Complex Permittivity Measurements of Karoo Soil for the SKA

Braam Otto

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EM Shielding Properties of Karoo Soil

Conclusions

Questions

Complex Permittivity Measurements of Karoo Soil for the Square Kilometre Array

ICEAA-IEEE APWC 2011

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jou kennisvennoot·your knowledge partner

University of Stellenbosch, Western Cape, South Africa

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Presentation Overview

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- Background & Research Objectives
- EM Shielding Properties of Karoo Soil
  - Complex Permittivity
  - Computational Modelling
  - Metrology: KAT-7 Site & Laboratory
  - Analytical Prediction: Attenuation of Karoo Soil
- Conclusions
- Questions

Karoo Array Telescope (KAT-7)

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- The Karoo region of the Northern Cape Province is ideal for radio astronomy
- Remote and sparsely populated, minimal RFI man-made sources
- Astronomy Geographic Advantage Act of 2007: astronomy advantage area
- 12.5 million hectares protected as a radio astronomy reserve
- Strict regulations controlling generation and transmission of RI signals

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Background

- SKA Freq Range: 70 MHz to > 25 GHz
- SKA Baseline: 3000 km
- 50 x more sensitive any imaging radio telescope
- Extremely sensitive radio receivers: 200 dB dynamic range

EMRIN Group's Research Objective

- System RFI mitigation through modelling and metrology

Scale and Computational Modelling

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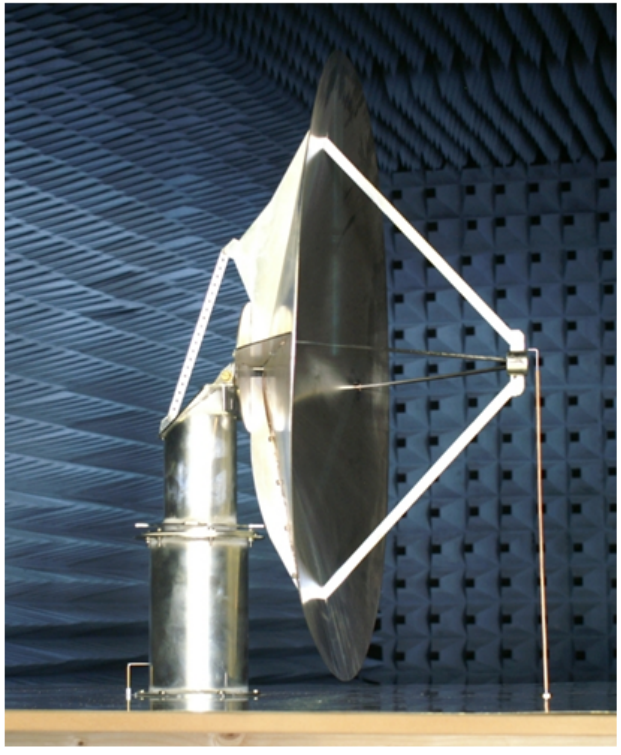

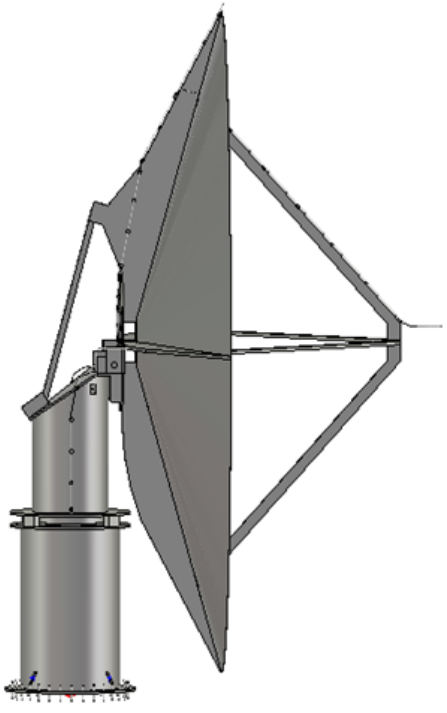

EM Shielding Properties of Karoo Soil

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Research Objective

- Attenuation of unwanted signals by burying cables and "noisy" equipment underground (bunkers) investigated
- Soil will also provide level of protection against oustide interference signals (ex. lightning)

Methodology

- Complex permittivity extraction methods
- Measurements: Laboratory & KAT-7 Site
- Computational Modelling
- Analytical Prediction

Complex Permittivity of Karoo Soil

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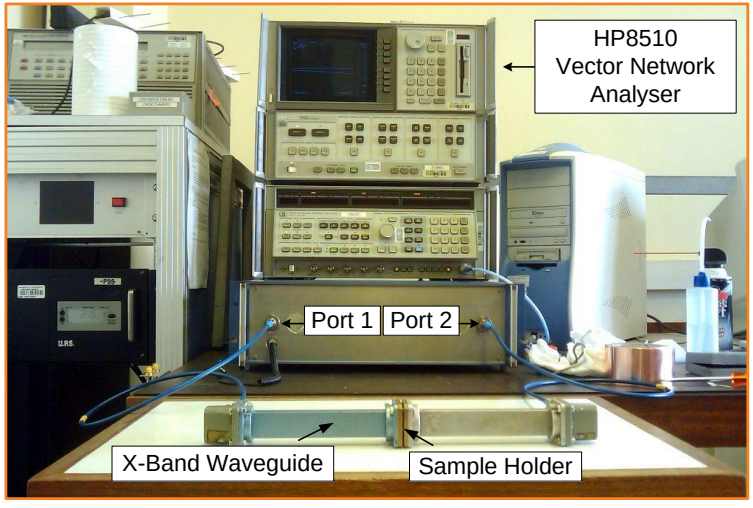
Waveguide Measurements

- WR284: S-band (2.6 to 3.95 GHz)
- WR90: X-band (8.2 to 12.4 GHz)

VNA: 2-Port S-Parameters



$$\epsilon_r = \epsilon_r' - j\epsilon_r''$$

$$\tan\delta = \frac{\epsilon_r''}{\epsilon_r'}$$

Baker-Jarvis Extraction Method

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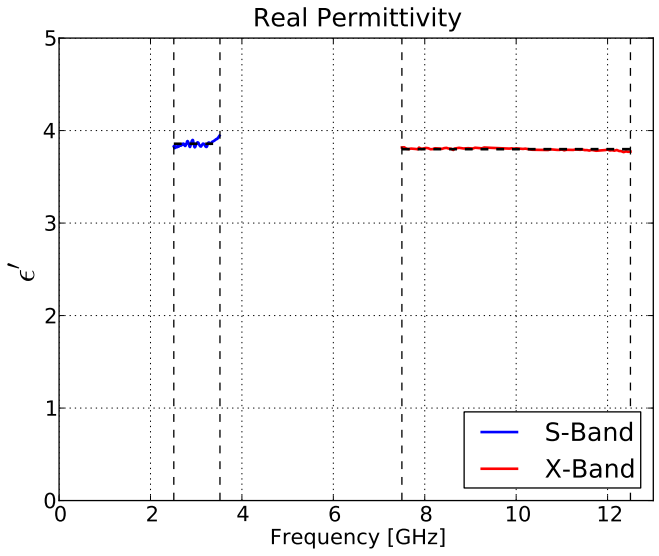
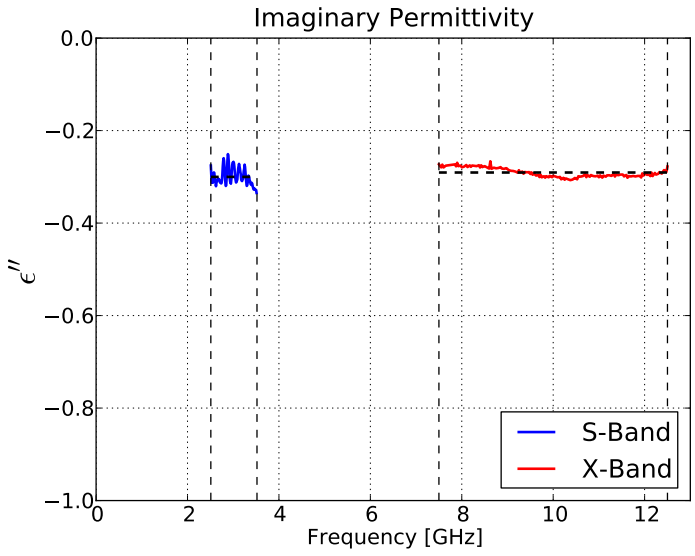
$$\frac{1}{2}\left([S_{12}+S_{21}]+\beta[S_{11}+S_{22}]\right)=\frac{z(1-\Gamma^2)+\beta\Gamma(1-z^2)}{1-z^2\Gamma^2}$$





$\epsilon_r' \approx 3.8$, $\epsilon_r'' \approx 0.29$ and $\tan\delta \approx 0.076$

Waveguide Computation

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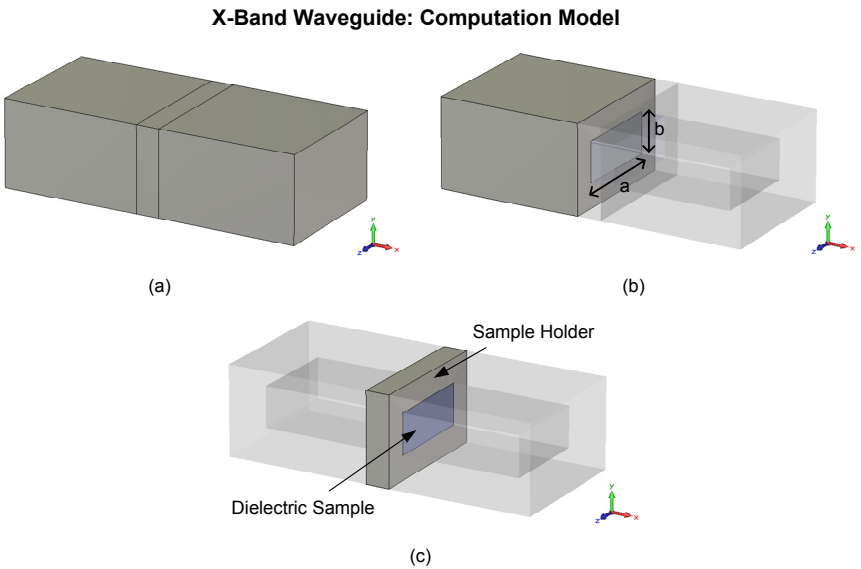

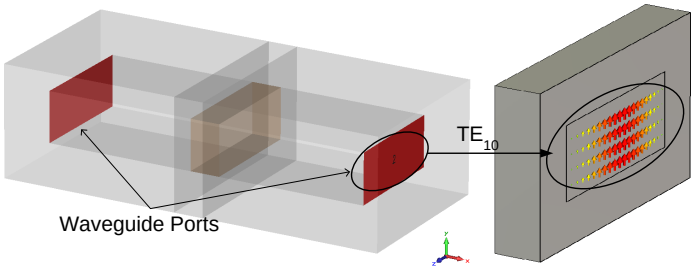

S-Parameters: Computation and Measurement

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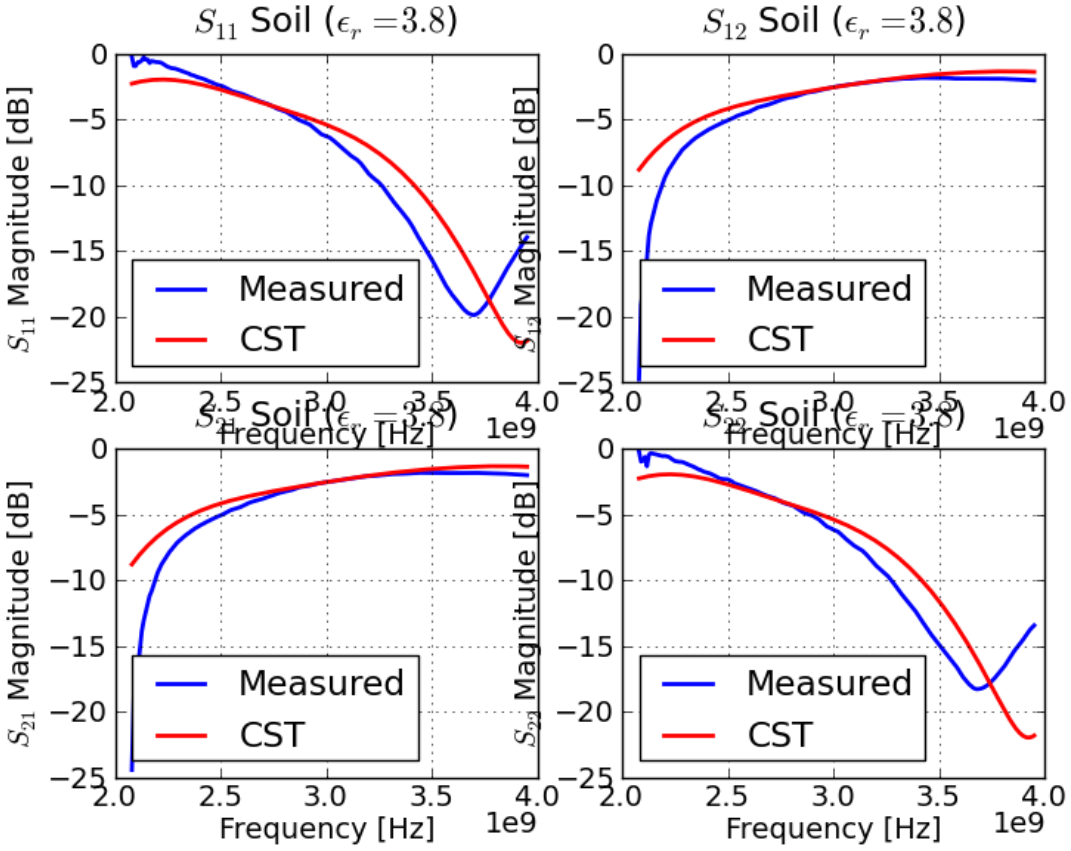

X-band Horn Antennas

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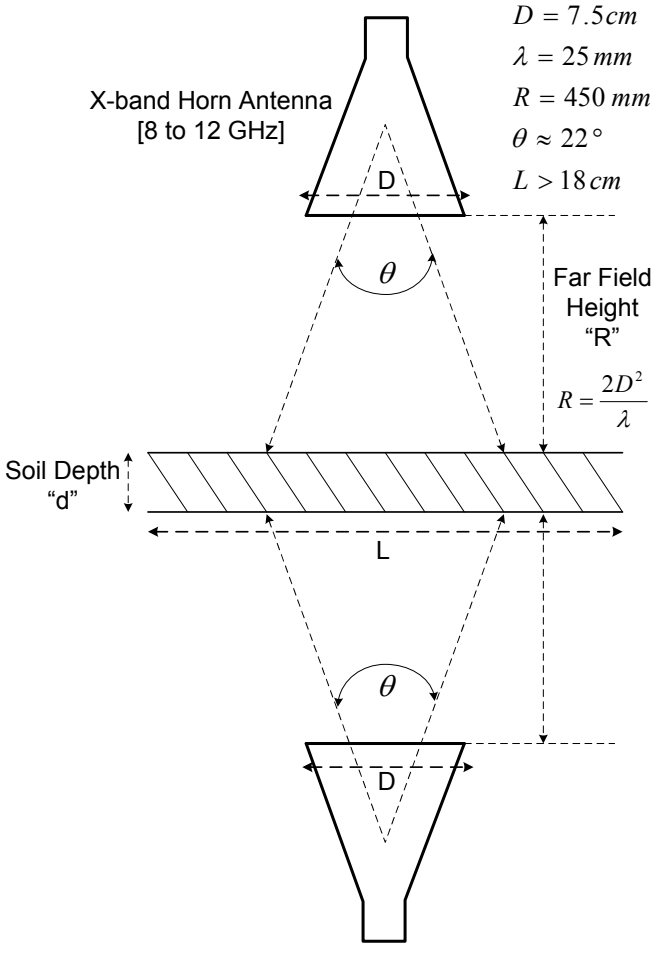
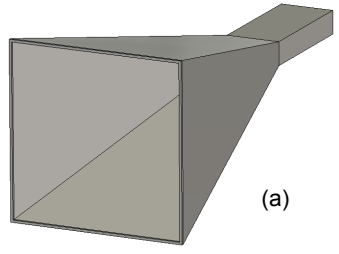
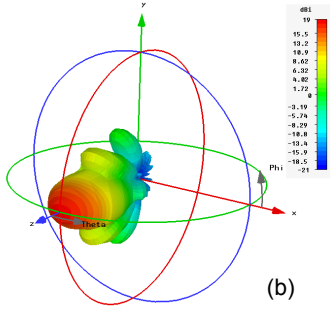
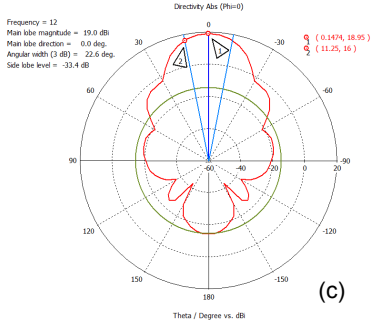


X-Band Horn Antenna: Computational Model







CST Computation: X-band Horn Antennas

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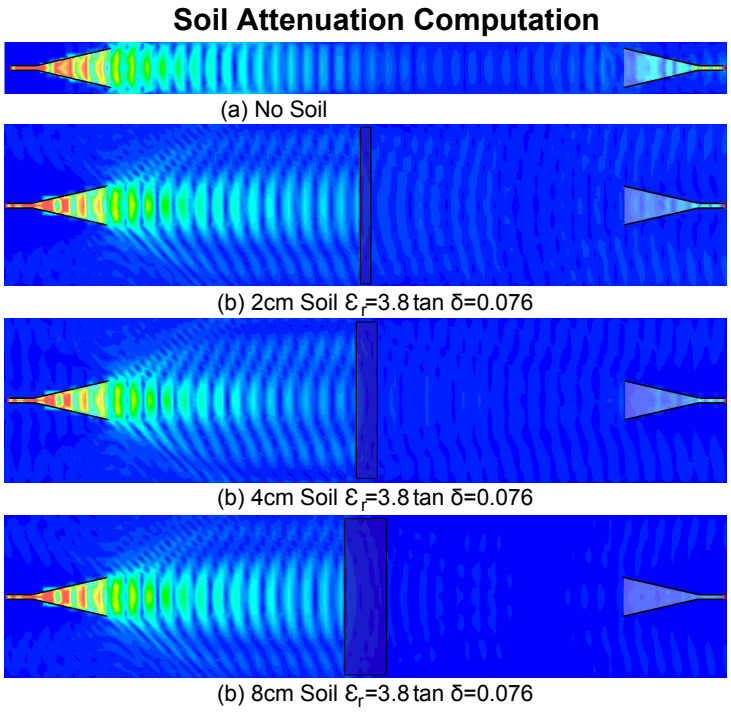

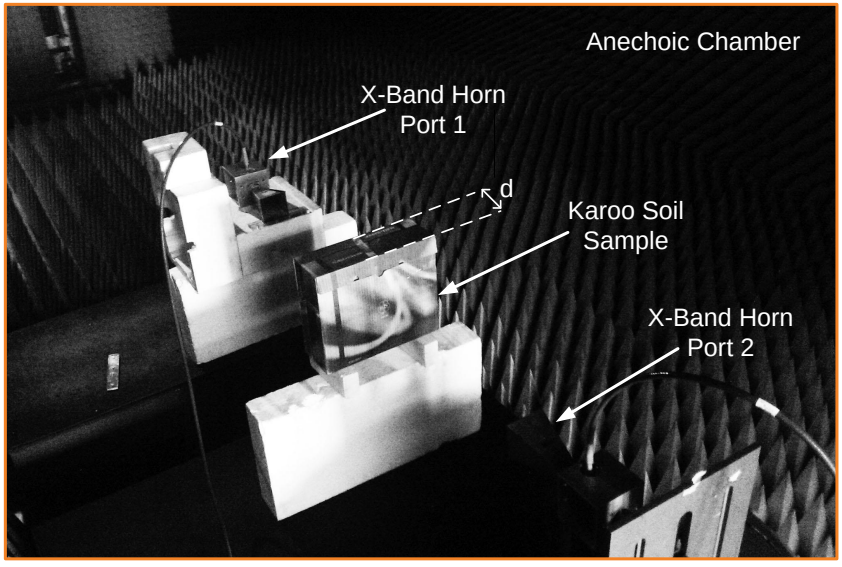

Karoo Measurements

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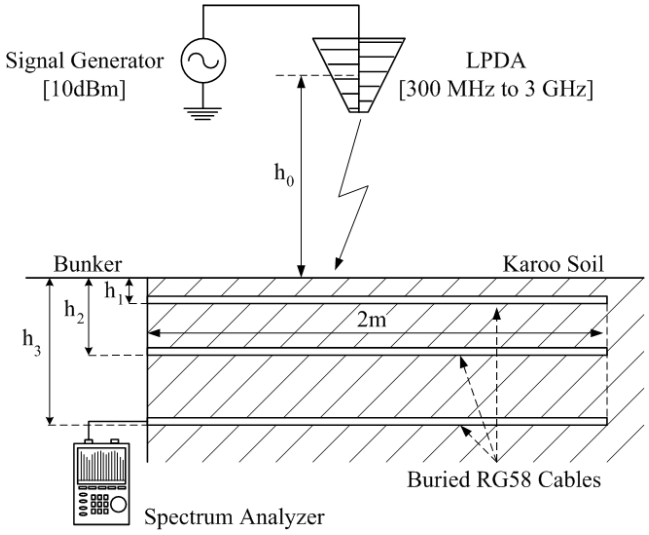

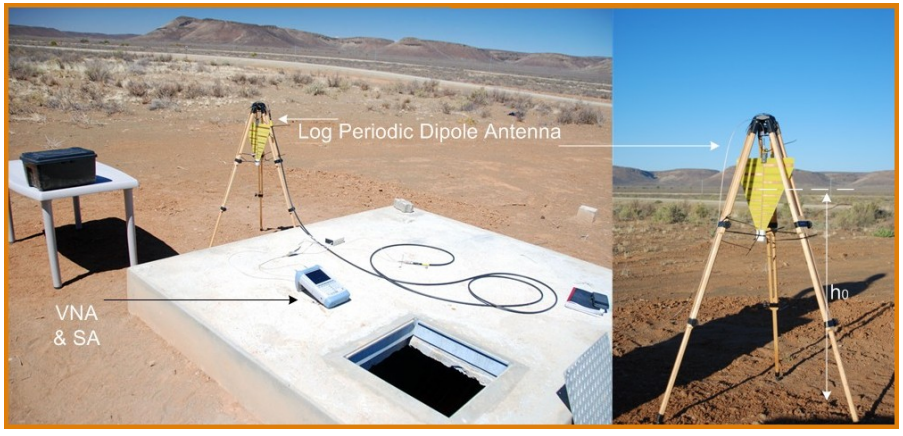

$$\alpha = 8.686 \times \frac{2\pi f}{c} \sqrt{\frac{\epsilon'_S}{2}\left(\sqrt{1+\left(\frac{\epsilon''_S}{\epsilon'_S}\right)^2}-1\right)} \ [\mathrm{dB/m}]$$

Results

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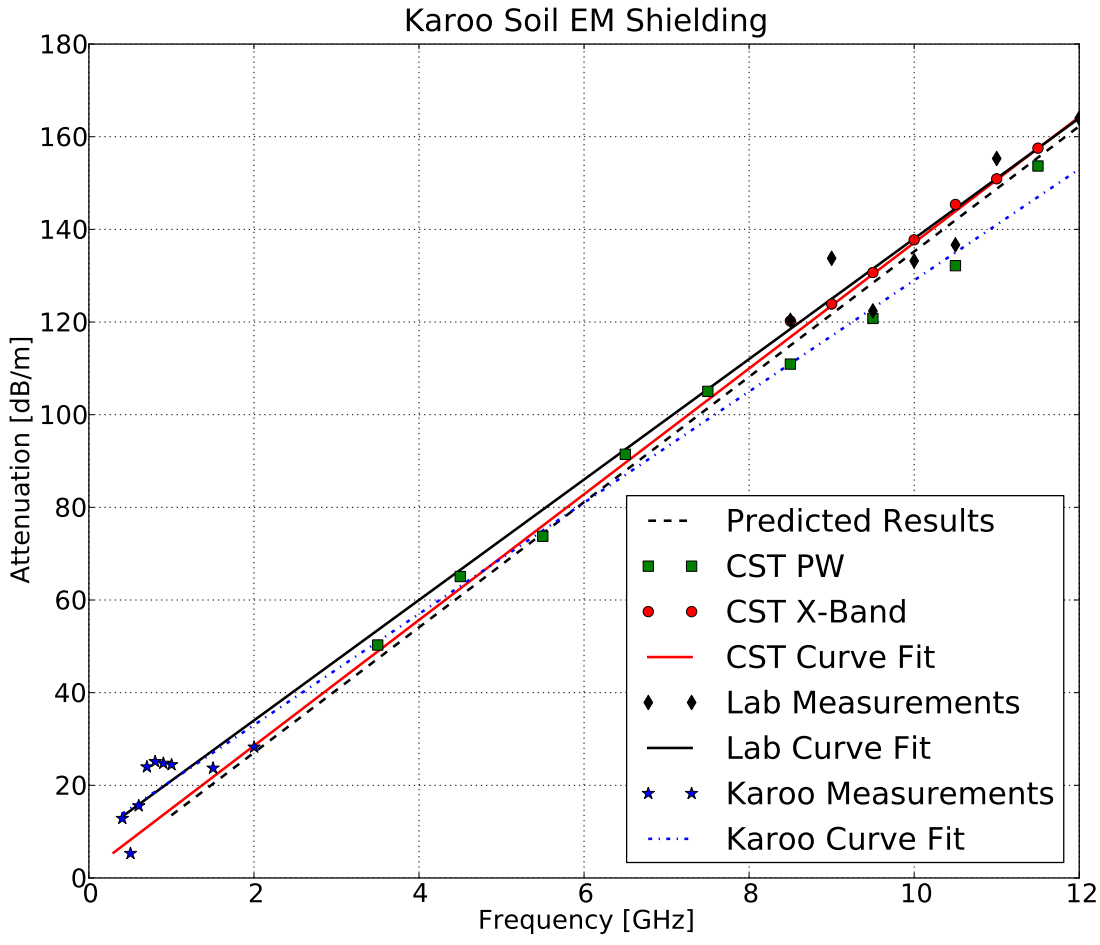

Conclusions

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Conclusions

- Complex permittivity values Karoo soil sample extracted (Waveguides & Baker-Jarvis extraction method)
- Predicted, numerically computed and measured attenuation levels for Karoo soil agree (KAT-7 site & laboratory)
- Study of "Cost" vs. "Attenuation Level" (depth under ground)
- One of several successful RFI mitigation studies by the Stellenbosch University's EMRIN Group

Questions

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Thank you!

Any questions?

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