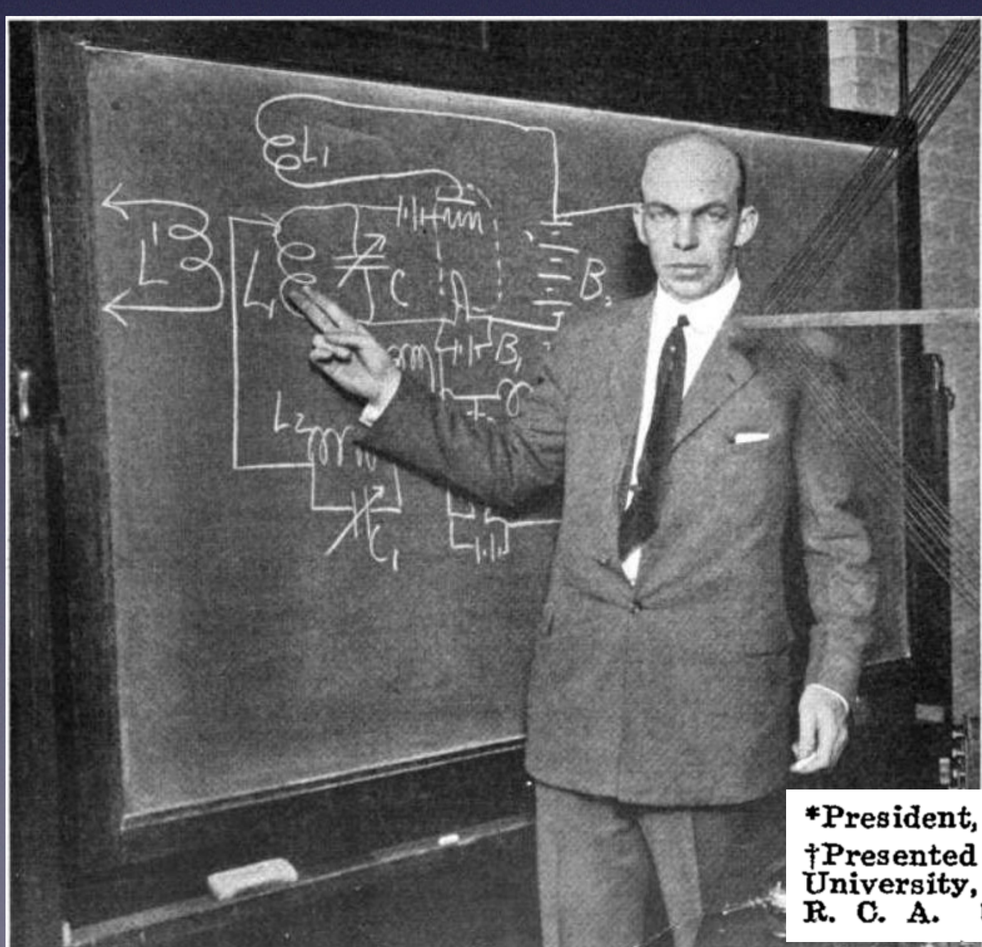
When Langmuir arrived at the Laboratory, the director, Willis R. Whitney, told him to look around and see if there was anything he would like to “play with.” Whitney would often ask him, “Are you having any fun today?” One day, after three years of apparently unproductive research, Langmuir answered, “I’m having a lot of fun, but I really don’t know what good this is to the General Electric Company.” Whitney replied. “That’s not your worry. That’s mine.”


MIT Haystack Observatory Complex
Westford, Massachusetts
Established 1956
Haystack Observatory
Radio Astronomy
Atmospheric Science
Space Surveillance
Radio Science
Education and Public Outreach
Millstone Hill
Observatory
Millstone Hill Radar
Firepond Optical
Facility


Millstone Hill 440 MHz Incoherent Scatter Radar
MISA 150-ft steerable antenna
transmitter →
Fixed zenith-pointing dish

Amateur Radio's Influence on Science and Technology





Edwin Howard Armstrong
1890-1954

Regeneration
Superregeneration
FM Modulation

Feb 1920

QST

A Magazine Devoted Exclusively to the Radio Amateur

A New Method for the Reception of Weak Signals at Short Wave Lengths †

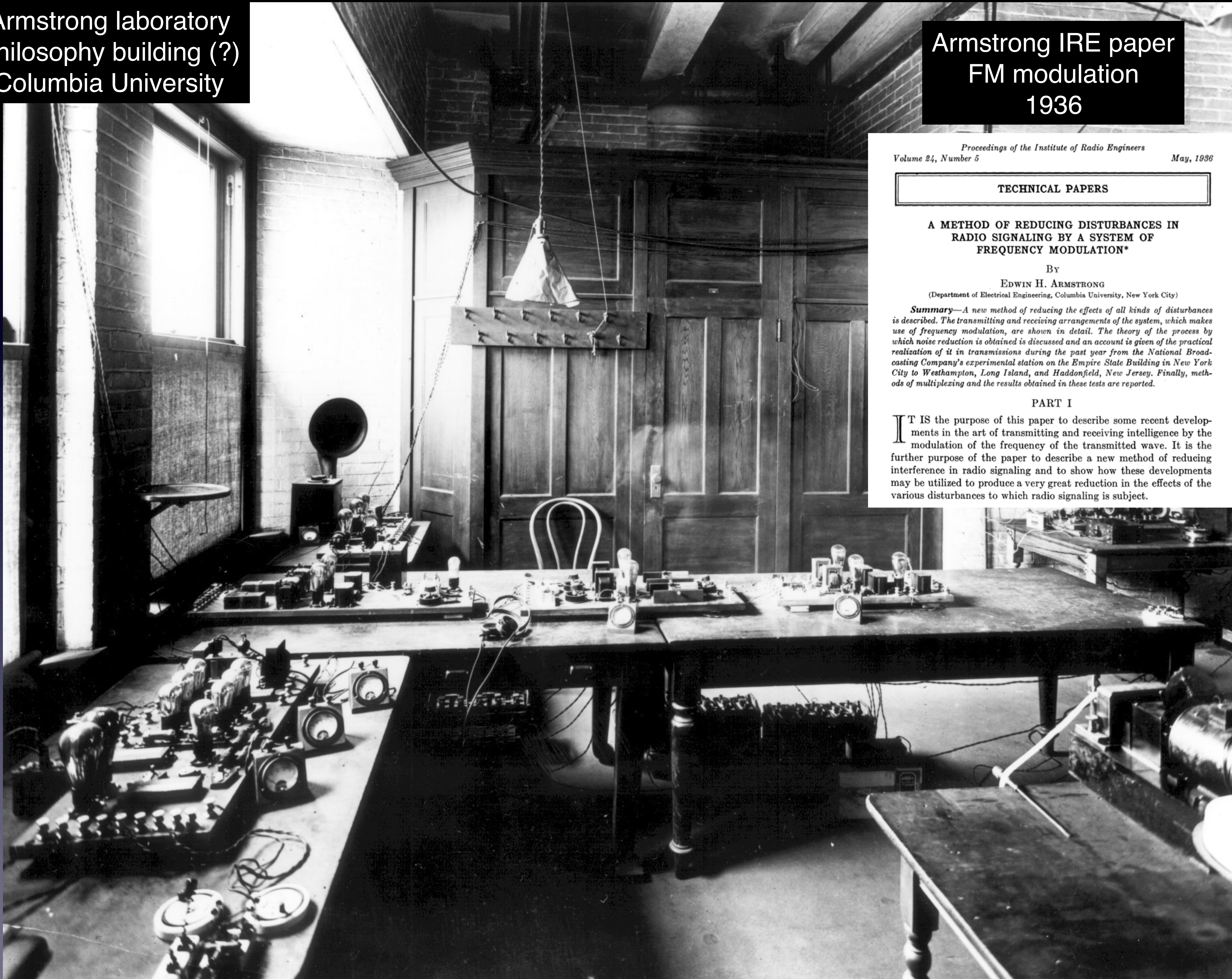
By Edwin H. Armstrong, E. E.*

THE problem of receiving weak signals of short wave length in a practical manner has become of great importance in recent years. This is especially true in connection with direction finding work where the receiver must respond to a very small fraction of the energy which can be picked up by a loop antenna.

The problem may be summed up in the following words:— construct a receiver for undamped, modulated continuous and damped oscillations which is substantially equally sensitive over a range of wave length from 50-600 meters; which is capable of rapid adjustment from one wave to another, and which does not distort or lose any characteristic note or the resulting low frequency current. Two limitations at once present themselves, one inherent in low frequency amplifiers and the other inherent in all known rectifiers. The limitation in the amplifier is the residual noise which makes it impractical to use effectively more than two stages of amplification. The second limitation lies in the characteristic of the detector or rectifier. All rectifiers have a characteristic such that the rectified or low frequency current is roughly proportional to the square of the impressed high frequency E. M. F. Hence the efficiency of rectification becomes increasingly poorer, the weaker the signal until a point is reached below which the detector practically ceases to respond.

*President, Radio Club of America.
†Presented at meeting of R. C. A. at Columbia University, Dec. 19, 1919. Publication courtesy R. C. A. Copyright 1920, A. R. R. L.

Armstrong laboratory
Philosophy building (?)
Columbia University



Armstrong IRE paper
FM modulation
1936

Proceedings of the Institute of Radio Engineers
Volume 24, Number 5 *May, 1936*

TECHNICAL PAPERS

A METHOD OF REDUCING DISTURBANCES IN RADIO SIGNALING BY A SYSTEM OF FREQUENCY MODULATION*

By
Edwin H. Armstrong
(Department of Electrical Engineering, Columbia University, New York City)

Summary—*A new method of reducing the effects of all kinds of disturbances is described. The transmitting and receiving arrangements of the system, which makes use of frequency modulation, are shown in detail. The theory of the process by which noise reduction is obtained is discussed and an account is given of the practical realization of it in transmissions during the past year from the National Broadcasting Company's experimental station on the Empire State Building in New York City to Westhampton, Long Island, and Haddonfield, New Jersey. Finally, methods of multiplexing and the results obtained in these tests are reported.*

PART I

IT IS the purpose of this paper to describe some recent developments in the art of transmitting and receiving intelligence by the modulation of the frequency of the transmitted wave. It is the further purpose of the paper to describe a new method of reducing interference in radio signaling and to show how these developments may be utilized to produce a very great reduction in the effects of the various disturbances to which radio signaling is subject.

Prior to the opening ceremony of WJZ in NYC, Armstrong climbed up the transmitter. Sarnoff was not amused.

Using Low-Cost COTS Software Defined Radios (SDR) for Phase Cal and RFI Monitoring

Tom Clark
NASA Goddard/NVI
k3io@verizon.net

Tom Clark K3IO
Leading authority on Very Long Baseline Interferometry; amateur satellite pioneer, president of AMSAT, digital communications pioneer.

INTRODUCTION TO IONOSPHERIC PHYSICS

Henry Rishbeth
SCIENCE RESEARCH COUNCIL
RADIO AND SPACE RESEARCH STATION
SLOUGH, ENGLAND

Owen K. Garriott
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

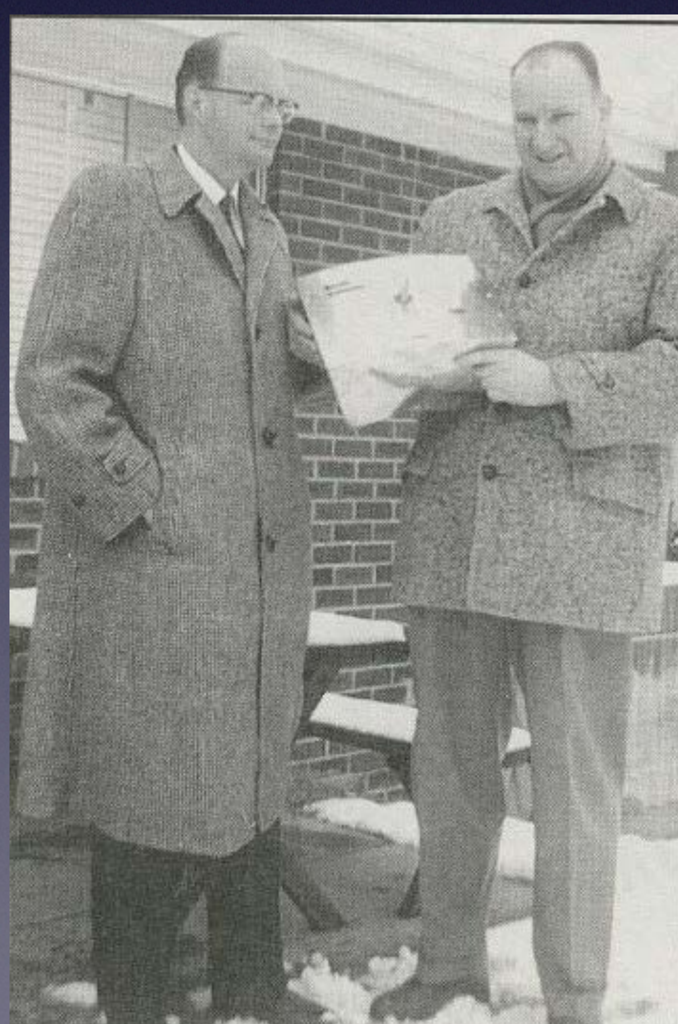
ACADEMIC PRESS New York and London 1969

Owen Garriott W5LFL
Pioneered the use of ham radio from Earth orbit during his "spare time" on shuttle flight STS-9 / Spacelab November 1983

(proposed doing this earlier during Skylab 3 July 1973)

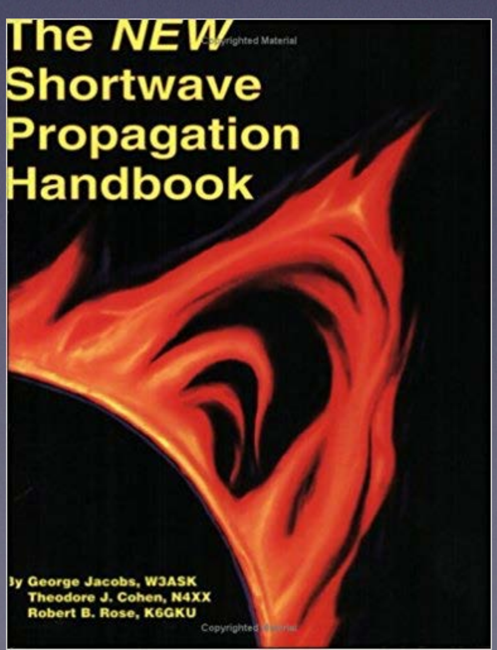
Father of Richard Garriott W5KWQ
Soyuz TMA-3 October 2008

Al Gross W8PAL
Invented handheld radio transceiver (walkie-talkie), telephone pager, and cordless telephone



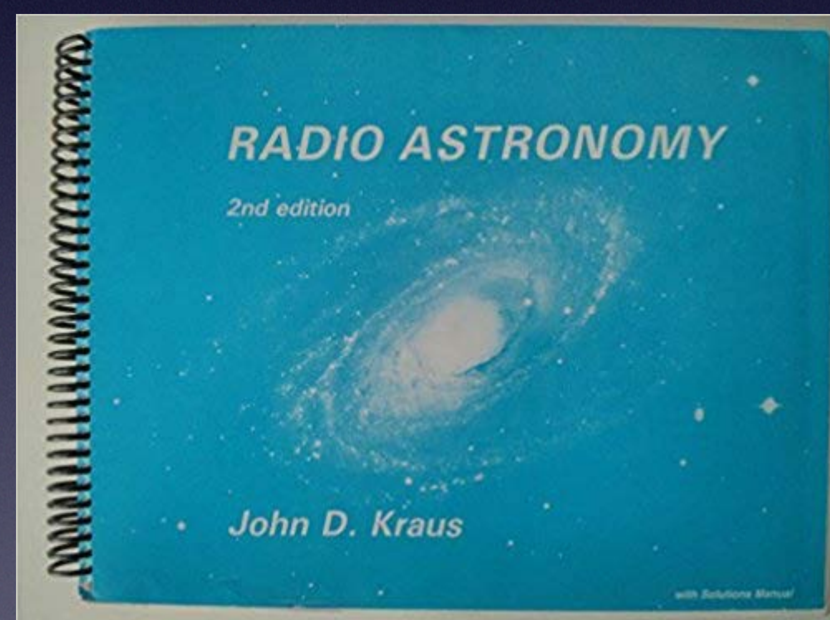
George Jacobs W3ASK
Amateur satellite pioneer. HF broadcast engineering expert, developed Voice of America's worldwide broadcasting system

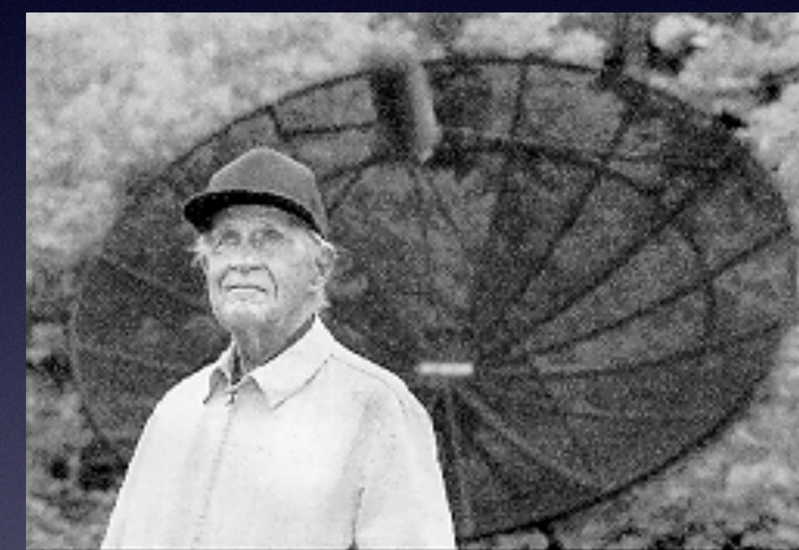
Left: holding OSCAR 1, 1961.

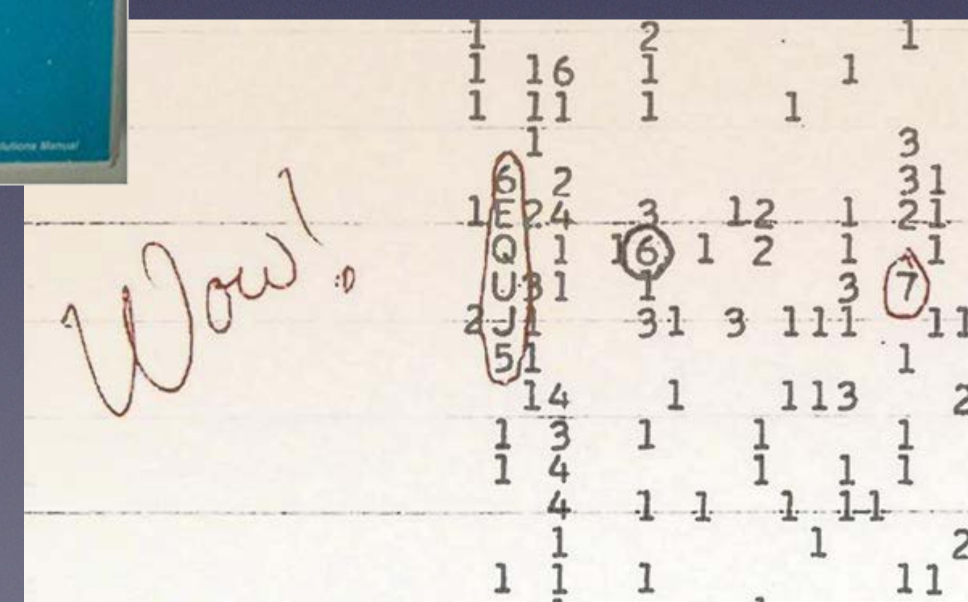


Phil Karn KA9Q
Developed basis for wireless internet communications by adapting Internet communications protocol (TCP/IP) for radio use

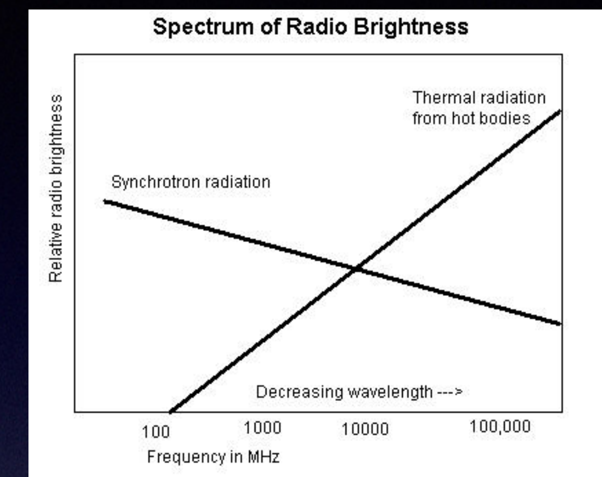
John Kraus W8JK
Radio astronomy pioneer
The “Big Ear” Radio Observatory (Ohio)





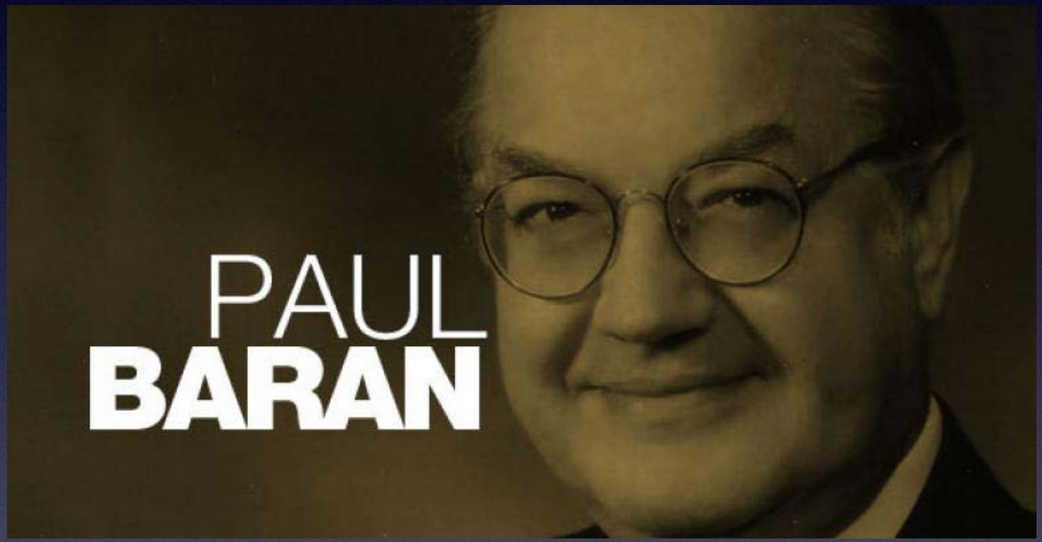


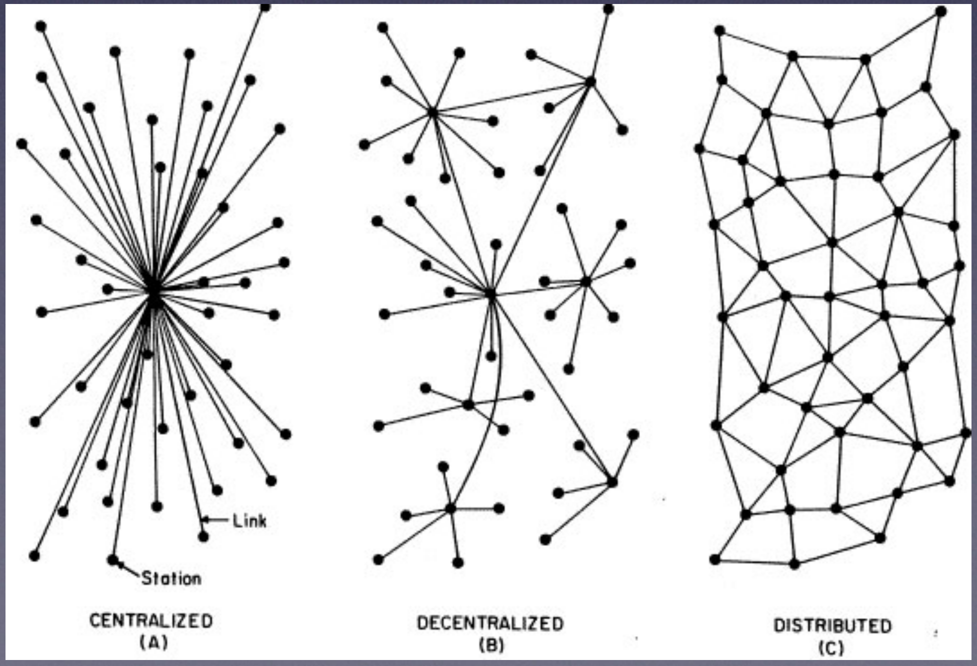
Grote Reber W9FGZ
“Father” of radio astronomy



Ernst Krenkel RAEM
Polar explorer, expedition communicator,
Russian radio hero, made first Arctic-Antarctic
radio contact

Eugene Senti WØROW
As engineer for Collins Radio, invented the radio transceiver (transmitter and receiver in a single package, with shared circuitry)





Paul Baran W3KAS
Invented packet switching, basis of Internet and other modern communication networks; developed first telemetry equipment for NASA

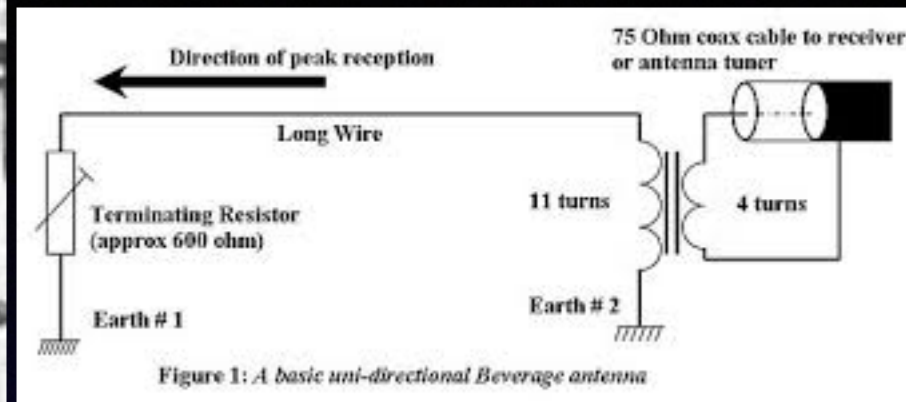
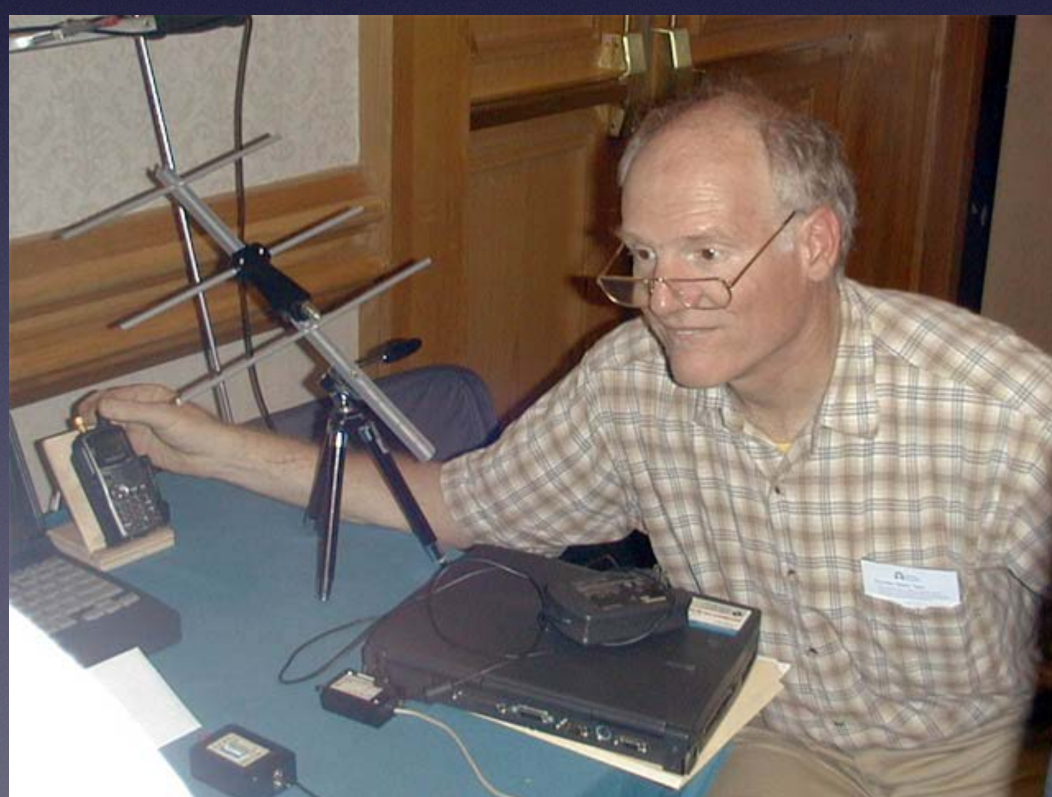
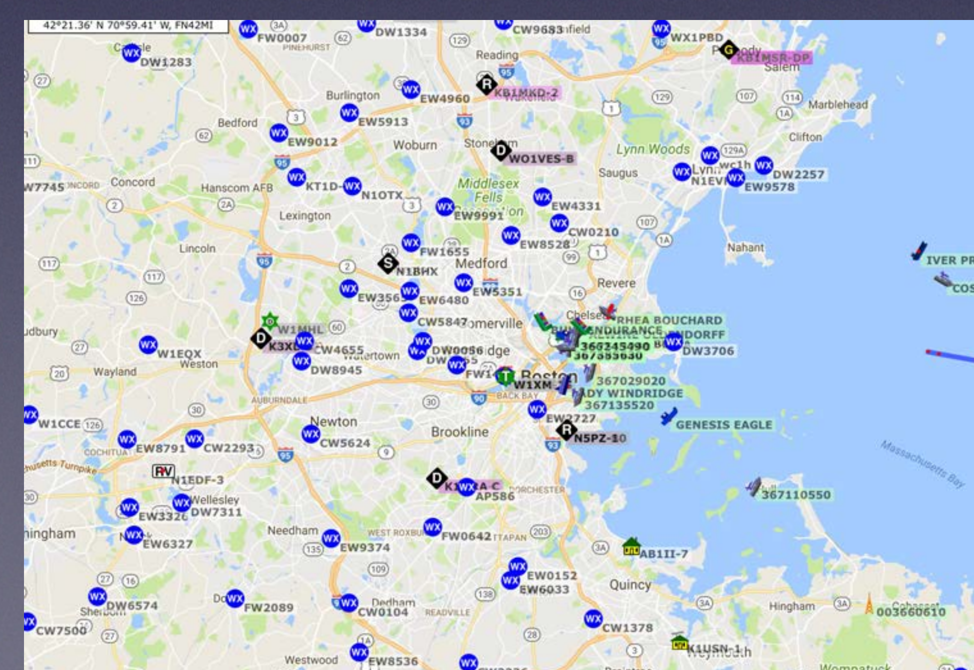


Figure 1: *A basic uni-directional Beverage antenna*

Harold Beverage W2BML
Inventor, Beverage antenna



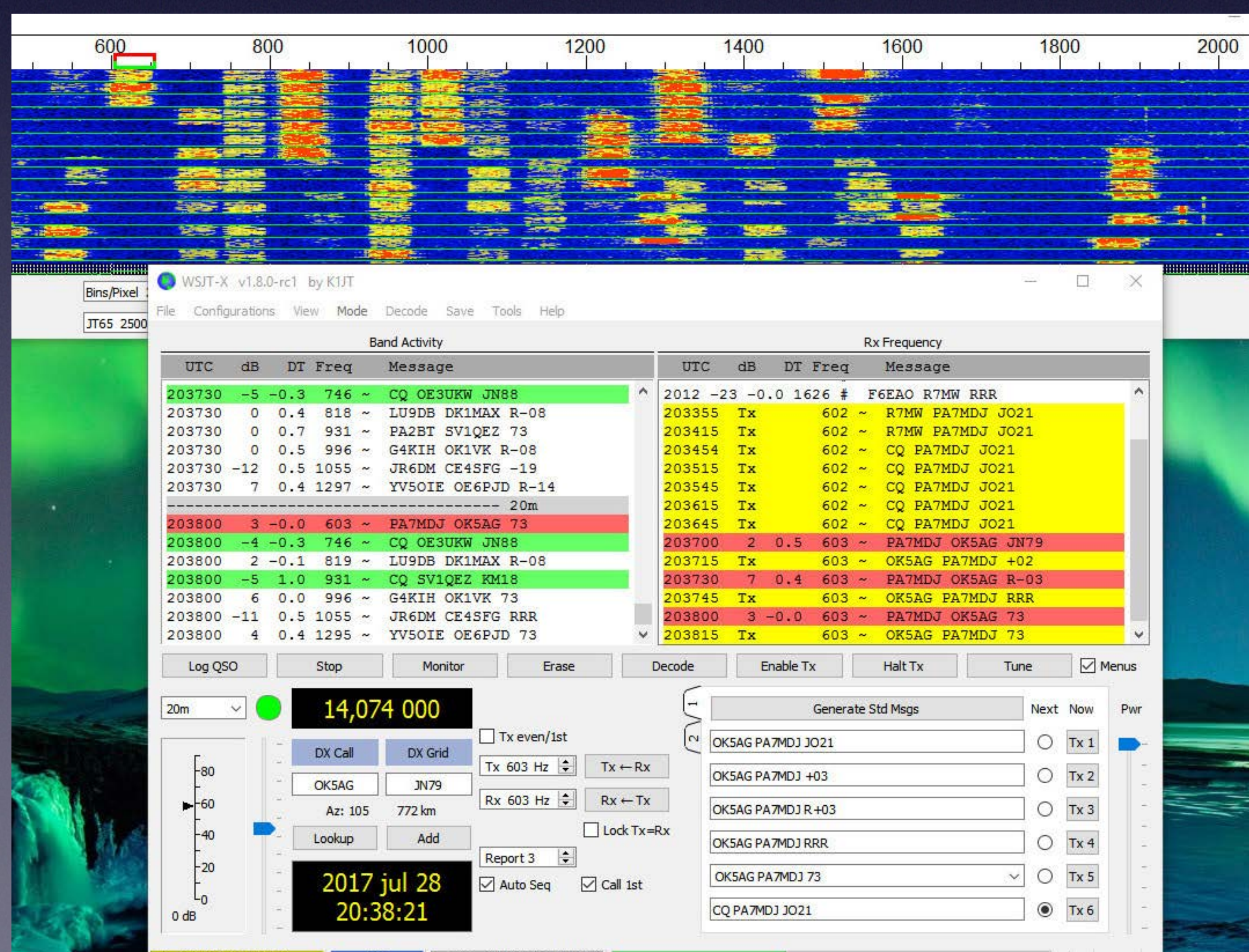
Bob Bruninga WB4APR
Developer of APRS (Automatic Position Reporting System)



Joe Taylor K1JT
Steve Franke K9AN

Developers of weak signal HF communications modes (JT65, JT9, FT8)

Taylor: radio astronomer
Nobel Prize, Physics
Binary pulsar discovery (with Russell Hulse)

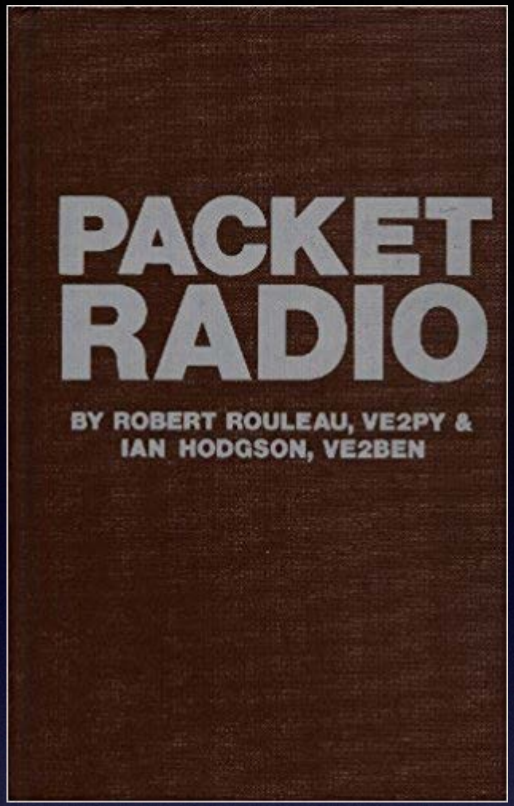


William Eitel W6UF
Co-founder, Eimac, with Jack McCullough, W6CHE

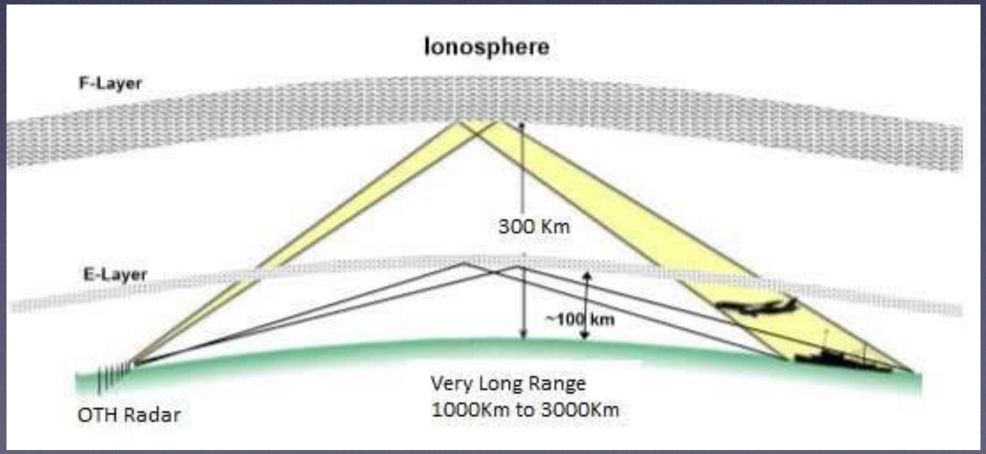
Sam Harris W1FZJ
VHF pioneer, QST columnist; made first EME contact, engineered Arecibo radiotelescope

Chuck Towns K6LFH
Amateur satellite pioneer; OSCARs I & II built in his garage

Antonio Elias KA1LLM
Executive Vice President and General Manager for Advanced Sciences, Orbital Sciences Corp
Led technical team that designed and built the air-launched Pegasus booster as well as the X-34 hypersonic research vehicle



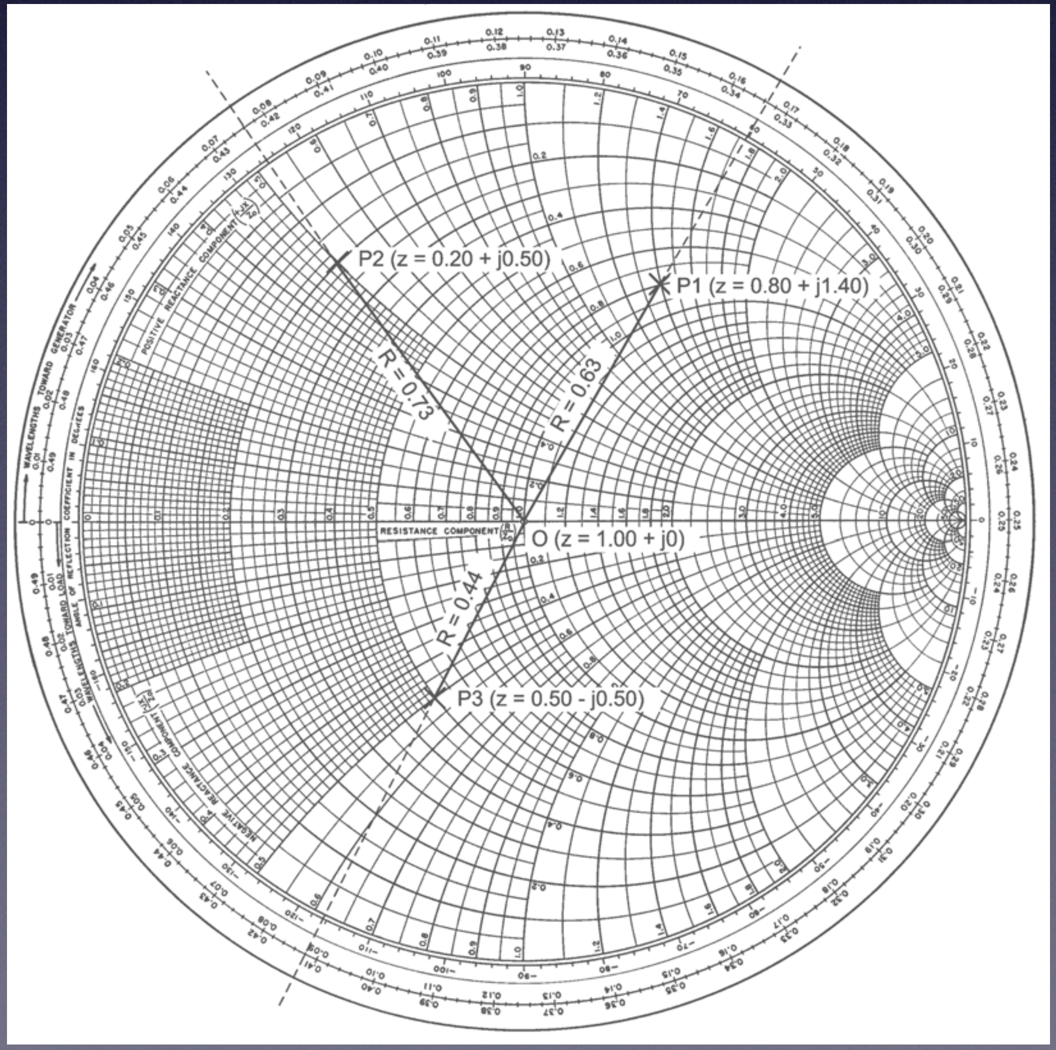
Bob Rouleau VE2PY
First to modify commercial digital communications protocol for amateur use, leading to development of amateur packet radio



Oswald Garrison “Mike” Villard, Jr. W6QYT

SSB pioneer, meteor scatter pioneer, invented over-the-horizon radar, developed “stealth” technology

Ivan “Sonny” Harrison W5HBE
Developed the “Carterphone” phone patch to connect radios to the telephone network, leading to the U.S. Supreme Court’s “Carterphone” decision, which opened the door for connecting all sorts of devices, including computers and modems, to the telephone network. This paved the way for widespread internet and e-mail access via “dialup” connections.



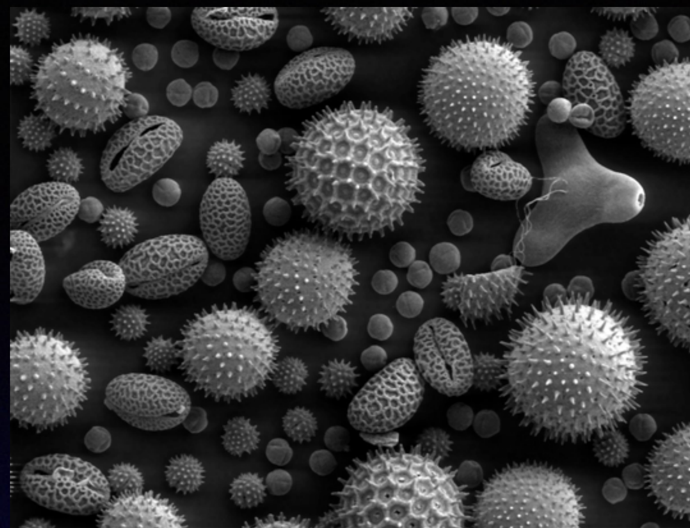
Phillip Smith 1ANB
Inventor of the Smith Chart for determining transmission-line impedances

Loyd Sigmon W6LQ
Developed first radio traffic alert system, “SigAlert,” in Los Angeles; precursor of today’s radio traffic reports.

Marshall Ensor W9BSP
Helped track down German “Wolf Pack” submarines during WW II by refining radio direction-finding (RDF) techniques

Reginald Fessenden VP9F
Father of radiotelephony; first wireless radio broadcasts (1906)

Hazard "Buzz" Reeves K2GL
President, Cinerama; developed method of affixing strip of magnetic oxide to movie film, making it possible to record pictures and sound simultaneously on one piece of film.



James Hillier ex-VE3SH
Co-inventor of scanning electron microscope; former head of RCA Labs.

John Kanzius K3TUP
Inventor of possible cure for cancer using RF energy; process for possible use of seawater as fuel.

William Bridges W6FA
Laser pioneer; developed first “noble gas” lasers (argon, krypton, xenon) and the dominant modulation system for feeding data into fiber-optic cables

George Smith AA2EJ
Inventor of the CCD (charge-coupled device) sensor, which revolutionized digital imaging; co-recipient of the 2009 Nobel Prize in Physics

Daily Mirror

ARMY RADAR CONTACTS MOON

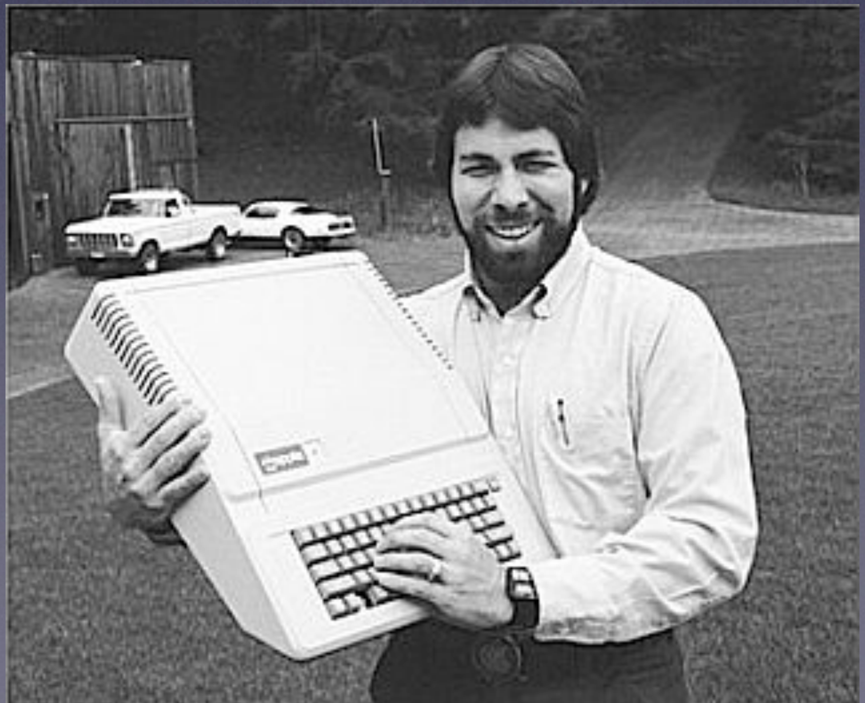
Story on Page 2

HOW EARTH "TOUCHED" SATELLITE . . .
Above is the mighty tower of steel at Belmar, N. J., utilized by Army scientists to send successive high frequency radar impulses to the moon, 238,857 miles away. Drawing at right, by Mirror artist [illegible], indicates how the electric impulses "bounced" back through interplanetary space in 2½ seconds. It was the Earth's first man-made contact with the Moon.

E. King Stodola W2AXO
Pioneer of EME (Earth-Moon-Earth communications).
Pioneer in development of radar; scientific director of Project Diana (Earth-moon radar signals in 1946; proof that radio could transit the ionosphere in both directions). Foundations of communication satellites and radio astronomy advances.

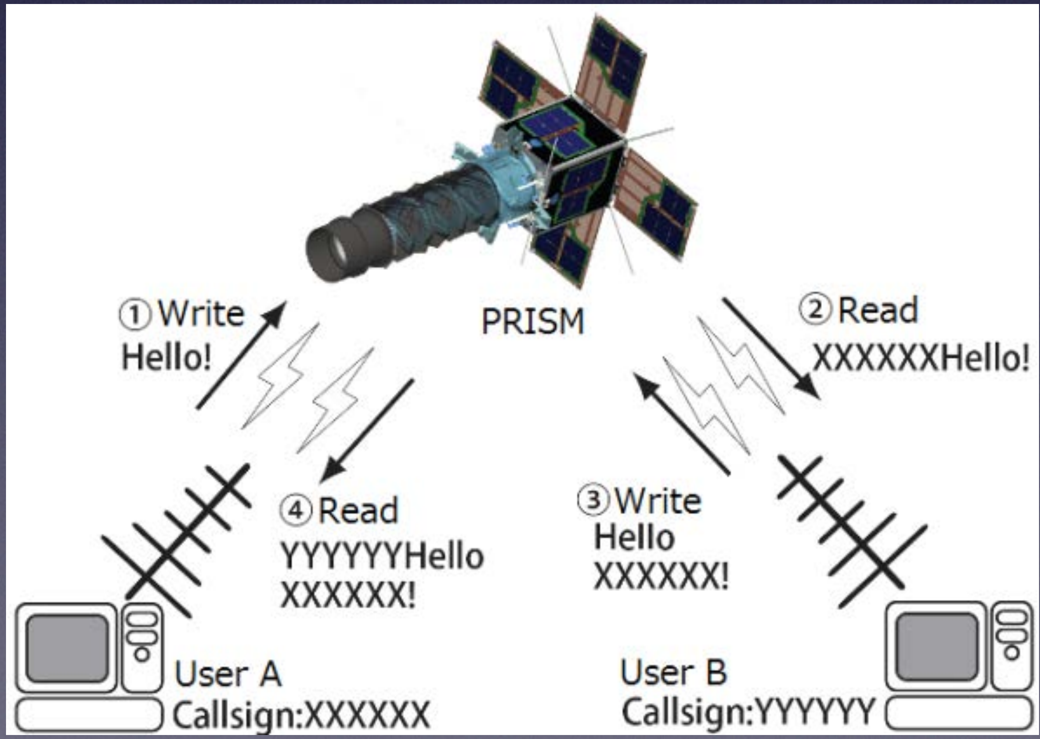
Clifford Berry W9TIJ
Co-inventor of the Atanasoff-Berry computer (or ABC), the precursor to virtually all electronic computers

Paul Laughton N6BVH
Apple's disk operating system;
Atari's operating system

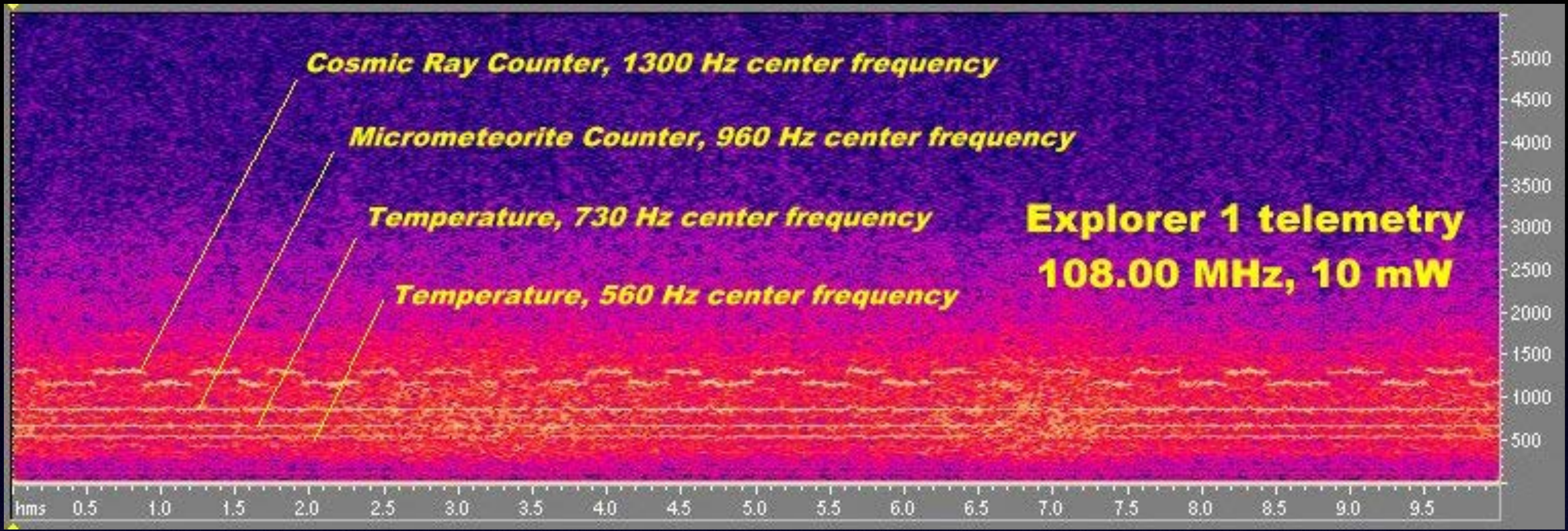


Steve Wozniak ex-WV6VLY
and ex-WA6BND
Co-founder of Apple
Computers.

Matt Ettus N2MJI
Software defined radio pioneer; developed first Universal Software Radio Peripheral (USRP) with GNU radio software support



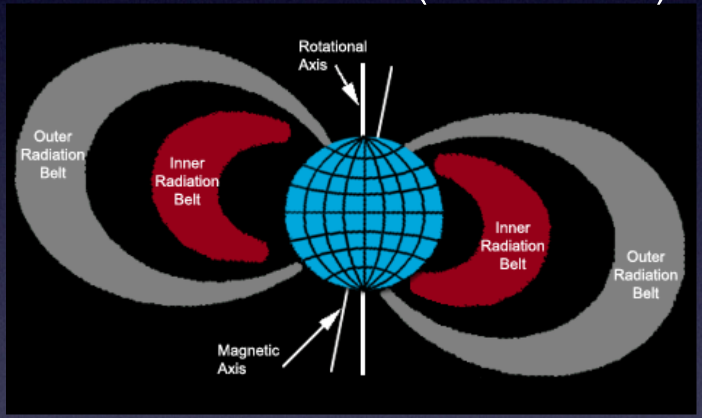
Terry Fox N4TLF
Packet radio pioneer; primary developer of AX.25 amateur packet protocol (also used in many cubesat radios)



Recording by
Roy Welch
Dallas, TX
Feb 11, 1958

(Sven Grahn)

Discovery of the Radiation Belts
Explorer 1 1958
James Van Allen



(Alan EE Rogers, Haystack Observatory; son of John Rogers, chief engineer for Van Allen at Iowa)

Future Shock:
Modern (and Disruptive) RF Technology
Hardware and Software

(e.g. John Ackermann N8UR)

KITS: 20M WSPR-Pi (QRPi)

Popular

- HackRF One
- HPSDR - TR-Plus
- Raspberry Pi WSPR TX module
- Pulse Puppy
- TASS - Coax Relay System
- TICC
- TNS-BUF

Raspberry Pi QRP TX Shield for WSPR on 20 Meters

Nowadays, one of the most impressive QRP modes is Joe Taylor, K1JT's WSPR (pronounce
WSPR stands for "Weak Signal Propagation Reporter." Programs written for WSPR mode a
sending and receiving low-power transmissions to test propagation paths on the MF, HF anc
bands. Users with Internet access can watch results in real time at wsprnet.org.

The QRPi board (or shield as referred by the community today) is an inexpensive way of tur
single-board computer into a QRP transmitter.

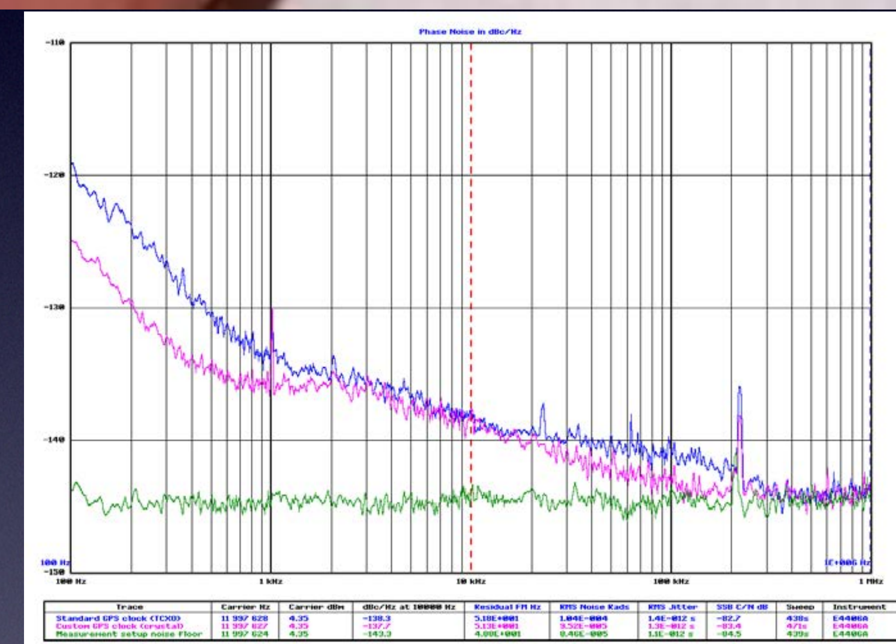
Traditionally, a LPF removes harmonics from a transmitter output, but leaves any broadbanc
noise is filtered by a BPF.

To protect the clock generator output stage of the Pi, a buffer amp is provided for isolation. T

Leo Bodnar electronics

Precision Frequency Reference (GPS Clock)

Price: 150.00GBP



QRP Labs

Hans Summers G0UPL

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Si5351A Synthesizer

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Shop order

$7.75

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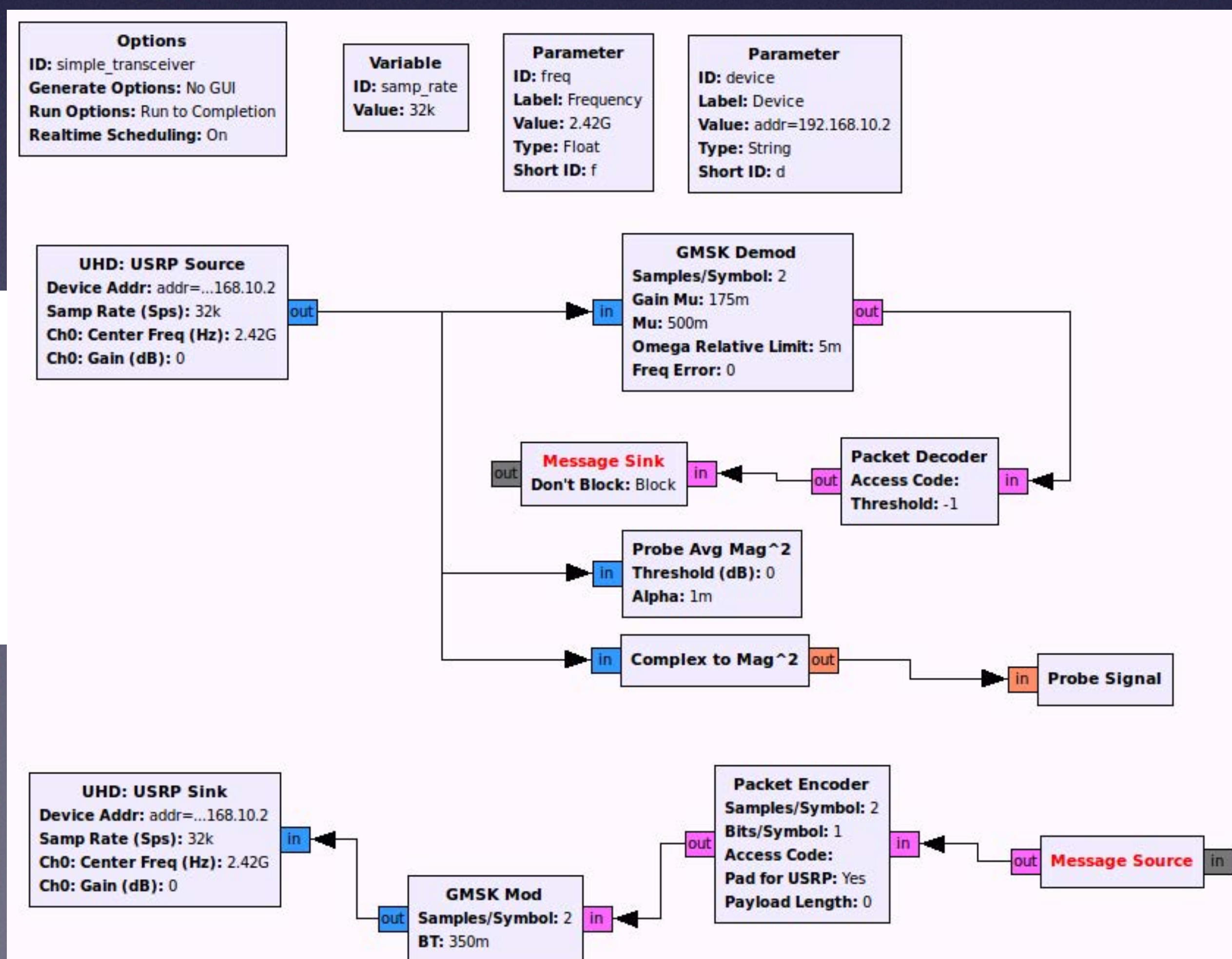
Part#	ADC Resolution	ADC Output Sample Rate (max)	ADC Channels	US Price 1000 to 4999	INL in LSB (typ)	ADC SNR in dBFS (typ)	SFDR-dBc (typ)	Power Dissipation (typ)	Operating Temp Range	Output Data Format
ad9625-2500	12	2.5 GSPS	1	$735.00	1	58.3	77	3.9 W	-40 to 85°C	JESD204B
AD9625	12	2 GSPS	1	-	-	-	-	3.48 W	-40 to 85°C	JESD204B
ad9625-2000	12	2 GSPS	1	$624.75	0.9	59.5	80	3.48 W	-40 to 85°C	JESD204B
AD9691	14	1250 MSPS	2	$692.75	2.6	63.4	77	3.8 W	-40 to 85°C	JESD204B
AD9234	12	1 GSPS	2	$238.00	3.5	-	-	3 W	-40 to 85°C	JESD204B
AD9680	14	1 GSPS	2	-	-	-	-	3.3 W	-40 to 85°C	JESD204B
AD9680-820	14	820 MSPS	2	$369.75	2.5	67.2	90	2.9 W	-40 to 85°C	JESD204B
AD9680-500	14	820 MSPS	2	$272.00	2.5	69.2	82	2.2 W	-40 to 85°C	JESD204B
AD9267	16	640 MSPS	2	$40.80	-	-	-	503 mW	-40 to 85°C	Serial
AD9684	14	500 MSPS	2	$272.00	2.5	69.2	82	2.2 W	-40 to 85°C	LVDS, Parallel
AD9690	14	500 MSPS	1	$136.00	2.5	-	-	1.5 W	-40 to 85°C	JESD204B
AD9484	8	500 MSPS	1	$36.00	0.1	47	82	670 W	-40 to 85°C	LVDS, Parallel
AD9286	8	500 MSPS	2	$36.00	0.1	49.3	70	315 mW	-40 to 85°C	LVDS, Parallel



GNU Radio

THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

Blurring the Hardware/Software Line for RF Transducers

TAYDA electronics

2N3904 NPN GENERAL PURPOSE TRANSISTOR $0.02

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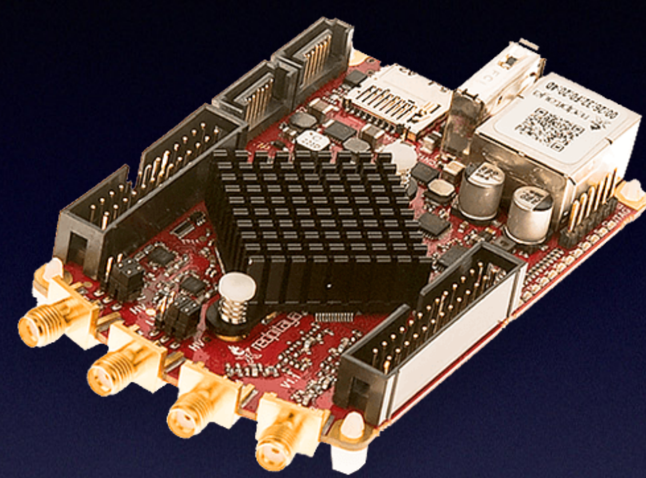

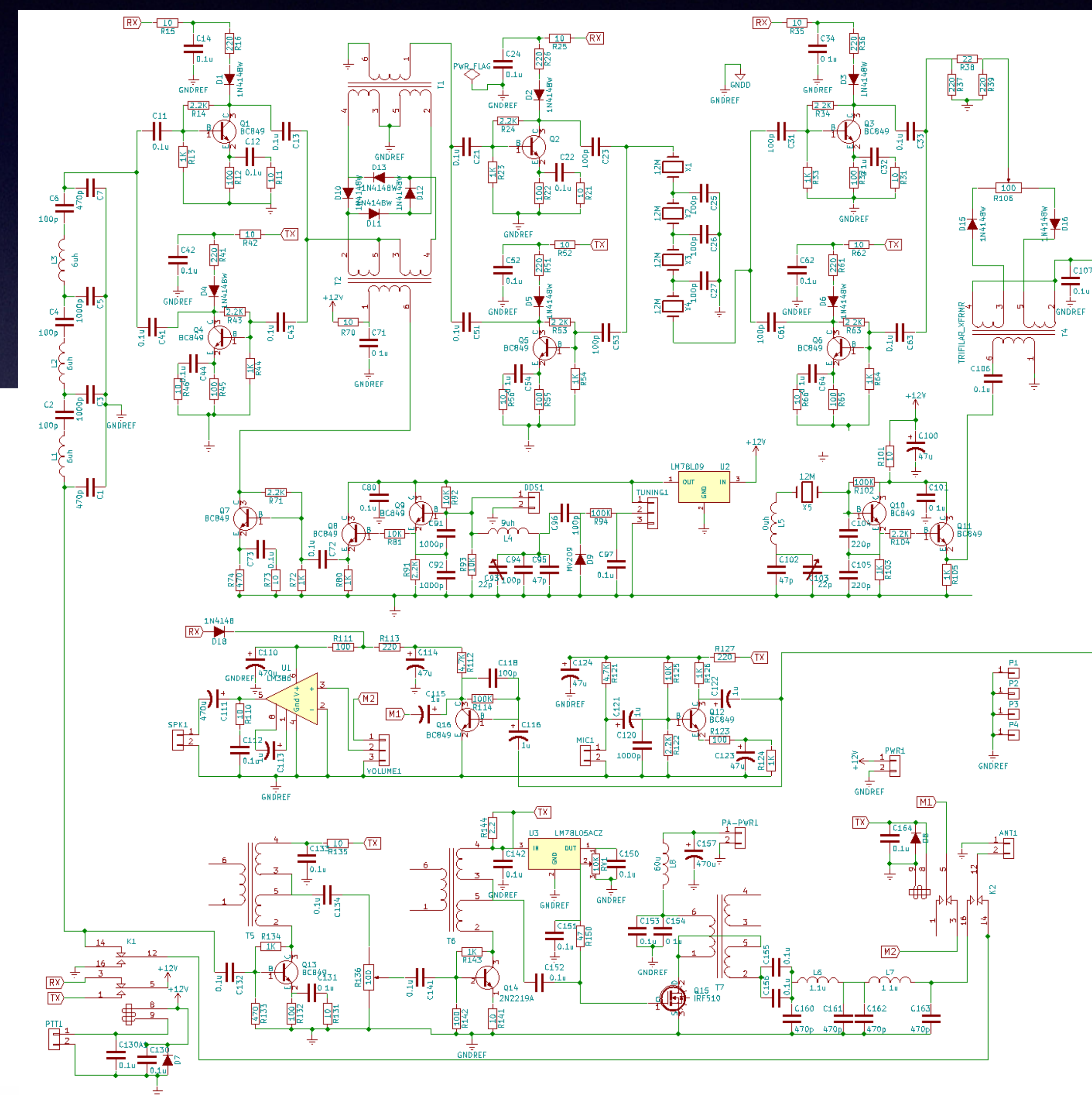

BITX40

Ashhar Farhan VU2ESE

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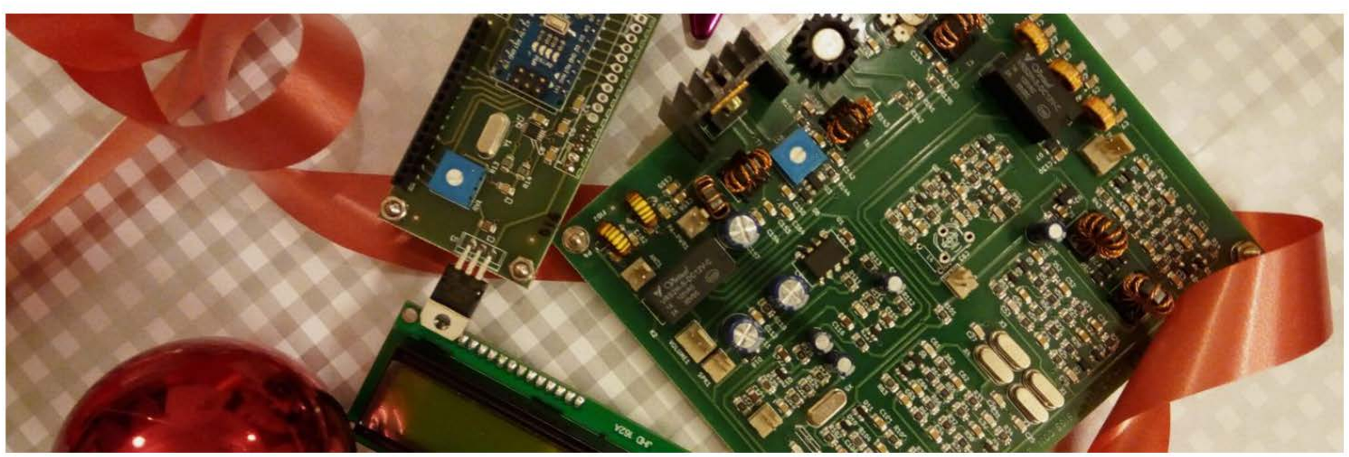

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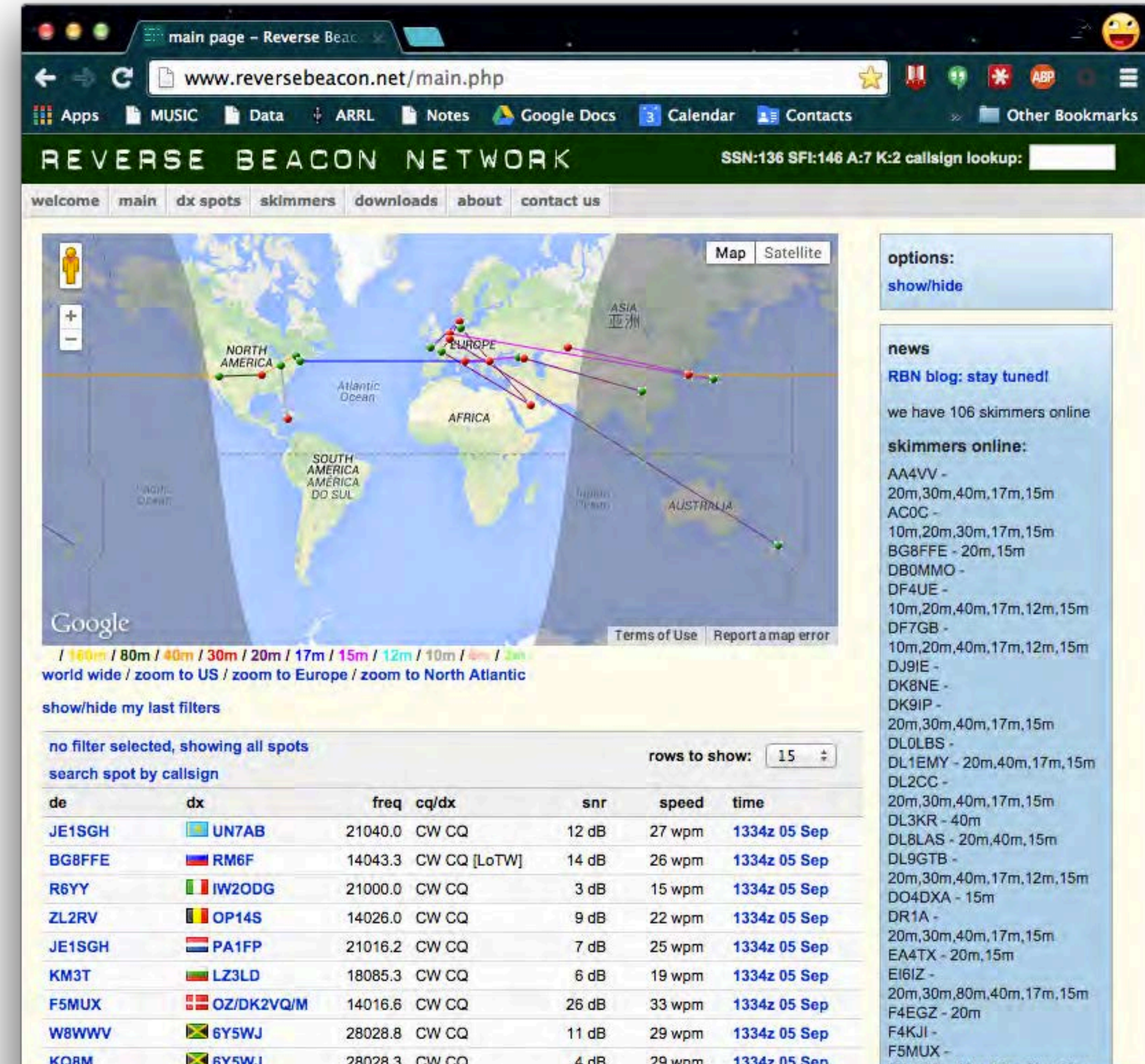
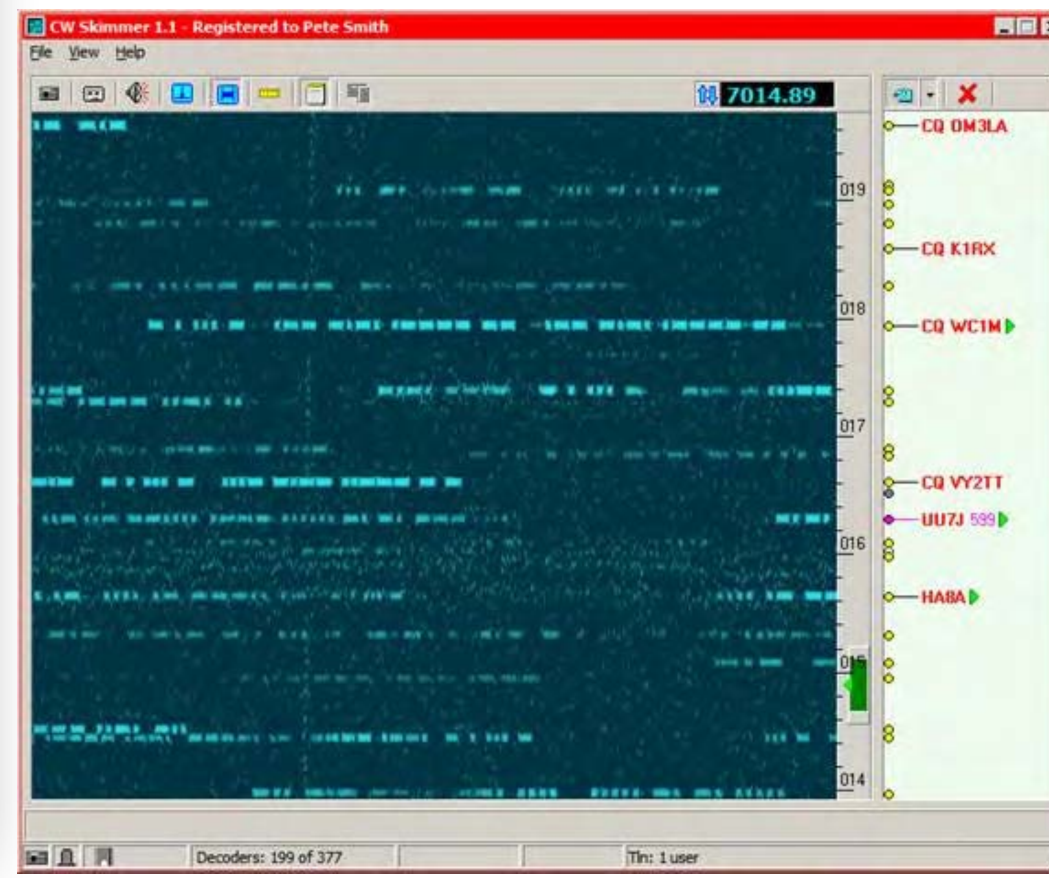
Disruptive Hardware: RF Tools of the Trade

Reverse Beacon Network



- **Volunteer Network**
- **~130 Nodes**
- **Data back to 2009**



nathaniel.a.frissell@njit.edu

Big Data – Other Ham Networks

Network	Start Year	# Spots	DB Size
WSPRNet	2008	535,000,000	44 GB
RBN	2009	578,000,000	36 GB
PSKReporter	2013	1,000,000,000	100 GB

- There is A LOT of data.
- This is not a "traditional" experiment.
- How do we analyze this?

Citizen Science: Early Forays

Feb. 1922

QST

A Magazine Devoted Exclusively to the Radio Amateur

The Story of the Transatlantics

By The Editor

THE signals of some thirty-odd American amateur radio stations, working on the short wave lengths and low power permitted amateurs, were heard across the Atlantic Ocean in the second series of Transatlantic Sending Tests conducted by the American Radio Relay League in December, 1921. This is a story of that achievement.

The First Attempt

The possibilities of transatlantic tests were first presented to the amateur world in 1920 by Mr. M. B. Sleeper, at that time radio editor of "Everyday Engineering". It is a subject that intrigues the amateur —his greatest desire in life is to get "distance" with his equipment. It has wonder-

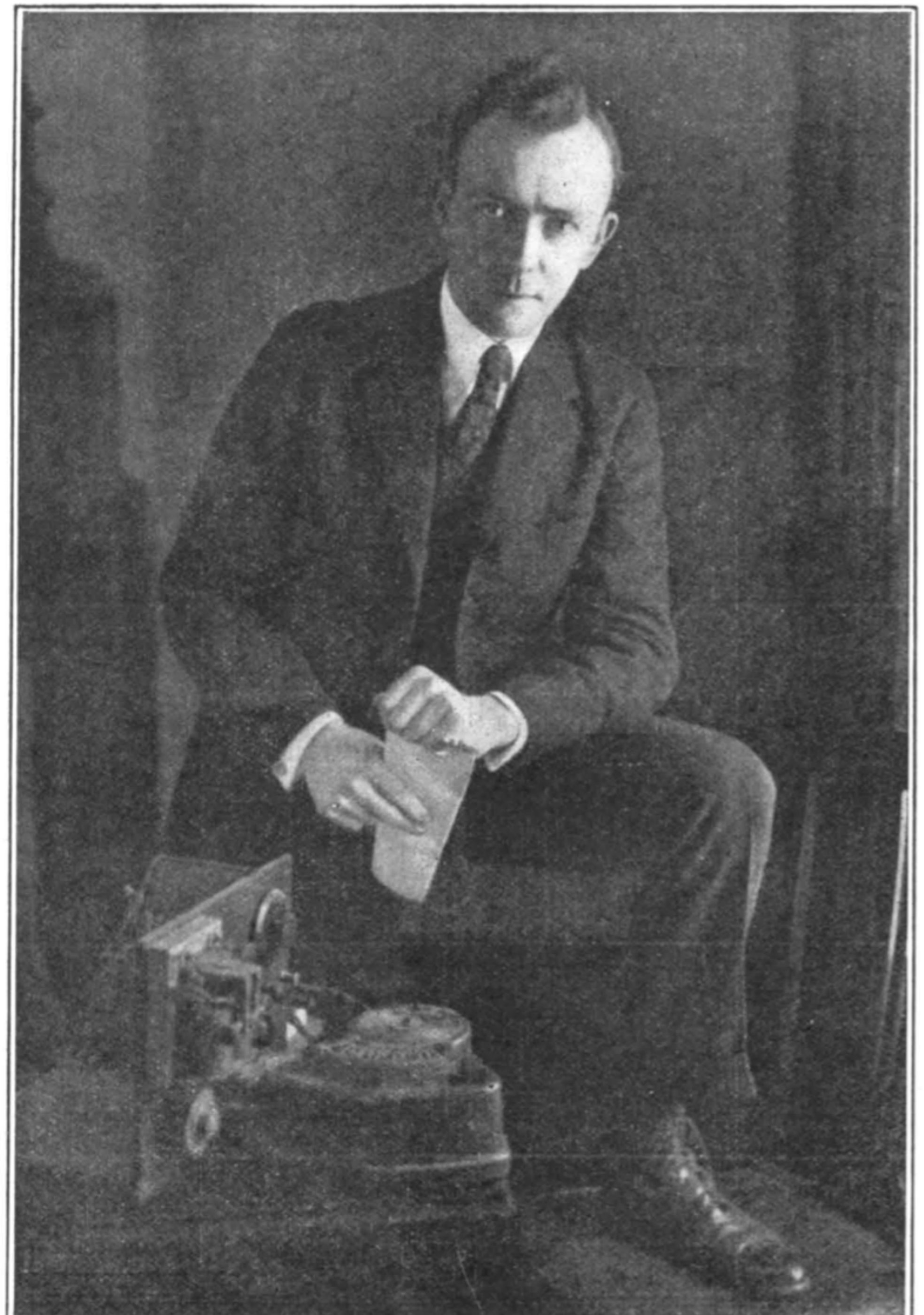
and we even made the boast in print that if a dyed-in-the-wool American ham could be sent across the water with a good American regenerator we knew signals could be copied; in fact, we bet our new spring hat on it. Ever since then we have been answering inquiries from England as to just what a "ham" is, particularly one who has been dyed while still in the wool. But we're used to questions.

To Try Again

And so the matter of additional tests was taken up with Mr. Philip R. Coursey, assistant editor of "The Radio Review", London, who had managed the British end of the first tests, and he, finding British amateurs desirous of giving the game a

The following table lists the entrants in the finals:

Call	Location	Type	Wave	Cypher
1AFV	Salem, Mass.	C.W.	200	YLPMV
1TS	Bristol, Conn.	C.W.	200	AOTRB
1RU	W. Hartford, Ct.	C.W.	200	BPUSC
1DA	Manchester, Mass.	C.W.	200	CQVTD
1AW	Hartford, Conn.	Spk.	210	DRWUF
1BCG	Greenwich, Conn.	C.W.	230	GODLY
2BML	Riverhead, L. I.	C.W.	200	FSXVG
2FD	New York City	C.W.	200	GTYWH
2FP	Brooklyn	C.W.	200	HUZXJ
2OM	Ridgewood, N. J.	Spk.	200	JVAYK
2EL	Freeport, L. I.	C.W.	200	KWBZL
3DH	Princeton, N. J.	C.W.	210	LXCAM
4GL	Savannah, Ga.	C.W.	200	MYDBN
3BP	Newmarket, Ont.	Spk.	200	NZFCO
8DR	Pittsburgh, Pa.	C.W.	200	OAGDP
9KO	St. Louis, Mo.	Spk.	200	PBHFQ
9AW	Toronto, Ont.	C.W.	200	QCJGR
1ZE	Marion, Mass.	C.W.	375	RDKHS
2ZL	Valley Stream, L. I.	C.W.	325	TGMKU
3ZO	Parkesburg, Pa.	C.W.	360	UHNLV
5ZZ	Blackwell, Okla.	Spk.	375	VJOMW
6XH	Stanford U., Cal.	C.W.	375	WKPNX
7ZG	Bear Creek, Mont.	Spk.	375	XLQOY
8XK	Pittsburgh, Pa.	C.W.	375	YMRPZ
9ZY	Lacrosse, Wis.	C.W.	260	RZQMY
9ZN	Chicago, Ill.	Spk.	375	ZNSQA
9XI	Minneapolis.	C.W.	300	SFLJT



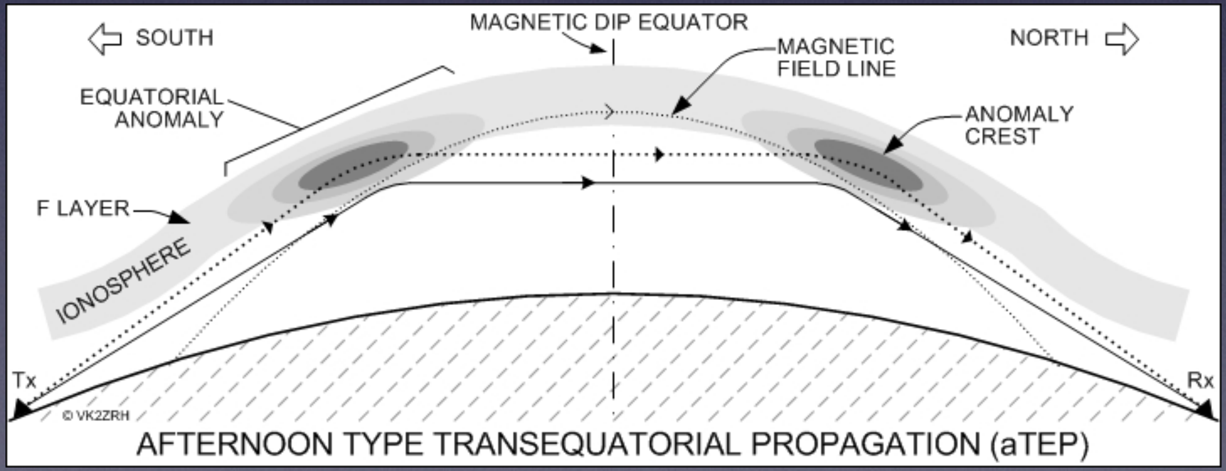
PAUL FORMAN GODLEY
A.R.R.L.'s Successful Overseas Listener
from a recent photograph taken at his home
in Cedar Grove, New Jersey

CQ Magazine sponsored
Radio Amateur Scientific Observations VHF project
late 1940s - early 1950s

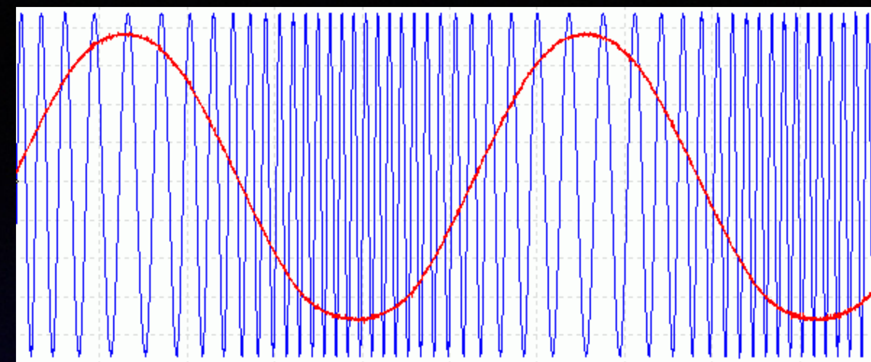
- Sponsored by CQ in coordination with the U.S.Air Force Geophysical Research Division
- Investigated ionospheric phenomena at 50 MHz
- Ran from May 1949 to May 1952 and involved over 500 registered amateurs in the western hemisphere
- More than 100,000 observations collected by CQ and forwarded to the Air Force
- All amateur participants were issued certificates of appreciation by the U.S. Air Force

Findings included:

- Prevalence of Trans-Equatorial propagation
- Frequent VHF openings between North and South America
- Connections to Sporadic E



Interconnections: Science, Commercial, Radio Physics



Jicamarca Radio Observatory
Jicamarca, Perú
50 MHz phased array
late 1950s construction
US National Bureau of Standards

Radio Amateur Scientific Observations

Contributions to scientific research fully credited to amateur radio as a means of perpetuating the hobby, is the motivating force behind this non-profit CQ activity.

FOR WELL OVER one year, the staff of *CQ* magazine has been giving serious thought to the future of amateur radio. All of us, at one time or another, have been told that being an amateur radio operator is a privilege and is something that must be earned. Unfortunately, once earning the privilege does not ensure its continuance for years to come. Instead, the desirability of allowing amateur radio to continue is always under scrutiny. This surveillance has been much greater in the postwar years and it is for the benefit of many radio amateurs that a few have exerted considerable effort to cast the hobby in a favorable light. The public and emergency services performed by radio amateurs are well known. In addition, the international aspects of the art should always be borne in mind, and only within the past few years have the experimental circuitry developments of amateur radio lagged behind the commercial laboratories. But expansion of any of these was not the problem facing this staff. Rather, how could amateur radio most benefit the present scientific trends in adjacent fields?

A study showed that the collaboration between "Vince" Dawson, WØZJB, our V.H.F. Editor, and "Perry" Ferrell, our Assistant Editor, in the field of radio wave propagation above 50.0 mc had uncovered several distinct phenomena. It was felt that if sufficiently accurate data were at hand we would find that the surface has only been scratched. As a result, several informal talks were held with various Governmental laboratories which might be interested in following up the suggested line of research. At the same time (i.e. last summer) a test run of the proposed 50-mc project was made. The response, although not as great as had been expected, was nevertheless large enough to definitely warrant a full-scale project, provided more amateurs cooperated. Believing in the intrinsic good judgment of a very large majority of the amateurs, this organization began negotiations with the Watson Laboratories, Air Material Command, U.S.A.F., for the purposes of obtaining a cost-reinbursement non-profit contract to supply certain radio amateur observations to the Geophysical Research Division of the Watson Laboratories.

The program as outlined in the negotiations was for Radio Magazines, Inc., to establish a separate section within its business organization, and to carry forth a project of collecting Radio Amateur Scientific Observations. The *Scientific Observations* section would be directed by Mr. Ferrell and would initially collect suitable data on the prevalence, distribution and intensity of radio signals propagated by means of sporadic-E ionized clouds, or by other means. Also, the *Scientific Observations* section would screen all data to insure their accuracy and reliability for use in further scientific investigations. Working on this basis, negotiations were completed and a formal contract for services and data was signed between the Government of the United States of America and Radio Magazines, Inc., on May 26, 1949.

By arbitrary definition, scientific observations in this project would consist for the present time of any and all reports of reception of radio signals above 50.0 mc and beyond the limit of the Tropospheric Wave. Thus, no special tests or equipment are required in this project. The 6-meter band is ideally situated in the radio spectum to detect and observe certain forms of sporadic-E ionization. Also, the most consistently active 6-meter operators are individuals who have been fascinated by the peculiar openings and opportunity to work DX under pretty much unpredicta-

(Continued on page 68)

Observers as of June 27, 1949

KH6PP
VE1QZ
VE3AAJ, AGB, AJS, ANY, ATB, AXT, BYZ, DDT, YY.
VE5NC
VE7AEZ, CN, OE
W1ATP, BWJ, CGY, CGX, CLH, CLS, DEO, DGV, DJ, EIO, GJO, GJZ, GHZ, HIL, HMS, JQA, KEX, KHL, LSN, MEP, MPO, OIR, QXE, RDA.
W2ADA, BAY, COT, GYV, IDZ, LAL, MEU, ORA, PWP, RLV, RUA, SYR.
W3CIR, CUB, FWO, GUF, HC, IZL, JVI, KEM, KKN, KXI, MFY, MQU, MXW, NKM, NSI, OJU, PCB, RUE.
W4AVT, BEN, BSS, CDC, CNK, COS, CPZ, CVQ, DRZ, EID, ENL, EQM, FBJ, FI, FLW, FNR, FQI, FWH, GMP, GYO, HBE, HHK, HVT, IUJ, KIP, KKU, KYW, LEC, LNB, LNG, LVA, MS, NEE, OVT, QN, RBK, WMI.
W5AJG, ATJ, BAJ, BFA, BHO, CXS, DFU, EKU, ELL, FFM, FRM, FSC, GNQ, GTP, HKI, HLD, HVP, IRP, IVU, JBW, JLY, JNG, JTI, KSW, KXO, LF, LIU, LWG, MAW, MJD, ML, MXI, NHD, NLP, NS, ONS, PFC, PFD, PKX, UW, VV, VWU, WX, ZZF.
W6AMD, ANN, BLZ, CAN, DQY, EIB, ERE, FFF, FPV, IWS, JRM, NAT, NAW, PSQ, PUZ, QUK, SFL, SUK, TMI, UOV, WNN.
W7ACD, DYD, ERA, FDJ, FGG, FIV, FLQ, GBI, GCS, HEA, ILL, JPA, JRG, JXC, KOP, LLO, MWQ, OWX, QAP, QLZ, QNC.
W8CMS, DGG, EP, FAZ, LBH, NBM, NQD, NSS, RDZ, TDJ, TOB, UZ, WSE, YLS.
W9ALU, AQQ, BIQ, GWL, HGE, KAJ, LMX, MBL, NJT, PK, QKM, QUV, RQM, UIA, UNS, VZP, ZBK ZHL.
WØBJV, BPL, CJS, DER, DNW, GSW, IFB, INI, IPI, IZF, JHS, JON, JRP, KRZ, KYF, LQW, MVG, PKD, QDH, QIN, SHW, SII, TKX, UEL, URQ, VMY, YXS, ZJB.
XE1GE, QE.
SWL's — Stan Horton

ZERO BIAS

E D I T O R I A L

… Here the need is to resolve theoretical concepts with observed phenomena.

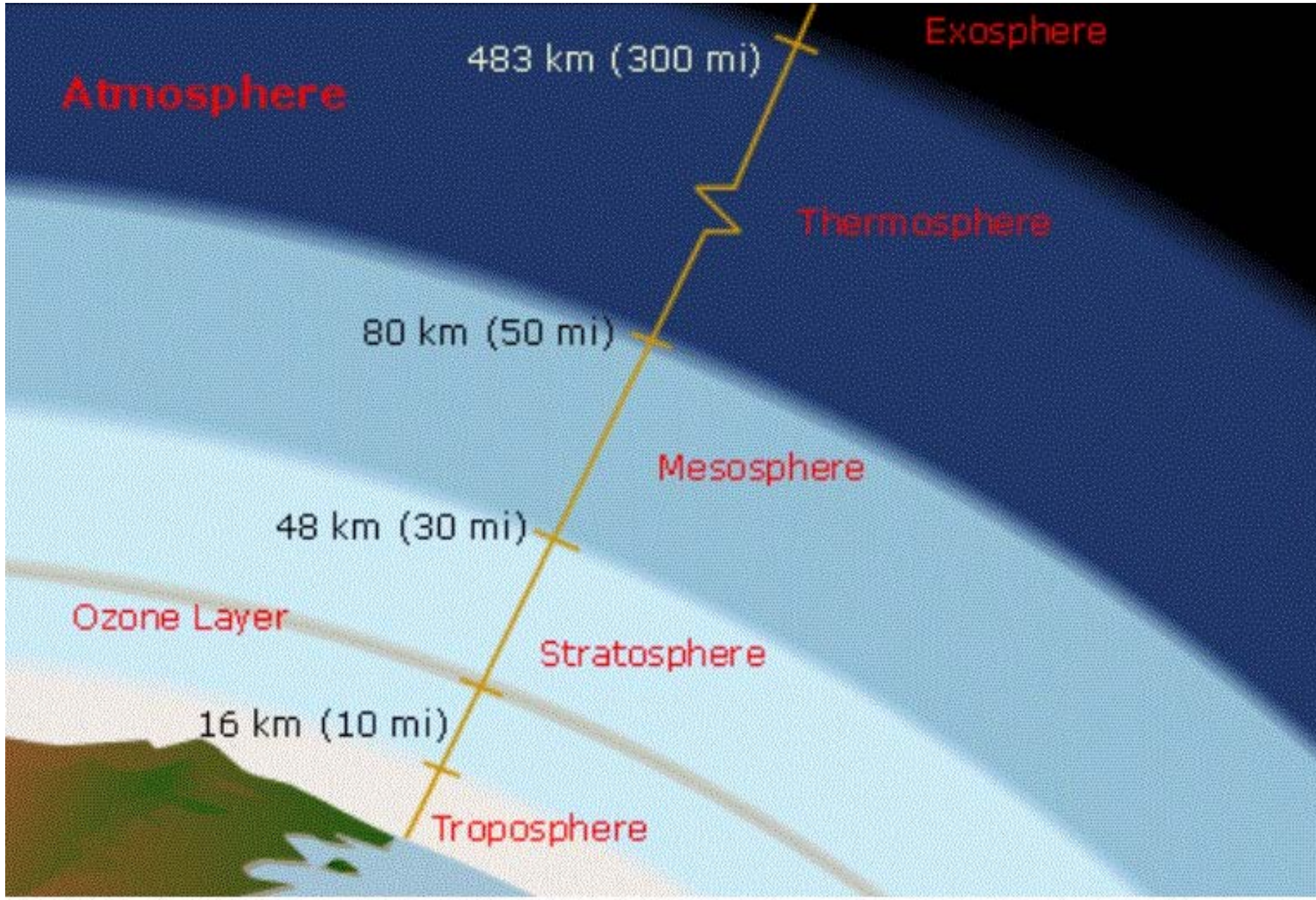
Today there is a definite need for competent observations of various effects in the very high frequency radio spectrum. Such observations are needed to **fill in many gaps in the theoretical basis of radio wave propagation**. The number of observations needed is **far greater** than the facilities of even the well organized government research establishments can provide.

… Observations by amateurs when **properly gathered, screened, and tabulated** are very likely to prove one of the most valuable instruments that our scientists have at hand.

The Geospace Environment: Much Left to Discover..

Earth's Ionosphere and Its Relation To The Atmosphere

Our planet's neutral atmosphere..

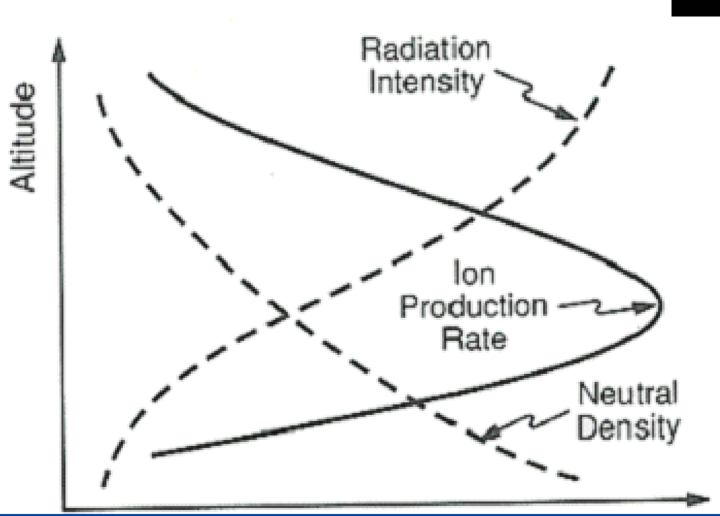


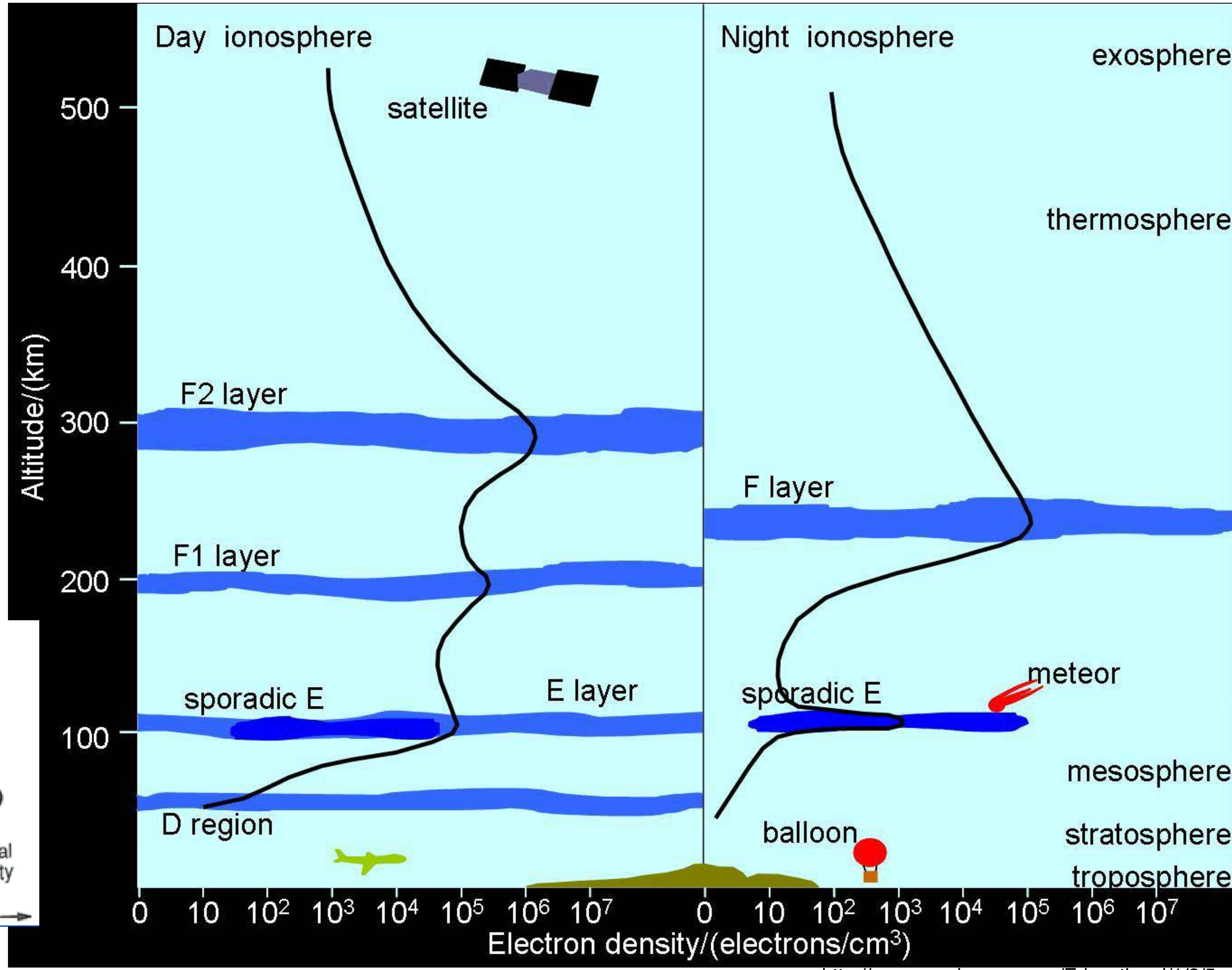
http://www.sws.bom.gov.au/Educational/1/2/5

Earth's Ionosphere and Its Relation To The Atmosphere

.. is the source for the ionosphere.

Sun's EUV rays ionize the neutral gas.





http://www.sws.bom.gov.au/Educational/1/2/5

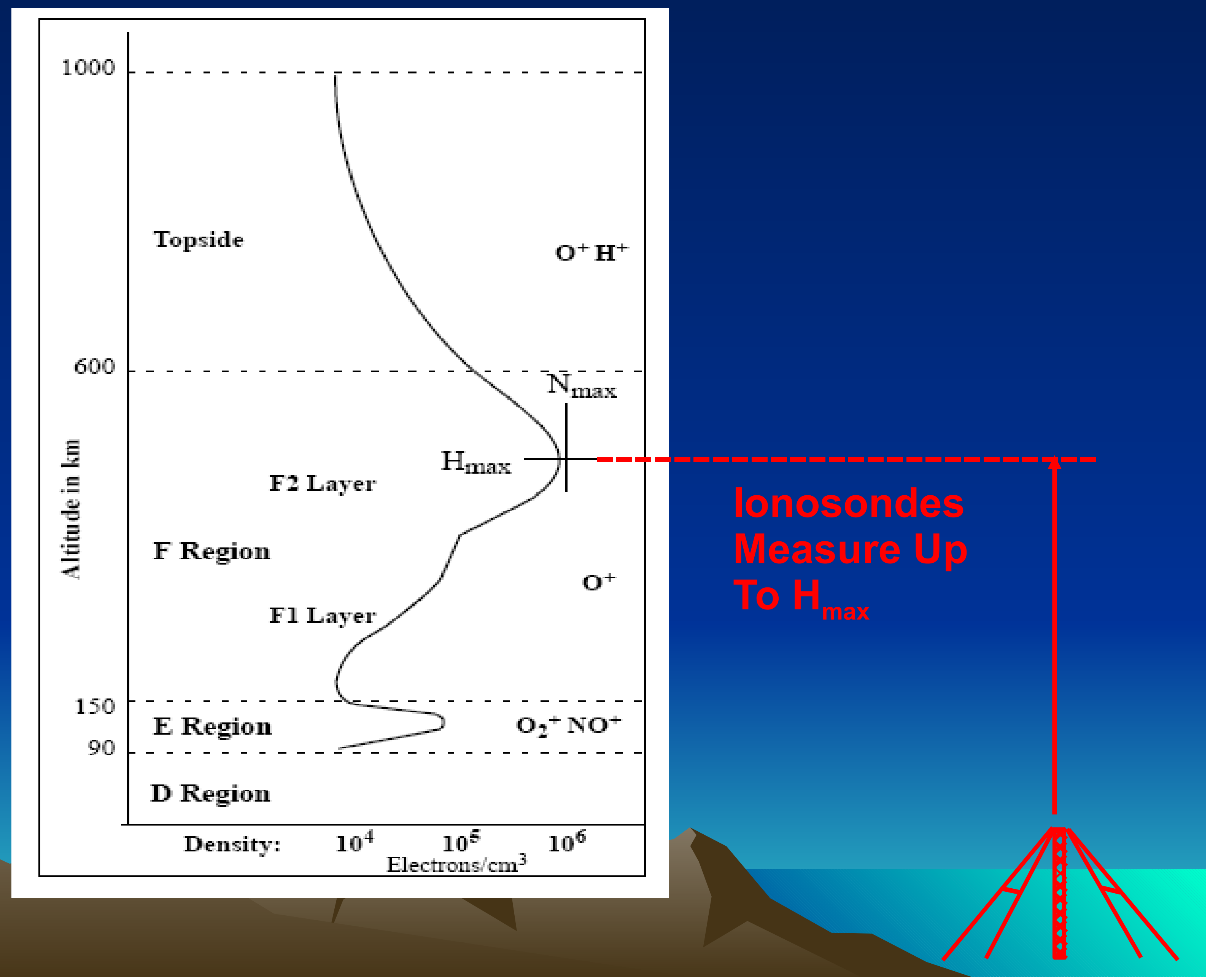
Ionosphere Vertical Structure

Ionosphere Vertical Electron Density Profile

The F2 region varies by 3-5X diurnally, highest just after noon, lowest before dawn.

The F1 region and E region dissipate at night.

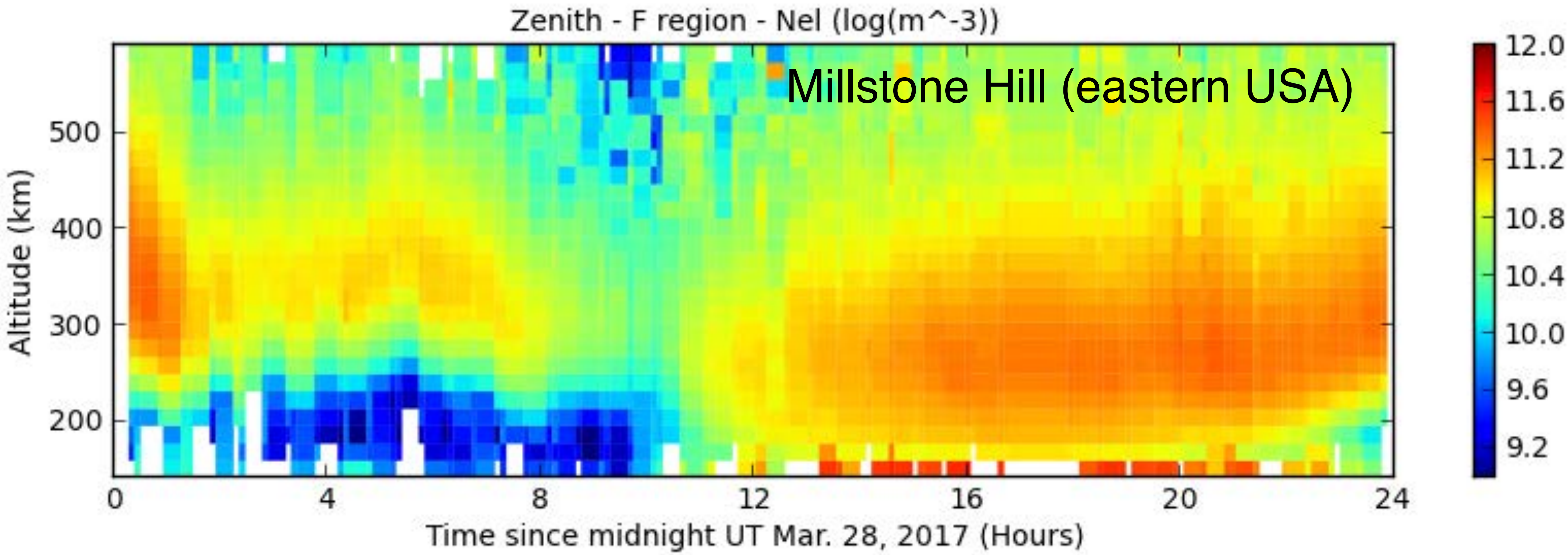
The D region is present only during daytime and in times of high activity.



(Terry Bullett)

Ionosphere Vertical Structure

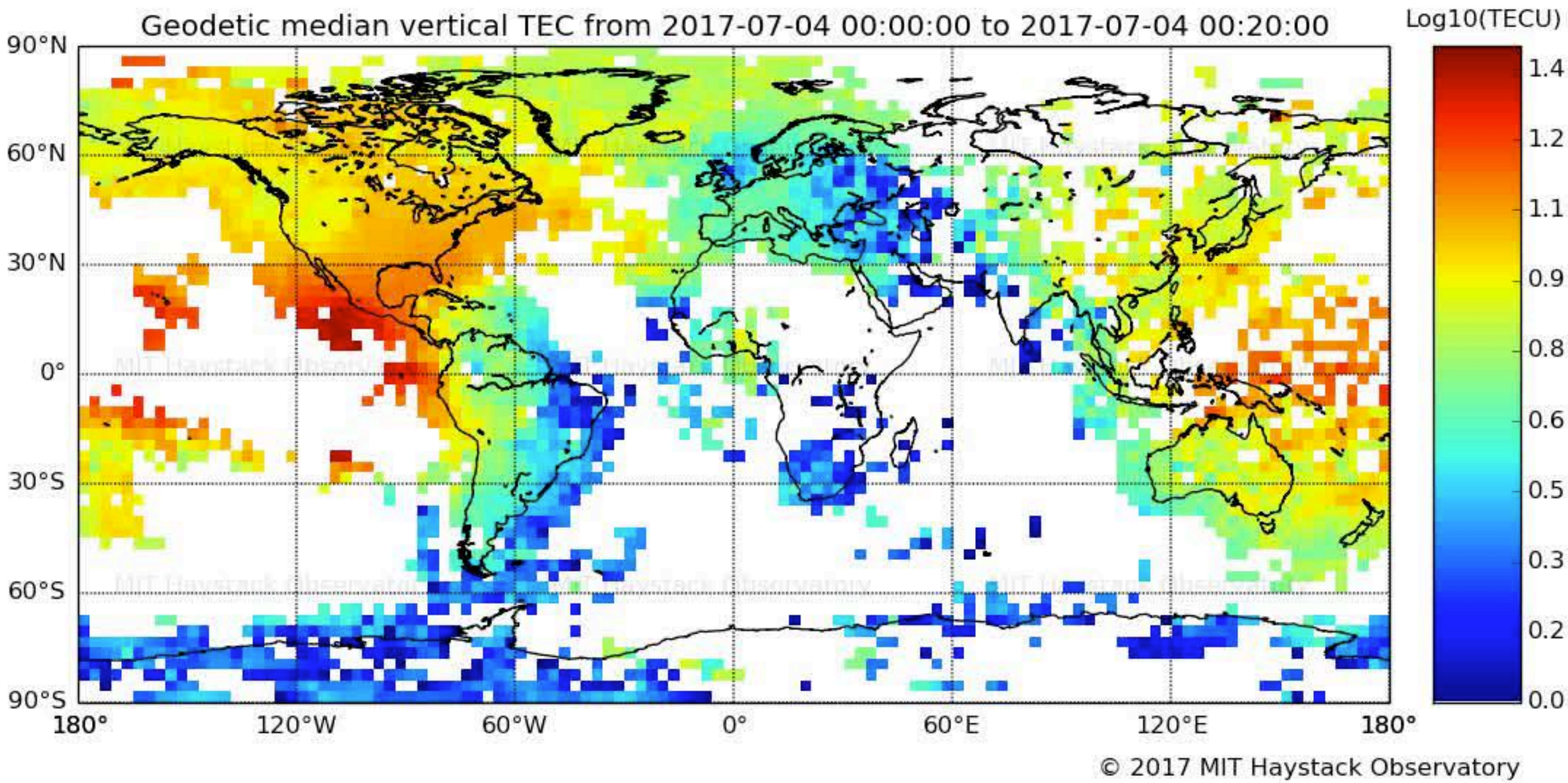
(red = more electrons, blue = less; log scale!)



Varies in Altitude: Space Weather

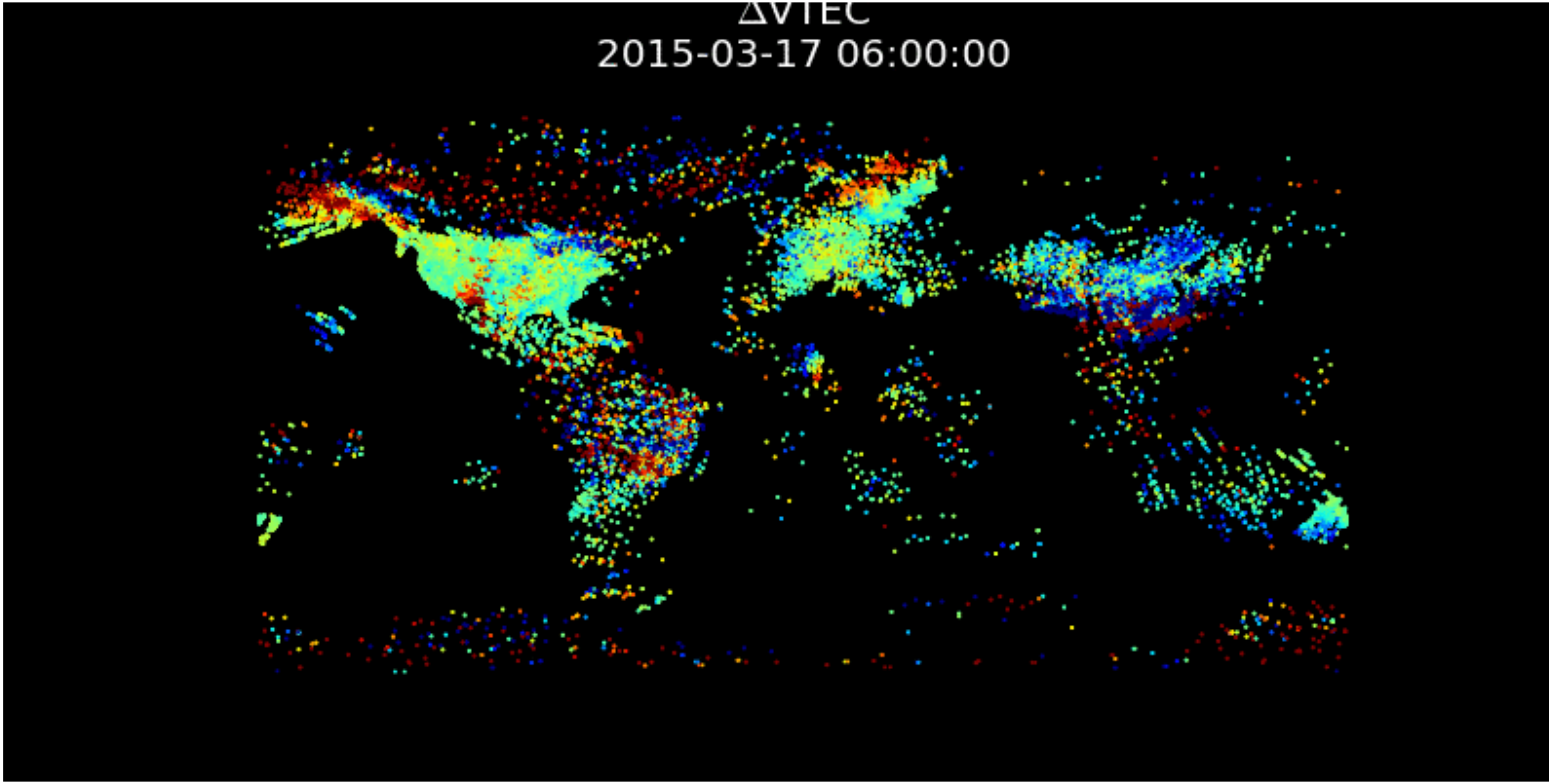
Ionosphere Horizontal Structure

(red = more electrons, blue = less; log scale!)



Varies in Space, Time: <u>Space Weather</u>

Ionosphere Has Lots of Traveling Waves



Vierinen, Rideout, Coster
MIT Haystack

Varies in Space, Time: Space Weather

Fundamental Equations: Production, Loss, Transport

SOLAR ECLIPSES AND IONOSPHERIC THEORY

H. RISHBETH

S.R.C., Radio and Space Research Station, Ditton Park, Slough, Bucks., England

(Received 1 March, 1968)

$$q(z) = [\text{density}]\,[\text{cross-section}]\,[\text{flux at z}] = n(z)\sigma[F_0 e^{-\tau(z)/\mu_0}],$$

$$\mathrm{d}N/\mathrm{d}t = E(t)\,q(t) - \alpha N^2 \quad \boxed{+\text{ transport}} \qquad \text{E layer}$$

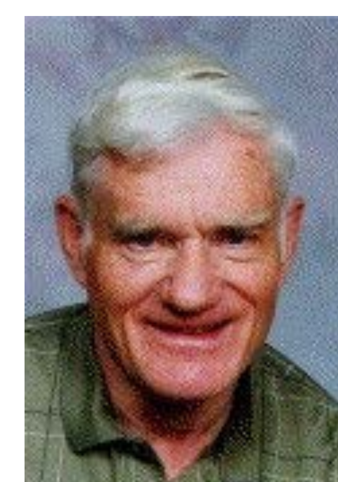
$$\mathrm{d}N/\mathrm{d}t = E(t)\,q(t) - \beta N \quad \boxed{+\text{ transport}} \qquad \text{F2 layer}$$

Eclipse obscuration function

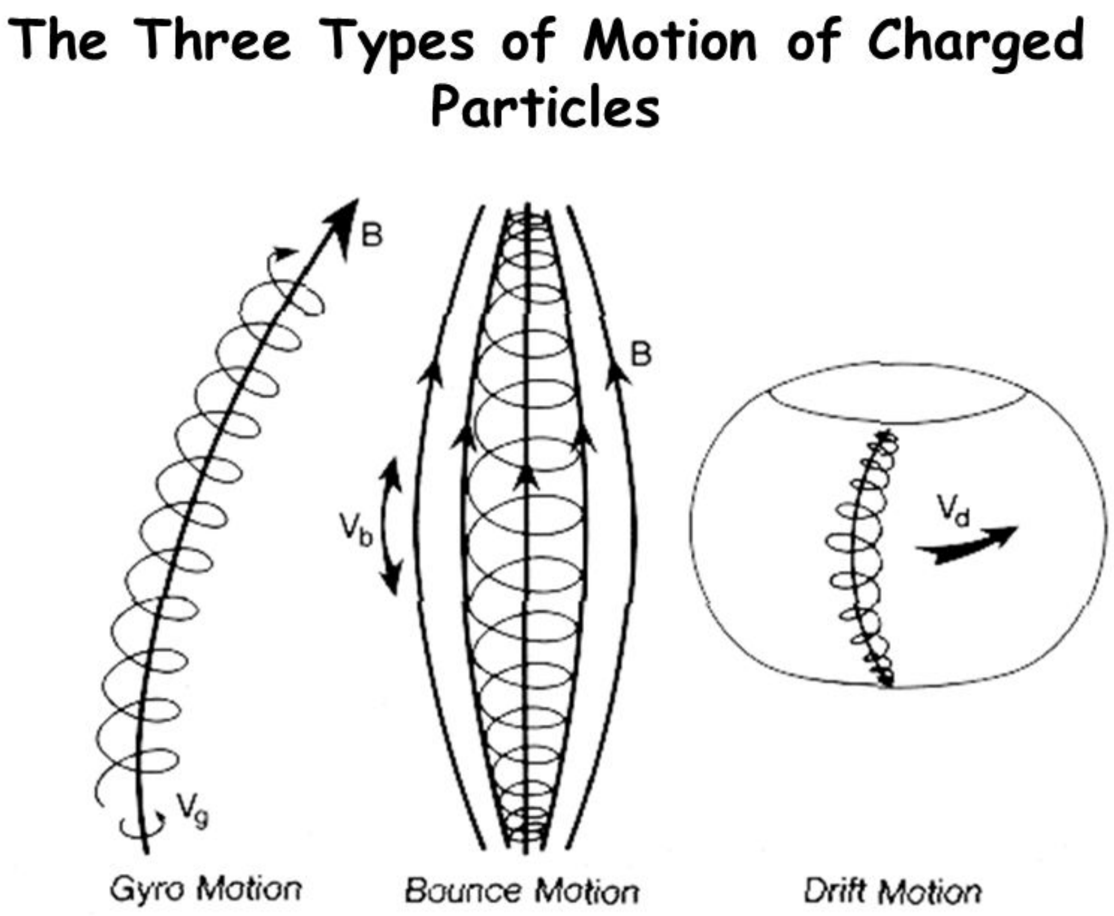
Normal production function

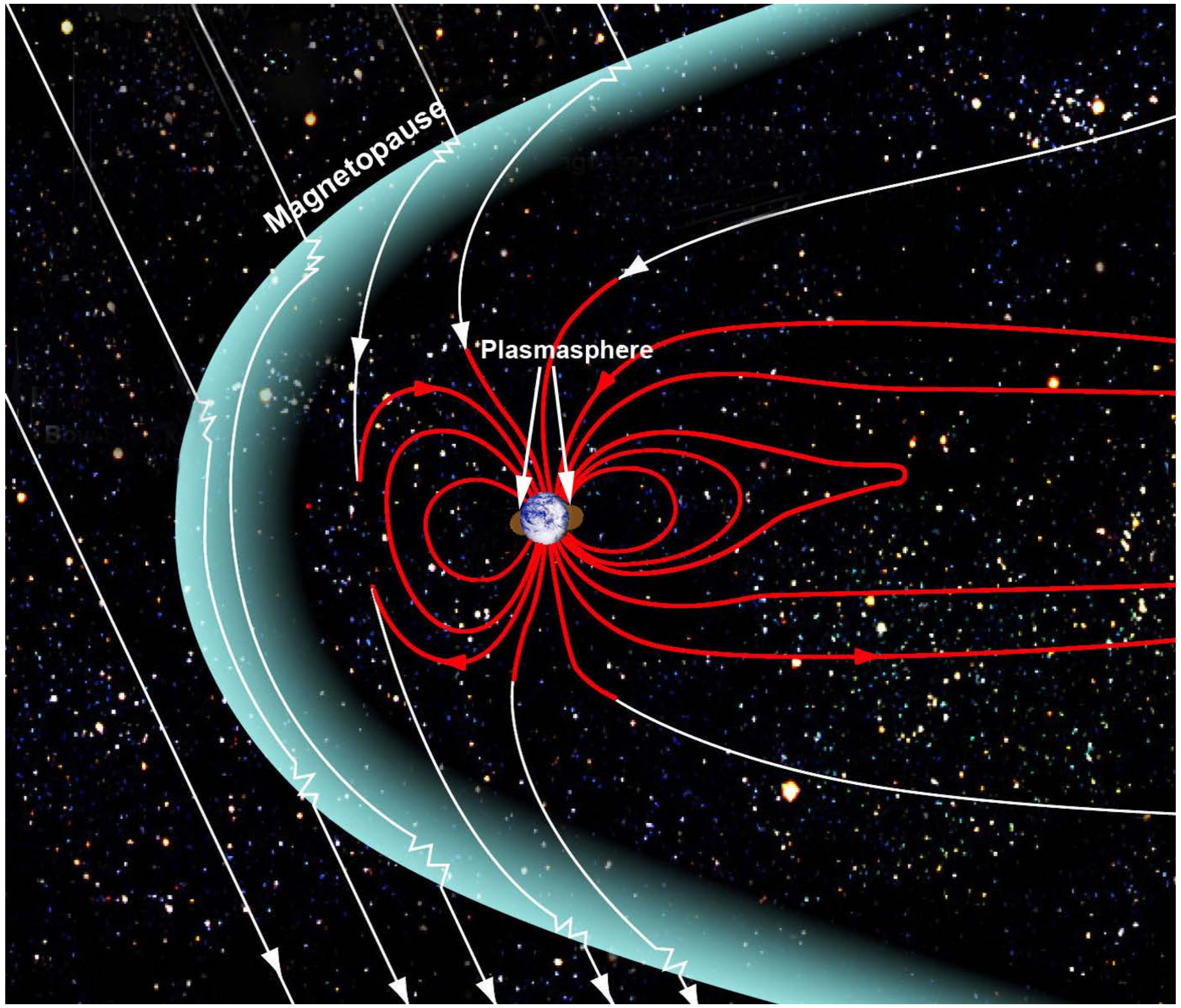
(TIDs, delayed response, etc.)

Observations during an eclipse offer a special opportunity for studying both the solar ionizing radiations and the earth's ionosphere. They are not ideal for this purpose. The ionospheric physicist might wish that the sun could be regarded as a constant, uniform source of ionizing radiation; but investigations of the sun show that it is not. The solar physicist would like to regard the ionosphere as a detector for ionizing radiation. But the ionosphere does not meet the basic requirements of a good detector: straightforward operation, reproduceability, and a linear or other convenient type of response.



Ionosphere Is Strongly Magnetized!





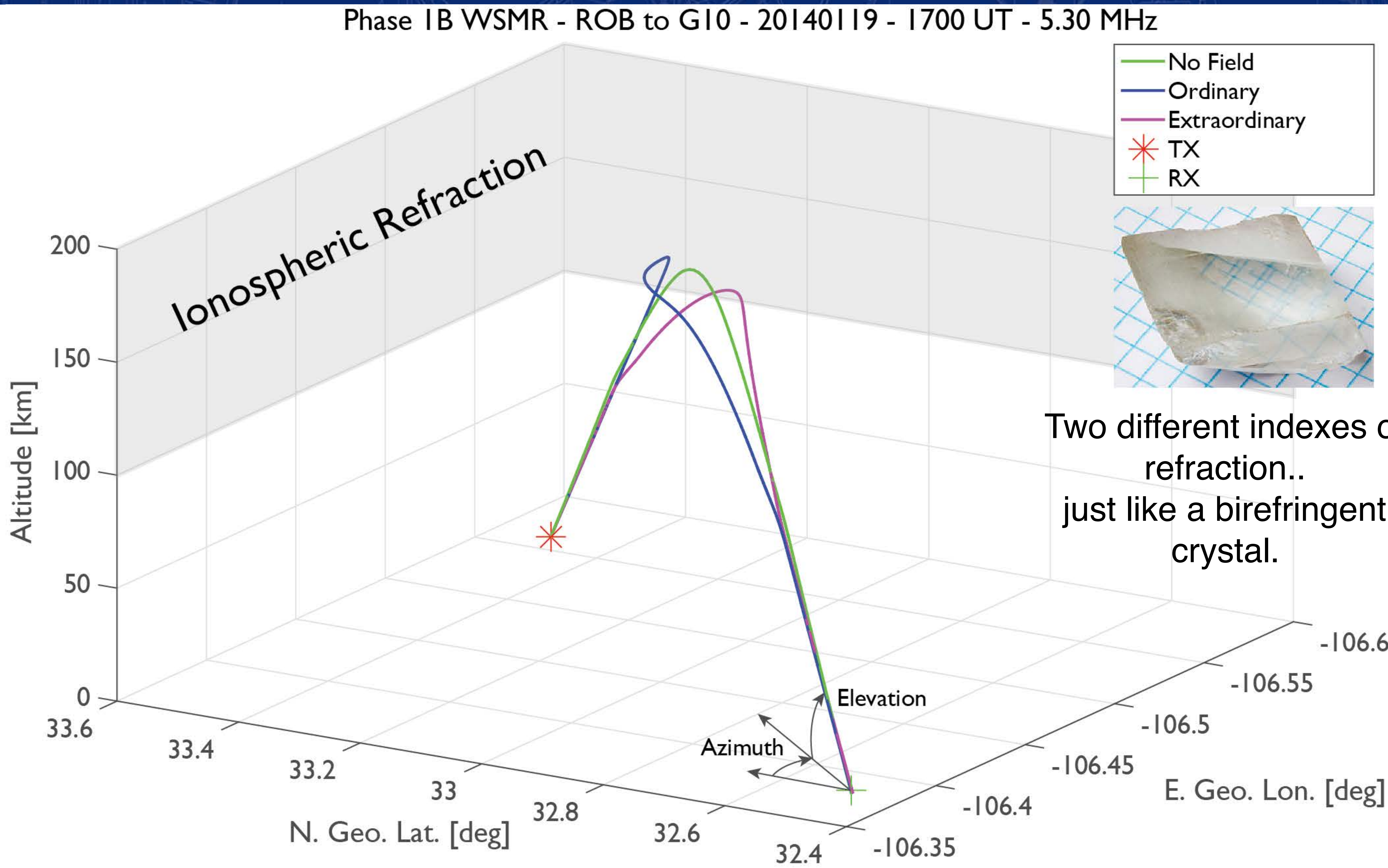
nasa.gov

Electrons cannot just go anywhere..
Gravity AND magnetic field direction are important

Study of this phenomena = **Magnetoionic Propagation**
This adds complexity to HF propagation predictions.

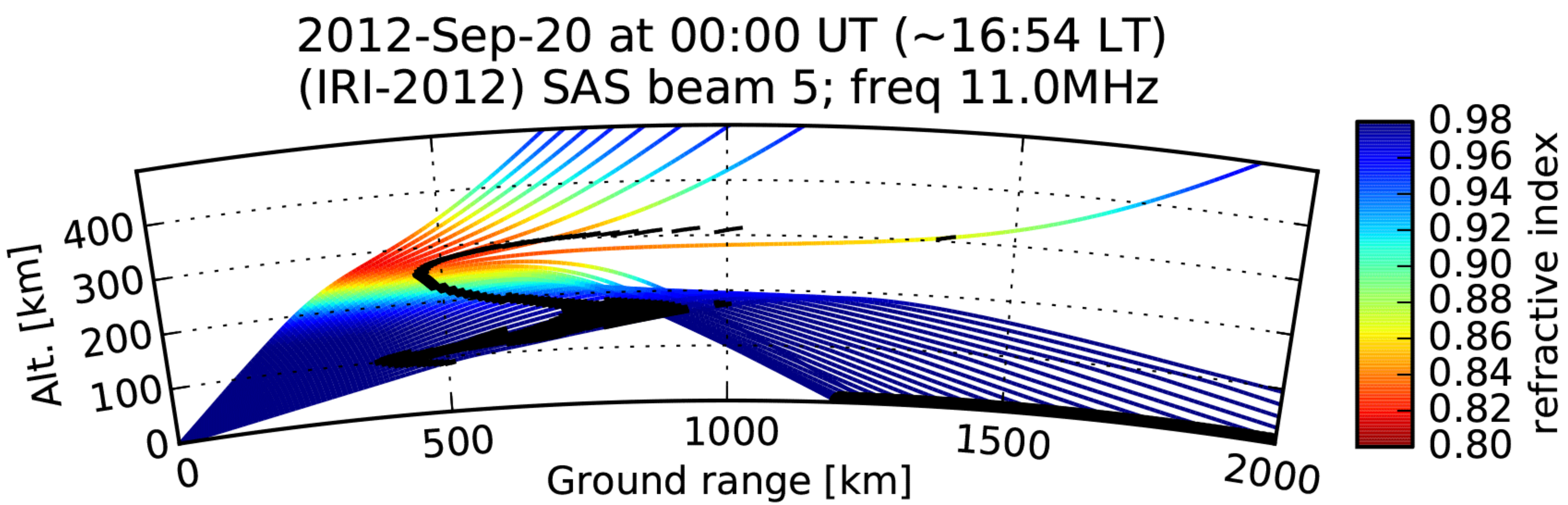
(Ethan Miller, JHU/APL)

Ionospheric Radio: Effects of Magnetic Field



Two different indexes of refraction..
just like a birefringent crystal.

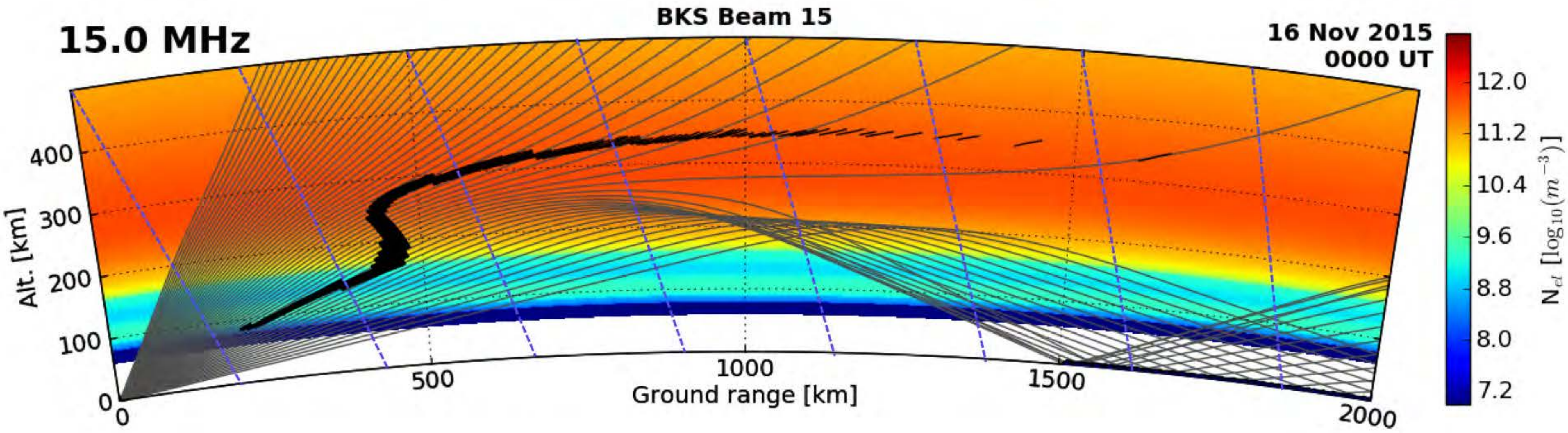
Ray-Tracing Shows Complexity of HF Paths

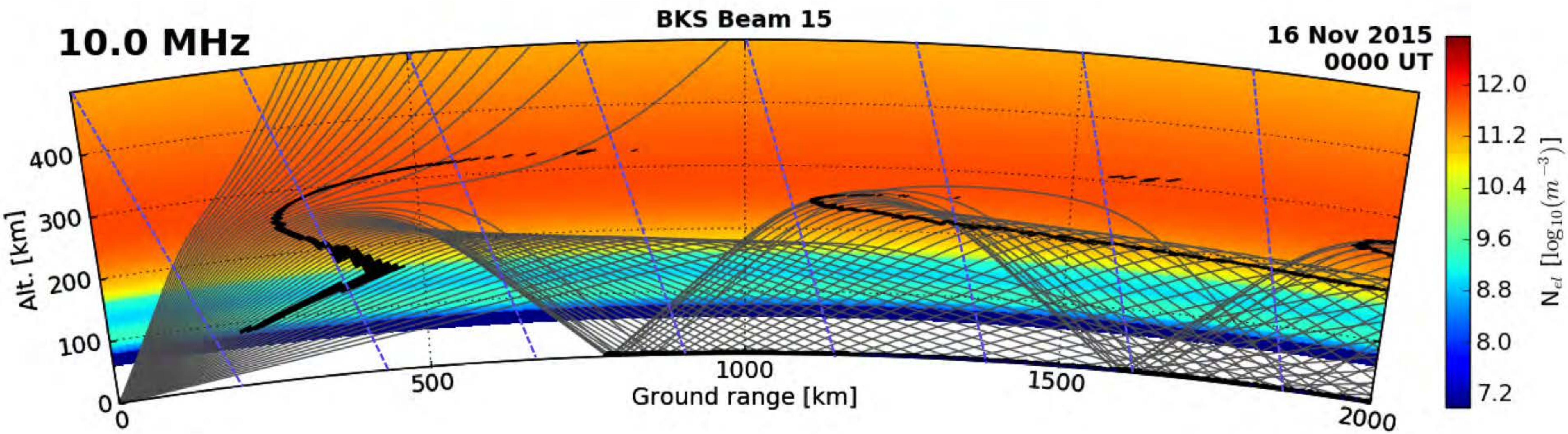


SuperDARN HF Radar Network

(J. M. Ruohoniemi)

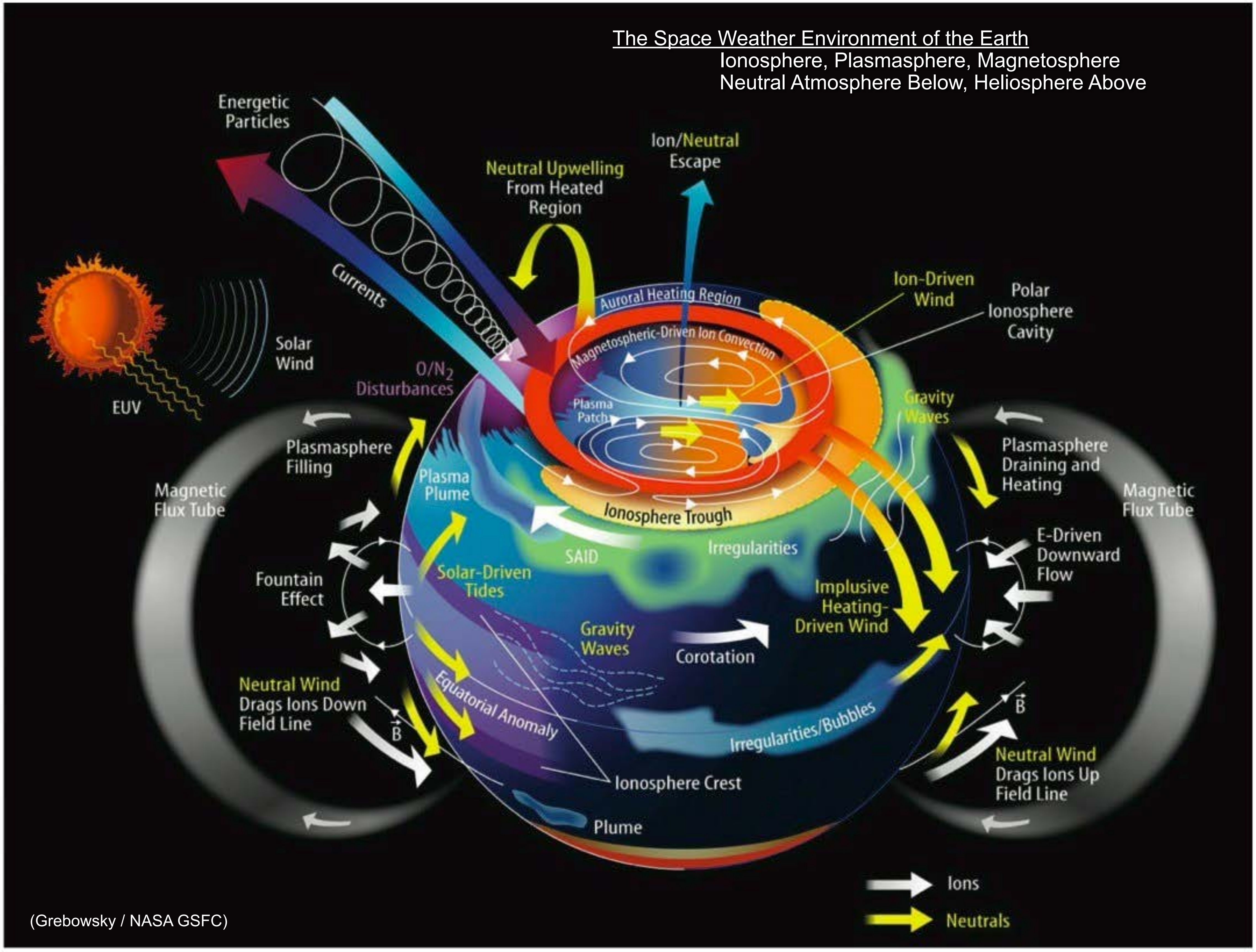
HF Propagation & The Ionosphere





nathaniel.a.frissell@njit.edu

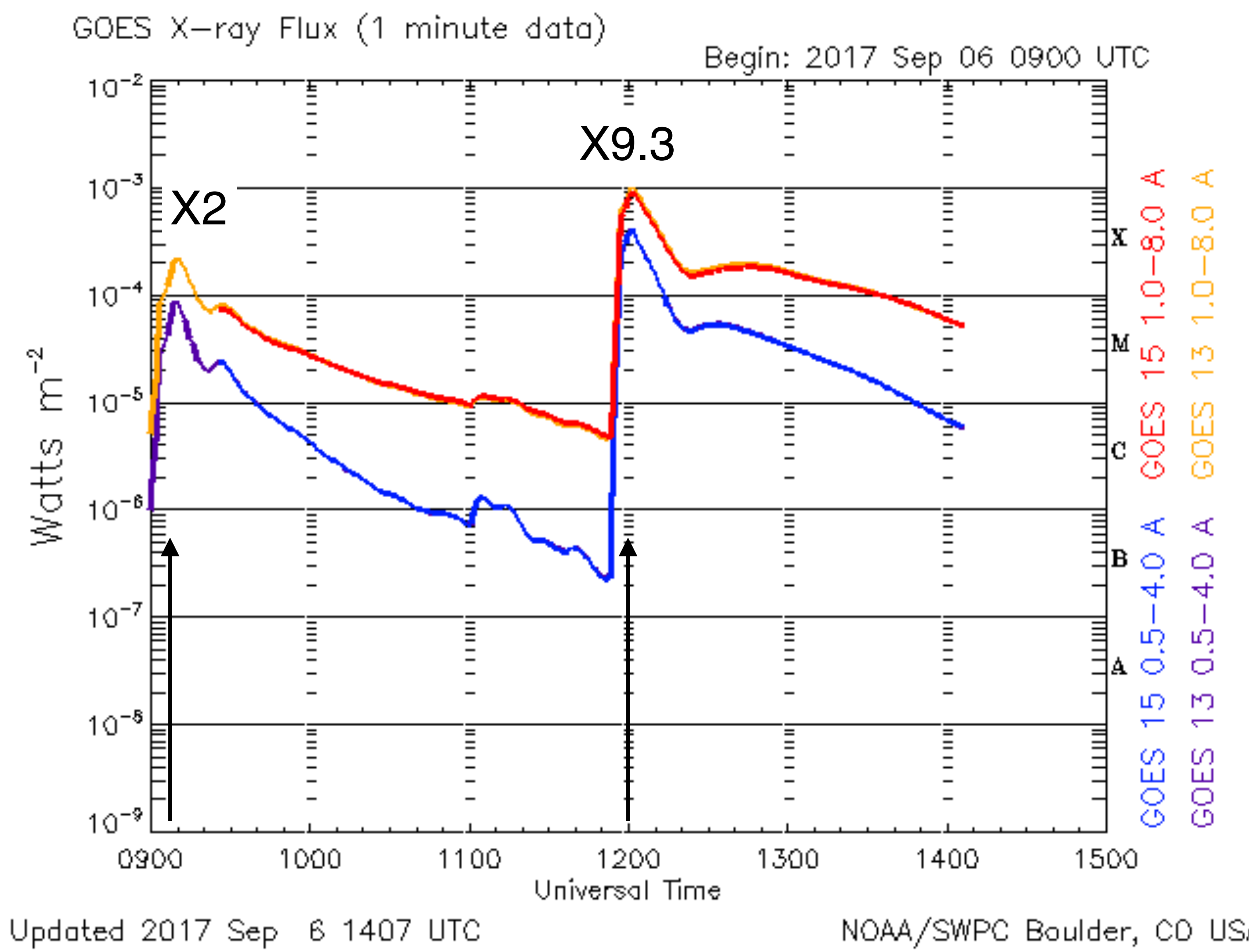
Geospace Environment: Complexity, Interconnectedness

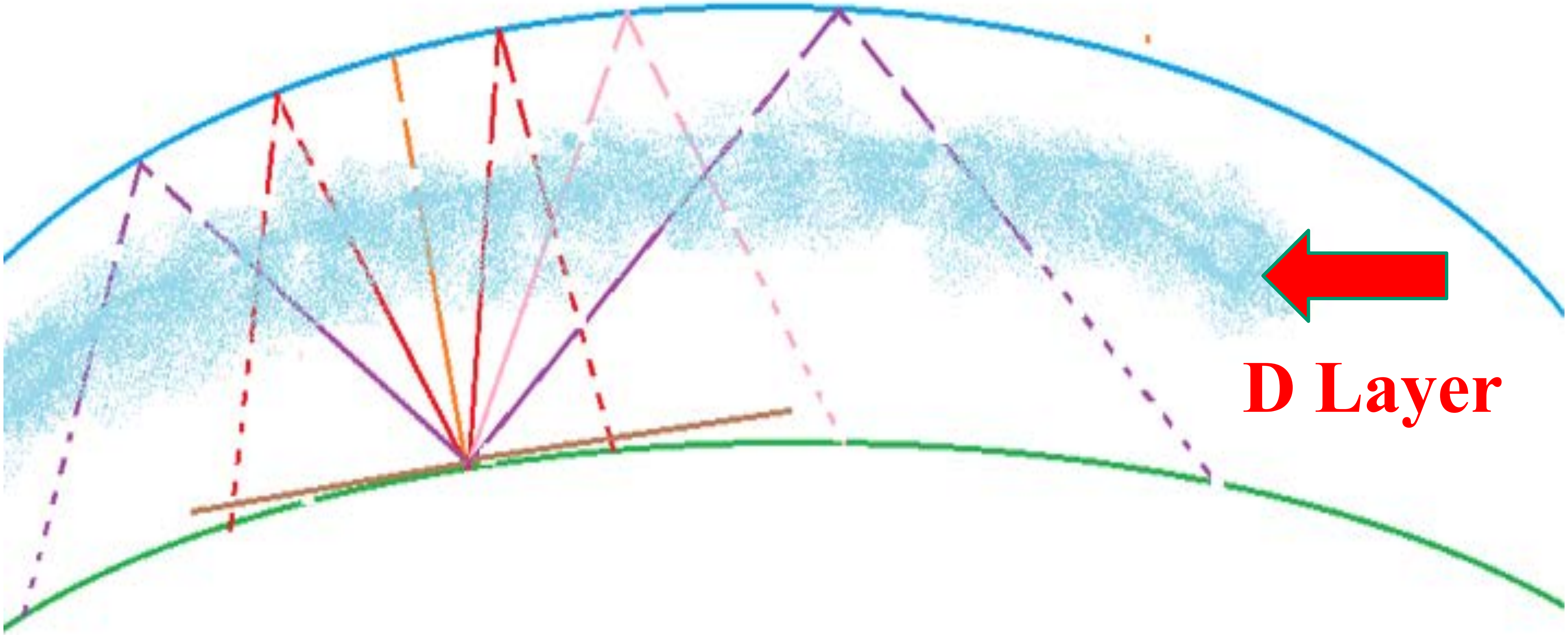


(Grebowsky / NASA GSFC)

Juicy Science Examples
(many more possible..)

2017-09-06 Solar Flares at Geosynchronous Orbit



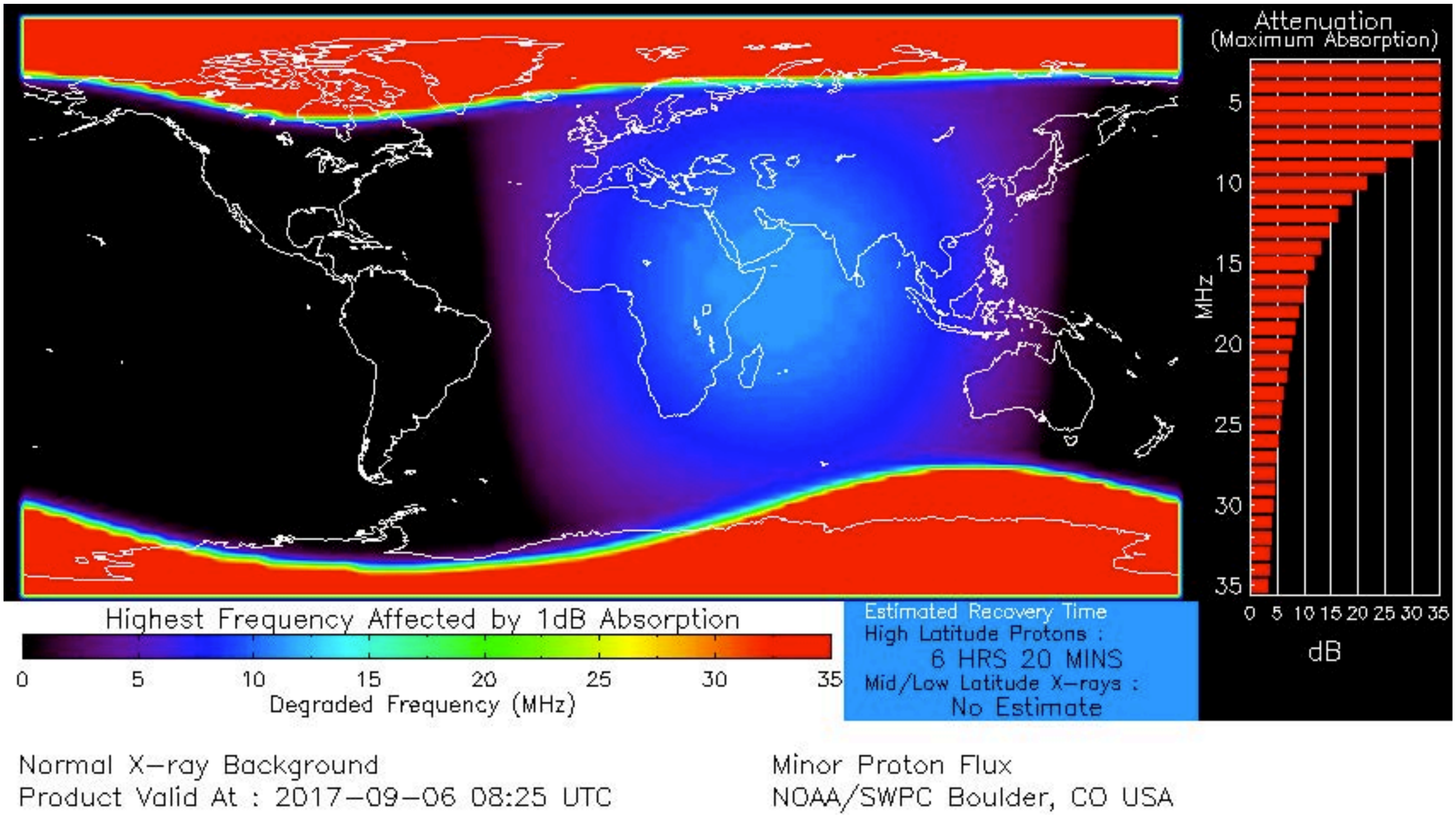


D Layer absorption affects lower freqs more than higher freqs.

Fades rapidly after sunset.

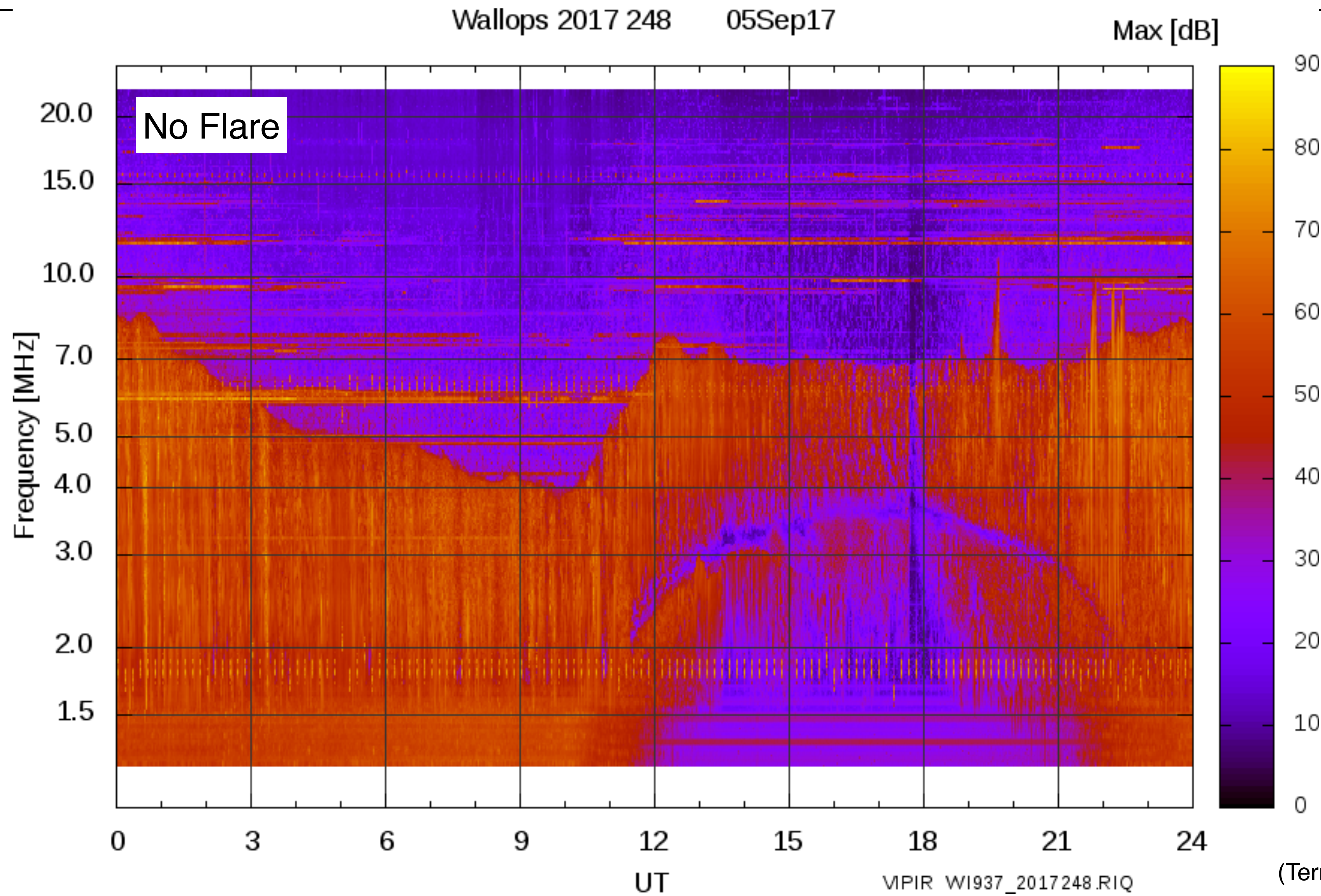
(Tom Carrigan, NE1R)

2017-09-06 Solar Flares: D Region Absorption



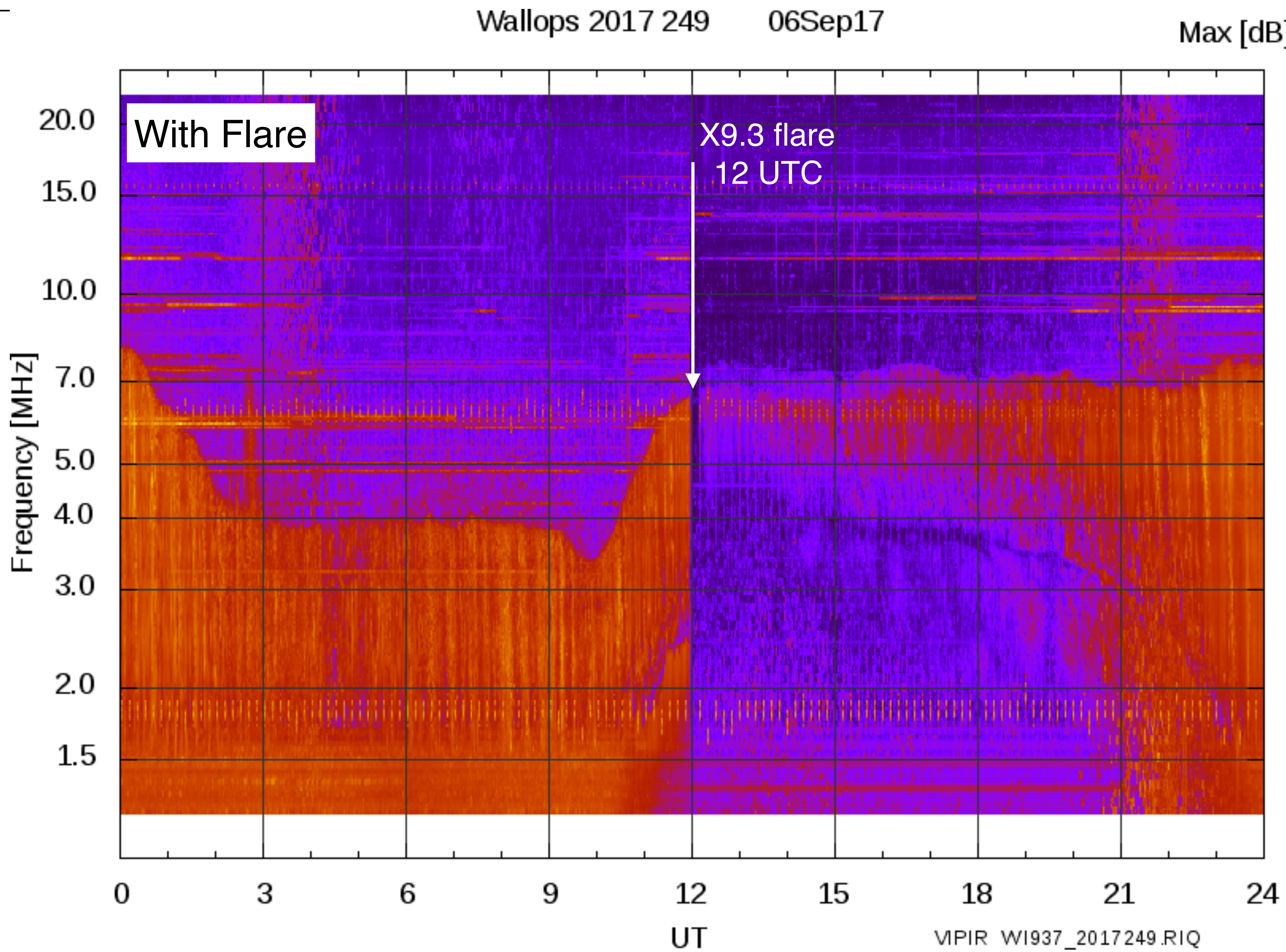
We need good worldwide coverage!

2017-09-05 Normal Conditions: Wallops, VA Ionosonde



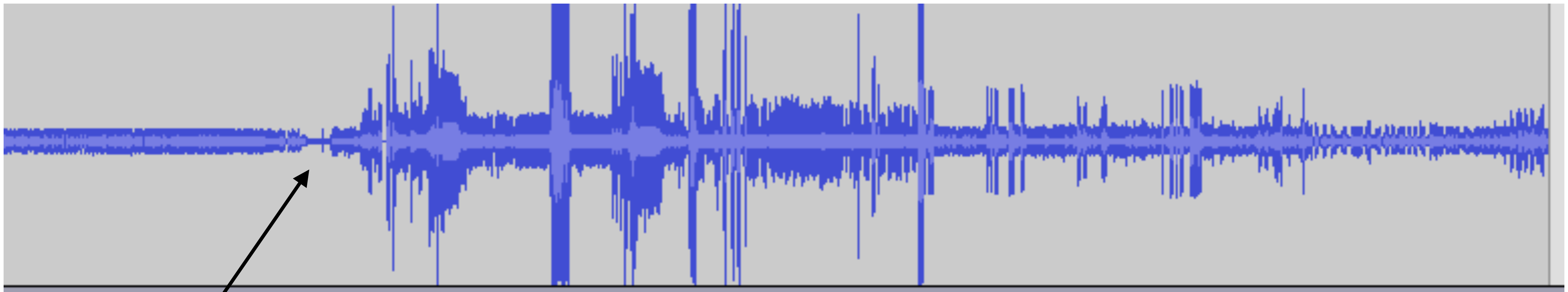
(Terry Bullett)

2017-09-06 Flare Effects: Wallops, VA Ionosonde



(Terry Bullett)

CW Contest Op Hears A Flare's HF Wipeout in Action..



X4.0 Solar Flare Arrival
at 1638 UTC

http://lists.contesting.com/archives//html/CQ-Contest/2009-12/msg00499.html

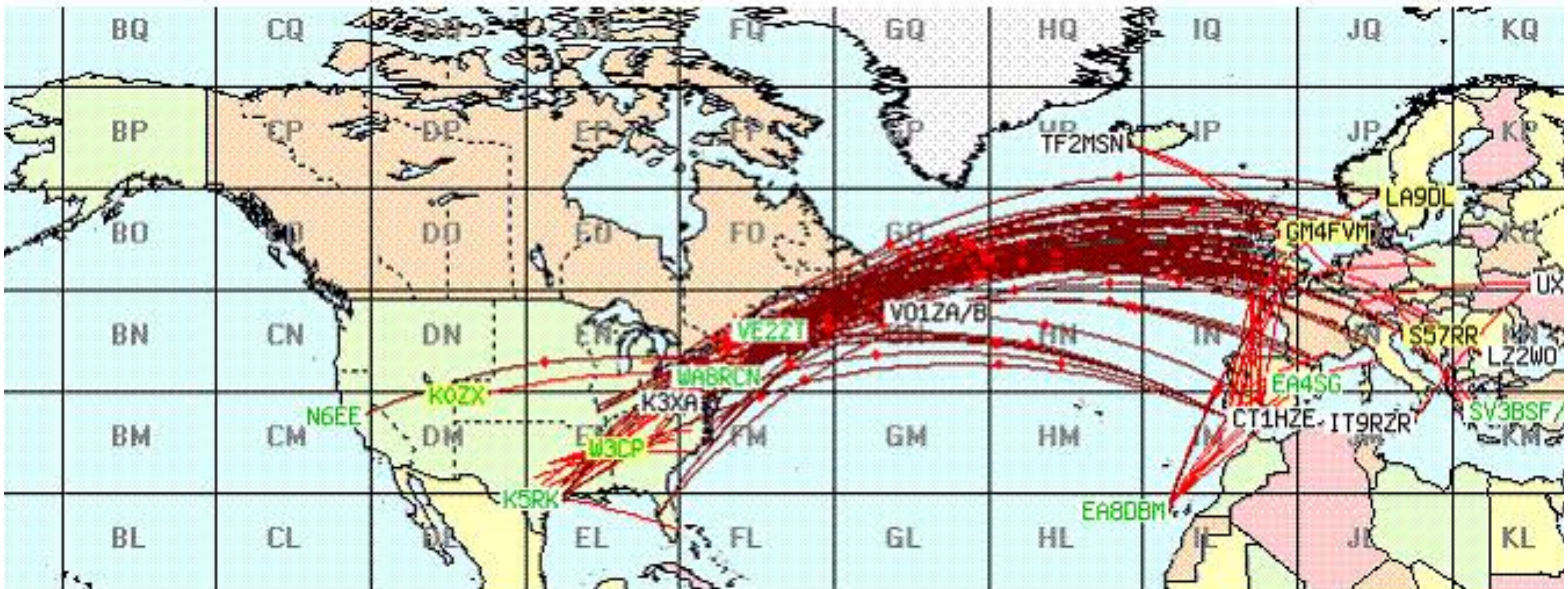
José Nunes, CT1BOH
(QTH = Portugal)

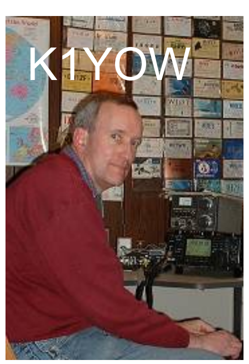
CQ WW CW contest
26 November 2000
1636 - 1702 UTC

Call = P40E at the time
QTH = Aruba

Joe Dzekevich K1YOW:
6 Meter VHF Connections to Tropospheric Weather

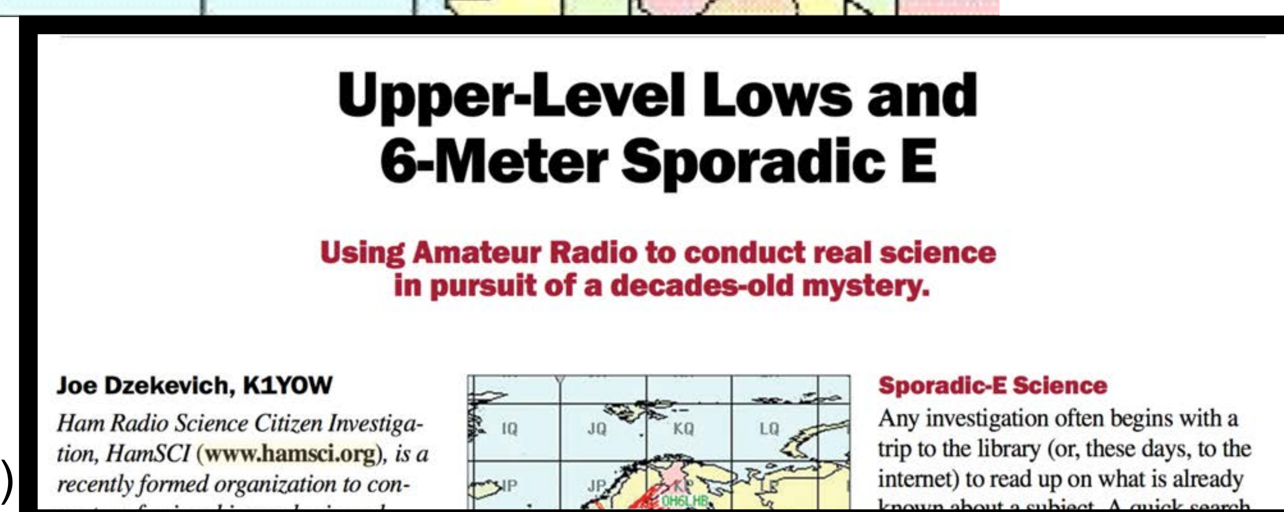
June 13, 2016 6 Meter Double Hop Trans Atlantic Es DX Map





The VHF Gods Were Smiling on us this Day!

(QST Dec 2017)



Upper-Level Lows and 6-Meter Sporadic E

Using Amateur Radio to conduct real science in pursuit of a decades-old mystery.

Joe Dzekevich, K1YOW

Ham Radio Science Citizen Investigation, HamSCI (www.hamsci.org), is a recently formed organization to con-

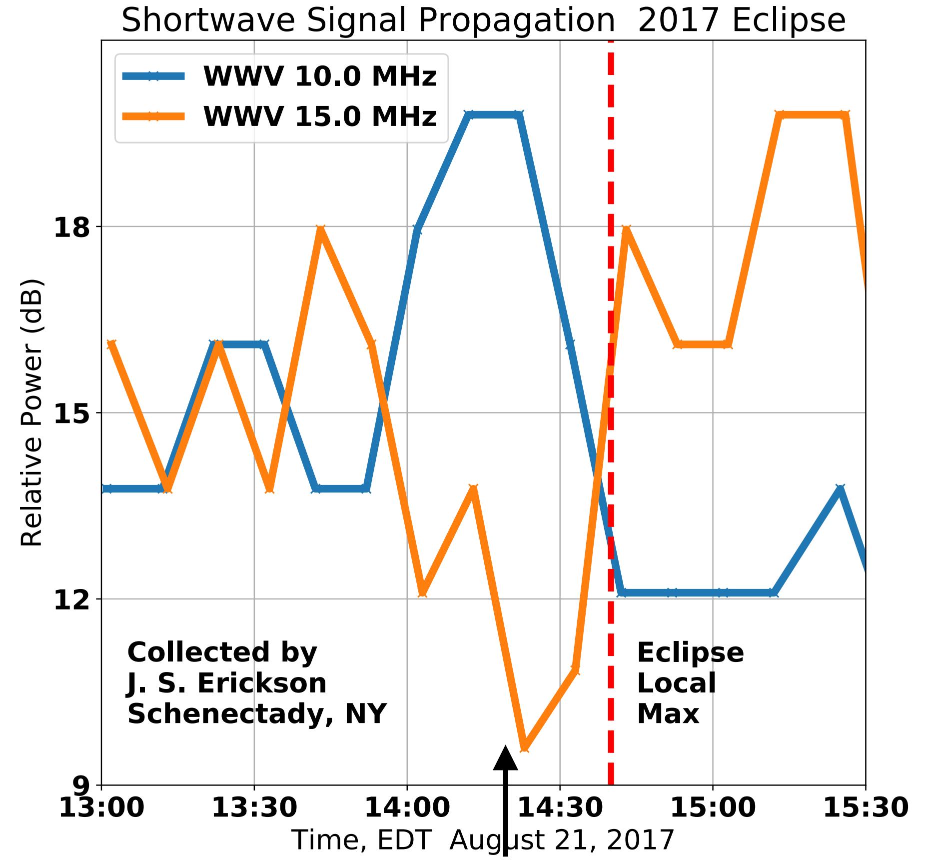
Sporadic-E Science

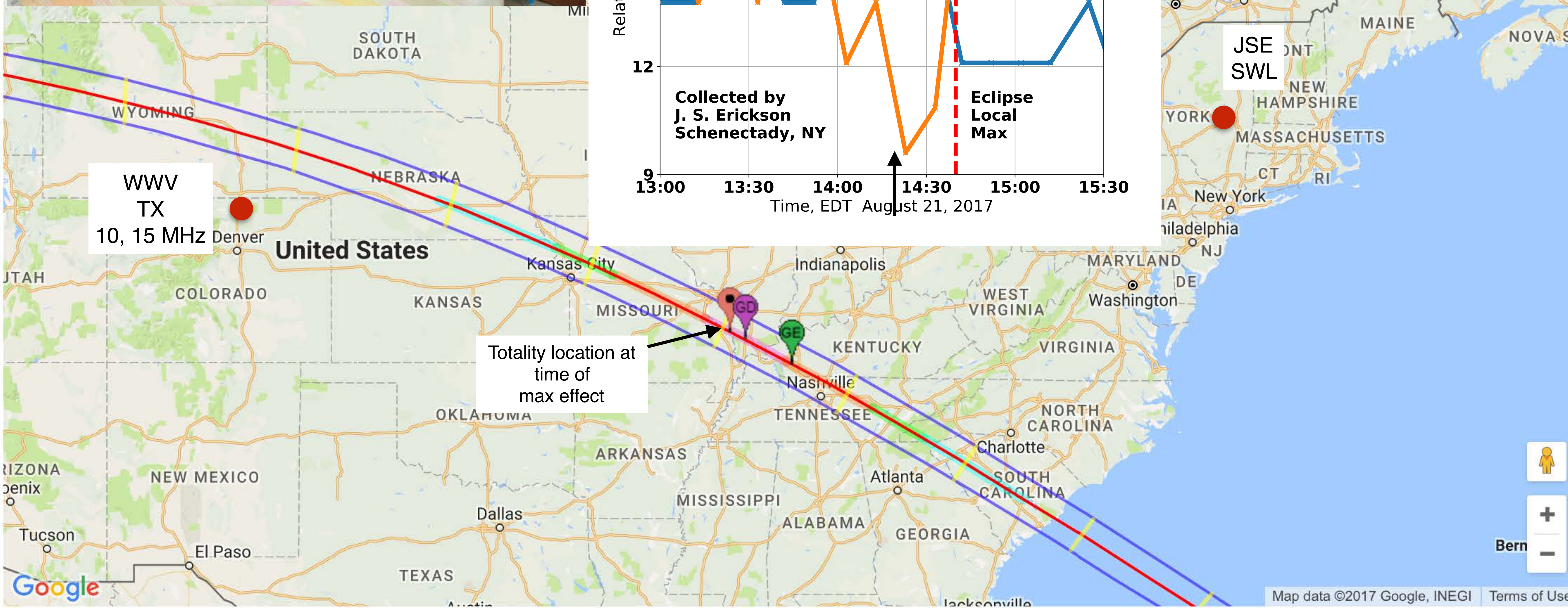
Any investigation often begins with a trip to the library (or, these days, to the internet) to read up on what is already

HamSCI
http://hamsci.org

Total Solar Eclipses

Citizen Science: SWL Eclipse Observations



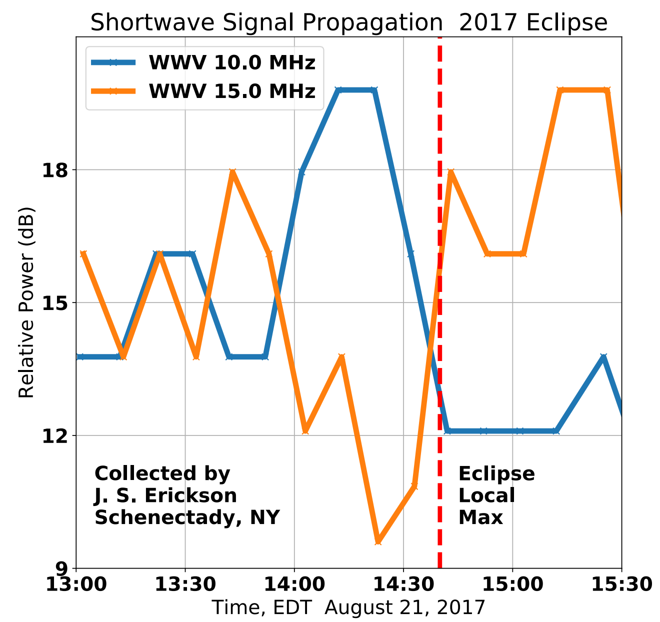


ARRL The national association for AMATEUR RADIO

NSF

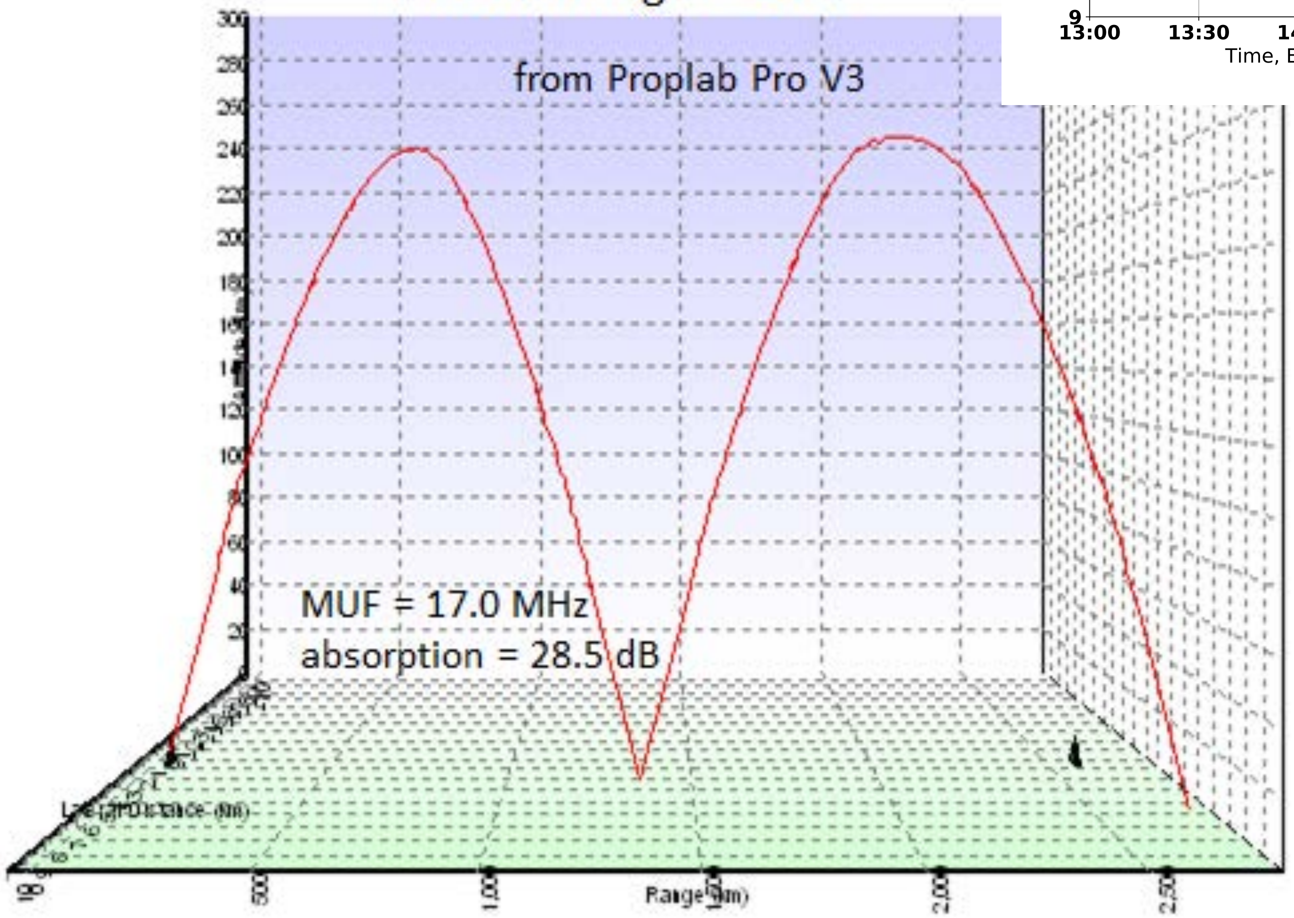
MIT HAYSTACK OBSERVATORY

Propagation Estimates (Carl Luetzelschwab K9LA)

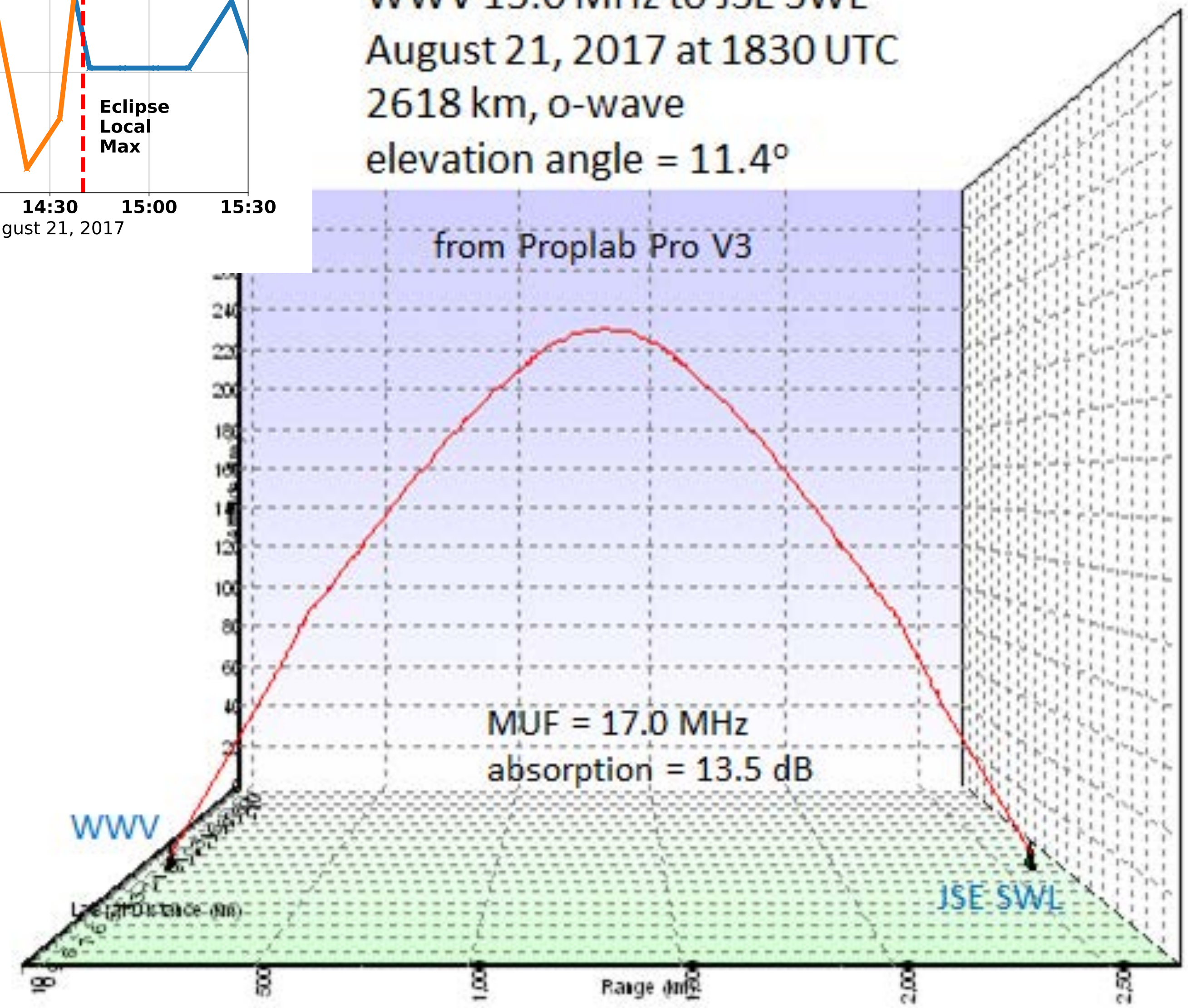


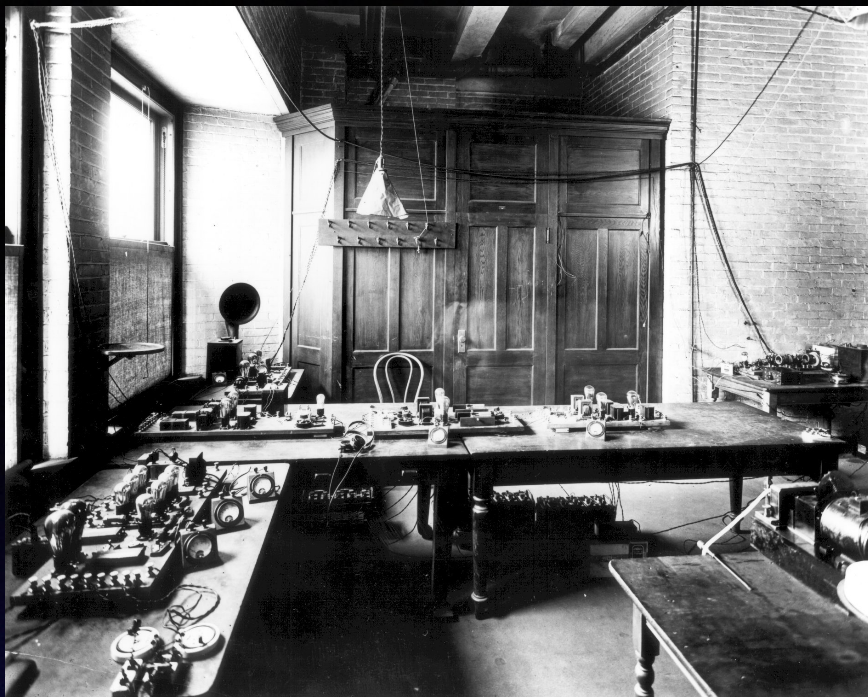
(non-eclipse ionosphere)

WWV 10.0 MHz to JSE SWL
August 21, 2017 at 1830 UTC
2618 km, o-wave
elevation angle = 26.0°



WWV 15.0 MHz to JSE SWL
August 21, 2017 at 1830 UTC
2618 km, o-wave
elevation angle = 11.4°





We are in an exciting discovery period

Remember (and mine) what has gone before

The following table lists the entrants in the finals:

Call	Location	Type	Wave	Cypher
1AFV	Salem, Mass.	C.W.	200	YLPMV
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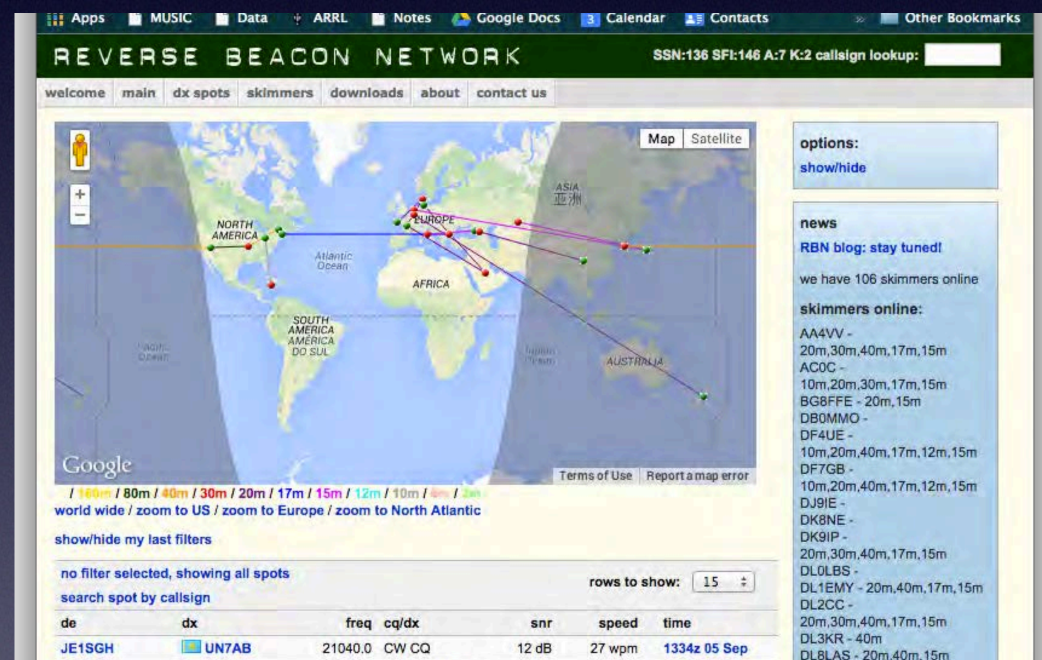
1AW	Hartford, Conn.	Spk.	210	DRWUF
1BCG	Greenwich, Conn.	C.W.	230	GODLY
2BML	Riverhead, L. I.	C.W.	200	FSXVG
2FD	New York City	C.W.	200	GTYWH
2FP	Brooklyn	C.W.	200	HUZXJ
2OM	Ridgewood, N. J.	Spk.	200	JVAYK
2EL	Freeport, L. I.	C.W.	200	KWBZL
3DH	Princeton, N. J.	C.W.	210	LXCAM
4GL	Savannah, Ga.	C.W.	200	MYDBN
3BP	Newmarket, Ont.	Spk.	200	NZFCO
8DR	Pittsburgh, Pa.	C.W.	200	OAGDP
9KO	St. Louis, Mo.	Spk.	200	PBHFQ
9AW	Toronto, Ont.	C.W.	200	QCJGR
1ZE	Marion, Mass.	C.W.	375	RDKHS
2ZL	Valley Stream, L. I.	C.W.	325	TGMKU
8ZO	Parkesburg, Pa.	C.W.	360	UHNLV
5ZZ	Blackwell, Okla.	Spk.	375	VJOMW
6XH	Stanford U., Cal.	C.W.	375	WKPNX
7ZG	Bear Creek, Mont.	Spk.	375	XLQOY
8XK	Pittsburgh, Pa.	C.W.	375	YMRPZ
9ZY	Lacrosse, Wis.	C.W.	260	RZQMY
9ZN	Chicago, Ill.	Spk.	375	ZNSQA
9XI	Minneapolis.	C.W.	300	SFLJT



Think about best tool use for science results

Great geospace science awaits.

Thanks.

pje@haystack.mit.edu