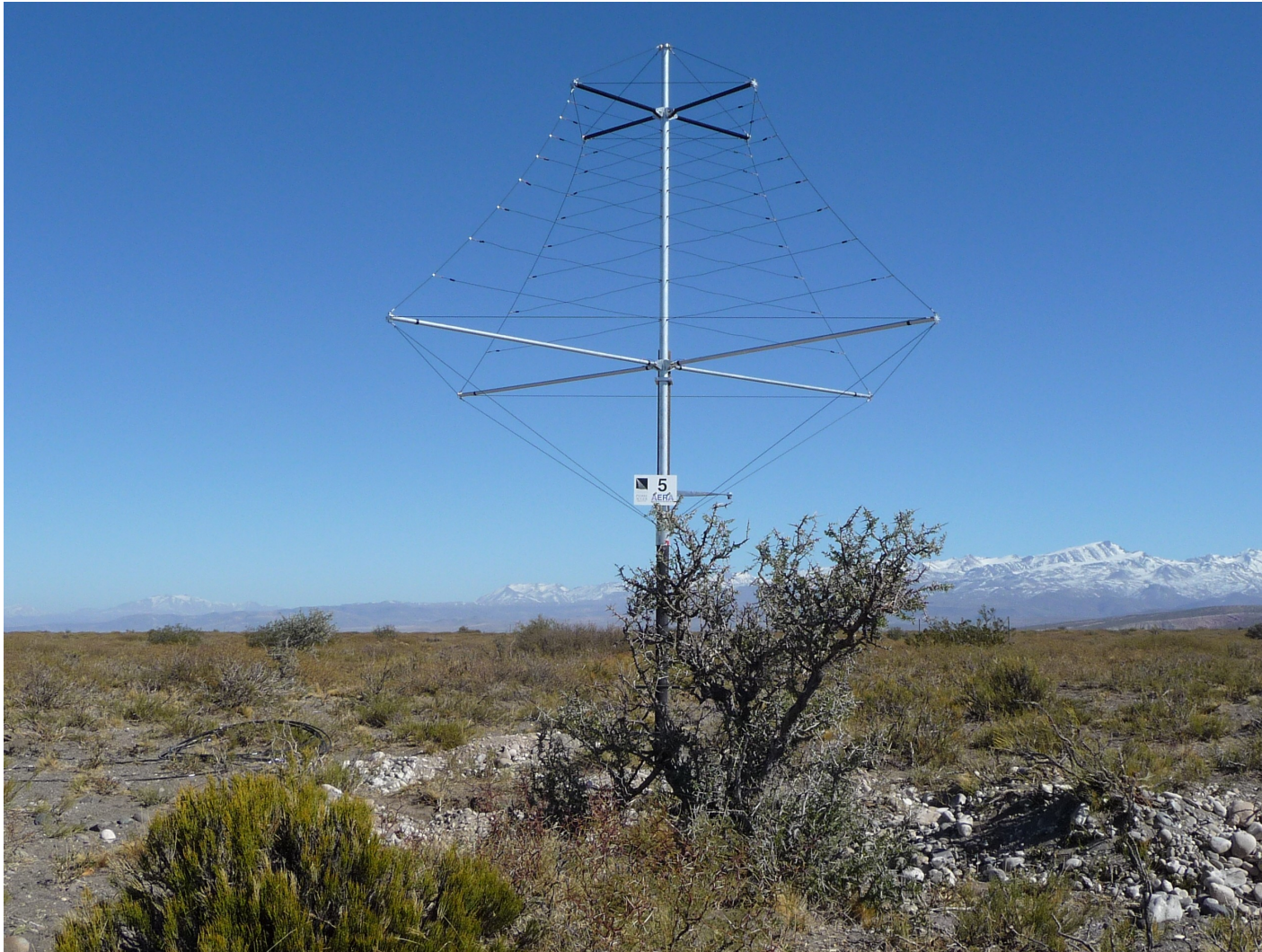
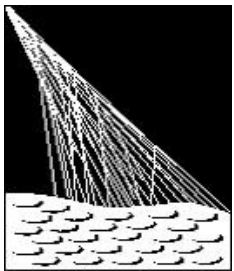


Logarithmic Periodic Dipole Antennas for the Auger Engineering Radio Array



Oliver Seeger for the Pierre Auger Collaboration



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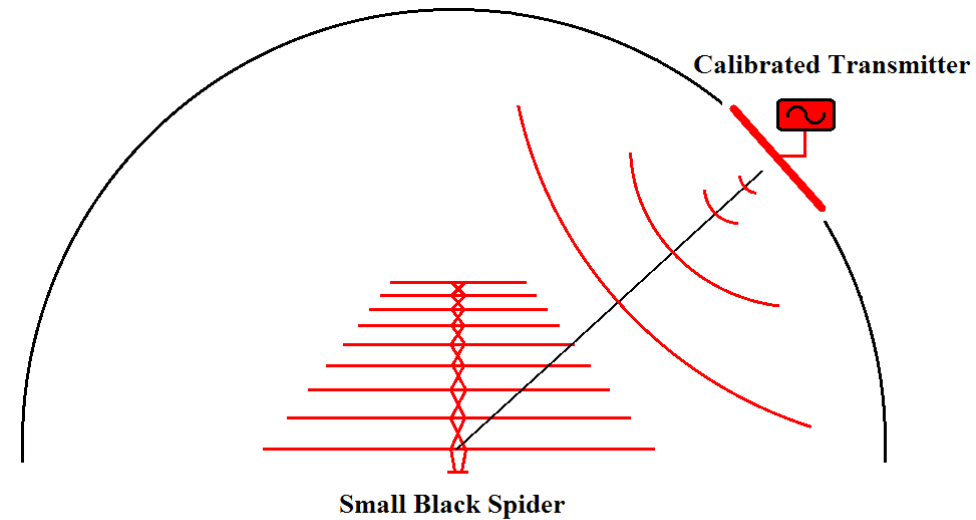


E-mail: seeger@physik.rwth-aachen.de

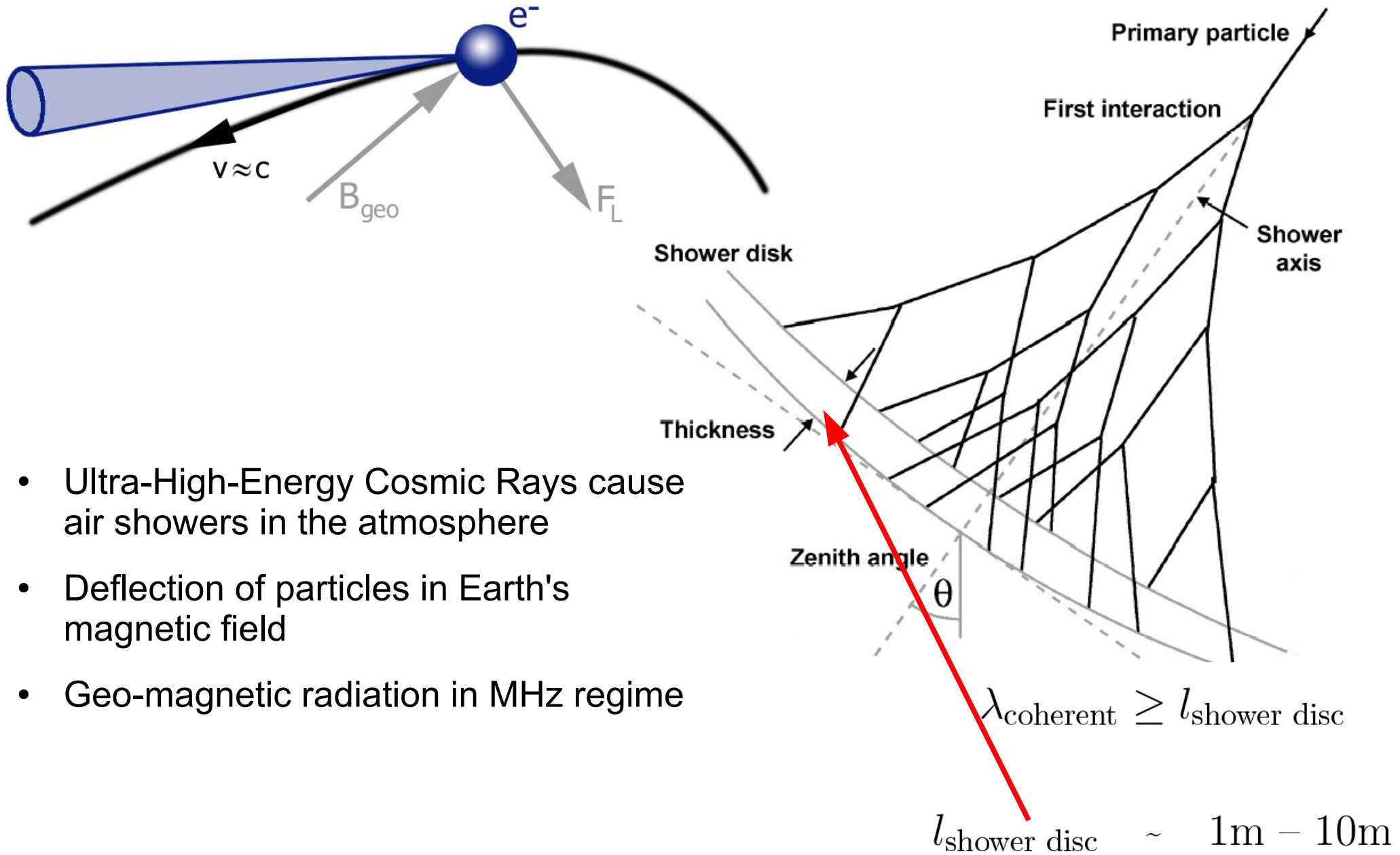
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Outline

- Antennas for air showers
- Why LPDAs ?
- The Small Black Spider LPDA
 - Basic properties
 - Transport to Argentina
 - Production quality
 - Calibration



Geo – Magnetic Radiation Model



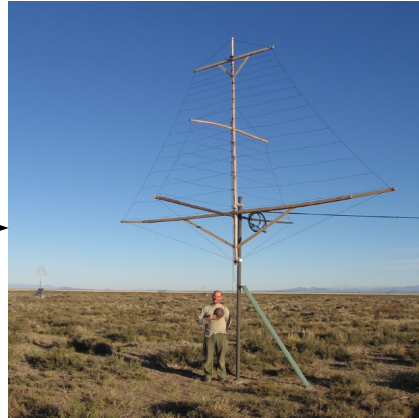
- Ultra-High-Energy Cosmic Rays cause air showers in the atmosphere
- Deflection of particles in Earth's magnetic field
- Geo-magnetic radiation in MHz regime

Antenna Evolution over Time

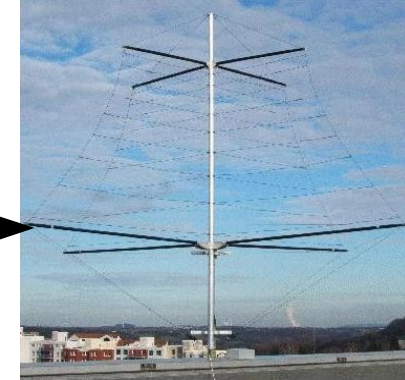


2006: Alu-LPDA

- First measurements of radio pulses at the Auger Site



First Wire-LPDA



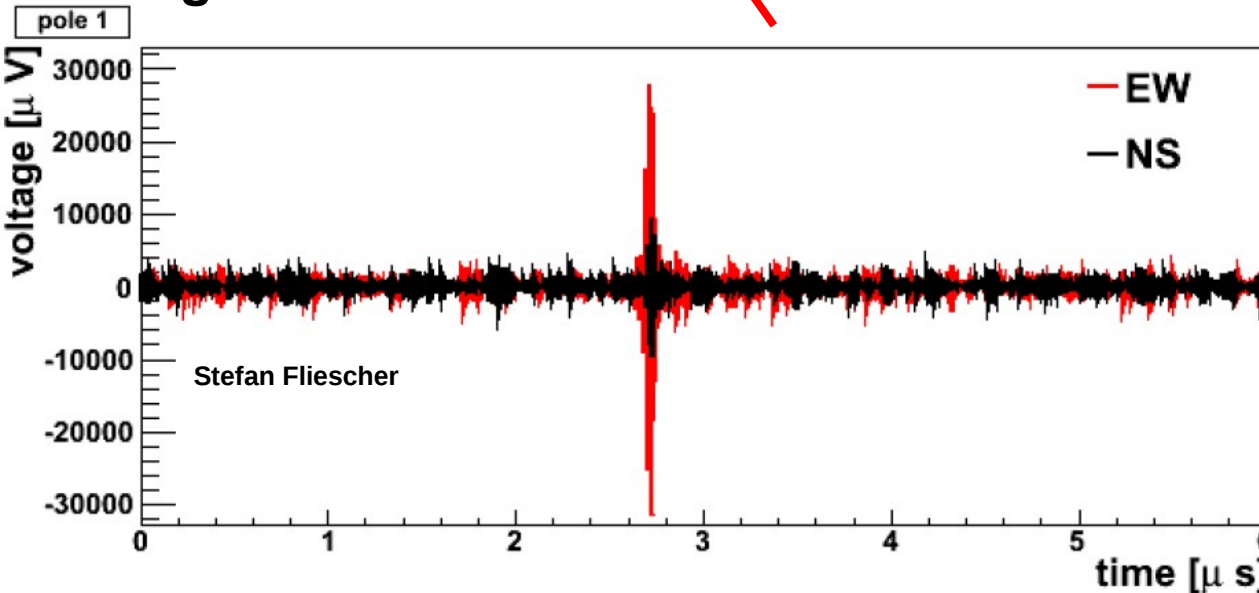
Black Spider



X-mas Tree



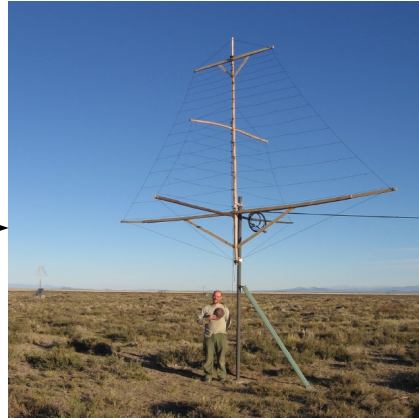
Small Black Spider



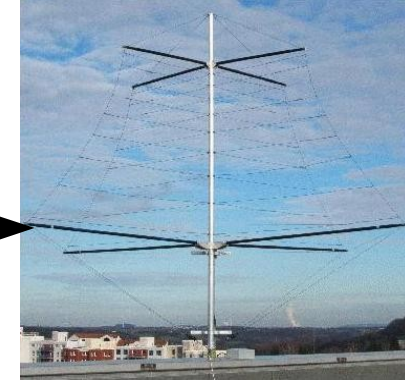
Antenna Evolution over Time



2006: Alu-LPDA



First Wire-LPDA



Black Spider



X-mas Tree



Small Black Spider

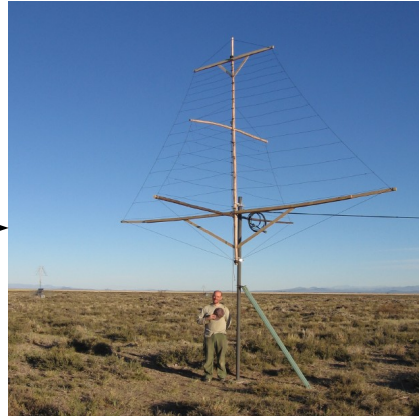


- Nine antennas have been set up in Argentinian Pampa
- No problems have occurred after two years

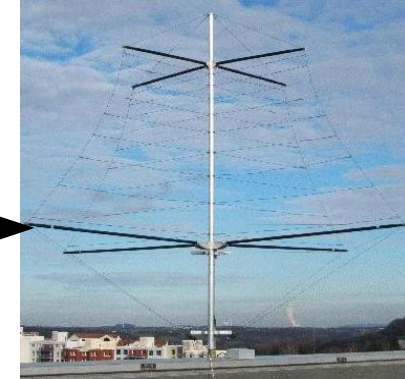
Antenna Evolution over Time



2006: Alu-LPDA



First Wire-LPDA



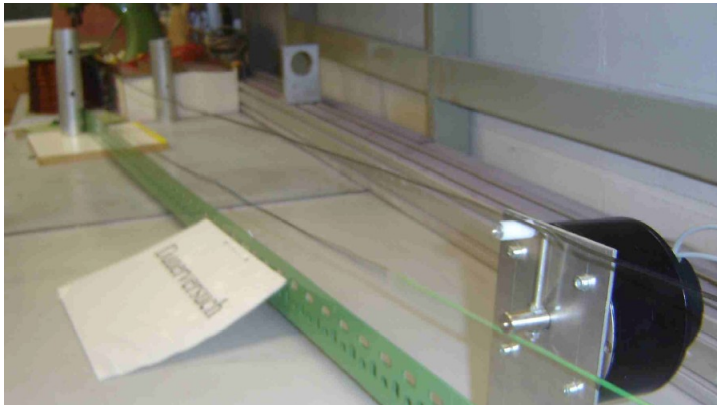
Black Spider



X-mas Tree



Small Black Spider



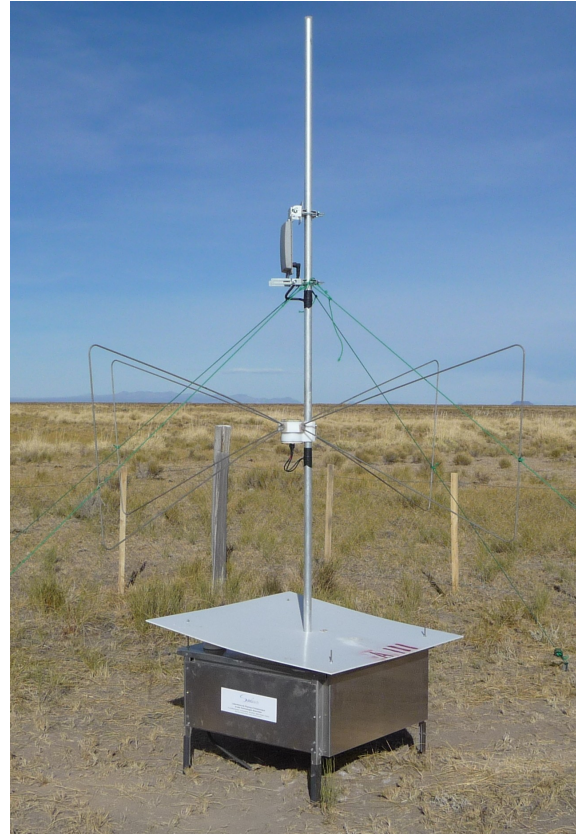
- Multiple in-between steps during LPDA evolution
- Extensive stress testing of dipole wire attachments
- 2 Hz oscillation of wire for one year
(63072000 cycles)

Antenna Evolution over Time

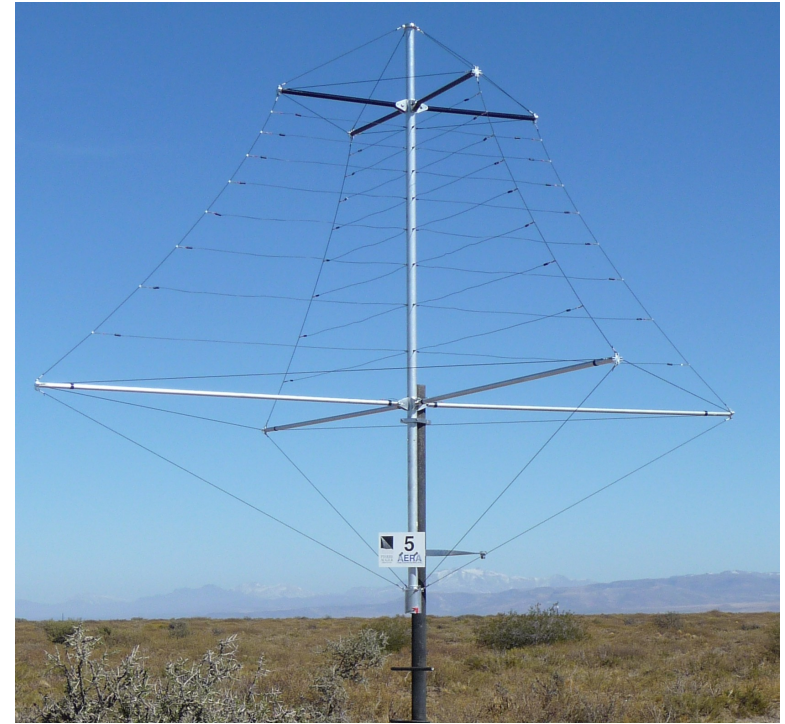
- Recently tested antenna types



SALLA (Karlsruhe)



Butterfly (Nantes)



Small Black Spider

Presentation of
Didier Charrier

Basic Facts on LPDAs

- **LPDA = Logarithmic Periodic Dipole Antenna**

- First assembled by D.E. Isbell in 1960

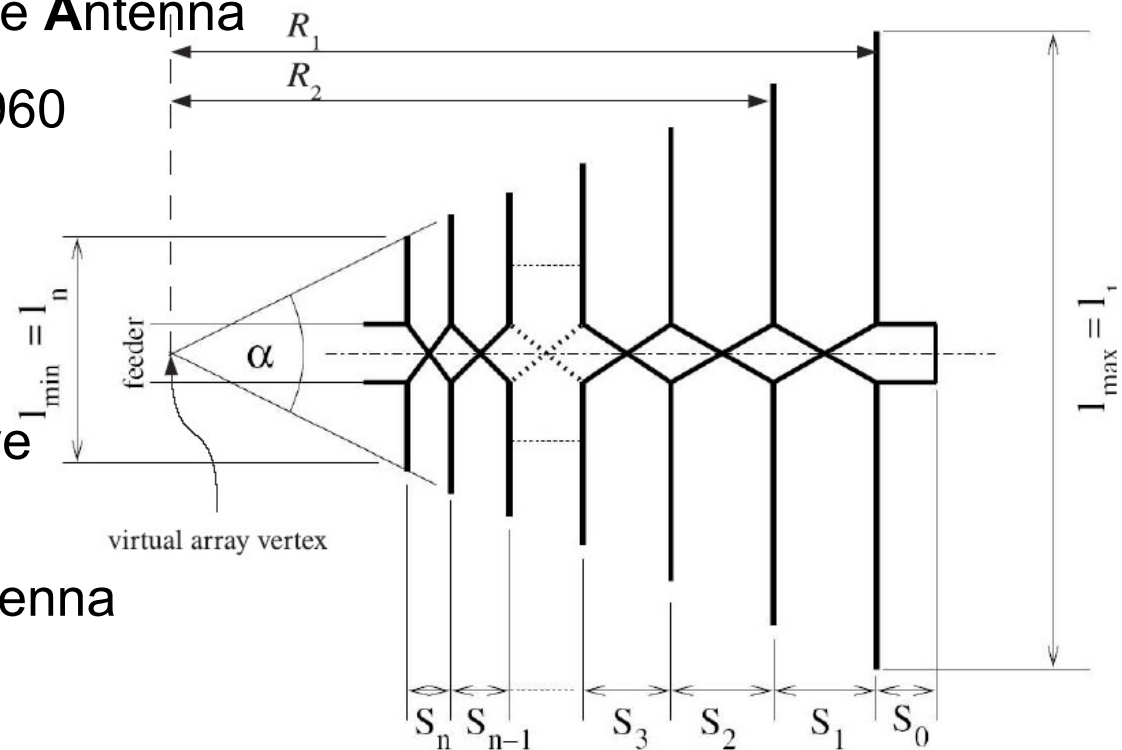
- Idea: gain a **large bandwidth** by assembling a sequence of half wave dipoles

- Waves add up constructively at antenna footpoint, if

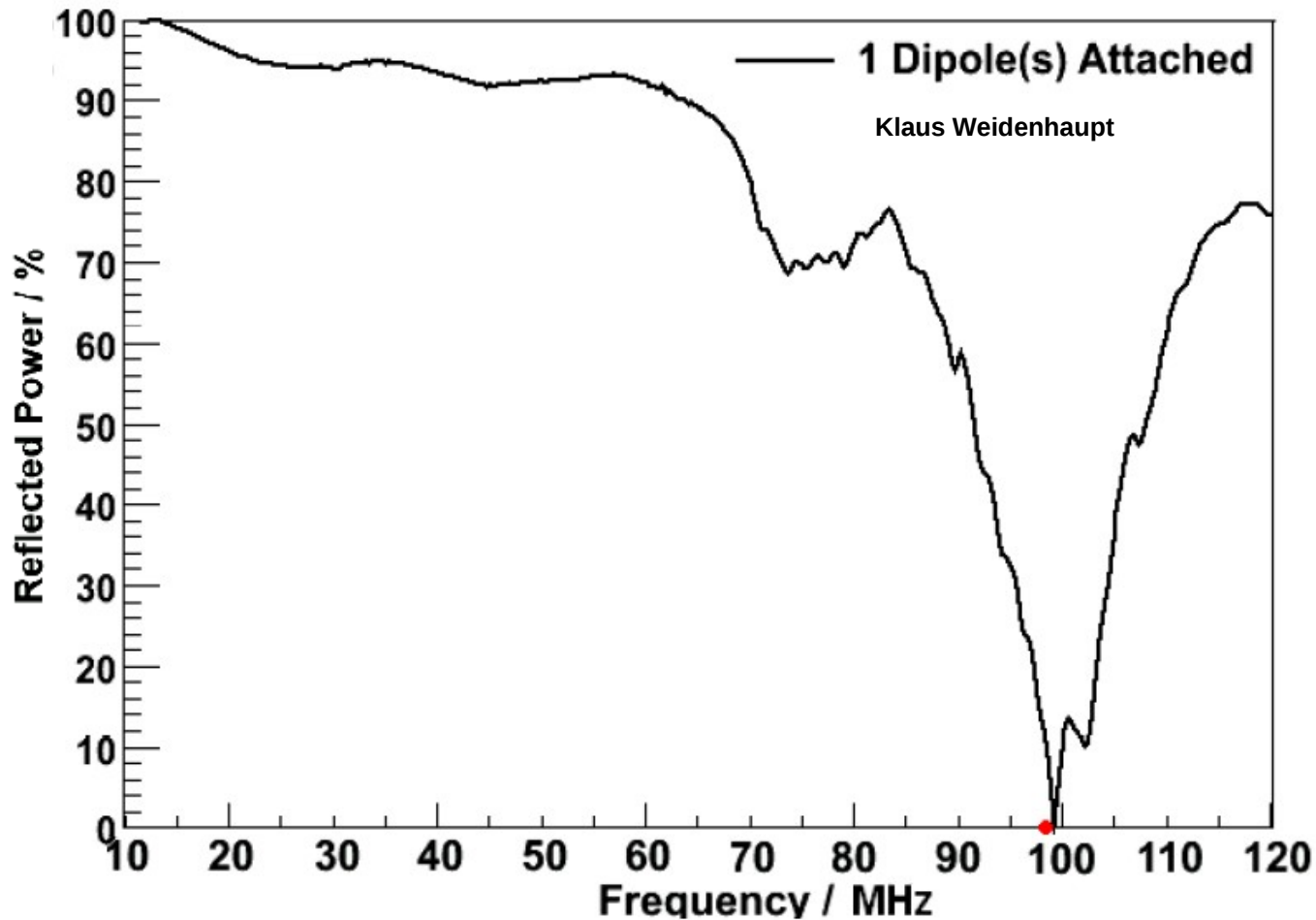
$$\frac{\lambda_i}{R_i} = \text{constant} \quad i = 1, \dots, n$$

- **High sensitivity towards sky** and reduced sensitivity towards horizon and ground

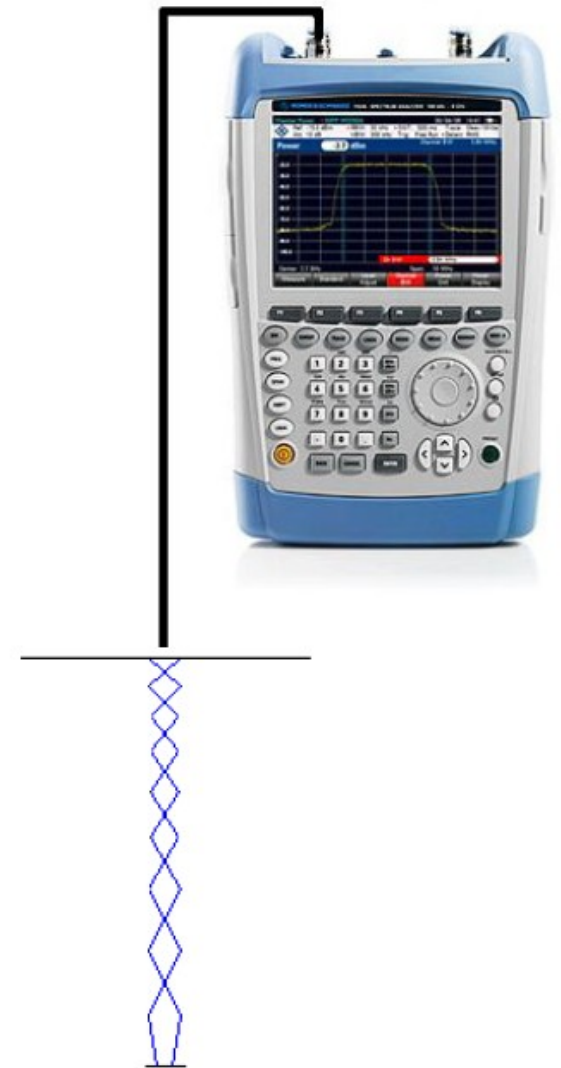
- Bandwidth observable in reflection measurement



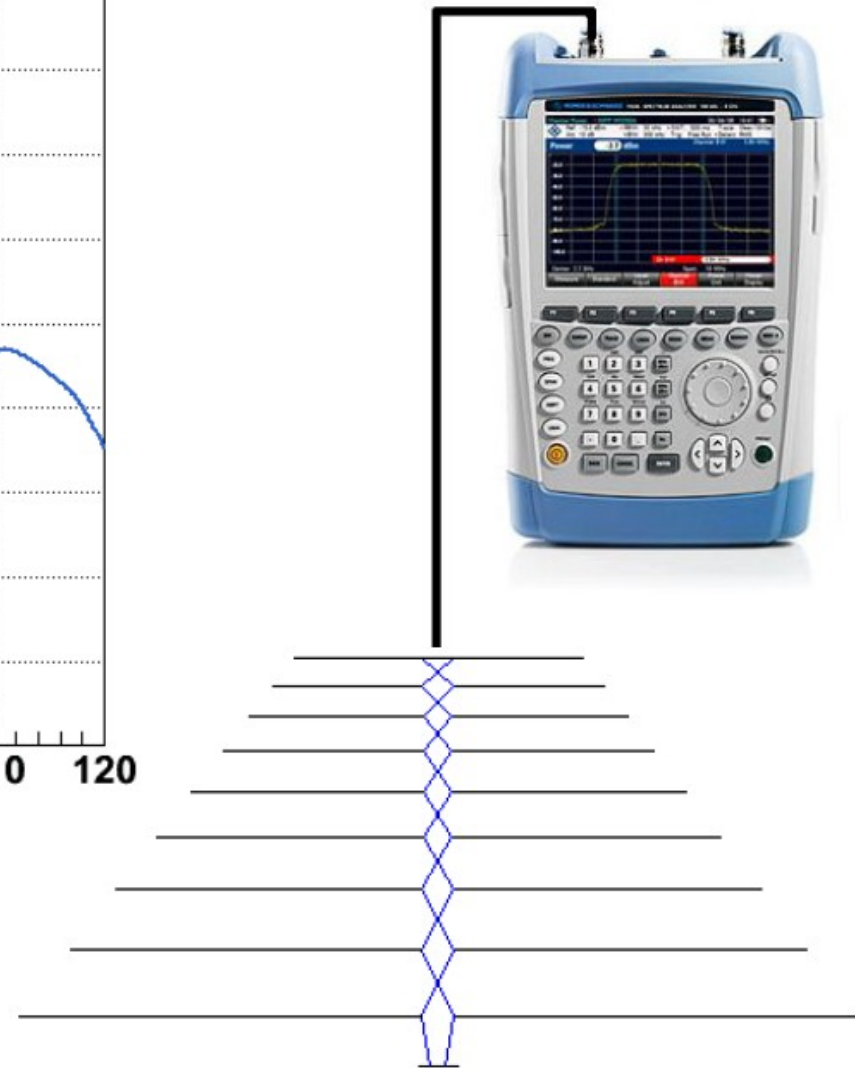
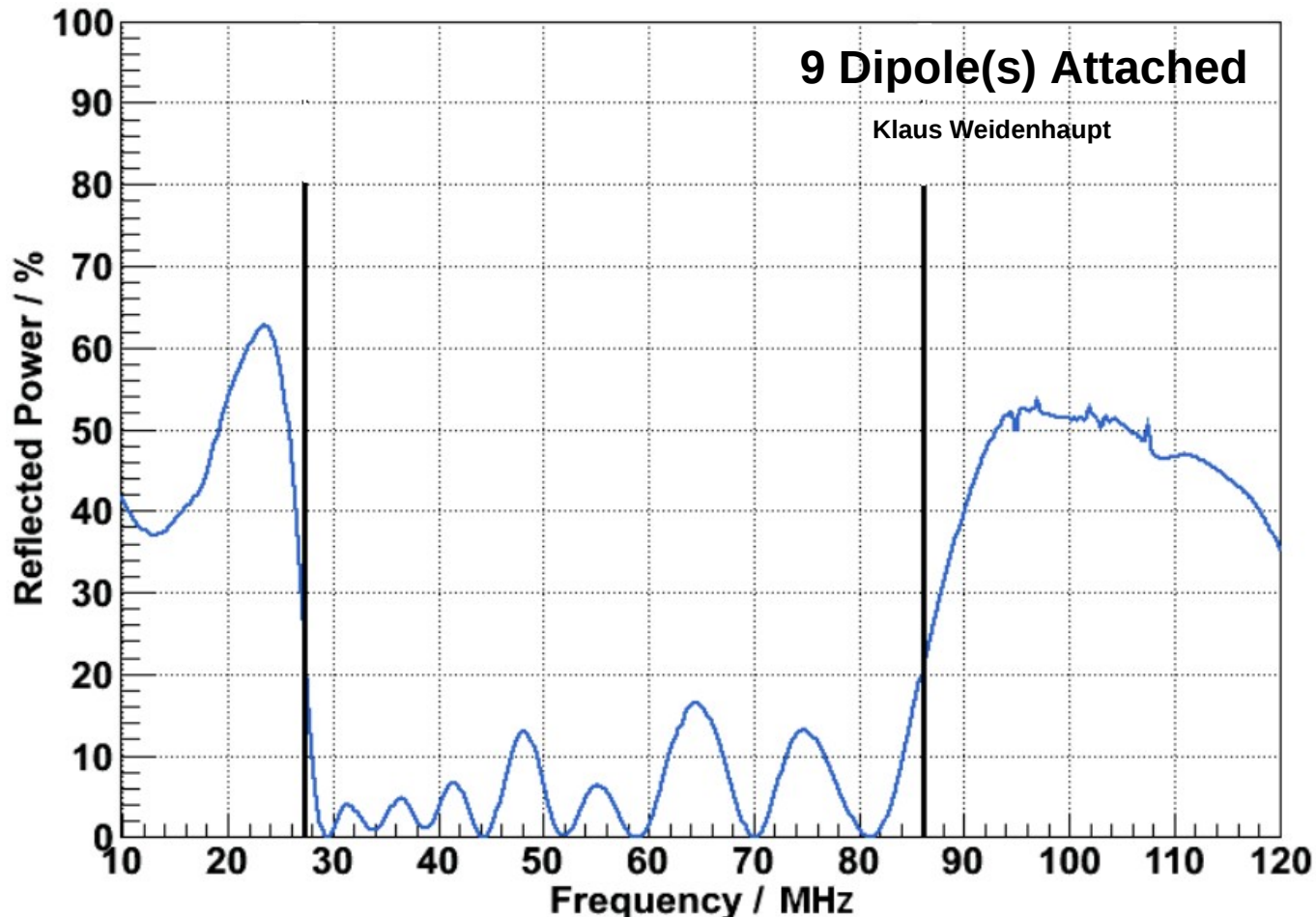
Constructing an LPDA



- Feed in signal with power P_0
- Plot ratio $\frac{P_R}{P_0}$ versus frequency



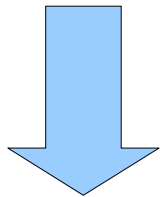
Constructing an LPDA



- Feed in signal with power P_0
- Plot ratio $\frac{P_R}{P_0}$ versus frequency

The Small Black Spider LPDA

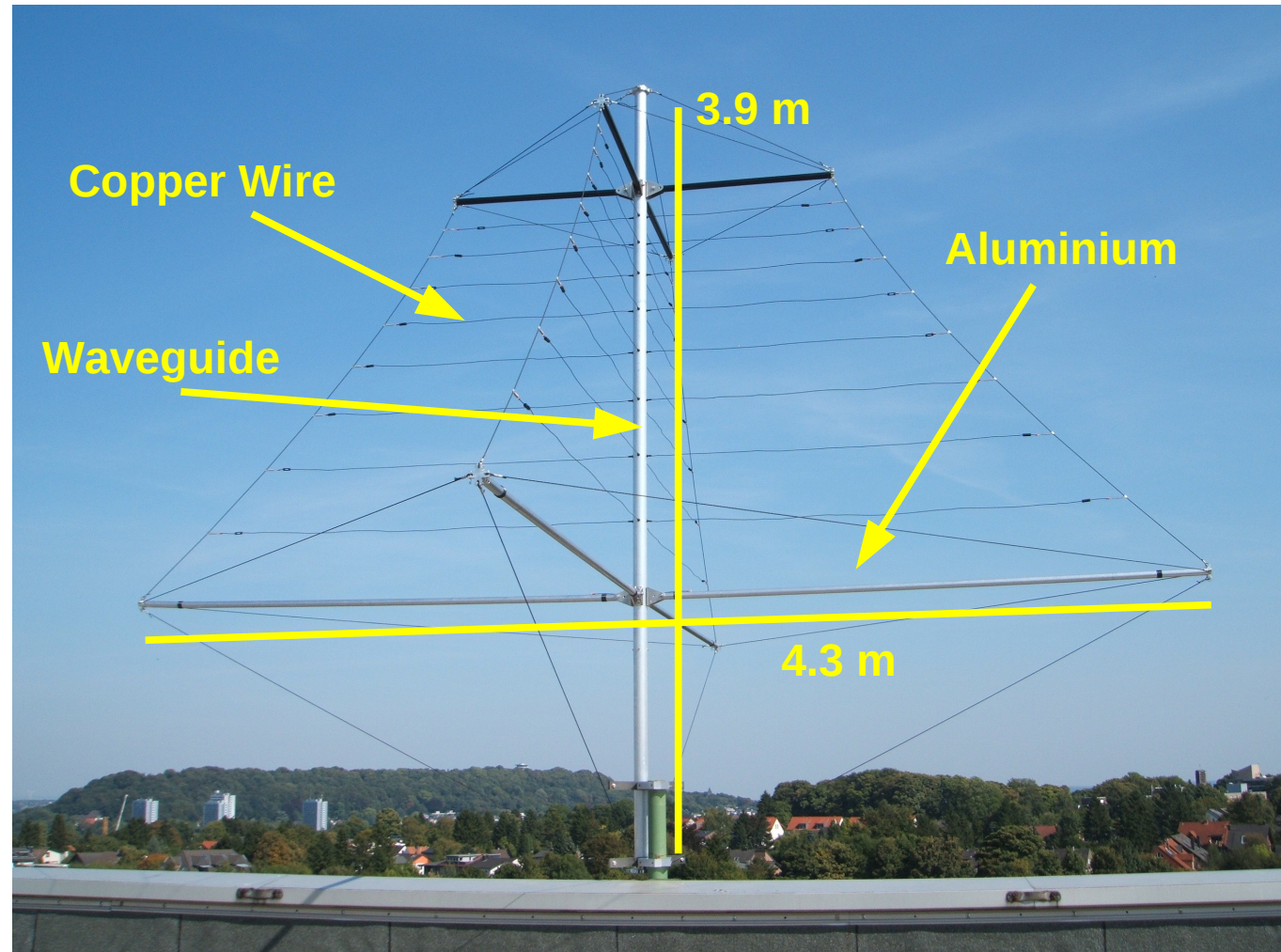
- 9 dipoles, bandwidth approximately 30 MHz to 80 MHz
- High wind-resistivity (storm Daisy, January 2010)
- Polarisation-sensitive due to „two antennas in one“ construction



Reconstruction of electric field vector possible, if you know the propagation direction of a radio pulse



Poster of Daniël Fraenkel



Transport to Argentina



July 1st 2010



Oliver Seeger

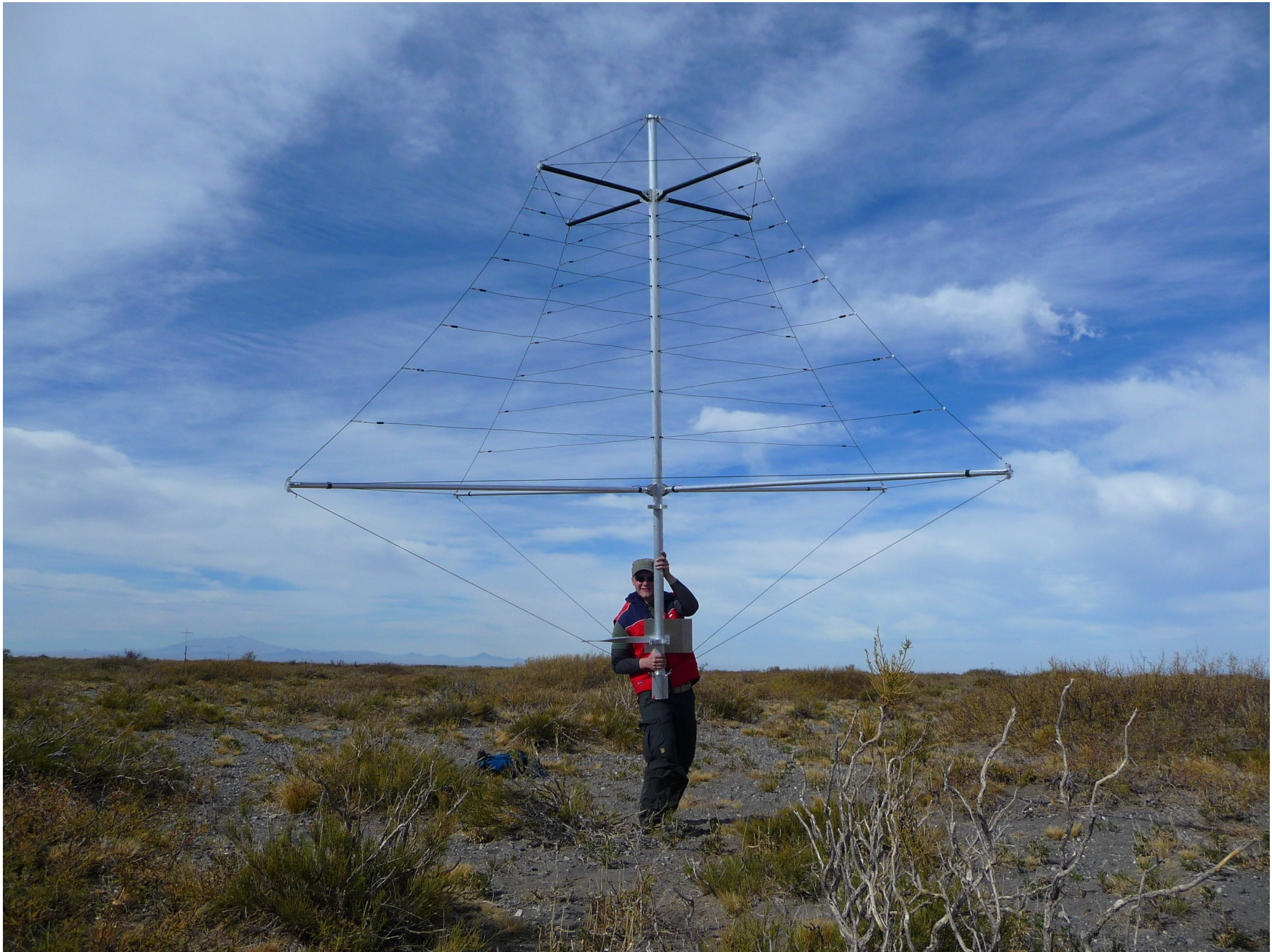


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Transport to Argentina



Small Black Spider in the Argentinian Pampa



July 1st 2010



Oliver Seeger



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Small Black Spider in the Argentinian Pampa



July 1st 2010



Oliver Seeger



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Small Black Spider in the Argentinian Pampa



July 1st 2010

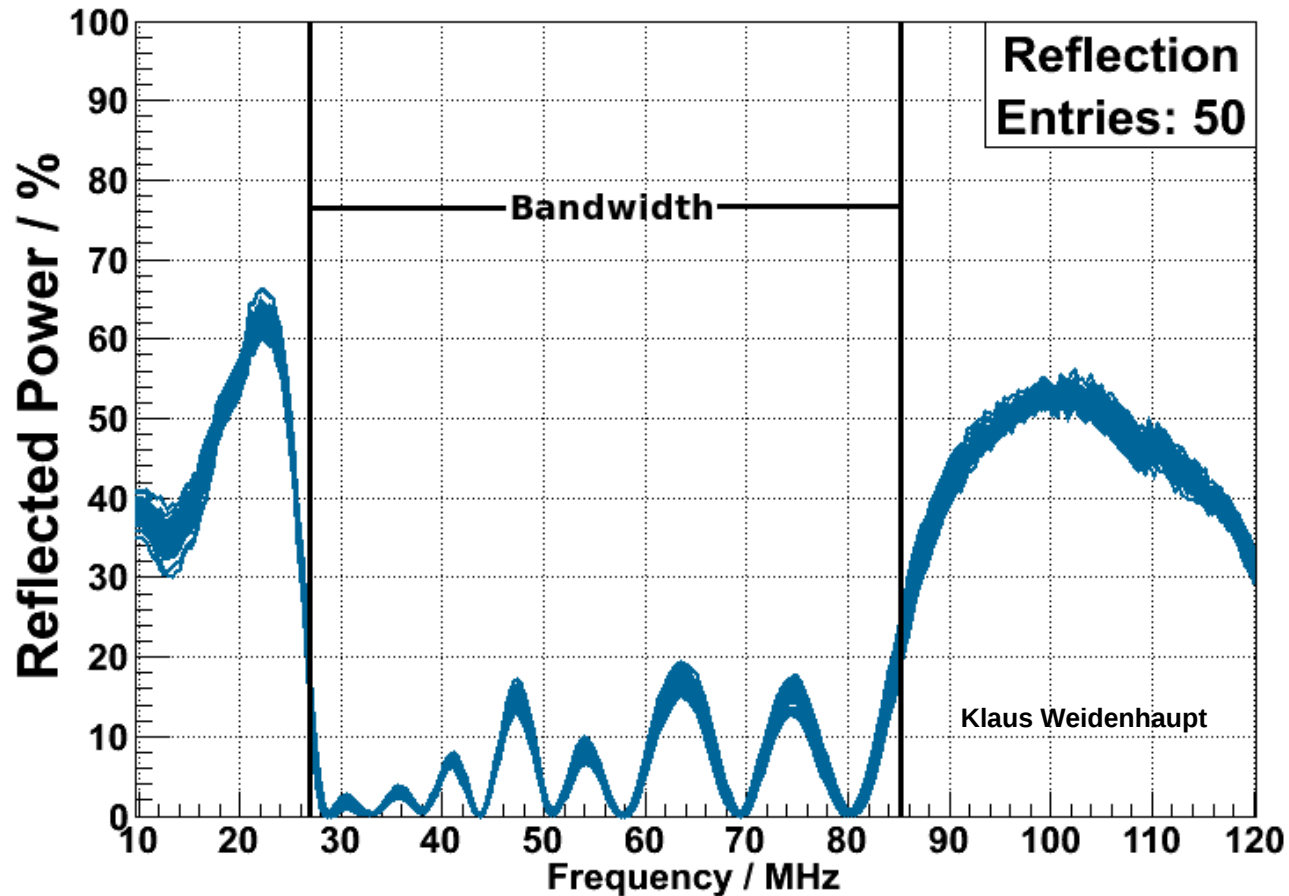


Oliver Seeger

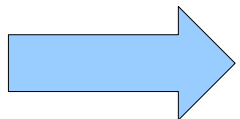


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Production Quality

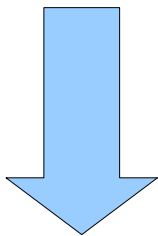
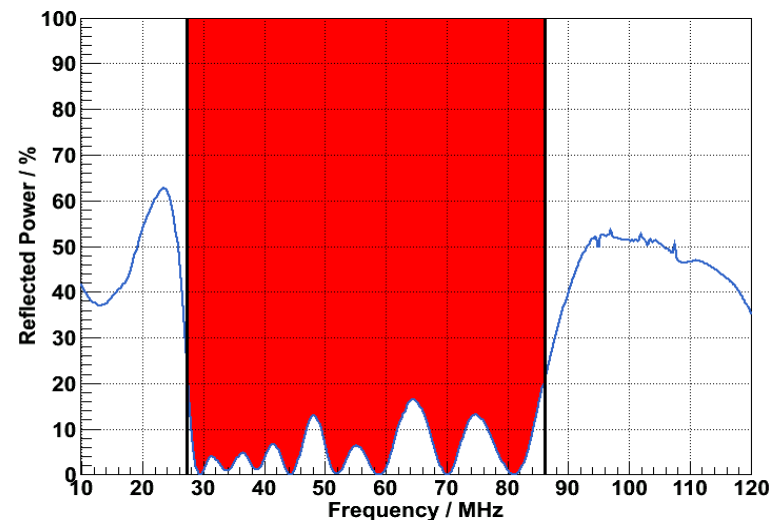


- 50 antenna planes
- We defined bandwidth at 20 % reflection
- 27.2 MHz to 86.1 MHz

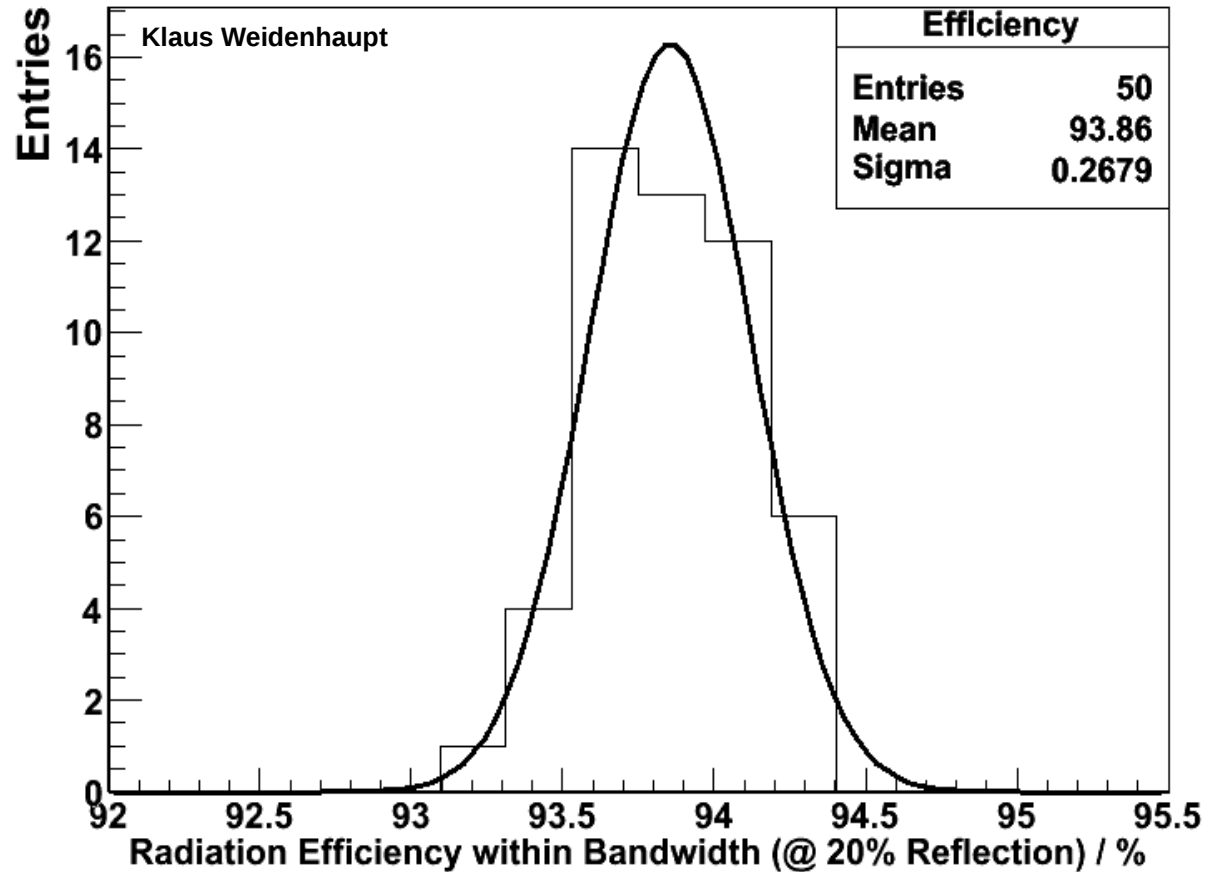


All antennas have perfectly survived the transport to Argentina!

Production Quality

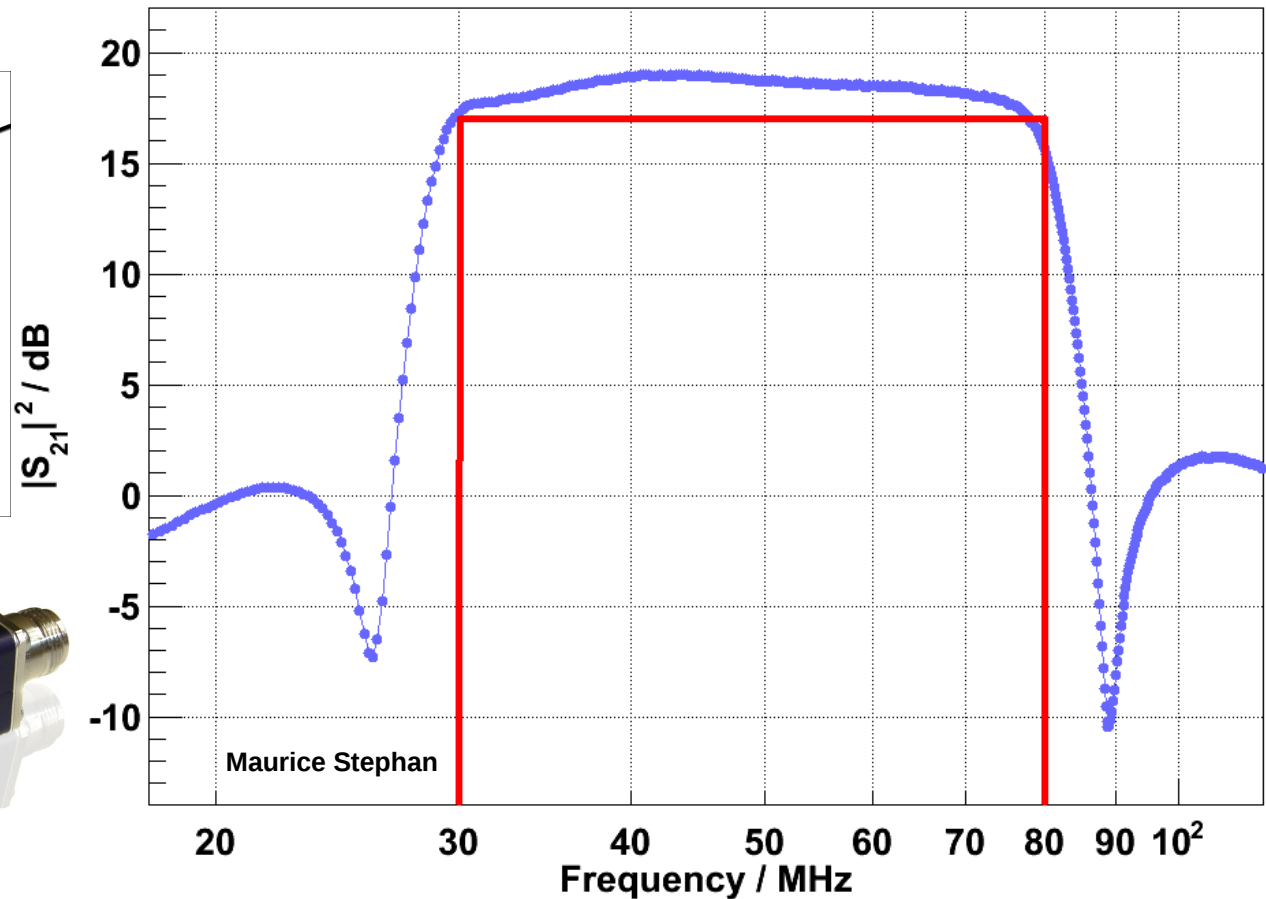
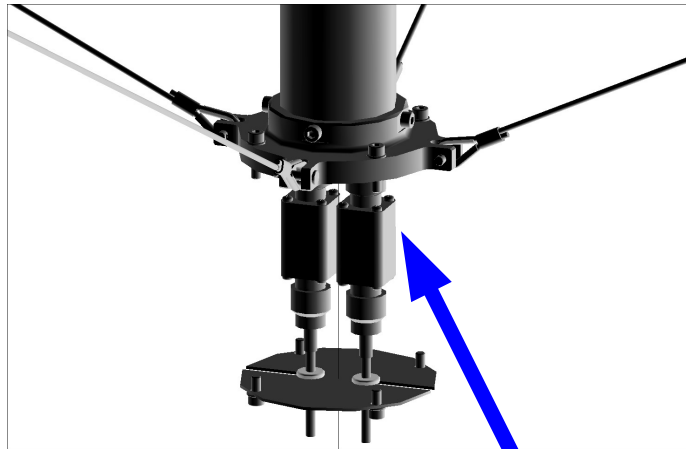


Efficiency



- Integral over power spectral density in bandwidth as estimator for radiated power
- Radiated power: $P_{\text{rad}} = (93.9 \pm 0.3) \%$

Integrated Low Noise Amplifiers and Filters



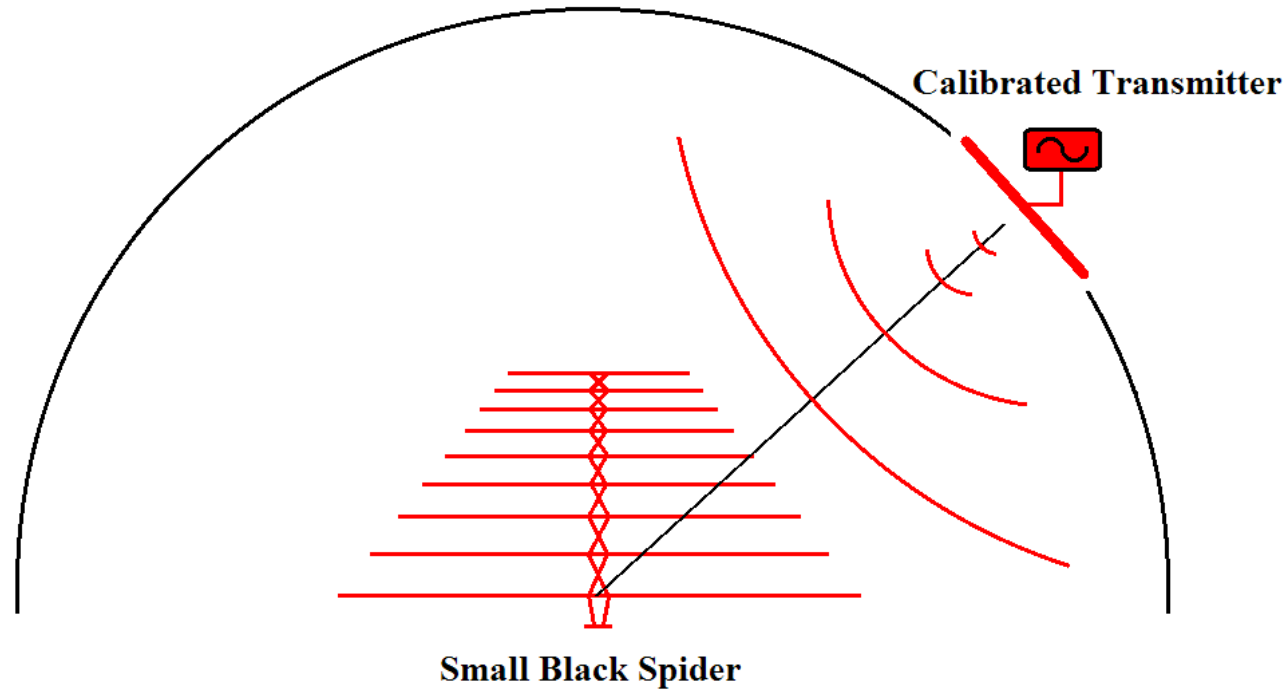
- 76 LNAs shipped to Argentina
- LNA well matched to antenna within bandwidth
- Filtering signals outside the bandwidth avoids intermodulation

Calibration

- Calibrate both polarisation planes of antenna and measure group delay
- Determine absolute gain with transmission measurement

$$S = \frac{P_R}{A_{\text{eff}}} = \frac{4\pi P_R}{\lambda^2 G_R}$$

$$S = \frac{P_T \cdot G_T}{4\pi r^2}$$

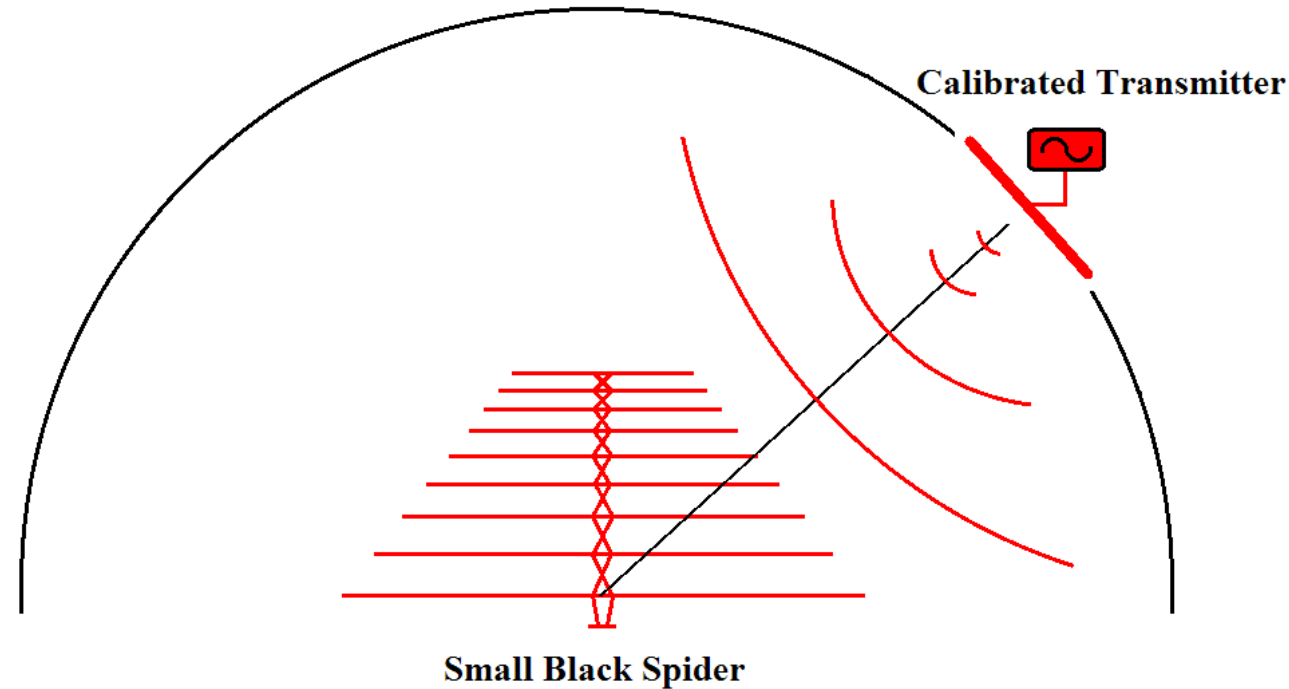


Calibration

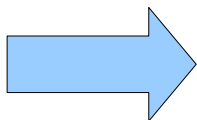
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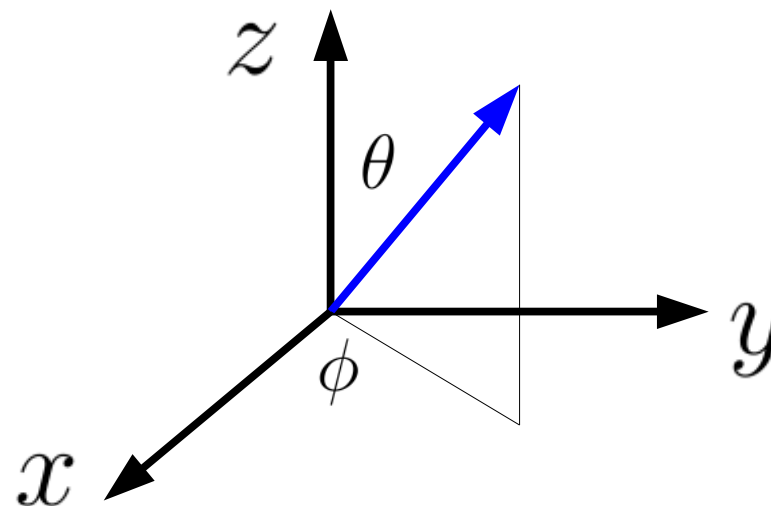
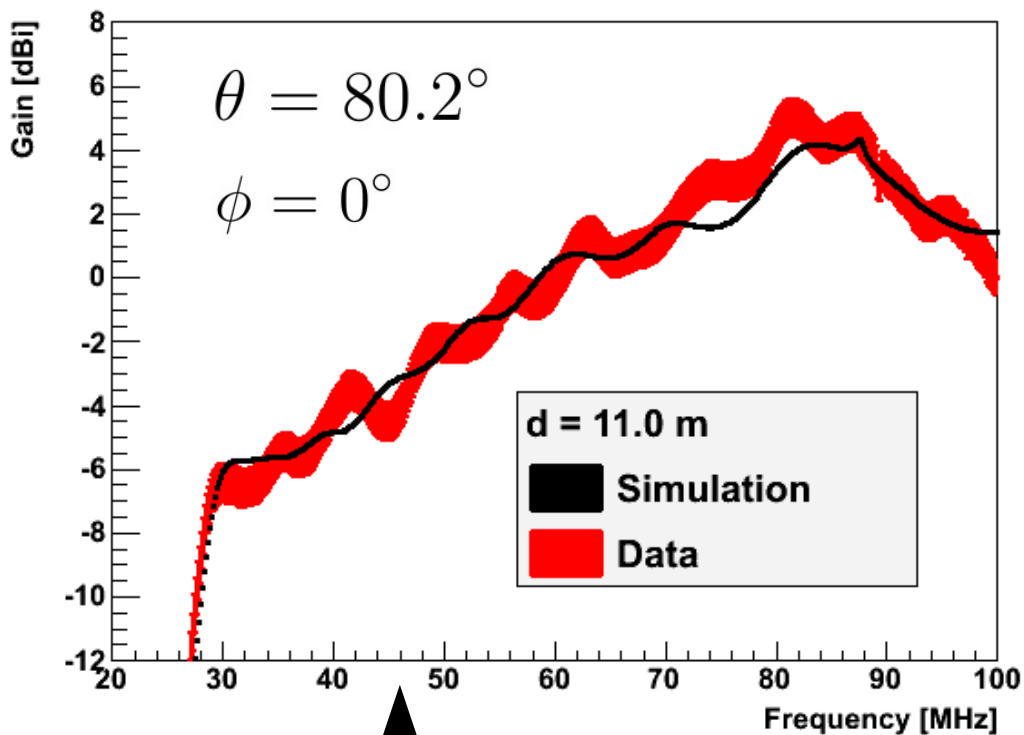
$$G_R(f, \theta, \phi) = \frac{16\pi^2 r^2}{c^2} f^2 \frac{P_R(f, \theta, \phi)}{P_T(f) G_T(f)}$$



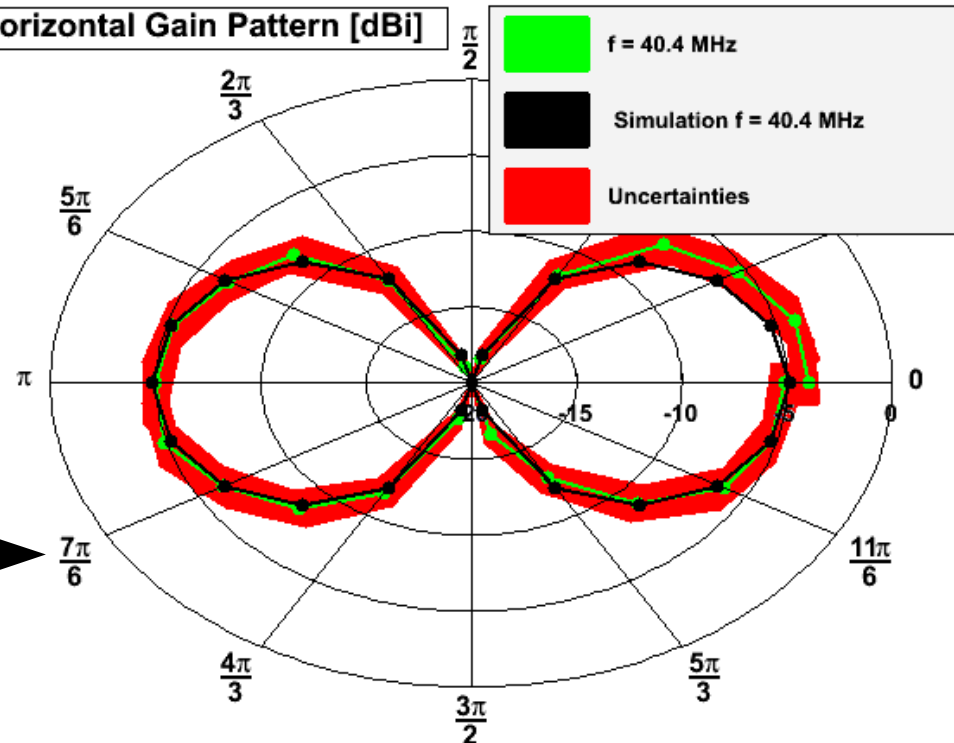
Sensitivity of Small Black Spider depends on direction and frequency of incoming signal

Near – Field Absolute Gain

SBS Absolute Gain versus Frequency (50 Ω System)



Horizontal Gain Pattern [dBi]



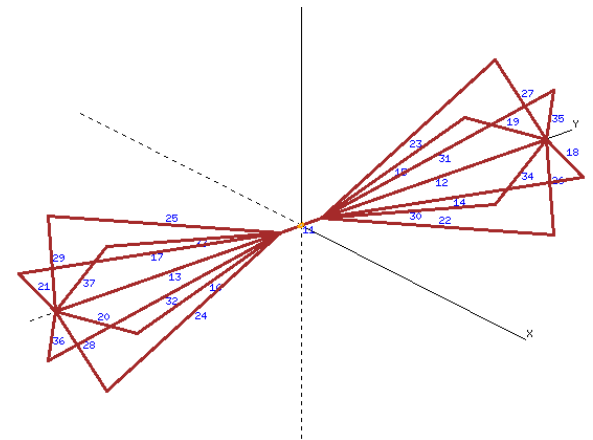
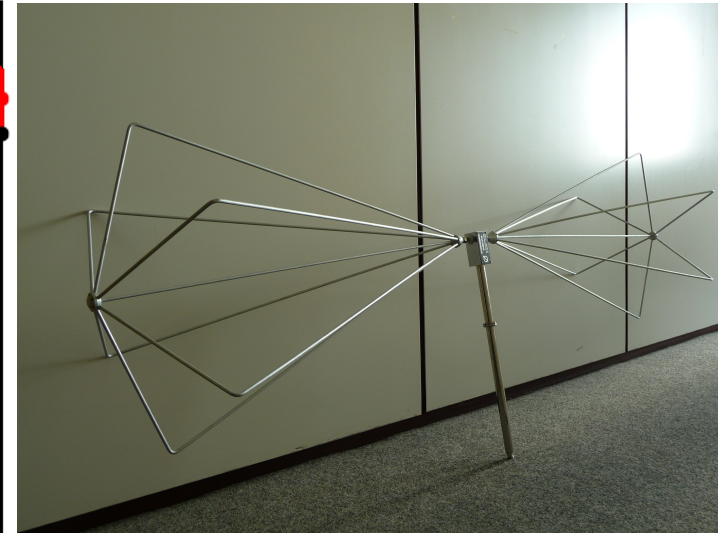
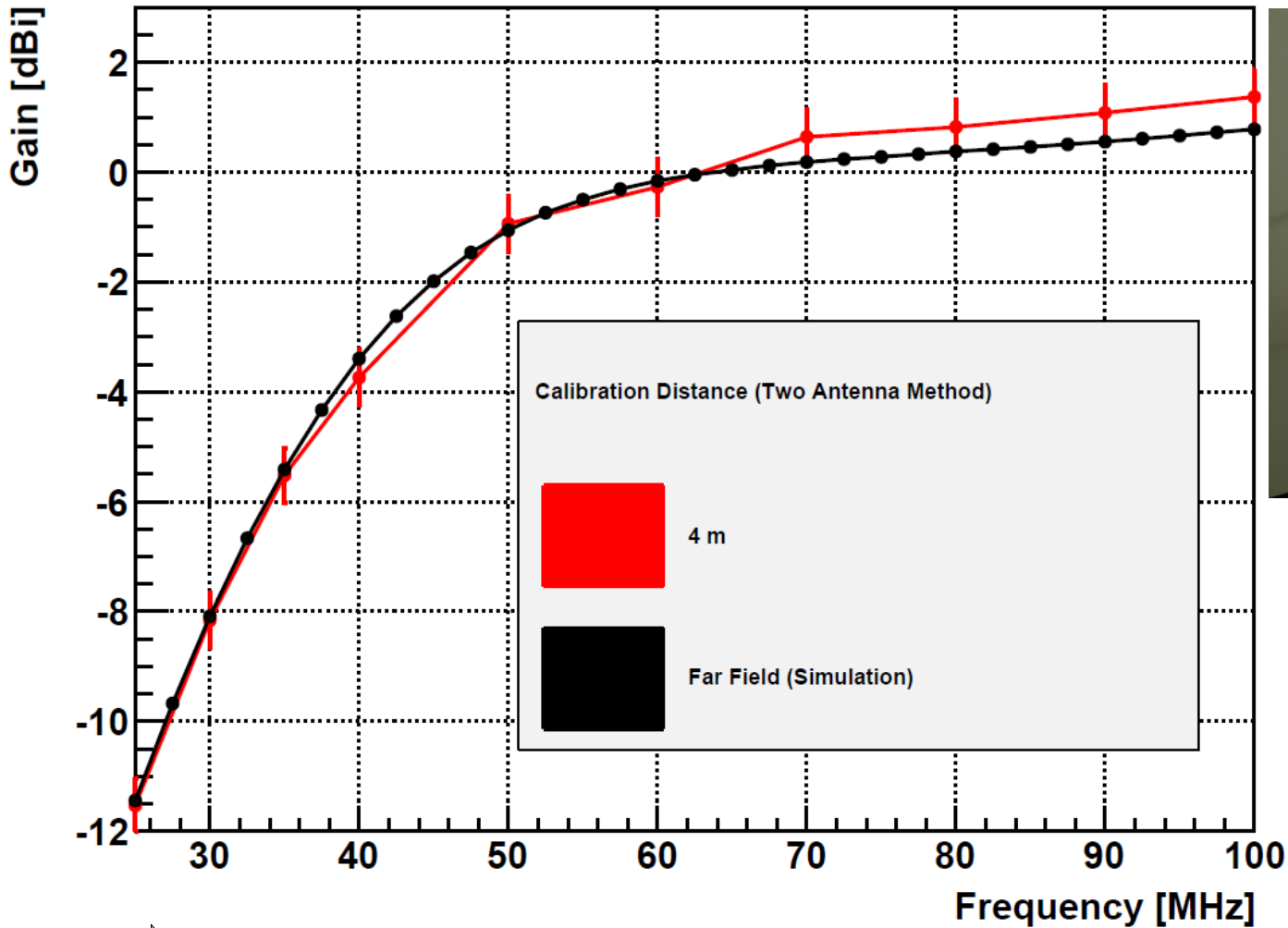
• Frequency pattern

• Azimuth pattern at $\theta = 80.2^\circ$

Pre – Calibrated Antenna

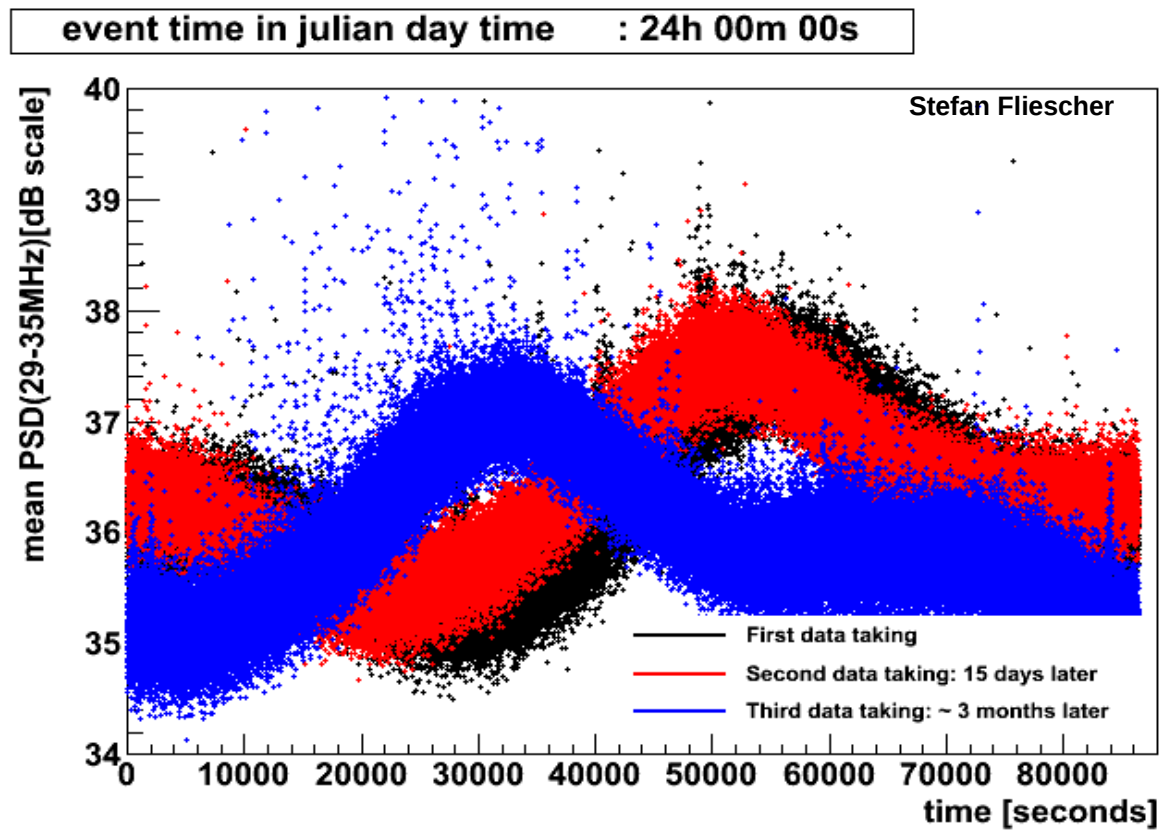
- Biconical antenna from Schwarzbeck

Biconical Antenna Absolute Gain versus Frequency



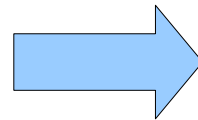
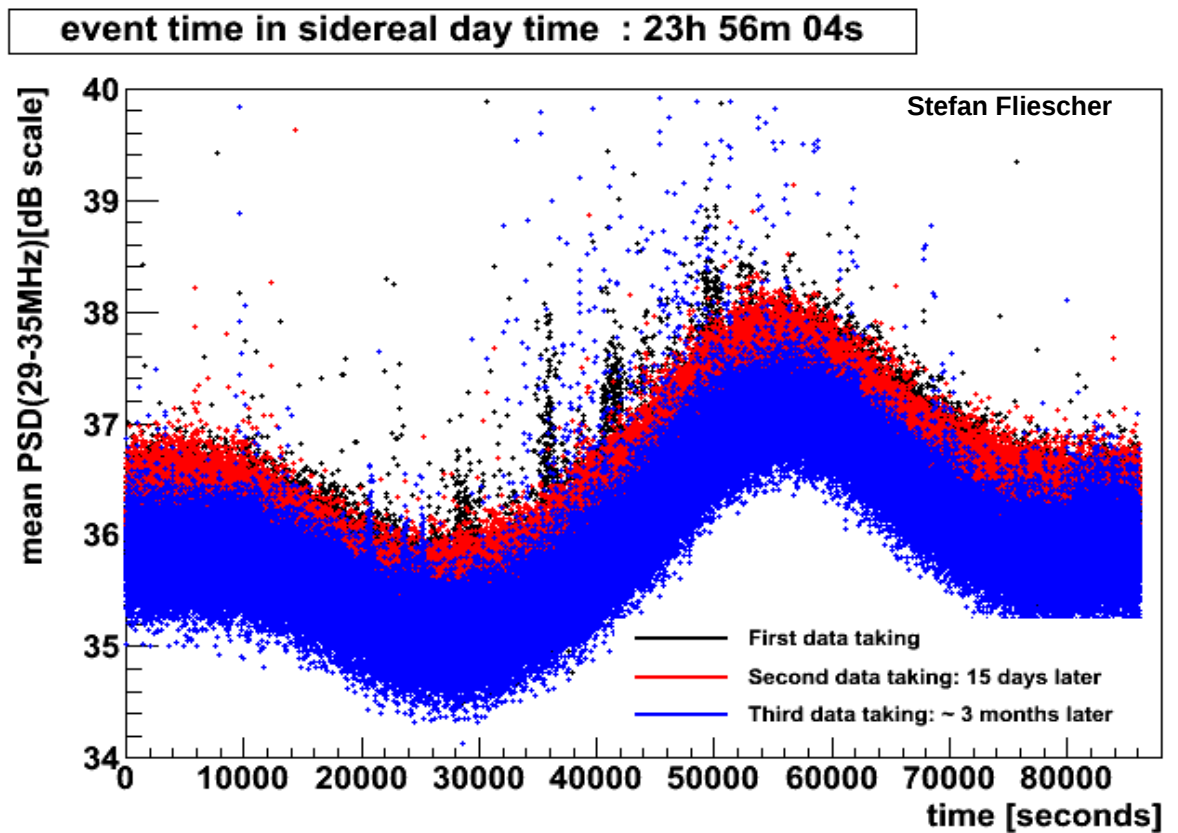
➔ Provided calibration data in good agreement with simulations

Galactic Radio Background Measured in Nancay



Special Thanks to Laurent Denis

Galactic Radio Background Measured in Nancay



Ascending and descending of
the galactic centre

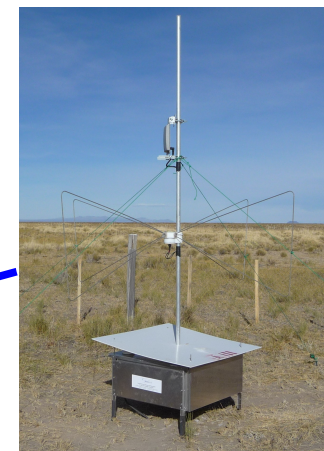
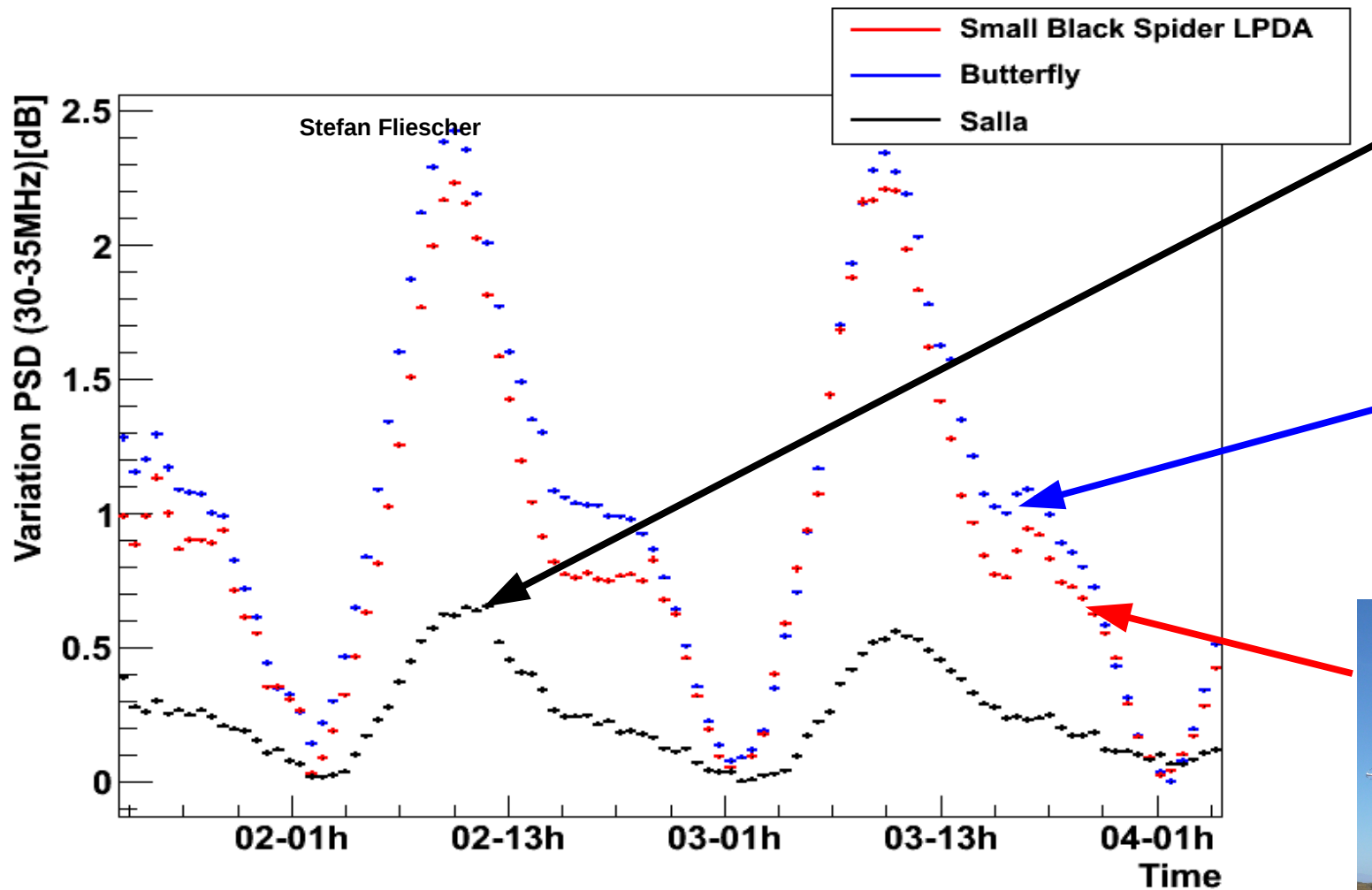
Special Thanks to Laurent Denis

Summary

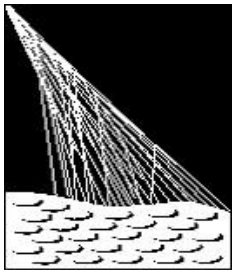
- Setup of **AERA phase one** in progress
- Galactic Radio Background **well observable** with Small Black Spider LPDA
- Galactic Radio Background **dominates noise spectrum** in current setup
- **Excellent quality** of LPDA series production

Outlook

- Completion of absolute calibration for Small Black Spider
- Comparison to other antenna types for phase two of AERA



Thank you for your attention!



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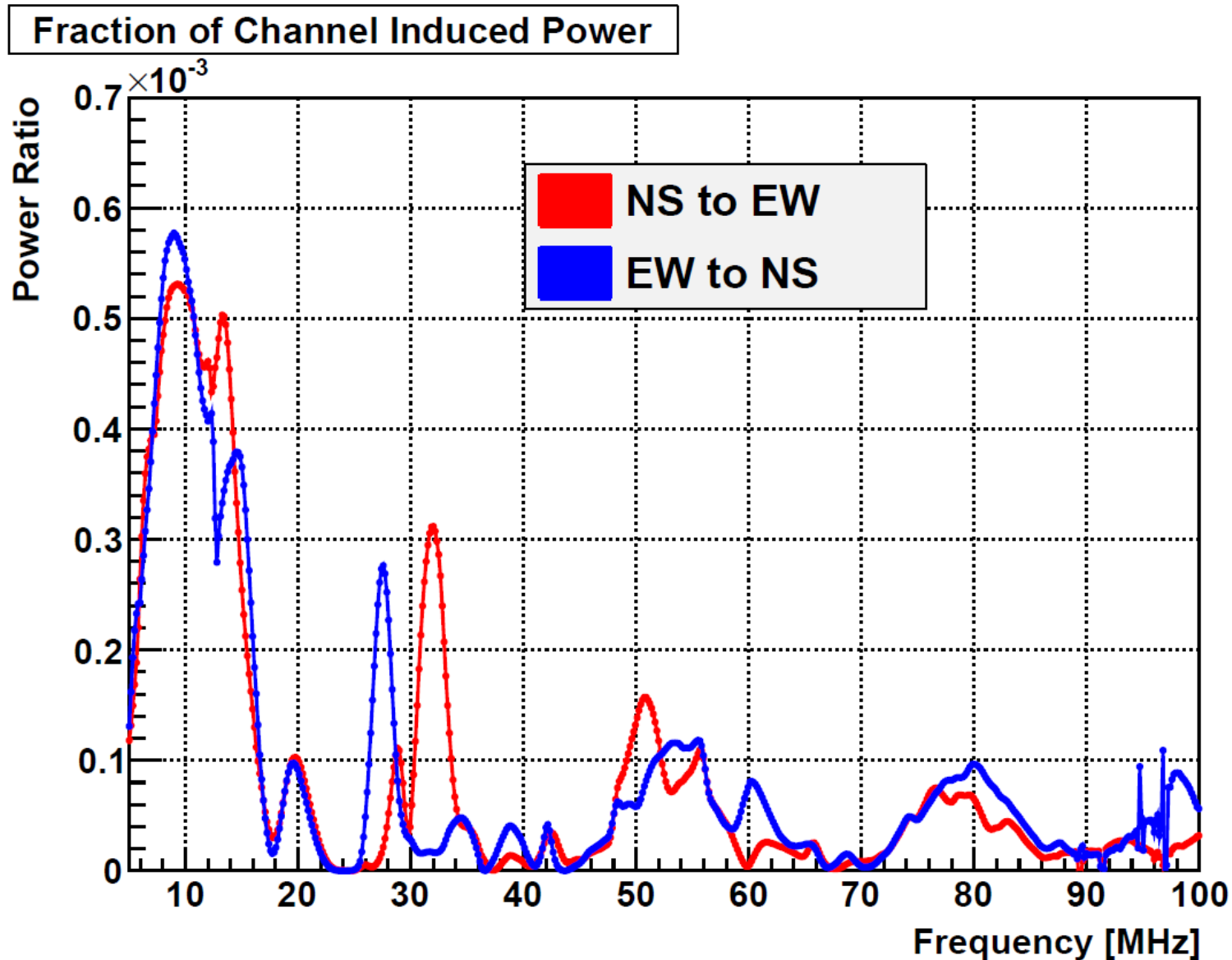
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Backup: CIP

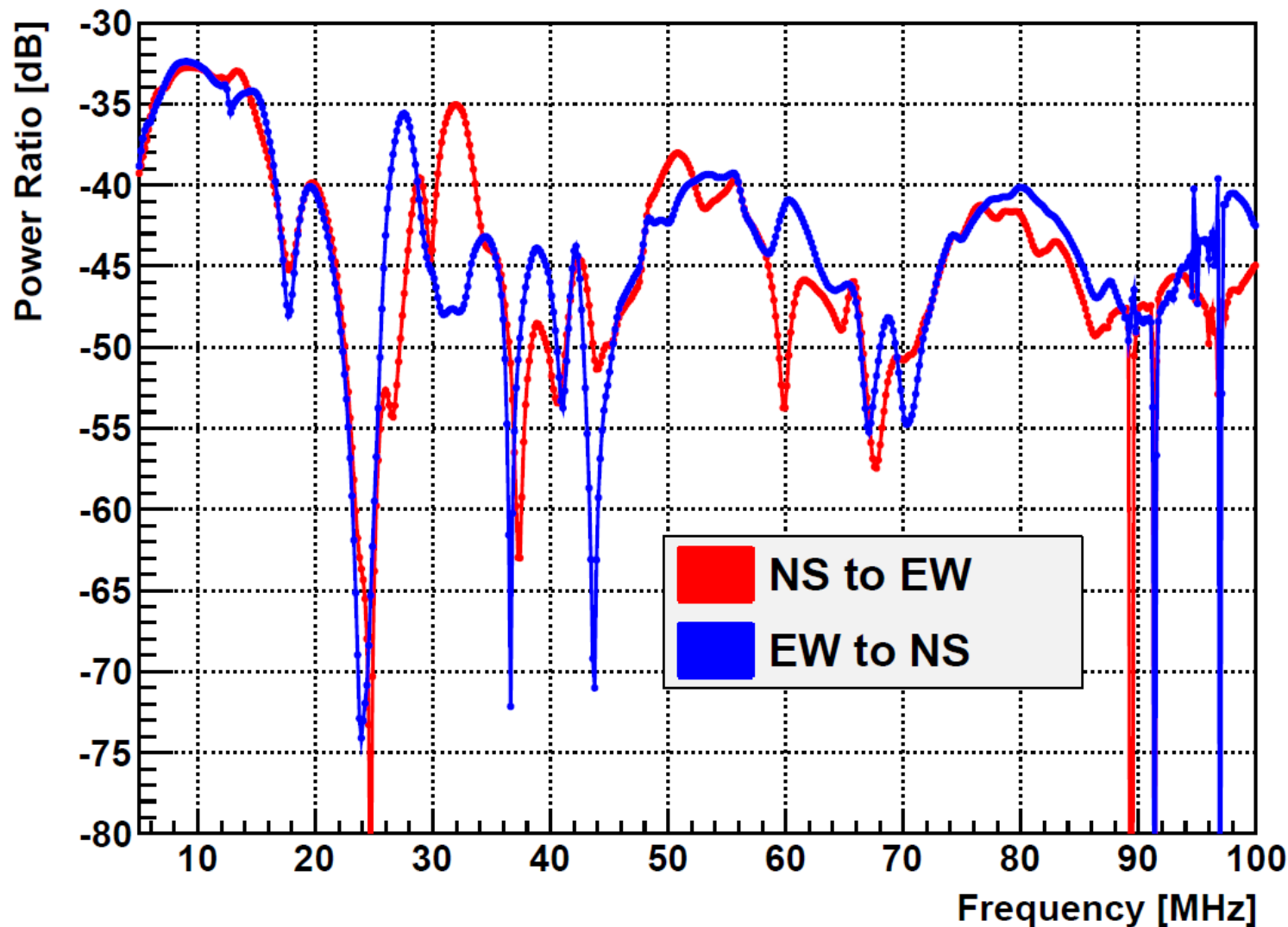
- Channel Induced Power in Small Black Spider antenna planes



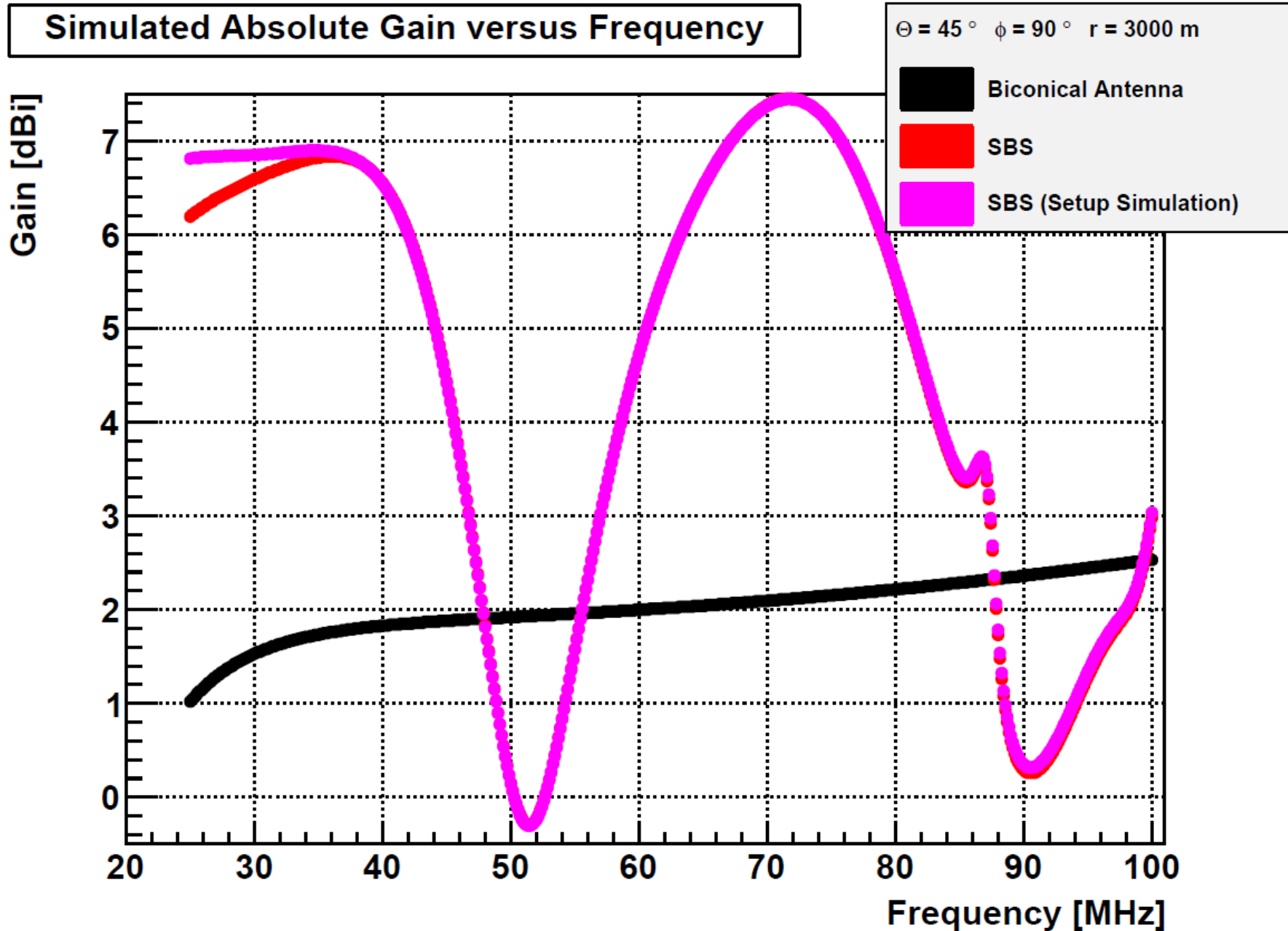
Backup: CIP

- Channel Induced Power in Small Black Spider antenna planes

Fraction of Channel Induced Power

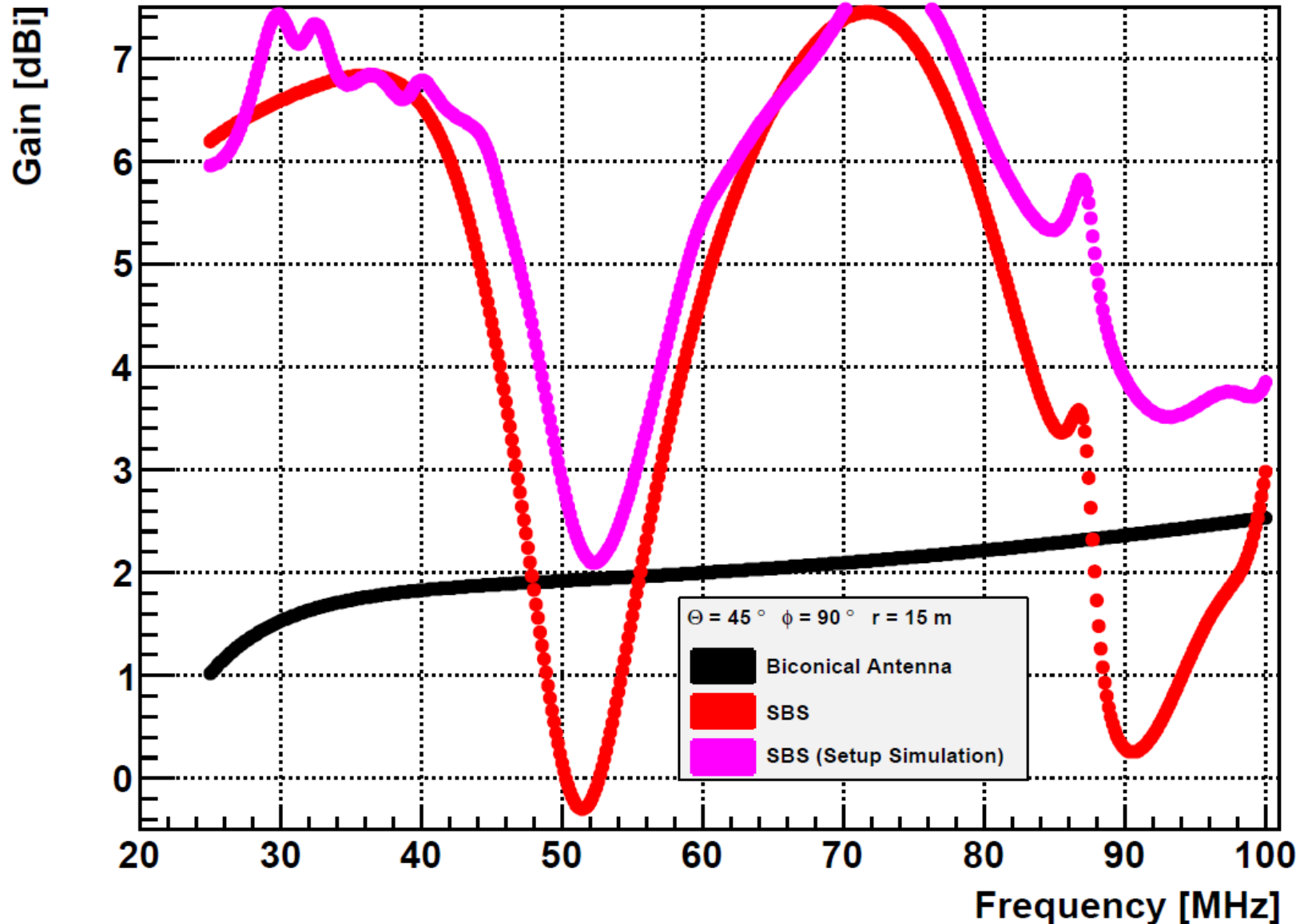


Backup: Simulation Far – Field Gain

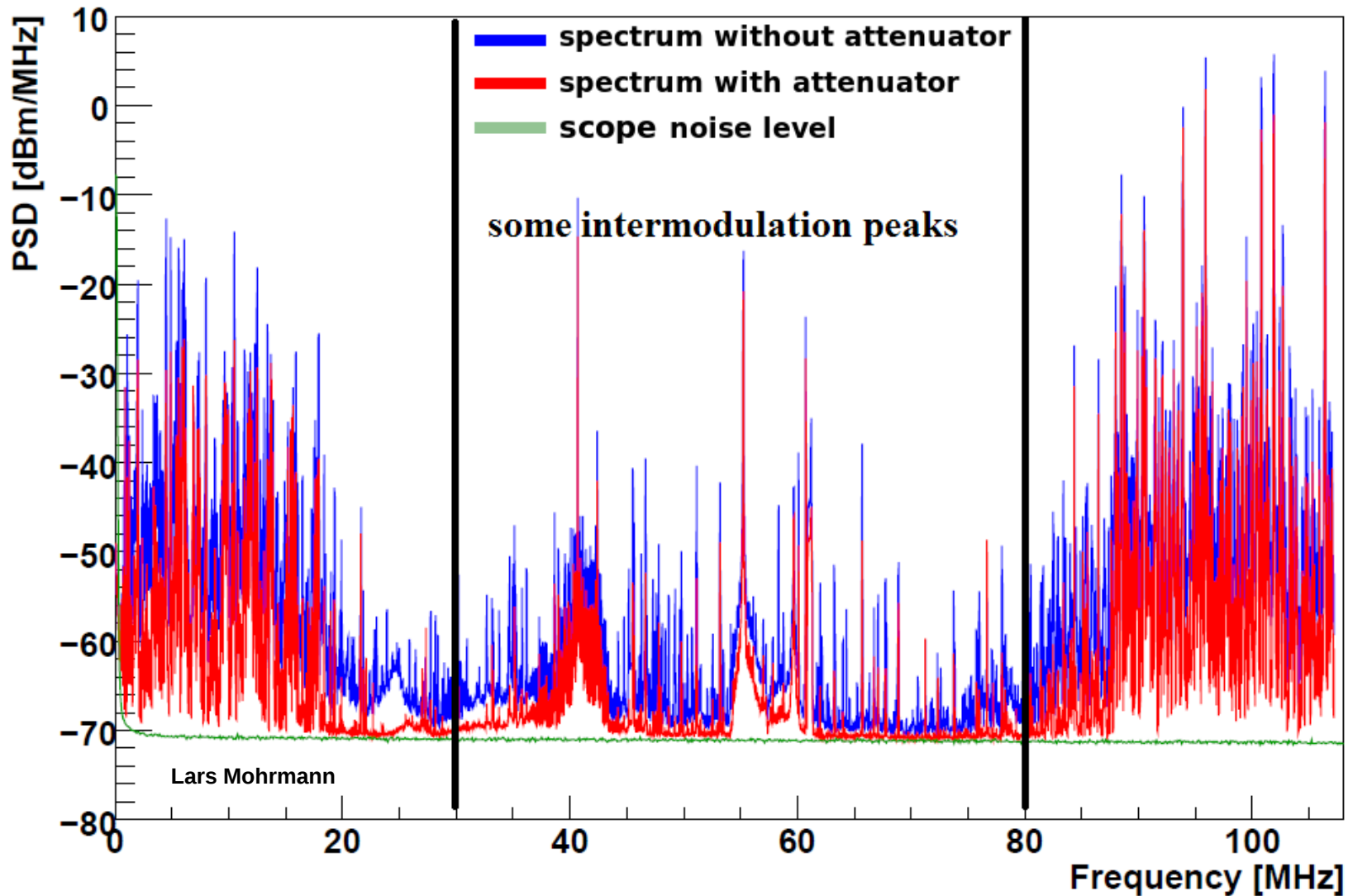


Backup: Near – Field Effects

Simulated Absolute Gain versus Frequency



Backup: Intermodulation



- Spectrum measured in Aachen
- Signals outside of bandwidth contribute to intermodulation within bandwidth

Backup: Inside of SBS

