What’s the difference?
Amateur radio and radio science

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PE5B
What’s the difference?
Amateur radio and radio science

dr. Ben Witvliet, PE5B

I’ve made my passion my work

<table>
<thead>
<tr>
<th>Amateur radio</th>
<th>Telecom industry</th>
<th>Applied research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973  NL4496 (SWL)</td>
<td>Trans World Radio – Monte-Carlo</td>
<td>Radiocommunications Agency Netherlands</td>
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<tr>
<td>1981  PA3BXC</td>
<td>KPN Telecom – The Netherlands</td>
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<tr>
<td>1982  3A/PA3BXC</td>
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<tr>
<td>1989  4X/PA3BXC</td>
<td>Radio Netherlands – Madagascar</td>
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<tr>
<td>1993  5R8DS</td>
<td></td>
<td></td>
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<tr>
<td>1996  PA5BW</td>
<td>Netherlands BC Transmitter Co.</td>
<td></td>
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<td>2013  PE5B</td>
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</table>

Academic research

University of Twente
The Netherlands

University of Bath
United Kingdom
Amateur radio and radio science

What’s the difference?

NVIS radio propagation experiments with dual circular polarization

Presentation tomorrow
13:45 RSGB Convention
Central question of this presentation:

How can amateur radio experiments make significant contributions to radio science?

To be demonstrated:

This does not require expensive lab equipment, but mainly a change in mind-set.
Contents

1. Amateur radio and radio science
2. Reliable scientific building blocks
3. “Experience-based opinions”
4. A practical experiment
5. What’s the difference?
6. Your questions
1. Amateur radio and radio science

*Radio amateurs* have valuable hands-on experience

- Spectrum management
- Radio wave propagation
- Noise and interference
- Antennas
- Transmitter and receiver performance
- Modulation / demodulation

They tend to be very enthusiastic about radio experiments, and are great in improvising new equipment for experiments.

Sometimes adhere to unverified “experience-based opinions”.
1. Amateur radio and radio science

Radio scientists have essential research skills

- Theoretical knowledge
- Access to the latest research
- Mathematical methods
- Scientific rigor and objectivity
- A network of peers to check their work

They tend to be enthusiastic about formulas and theoretical solutions, and are rather serious about their work. Sometimes lack the practical experience.
1. Amateur radio and radio science

A fusion between those two would create magic!
(but cooperation would also do 😊)
1. Amateur radio and radio science

A fusion between those two would create magic!

(but cooperation would also do ☺)
2. Reliable scientific building blocks

Science is about knowledge of the world around us

But to reach high

Science needs reliable building blocks
2. Reliable scientific building blocks

Empirical verification
2. Reliable scientific building blocks

Peer review of claimed results
3. “Experience-based opinions”

Brief experiments with lots of uncontrolled variables may lead to “experience-based opinions” or myths.

Example from Near Vertical Incidence Skywave (NVIS) propagation research

**Myth:**

*The NVIS antenna must be installed as low as possible*
3. “Experience-based opinions”

“Antenna 2 is better”

“This is antenna number 1!
This is antenna number 2!
Which one is better?”

What’s the difference?
Amateur radio and radio science
3. “Experience-based opinions”

- “I tried it: the low antenna was better”
- “The lower antenna is better”

Radio amateurs

Myths can have serious consequences e.g. for disaster relief communications!
3. “Experience-based opinions”

Many uncontrolled variables:

* **Antennas under test**
  - Coupling between the antennas
  - Buildings in proximity

* **Transmitted test signal**
  - Voice power not constant
  - Cable loss not identical
  - Loading impedance different

**Radio wave propagation**
- Multipath fading
- Variation of elevation angle
- Ground wave component

**Measurement**
- Wrong receive antenna
- Poor meter linearity
- Sample, average, peak, RMS?
- Interference

**Methodology**
- Very few observations
- Manual observations
3. “Experience-based opinions”

Short-term ionospheric signal comparisons are meaningless

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What's the difference?
Amateur radio and radio science

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[Graph showing signal strength comparison between antenna 1 and antenna 2]
4. A practical experiment

But histograms will provide information on mean value and fading.
4. A practical experiment

And allow a fair comparison

\[ \text{Signal [dBuV]} \rightarrow \]

\[ \text{Number of samples} \]

- 0.8 dB
- 30 dB
4. A practical experiment

Research verification with a clear research question

To be verified:
The optimum antenna height for NVIS propagation is between 0.18 $\lambda$ and 0.22 $\lambda$ above farmland

Myth to be countered:
not “as low as possible”
4. A practical experiment

Comparison of NVIS antenna gain in the presence of multipath fading
4. A practical experiment

Antennas under test

Heights: 1, 3, 5, 9 and 12.5 m, 0.02, 0.05, 0.09, 0.16 and 0.22 λ.

Soil: farmland (σ=20 mS/m, $\varepsilon_r=17$).
4. A practical experiment

Detuning of unused dipole antennas

high Z

\( \frac{3}{4} \lambda \)

shorted

switch

to receiver

connected

\( \frac{3}{4} \lambda \)
4. A practical experiment

Measurement receiver and automation

Rohde & Schwarz FSMR-26

£ 90.000
4. **A practical experiment**

Measurement receiver and automation

£ 4.000

High performance SDR

2 directly sampled synchronous antenna inputs

Software K5SO

www.OpenHPSDR.com
4. A practical experiment

Stable beacon transmitter

P = 800 Watts, $\Delta P < 0.1$ dB

f = 5.39 MHz, $\Delta f < 5$ Hz

1 minute on / 1 minute off

DCF controlled timing
What's the difference?
Amateur radio and radio science

4. A practical experiment

Interference monitoring
4. A practical experiment

Experiment 1

-11.0 dB !

3500 measurements
4. A practical experiment

Experiment 2

-11.8 dB !

3500 measurements
## 4. A practical experiment

<table>
<thead>
<tr>
<th>Antenna height</th>
<th>NVIS Antenna Gain</th>
<th>Simulated</th>
<th>Meas.1</th>
<th>Meas.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 m 0.22 λ</td>
<td></td>
<td>-0.2 dB</td>
<td>0.0 dB</td>
<td>0.0 dB</td>
</tr>
<tr>
<td>9 m 0.16 λ</td>
<td></td>
<td>-0.0 dB</td>
<td>-0.8 dB</td>
<td>0.0 dB</td>
</tr>
<tr>
<td>5 m 0.09 λ</td>
<td></td>
<td>-1.5 dB</td>
<td>-2.6 dB</td>
<td>-3.0 dB</td>
</tr>
<tr>
<td>3 m 0.05 λ</td>
<td></td>
<td>-5.0 dB</td>
<td>-6.1 dB</td>
<td>-5.8 dB</td>
</tr>
<tr>
<td>1 m 0.02 λ</td>
<td></td>
<td>-12.0 dB</td>
<td>-11.0 dB</td>
<td>-11.8 dB</td>
</tr>
</tbody>
</table>

Very good correspondence of theory and experiment! Experiment confirms the NEC 4.1 simulations.
5. What's the difference?

This “improved experiment” was conducted by 4 radio amateurs and 1 scientist / radio amateur

So what’s the difference?

• Thorough preparation
• Control of as many unwanted variables as possible
• Low measurement uncertainty
• Precise description, peer review, scientific publication [1]

5. **What’s the difference?**

What’s can radio scientists offer radio amateurs?

- Encouragement
- Theoretical basis
- Advice on improvements of experiments 😊
- Feedback on flawed or incomplete work 😞
- Cooperation and joined publication
6. Your questions

Free publication download from
https://www.researchgate.net/profile/Ben_Witvliet/publications

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