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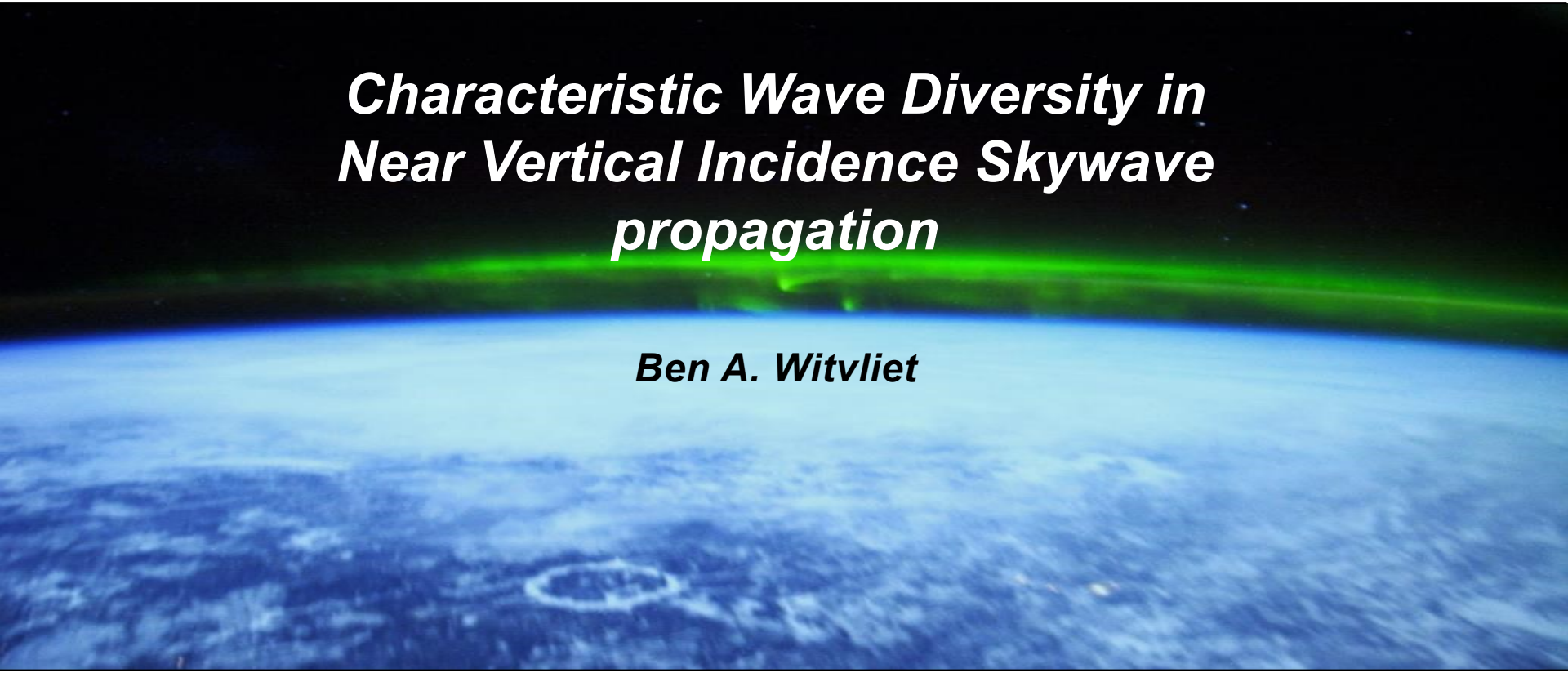
Radio Communications Agency Netherlands

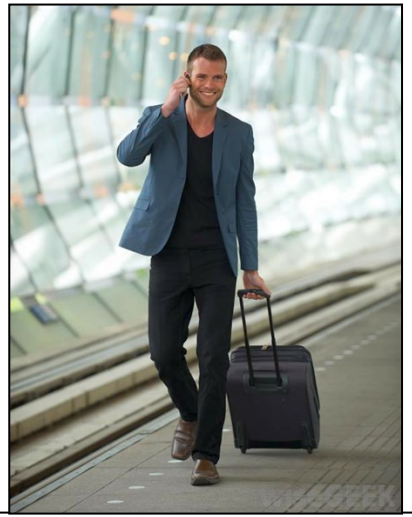


Characteristic Wave Diversity in Near Vertical Incidence Skywave propagation

Ben A. Witvliet

European Conference on Antennas and Propagation **Lisbon, 16 April 2015**

We often take our telecommunication infrastructure for granted...



But what if were unreliable..?

What if there was nothing at all..?

What if our infrastructure were suddenly destroyed..?

What if our infrastructure were suddenly destroyed..?

[1] B. Sims, “The Day after the Hurricane: Infrastructure, Order, and the New Orleans Police Department's Response to Hurricane Katrina,” in Social Studies of Science, vol. 37, no. 1, Feb. 2007, pp. 111-118.

[2] L. K. Comfort, "Cities at Risk: Hurricane Katrina and the Drowning of New Orleans," in Urban Affairs Review, vol. 41, no. 4, March 2006, pp. 501-516.

[3] A. Kwasinski, W. W. Weaver, P. L. Chapman, P. T. Krein, "Telecommunications Power Plant Damage Assessment caused by Hurricane Katrina – Site Survey and Follow-Up Results," presented at INTELEC, Providence, Sept. 2006.

[4] M. Kobayashi, "Experience of Infrastructure Damage Caused by the Great East Japan Earthquake and Countermeasures against Future Disasters," in IEEE Communications Magazine, March 2014, pp. 23-29.

[5] L. K. Comfort, T. W. Haases, "Communication, Coherence and Collective Action: The Impact of Hurricane Katrina on Communications Infrastructure," in Public Works Management & Policy, vol. 10, no. 4, Apr. 2006.

[6] D. Bodson, E. Harris, "When the Lines Go Down," IEEE Spectrum, March 1992, pp. 40-44.

[7] A. Tang, et al., "Lifeline Systems in the Andaman and Nicobar Islands (India) after the December 2004 Great Sumatra Earthquake and Indian Ocean Tsunami," Earthquake Spectra, vol. 22, no. S3, June 2006, pp. S581–S606.

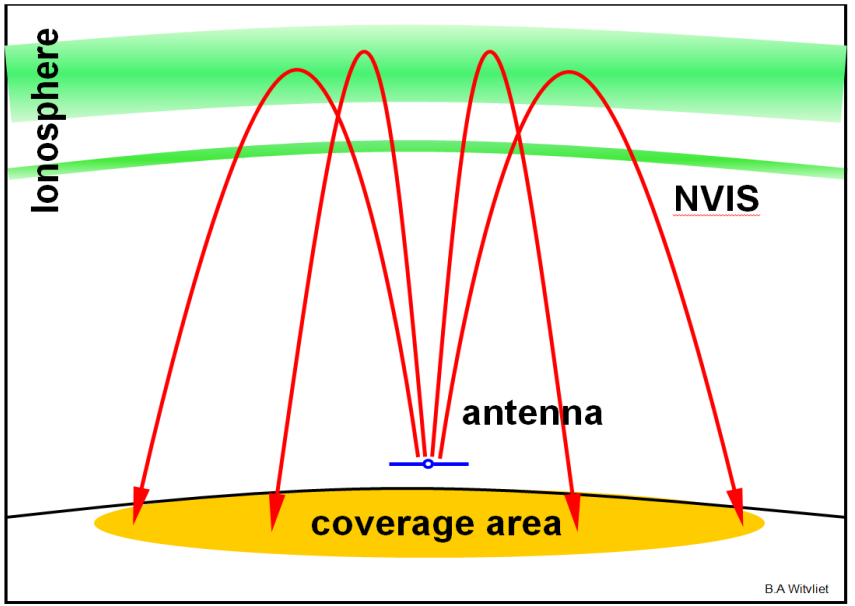
[8] H. Gerritsen, "What happened in 1953? The Big Flood in the Netherlands in retrospect," in Phil. Trans. R. Soc. A, vol. 363, no. 1831, June 2005, pp. 1271-1291.

Could nature also provide a solution..?

Near Vertical Incidence Skywave (NVIS) propagation

can be used to cover a continuous area of 400 x 400 km
without a network infrastructure.
Frequency 2-12 MHz.

+ No rain attenuation.
+ No blocking by collapsed buildings or structures.
+ Works within canyons and urban canyons.
+ No antenna beam pointing.
+ No subscription, no fees.



Near Vertical Incidence Skywave (NVIS) propagation

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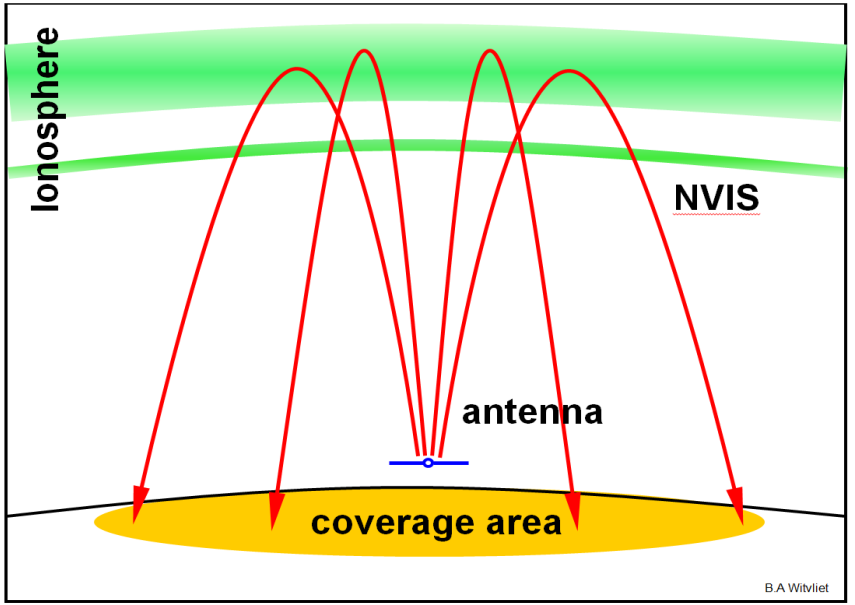
- Frequency selective propagation.
- Depends on solar radiation and geomagnetic field.
- Limited bandwidth.
- Multipath fading.



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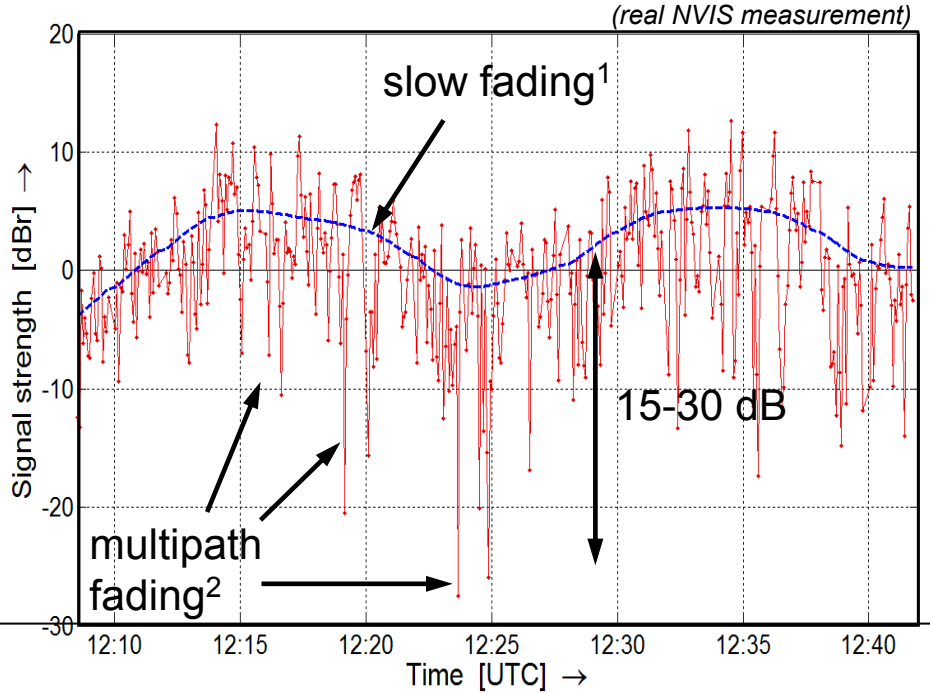


[1] 2.5 minute mean.
[2] 5 second samples.

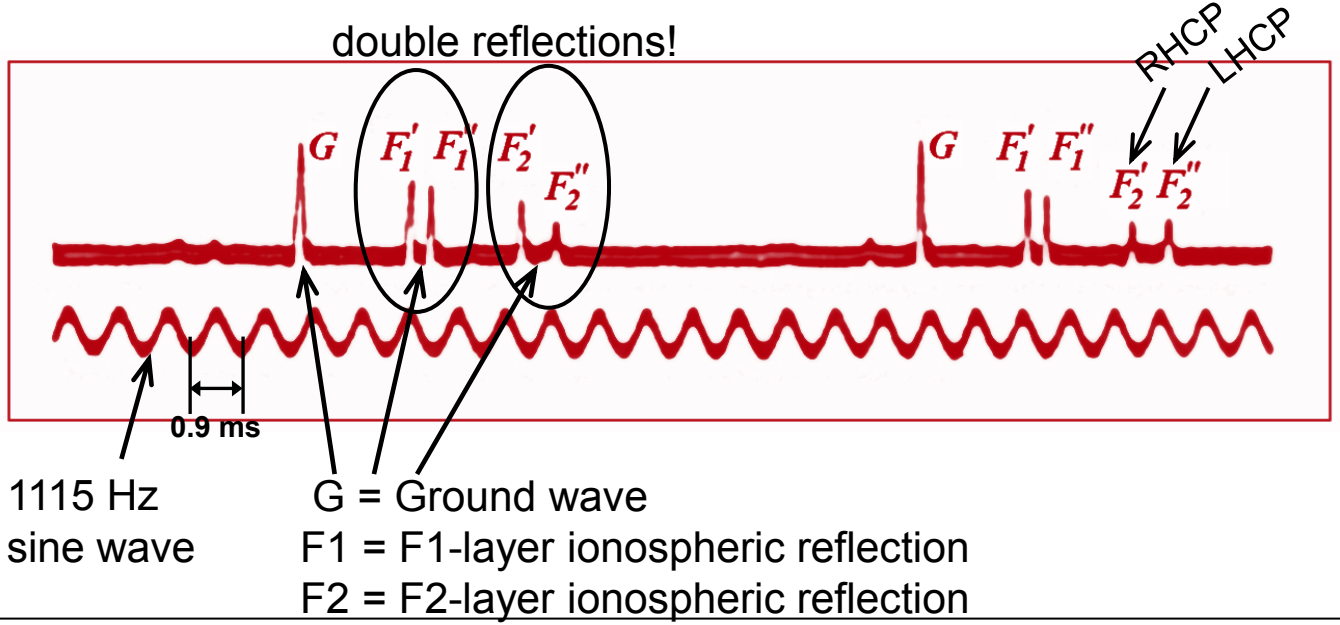
NVIS antenna diversity experiments to reduce fading or realize MIMO

• Strangeways, 2006	sim. correlation 0.8	500m antenna separation
• Guneshekar et al., 2009	meas. corr. 0.9-1.0	monopoles spaced 15m
	meas. corr. 0.3-0.9	monopoles spaced 45m
	meas. corr. 0.3-0.6	crossed dipoles
	meas. corr. 0.2-0.8	loop array radius 25m
• Daniels et al., 2013	meas. corr. 0.5-0.9	crossed loops
• Ndao et al., 2013	meas. corr. 0.2-0.9	spiral cone and delta

Can we decrease the antenna correlation?

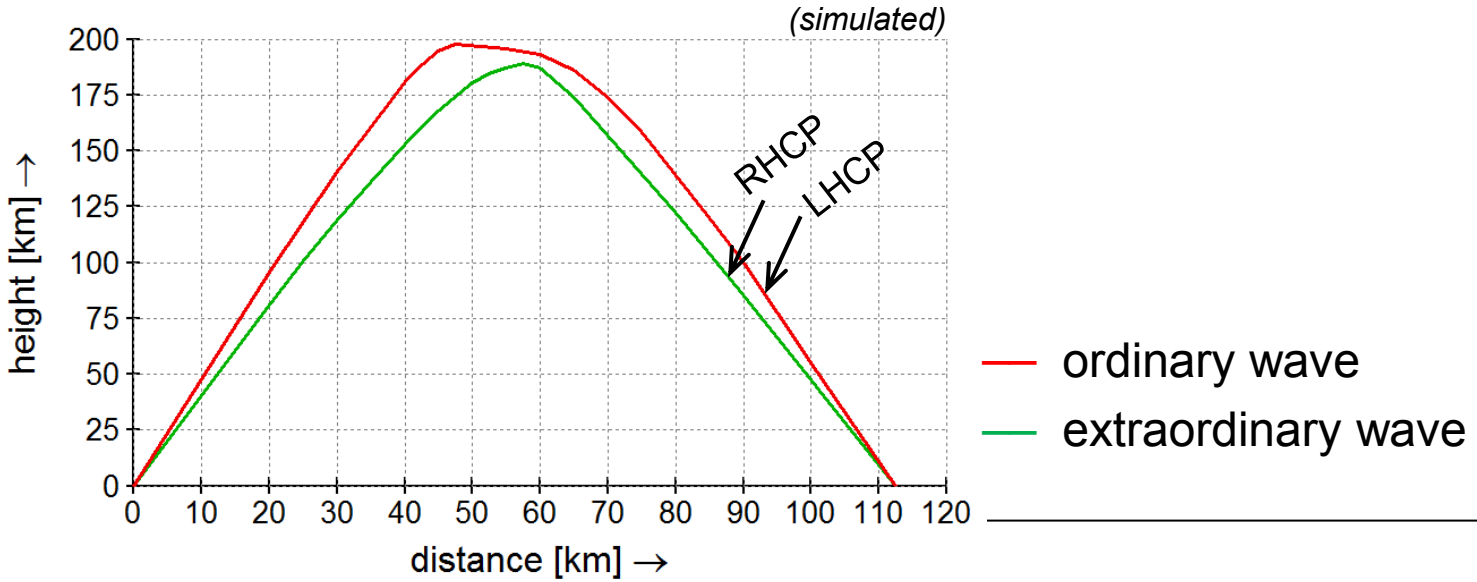
Appleton's experiments (1931-32)

Pulsed transmissions to measure the effective ionosphere reflection height.



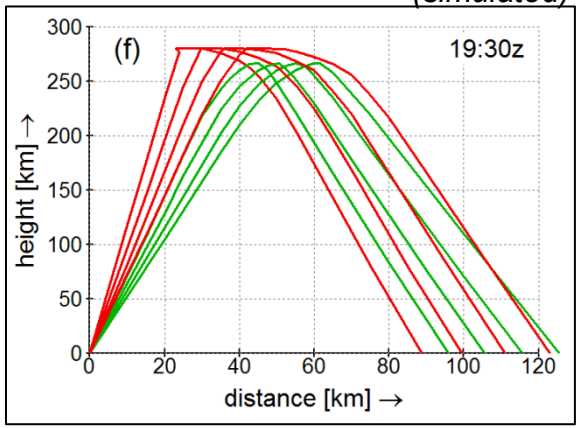
Appleton's experiments (1931-32)

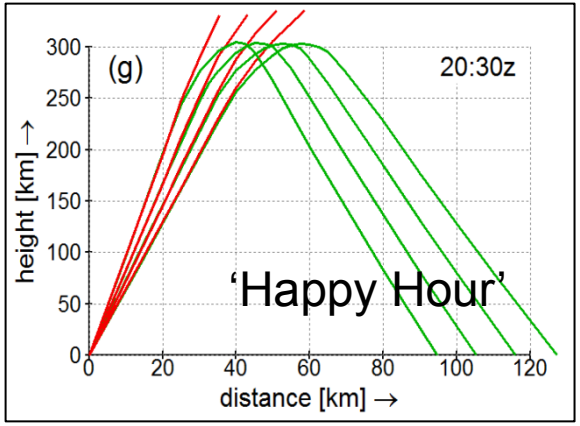
Magneto-ionic theory: the upwards waves are split into two characteristic waves: the ordinary and extraordinary wave.

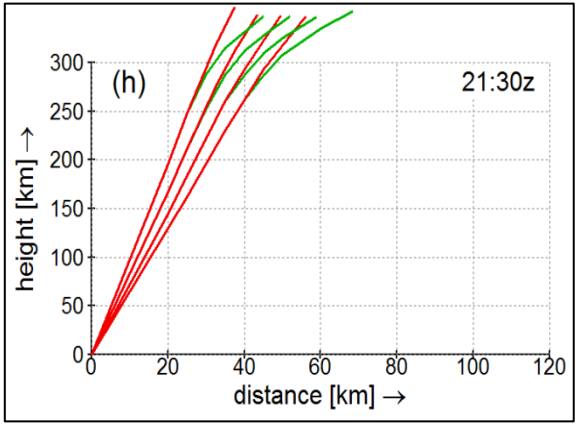


Measuring the Isolation between the Characteristic Waves

(simulated)







— extraordinary wave

— ordinary wave

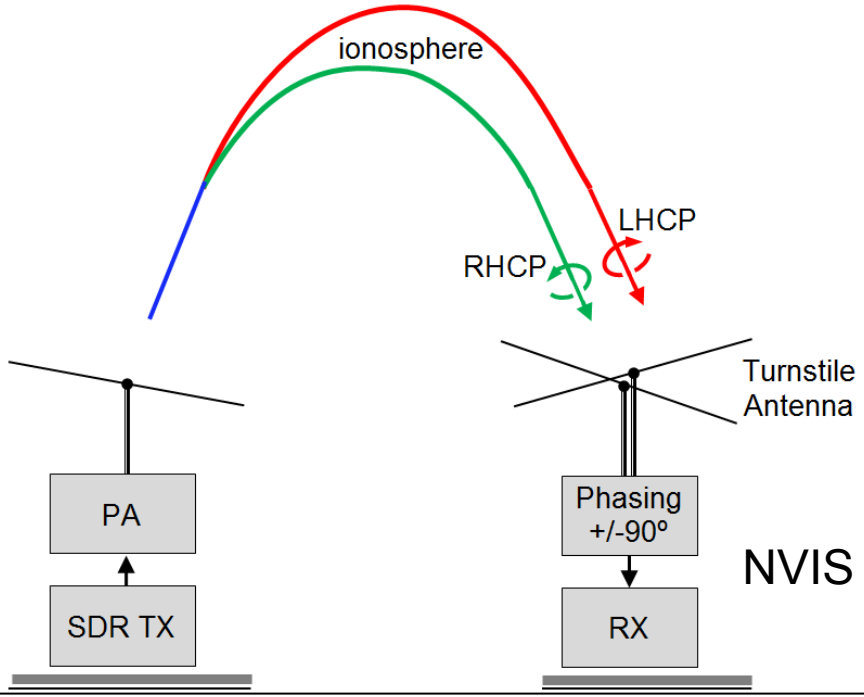
Here only the extraordinary wave Is received (RHCP)

Measuring the Isolation between the Characteristic Waves

We thought our research was unique…

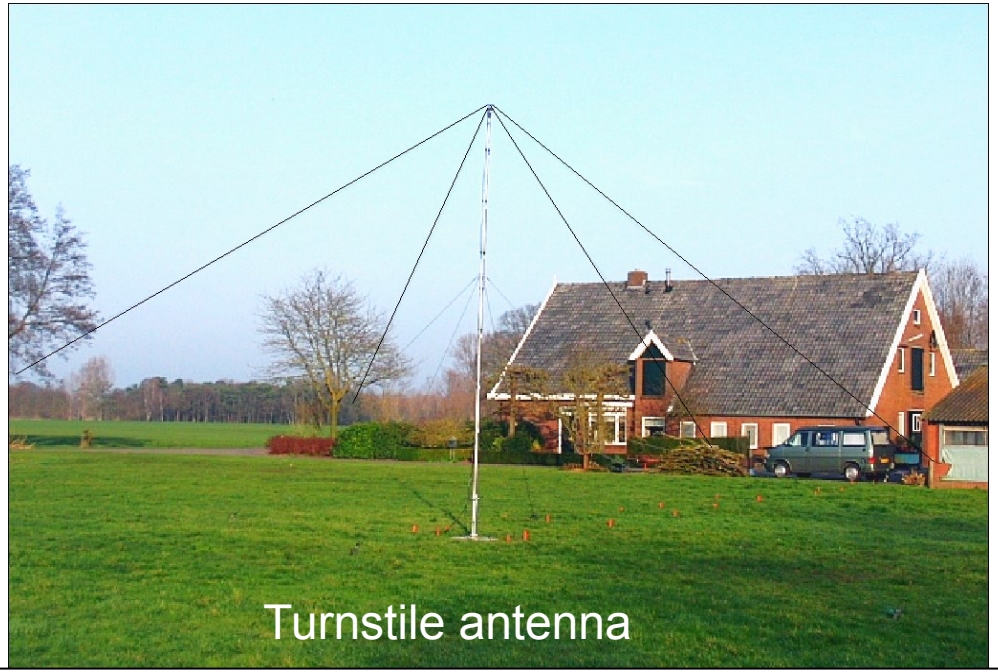
Until we discovered this publication in Lisbon! ☺

Measuring the Isolation between the Characteristic Waves

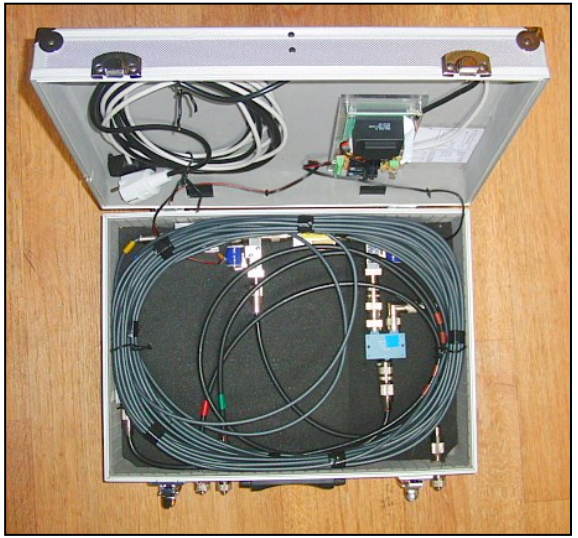


NVIS experiment over 110 km

Measuring the Isolation between the Characteristic Waves



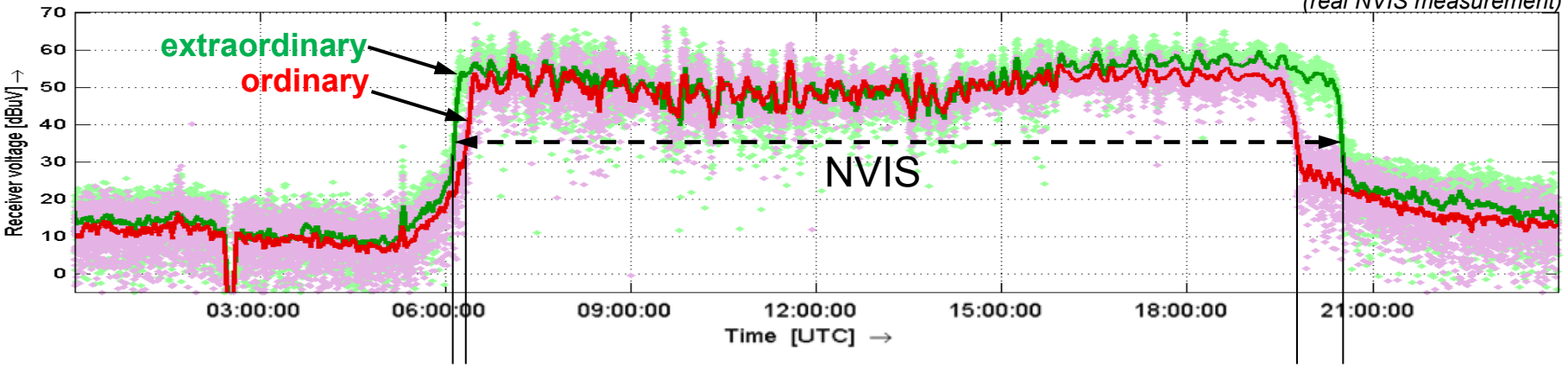
Turnstile antenna



Phasing unit

Measuring the Isolation between the Characteristic Waves

(real NVIS measurement)

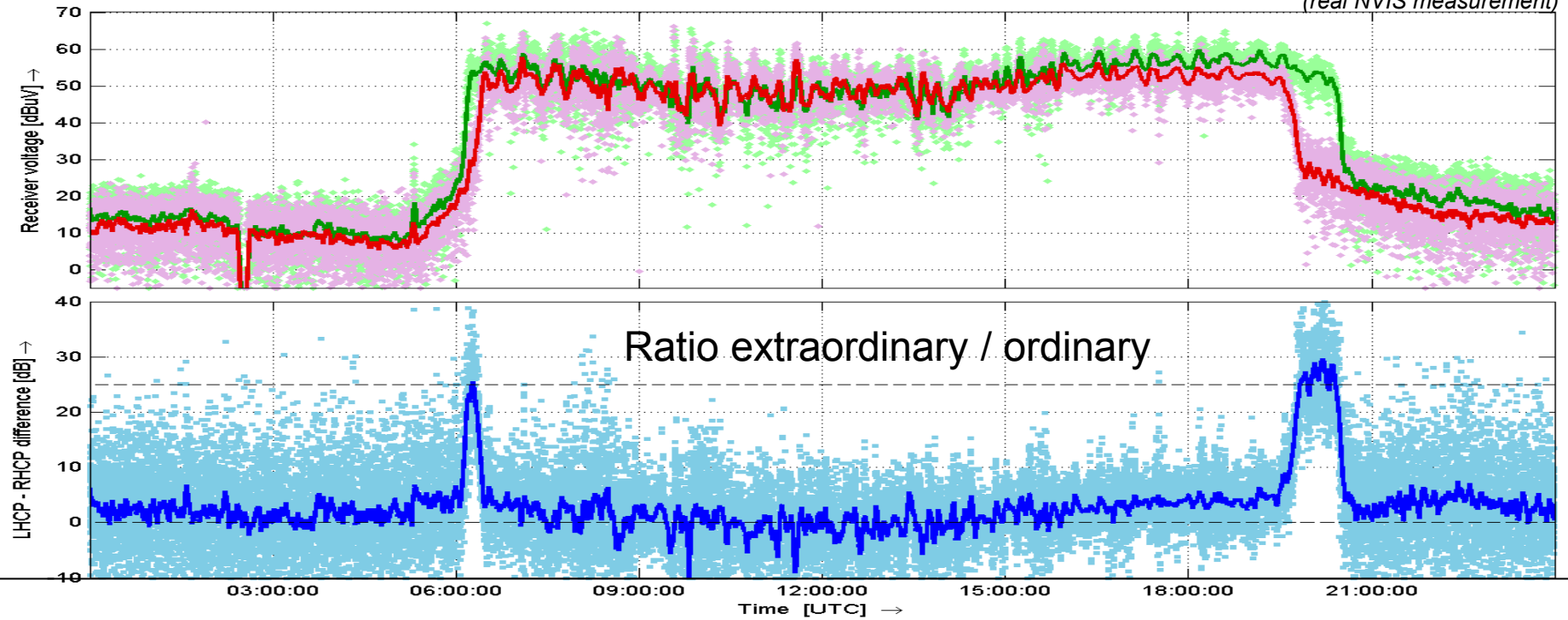


Happy Hour

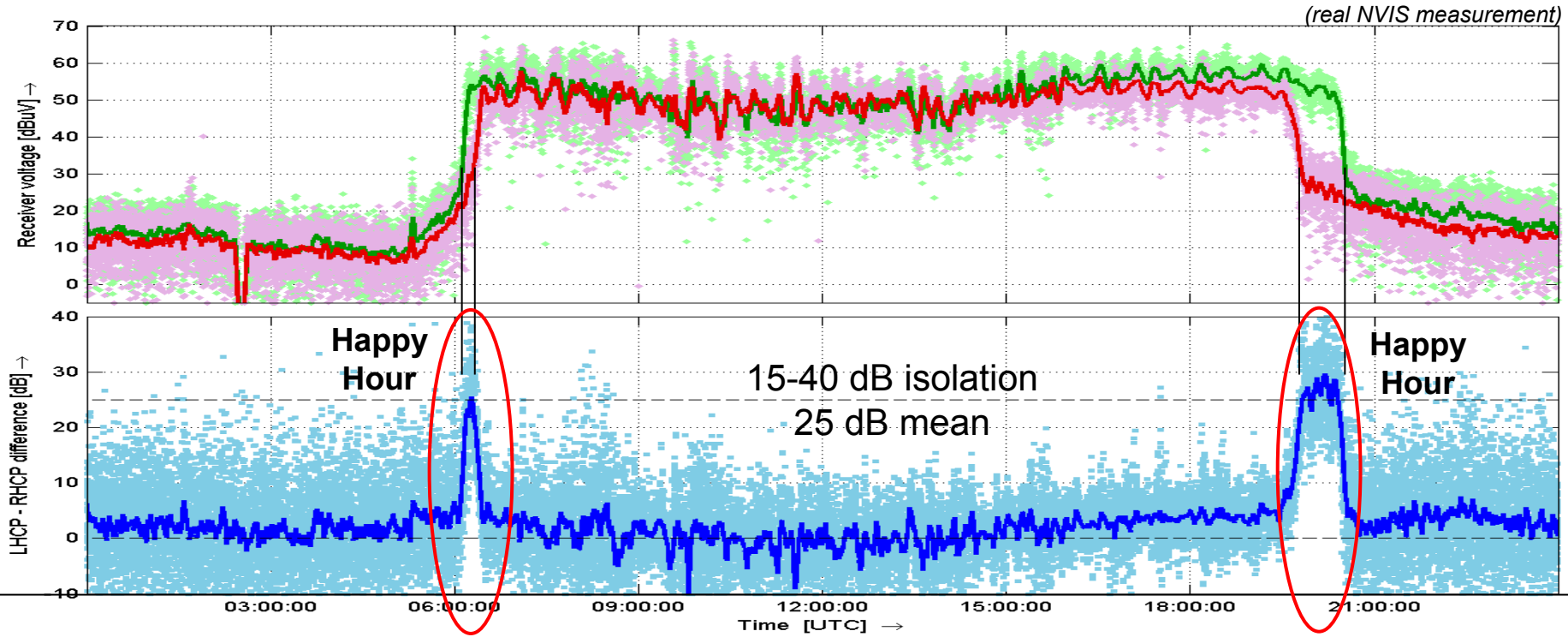
Happy Hour

Measuring the Isolation between the Characteristic Waves

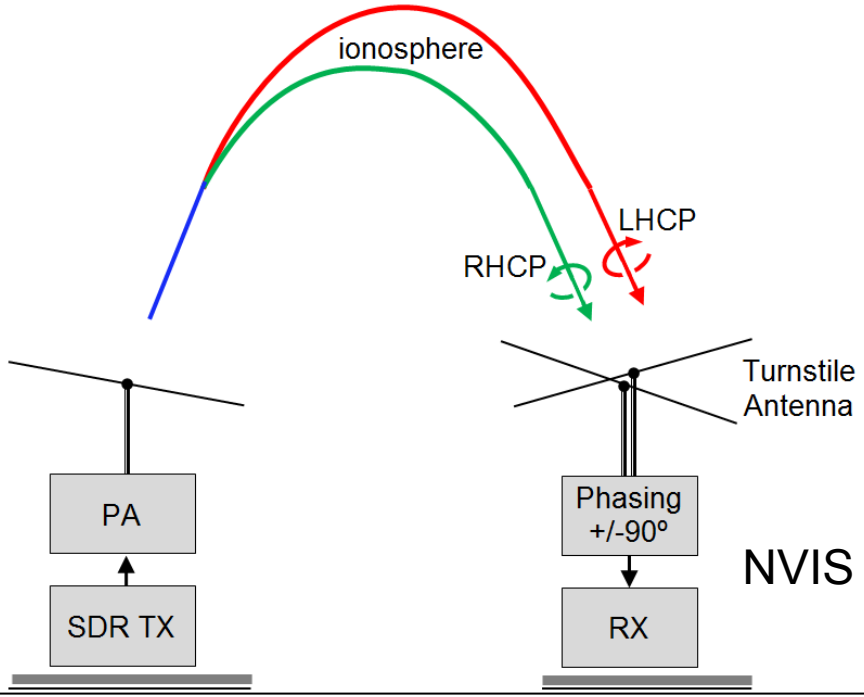
(real NVIS measurement)



Measuring the Isolation between the Characteristic Waves

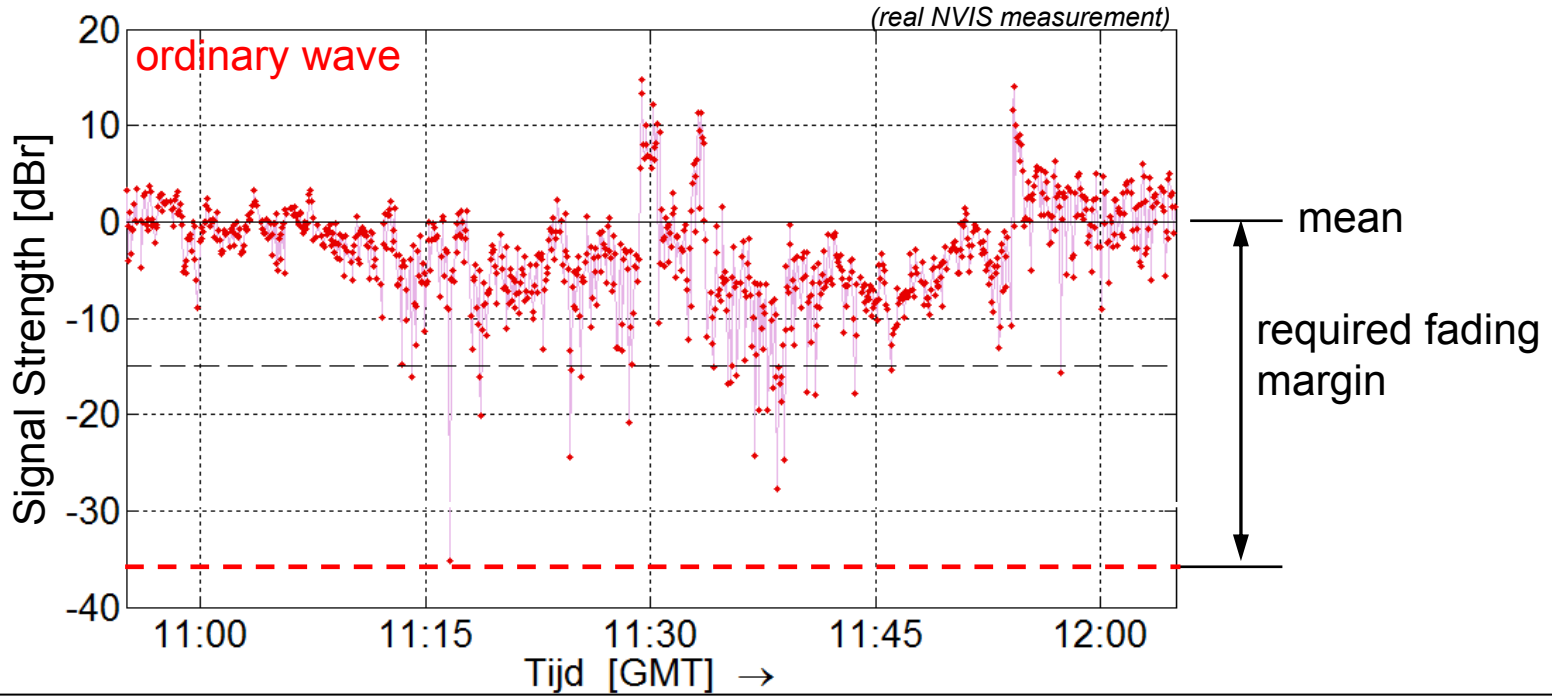


Characteristic Wave Diversity

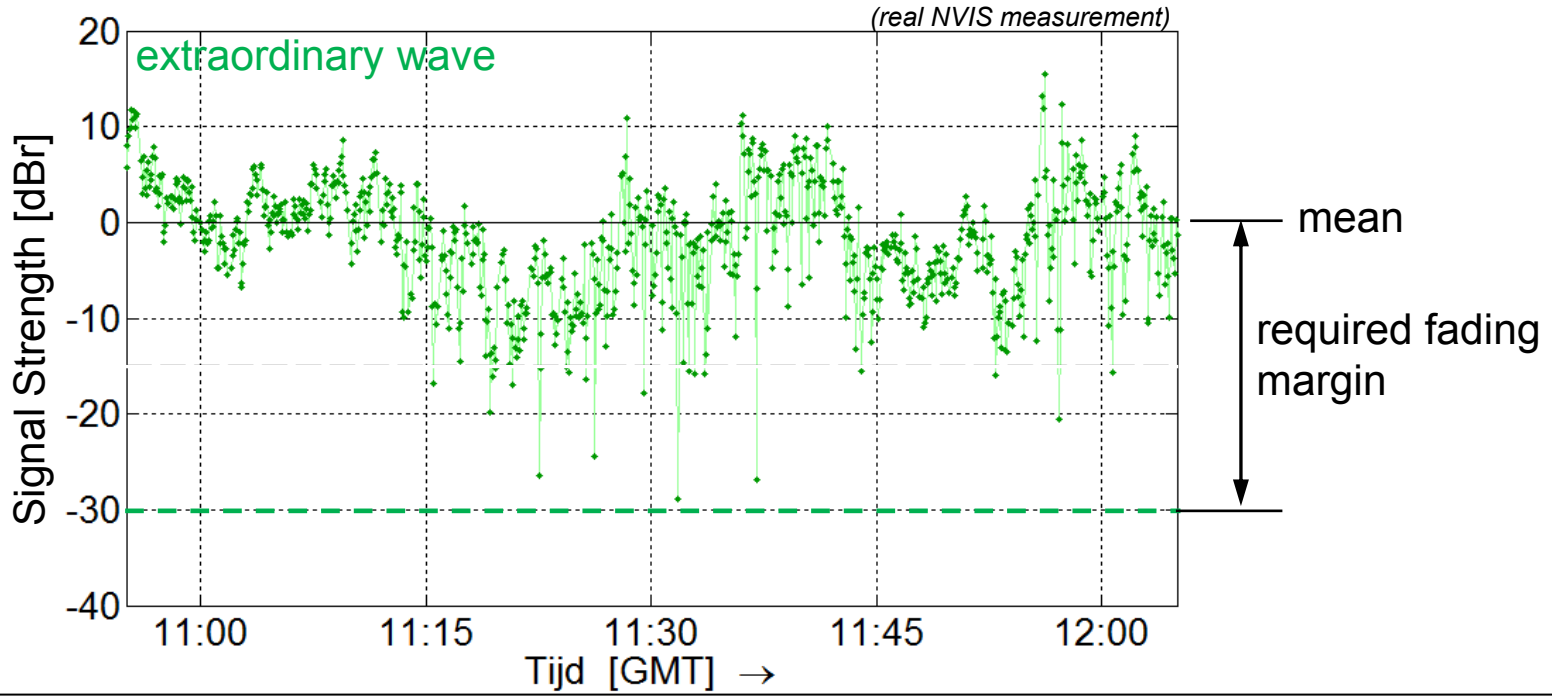


NVIS experiment over 110 km

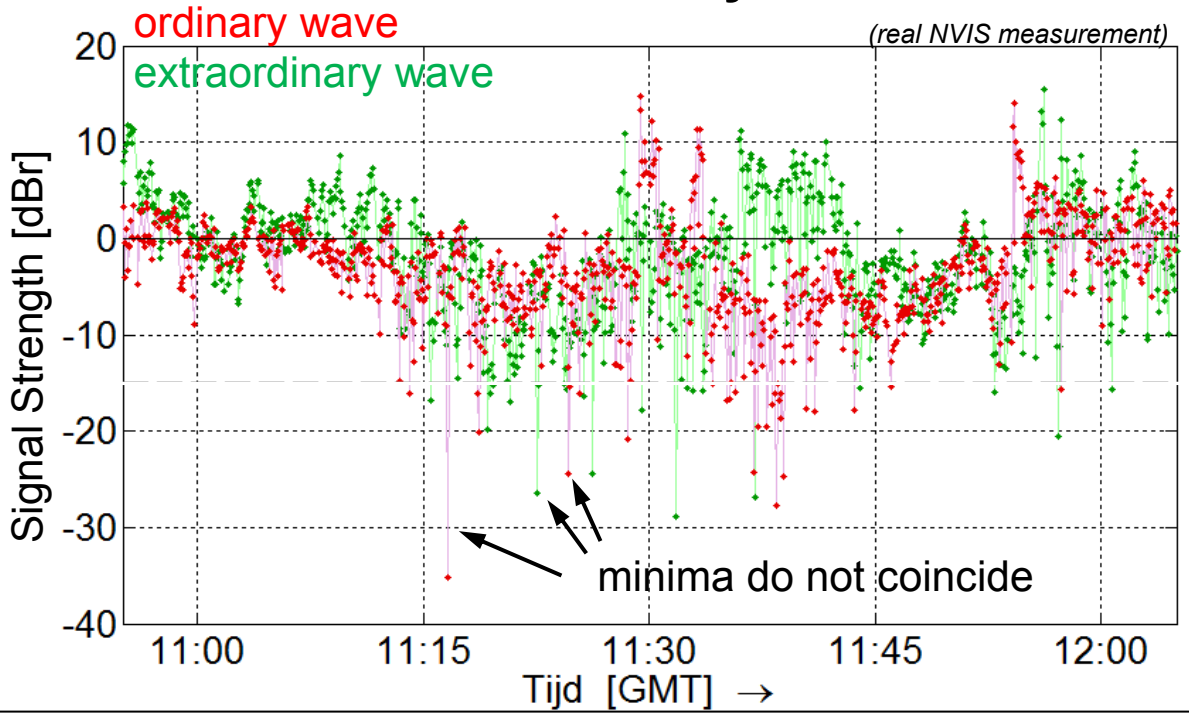
Characteristic Wave Diversity



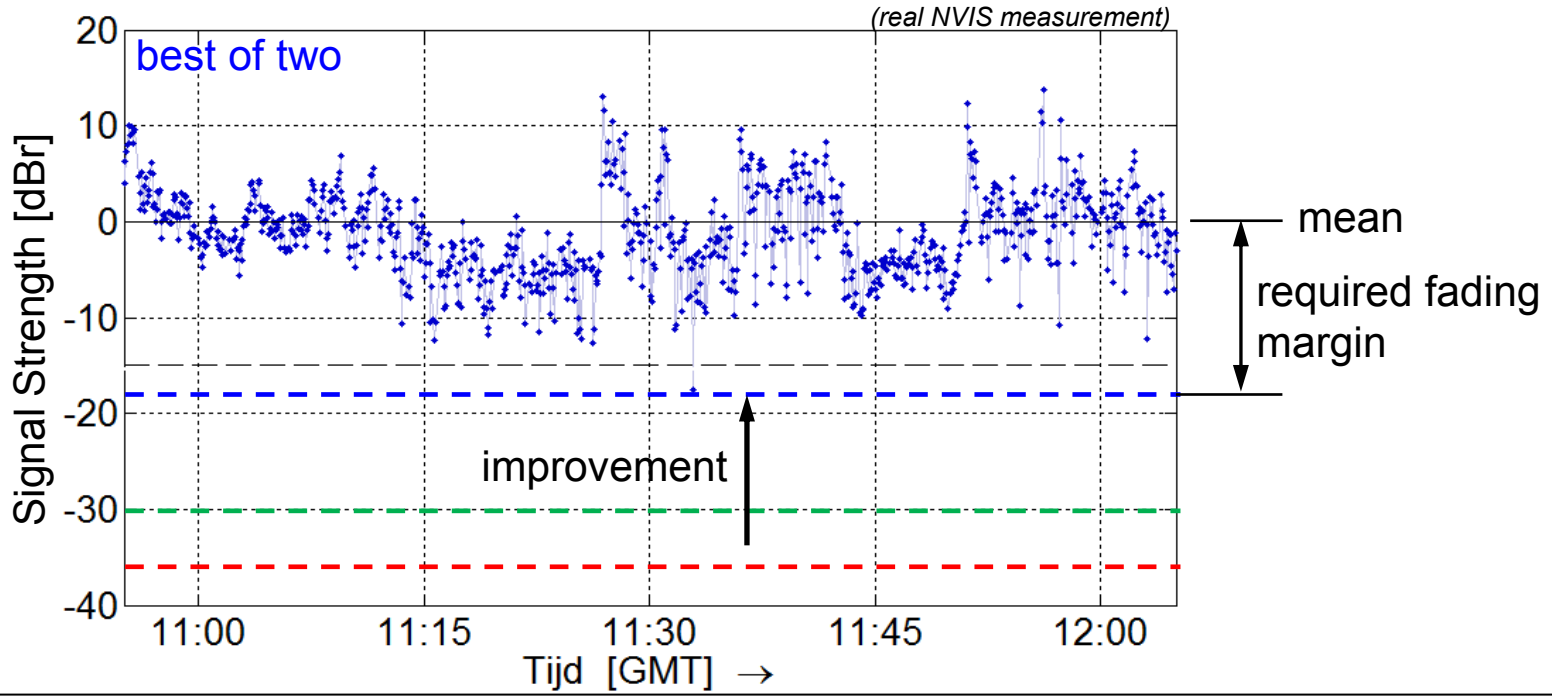
Characteristic Wave Diversity



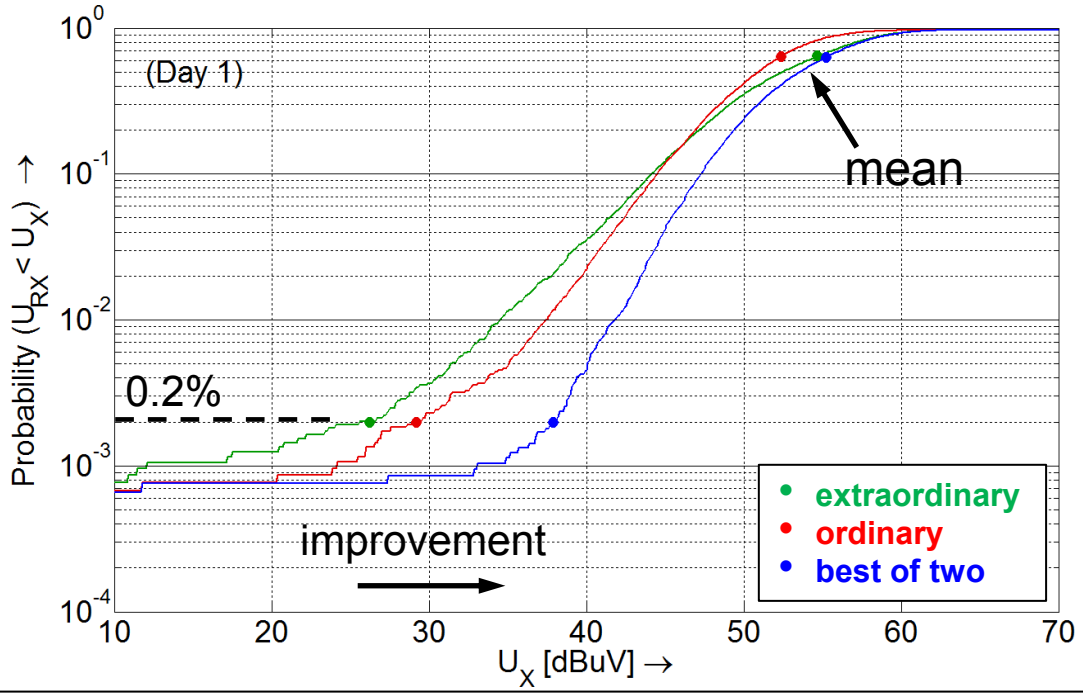
Characteristic Wave Diversity



Characteristic Wave Diversity



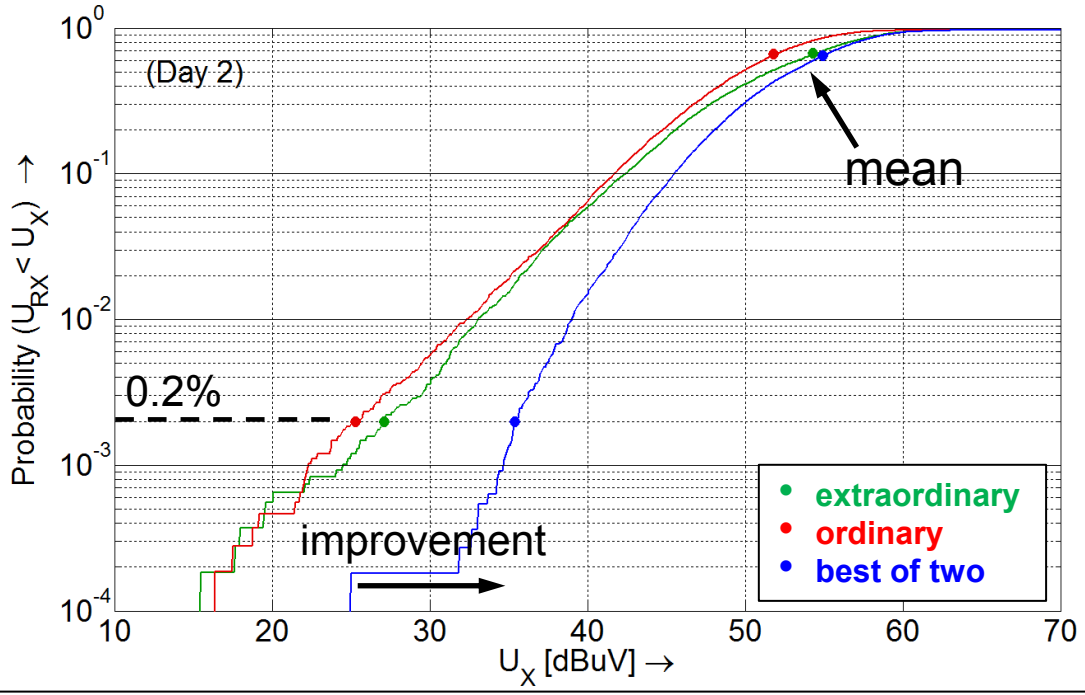
Characteristic Wave Diversity



First measurement day:
>10.000 samples
5 sec. data

10.2 dB improvement over one characteristic wave

Characteristic Wave Diversity



Second measurement day:
>10.000 samples
5 sec. data

9.2 dB improvement over one characteristic wave

Characteristic Wave Diversity

Mean signal strength	Day 1	Day2
RHCP mean	54.7 dBuV	54.3 dBuV
LHCP mean	52.4 dBuV	51.8 dBuV
Char. Wave Div. mean	55.2 dBuV	54.9 dBuV

0.2% time threshold	Day 1	Day2
RHCP 0.2%	26.2 dBuV	27.1 dBuV
LHCP 0.2%	29.2 dBuV	25.3 dBuV
Char. Wave Div. 0.2%	37.9 dBuV	35.4 dBuV
Diversity gain	**10.2 dB**	**9.2 dB**

Summary / Conclusions

- When all lines are down, NVIS can provide a solution.
- Ionospheric fading costs 10-30 dB additional link budget.
- Diversity could help, but antenna correlation is high.
- Circular Polarization provides 25 dB channel isolation.
- 10 dB improvement demonstrated with Characteristic Wave Diversity.

Future research

- Higher sampling speeds.
- Synchronous measurement on Linear Polarization, LHCP and RHCP.
- Demonstration at other distances, azimuths and geomagnetic latitudes.
- Polarization matching.

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Characteristic Wave Diversity in Near Vertical Incidence Skywave propagation

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