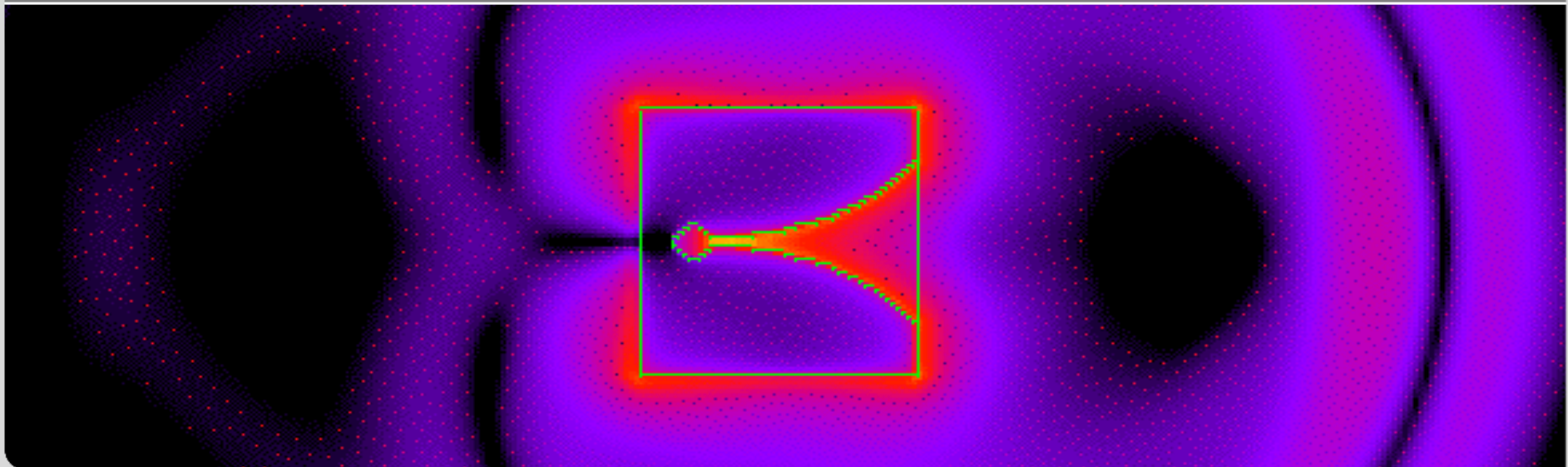


WattGuard – a high accurate, easy to use software for 3D calculation of the exposition of amateur radio stations

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Prof. Dr.-Ing. Dr. h.c. Dr.-Ing. E.h. mult. Werner Wiesbeck

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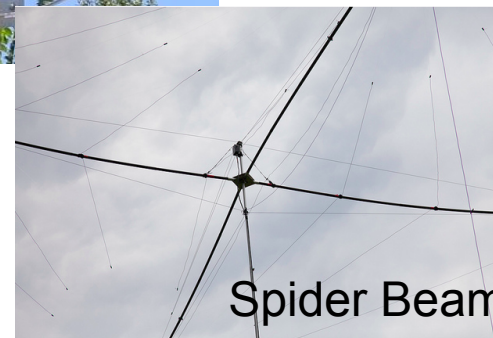
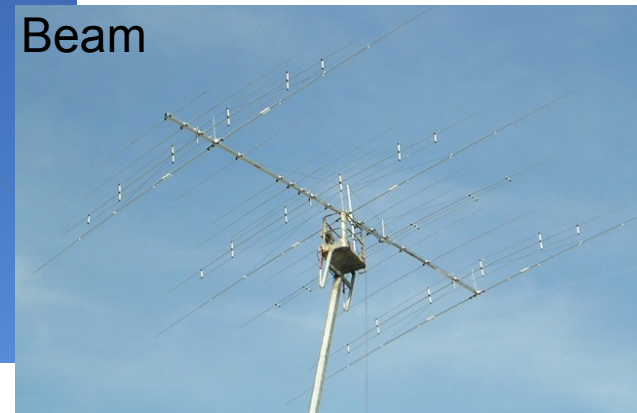
Amateur Radio in Germany and World Wide

- Approx. 80 000 radio amateurs in Germany, approx. 2.8 millions worldwide
- Hobby and communication in emergency cases
- License necessary
- Frequency from 135 kHz to 250 GHz
Transmit power up to 750 W PEP

Important Frequency Bands

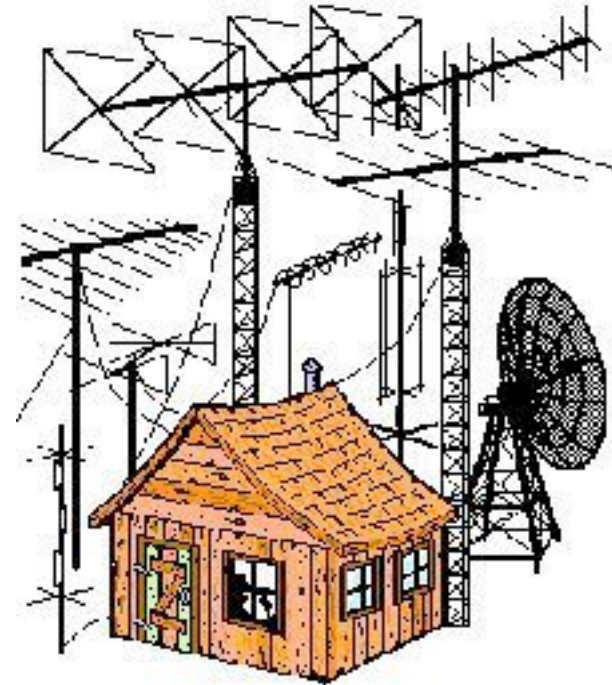
frequency in MHz	wavelength in m
1.81 – 1.85	160
3.5 – 3.8	80
7.1 – 7.2	40
14 – 14.35	20
18.068 – 18.168	17
21 – 21.45	15
24.89 – 24.99	12
28 – 29.7	10
50.08 – 51	6
144 – 146	2

Typical Amateur Radio Antennas



Problem and Solution

- Stationary amateur radio station must be safe
- It has to be assured that the EM exposition is not exceeding the limits for the public areas
- Nearfield and farfield data has to be taken into account as well as ground reflections
- Calculation should be possible for almost all antenna configurations

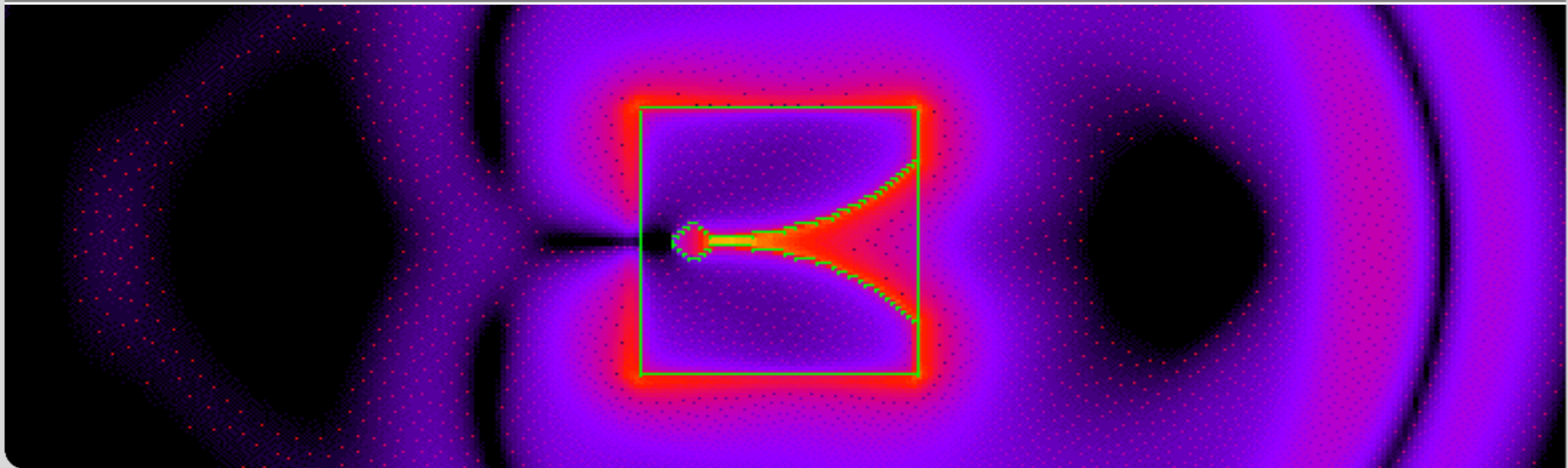


Software for the calculation of safety distances

- easy to use, fast and accurate
- provides nearfield calculations, ground reflections, superposition of several stations

Basics for EM Field Calculations

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Elementary Radiator: Fields of the Hertzian Dipol

E-Feld

$$\vec{E}_r = -I\Delta z \frac{\mu}{4\pi} \frac{e^{-j\beta r}}{r} j\omega \left(\frac{2j}{\beta r} + \frac{2}{(\beta r)^2} \right) \cos\theta$$

$$\vec{E}_\theta = I\Delta z \frac{\mu}{4\pi} \frac{e^{-j\beta r}}{r} j\omega \left(1 - \frac{j}{\beta r} - \frac{2}{(\beta r)^2} \right) \sin\theta$$

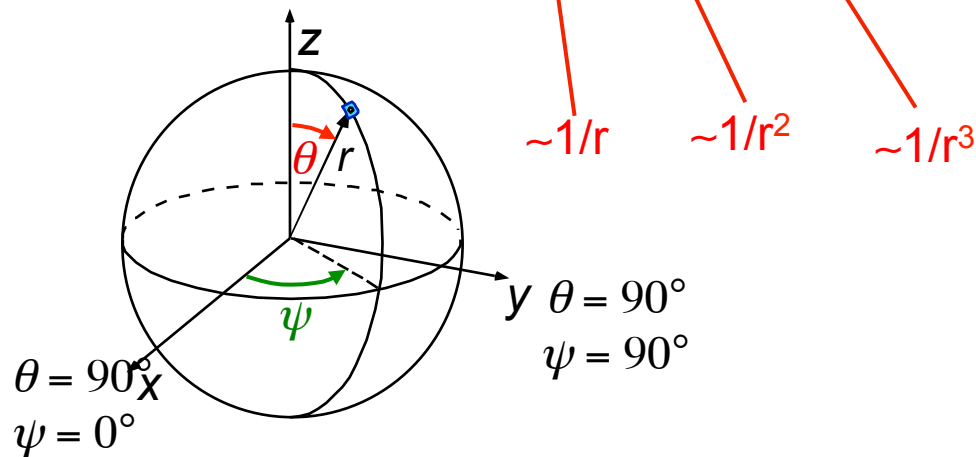
$$\vec{E}_\psi = 0$$

H-Feld

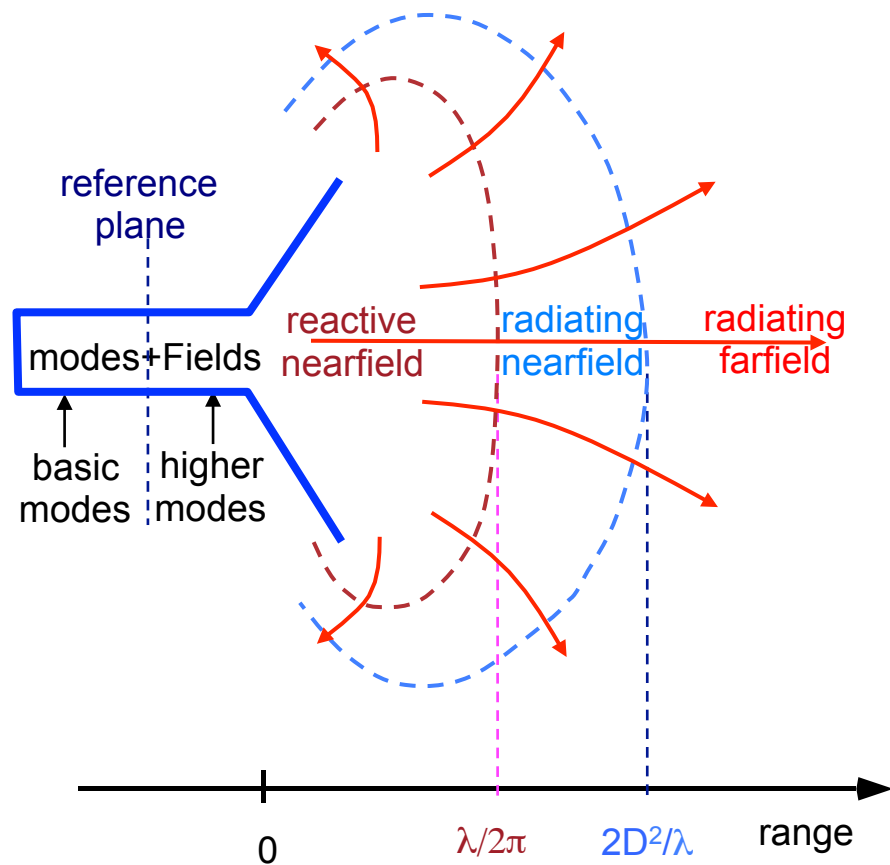
$$\vec{H}_r = 0$$

$$\vec{H}_\theta = 0$$

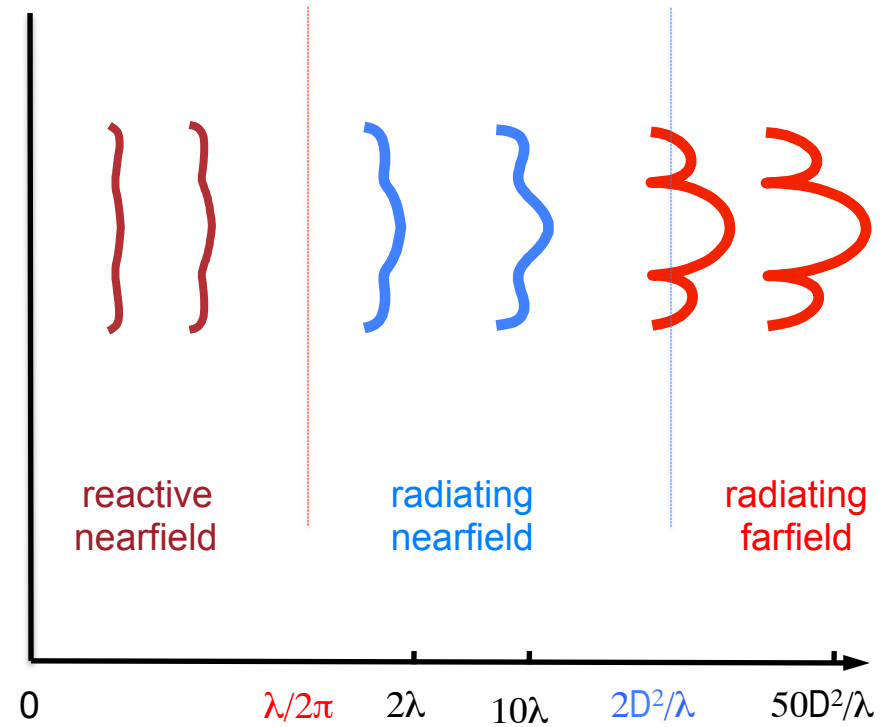
$$\vec{H}_\psi = I\Delta z \frac{1}{4\pi} \frac{e^{-j\beta r}}{r} j\beta \left(1 - \frac{j}{\beta r} \right) \sin\theta$$



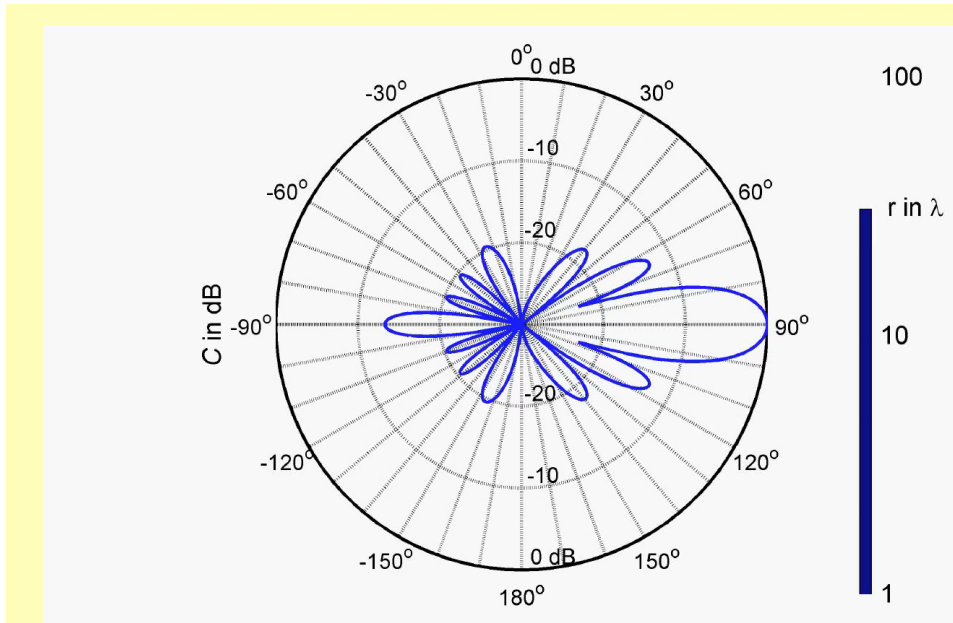
Antenna Near Field to Far Field Transition



Radiation characteristic



Transition Near Field – Far Field Fitting $C_{\text{fit}}(r, \theta, \psi)$



- Antenna pattern depends on distance

- Separate fitting für near field and far field

$C(\theta, \psi)$ Far field

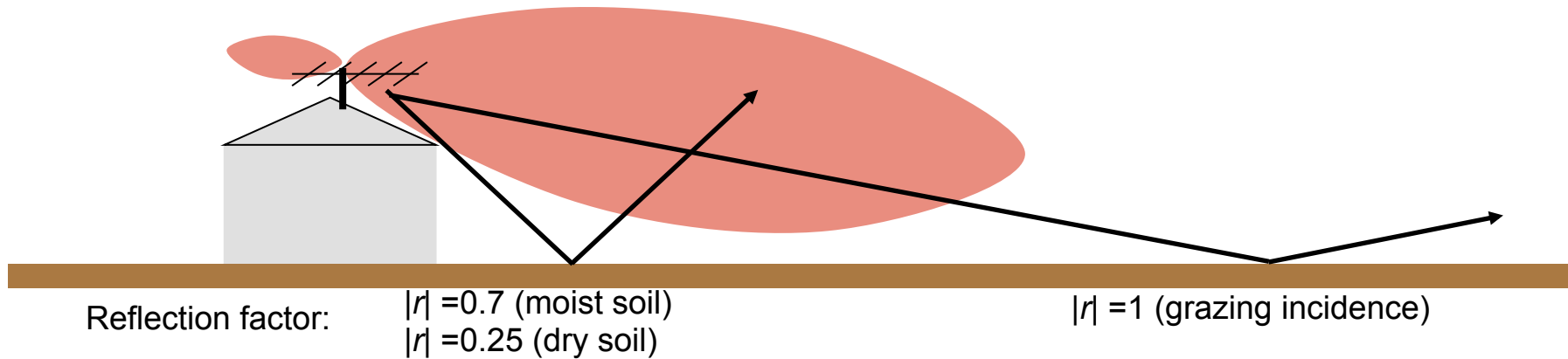
$C_E(r, \theta, \psi)$
 $C_H(r, \theta, \psi)$ } Near field

$C_{\text{fit}}(r, \theta, \psi)$ describes angle dependency of far field und near fields

with numerical available data C_{fit} can be calculated directly

- else: approximation by similar antennas
- approximation of near field pattern by far field in certain distances
- in close vicinity isotropic approximation (worst-case)

Determination of the Reflected Field



subsurface	permittivity ϵ
dry soil	2 ... 10
moist soil	30
grass	10 ... 15
concrete	6.4 ... 7

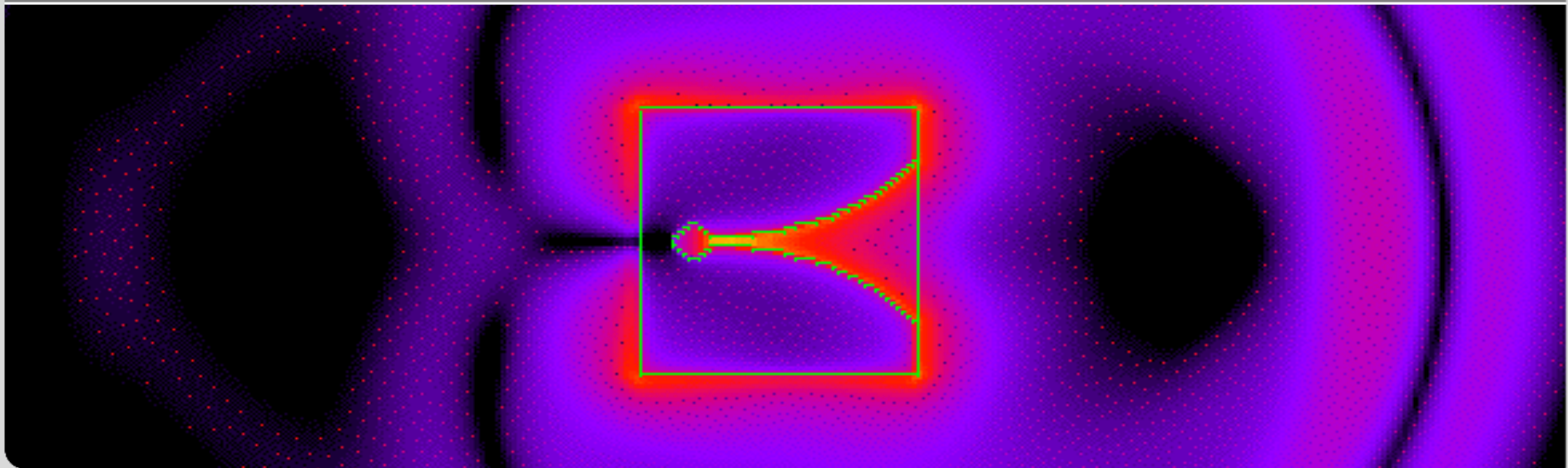
$$E_{total} = |E_{direct}| + |E_{reflect}|$$

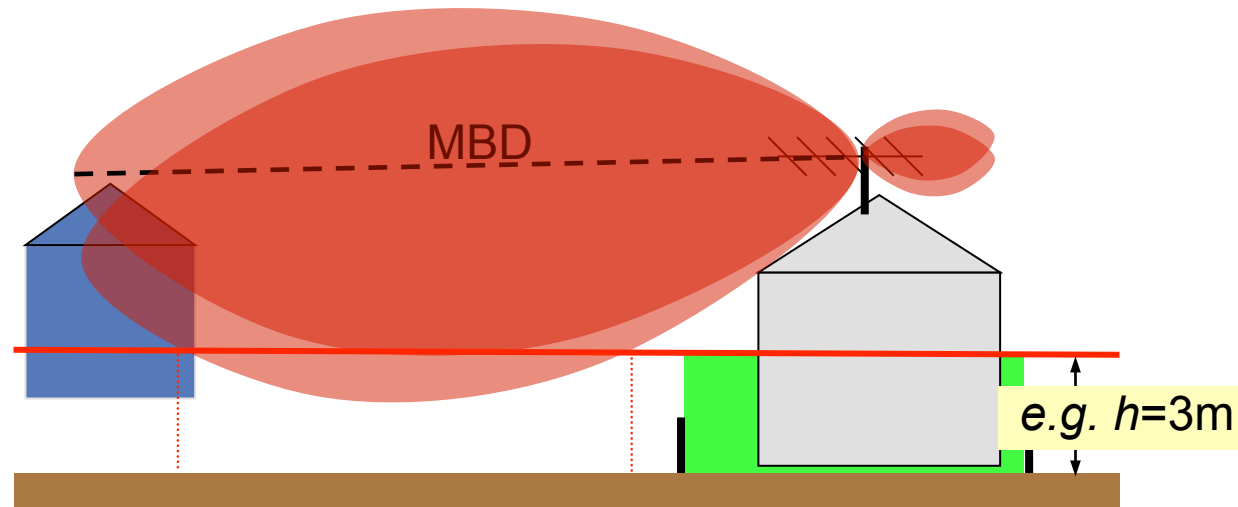
WattGuard

- reflected field is calculated by mirroring method
- worst-case approximation: total reflection, but can be varied in a certain range (0.3 – 1)
- ground reflection can also be considered using NEC data

Calculation of the Safety Area with WattGuard

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- Region between ground surface and height of e.g. 3m is considered
- Orthogonal projection to ground surface

- Safety distance is a function of the elevation angle

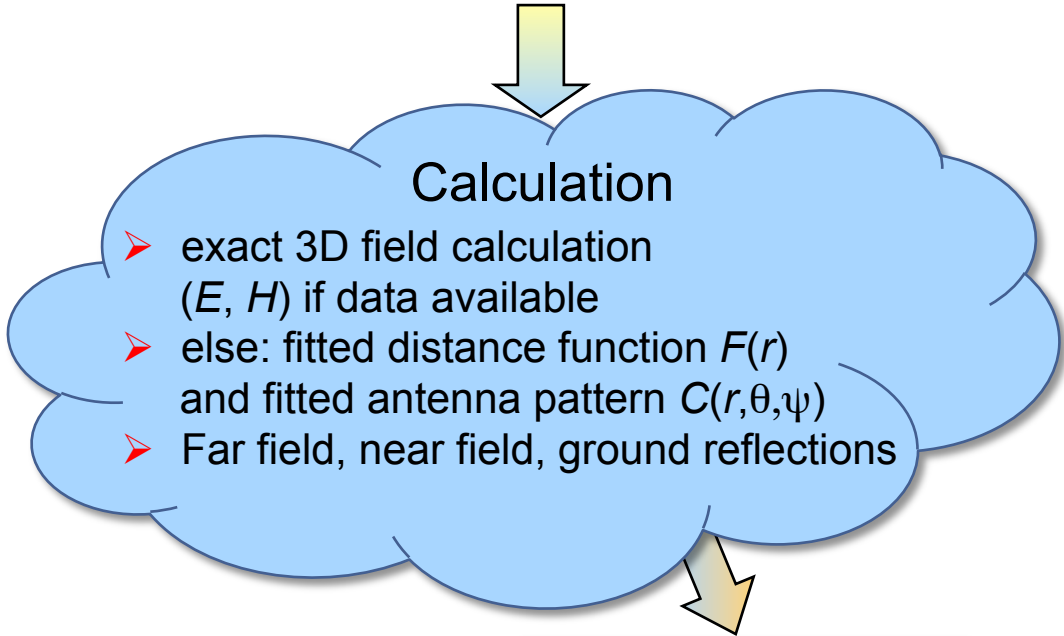
Calculation of the maximum of the safety area in Main Beam Direction (MBD)

- Is there a building in this area ?
- Are there any persons in this area ?

Definition in cooperation with the German Federal Network Agency
in clearance with the Radio Amateur Association (RTA)

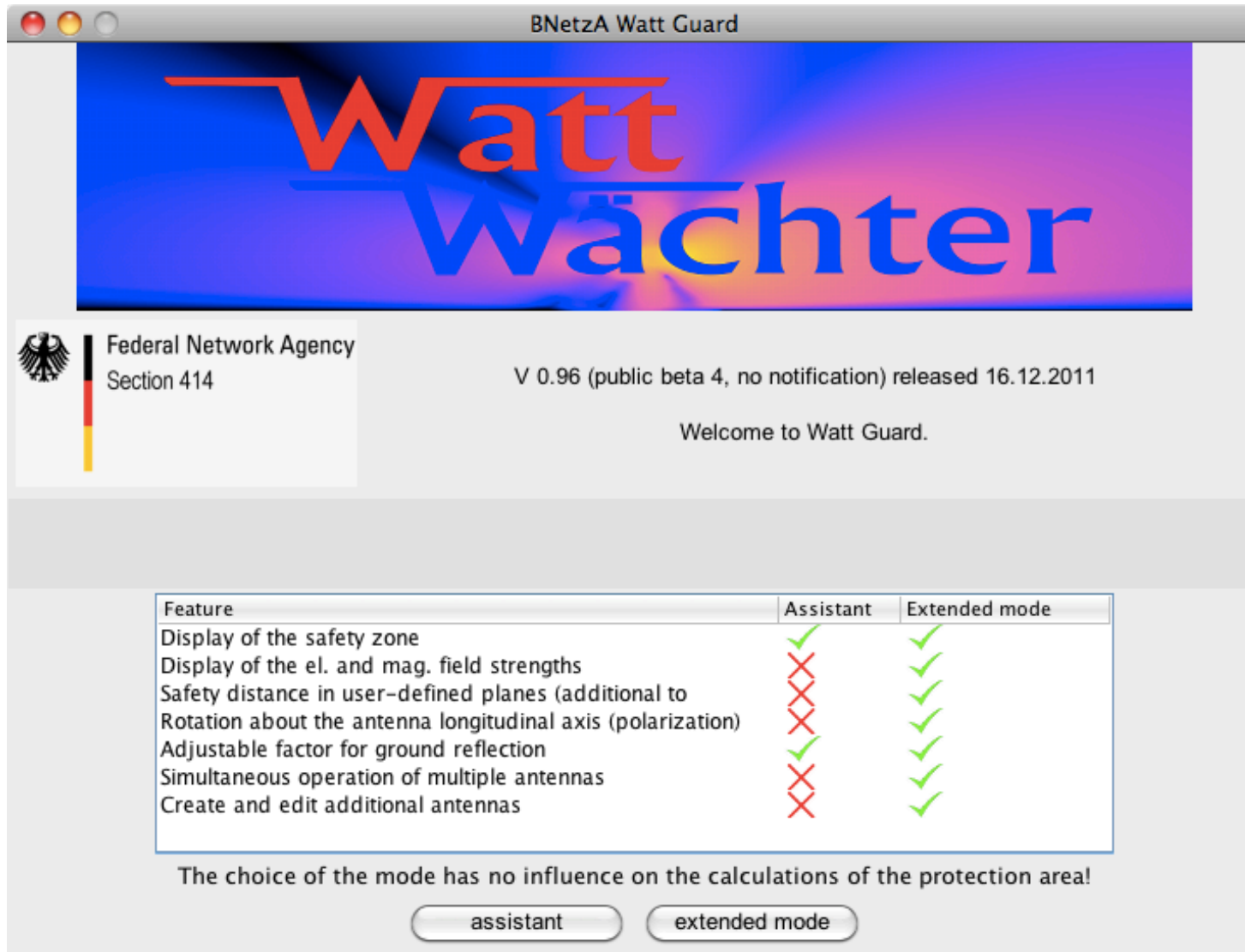
- Input Data**
- Antenna Data
 - Frequency
 - Position/Height
 - Orientation
 - Transmit Power
 - Cable Attenuation
 - Modulation

Exposure Limits




Safety Area (3D)

Program Start



BNetzA Watt Guard

Watt Wächter

 Federal Network Agency
Section 414

V 0.96 (public beta 4, no notification) released 16.12.2011

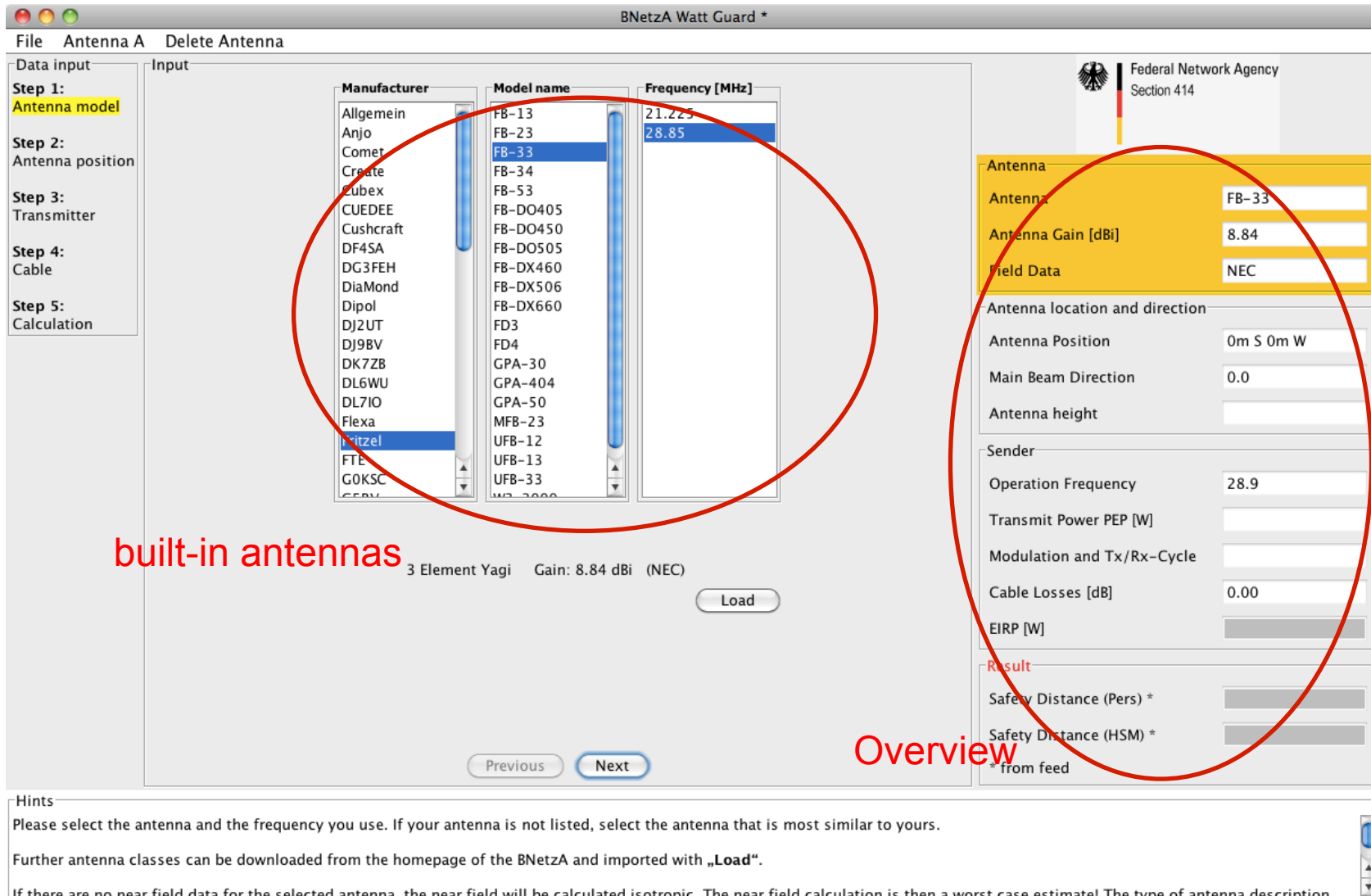
Welcome to Watt Guard.

Feature	Assistant	Extended mode
Display of the safety zone	✓	✓
Display of the el. and mag. field strengths	✗	✓
Safety distance in user-defined planes (additional to	✗	✓
Rotation about the antenna longitudinal axis (polarization)	✗	✓
Adjustable factor for ground reflection	✓	✓
Simultaneous operation of multiple antennas	✗	✓
Create and edit additional antennas	✗	✓

The choice of the mode has no influence on the calculations of the protection area!

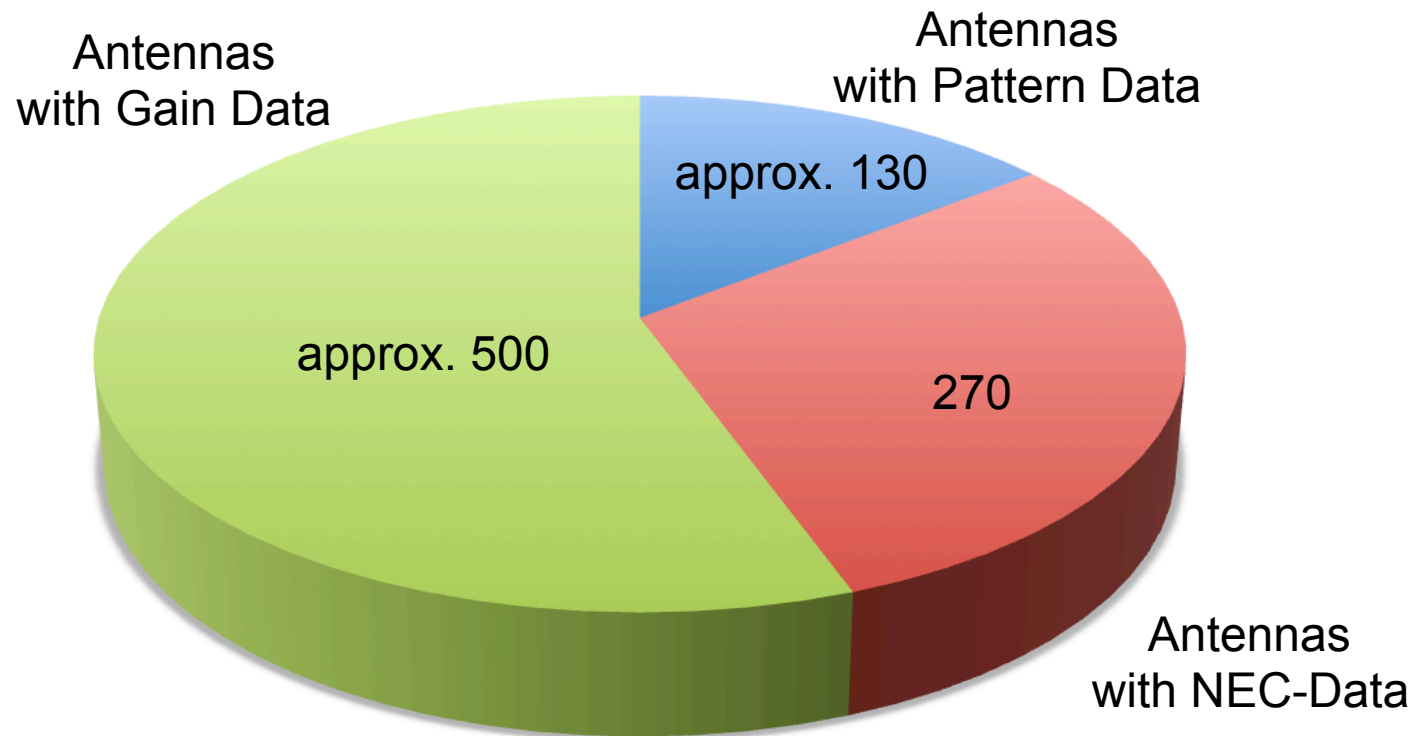
assistant extended mode

Program Step 1/5: Antenna Data



The screenshot shows the 'BNetzA Watt Guard' software interface. The main window is titled 'Antenna A' and has a menu bar with 'File', 'Antenna A', and 'Delete Antenna'. On the left, there is a 'Data input' sidebar with five steps: Step 1: Antenna model (highlighted in yellow), Step 2: Antenna position, Step 3: Transmitter, Step 4: Cable, and Step 5: Calculation. The main area is divided into two sections. The left section, titled 'Input', contains three columns: 'Manufacturer', 'Model name', and 'Frequency [MHz]'. A red circle highlights this section, with the text 'built-in antennas' written in red below it. The 'Manufacturer' column lists various manufacturers like Allgemein, Anjo, Comet, etc. The 'Model name' column lists models like FB-13, FB-23, FB-33, etc. The 'Frequency [MHz]' column shows values like 21.225 and 28.85. The 'FB-33' model is selected. Below the columns, it says '3 Element Yagi Gain: 8.84 dBi (NEC)' and has a 'Load' button. The right section, titled 'Antenna', is highlighted with a red circle and the text 'Overview' written in red below it. It contains several input fields: 'Antenna' (FB-33), 'Antenna Gain [dBi]' (8.84), 'Field Data' (NEC), 'Antenna location and direction' (Antenna Position: 0m S 0m W, Main Beam Direction: 0.0, Antenna height: empty), 'Sender' (Operation Frequency: 28.9, Transmit Power PEP [W]: empty, Modulation and Tx/Rx-Cycle: empty, Cable Losses [dB]: 0.00, EIRP [W]: empty), and 'Result' (Safety Distance (Pers) *, Safety Distance (HSM) *, * from feed). At the bottom, there is a 'Hints' section with text: 'Please select the antenna and the frequency you use. If your antenna is not listed, select the antenna that is most similar to yours. Further antenna classes can be downloaded from the homepage of the BNetzA and imported with „Load“. If there are no near field data for the selected antenna, the near field will be calculated isotropic. The near field calculation is then a worst case estimate! The type of antenna description'.

Integrated Antennas



- Pattern- or NEC-Data: Exact Calculation of Safety Area
- Gain Data: Isotropic Approximation-> worst-case-consideration
- Antenna Base in Coordination with Radio Amateurs and Fed. Network Agency

Program Step 2/5: Position Data

BNetzA Watt Guard *

File Antenna A Delete Antenna

Data input

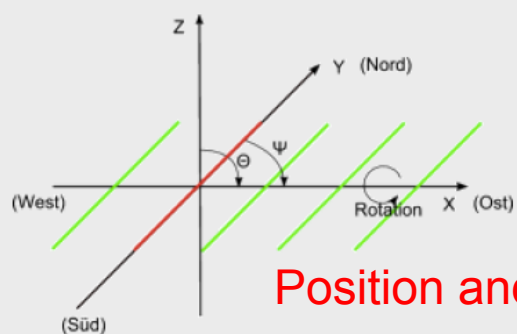
Step 1: Antenna model

Step 2: **Antenna position**

Step 3: Transmitter

Step 4: Cable

Step 5: Calculation



Position and Rotation

Position

North + / South - 0.00 m

East + / West - 0.00 m

Height above ground 10.00 m

Main beam direction

min. max.

Azimuth Ψ [°] 0 0 turnable

Elevation Θ [°] 90 90 turnable

Ground Factor (1.3 - 2) 2.00

Previous Next

Federal Network Agency
Section 414

Antenna

Antenna FB-33

Antenna Gain [dBi] 8.84

Field Data NEC

Antenna location and direction

Antenna Position 0m S 0m W

Main Beam Direction 0.0

Antenna height 10.00

Sender

Operation Frequency 28.9

Transmit Power PEP [W]

Modulation and Tx/Rx-Cycle

Cable Losses [dB] 0.00

EIRP [W]

Result

Safety Distance (Pers) *

Safety Distance (HSM) *

* from feed

Hints

Please enter the antenna position in relation to the reference point (position of the first antenna A). If there is only a single antenna location, please enter 0 for North/South and East/West. If you want to calculate for multiple antennas, enter the position for the following antennas relatively to the first antenna.

A sketch of the selected antenna class illustrates the antenna's orientation.

Program Step 3/5: Modulation, Transmit Power

BNetzA Watt Guard *

File Antenna A Delete Antenna

Data input Input

Step 1:
Antenna model

Step 2:
Antenna position

Step 3:
Transmitter

Step 4:
Cable

Step 5:
Calculation

Modulation and Transmit Power


Transmit Scheme (VDE 0848 Part 3-1/A1)

CW AM TV DTX
 SSB FM GSM all

Transmit-Receive-Cycle (Tx-Rx in minutes)

Tx6 - Rx0 Tx4 - Rx2 Tx2 - Rx4
 Tx5 - Rx1 Tx3 - Rx3 Tx1 - Rx5

Transmit Power PEP [W]

 Federal Network Agency
Section 414

Antenna

Antenna

Antenna Gain [dBi]

Field Data

Antenna location and direction

Antenna Position

Main Beam Direction

Antenna height

Sender

Operation Frequency

Transmit Power PEP [W]

Modulation and Tx/Rx-Cycle

Cable Losses [dB]

EIRP [W]

Result

Safety Distance (Pers) *

Safety Distance (HSM) *

* from feed

Hints

Please enter the operation mode and transmission power.

Transmission mode

Enter the modulation type. If "all" is chosen, the worst case is used for calculating the guard distance.

Program Step 4/5: Cable Attenuation

BNetzA Watt Guard *

File Antenna A Delete Antenna

Data input

Step 1: Antenna model

Step 2: Antenna position

Step 3: Transmitter

Step 4: Cable

Step 5: Calculation

Input

Cable

- Aircell 7
- Aircom plus
- EcoFlex 10
- EcoFlex 15
- H100
- H155
- H2000
- RG11
- RG142
- RG174
- RG212
- RG213
- RG213Foam
- RG214
- RG217
- RG218
- RG220
- RG400
- RG58**
- RG59

Attenuation per 100m [dB] 8.0

Cable Length [m] 25.00

Cable Attenuation [dB] 2.0

Additional Attenuation [dB] 0.2

Total Attenuation [dB] 2.2

Federal Network Agency
Section 414

Antenna

Antenna FB-33

Antenna Gain [dBi] 8.84

Field Data NEC

Antenna location and direction

Antenna Position 0m S 0m W

Main Beam Direction 0.0

Antenna height 10.00

Sender

Operation Frequency 28.9

Transmit Power PEP [W] 100.0

Modulation and Tx/Rx-Cycle SSB 6/0

Cable Losses [dB] 2.20

EIRP [W] 461

Result

Safety Distance (Pers) *

Safety Distance (HSM) *

* from feed

Previous Next

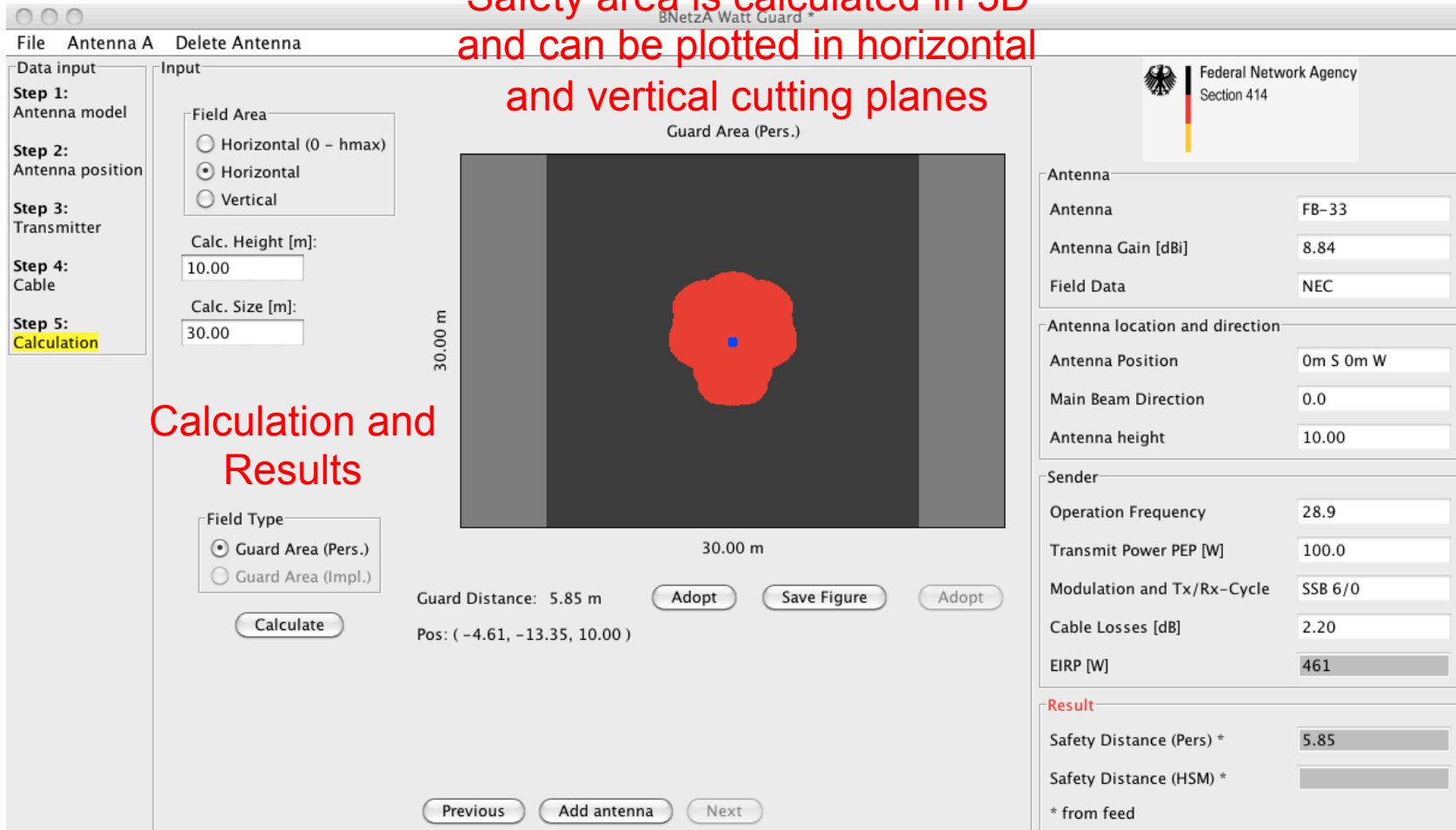
Hints

Please choose the cable in use and enter the length. You can also enter addition attenuation values for connectors etc. (e.g. 0.2dB per connection).

Cable and additional Attenuation

Program Step 5/5: Safety Area

Safety area is calculated in 3D
and can be plotted in horizontal
and vertical cutting planes



Calculation and Results

Input

Field Area

- Horizontal (0 - hmax)
- Horizontal
- Vertical

Calc. Height [m]: 10.00

Calc. Size [m]: 30.00

Field Type

- Guard Area (Pers.)
- Guard Area (Impl.)

Calculate

Guard Distance: 5.85 m

Pos: (-4.61, -13.35, 10.00)

Antenna

Antenna: FB-33

Antenna Gain [dBi]: 8.84

Field Data: NEC

Antenna location and direction

Antenna Position: 0m S 0m W

Main Beam Direction: 0.0

Antenna height: 10.00

Sender

Operation Frequency: 28.9

Transmit Power PEP [W]: 100.0

Modulation and Tx/Rx-Cycle: SSB 6/0

Cable Losses [dB]: 2.20

EIRP [W]: 461

Result

Safety Distance (Pers) *: 5.85

Safety Distance (HSM) *

* from feed

Hints
Please run the calculation for every antenna and confirm the guard distance before going to the next step.

Summary Assisted Mode

- totally free of charge
- license free
- can be downloaded from BNetzA server (and ITU – if possible)
- no special equipment required
- runs on nearly every PC
- large antenna base, can be extended
approx. 95% of the typically used amateur radio antennas are covered
- small program, no complicated installation needed
- easy to handle without special knowledge about electromagnetics or special training
- fast and accurate

Why WattGuard ?

- Approved and accepted calculation method
- Easy to use with user guidance in Assisted Mode
- Enhanced Mode for experienced users
- Large antenna base
- Modular: further antennas, different exposure limits and additional propagation models are easy to integrate
- Fast 3D calculation of the safety area with near field consideration
- NEC data can be imported for taking into account the environment
- Export function for graphical display of safety area
- Display of field strengths possible
- Simultaneous operation of multiple antennas or stations
- System/platform independent software