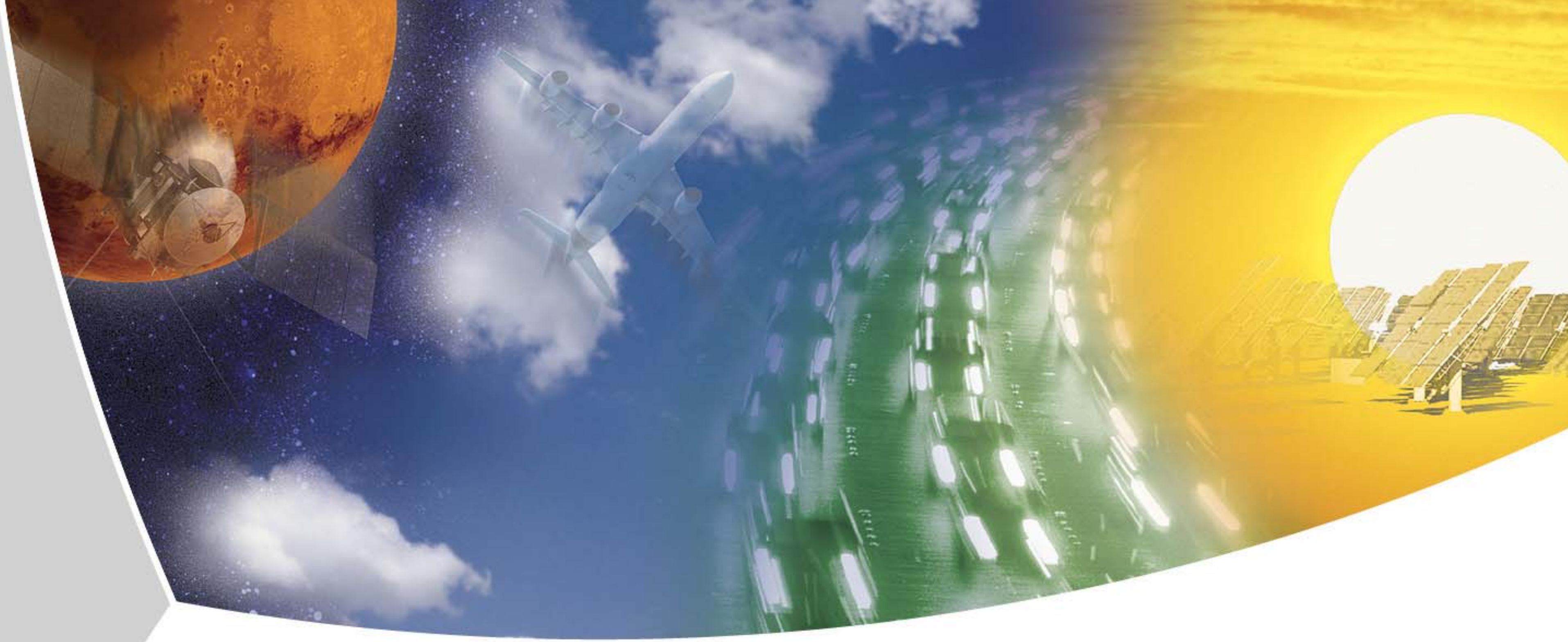


Investigations on the Polarimetric Behavior of a Target near the Soil

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

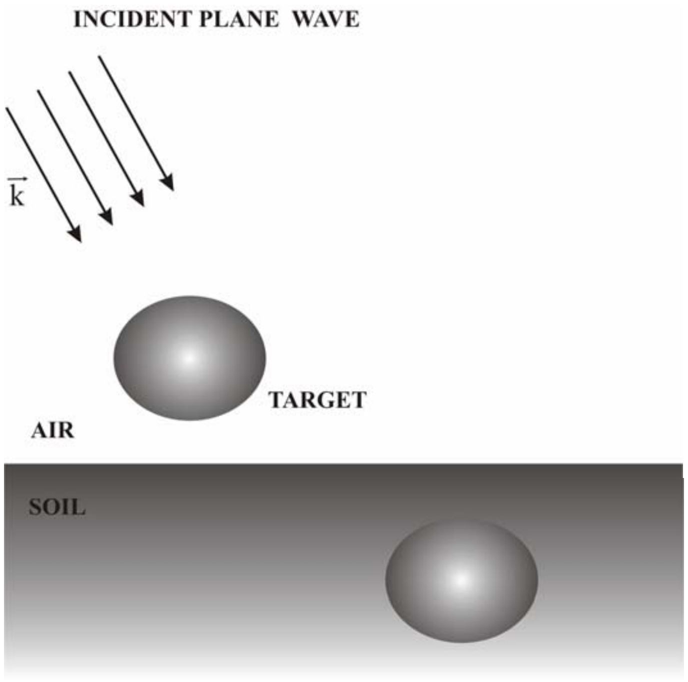
WFMN 2007: 5. July 2007

N. P. Marquart

Contents

- Motivation
- Ray field + Transition zones
- Numerical results + Validation
- Representation on the Poincaré sphere
- Conclusions

Background



- Object situated close to an interface
- An extensive literature exists on this topic

A more refined ray model system according to the ***G***eometrical ***T***heory of ***D***iffraction (GTD)

e.g.:

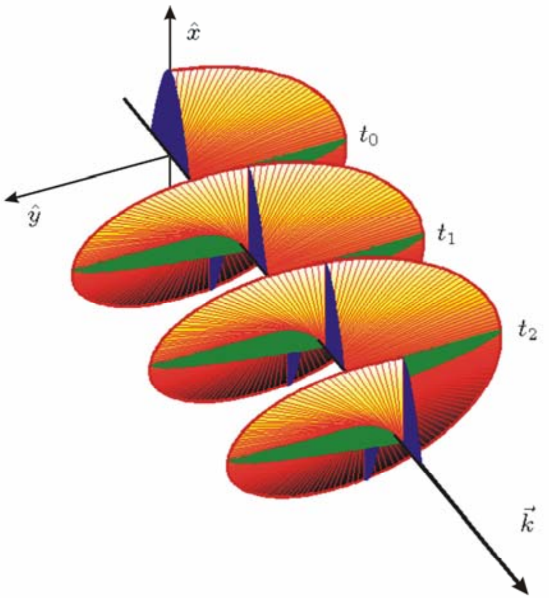
- C. M. Butler and Xu Xiao-Bang and A. Glisson: „*Current induced on a conducting cylinder located near the planar interface between two semi-infinite half-spaces*" , IEEE Transactions on Antennas and Propagation, vol.33, March 1990

- Q. Chen and D. R. Wilton: „ Electromagnetic Scattering by three-dimensional arbitrary complex- conducting bodies", Antennas and Propagation Society International Symposium, vol.2, May 1990

- N. Geng: „ Fast Multipole Method for Scattering from an arbitrary PEC target above or buried in a lossy half space", IEEE Transactions on Antennas and Propagation, vol.49, May 2001

- A. Michalski and D. Zheng: „ Electromagnetic Scattering and Radiation by surfaces of arbitrary shape in layered media, Part I: Theory", IEEE Transactions on Antennas and Propagation, vol. 38, March 1990

Objectives



- Only few publications on the polarimetric behavior

- ***G***eometrical ***O***ptic (GO)
  e.g. single (→ odd) and double bounce (→ even) effects

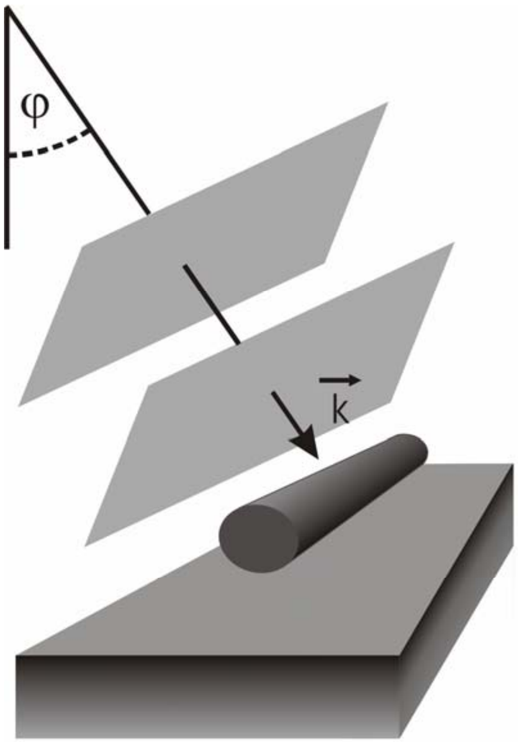
Emphasis on the transition zones
polarimetric behavior in such regions?

Geometrical parameters or geophysical properties?
Look angle (0°-90°)

The Target Model

Monostatic

Transmitter-Receiver Alignment

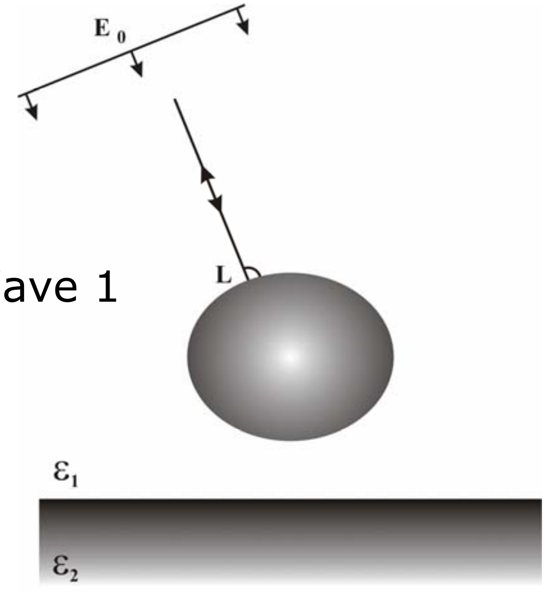


- Object e.g. r >> λ_{inc}
- ***G***eometrical ***T***heory of ***D***iffraction (GTD)
- Localization Phenomenon
- Complex target is replaced by a canonical object
- Sphere or Cylinder

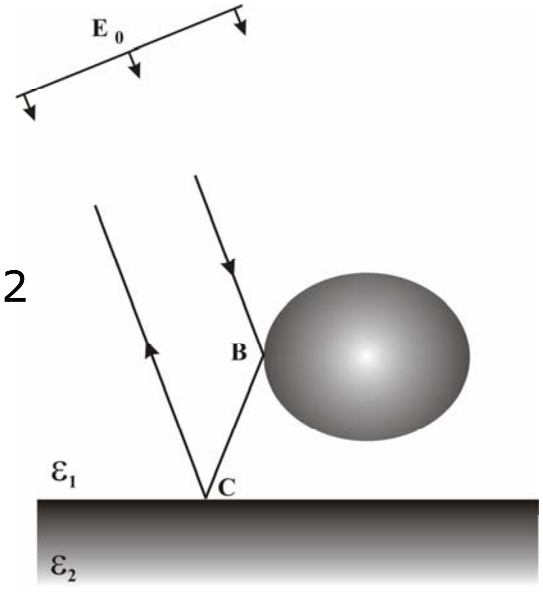
GTD ray system of 13 waves
spatial and creeping waves

Spatial Waves

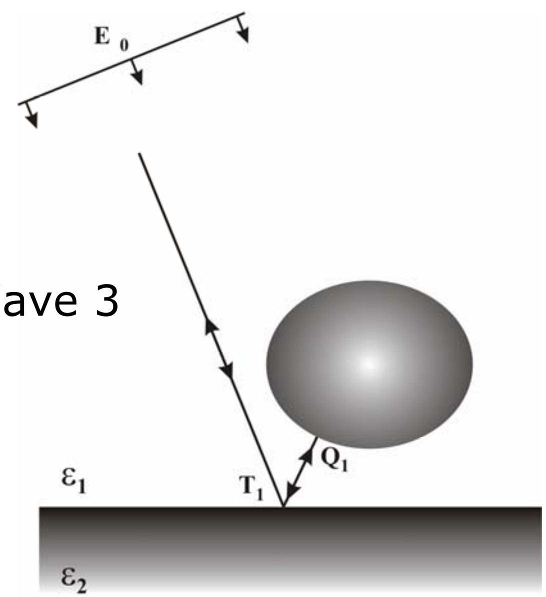
Wave 1



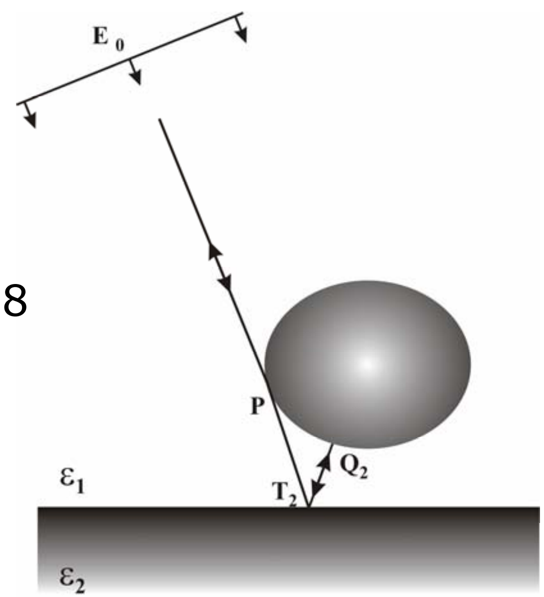
Wave 2



Wave 3

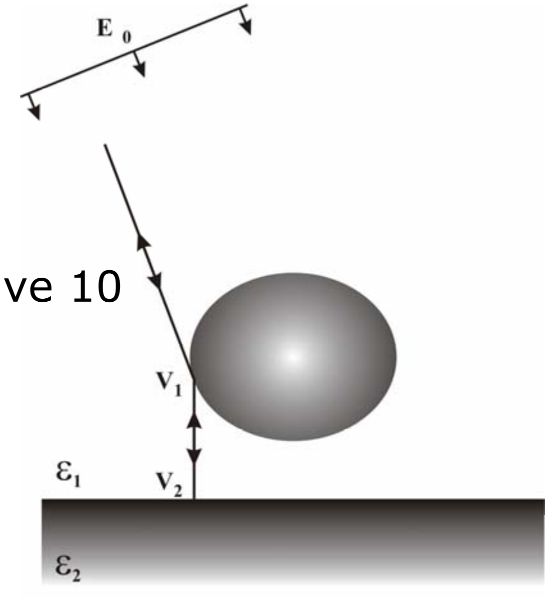


Wave 8

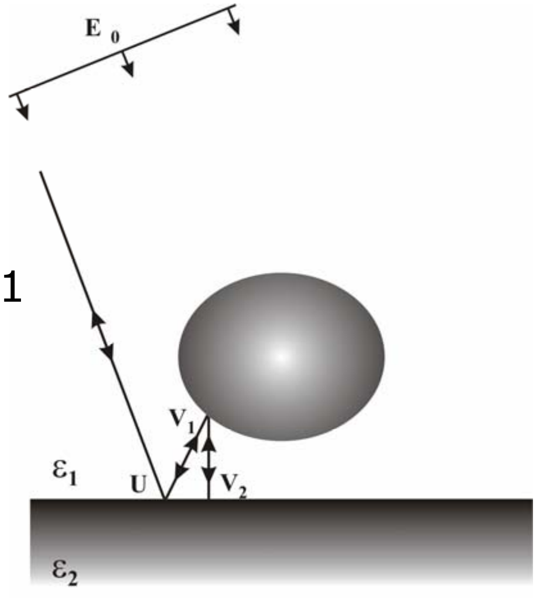


Spatial Waves

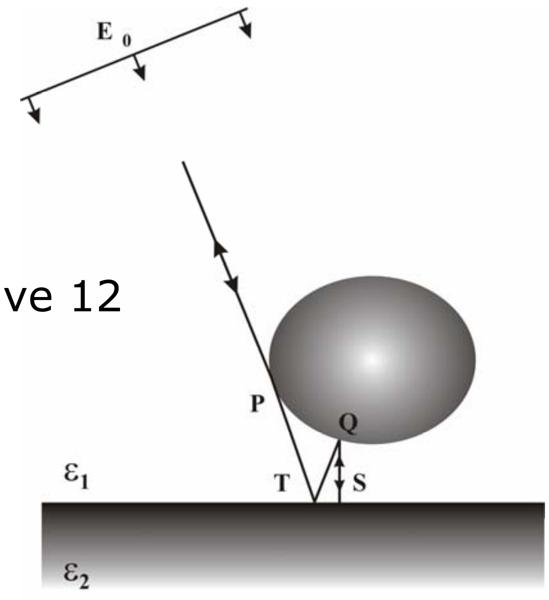
Wave 10



Wave 11

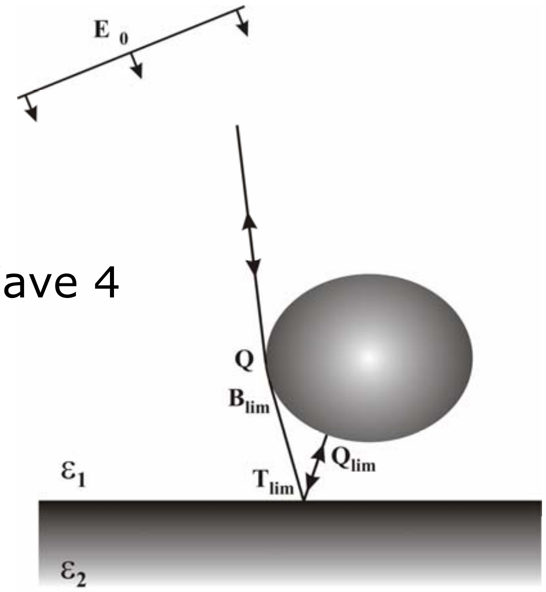


Wave 12

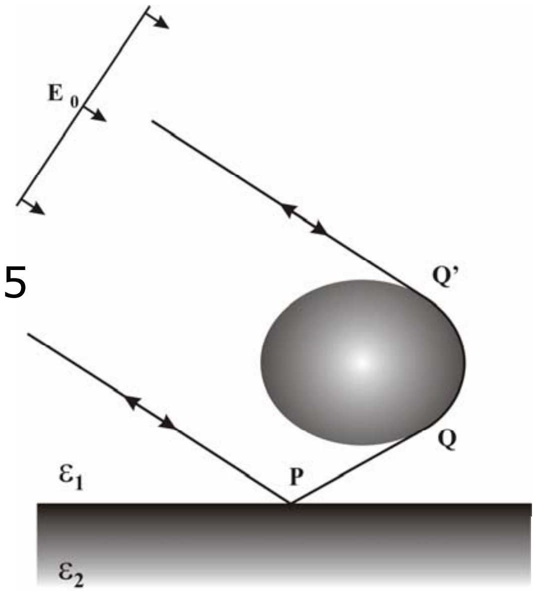


Creeping Waves

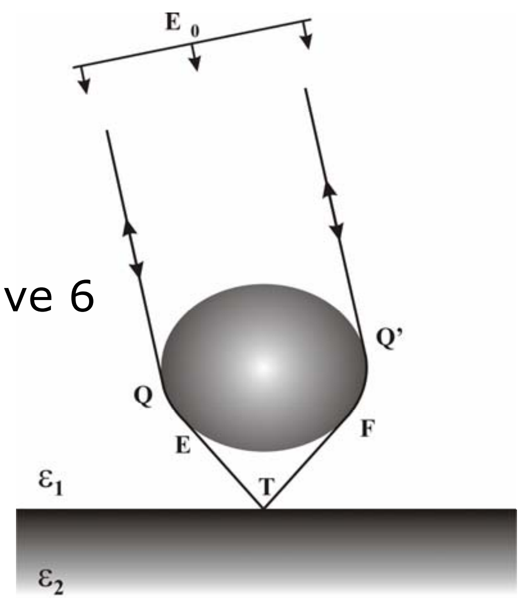
Wave 4



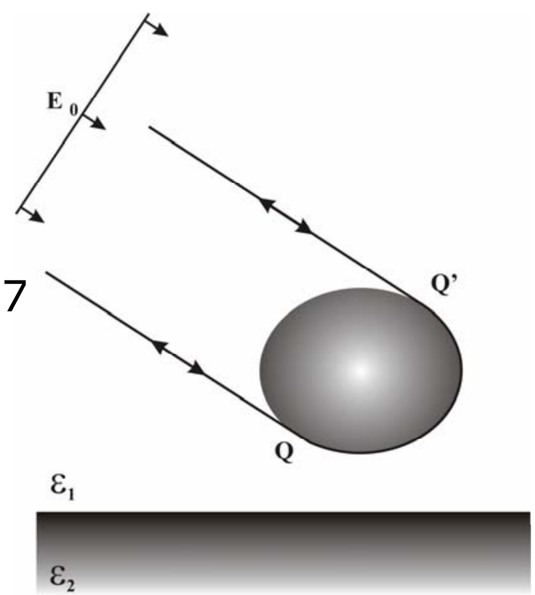
Wave 5



Wave 6

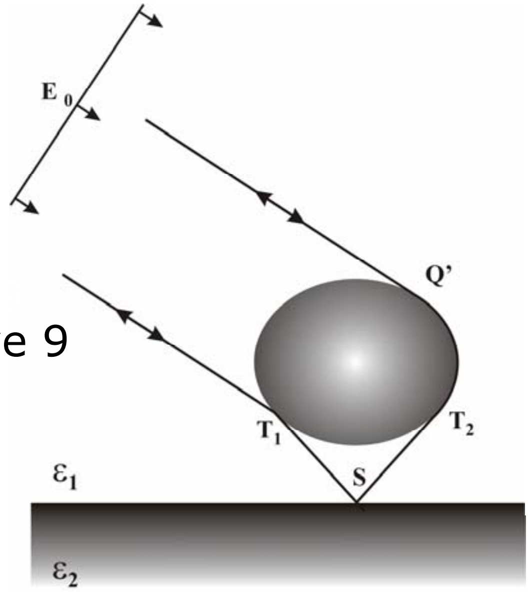


Wave 7

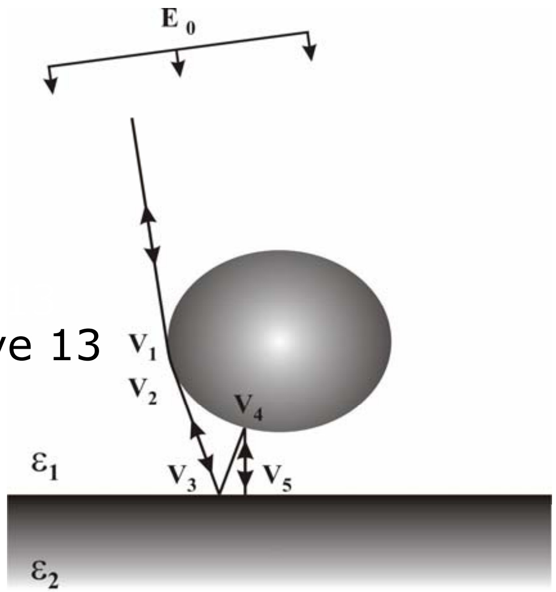


Creeping Waves

Wave 9



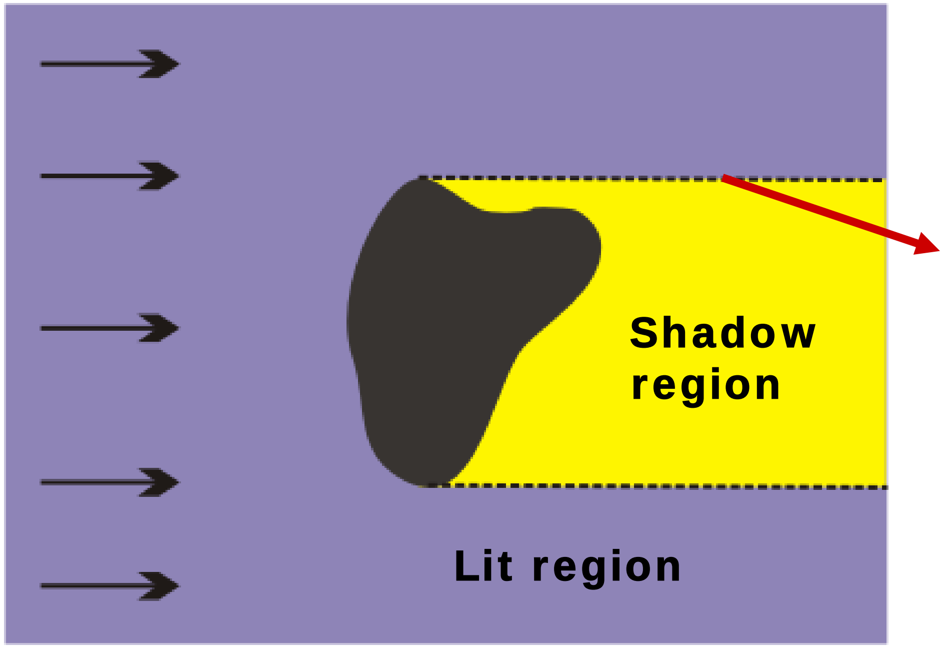
Wave 13



Numerical implementation spatial and creeping Waves for a varying incidence angle

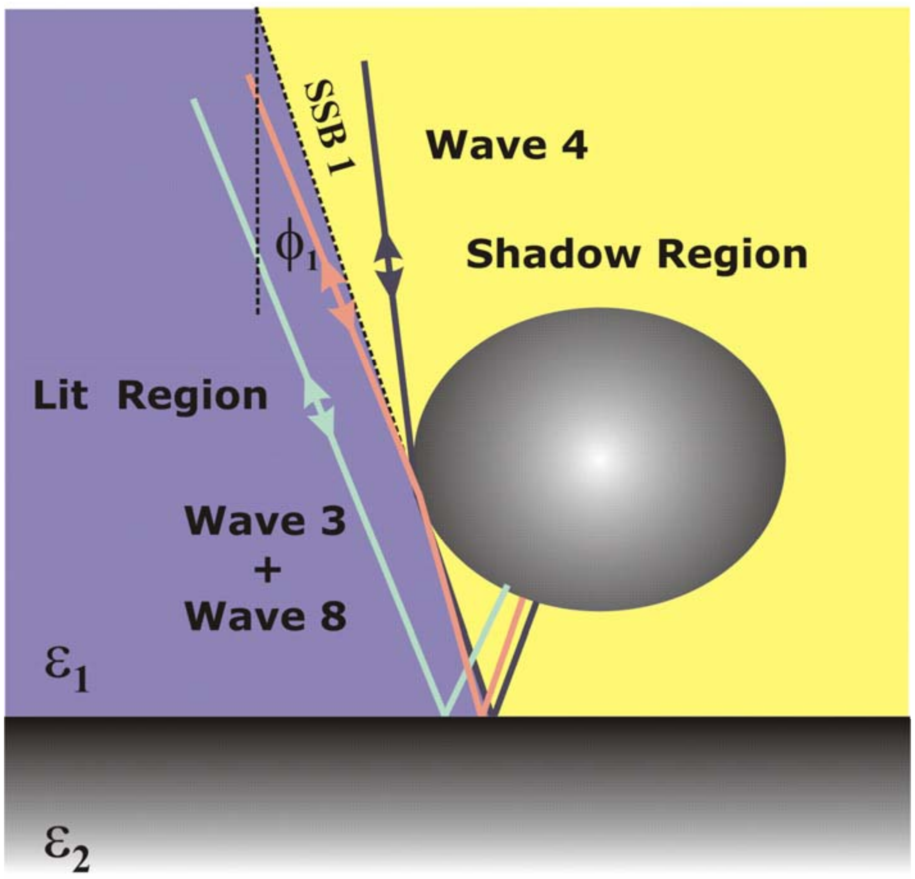
Shadow Boundary

GO ray field

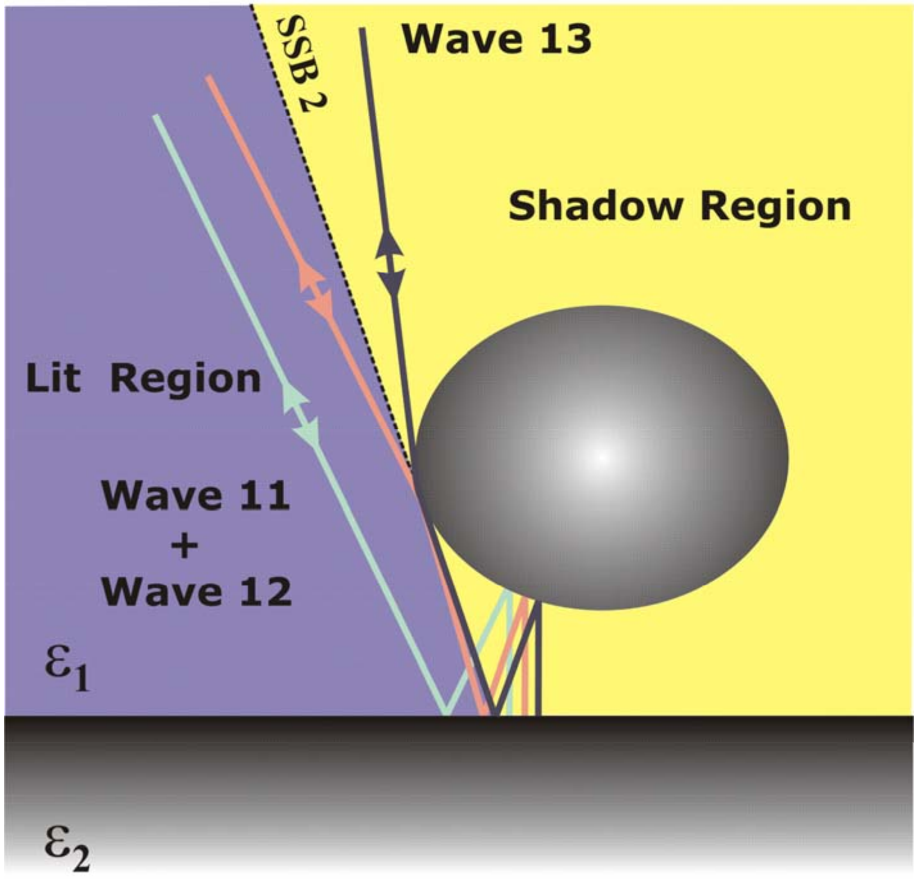


***S**urface **S**hadow*
***B**oundary (SSB)*

Transition Zones 1 and 2

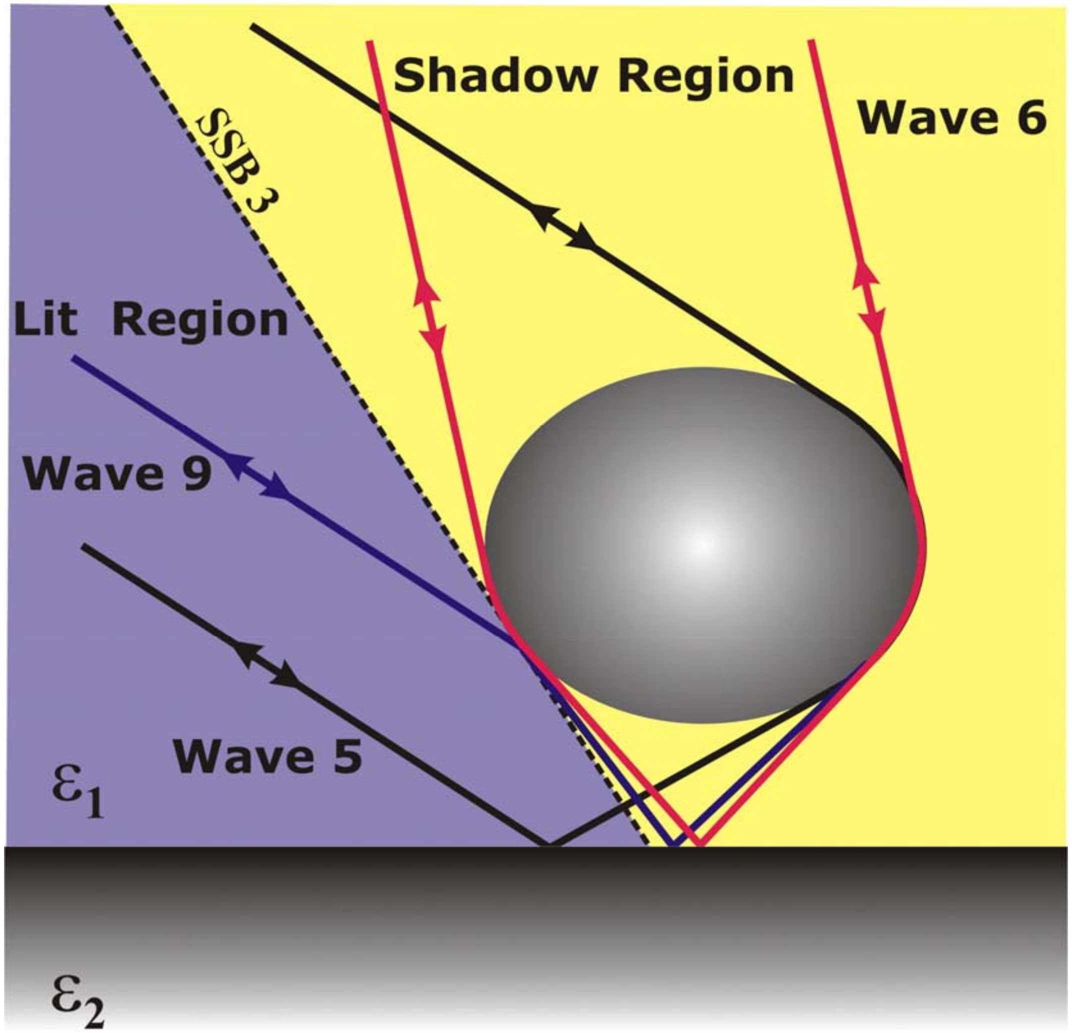


SSB 1



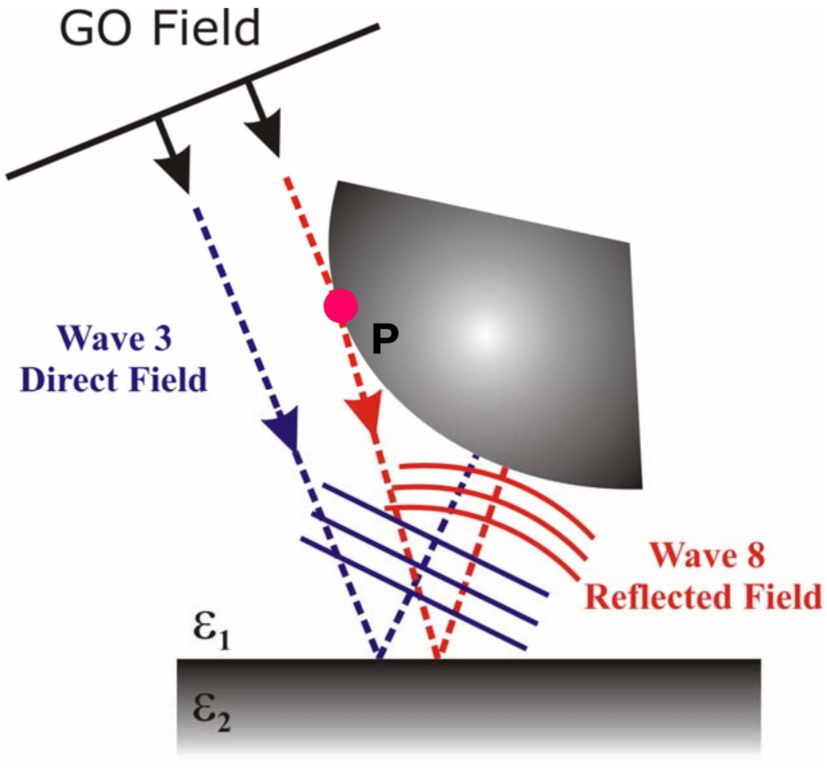
SSB 2

Transition Zones 3

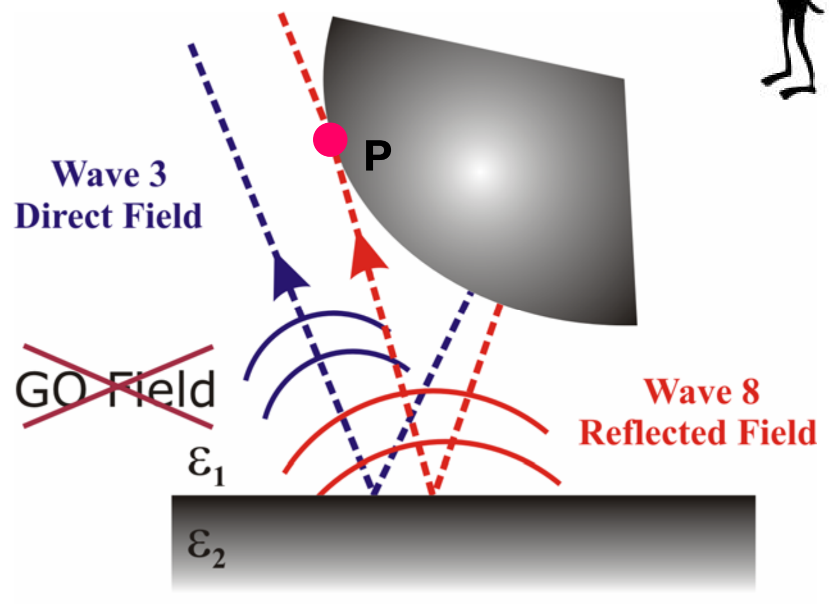


SSB: GTD → ***U***niform ***T***heory of ***D***iffraction (UTD)

UTD → GO type field



"Classical" UTD

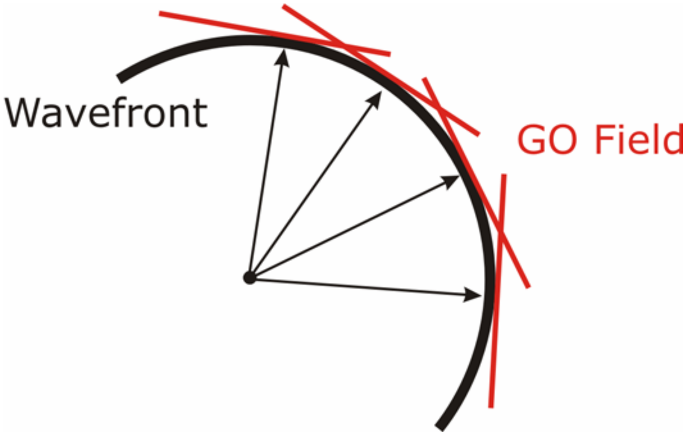


Different radii of curvatures: $\rho_3 \neq \rho_8$

No accuracy according to the UTD

Exact Method

Fourier decomposition



UTD
Applicable for each single component

Time consuming
Computation

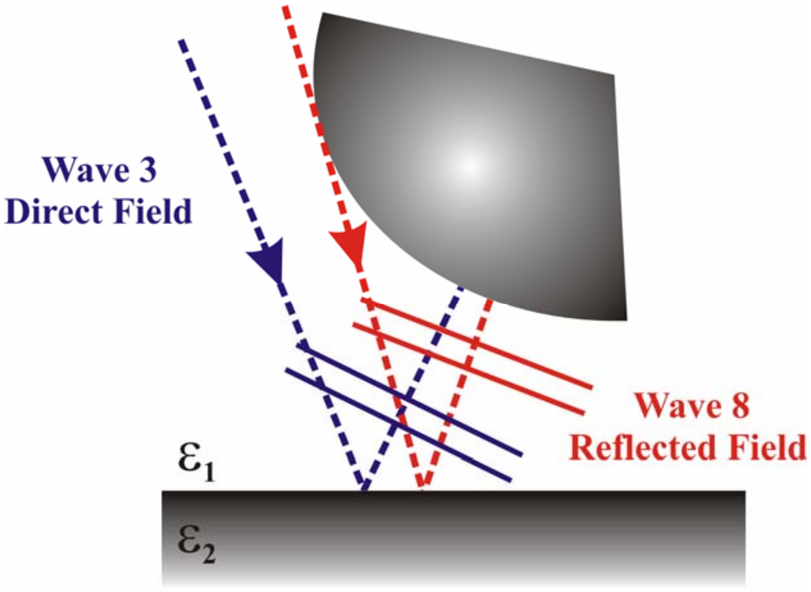
Approached Method

The total field at the shadow boundary must be continuous !

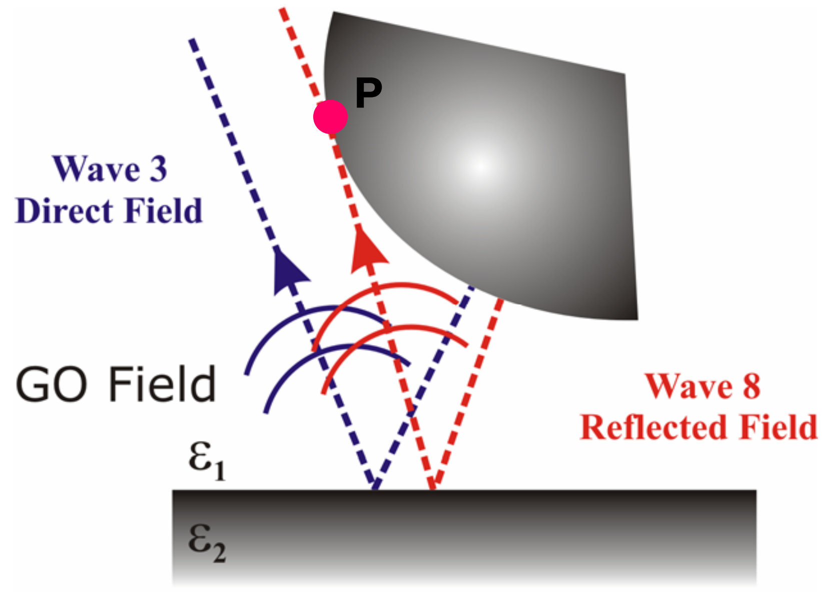
- Locally plane waves at the SSB
- Implies that the two waves are also locally plane!
- Fourier components have a preferential contribution
- Only valid near the shadow boundary

Approached method

Near the SSB 1



Incident plane wave



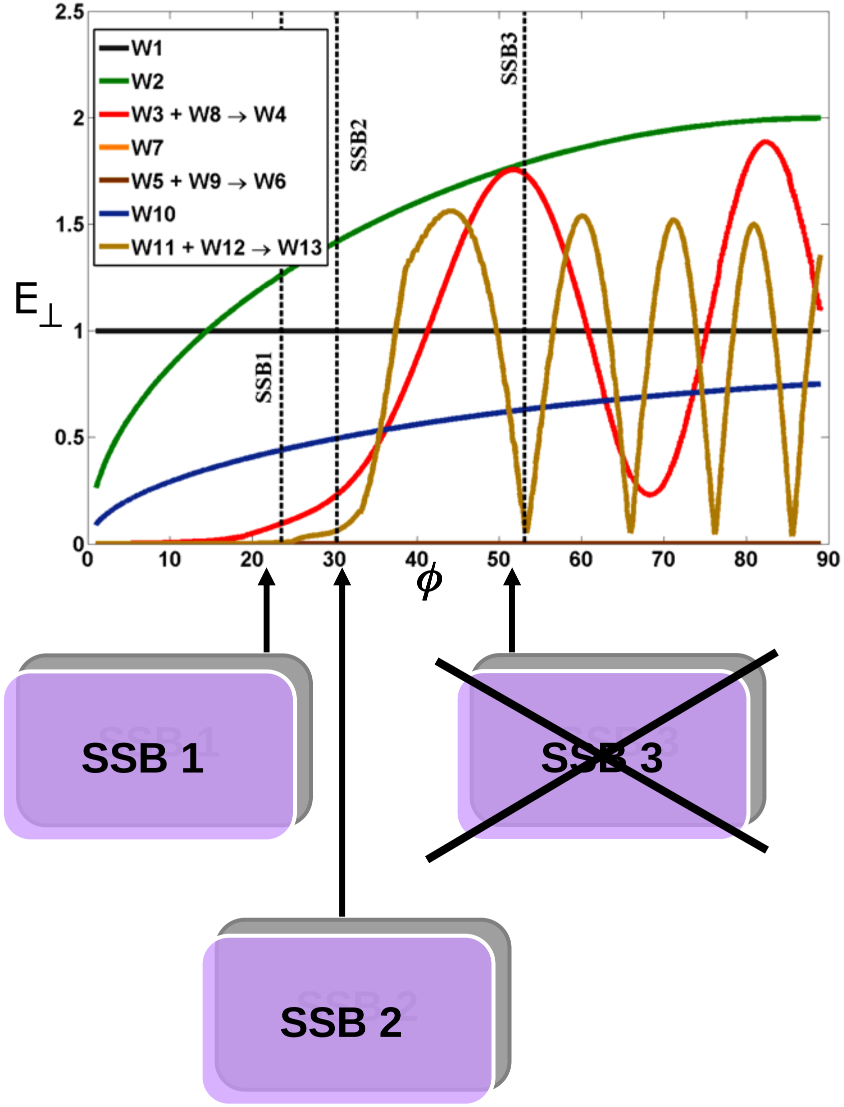
Equal radii of curvatures: $\rho_3 = \rho_8$

UTD valid

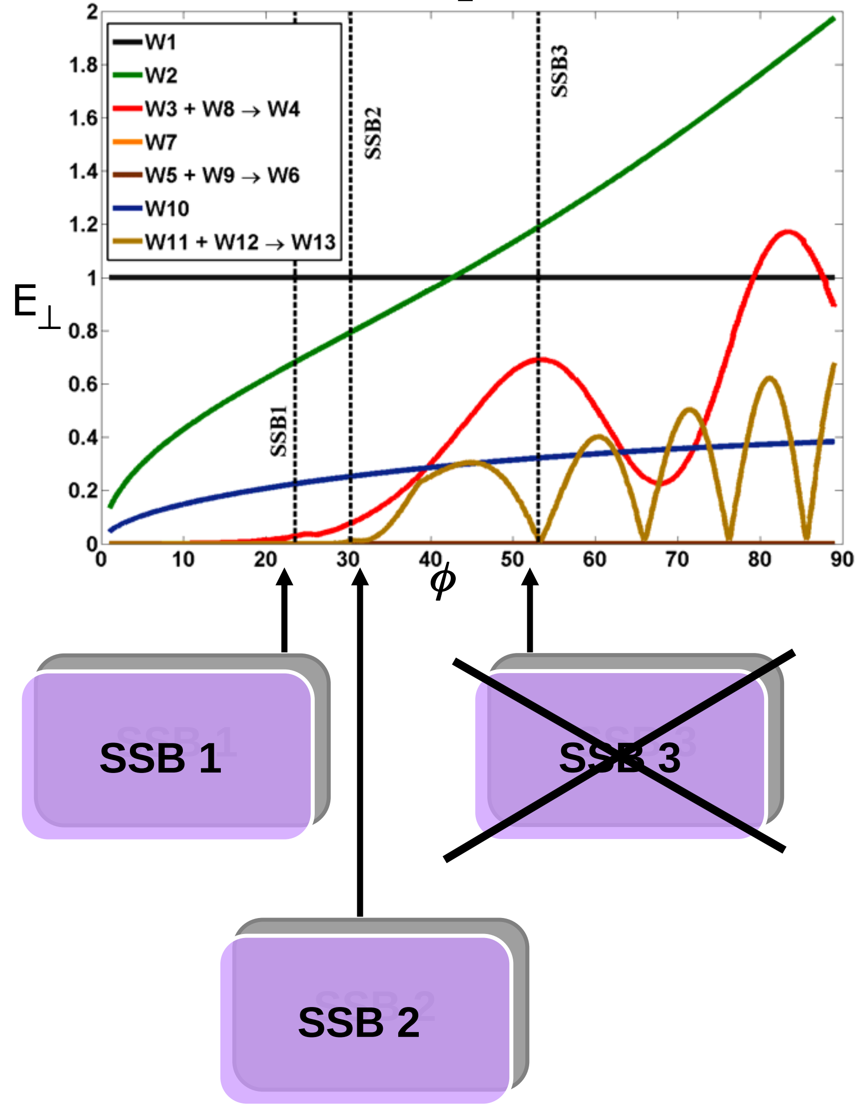
Wave Contributions

[h=0.5m, a=2m & f=500MHz]

Perfect conductor (PC)



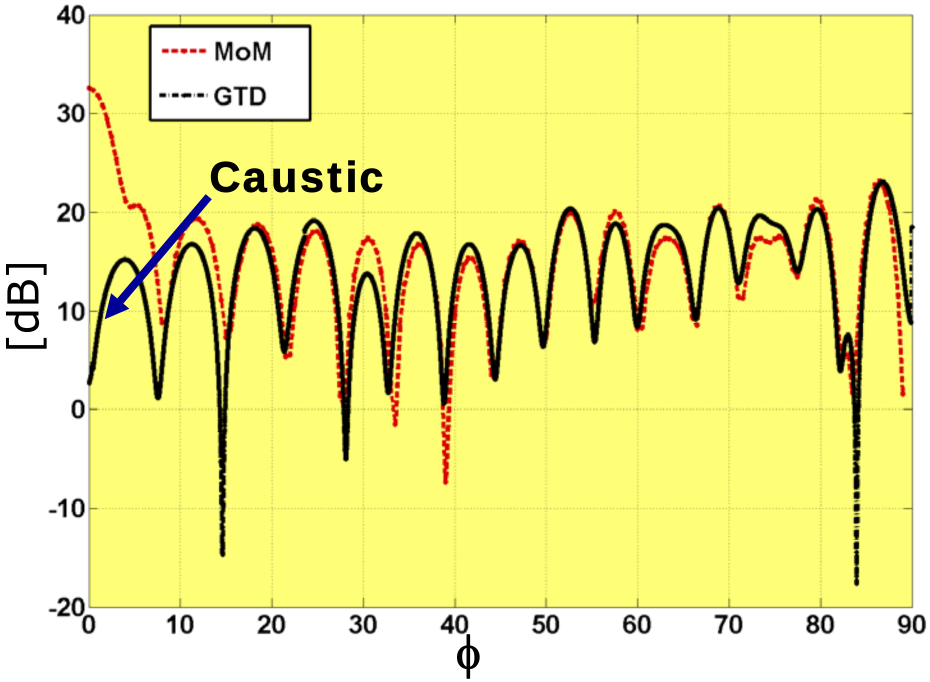
$\mathcal{E}_2 = 9.6$



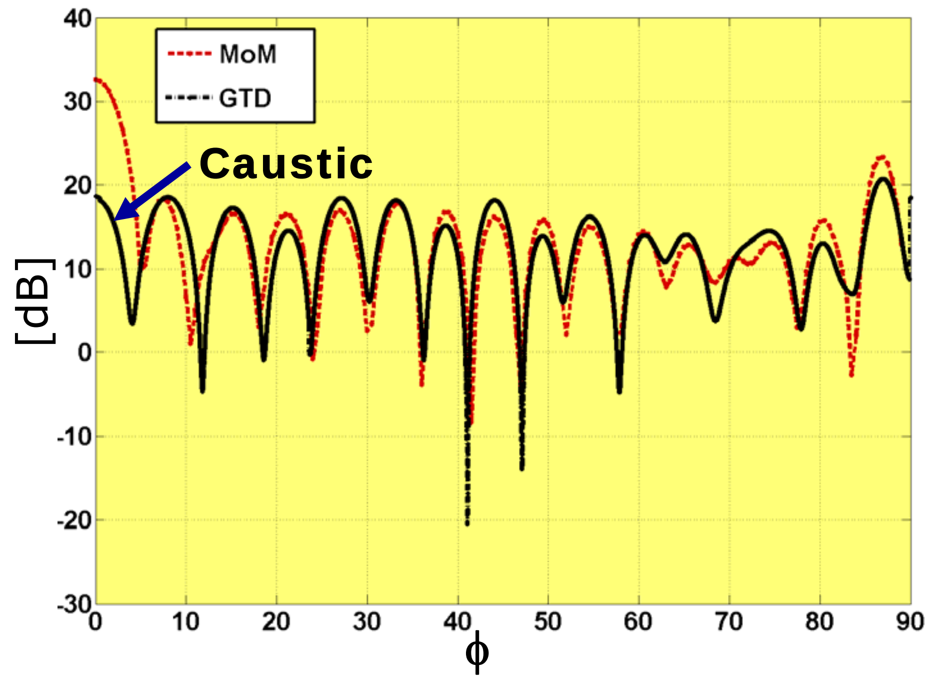
Validation

RCS sphere [a=2.0m, h=0.5m, f=500MHz and ε_2=9.6]

$E_\perp$



$E_{||}$



✓ **Implemented UTD field**

Polarimetry

In general:

$$\vec{E}(z,t) = \begin{cases} E_x = E_{0x} \cos(\omega t - kz - \delta_x) \\ E_y = E_{0y} \cos(\omega t - kz - \delta_y) \\ E_z = 0 \end{cases}$$

Rewritten as:

$$\vec{E}(z,t) = \Re\left(\underline{E} e^{j(\omega t - kz)} \right)$$

Phasor → Jones vector

$$\underline{E} = \begin{bmatrix} E_x = E_{ox} e^{j\delta_x} \\ E_y = E_{oy} e^{j\delta_y} \end{bmatrix}$$

Stokes vector

$$\underline{g}_{\underline{E}} = \begin{bmatrix} g_0 = |E_x|^2 + |E_y|^2 \\ g_1 = |E_x|^2 - |E_y|^2 \\ g_2 = 2\Re(E_x E_y^*) \\ g_3 = -2\Im(E_x E_y^*) \end{bmatrix}$$

WAVE POLARISATION STATE ESTIMATION FROM INTENSITIES MEASUREMENTS

Stokes Vector

$\{g_0\}$ TOTAL WAVE INTENSITY

$\{g_1, g_2, g_3\}$ POLARISED WAVE INTENSITIES

↓

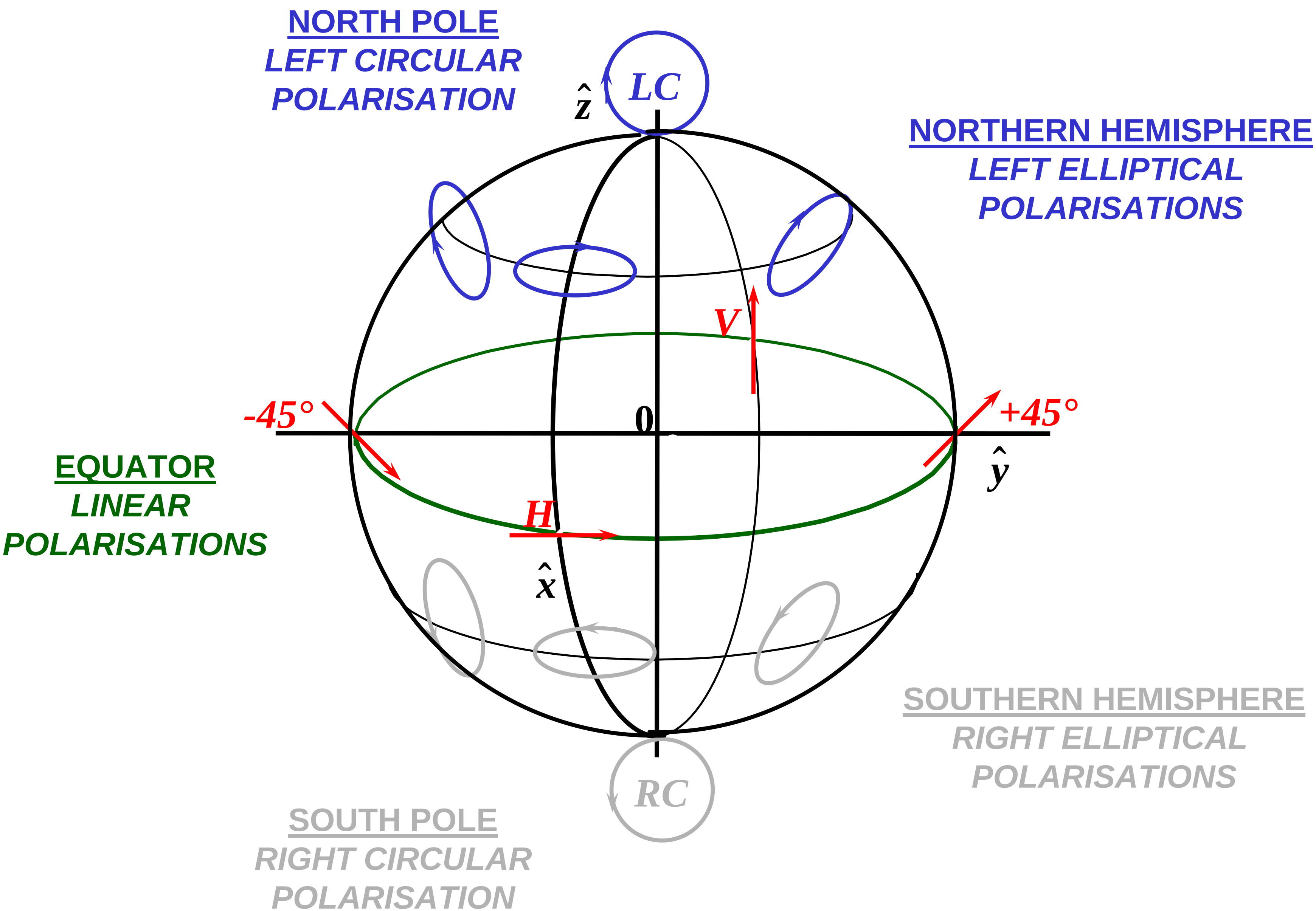
$$g_0^2 = g_1^2 + g_2^2 + g_3^2$$ WAVE FULLY POLARISED

$\{g_1, g_2, g_3\}$ Spherical Coordinates of a point P on a sphere with radius g_0

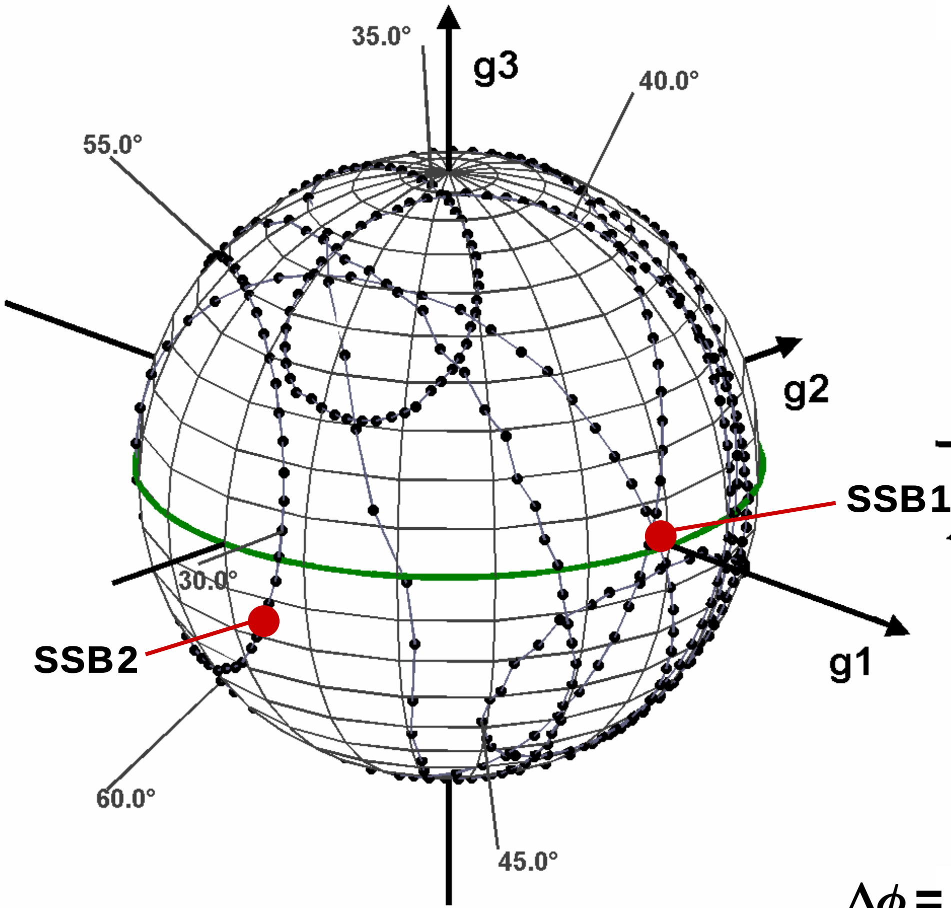
↓

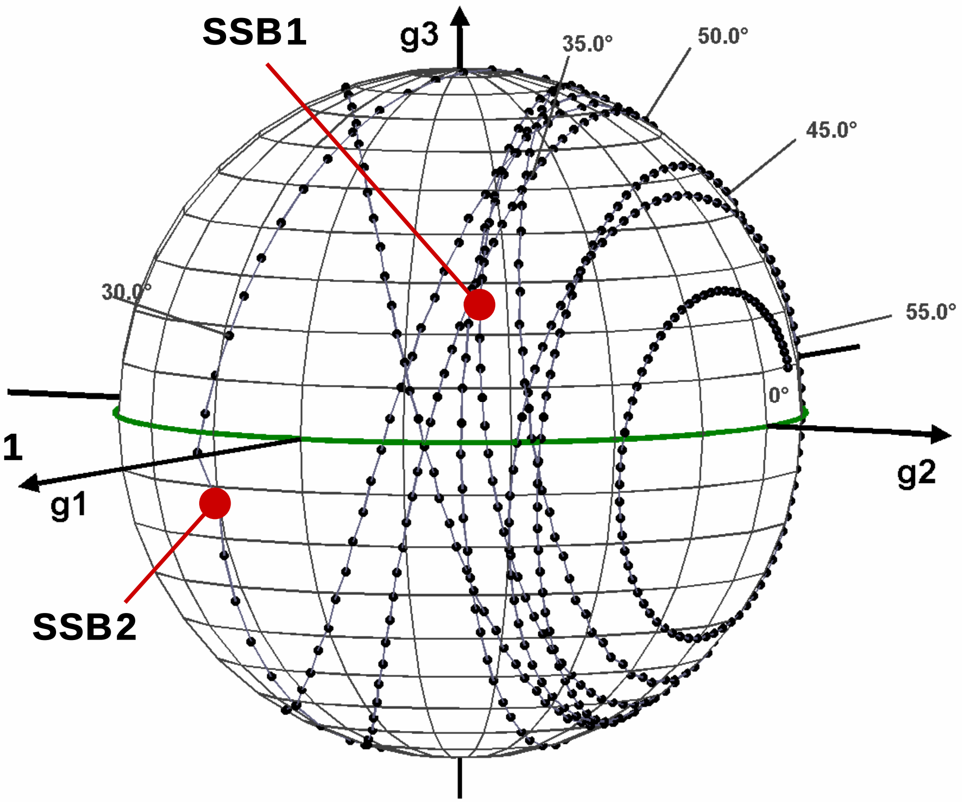
Poincaré Sphere

Poincaré Sphere



Poincaré Sphere





$\Delta\phi = 0.1°$

Linear polarized incident field ε_2=PC

Linear polarized incident field ε_2=9.6

Conclusions

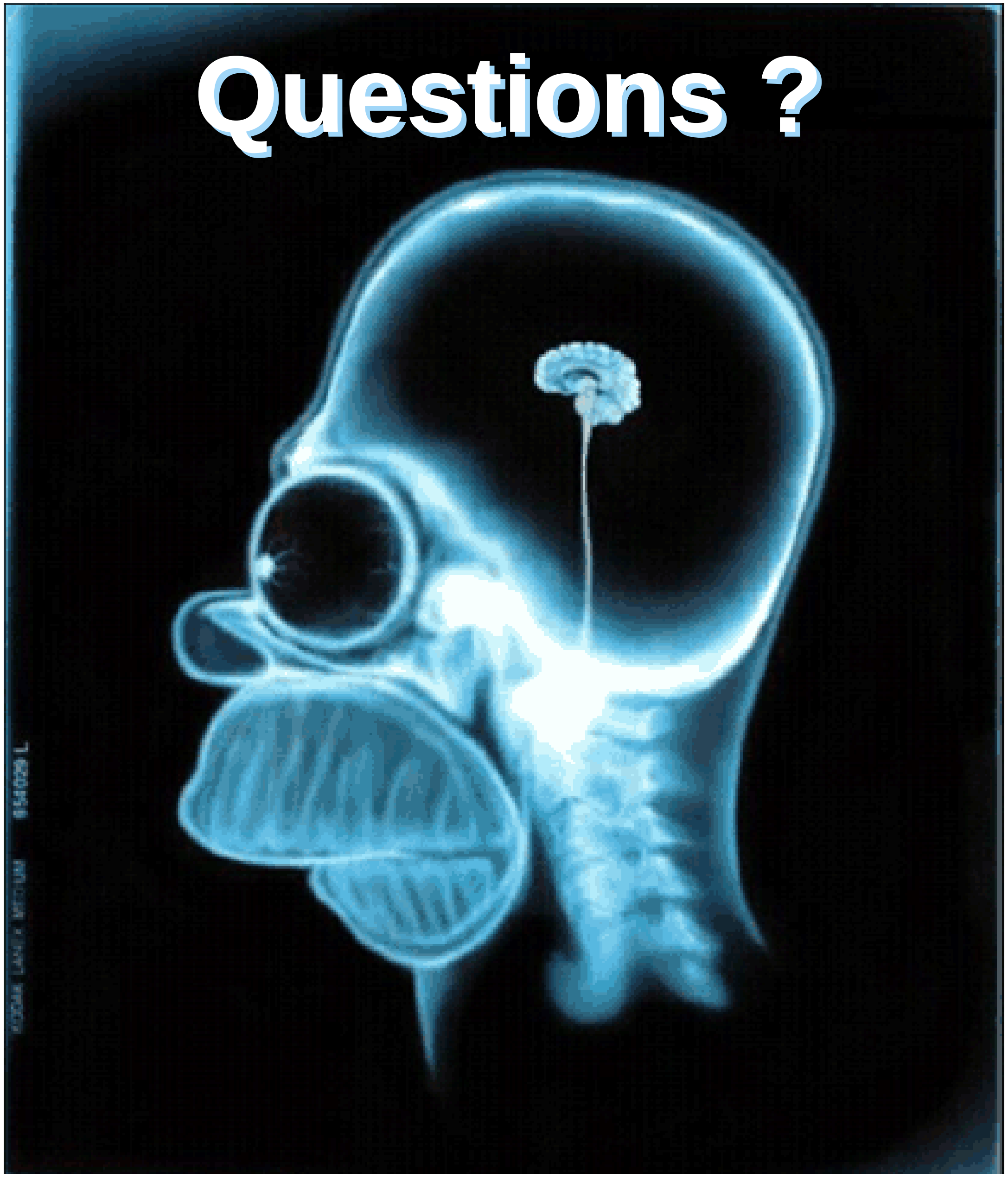
- ✓ GTD Ray system of 13 waves
- ✓ Special emphasis on the Transition Zones
- ✓ The UTD Approached Method
- ✓ Agreement with the MoM
- ✓ Slight depolarization close to the SSB
- ✓ Significant locations on the Poincaré sphere

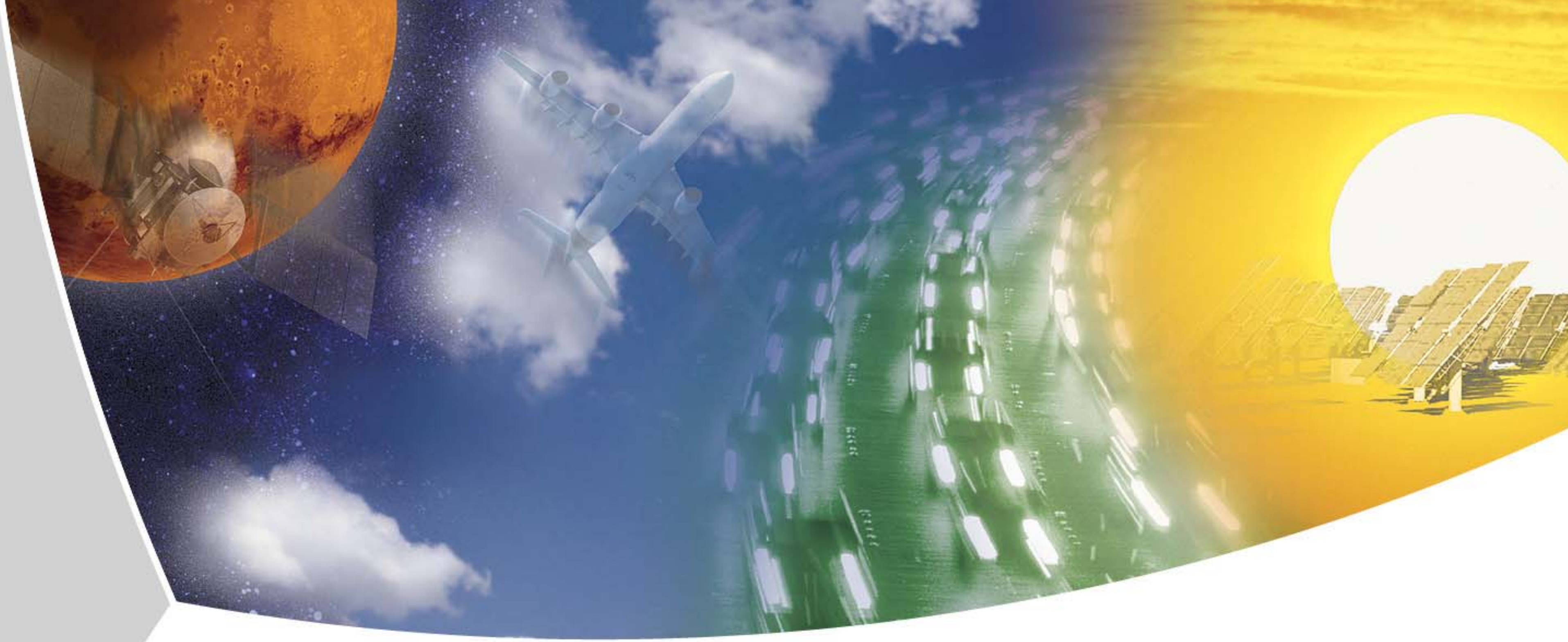
Close to transition zones the backscattered field is barely depolarized

→ Geometrical parameters

➢ N. P. Marquart, F. Molinet and E. Pottier:
„Investigations on the Polarimetric Behavior of a Target Near the Soil" ,
IEEE Transactions on Geoscience and Remote Sensing, vol.44, no. 10, 2899-2907, 2006.
DOI: 10.1109/TGRS.2006.877288

➢ N. P. Marquart, J. Fortuny and F. Molinet:
„Experimental Anechoic Chamber Measurements of a Target Near an Interface",
Progress In Electromagnetics Research, PIER 61, 143-158, 2006.
DOI:10.2528/PIER.06031003


Questions ?



Investigations on the Polarimetric Behavior of a Target near the Soil

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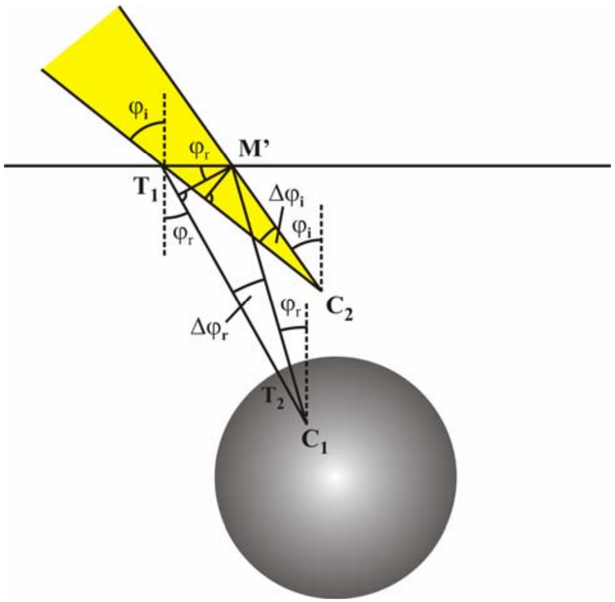
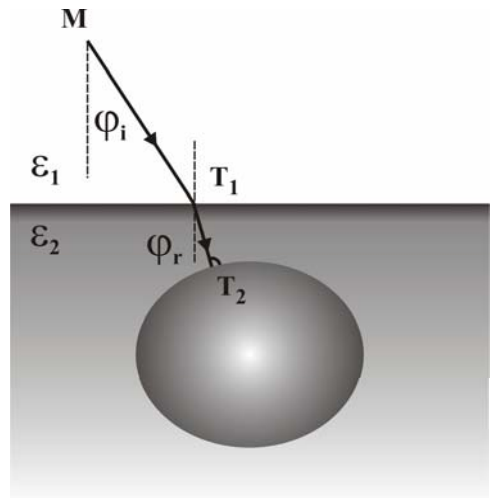
in der Helmholtz-Gemeinschaft

WFMN 2007: 5. July 2007

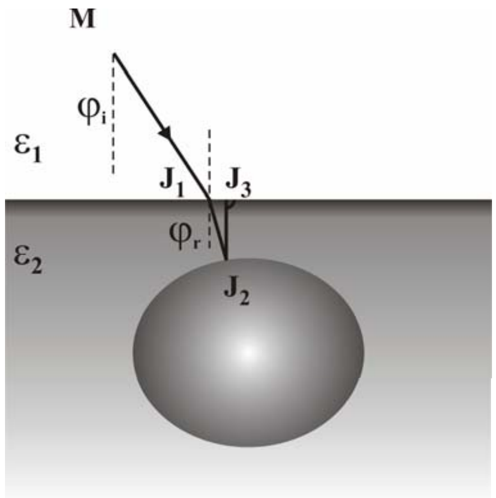
N. P. Marquart

Next step was …



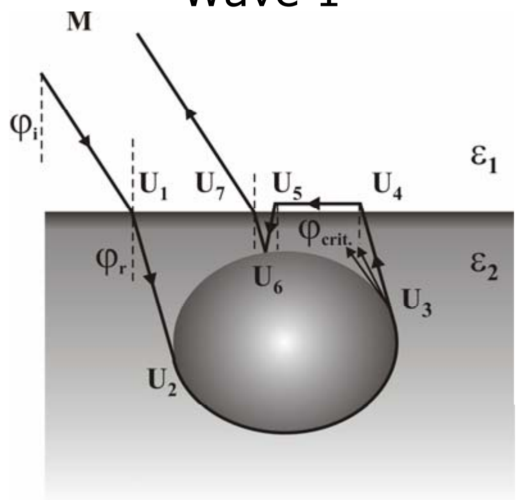


Wave 1

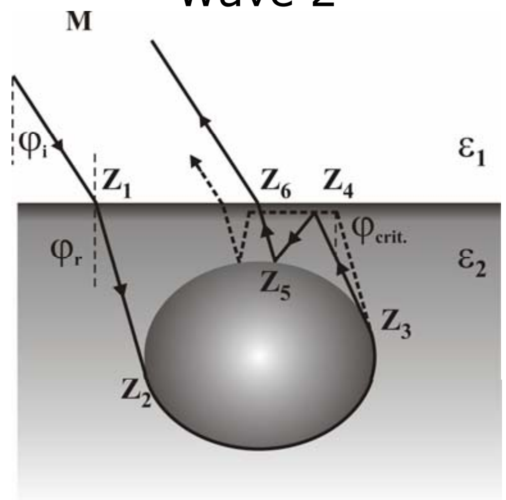


Wave 2

$$\mathcal{D}(n,\varphi) = \frac{1}{n}\left[\frac{\cos^2\varphi_i}{\cos^2\varphi_r}\right]$$



Wave 3



Wave 4

- **N. P. Marquart, F. Molinet and E. Pottier:**
  „A Refined GTD Ray System for an Embedded Object and its Polarimetric Behavior" **,**
  submitted IEEE Transactions on Geoscience and Remote Sensing