RADIO PROPAGATION FROM NO DATA TO BIG DATA

Neville Palmer

100 YEARS AGO THIS DECEMBER!

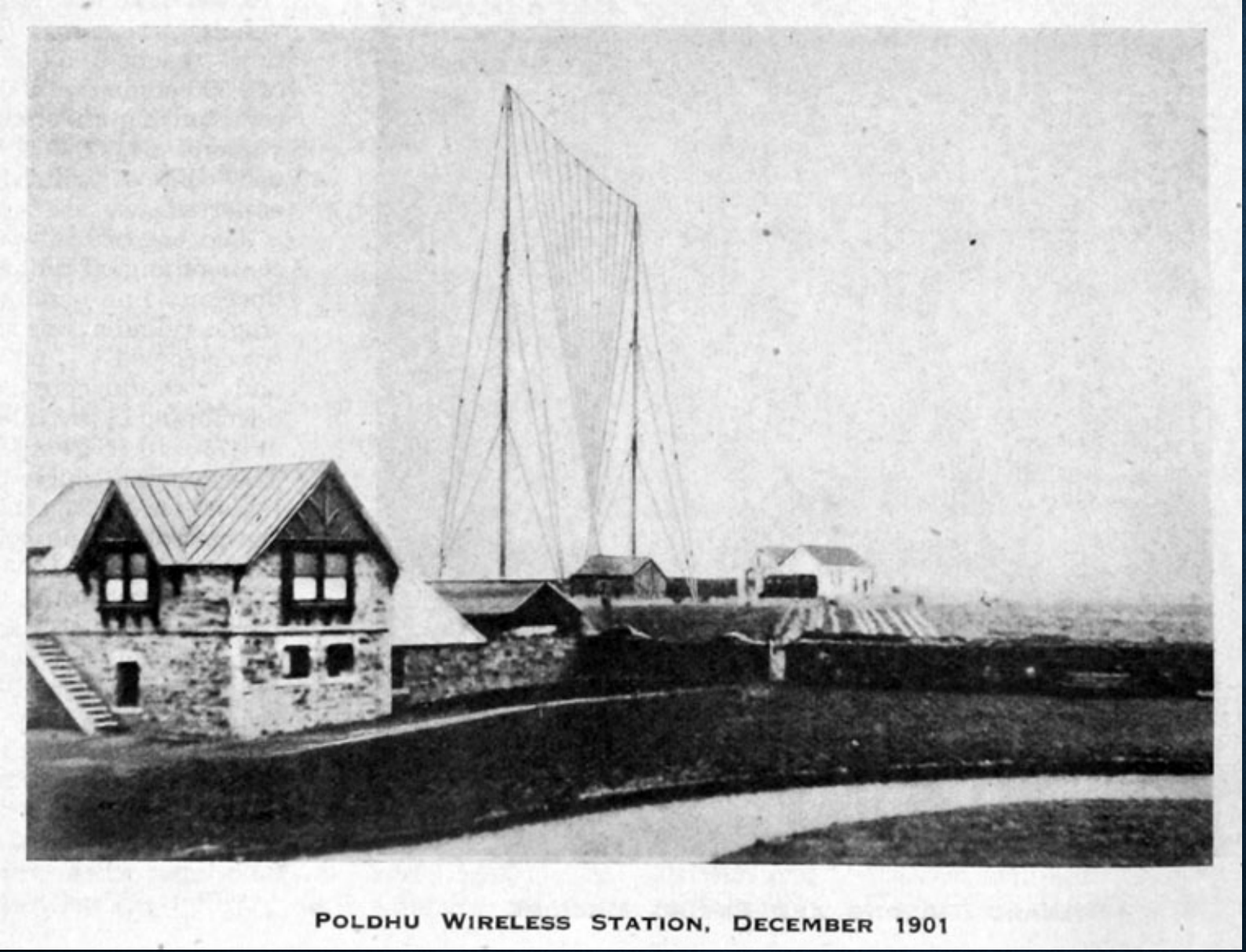
- Reception of High Frequency signals from across the Atlantic
- Started step change in understanding of radio propagation
- Today:
  - Prediction software
  - Digital techniques
  - Automated data gathering
  - Research
    - Propagation
    - Solar activity

1900

- Little data about radio propagation
- Transatlantic wireless believed impossible

Marconi disagreed!

POLDHU, CORNWALL, 1901



POLDHU WIRELESS STATION, DECEMBER 1901

Transmitter about
10 to 12 kW
On about 500kHz

Antenna:
50 wire fan between two
61m masts

- The original 20 mast array fell down in a storm!

ST. JOHN'S, NEWFOUNDLAND, 1901

Marconi's Atlantic leap!

Kite receiving antenna

Received three dots (letter S) on 12th December

(Bussey, 2001)

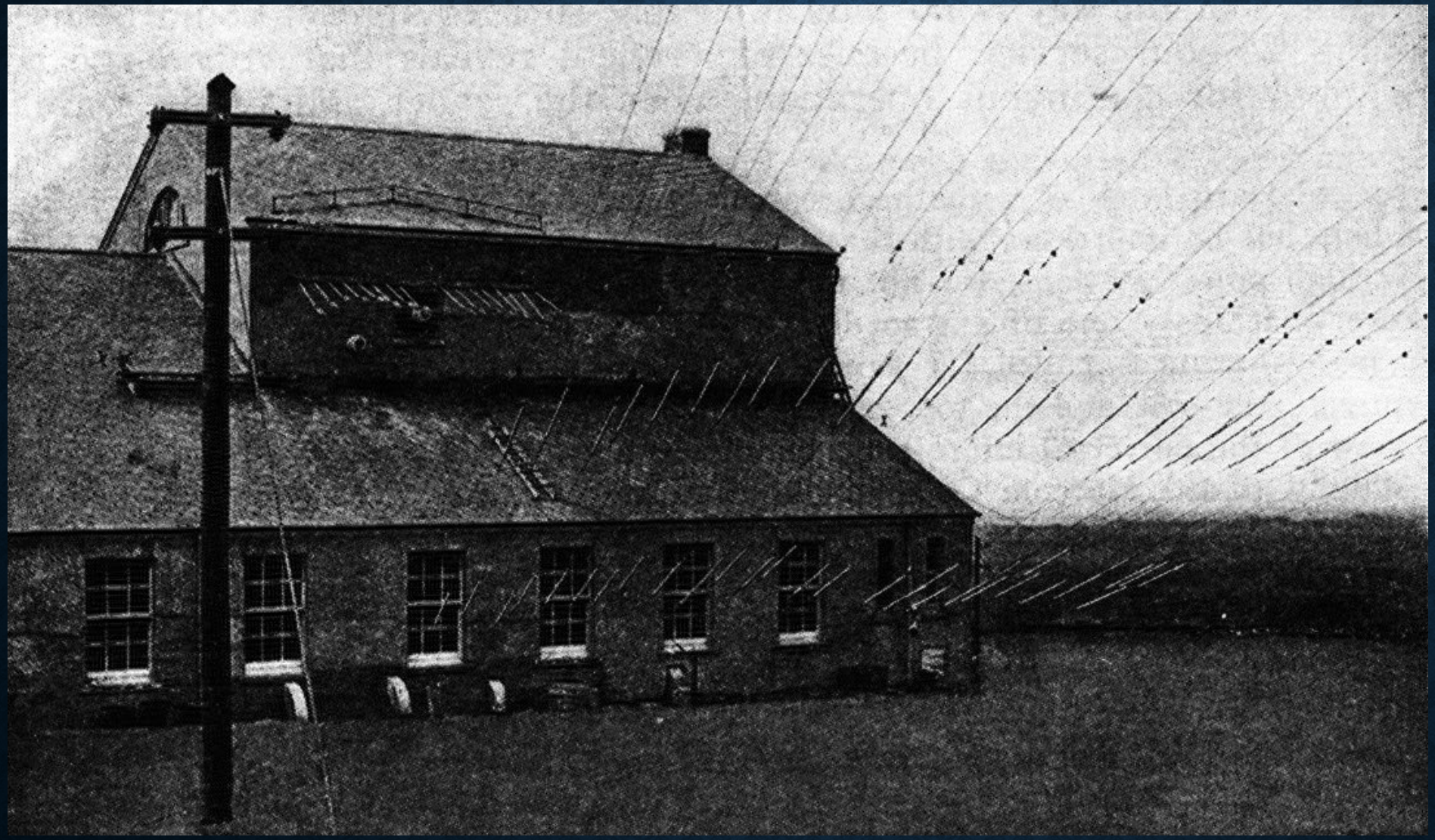
HEAVISIDE IN UK AND KENNELLY IN USA

- 1902
- Predict that Marconi's Atlantic signals must be due to unseen reflective layer in the upper atmosphere
- Named Kennelly-Heaviside layer

FURTHER TESTS

- December 1902 – first message from Glace Bay, Nova Scotia to Poldhu
- Commercial radio system
  - Clifden, Ireland to Glace Bay, Nova Scotia – 1907
- Jointly awarded Nobel Prize for Physics in 1909

CAERNARFON, WALES – TRANSATLANTIC STATION – 1916 – CALL "MUU"



1,200 metre antenna fed by 36 wires

Power: 200 kiloWatts (considered low power) On 21 kHz

Wavelength 14 km - Ideal antenna length 3.5 km!

For two way transmissions between UK – Canada/USA

(Wikepedia, 2021a)

(Bull, 2018)

CAERNARFON TO SYDNEY - 1918

- 22nd September 1918
- Edward Fisk
- receives first wireless messages direct from UK
- signals weak and only audible at certain times

Amalgamated Wireless Australasia (AWA) builds first direct two way low frequency wireless communications system to UK

Receiving antenna - Sydney

(Naval Historical Society of Australia, 2018)

POST WW1

- 1919 - amateur radio activity resumes
- Amateurs allocated commercially useless frequencies below 200 metres (1500 kHz)
  - in today's medium wave broadcast band
  - Maximum 1kW (in USA)
- Most operated close to 1500 kHz
  - Shorter range on higher frequencies (shorter ground wave)
  - Difficult to transmit on higher frequencies

Noticed: Longer range at night (and winter)

Q. Would it be possible to span the Atlantic even at these frequencies?

(RSGB, 2021)

VEALS FARM 1557 KHZ

- Local radio transmitter
- Near Hythe
- 500 Watts on 1557 kHz
- Serves Southampton and New Forest up to 15 miles

Heard From America?

FEBRUARY 1921

- UK amateurs listened for 25 active US transmitters
  - Nothing heard
  - Too much interference!

NOVEMBER 1921

- ARRL sends Paul Godley, 2ZE to UK
- Expert radio systems engineer
- On SS Aquitania
- Assistance of Marconi Company
- To Ardrossan, Scotland
  - Quiet location
- Latest superheterodyne receiver
- “Beverage antenna” – 1300 ft long wire

12TH DECEMBER 1921

- Success!
- USA received during the night
- Special codes confirm reception
- Sent via Marconi station at Caernarfon to USA

WHAT OF TWO WAY COMMUNICATION?

- 1923: In France Leon Deloy, 8AB, uses shorter wavelength 100m (3 MHz)
- Easily made two way contact with USA!

Finding:

- Shorter wavelengths and higher frequencies give greater range more reliably!
- With less power
- Smaller antennas (shorter wavelength)

Those useless short waves weren't so useless after all!

MARCONI 1923 -24

- Yacht Elettra
- Conducted short wave tests at sea
- Successful!
- Opened Beam Wireless Service for GPO:
  - Bodmin to Canada 1926
  - Bodmin to Australia 1927

All the low frequency high power stations – scrapped!

1924

- 1922 Medium wave broadcasting starts
- Edward Appleton at Rutherford lab notices that medium wave transmissions from Bournemouth are constant during the day, but fade up and down at night
- Must be two paths!
- Proves by measurement that there is a "sky wave" refracted from an unknown layer – E layer
- Higher layers are responsible for long range propagation – F layers
- Ionised layers – solar radiation

Awarded Nobel Prize

Heaviside and Kennelly were right!

Method of reflecting radio waves from ionosphere later used by Watson-Watt to invent Radar!

PROPAGATION PREDICTION

- Slowly data is gathered over many years
- Varies due to:
  - Time of day
  - Season
  - Distance
  - Frequency
  - Solar activity
    - Sunspots and cycle (11 years)
    - Solar wind
    - Solar flares (disruptive)

PREDICTION AND DATA GATHERING

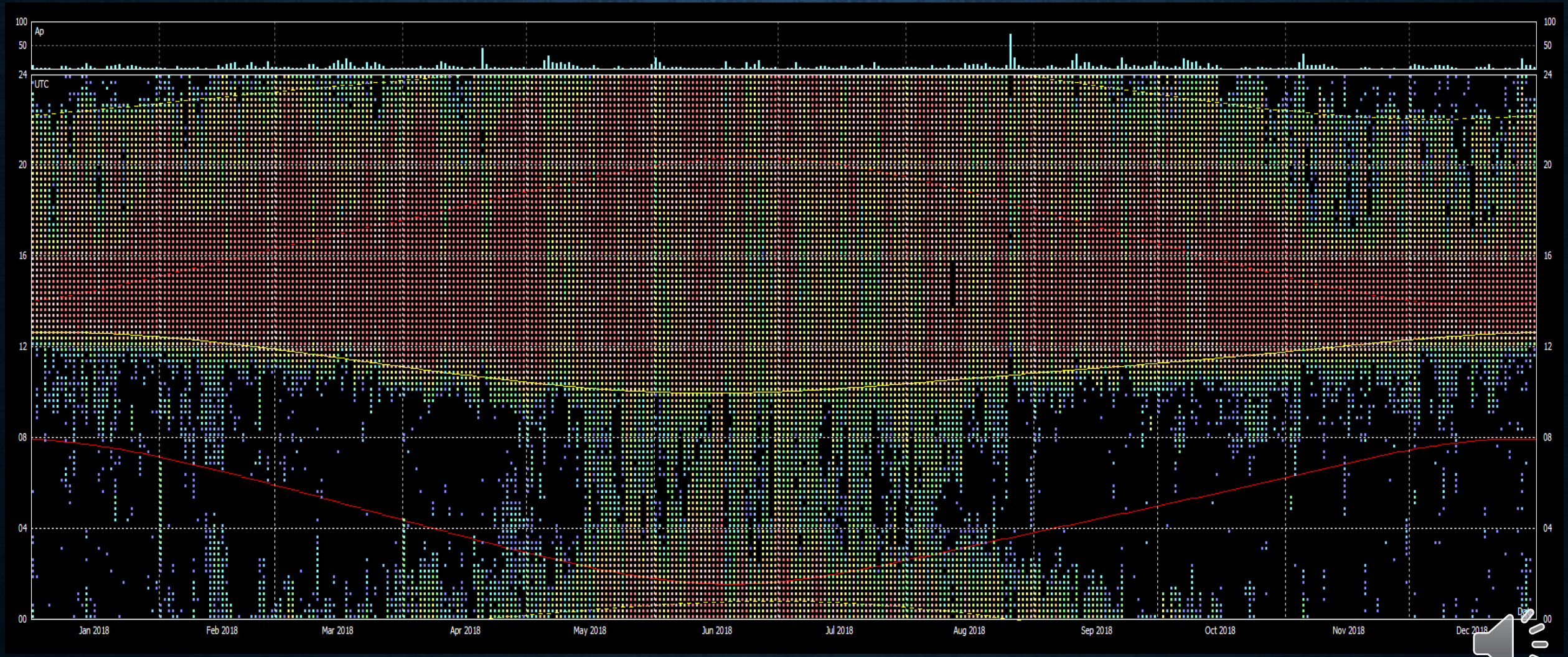
- Propagation prediction
  - Software
- Data gathering
  - Big Data
  - Research
    - Propagation
    - Solar

PROPAGATION PREDICTION SOFTWARE

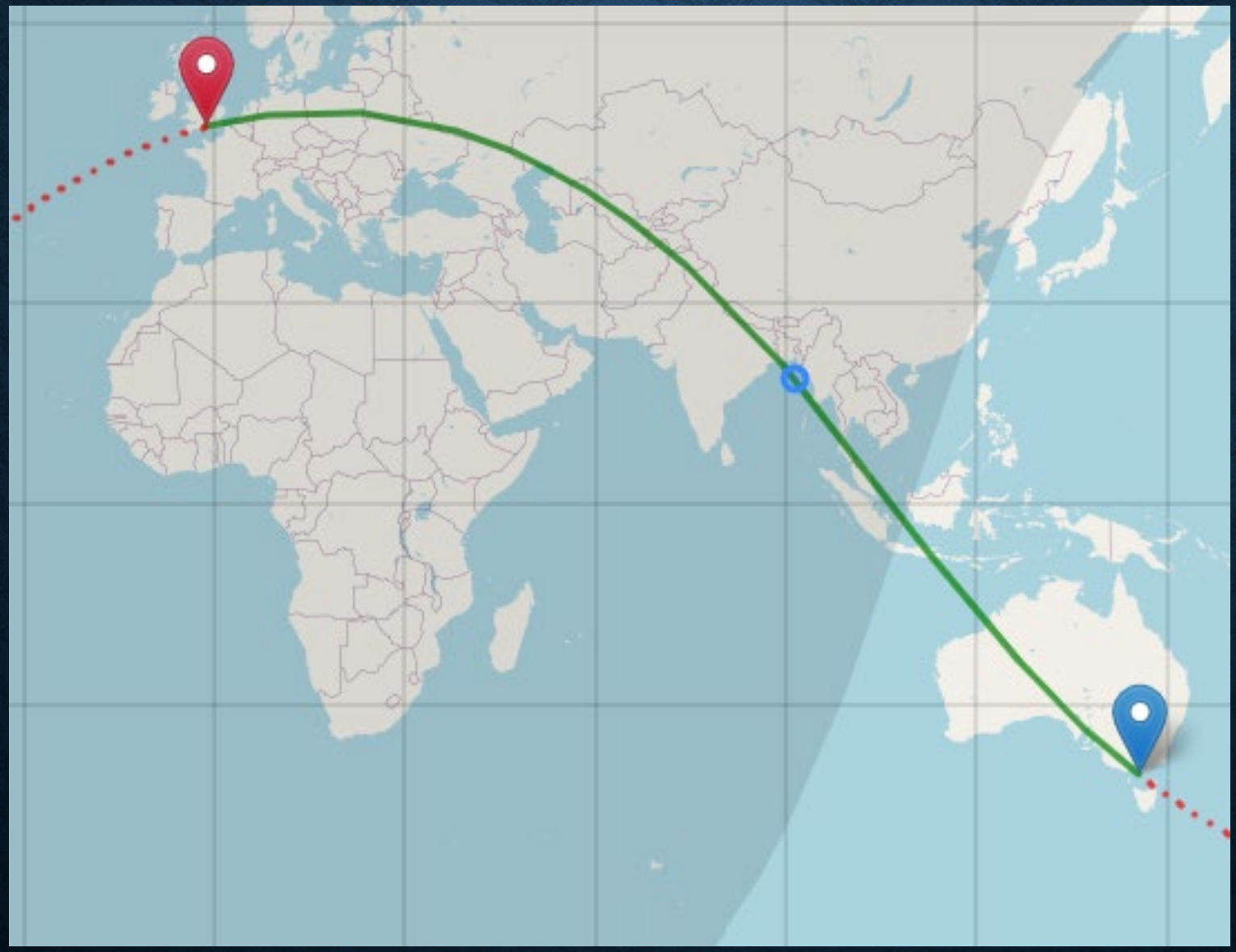
- VOACAP
- Voice of America Coverage Analysis Program
- https://www.voacap.com/
- Now uses FT8 data gathered by radio amateur
- eg. 20m or 14 MHz band

(Perkiömäki, 2021)

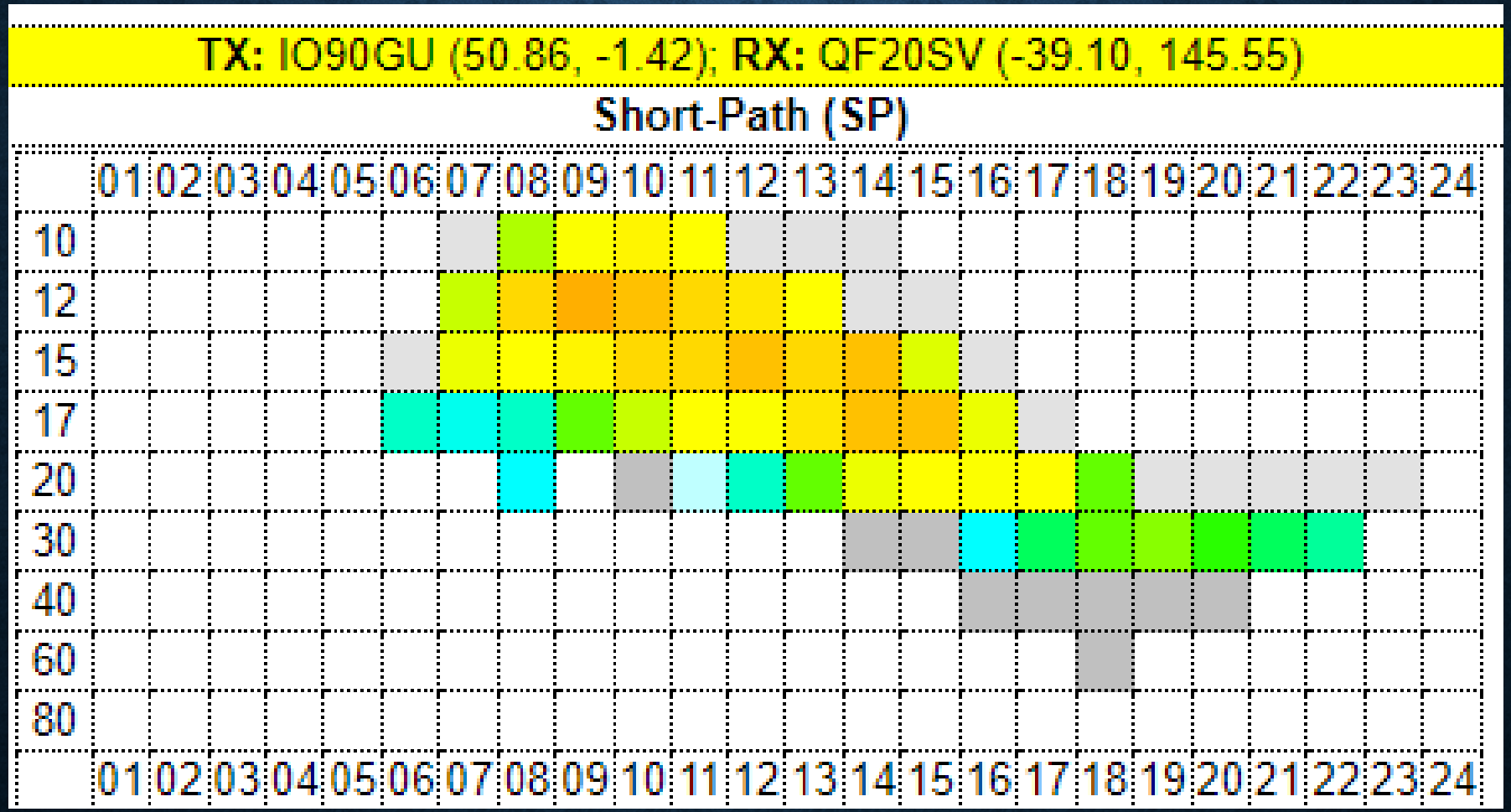
VOACAP DATA FROM FT8 DATA FOR 2018



EXAMPLE: PATH UK TO AUSTRALIA (SHORT PATH)



PROPAGATION PREDICTION UK TO AUSTRALIA



Band (m)

Time h

For the month of November 2021

OPTIMUM TRAFFIC FREQUENCY/TIME DAY

voacap.com/hf/best_freq.html

```
  Nov     2021          SSN =  32.                Minimum Angle= 3.000 degrees
  IO90gu               QF20sv                 AZIMUTHS          N. MI.      KM
  50.86 N    1.42 W - 39.10 S  145.55 E      75.86  307.93     9253.8  17136.6
  REQ.SNR = 19 dB, TX POWER = 0.08 kW, SHORT-PATH

The best operating frequencies (FREQ1, FREQ2, FREQ3) by hour

UTC    SDBW      ΔSIG    REL   SNR   ΔSNR  MUFday     FOT     MUF     HPF   FREQ1   FREQ2   FREQ3

01  -211 (-- )   40.1     0%   -45   42.9     59%     8.4    10.5    12.5   10.1-   14.1-   21.1-
02  -224 (-- )   42.3     0%   -59   44.0     50%     8.1    10.1    12.0   10.1-   14.1-   21.1-
03  -247 (-- )   45.1     0%   -82   47.7*    42%     7.8     9.8    11.7   10.1-   14.1-   24.9-
04  -247 (-- )   41.1     0%   -83   42.8     59%     8.5    10.4    12.5   10.1-   14.1-   24.9-
05  -206 (-- )   50.0*    0%   -39   51.5*    32%    10.6    13.1    15.8   14.1-   18.1-   10.1-
06  -176 (-- )   50.0*   14%    -3   51.5*    31%    13.6    16.8    20.1   18.1-   14.1-   21.1-
07  -154 (S0 )   50.0*   54%    21   51.6*    54%    17.4    21.5    25.7   21.1    24.9    18.1*
08  -147 (S2 )   50.0*   72%    31   52.6*    46%    18.7    24.5    29.0   24.9    21.1    14.1
09  -141 (S3 )   46.9    81%    37   49.6*    57%    19.6    25.8    30.5   24.9    21.1    28.2
10  -144 (S3 )   50.0*   77%    34   52.6*    43%    17.7    24.0    30.7   24.9    21.1    28.2
11  -143 (S3 )   48.9*   75%    33   51.5*    63%    16.7    22.6    28.9   21.1    24.9    18.1
12  -142 (S3 )   50.0*   76%    34   52.6*    51%    15.7    21.2    27.2   21.1    18.1    24.9
13  -143 (S3 )   50.0*   74%    32   51.6*    44%    15.1    20.4    26.2   21.1    18.1    24.9
14  -140 (S3 )   43.6    76%    34   46.3     73%    15.8    20.2    24.7   18.1    21.1    14.1
15  -138 (S4 )   47.3*   79%    36   50.0*    59%    15.2    18.8    21.8   18.1    14.1    21.1
16  -144 (S3 )   50.0*   63%    26   52.5*    66%    11.6    15.3    19.3   14.1    18.1    10.1
17  -147 (S2 )   50.0*   57%    23   51.5*    38%    10.1    13.3    16.7   14.1    10.1     7.1-
18  -150 (S2 )   44.9    35%    13   46.6     74%     8.7    11.5    14.5   10.1     7.1    14.1-
19  -149 (S2 )   50.0*   39%    14   52.7*    59%     8.0    10.6    13.3   10.1     7.1-    5.4-
20  -154 (S0 )   50.0*   31%     9   51.8*    49%     7.5    10.1    12.7   10.1     7.1-   14.1-
21  -161 (S0 )   50.0*   20%     2   51.7*    49%     7.6    10.1    12.7   10.1    14.1-    7.1-
22  -164 (S0 )   49.9*   18%     1   52.4*    57%     7.9    10.5    13.2   10.1*   14.1-    7.1-
23  -183 (-- )   50.0*    5%   -13   52.5*     7%     8.1    10.8    13.7   14.1-   10.1-    7.1-
24  -198 (-- )   38.3     0%   -32   41.2     66%     8.6    10.8    12.8   10.1-   14.1-    7.1-
```

View the prediction as text.

<- optimum frequency for UK to Australia (short path)
19.6 MHz at 09.00 utc (Nov 21)
81% reliability

K1JT – JOE TAYLOR

(Wikipedia, 2021b)

Nobel Prize for Physics – discovery of a new type of binary Pulsar at Arecibo radio observatory in 1974

Also developed a number of weak signal digital communication modes initially for Moon bounce:

- FT8
- JT9
- JT65
- etc.
- and WSPR
- at Princeton Uni.

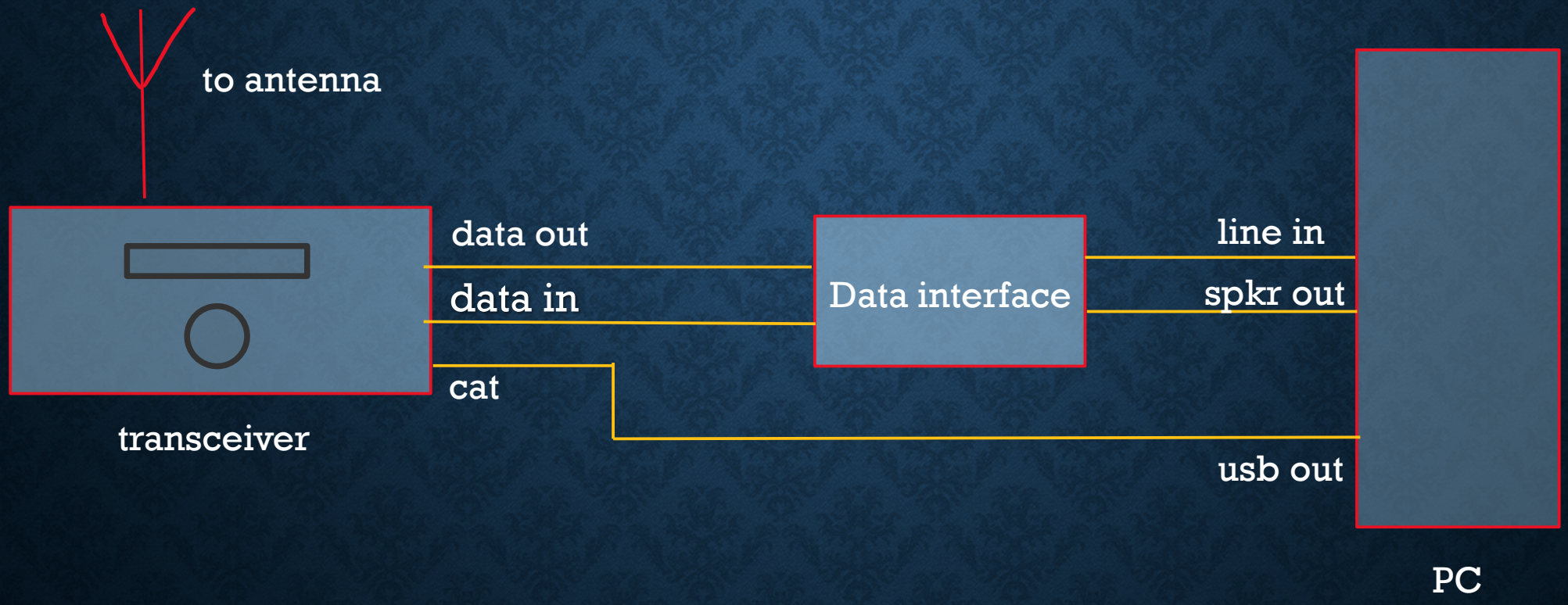
(Seife, 1995)

BIG DATA AND PROPAGATION

- Weak Signal Propagation Reporter (WSPR)
  - Beacon station
  - Low power (100mW to 5W typically)
  - Transmits every 10-20 minutes
  - For 2 minutes
  - Transmits:
    - Callsign
    - Position locator
  - Receiving stations:
    - Decode signals
    - Upload to https://www.wsprnet.org/drupal/
  - All stations run WSJT-X encode/decode software and reporter

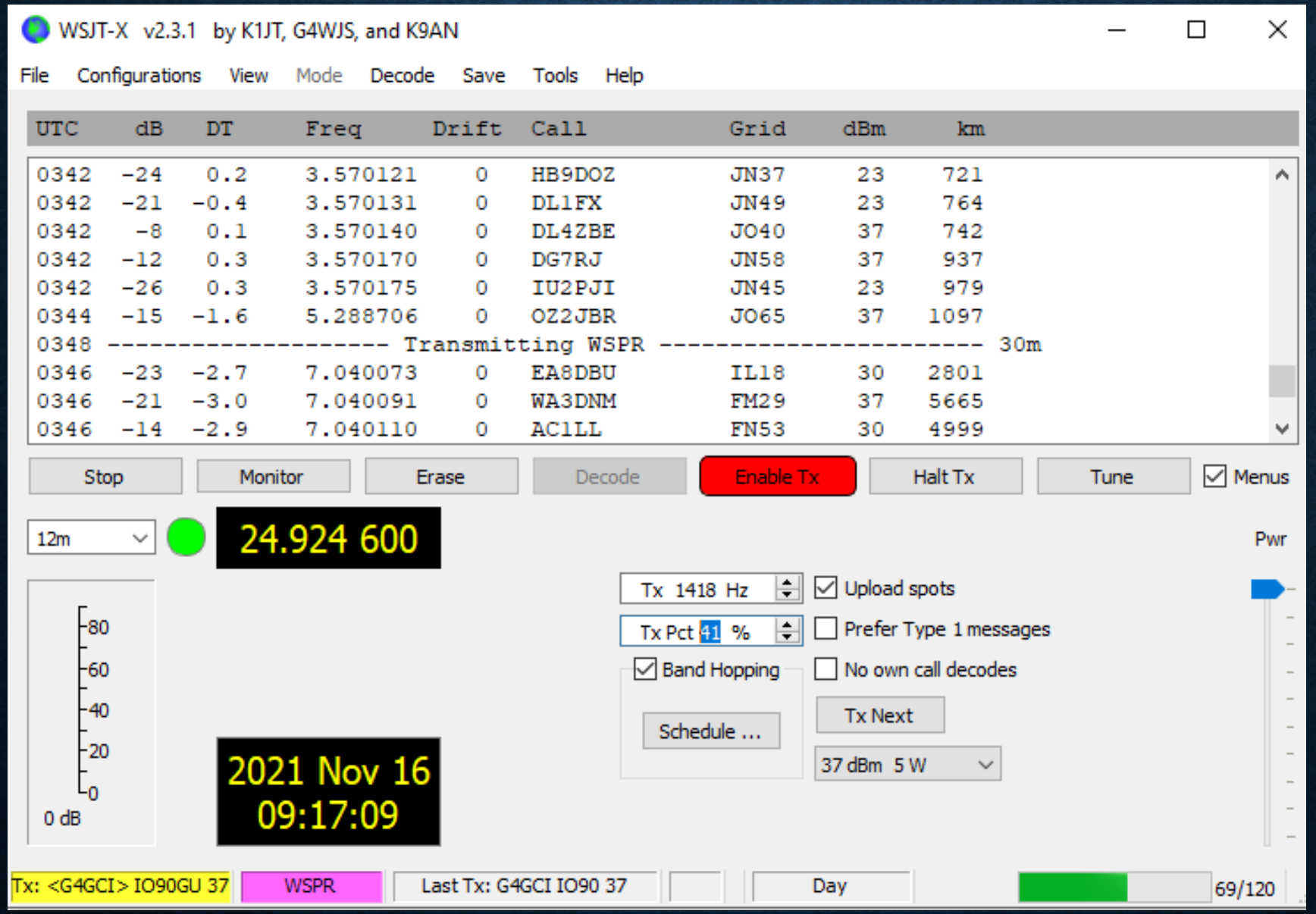
(Taylor, 2020) (Wsprnet.org)

DIGITAL COMMUNICATION SYSTEM

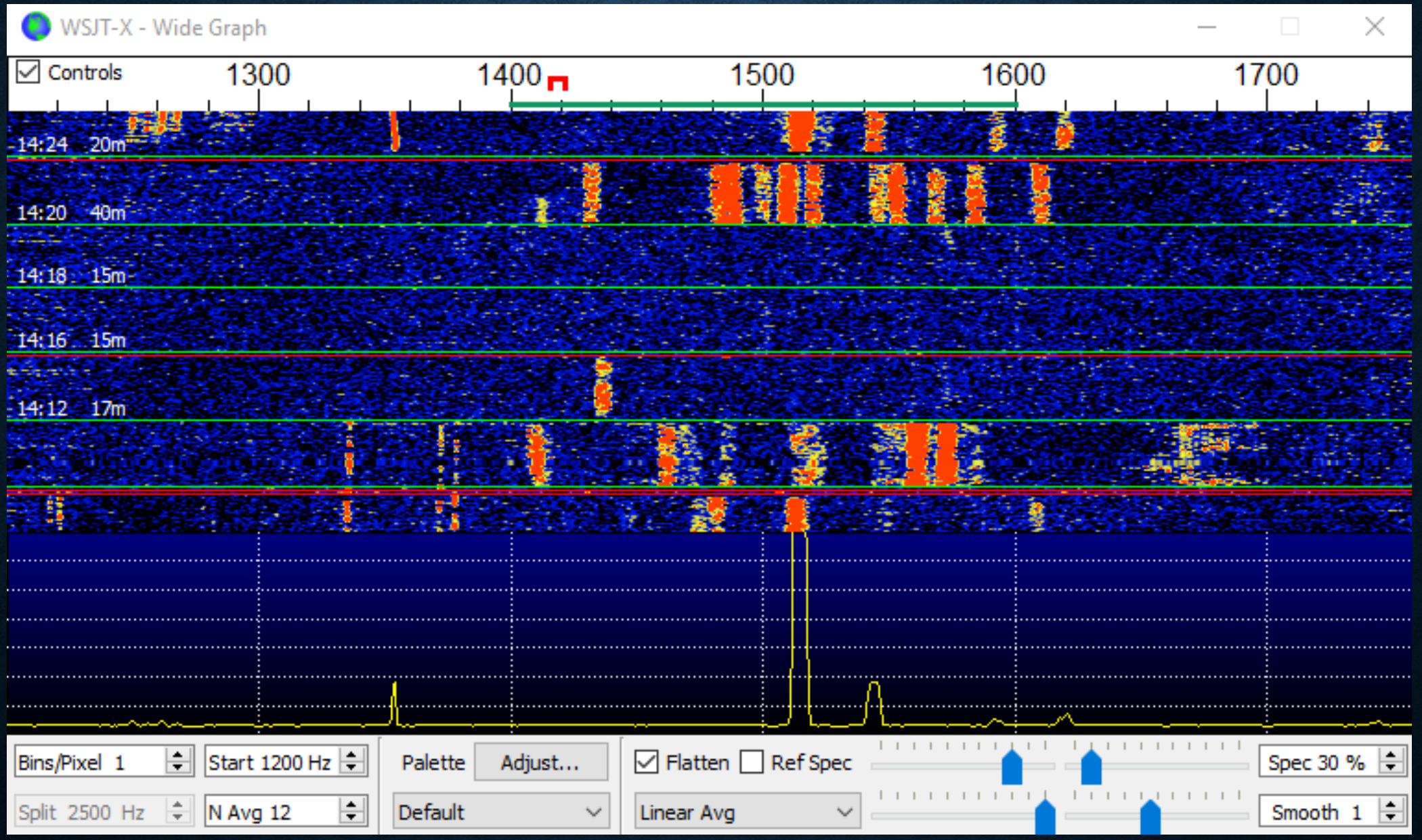


cat = computer aided tuning

WSJT-X IN WSPR MODE



WSJT-X SPECTRUM



RECEIVED DATA - DATABASE

WSPR Spot Database

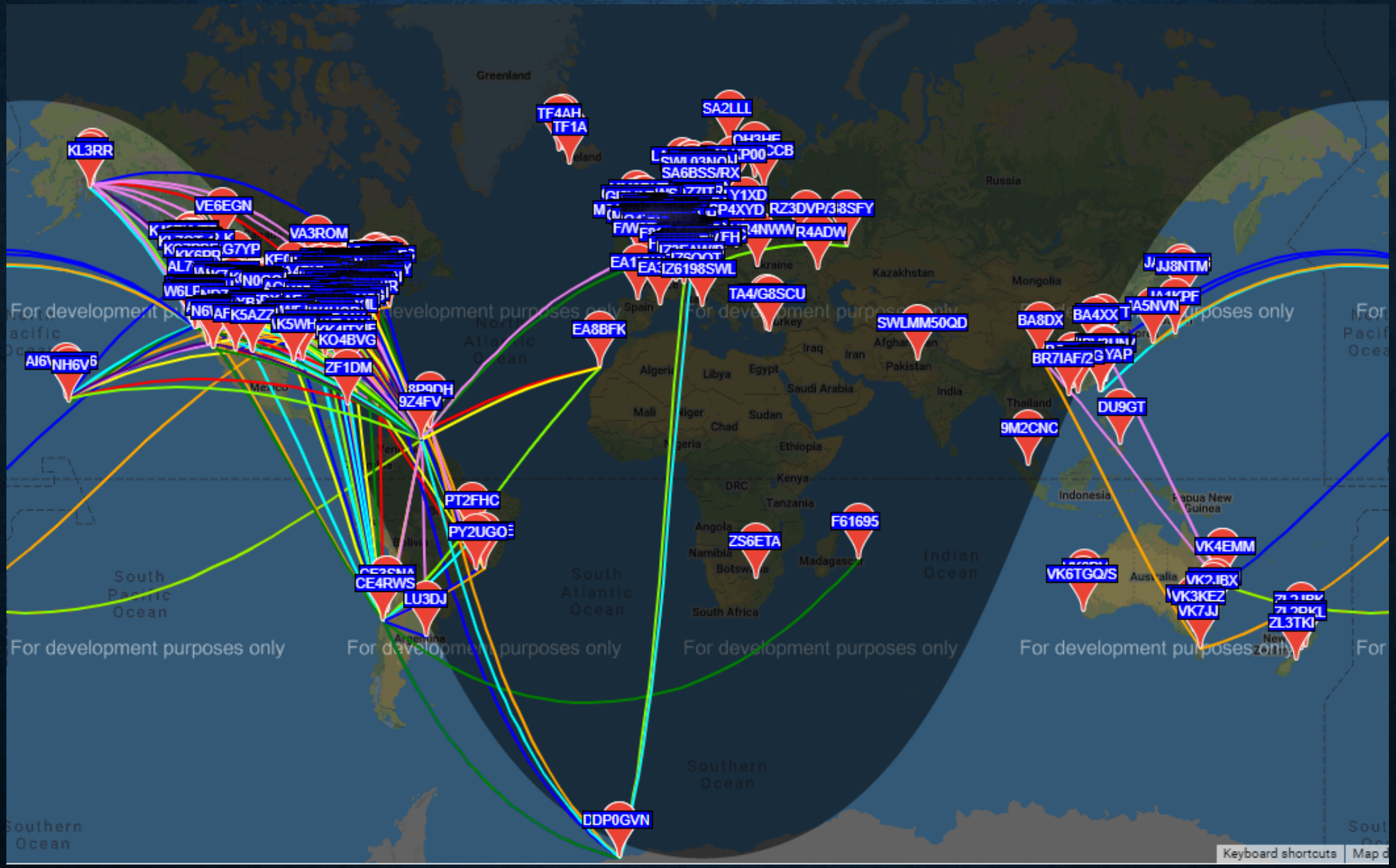
WSPRnet.org Home Sked/Chat page

Display options

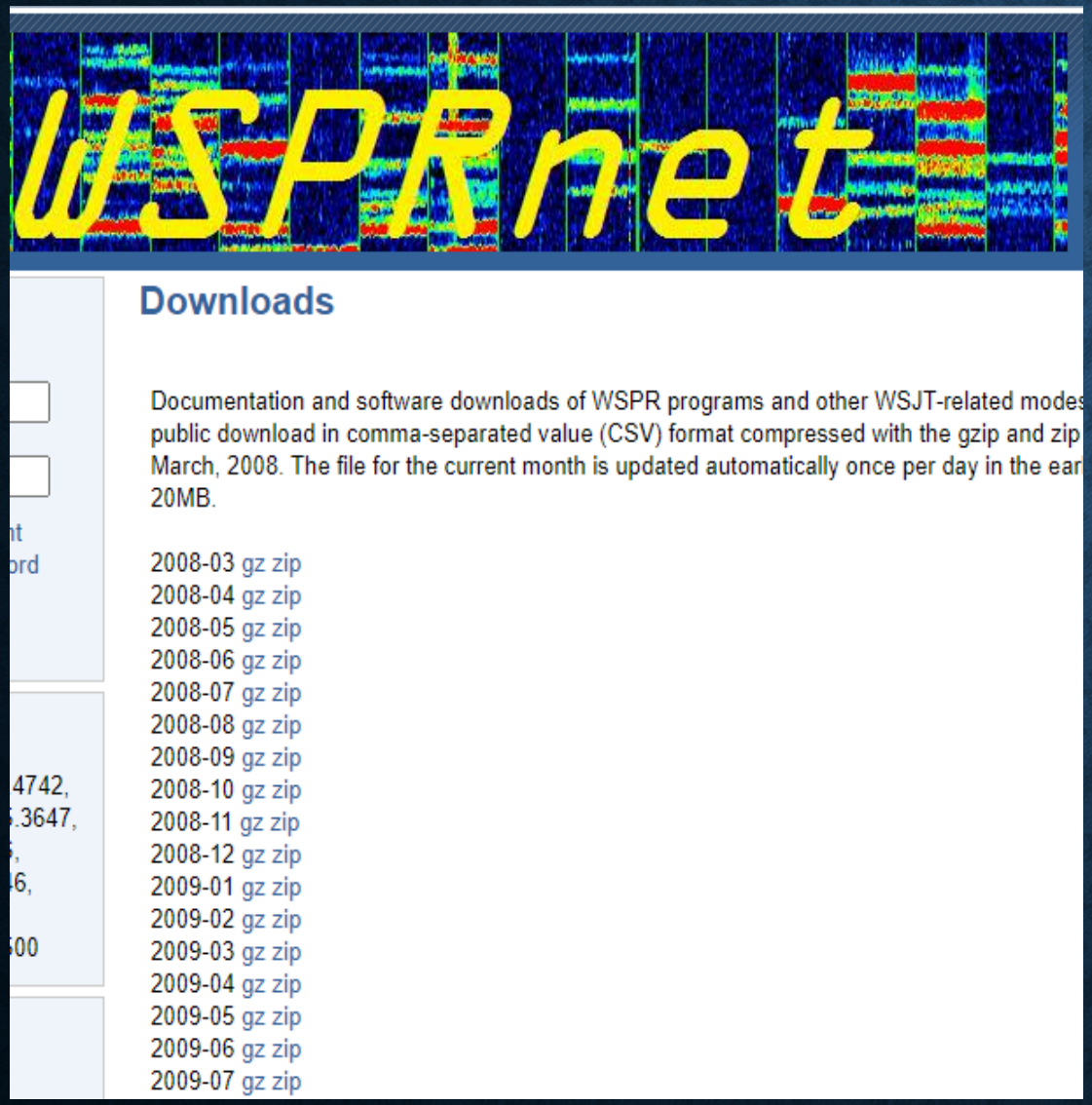
Band: 20m
Number of spots (max 10,000): 50
Search for call:
Show spots heard by:
Sort by: Date Reverse order
Find unique calls Find unique reporters
Go! Reset

						Power		Reported		Distance		
Date	Call	Frequency	SNR	Drift	Grid	dBm	W	by	loc	km	mi	Mode
2021-11-14 23:06	K5SWA	14.097058	-12	0	EM12ox	+37	5.012	KA7OEI	DN40ao	1591	989	WSPR-2
2021-11-14 23:06	NI5F	14.097102	-27	0	EM70	+37	5.012	KA7OEI	DN40ao	2669	1658	WSPR-2
2021-11-14 23:06	TA4/G8SCU	14.097171	-29	0	KM56vo	+37	5.012	IW2NKE	JN63np	1764	1096	WSPR-2
2021-11-14 23:06	HB9GPU	14.097072	-22	0	JN47re	+20	0.100	OE9TAV	JN47tk	31	19	WSPR-2
2021-11-14 23:06	K0WET	14.097155	-23	-4	DM79	+23	0.200	KF7FBF	CN87uq	1657	1030	WSPR-2
2021-11-14 23:06	KE9MOW	14.097056	-23	0	EM57kq	+37	5.012	KF7FBF	CN87uq	2902	1803	WSPR-2
2021-11-14 23:06	N6RQW	14.097177	-23	0	DM14ga	+23	0.200	KF7FBF	CN87uq	1572	977	WSPR-2
2021-11-14 23:06	KE9MOW	14.097034	-13	0	EM57kq	+37	5.012	WO7I	DN10cw	2481	1542	WSPR-2
2021-11-14 23:06	K5SWA	14.097058	-14	0	EM12ox	+37	5.012	WO7I	DN10cw	2058	1279	WSPR-2
2021-11-14 23:06	AF7XZ	14.097084	-5	0	DM42mf	+23	0.200	WO7I	DN10cw	1144	711	WSPR-2
2021-11-14 23:06	N2HQI	14.097120	-9	0	FN13sa	+37	5.012	KF7FBF	CN87uq	3566	2216	WSPR-2
2021-11-14 23:06	W1STR	14.097085	-19	0	FN42hh	+33	1.995	WO7I	DN10cw	3813	2369	WSPR-2
2021-11-14 23:06	K7RJ	14.097102	-1	0	DM42lh	+23	0.200	WO7I	DN10cw	1132	703	WSPR-2
2021-11-14 23:06	NI5F	14.097102	-12	0	EM70	+37	5.012	WO7I	DN10cw	3155	1960	WSPR-2
2021-11-14 23:06	KJ6SVA	14.097162	+4	2	DM13hw	+23	0.200	NH6Y	BL10ts	4091	2542	WSPR-2
2021-11-14 23:06	N4TVC	14.097117	-15	0	FM18is	+20	0.100	WO7I	DN10cw	3435	2134	WSPR-2
2021-11-14 23:06	AC1JS	14.097148	-22	0	FN54	+23	0.200	WO7I	DN10cw	3943	2450	WSPR-2

PROPAGATION DATA GATHERING ON A GLOBAL SCALE



PROPAGATION DATA AVAILABLE FOR ALMOST 14 YEARS

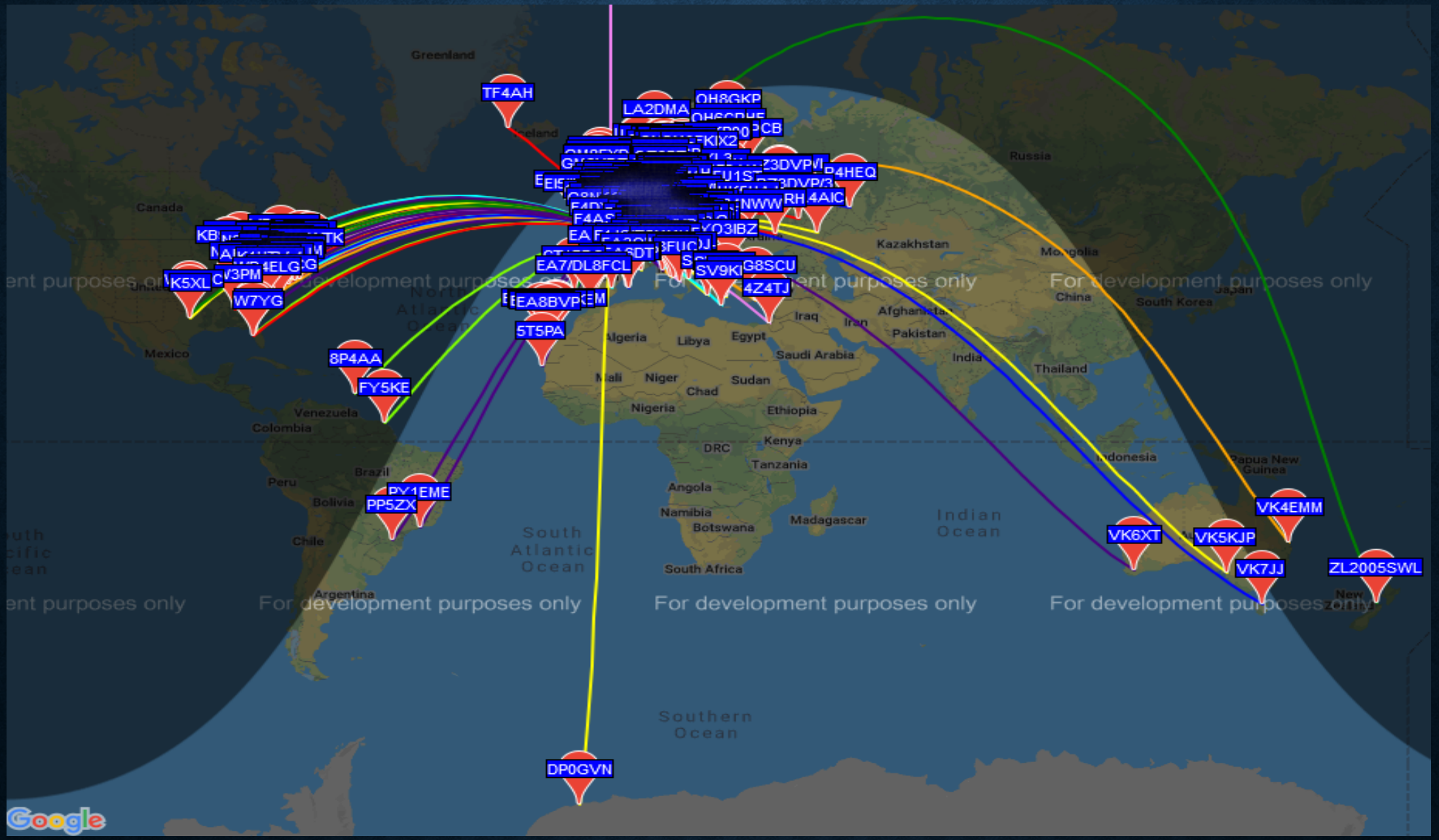


- Several Gb of data for each year
- Hundreds of stations

Used to better inform worldwide propagation prediction

https://www.wsprnet.org/drupal/wsprnet/map

WSPR AT G4GCI



WHY HF WAS THOUGHT TO BE USELESS?

	My call	MHz	SNR					reporter		distance		
2021-11-18 14:06	G4GCI	10.140110	-18	0	IO90gu	+37	5.012	WA2TP	FN30lu	5431	3375	WSPR-2
2021-11-18 14:06	G4GCI	10.140113	+1	0	IO90gu	+37	5.012	DJ9PC	JN59po	916	569	WSPR-2
2021-11-18 14:06	G4GCI	10.140111	-28	0	IO90gu	+37	5.012	G7ELK	IO90jv	18	11	WSPR-2
2021-11-18 14:06	G4GCI	10.140110	-10	0	IO90gu	+37	5.012	DC1RDB	JN58ss	960	597	WSPR-2
2021-11-18 14:06	G4GCI	10.140101	-26	0	IO90gu	+37	5.012	VK4CT	QG62jv	16597	10313	WSPR-2

- Frequency: HF ~ 10 MHz (30m band)
- Signals 11 miles away weaker than signals 10,000 miles away!
- Strong in Germany, but not 11 miles down the road!

THANKS FOR LISTENING!

- Questions?

REFERENCES

- Bussey, G. (2001). Marconi's Atlantic Leap. UK: Marconi Communications
- Wikipedia (2021a). Spark-gap transmitter. Available at: https://en.wikipedia.org/wiki/Spark-gap_transmitter [accessed 16th Nov 21]
- Naval Historical Society of Australia (2018). The First Direct Wireless Messages from the United Kingdom to Australia. Available at: https://www.navyhistory.org.au/the-first-direct-wireless-messages-from-the-united-kingdom-to-australia/ [accessed 16th Nov 21]
- Bull, P. (2018). The First Direct Wireless Messages from the United Kingdom to Australia. Available at: http://www.otva.com/blog/the-first-direct-wireless-messages-from-england-to-australia/ [accessed 16th Nov 2021]
- RSGB (2021). Transatlantic Tests. Available at: https://rsgb.org/main/activity/transatlantic-tests/ [accessed 16th Nov 21]
- Perkiömäki, J (2021). VOACAP Quick Guide. Available at: https://www.voacap.com/. [accessed 16th Nov 21]
- Seife, C. (1995). Spin Doctor Nobel Physicist Joseph Taylor Takes the "Pulse" of Dying Stars. Available at: http://www.princeton.edu/~paw/archive_old/PAW95-96/02_9596/1011feat.html [accessed 16th Nov 2021]
- Wikipedia (2021b). Joseph Hooton Taylor, Jr. Available at: https://en.wikipedia.org/wiki/Joseph_Hooton_Taylor_Jr. [accessed 16th Nov 21]
- Taylor, J. (2020). WSJT Home Page. Available at: https://www.physics.princeton.edu/pulsar/K1JT/ [accessed 16th Nov 21]
- Wsprnet.org (n/d). WSPRNET. Available from: https://www.wsprnet.org/ [accessed 16th Nov 21]