NVIS Field Research in Spain
Science or Adventure?

dr. ing. B. A. Witvliet [wit fleet]

PE5B, MØIJQ



UNIVERSITY OF BATH

Radiocommunications Agency Netherlands

HamSCI meeting
NJIT, Newark, NJ, USA
23-24 February 2018

f1qm@orange.fr

https://www.qrz.com/db/F1QM

Introduction

Ben Witvliet [wit fleet]

Born in 1961 in Netherlands New Guinea
Father JZoCW, brother OZ1KGU, uncle PAoWDW

1973	NL4496 (SWL)
1981	PA3BXC
1982	3A/PA3BXC
1989	4X/PA3BXC
1993	5R8DS
1996	PA5BW
2016	PE5B
2017	MØIJQ

My first receiver



Otra 9R-4J vacuum tube receiver with BFO

Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

f1qm@orange.fr

https://www.qrz.com/db/F1QM

Introduction

Ben Witvliet [wit fleet]

I have made my passion my work

Telecom industry

Trans World Radio – Monte-Carlo, Monaco

KPN Telecom – The Netherlands

Radio Netherlands – Madagascar

Netherlands Broadcasting Company

Applied research

Radiocommunications Agency Netherlands 50%

Academic research

University of Twente The Netherlands

University of Bath United Kingdom 50%

The story

I will tell you the story of **curiosity-driven** research into the role of radio wave **polarization** in short-distance HF communication (**NVIS**).

Hidden messages:

☺ *Prepare well, and you will find amazing things!*

☺ *Science is adventure!*

Just an ordinary day at the office (2008)



Radiocommunications Agency Netherlands

UNIVERSITY OF BATH

But then it happened …

PAØSIM:

> "*I receive local stations on 3.5 MHz with Right-Hand Circular Polarization, and Jugoslav stations with Left-Hand Circular Polarization, and …* "

We: "*You … what !?*"



?

real / not real

Radiocommunications Agency Netherlands

UNIVERSITY OF BATH

f1qm@orange.fr

https://www.qrz.com/db/F1QM

But then it happened …

We decided to visit him. And we stayed very late..!!

Wow!

2x Alford loop



2x modified FT1000MP



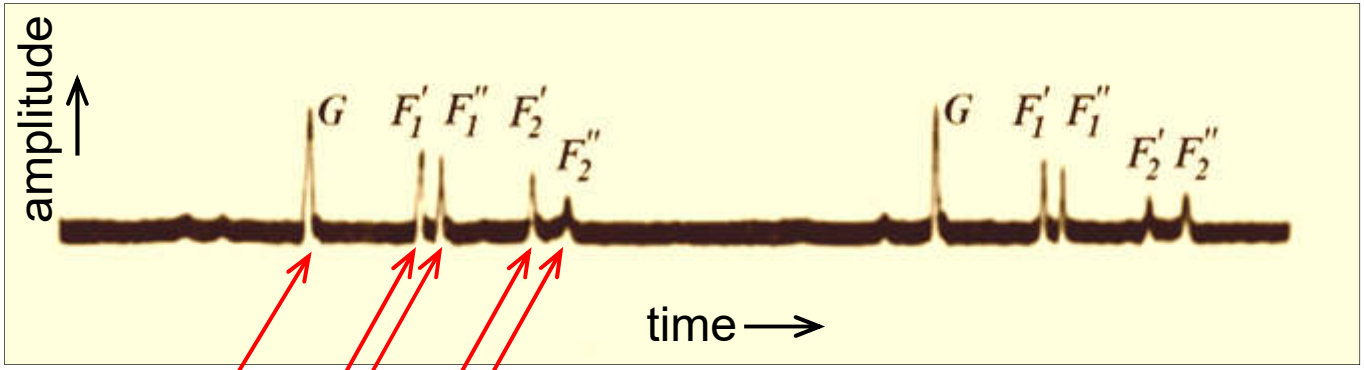
http://www.pa0sim.nl/

UNIVERSITY OF BATH

This is where the journey starts …

0:03

We re-discovered the work of Appleton (1933) …



ground wave

circularly polarized, with clockwise rotation (RHCP)

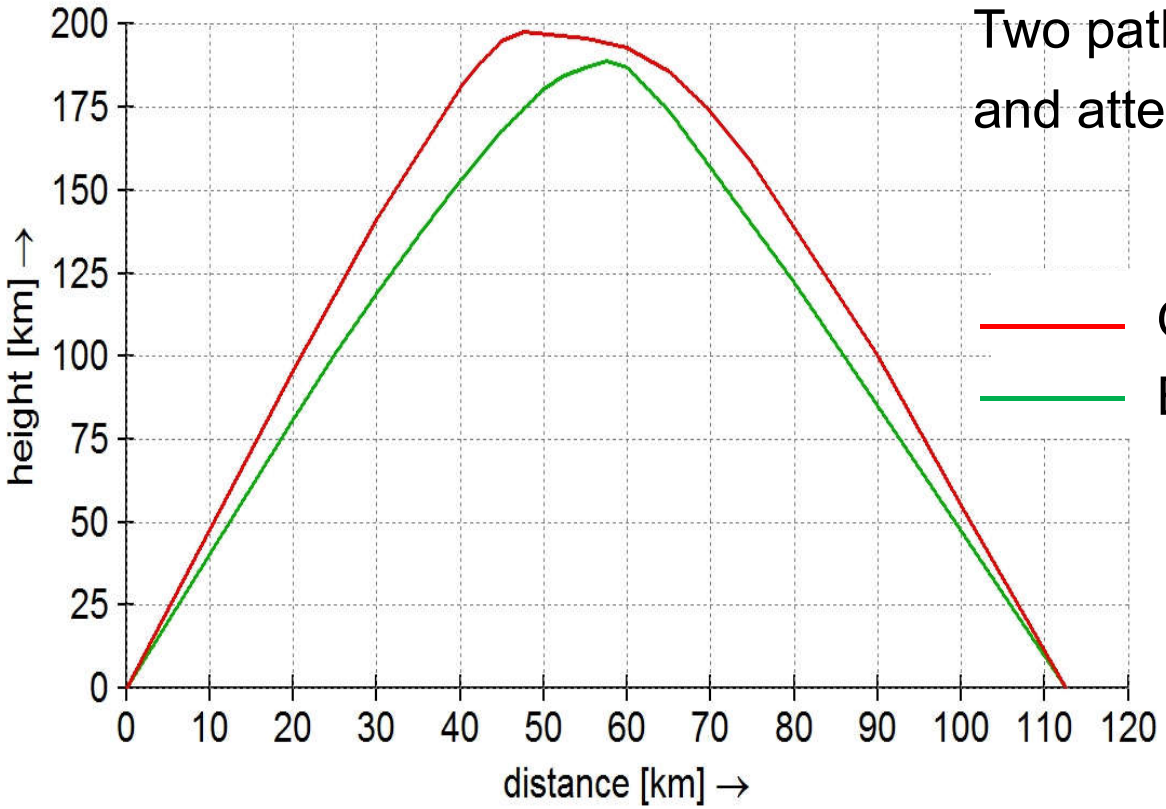
circularly polarized, with counter-clockwise (LHCP)

Appleton, E. V., and G. Builder (1933), "The Ionosphere as a Doubly-Refracting Medium," Proc. Phys. Soc., 45, (2), pp. 208-220.

UNIVERSITY OF BATH

This is where the journey starts …

… and combined it with ionospheric simulations



Two paths with different delay and attenuation (varying)

Ordinary wave

Extraordinary wave

Radiocommunications Agency Netherlands

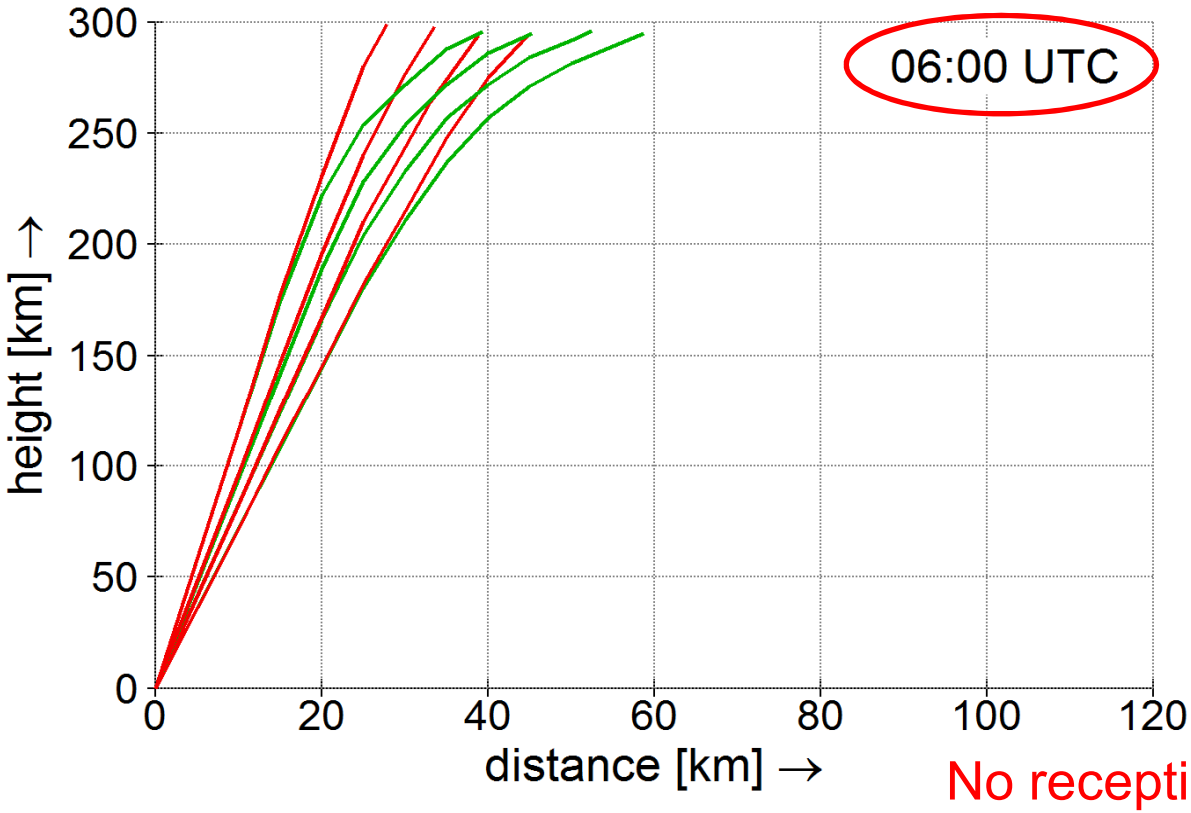
UNIVERSITY OF BATH

f1qm@orange.fr

https://www.qrz.com/db/F1QM

This is where the journey starts …

We followed the changing propagation over the day



9 March 2014

Ray-tracing simulations
The Netherlands
7 MHz, SSN 79

Ordinary wave
Extraordinary wave

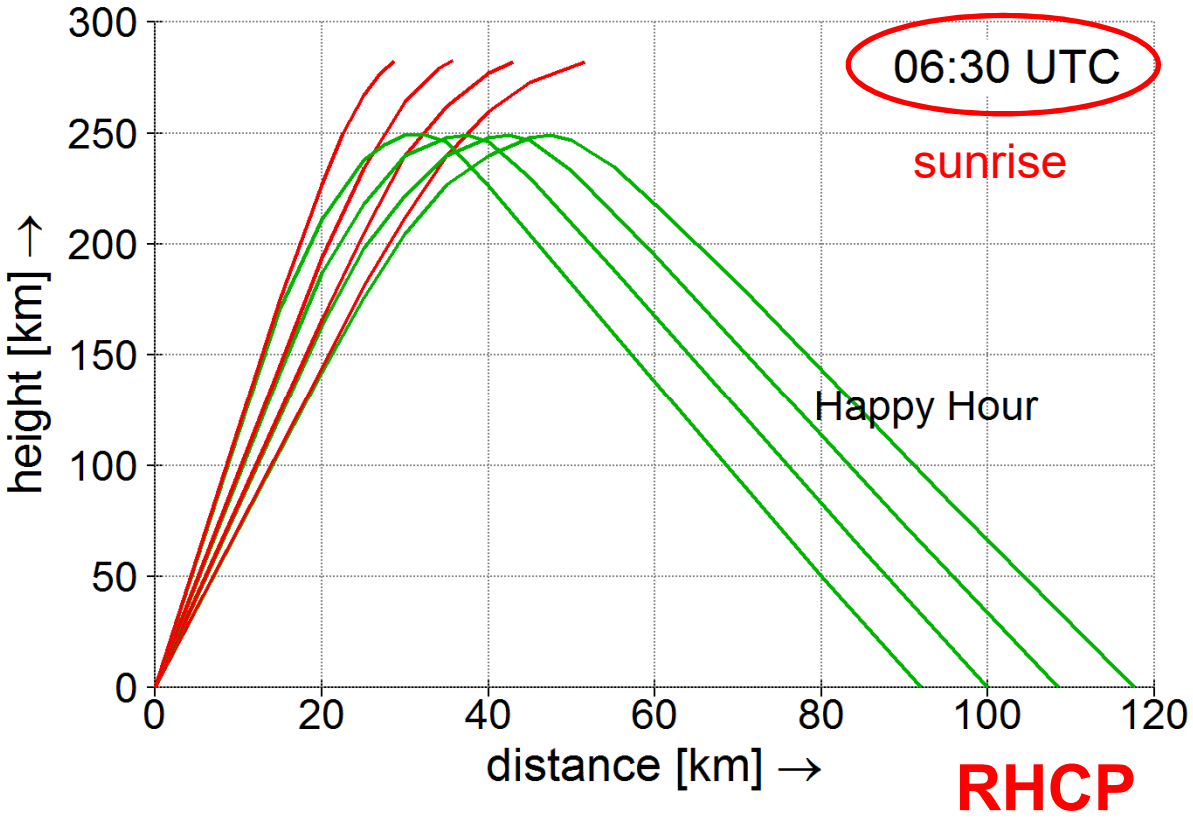
No reception

Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

We followed the changing propagation over the day



9 March 2014

Ray-tracing simulations

The Netherlands

7 MHz, SSN 79

Ordinary wave

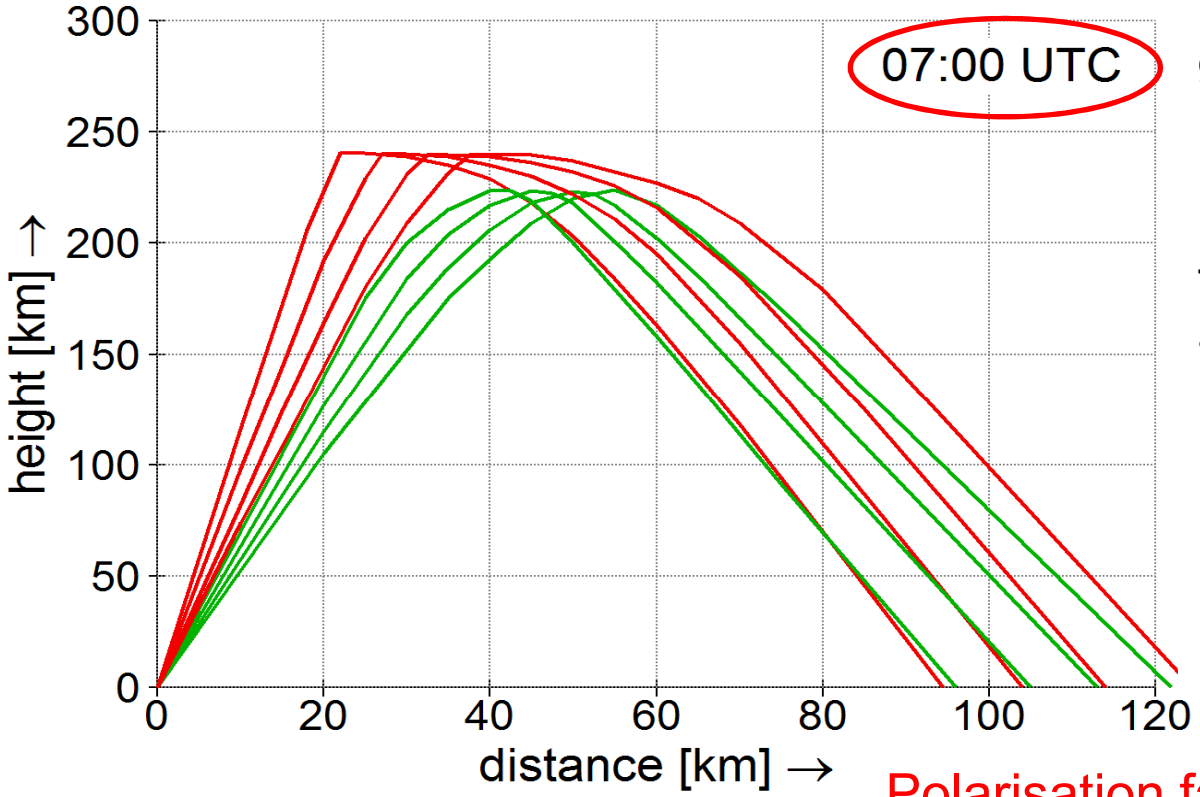
Extraordinary wave

Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

We followed the changing propagation over the day



9 March 2014

Ray-tracing simulations

The Netherlands

7 MHz, SSN 79

Ordinary wave

Extraordinary wave

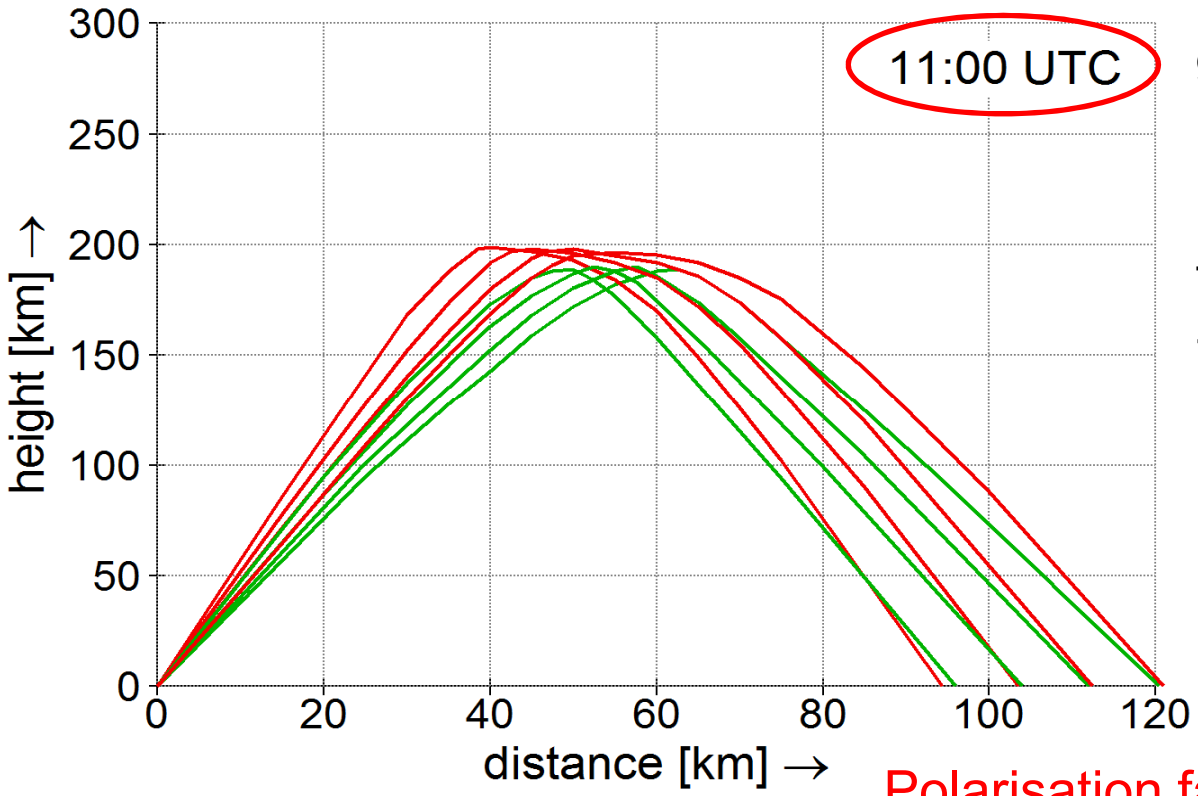
Polarisation fading

Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

We followed the changing propagation over the day

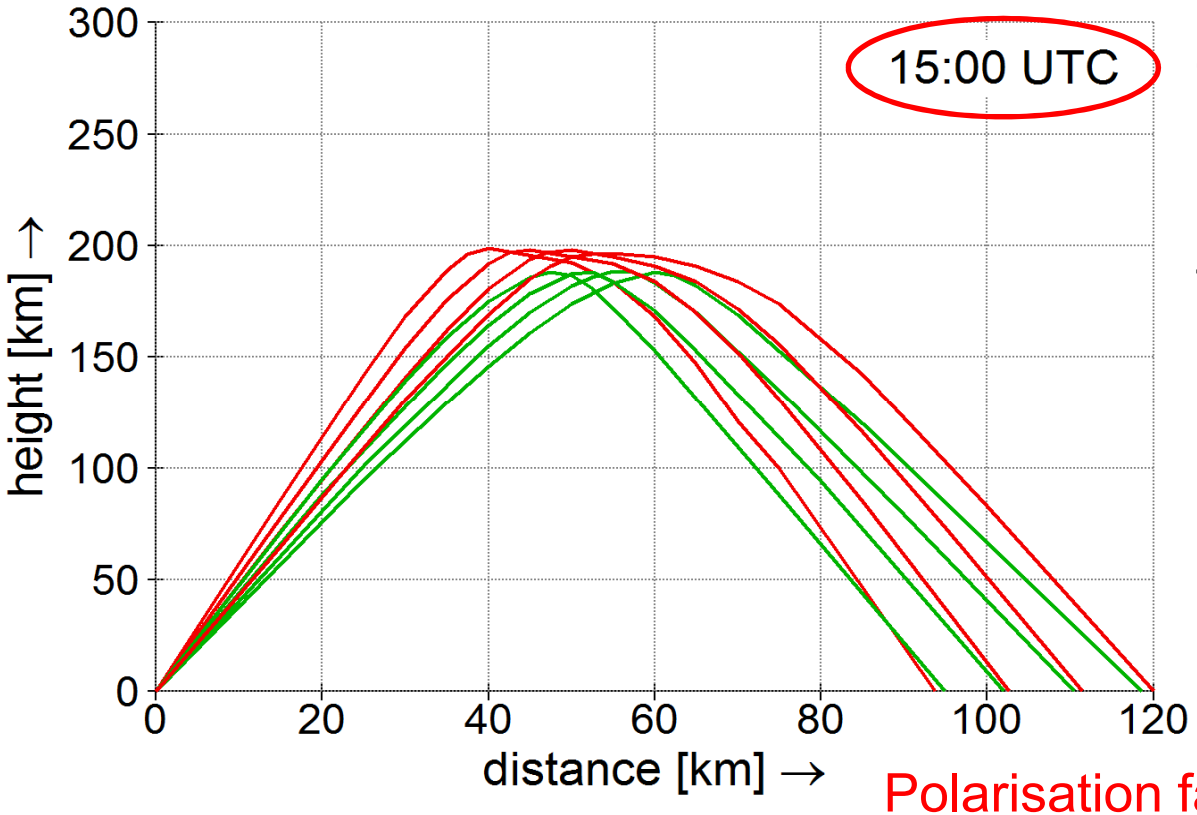


Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

We followed the changing propagation over the day

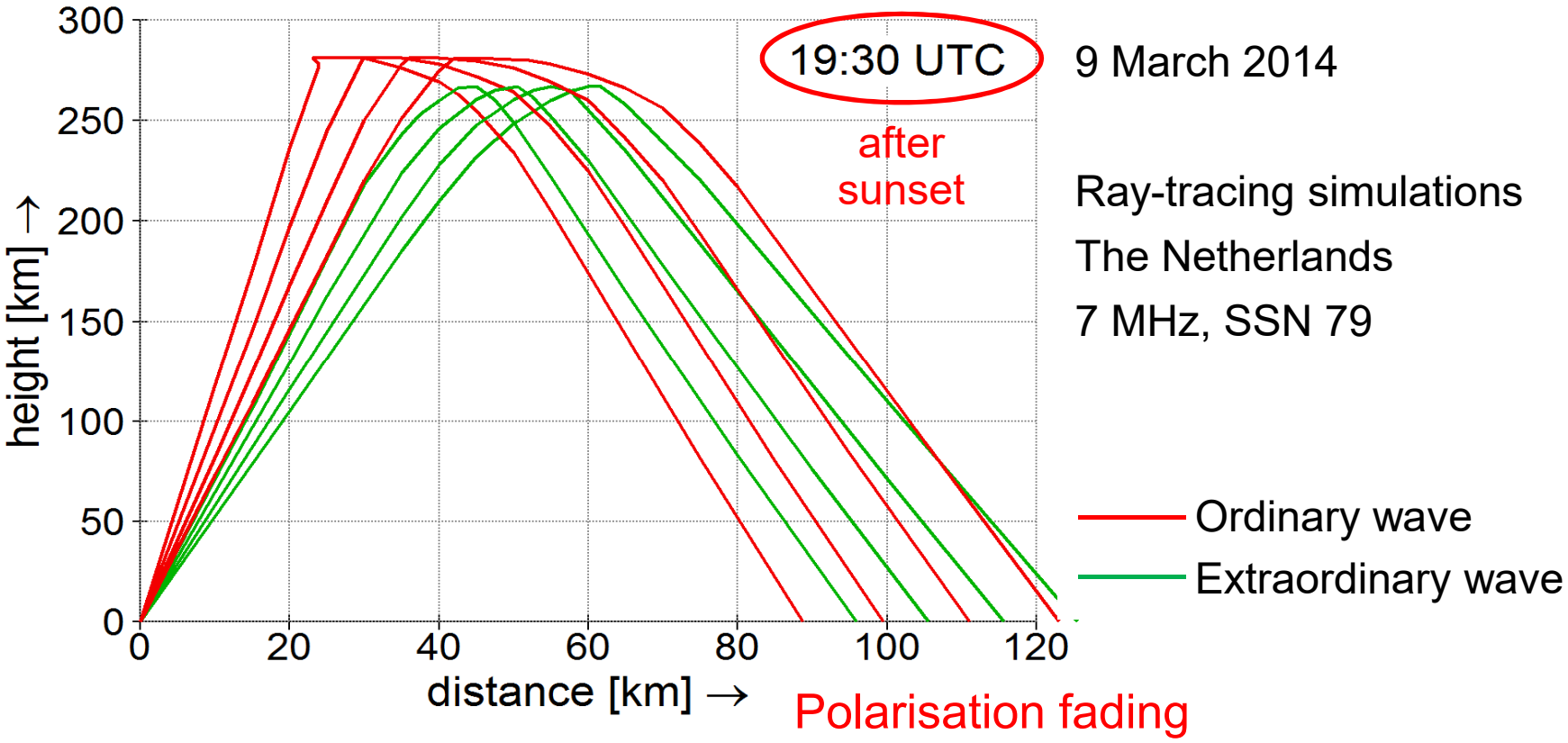


Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

We followed the changing propagation over the day

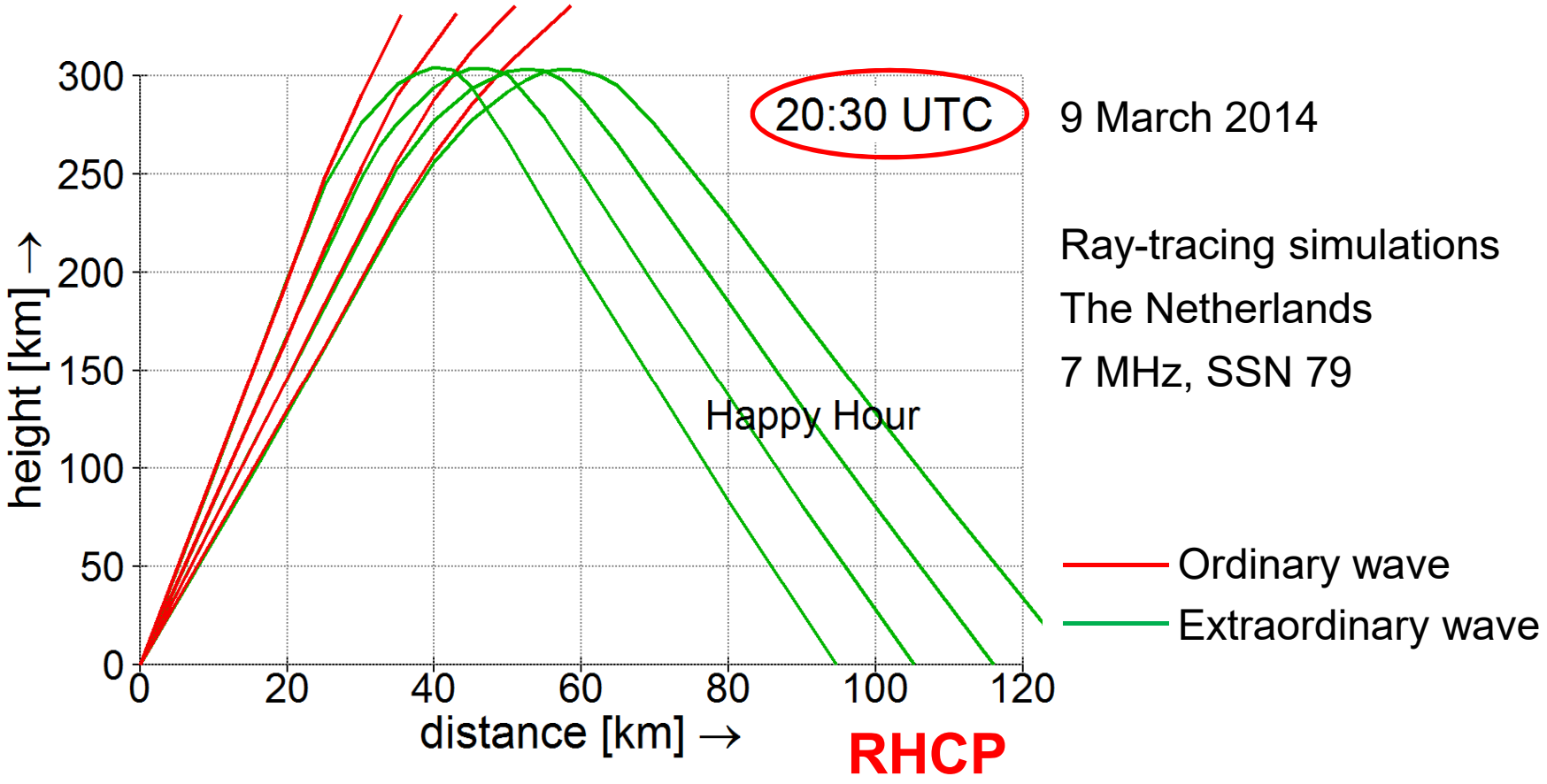


Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

We followed the changing propagation over the day



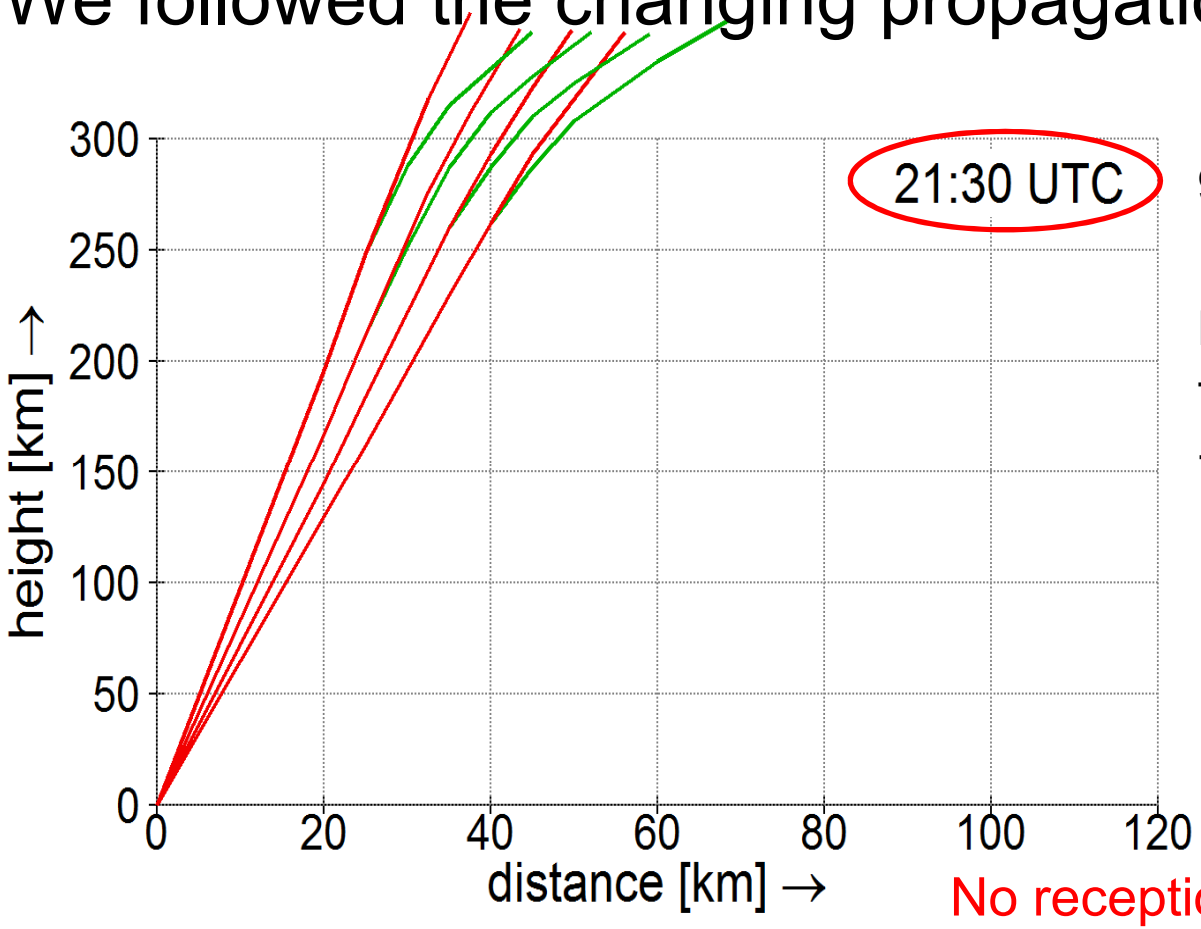
Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

0:05

We followed the changing propagation over the day



9 March 2014

Ray-tracing simulations

The Netherlands

7 MHz, SSN 79

Ordinary wave

Extraordinary wave

Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

This is where the journey starts …

… and divined the location of the Pot of Gold



Radiocommunications
Agency Netherlands

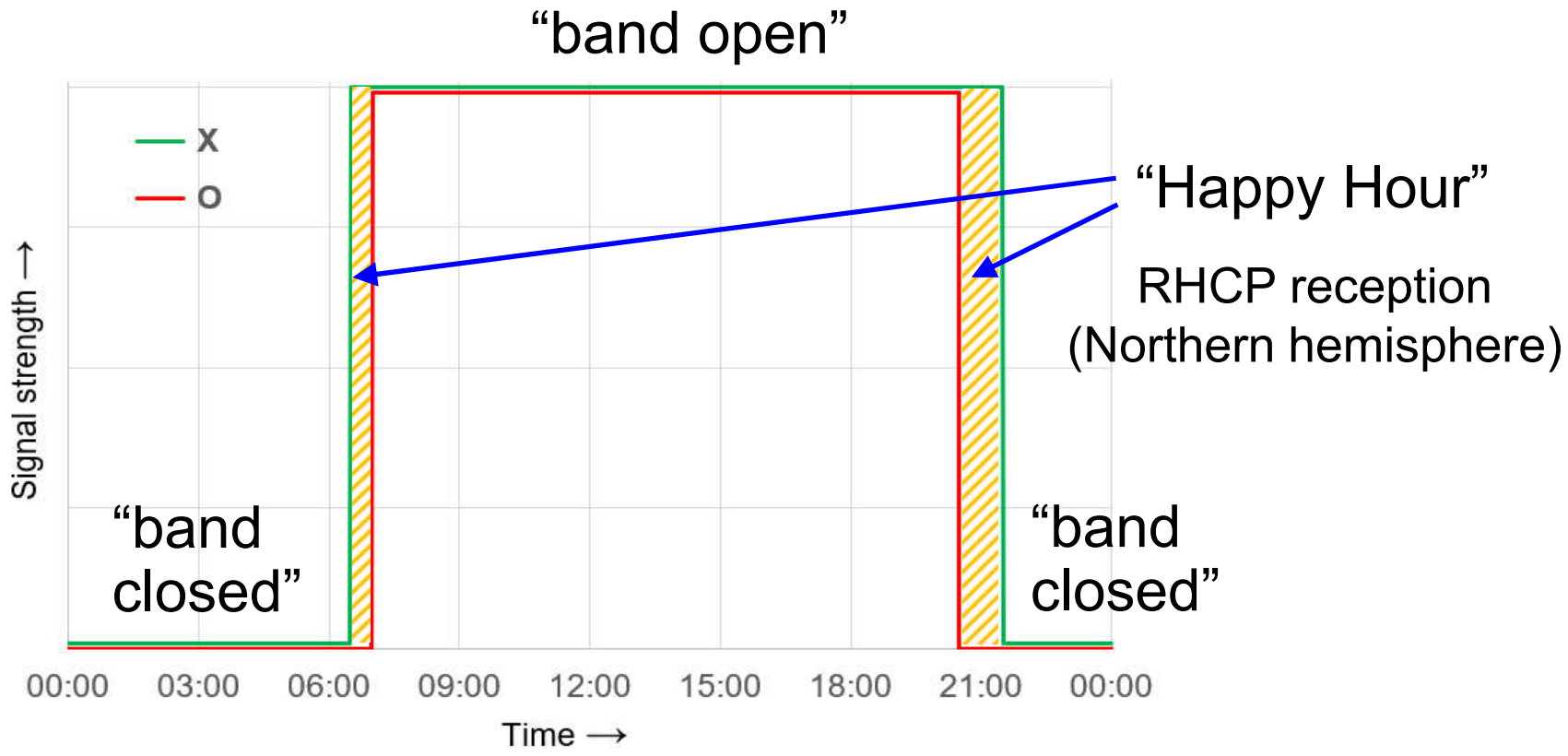
UNIVERSITY OF BATH

f1qm@orange.fr

https://www.qrz.com/db/F1QM

This is where the journey starts …

… and divined the location of the Pot of Gold



Radiocommunications Agency Netherlands

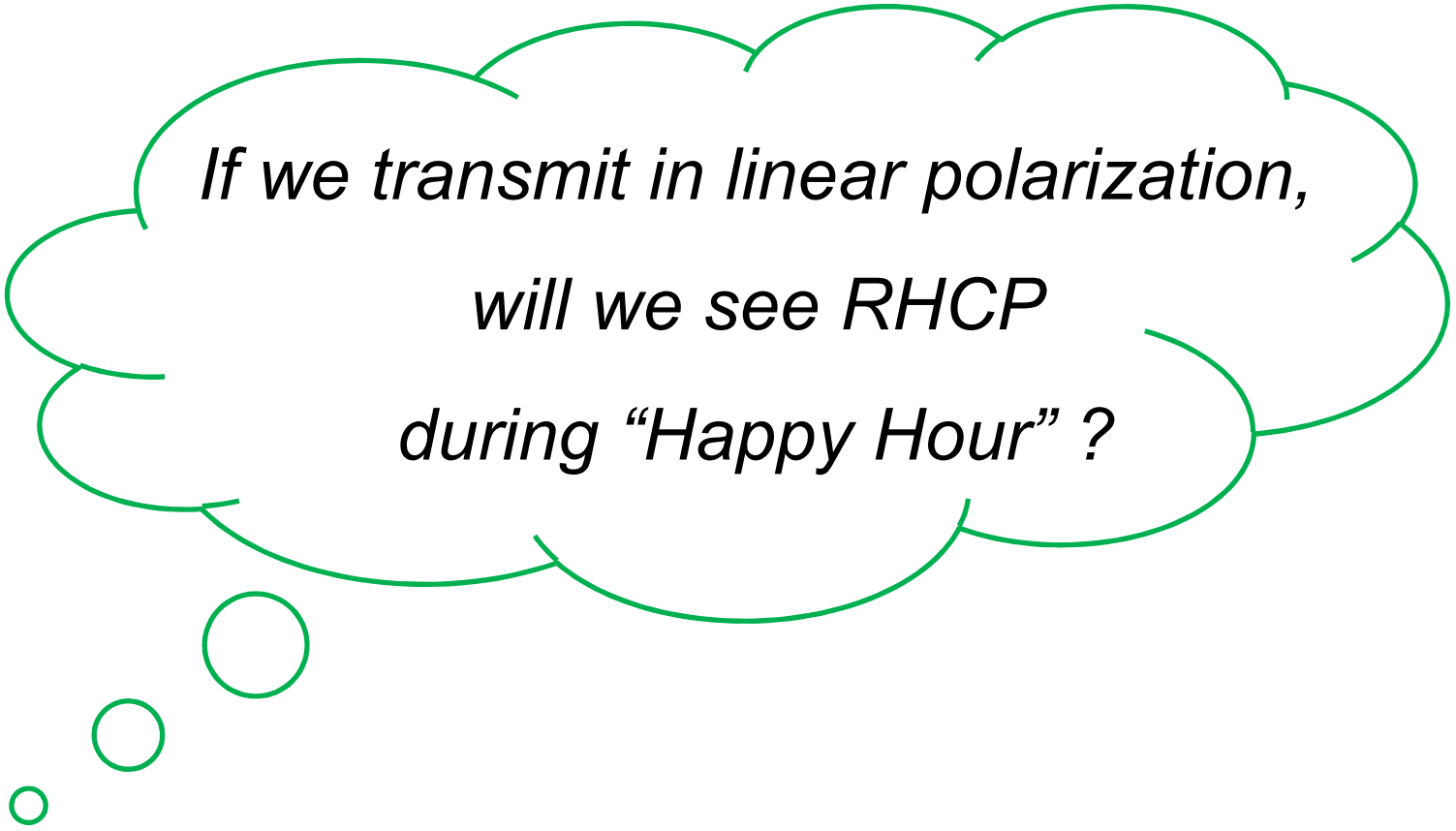
UNIVERSITY OF BATH

f1qm@orange.fr

https://www.qrz.com/db/F1QM

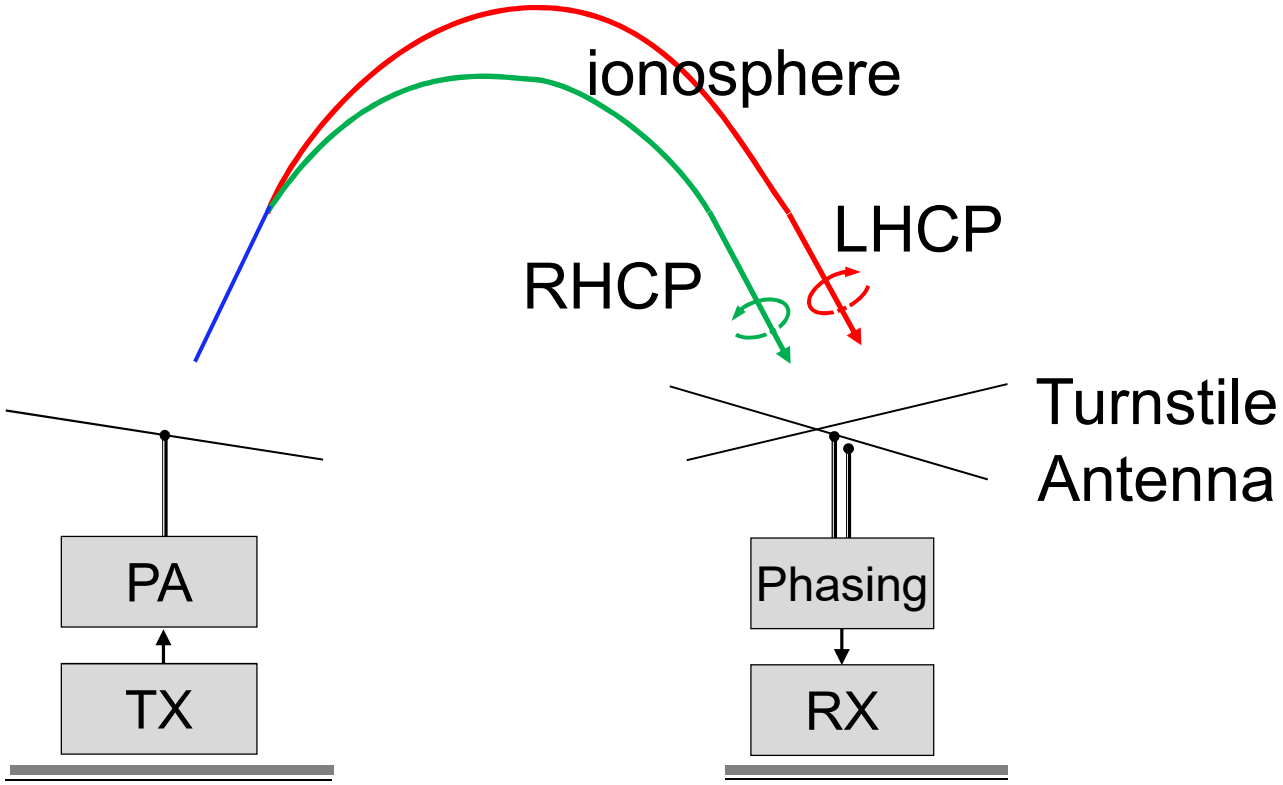
This is where the journey starts …

This led to a curiosity-driven experiment …



A very adventurous journey (first leg)

This led to a curiosity-driven experiment …



Witvliet, Ben A., et al. "The importance of circular polarization for diversity reception and MIMO in NVIS propagation." Antennas and Propagation (EuCAP), 2014 8th European Conference on. IEEE, 2014.

UNIVERSITY OF BATH

A very adventurous journey (first leg)

… using equipment that was “just lying around” ☺

5.39 MHz Turnstile Antenna

Rohde & Schwarz FSMR26

$100,000

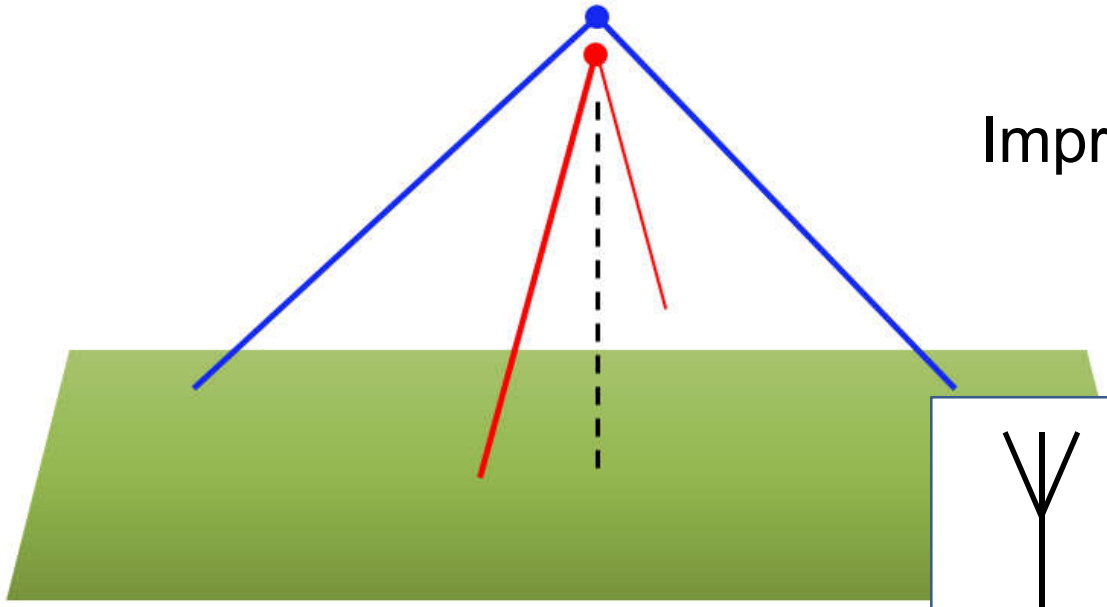


Witvliet, Ben A., et al. "The importance of circular polarization for diversity reception and MIMO in NVIS propagation." Antennas and Propagation (EuCAP), 2014 8th European Conference on. IEEE, 2014.

UNIVERSITY OF BATH

A very adventurous journey (first leg)

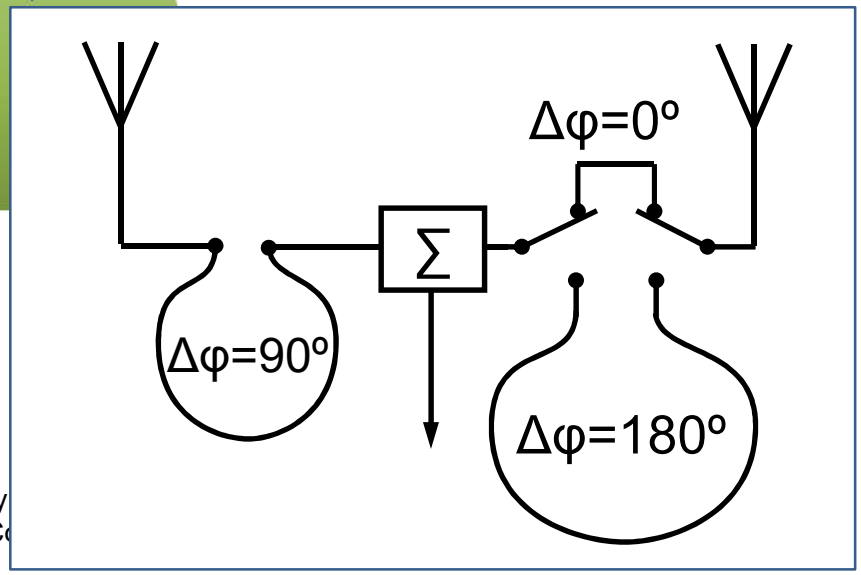
… using equipment that was “just lying around” ☺



Improvised phasing network

Δφ = +90º or -90º

(switched)



Witvliet, Ben A., et al. "The importance of circular polarization for diversity
propagation." Antennas and Propagation (EuCAP), 2014 8th European C

A very adventurous journey (first leg)

… using equipment that was “just lying around” ☺

Scrap-heap challenge

PAØA transmitter on 5.39 MHz

P = 800 Watts, ΔP < 0.1 dB

f = 5.39 MHz, Δf < 5 Hz

1 minute on / 1 minute off

DCF controlled timing

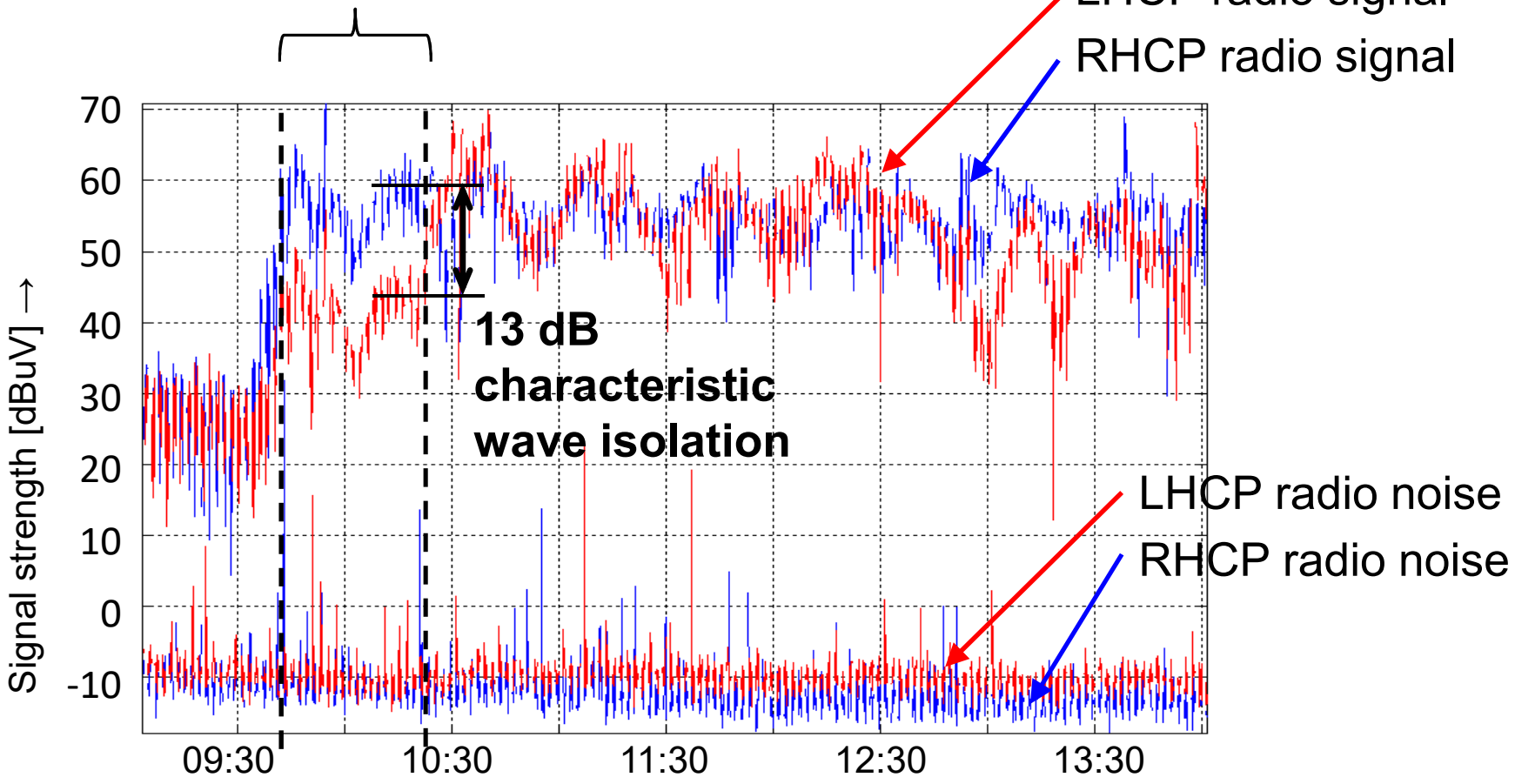


Witvliet, Ben A., et al. "The importance of circular polarization for diversity reception and MIMO in NVIS propagation." Antennas and Propagation (EuCAP), 2014 8th European Conference on. IEEE, 2014.

UNIVERSITY OF BATH

Results of the first leg

First “Happy Hour” observations!

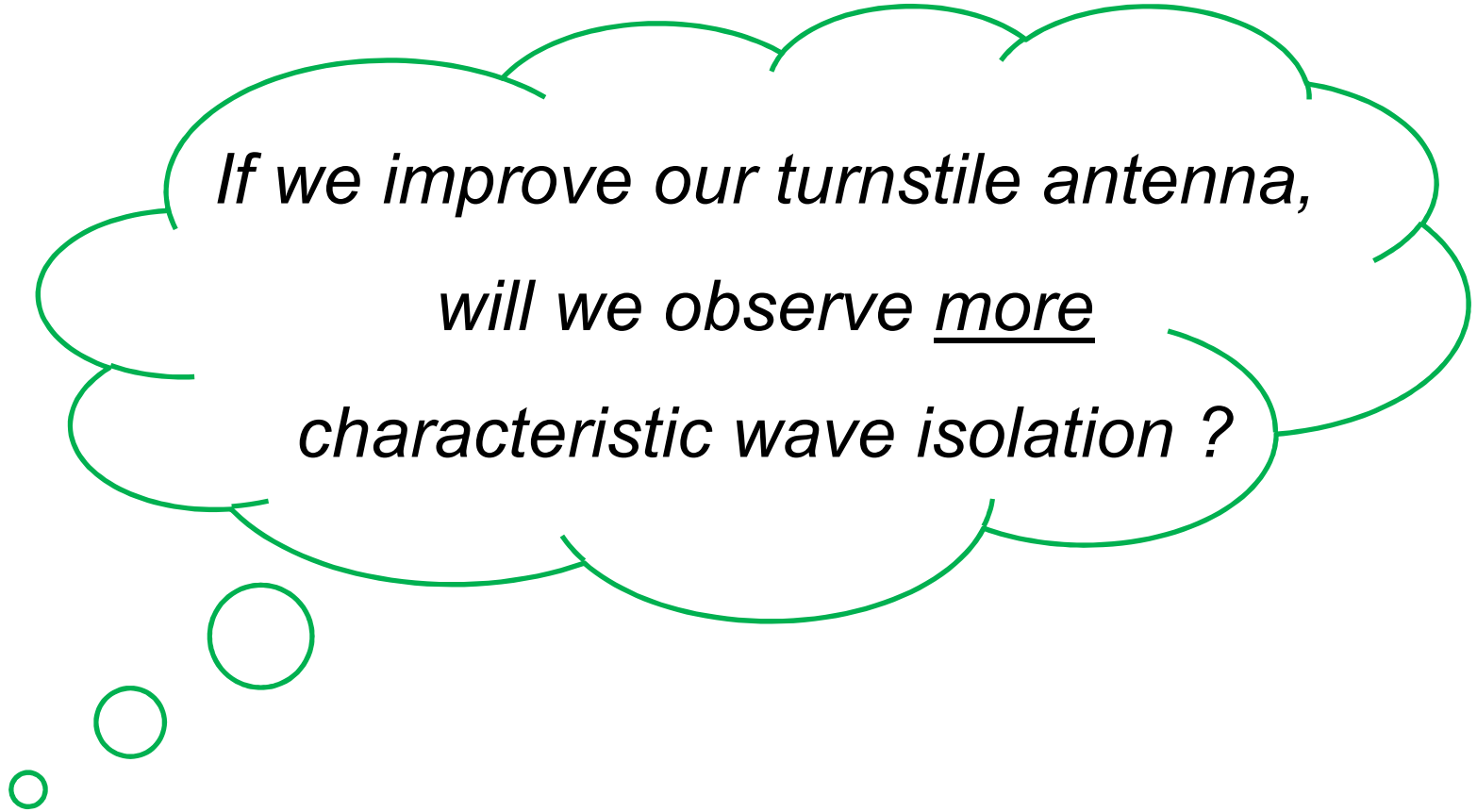


Witvliet, Ben A., et al. "The importance of circular polarization for diversity reception and MIMO in NVIS propagation." Antennas and Propagation (EuCAP), 2014 8th European Conference on. IEEE, 2014.

UNIVERSITY OF BATH

Results of the first leg

Arrived at the horizon, a new one that beckons …



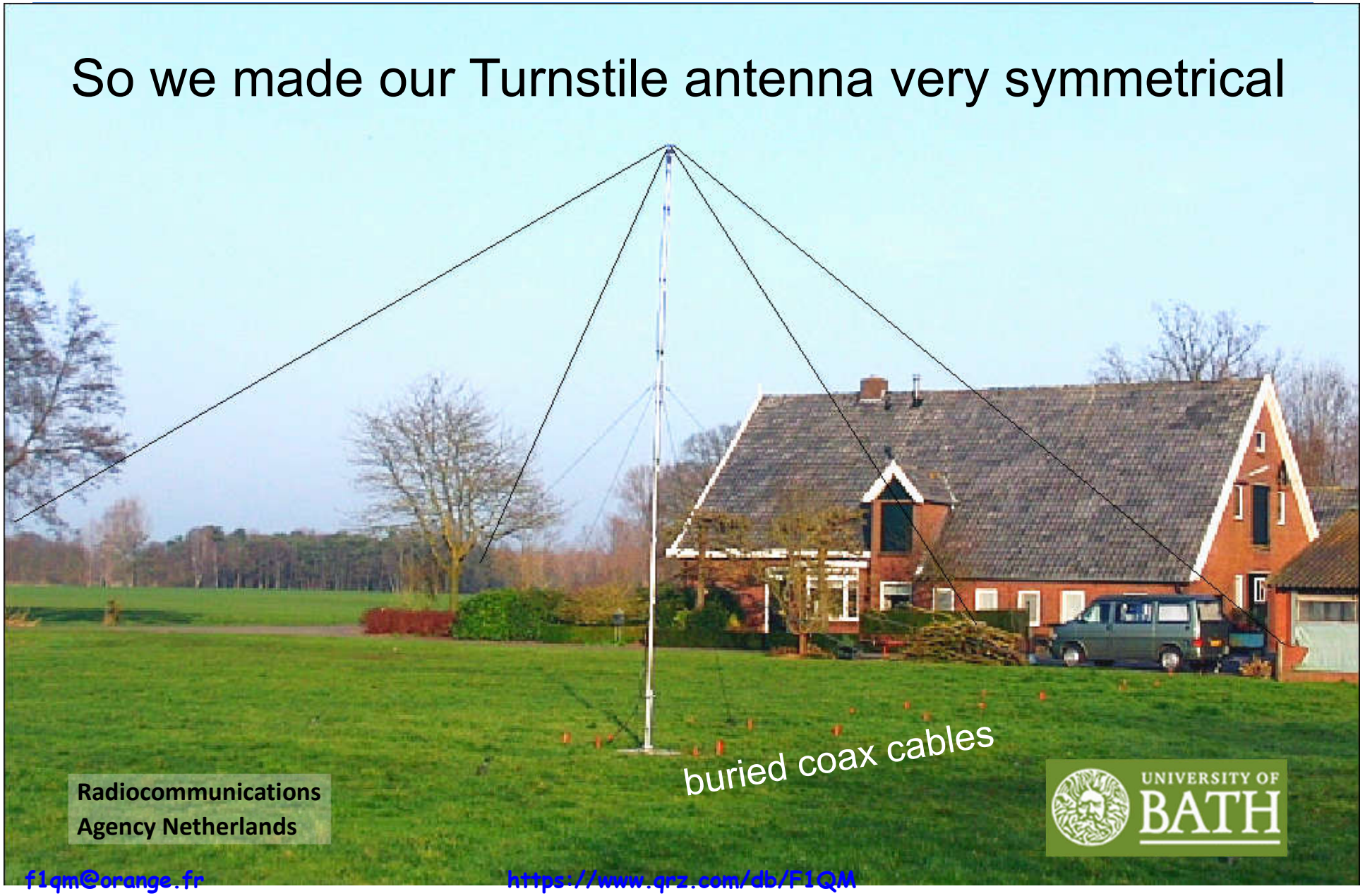
Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

f1qm@orange.fr

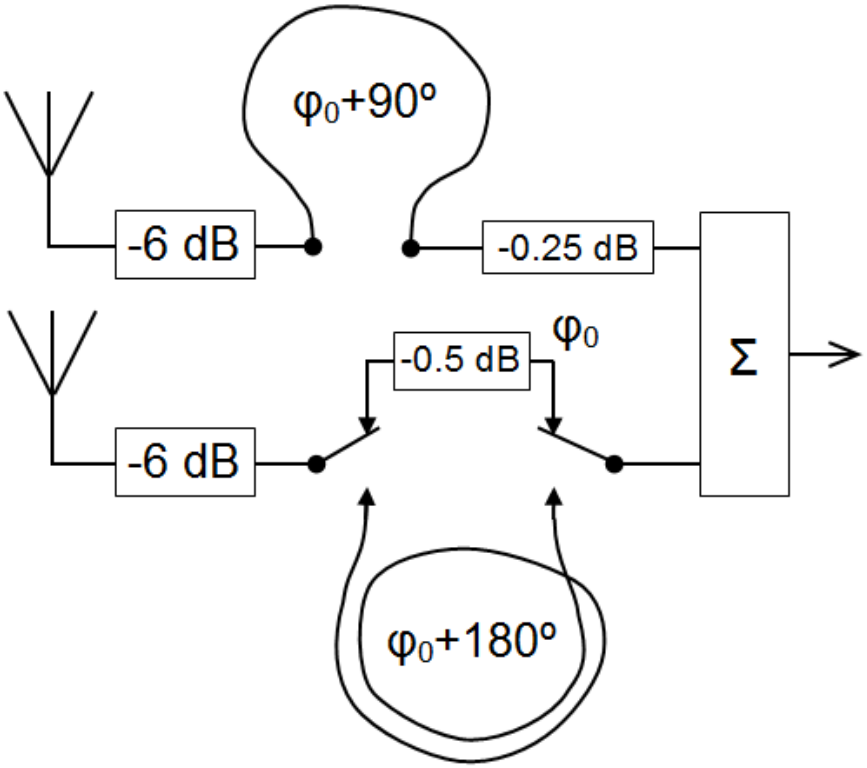
https://www.qrz.com/db/F1QM

A very adventurous journey (second leg)

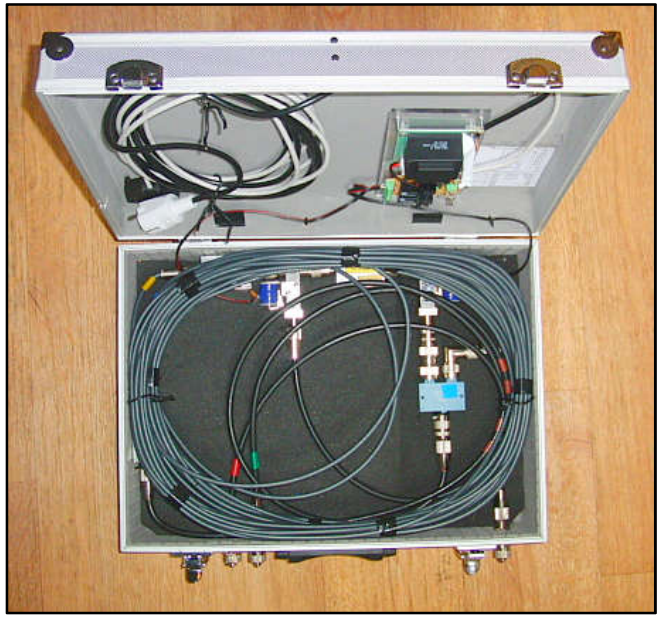


A very adventurous journey (second leg)

… perfected the phasing network …



$\Delta\varphi = 0.1°, \ \Delta P < 0.05$ dB

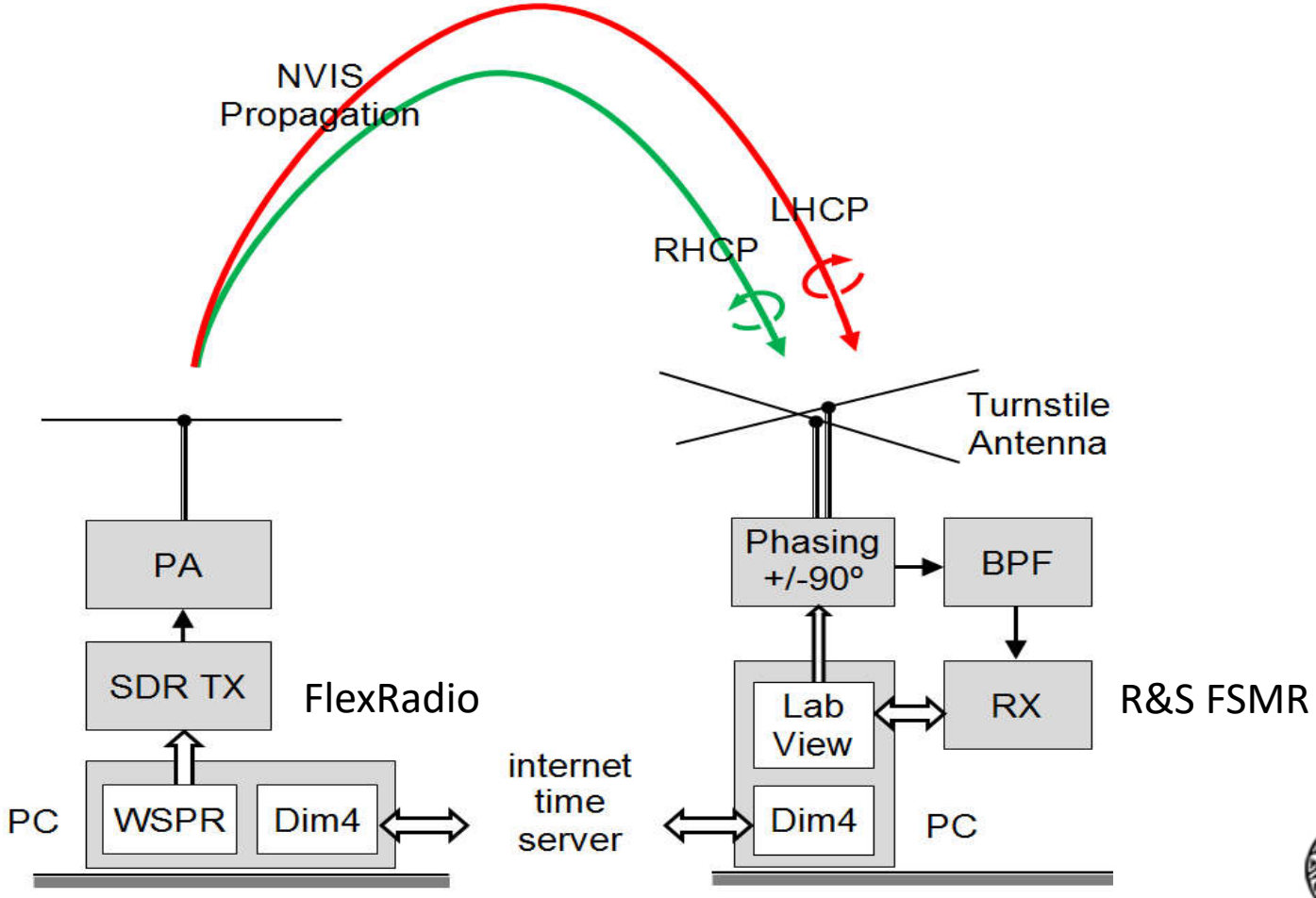


Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

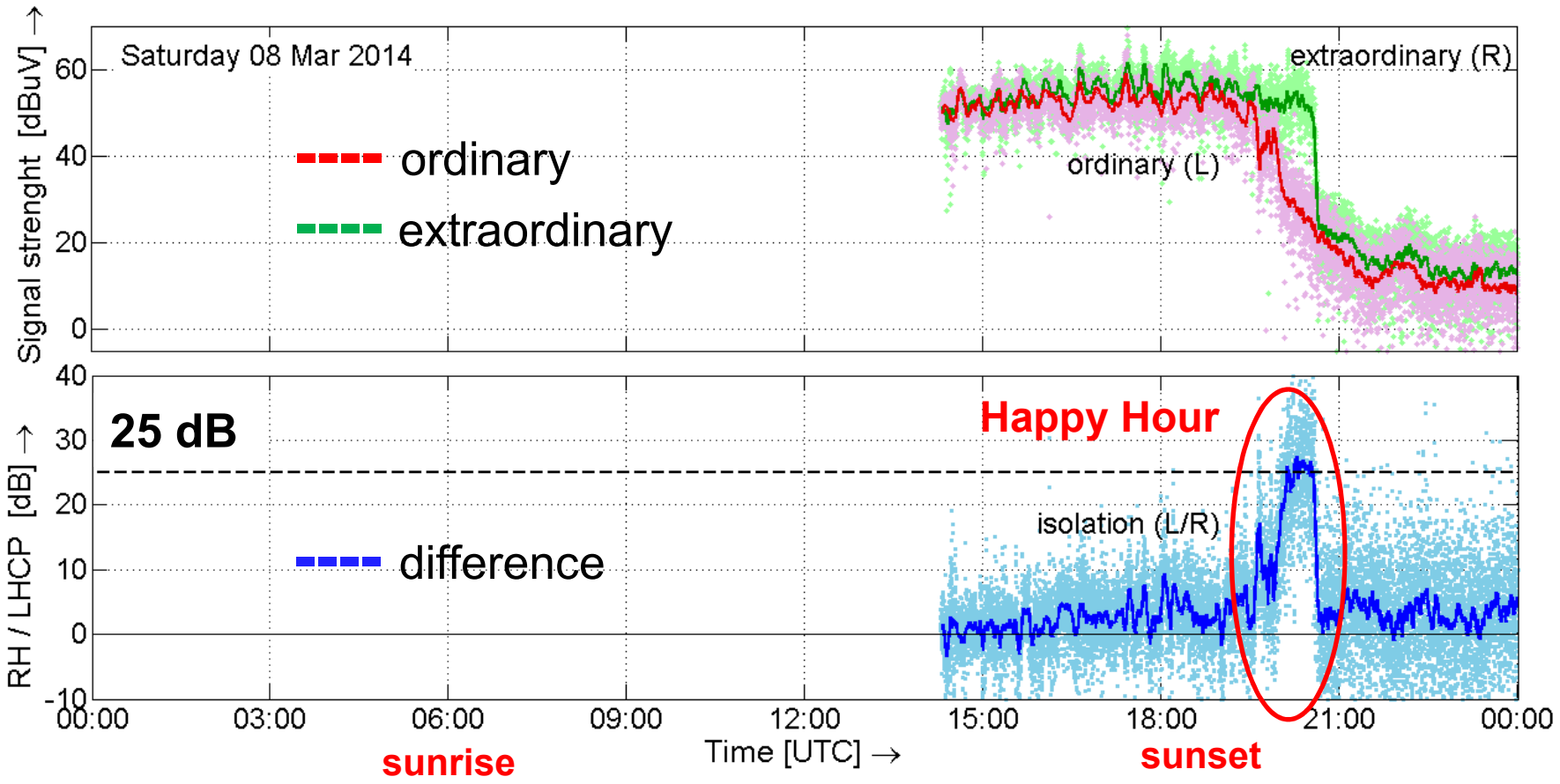
A very adventurous journey (second leg)

… and increased the measurement speed 30x



Results of the second leg

Now we see 25 dB characteristic wave isolation!



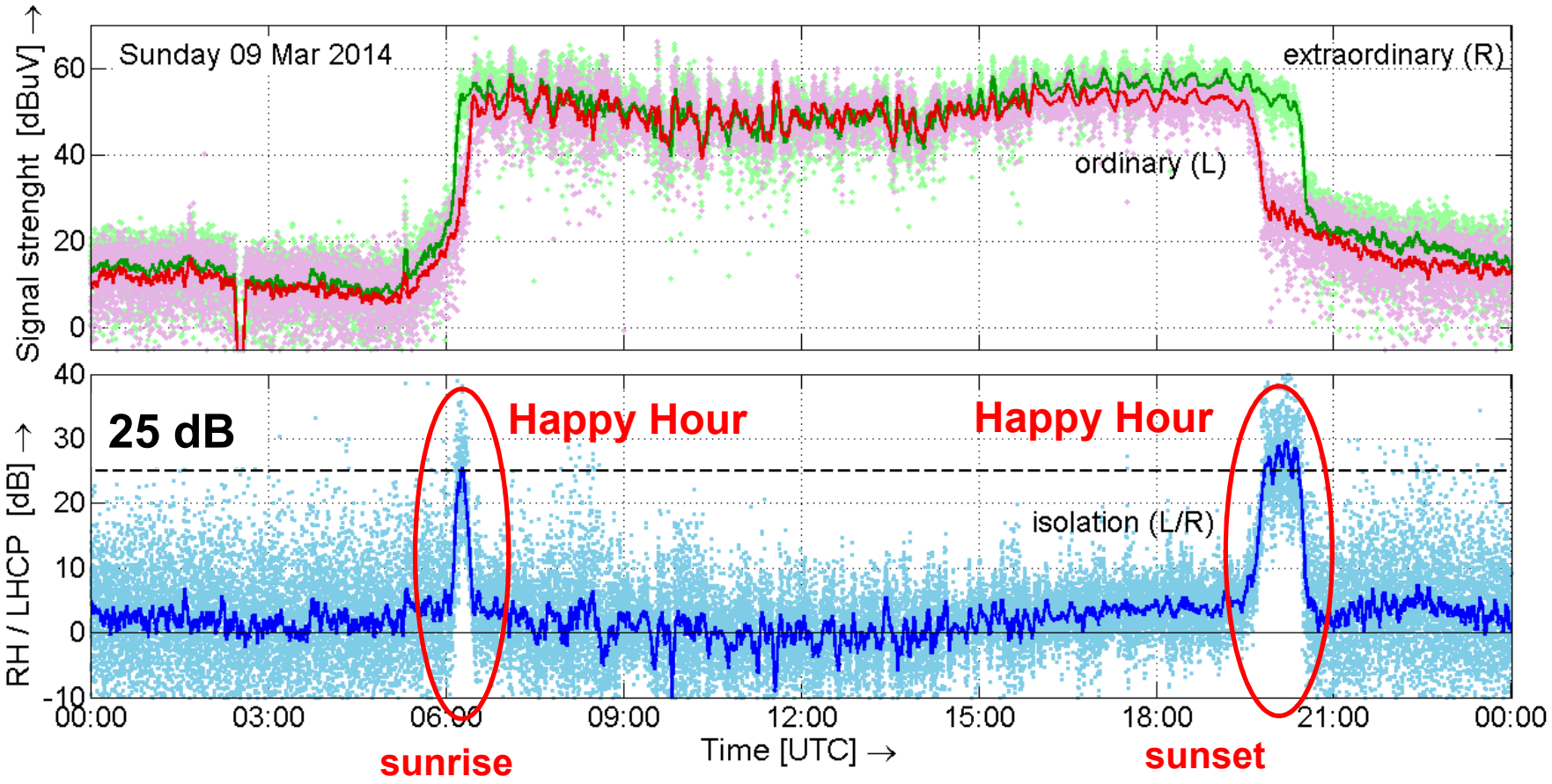
Radiocommunications Agency Netherlands

UNIVERSITY OF BATH

Results of the second leg

0:10

Now we see 25 dB characteristic wave isolation!

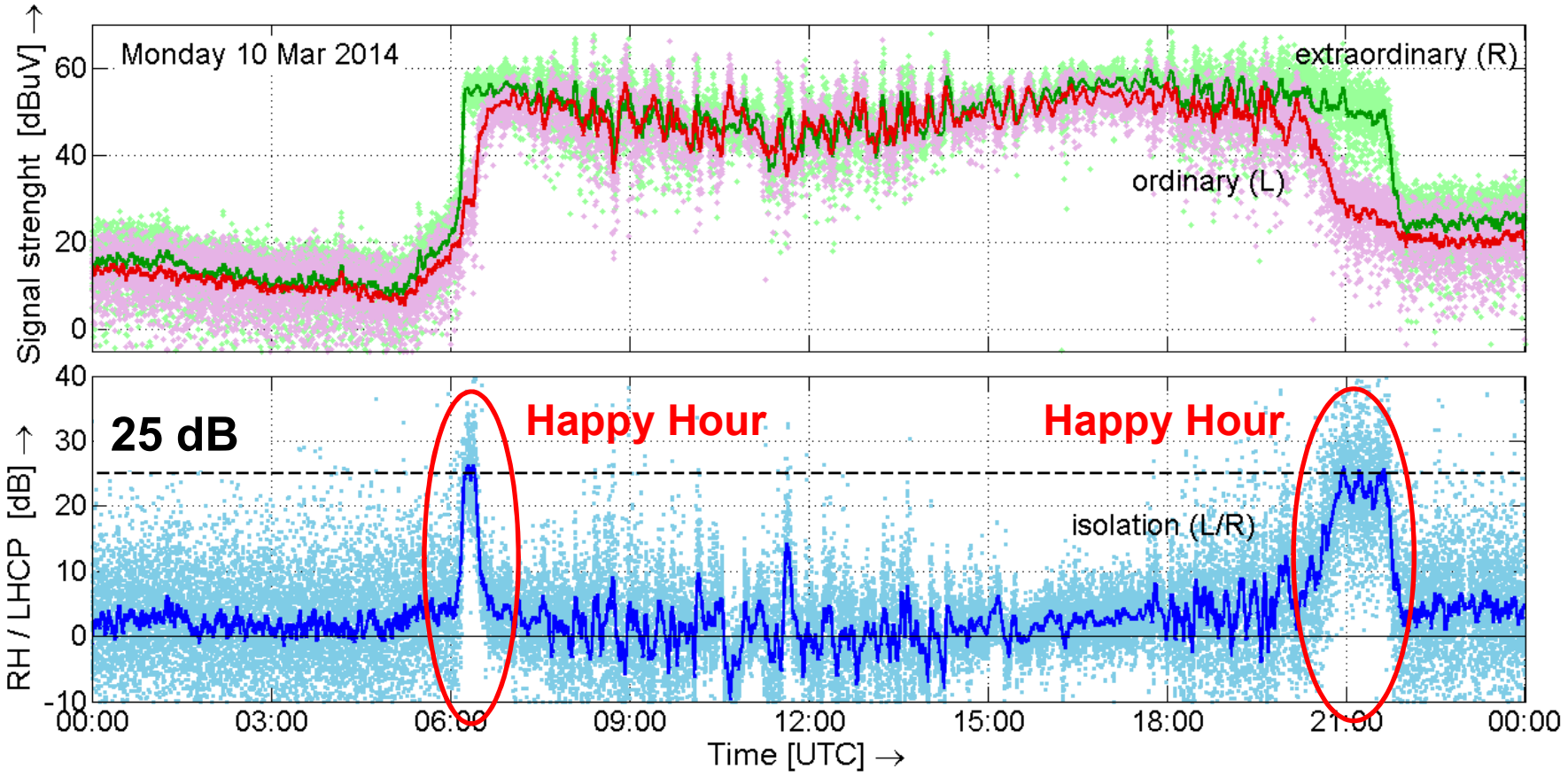


Radiocommunications Agency Netherlands

UNIVERSITY OF BATH

Results of the second leg

Now we see 25 dB characteristic wave isolation!



Witvliet, Ben A., et al. "Measuring the Isolation of the Circularly Polarized Characteristic Waves in NVIS Propagation [Measurements Corner]." IEEE Antennas and Propagation Magazine 57.3 (2015): 120-145.

UNIVERSITY OF BATH

Results of the second leg

All our measurements were on 1 path at 53° North.



Results of the second leg

So that made us wonder:

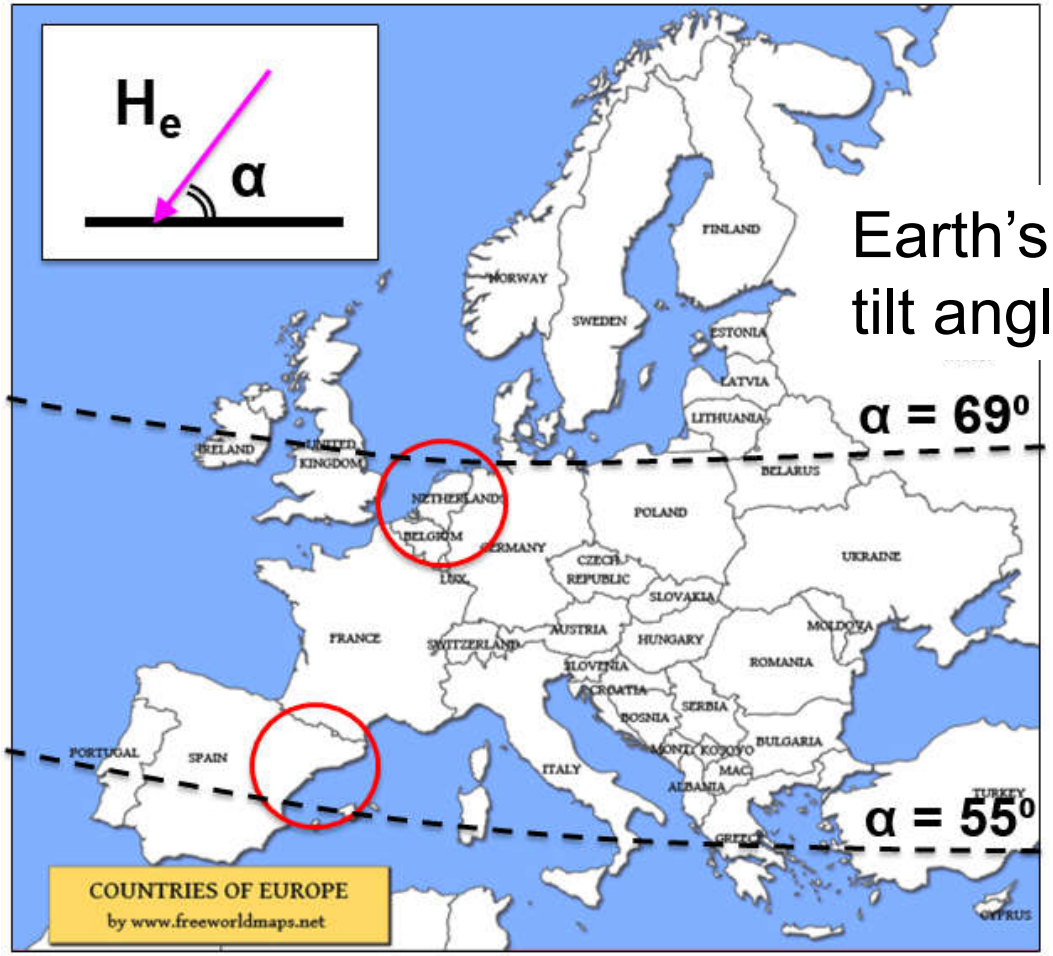
Can we confirm these results at a different latitude, other distances and azimuths?

Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

A very adventurous journey (third leg)

What if we'd change latitude … ?



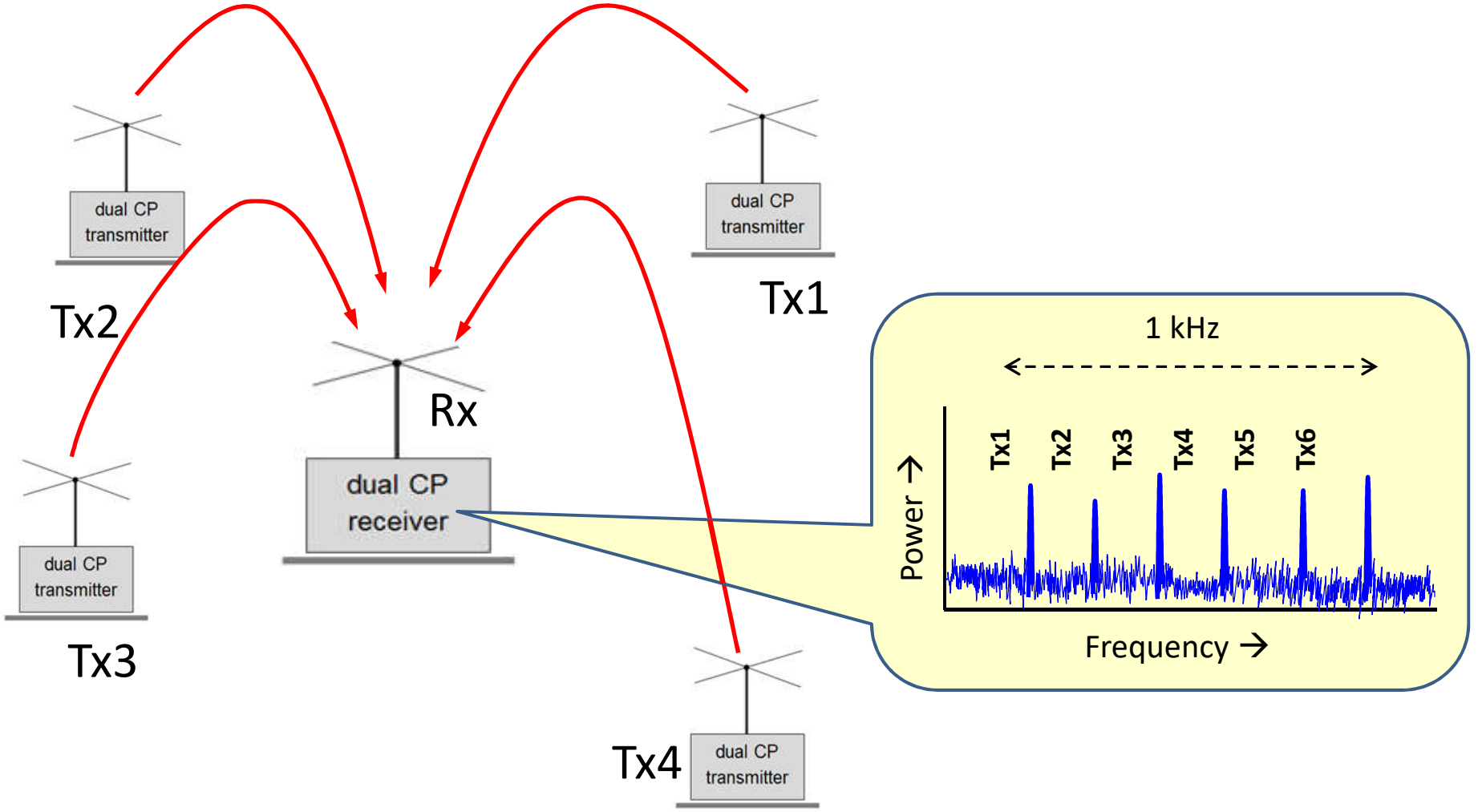
Earth's magnetic field tilt angle

The Netherlands

Barcelona, Spain

A very adventurous journey (third leg)

… and measure 6 paths simultaneously?



A very adventurous journey (third leg)

… and measure 6 paths simultaneously?



Cooperation with
LaSalle University
of Barcelona, Spain

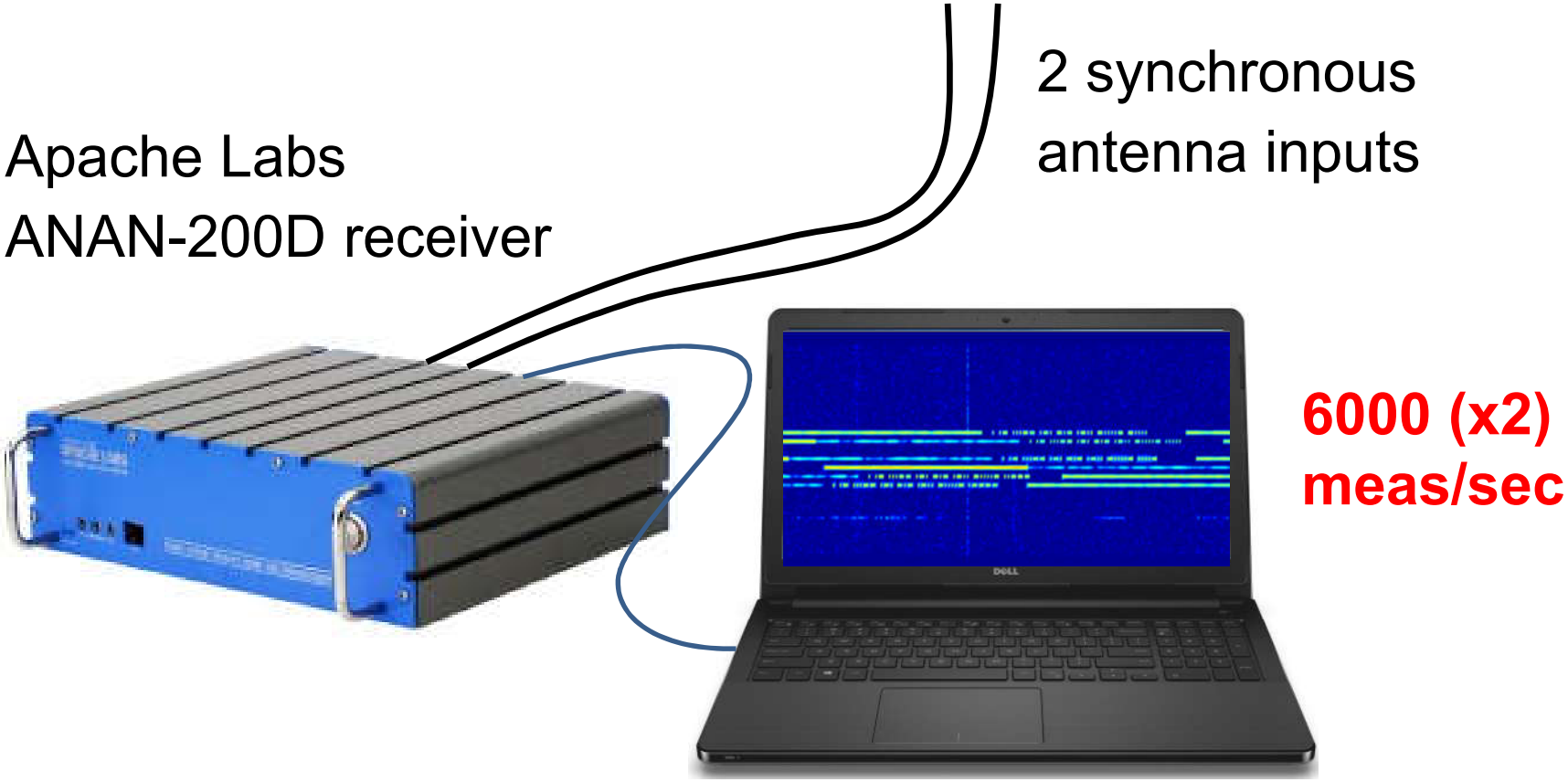
UNIVERSITY OF BATH

A very adventurous journey (third leg)

… and measure 6 paths simultaneously?

Apache Labs
ANAN-200D receiver

2 synchronous
antenna inputs



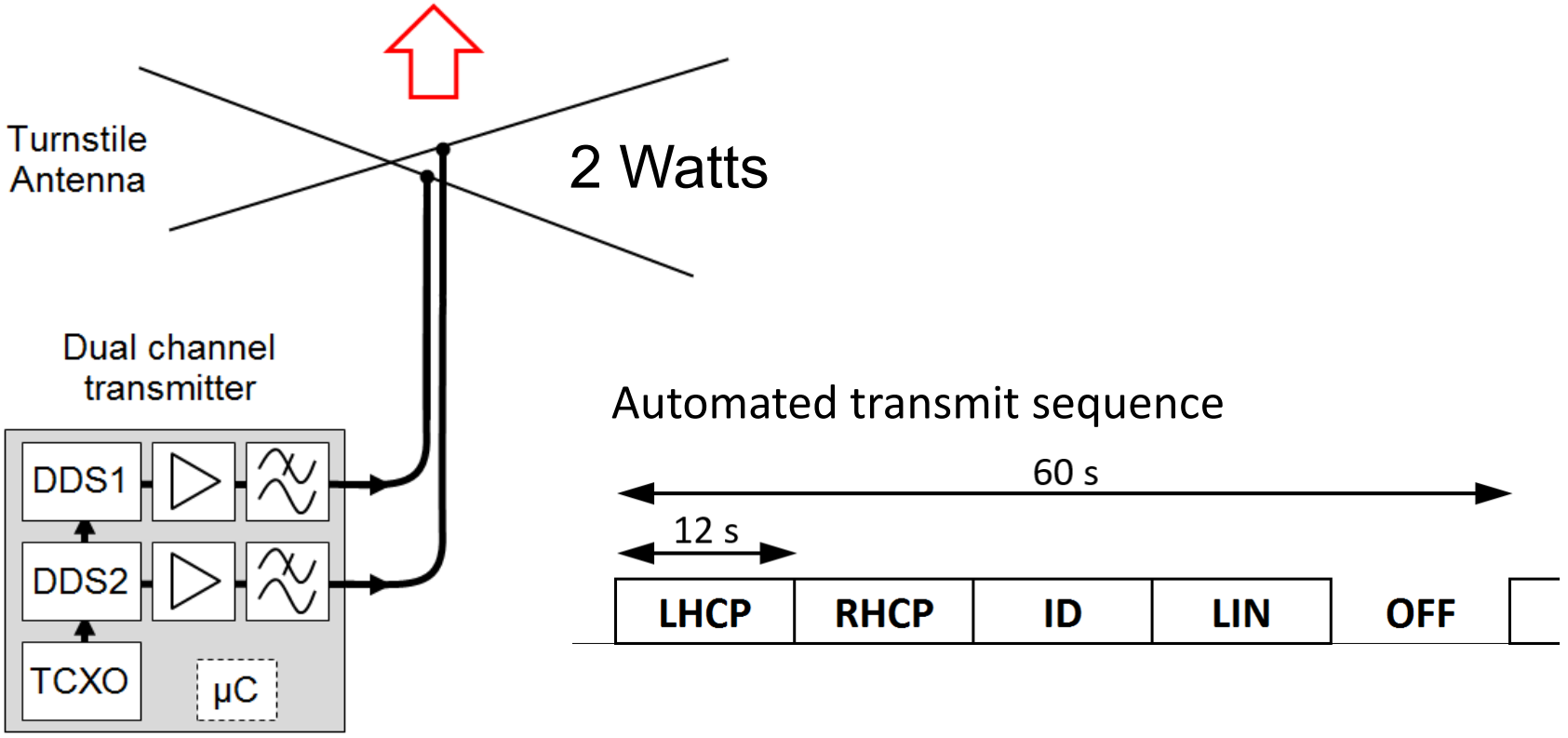
6000 (x2)
meas/sec

Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

A very adventurous journey (third leg)

No more scrap-heap challenge transmitters!



Witvliet, Ben A., et al., "A transportable hybrid antenna-transmitter system for the generation of elliptically polarized waves for NVIS propagation research]," European Conference on Antennas and Propagation, Davos, 2016.

UNIVERSITY OF BATH

A very adventurous journey (third leg)

No more scrap-heap challenge transmitters!

Wire antenna elements and baluns

Beacon transmitter

Mast 6.3 m

Mastfoot

Battery



Radiocommunications Agency Netherlands

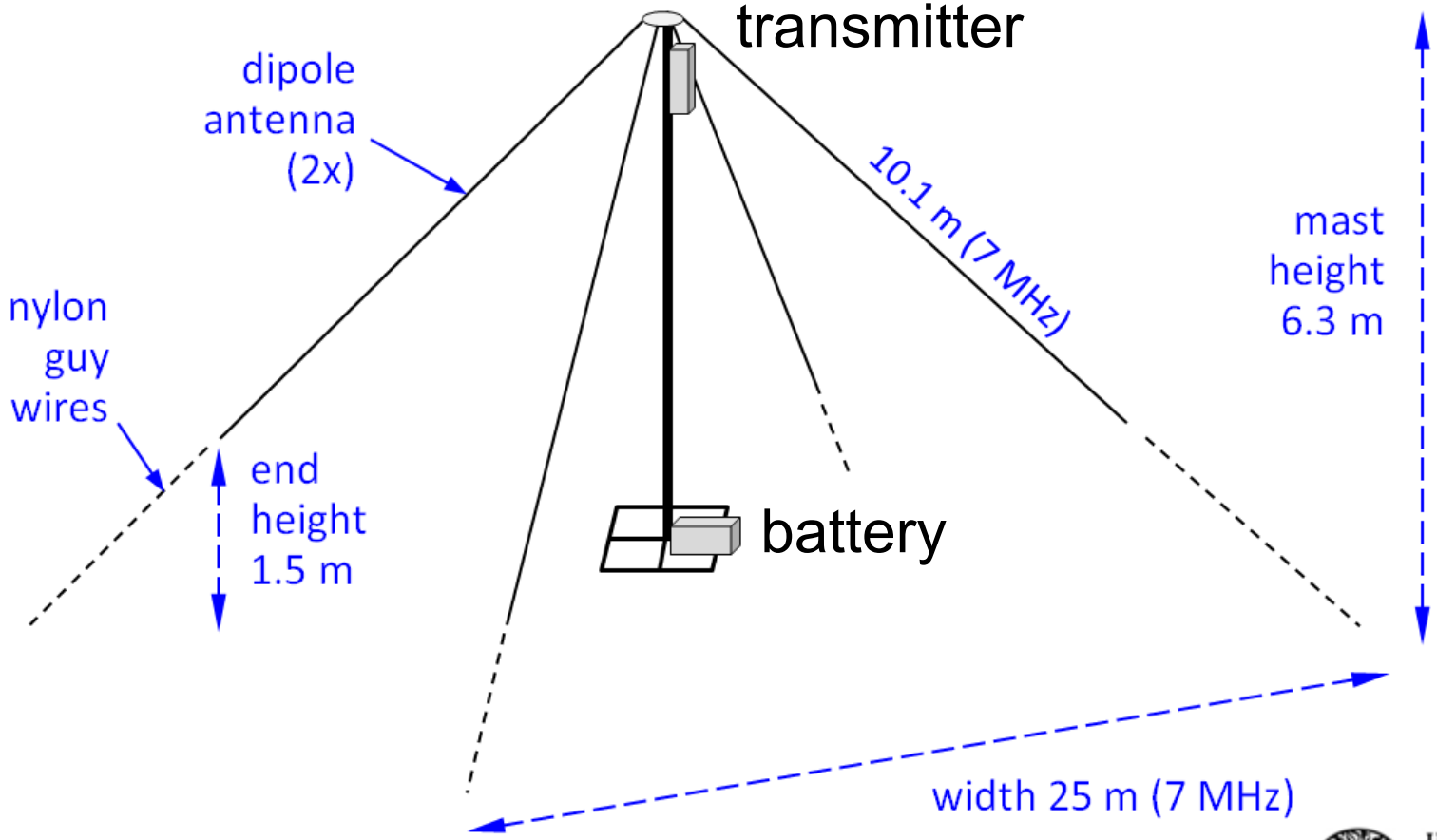
f1qm@orange.fr

https://www.qrz.com/db/F1QM

UNIVERSITY OF BATH

A very adventurous journey (third leg)

No more scrap-heap challenge transmitters!



Witvliet, Ben A., et al., "A transportable hybrid antenna-transmitter system for the generation of elliptically polarized waves for NVIS propagation research]," European Conference on Antennas and Propagation, Davos, 2016.

UNIVERSITY OF BATH

A very adventurous journey (third leg)

12 months later, time to hit the road!



8	antenna masts
16	dipole antennas
8	beacon transmitters
2	meas. receivers
10	batteries
32	guy wires
2	tool sets
(3	researchers)

Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

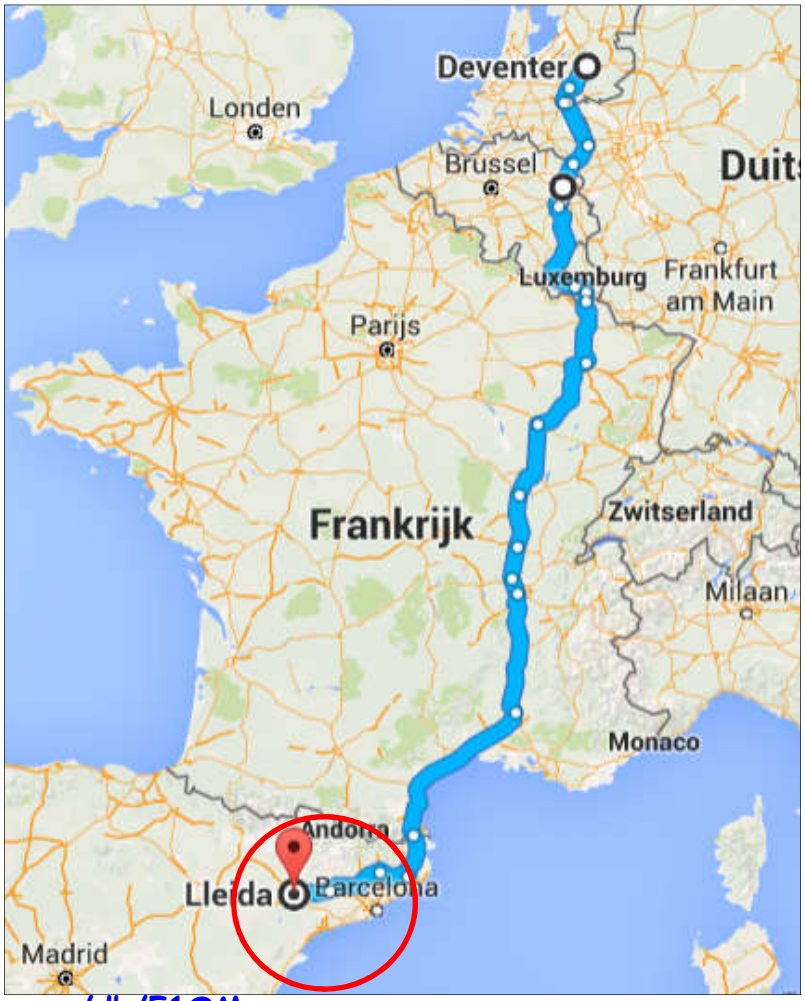
f1qm@orange.fr

https://www.qrz.com/db/F1QM

A very adventurous journey (third leg)

12 months later, time to hit the road!

Travel to Spain	1800 km
Visit University Barça	200 km
Installing beacons	900 km
Retrieving beacons	900 km
Travel back	1800 km +
Total	**5600 km**
	(3,500 mls)



Radiocommunications Agency Netherlands

f1qm@orange.fr

A very adventurous journey (third leg)

Interesting field work!



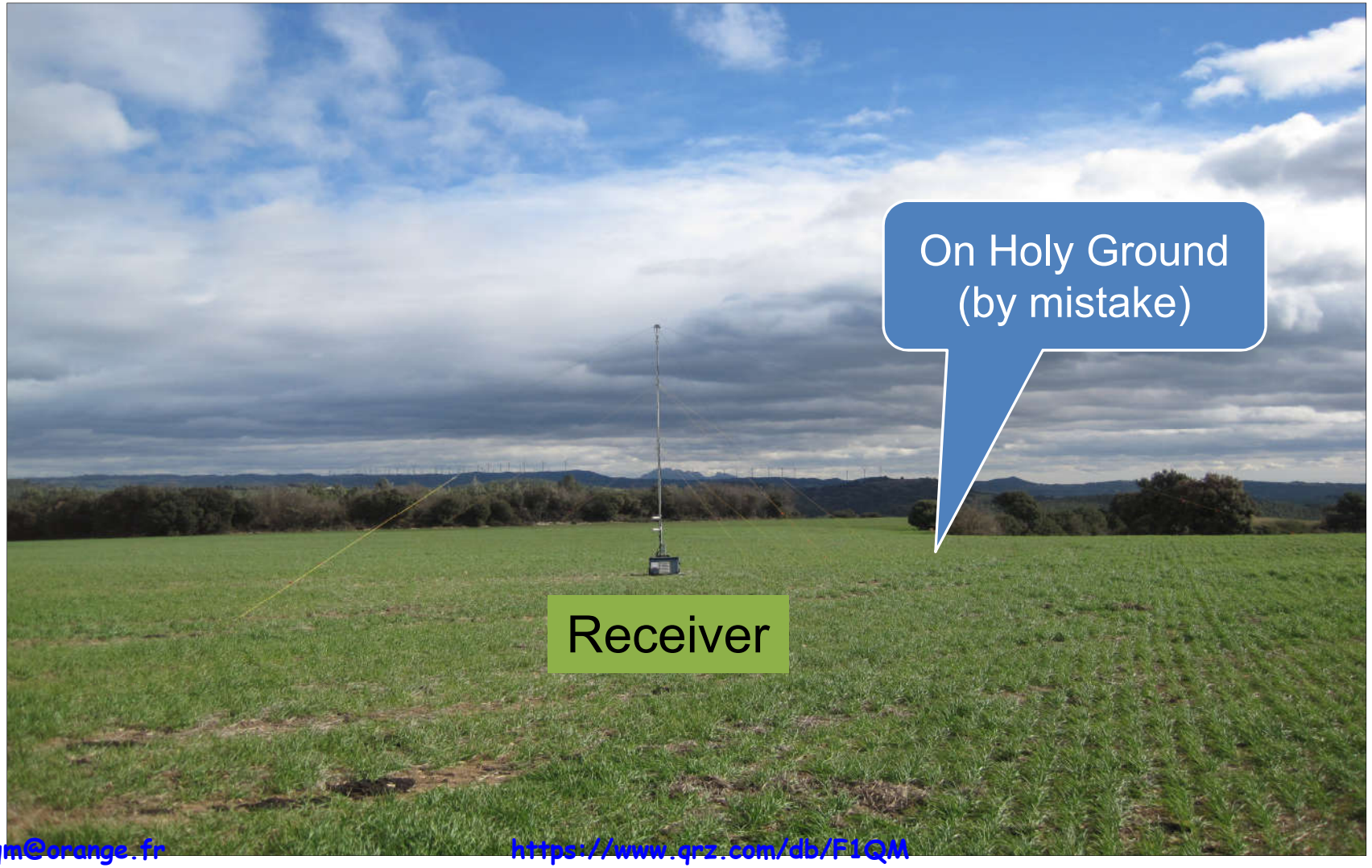
A very adventurous journey (third leg)

Interesting field work!



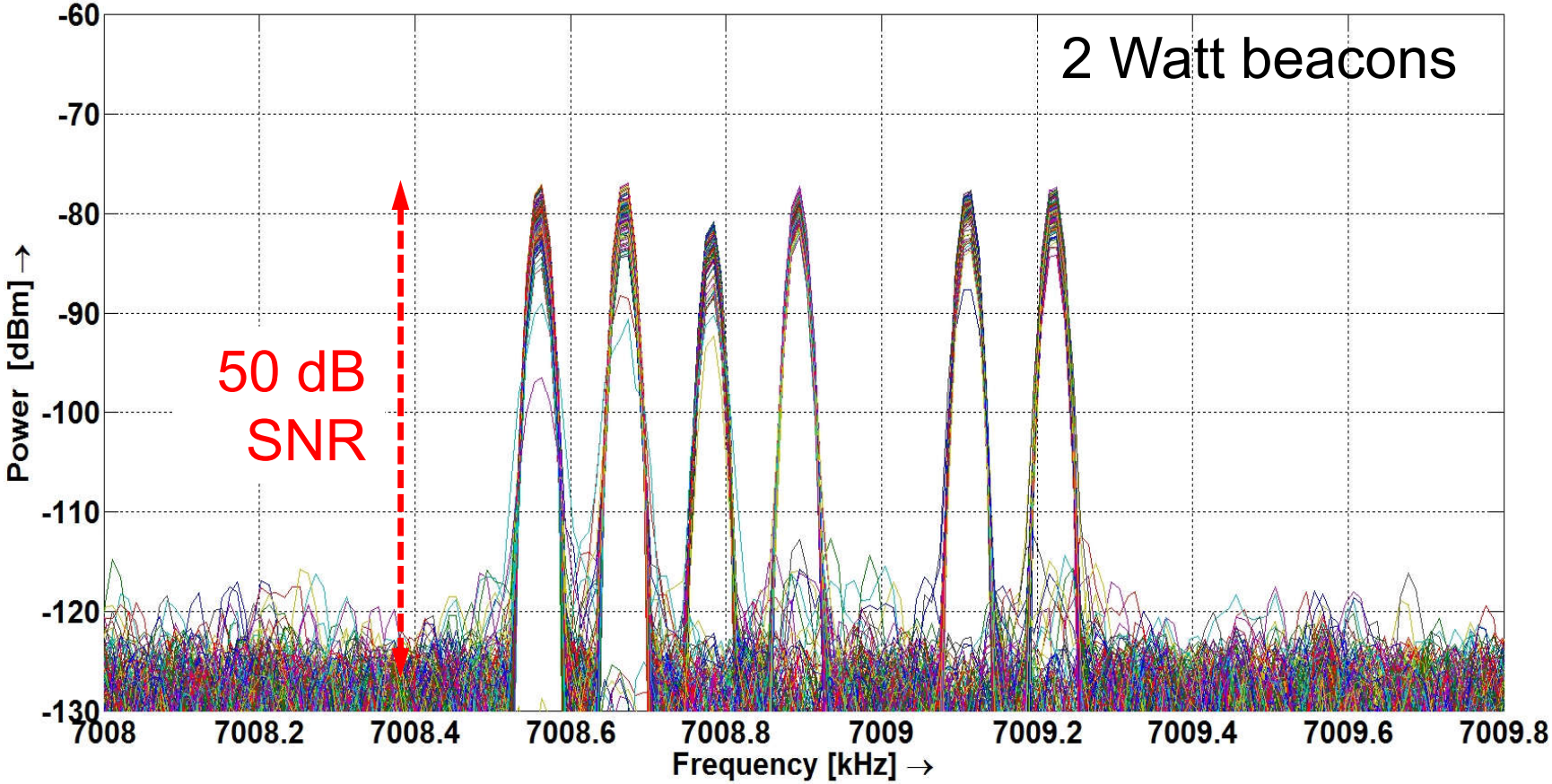
A very adventurous journey (third leg)

Interesting field work!



Results of the third leg

And interesting results!



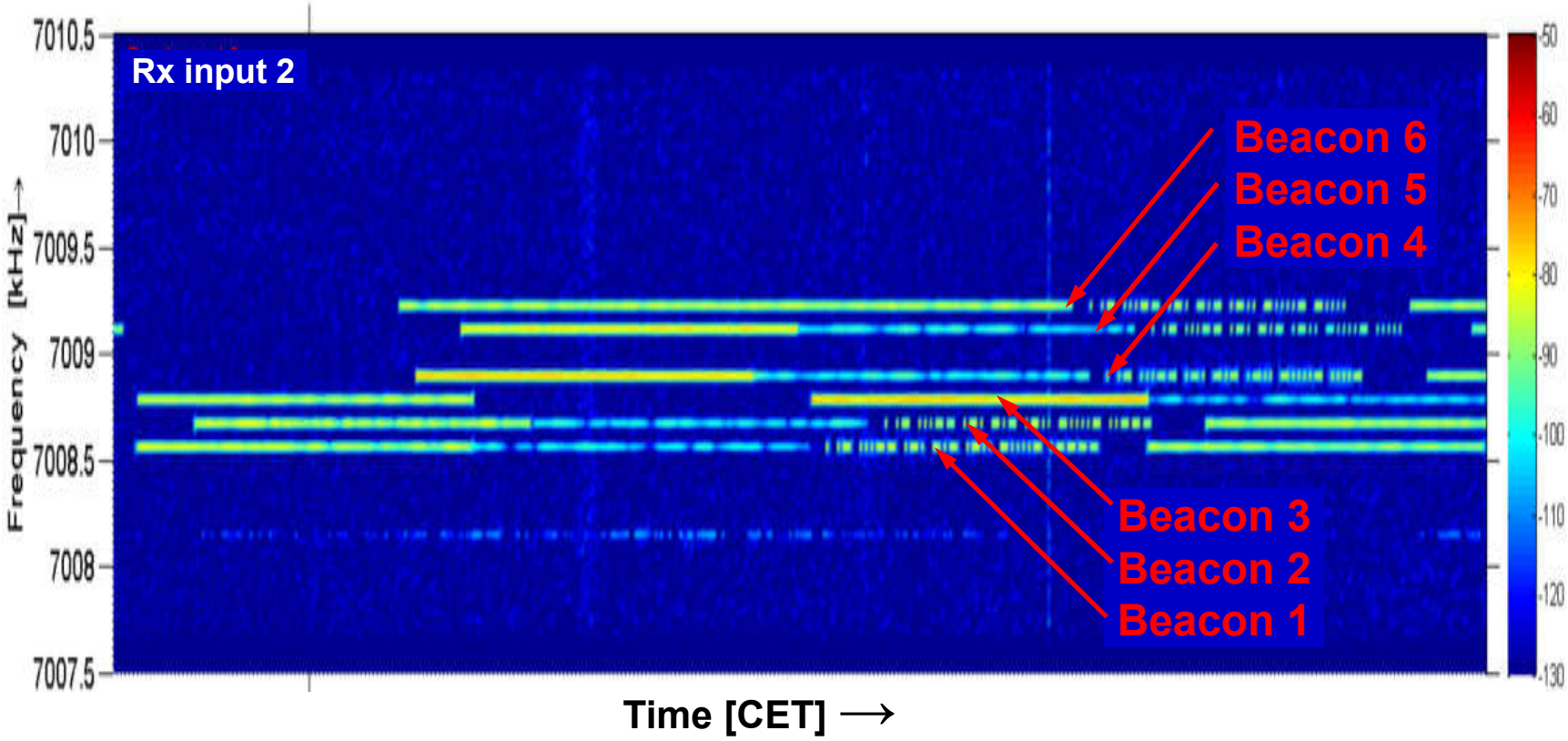
Radiocommunications Agency Netherlands

UNIVERSITY OF BATH

Results of the third leg

0:17

And interesting results!

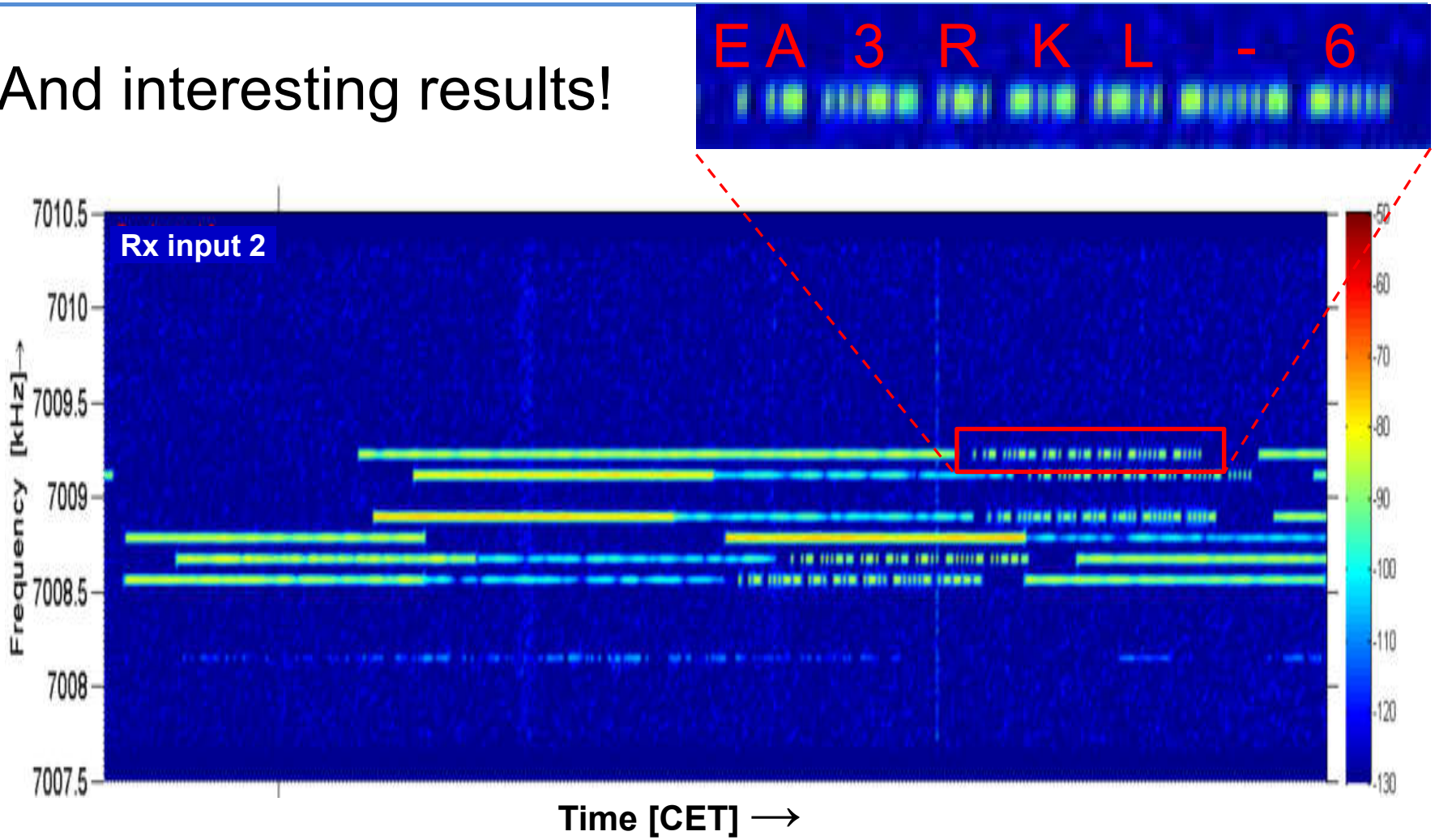


Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

Results of the third leg

And interesting results!

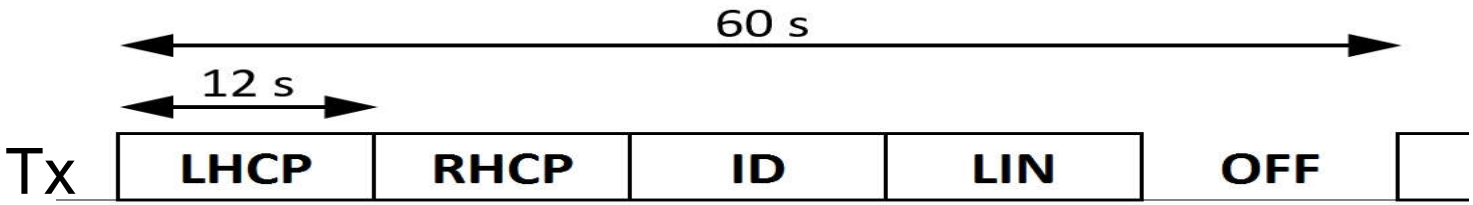


Radiocommunications
Agency Netherlands

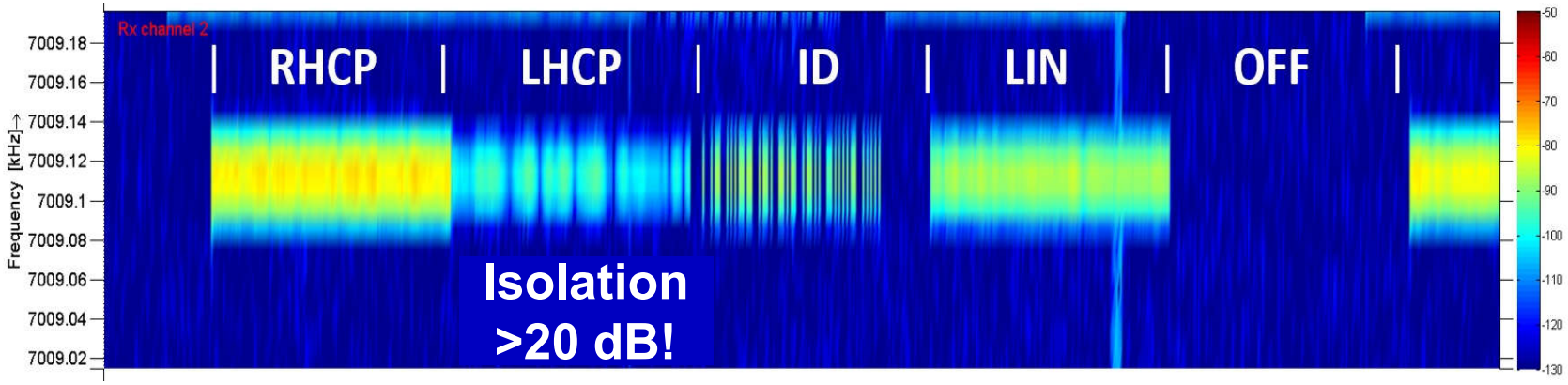
UNIVERSITY OF BATH

Results of the third leg

Morning Happy Hour, beacon 1



Happy Hour reception in linear polarization



Time ⟶

Radiocommunications Agency Netherlands

UNIVERSITY OF BATH

Results of the third leg

0:20

Interesting results

- Happy Hour propagation very well visible
- >20 dB isolation between ordinary and extraordinary wave
- Fading much more pronounced in linear polarization
- 2 Watt beacons produced excellent SNR

And they lived happily ever after…

What brought this adventure us?

- Increased knowledge of NVIS propagation
- New ideas to improve NVIS links
- Friendship with LaSalle University of Barcelona staff
- A lot of nice stories to tell

NVIS Field Research in Spain

Questions?



Radiocommunications
Agency Netherlands

UNIVERSITY OF BATH

f1qm@orange.fr

NVIS Field Research in Spain

Contact information

dr. ing. Ben A. Witvliet

email pe5b@xs4all.nl, b.a.witvliet@bath.ac.uk

Free publication download from

https://www.researchgate.net/profile/Ben_Witvliet/publications

NVIS Field Research in Spain

With thanks to:

The staff of the Roquettes, Dourbes and Juliusruh ionosondes, PAoA, PA5G, PA3DES, PAoSIR, Geert-Jan Laanstra and many others.

With thanks to the colleagues of Lasalle Ramon Llull Universitat de Barcelona (EA3RKL) for the excellent cooperation!

The NVIS research in Catalonia, Spain was sponsored by the European Association on Antennas and Propagation (EurAAP)

Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz

Liens vers d'autres antennes et calculateurs

http://www.qsl.net/dk7zb/Cross-Yagi/crossyagi.htm

http://www.wa7x.com/cycloid_info.html

http://www.ws6x.com/ant_calc.htm

Enter primary operating frequency in Mhz.

51

Inverted Vee, approximate angle from horizontal. 45 Degree - 5% shorter

Click to Calculate Length or Clear Values

Inverted Vee		
Inverted Vee Length	2.66-m or (8 ft. 8.64 inches)	Assuming level ground, the minimum height of vee will be (length of leg * sin(angle from horizontal) plus the height of end points of vee above ground. The horizontal spread of Vee will be the distance from end point to end point, plus the tie off points.
Inverted Vee each leg	1.33-m or (4 ft. 4.32 inches)	
Minimum vertical height	0.94-m or (3.08 ft.)	
Minimum horizontal spread	1.88-m or (6.16 ft.)	
Standard (straight) dipole		
Standard dipole length	2.8-m or (9 ft. 2.11 inches)	
Each leg	1.4-m or (4 ft. 7.06 inches)	

Enter primary operating frequency in mHz. 51

Inverted Vee, approximate angle from horizontal. 22 Degree - 2% shorter

Click to Calculate or Reset

Standard Flat-Top Dipole

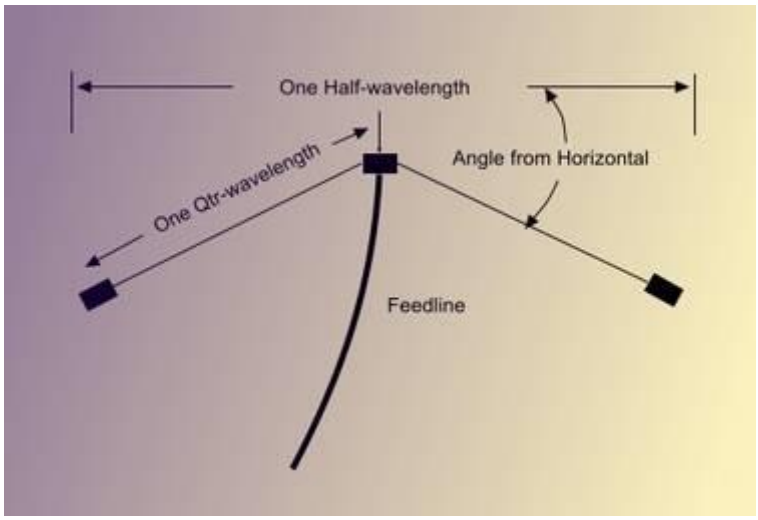
Full Half-Wavelength Dipole	9 ft. 2.2 inches (2.8 mtrs.)	For optimal performance over average ground, the half-wave dipole should be installed a minimum of 1/2 wavelength above ground. See drawings.
Each Leg	4 ft. 7.1 inches (1.4 mtrs.)	

Inverted Vee

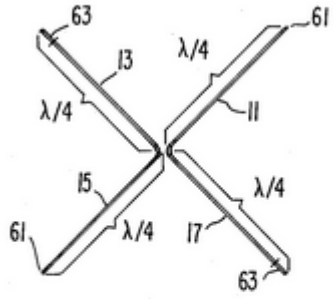
Full Half-Wave Inverted Vee	8 ft. 11.9 inches (2.7 mtrs.)	Over level ground, the minimum height for the apex (feedpoint) of an Inverted Vee is determined by the angle (downward slope) of the Vee legs. BE SURE to add the height above ground of the end supports. The horizontal spread of Vee will be the distance from end point to end point, plus the tie off points. See drawings.
Inverted Vee, Each leg	4 ft. 5.9 inches (1.4 mtrs.)	
Minimum Vertical Height	1 ft. 8.4 inches (0.5 mtrs.)	
Minimum Horizontal Spread	8 ft. 3.6 inches (5 mtrs.)	

Calculs comparatifs

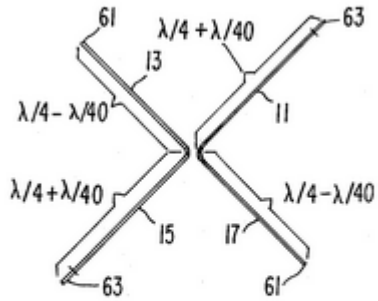
Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz



https://www.google.com/patents/US6271800
https://www.google.com/patents/US4446465
https://www.google.com/patents/US4062019



LINEAR POLARIZATION
Fig.5b.



CIRCULAR POLARIZATION
Fig.5c.

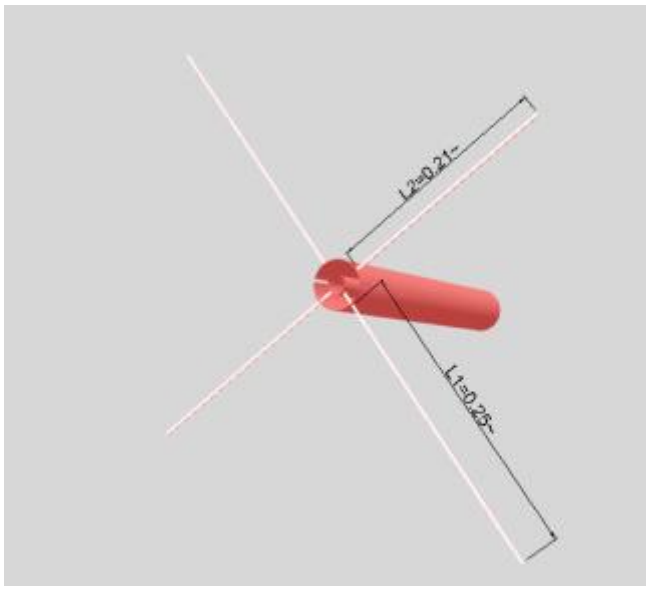


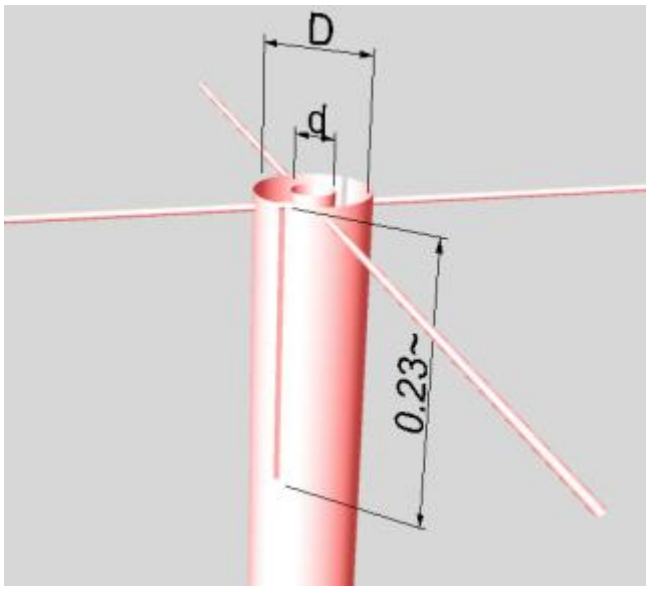
Un brin de 1.5 mètre plus 15 cm (165 cm) et un brin de 1.5 mètres -15 cm (135 cm) cela fait une RHCP ou une LHCP selon la position !, comme couper un coin à un panneau de planar cela me semble moins cher que un harnais ou un coupleur Hybride et 3dB de pertes en moins ??

http://diydrones.com/profiles/blogs/antenna-feedpoint-matching-baluns-turnstiles-and-why-homegrown

For the higher microwave frequencies, a plumbing type version is more appropriate. This is called the spilt tube or split sheath balun, and looks like this when used as a feed for a pair of crossed dipoles.

Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz





The balun and feed match consists of an outer and an inner tube. The ration of diameters D/d is chosen to give the desired impedance:

D/d = 1.86 for 75ohms, and 1.5 for 50 ohms.

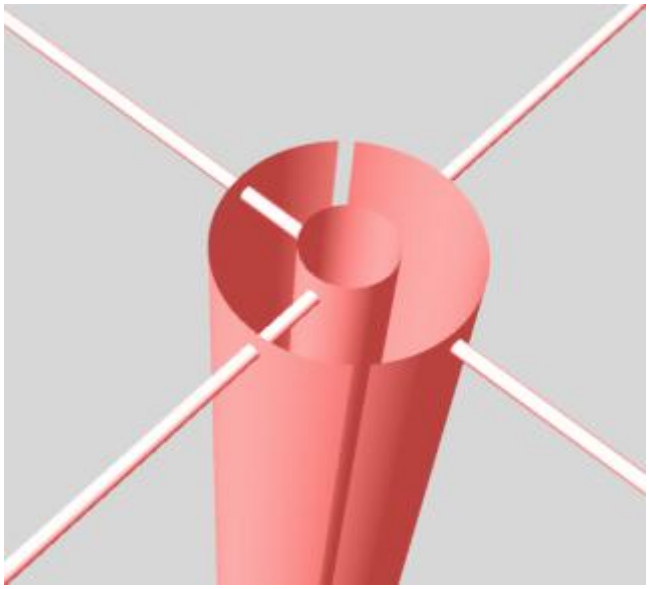
Typically the outer tube would be around 8mm for use at 2.4GHz.

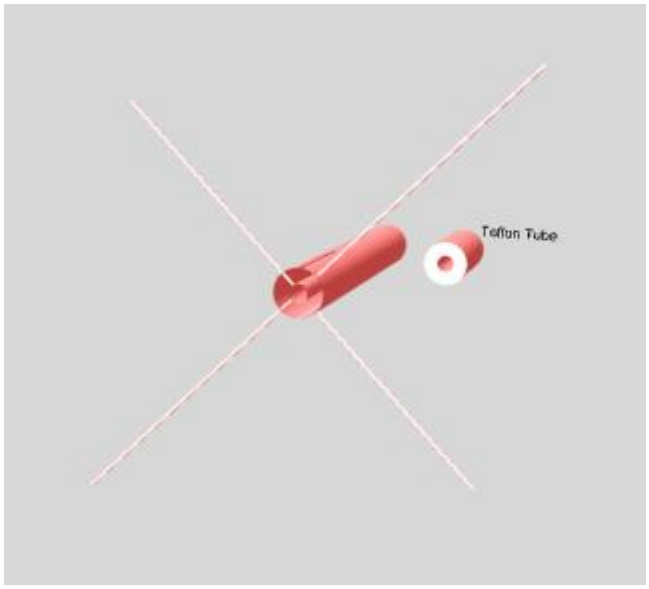
In order to obtain circular polarisation, I mentioned that the two dipole have to be fed 90deg apart (phase quadrature).

This can be done as in the coax balun version above (inserting an extra 1/4wave length of coax in the leg to one dipole gives an extra electrical wavelegnth of 90 degerees).

Or, this can be achieved by slightly lengthening the one element (becomes more inductive) and shortening the other(becomes more capacitive) - this also introduces the required phase difference between the elements.

This can be seen in the images above - the one element is typically around 0.21 wavelength per half, while the other is around 0.25 wavelength. One short and one long element penetrate the outer tube and are connected to the inner tube, while the opposite pair of elements are connected only to the outer tube. The outer tube is split or slotted (0.5mm width slot). The slot is approx 0.23 wavelength long.





The relationship in length between the two dipoles is critical, typically this would be measured on a network analyser and the feed impedance of each element set to say R+j45 ohms (longer dipole) and the other to R-j45 ohms. This will give the correct phase relationship between elements. A half mm variation can have a great effect, turning a good antenna into a mediocre one..

The last image above shows a teflon tube - this is inserted in the tube from below, and fits snugly inside the outer tube, and over the inner tube. This is then slid up and down to adjust the 'R' part of R+-jX, till the match is a good 50ohms. This does not affect the antenna radiation pattern or characteristics. Obtaining a 50ohm impedance match can be done by

trimming the element lengths as well, at the same time destroying the antenna radiation pattern and circularity.

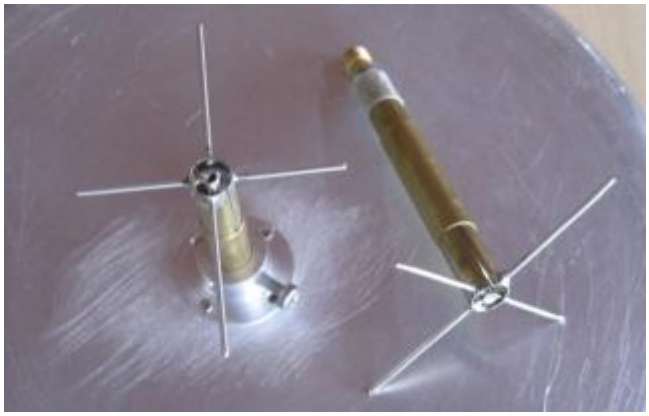
And that is why it is not so simple to do at home, and why the 'Hobby King' et al variants sold everywhere are mostly trash..You will probably achieve a few km range with those- remember, any old piece of wire will radiate - I easily achieve 15km with 500milliwats at 2.4GHz using two split sheath balun , properly matched and trimmed, crossed dipoles..

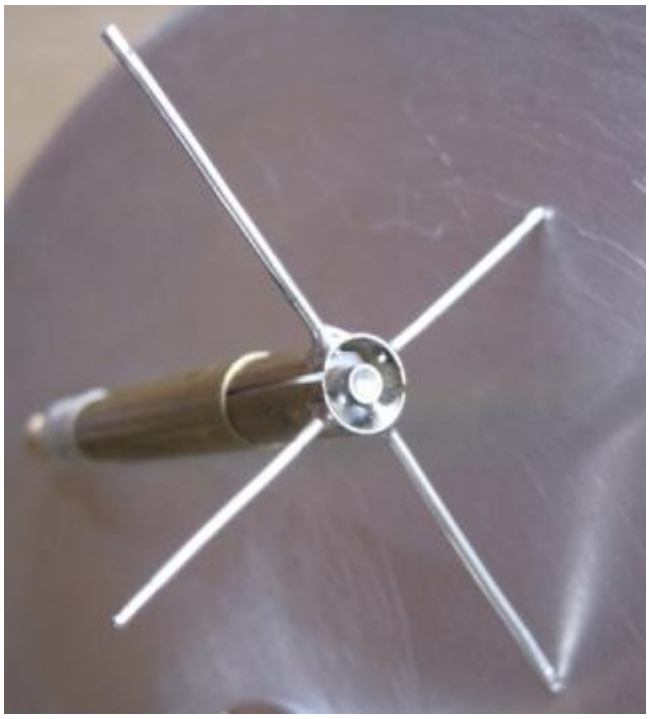
For those interested:

References are - RSGB VHF/UHF Manual - page 8.45

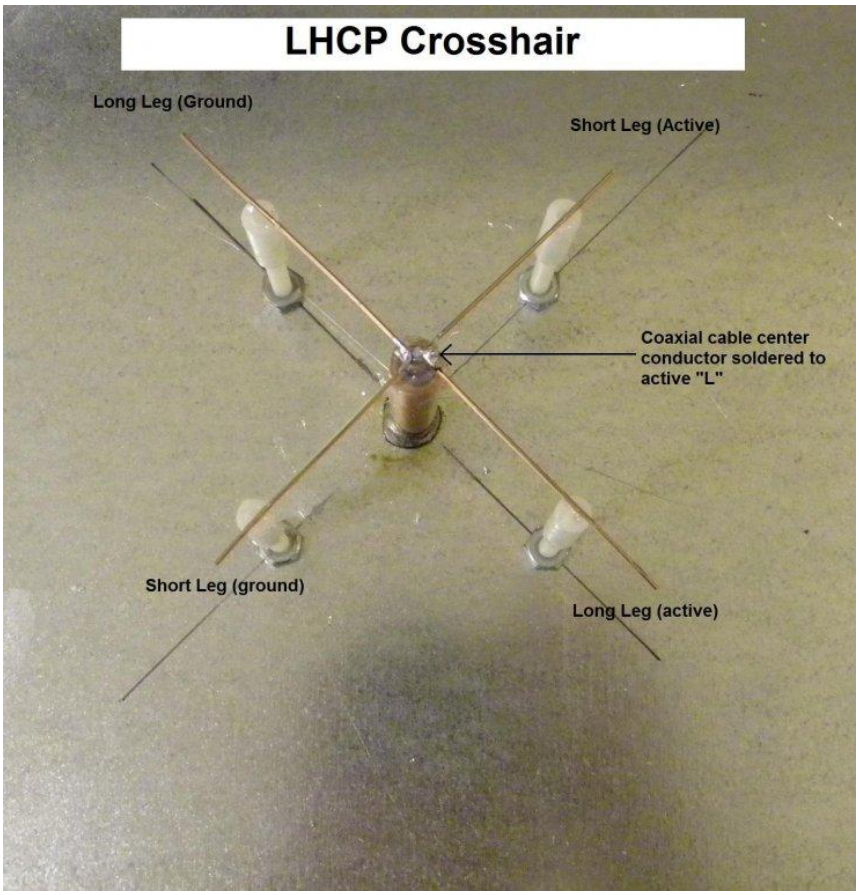
Modern Antenna Design - Page 255

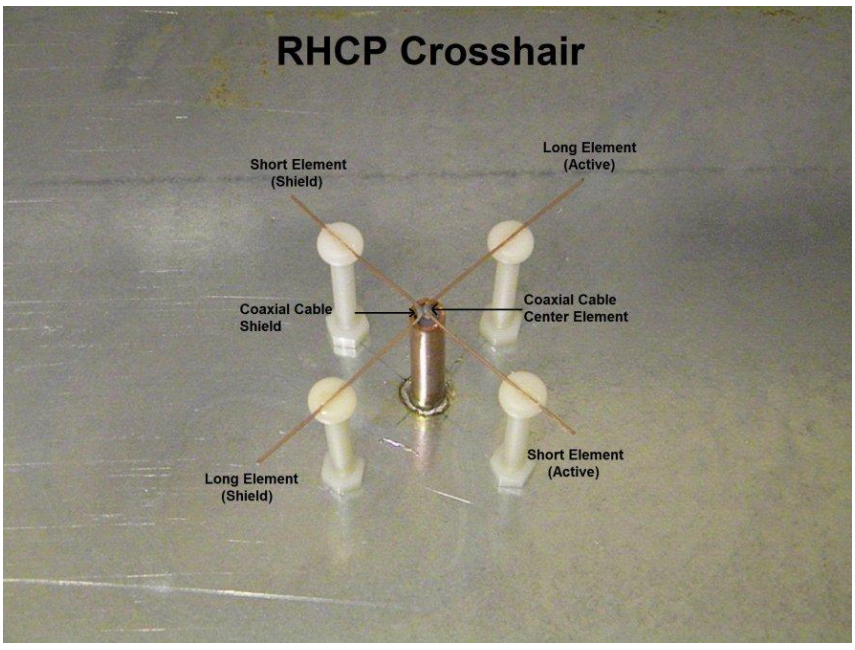
Here are some images of my split sheath balun crossed dipoles..





Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz





Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz

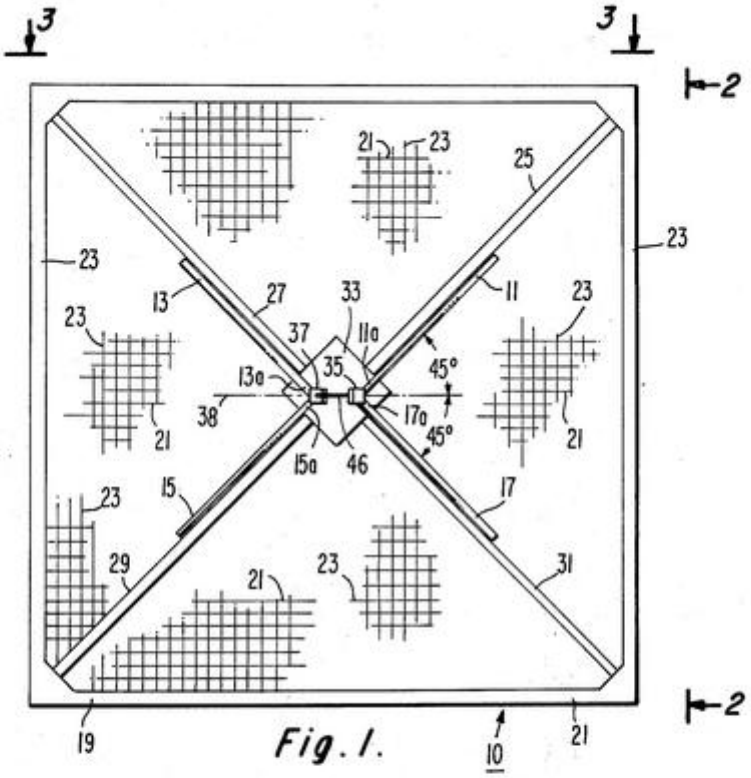


Fig. 1.

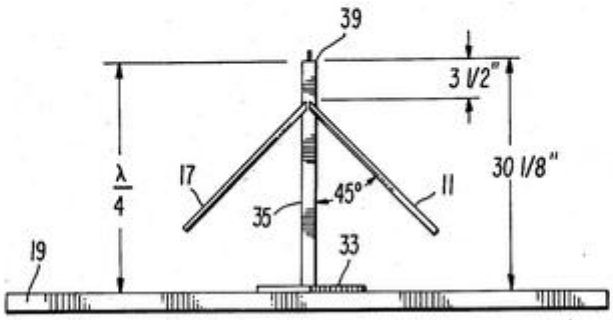
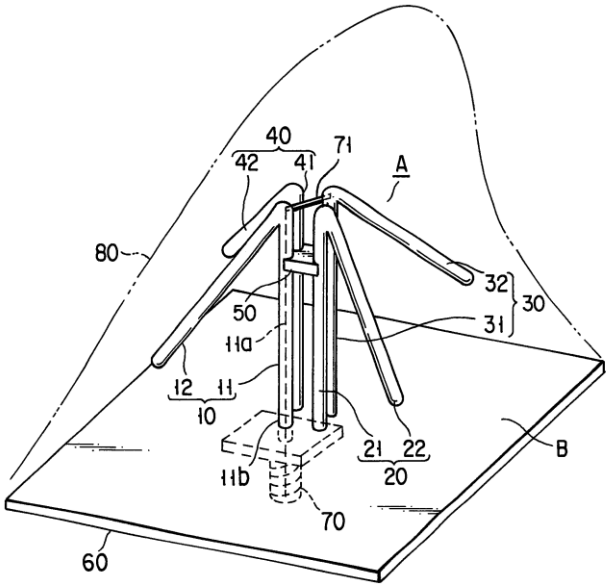
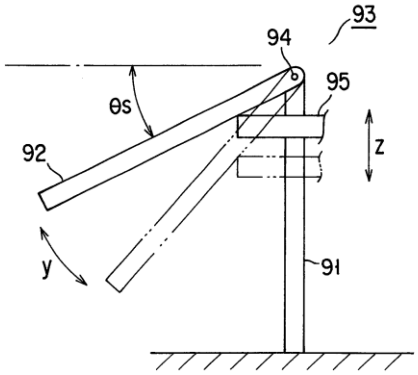
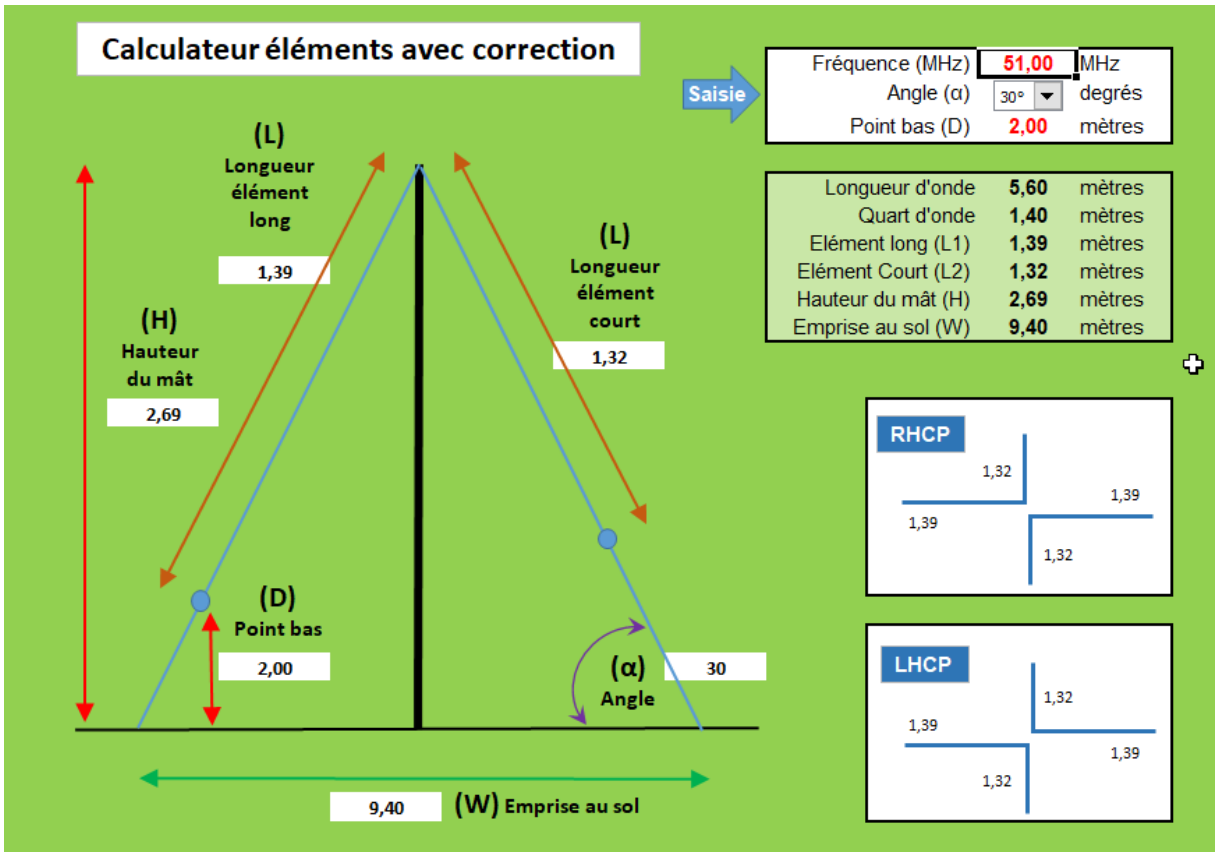


Fig. 2.

Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz

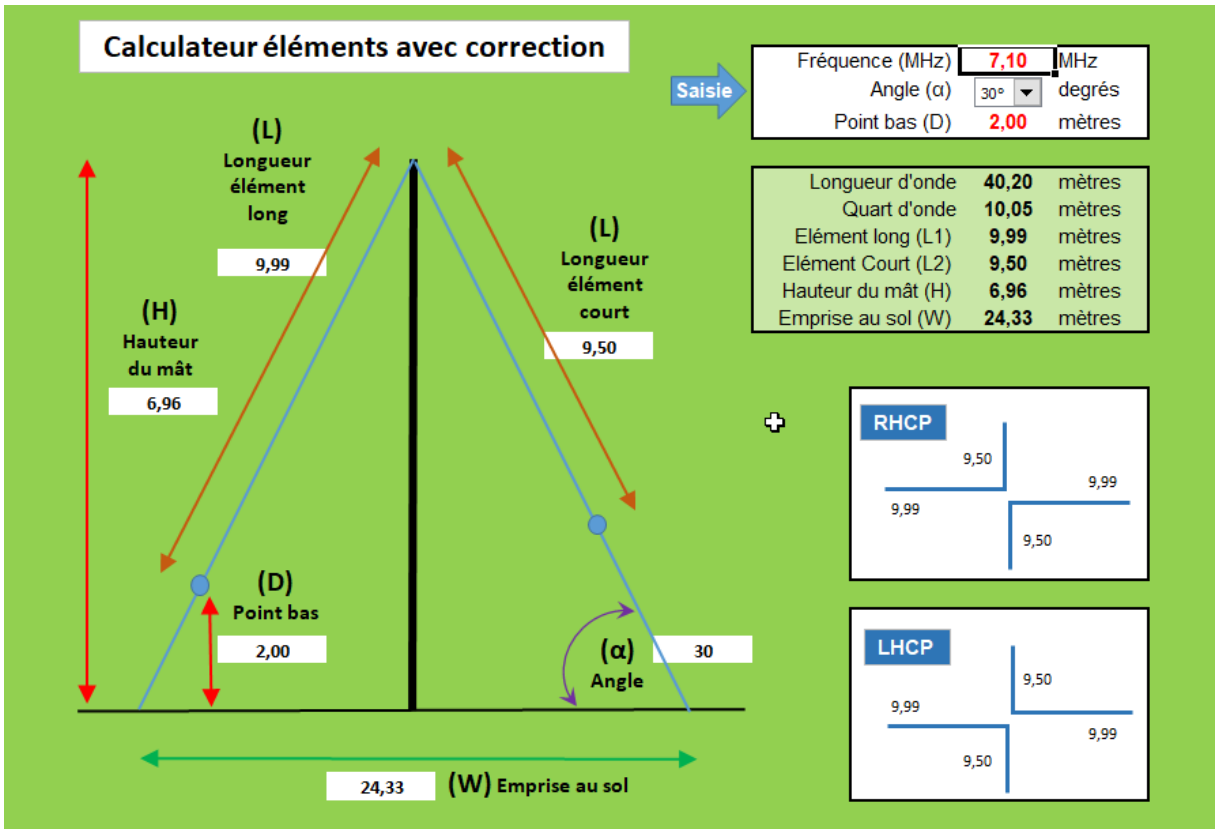






Antenne 51 MHz en V inversé en polarisation circulaire RHCP ou LHCP

Antennes V inversé en polarisation circulaire de 3.5 MHz à 5 GHz



Antenne 7.100 KHz en V inversé en polarisation circulaire RHCP ou LHCP