Millimeterwellen-Antennen auf der Basis planarer Reflektoren

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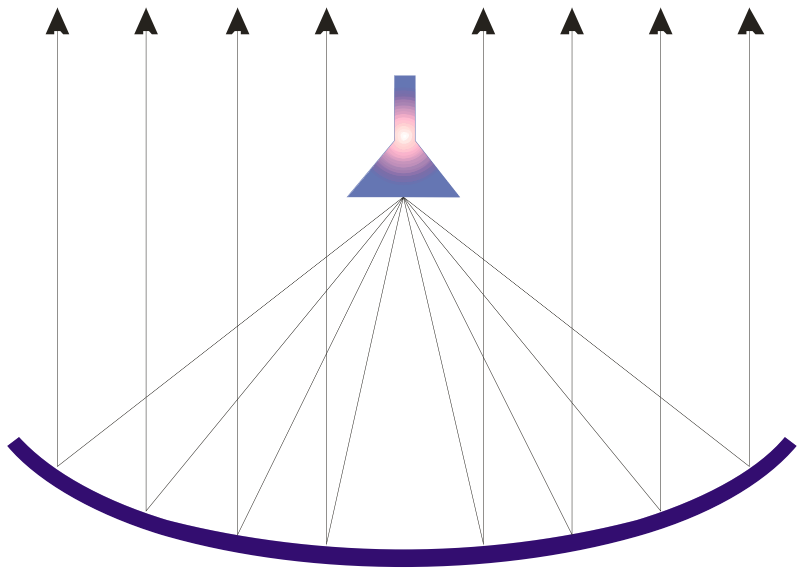
Inhalt - Übersicht

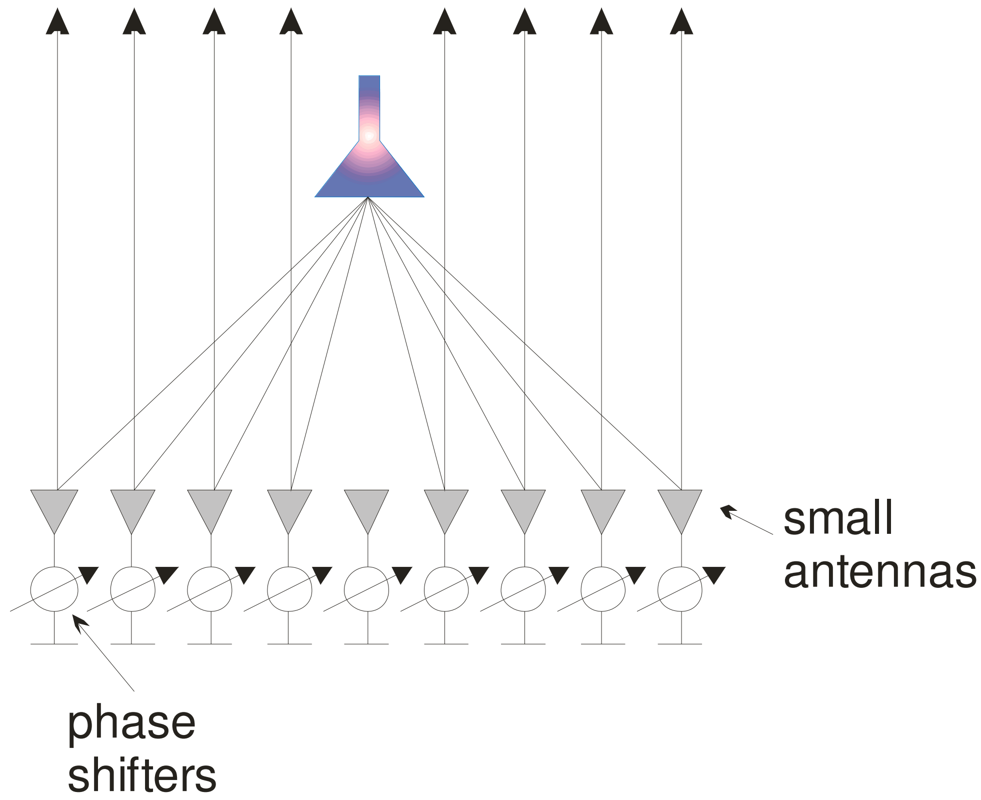
- **Das Prinzip planarer Reflektorantennen**
- **Berechnung von planaren Strukturen**
- **Antennentypen:**
  - Offset-gespeiste planare Reflektorantenne
  - Reflektorantenne mit Ausnutzung von zwei Polarisationen
  - Reflektorantenne für zwei Frequenzen
  - Gefaltete Reflektorantenne
  - Schwenkung der Antennenkeule
  - Bifokale Reflektorantennen
  - Antennen mit Sektor- und Rundum-Charakteristik

Prinziple of Planar Reflector Antennas

Parabolic Reflector

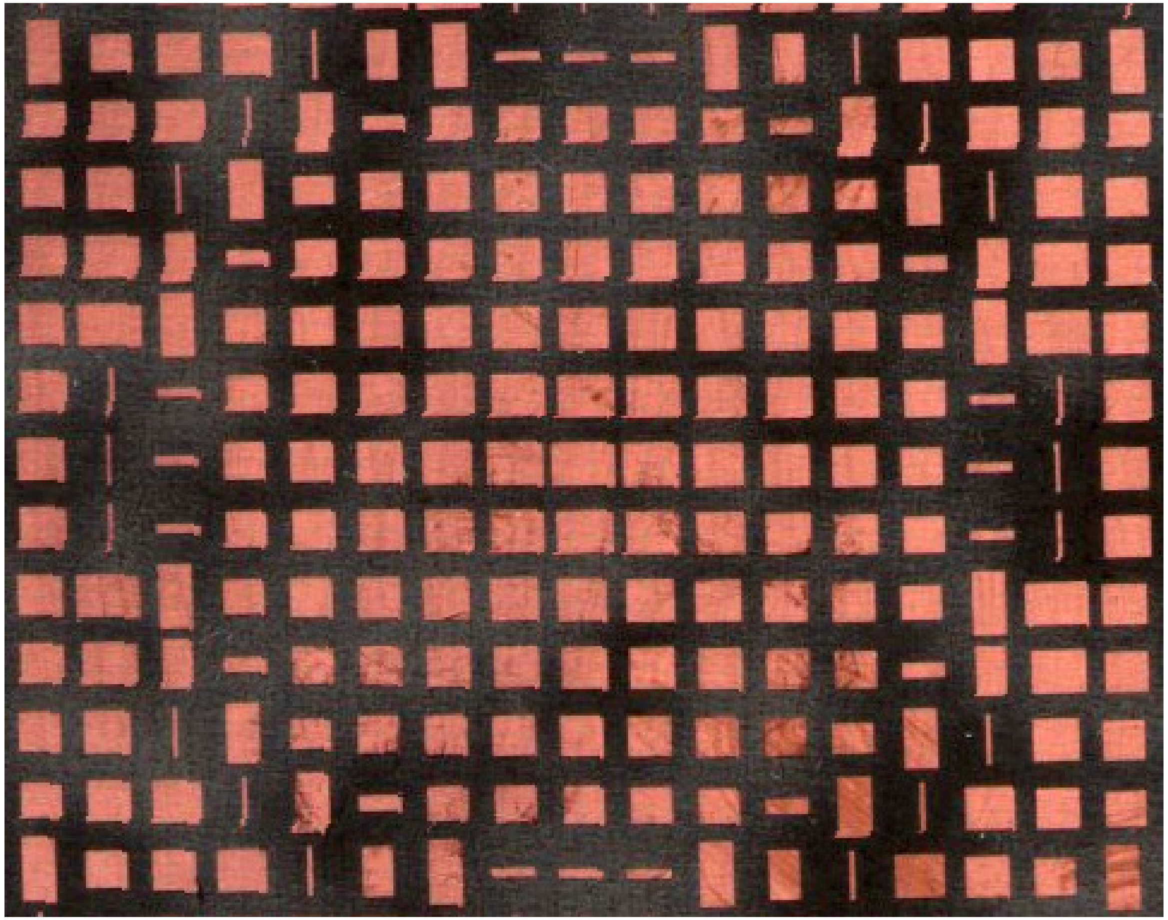


Planar Principle

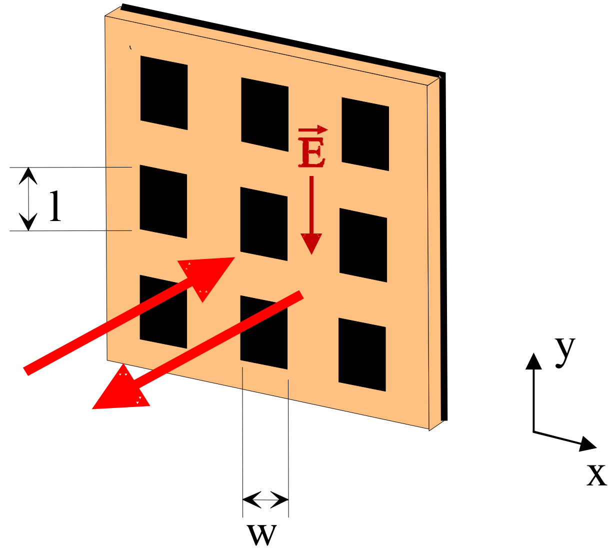


Example for Planar Reflector

Dipoles of different size on substrate with backside metalization change phase of reflected wave in terms of dipole dimensions.



$$\vec{\tilde{E}}_{total} = \vec{\tilde{E}}_{in} + \vec{\tilde{E}}_{refl} + \overset{\leftrightarrow}{\tilde{Z}} \cdot \vec{\tilde{J}}$$



$$\overset{\leftrightarrow}{\tilde{Z}} = \begin{pmatrix} \tilde{Z}_{xx} & \tilde{Z}_{xy} \\ \tilde{Z}_{xy} & \tilde{Z}_{yy} \end{pmatrix}$$

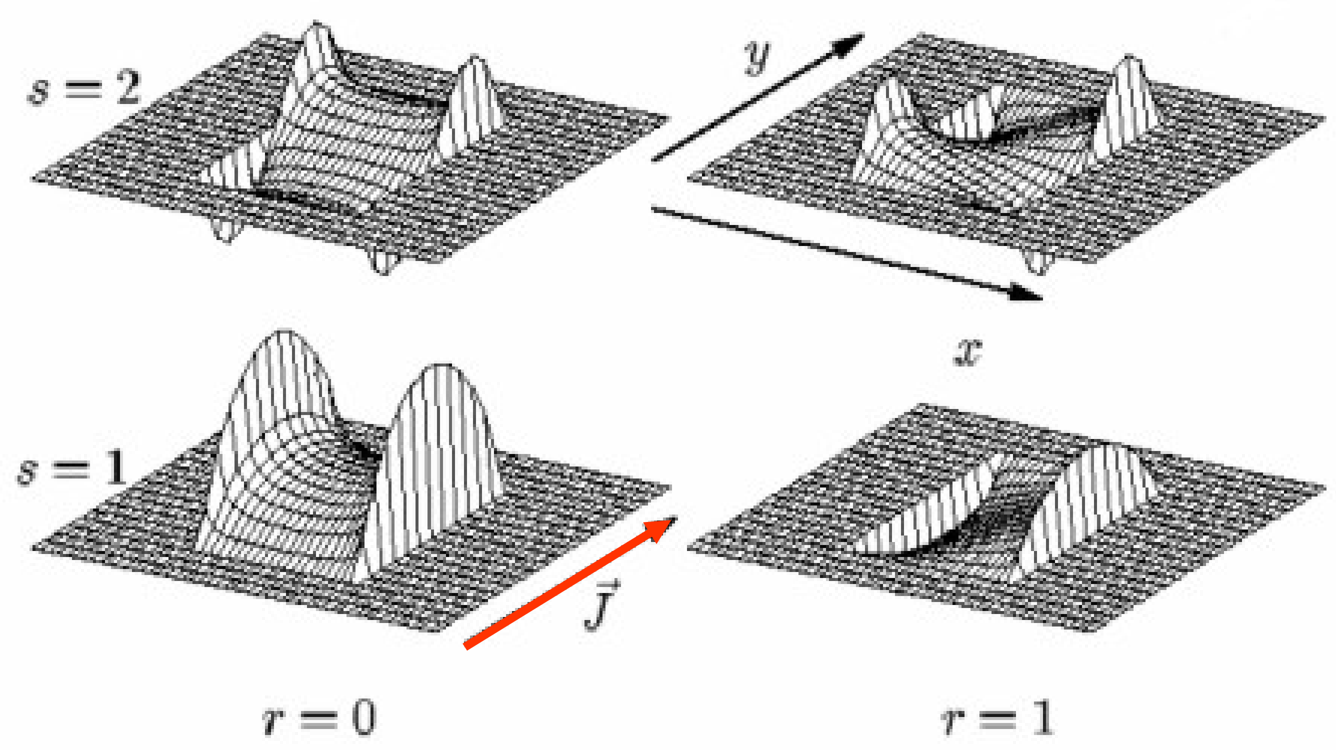
$$\tilde{Z}_{xx} = -\frac{\alpha^2 Z_e + \beta^2 Z_h}{\alpha^2 + \beta^2}, \quad \tilde{Z}_{yy} = -\frac{\beta^2 Z_e + \alpha^2 Z_h}{\alpha^2 + \beta^2}, \quad \tilde{Z}_{xy} = -\frac{\alpha\beta(Z_e - Z_h)}{\alpha^2 + \beta^2},$$

$$Z_e = \frac{1}{\frac{j\omega\varepsilon_0\varepsilon_r}{\gamma_2} coth(\gamma_2 h) + \frac{j\omega\varepsilon_0}{\gamma_1}}, \quad Z_h = \frac{1}{\frac{\gamma_2}{j\omega\mu_0} coth(\gamma_2 h) + \frac{\gamma_1}{j\omega\mu_0}}$$

$$\gamma_i = \sqrt{\alpha^2 + \beta^2 - k_0^2 \cdot \varepsilon_{ri}}.$$

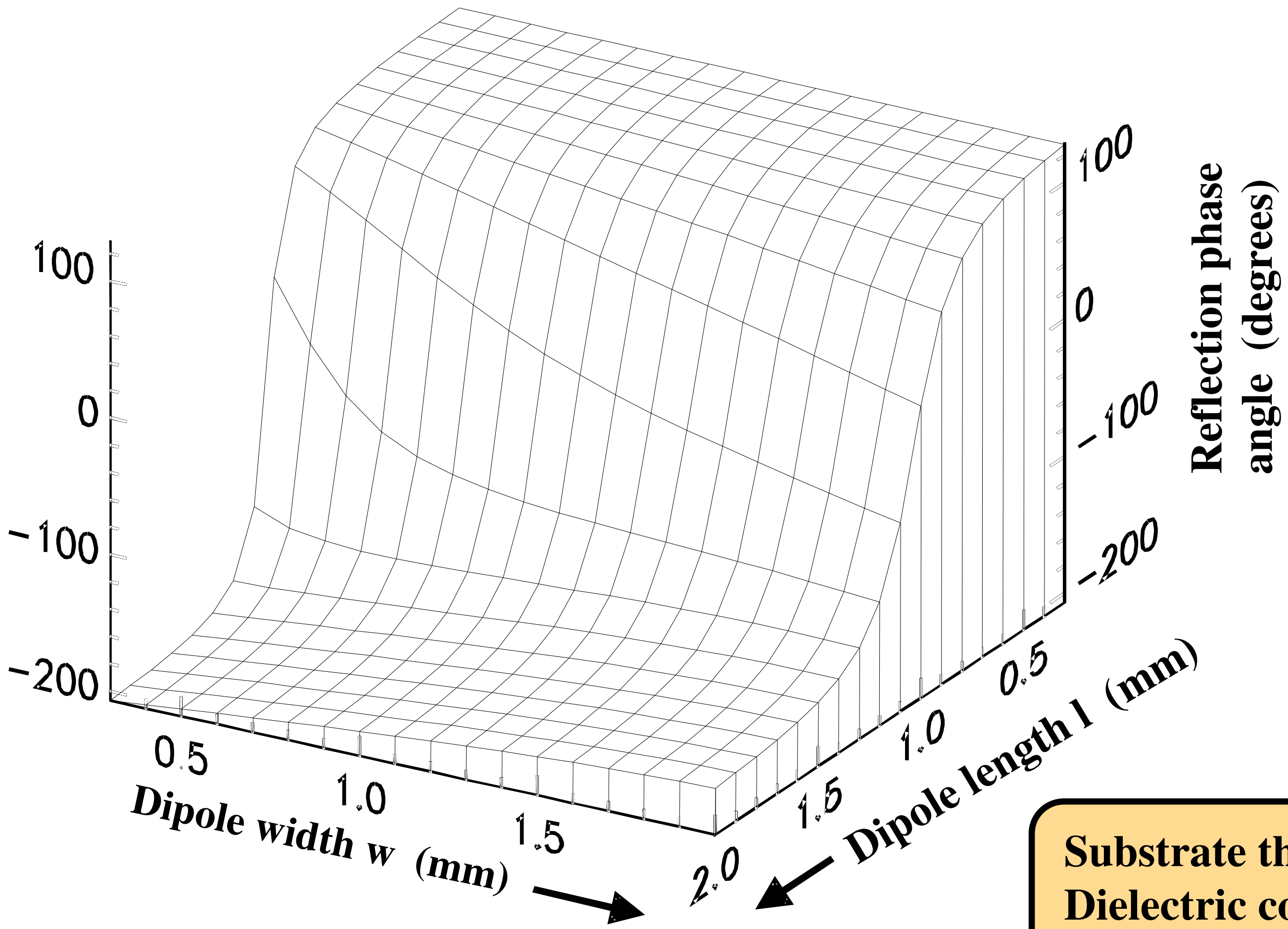
Currents on rectangular patch

- Selection of suitable current density basis functions



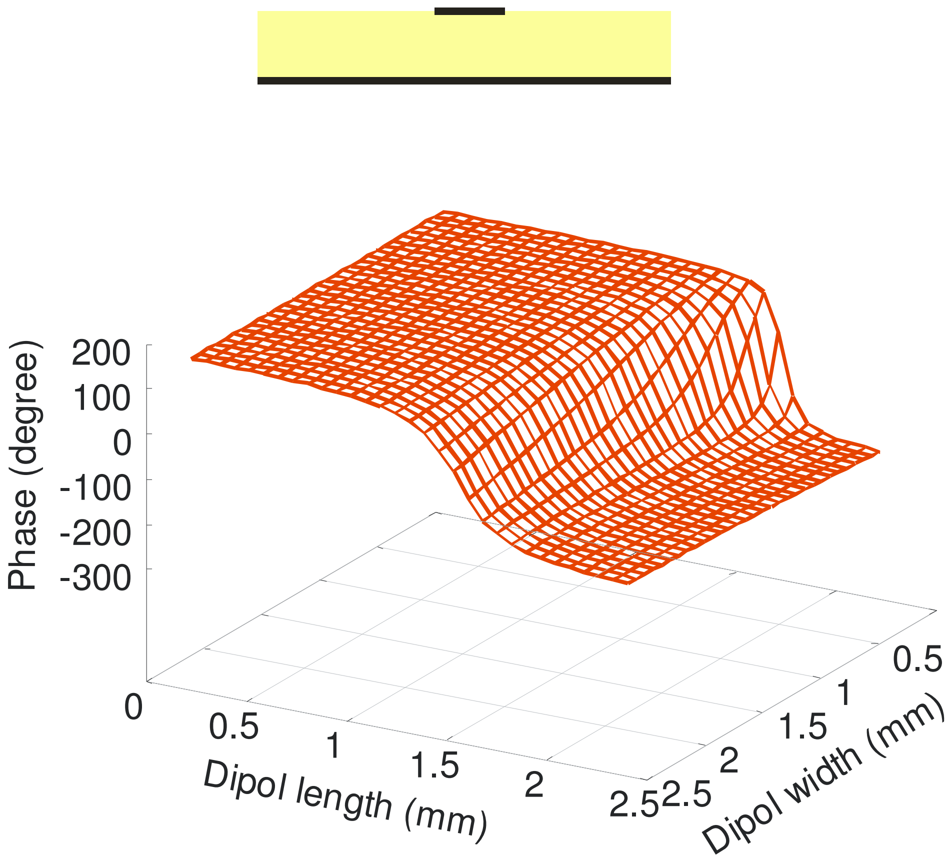
- Application of Galerkins principle
- Solution of a system of equations with appropriate excitation

Reflection phase angle of a plane wave incident on a periodic structure of dipoles

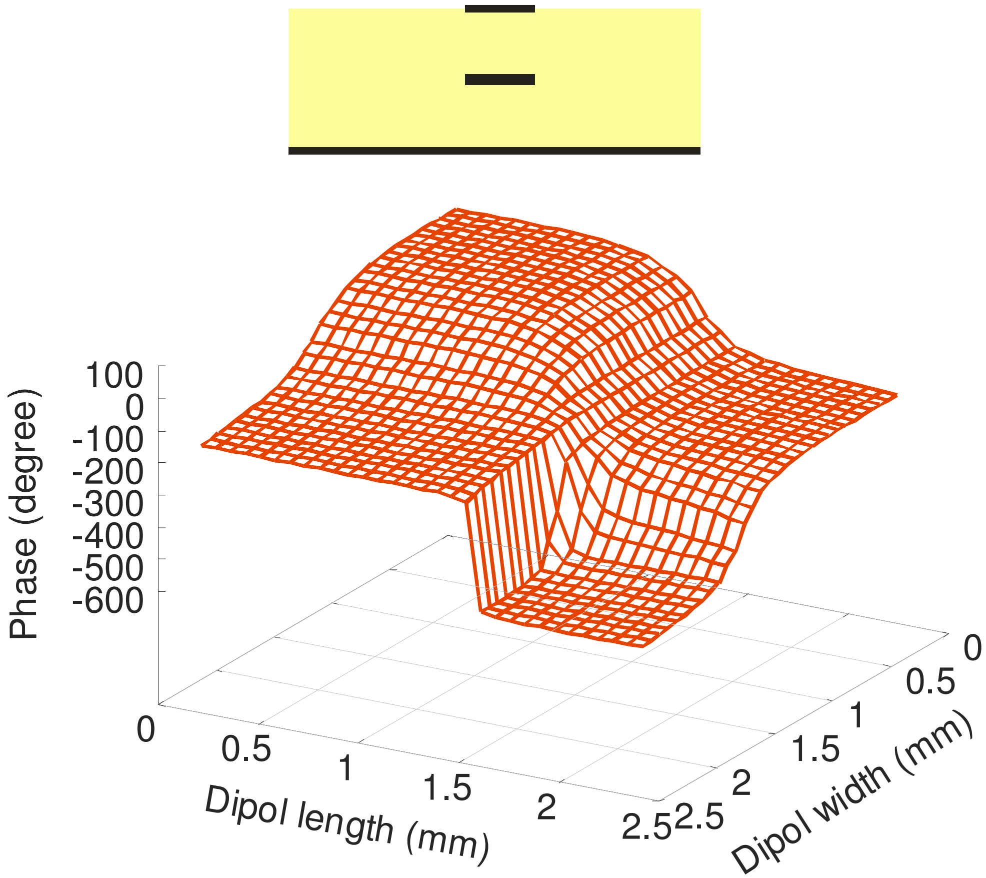


Substrate thickness	0.254 mm
Dielectric constant	2.22
Distance between dipoles	2.2 × 2.2 mm
Frequency	76.5 GHz

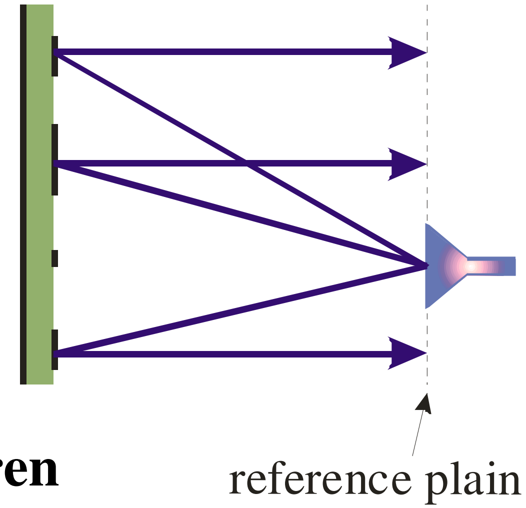
Single-Layer



Multi-Layer



Entwurf des planaren Reflektors



Berechnung des lokalen Phasenwinkel auf der Basis

- eines periodischen Dipolarrays
- einer senkrecht einfallenden Welle

Vollwellenberechnung mit dem Spektralbereichsverfahren

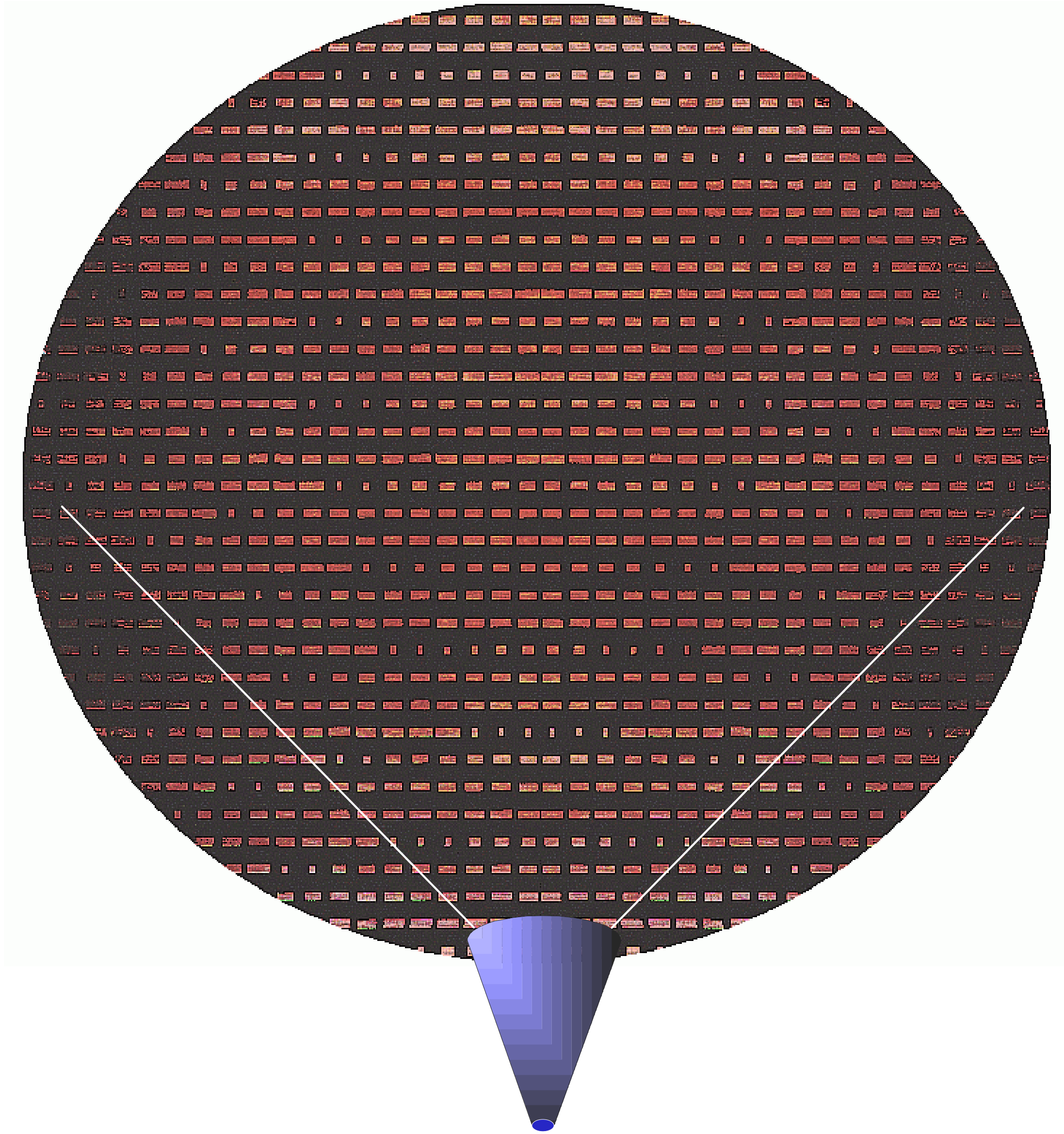
- Feldverteilung des Feeds
- unterschiedliche Stromverteilung auf allen Dipolen

$\Downarrow$

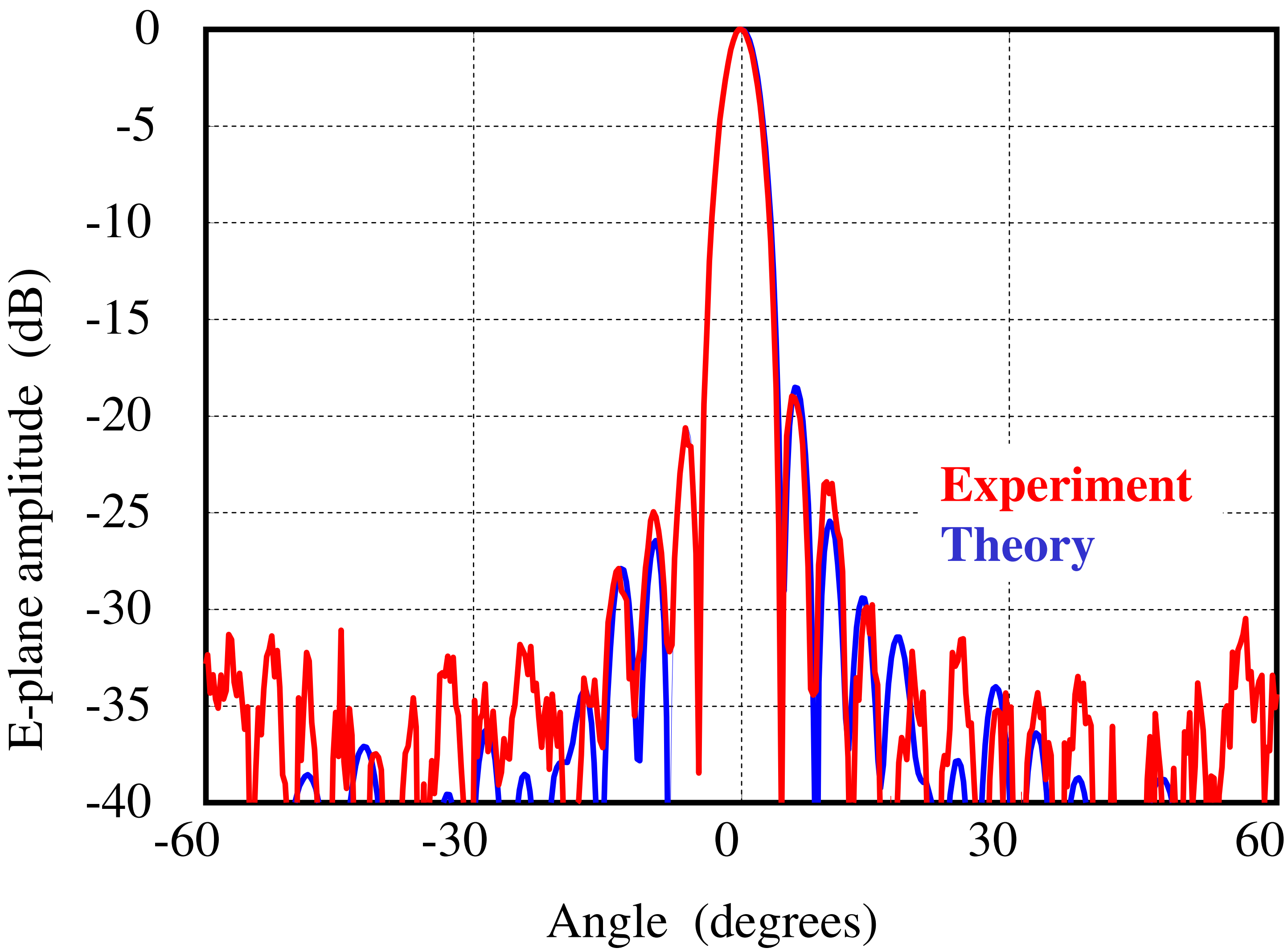
Strahlungsdiagramm
Phasenverteilung der reflektierten ebenen Welle

$\Rightarrow$ **prinzipielle Möglichkeit zur Optimierung**

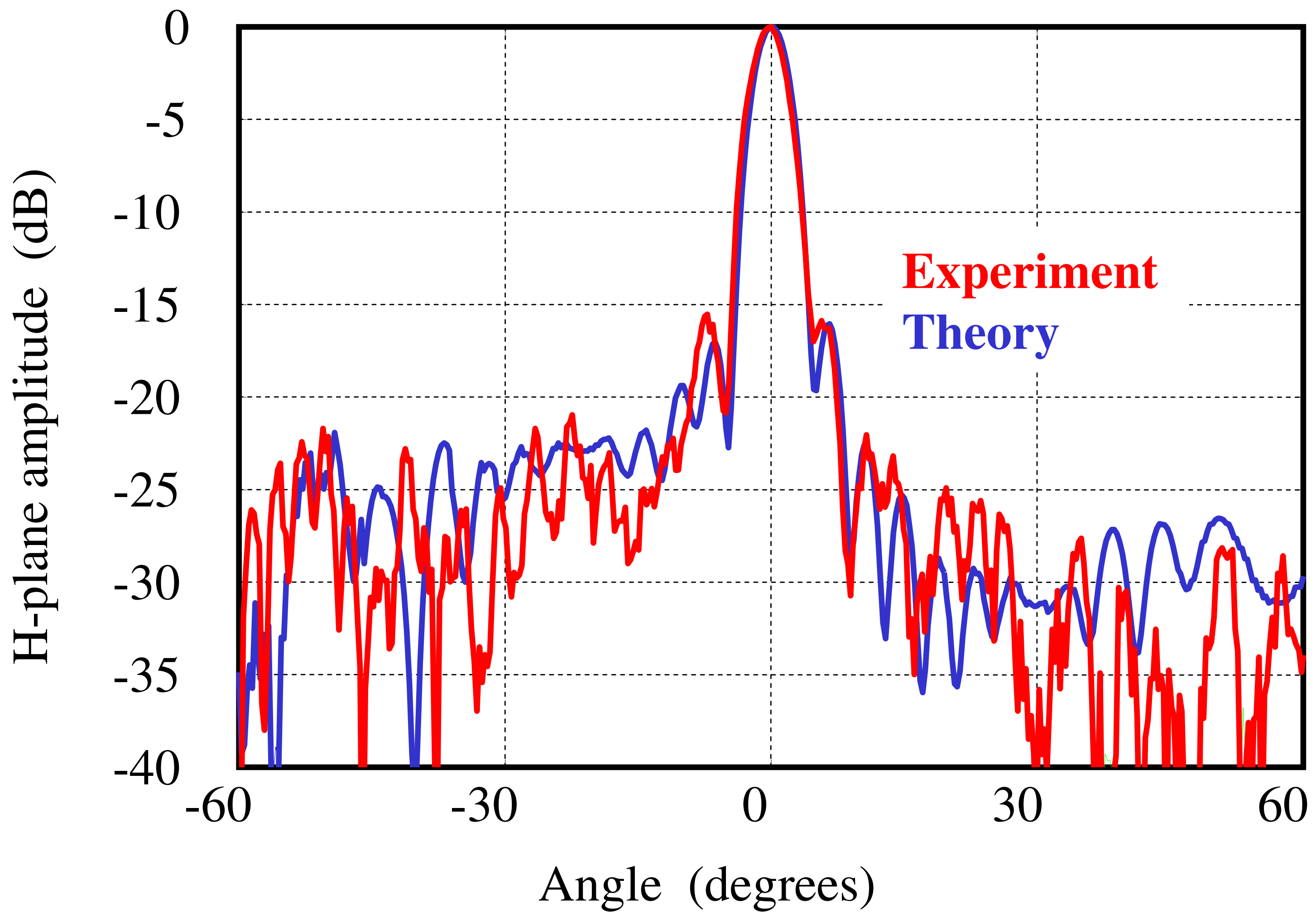
Offset-fed planar reflector antenna



Theoretical and experimental results of (offset) printed reflector antenna



Theoretical and experimental results of (offset) printed reflector antenna



Ausnutzung beider Polarisationen:

- unabhängige Strahlungsdiagramme in unterschiedlichen Polarisationen (ggf. mit unterschiedlichen Feedpositionen)
- Strahlungsdiagramme bei unterschiedlichen Frequenzen in unterschiedlichen Polarisationen
- Zirkular Polarisation (90° Phasenunterschied zwischen beiden Polaritionen)
- Polarisationsdrehung (180° Phasenunterschied zwischen beiden Polaritionen)

➔ Gefaltete Reflektorantennen

Dual polarization planar reflector antenna

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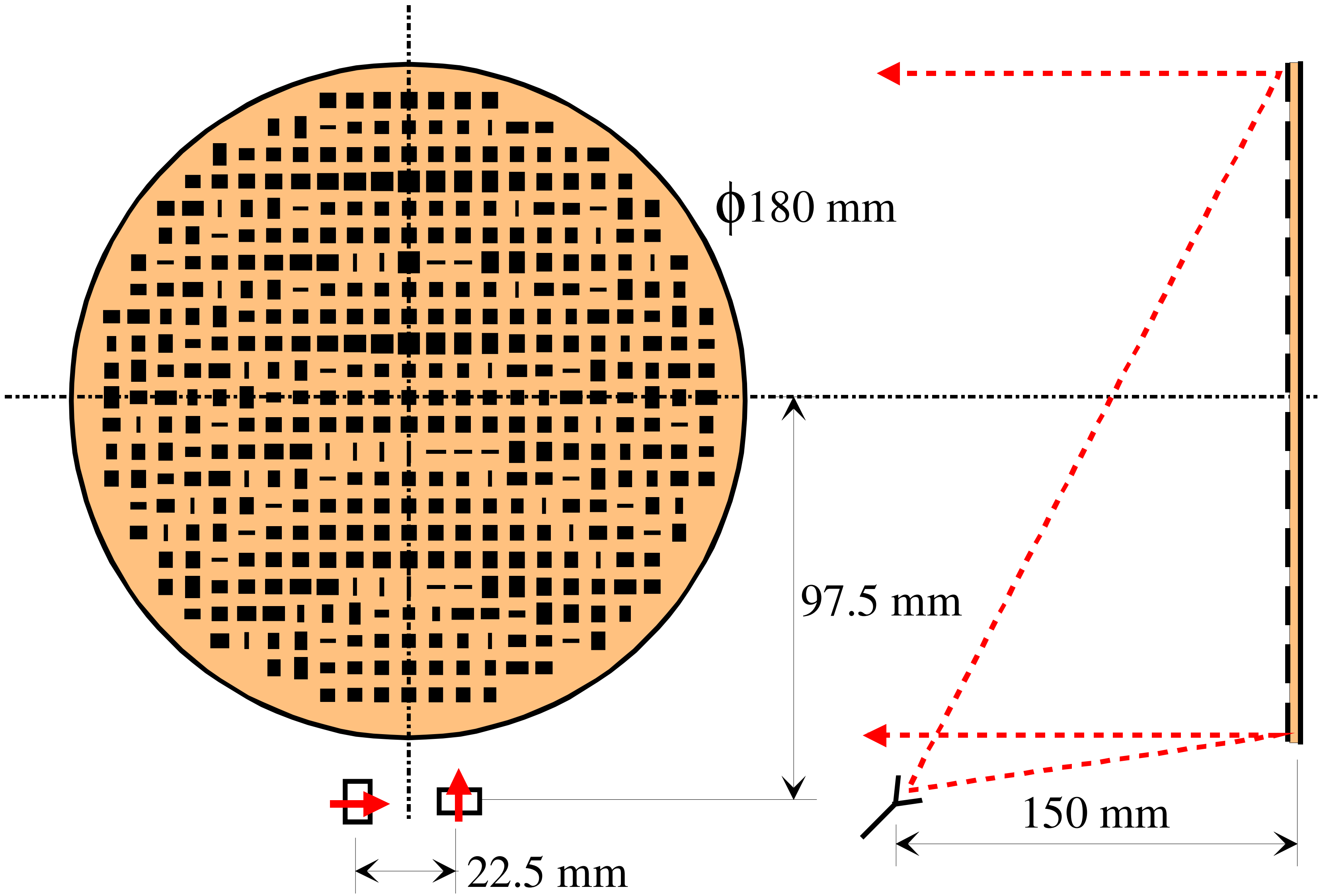

Radiation diagrams of a dual polarization planar reflector antenna

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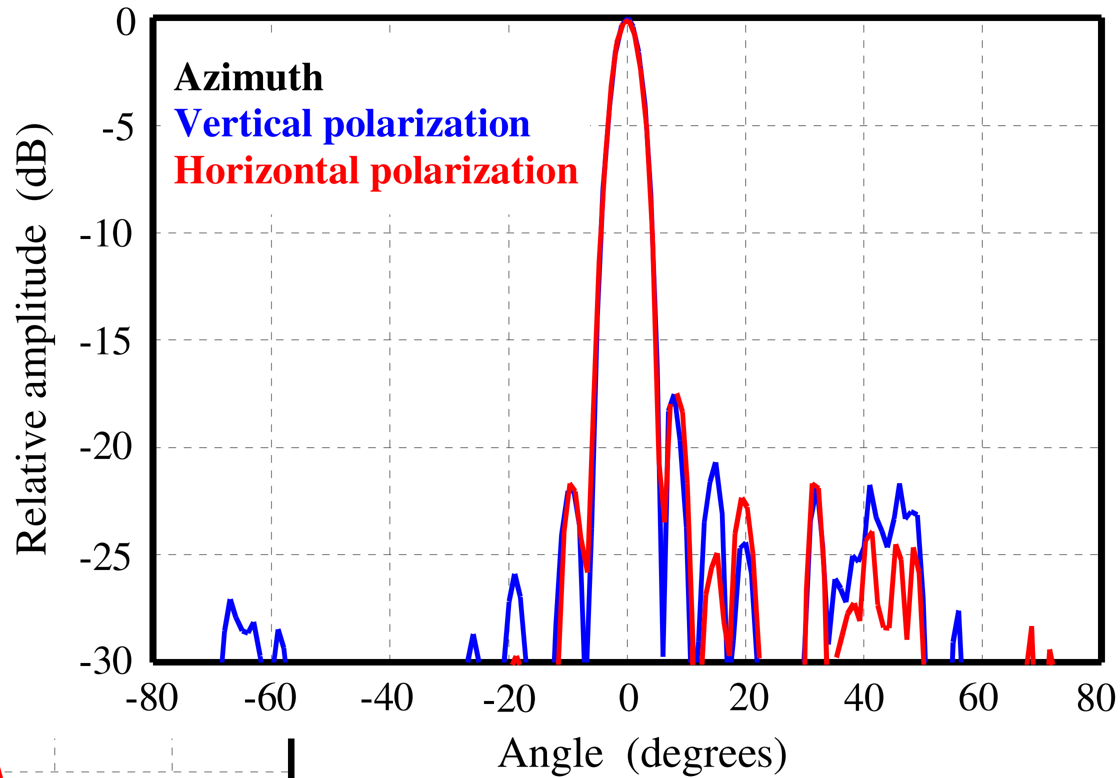
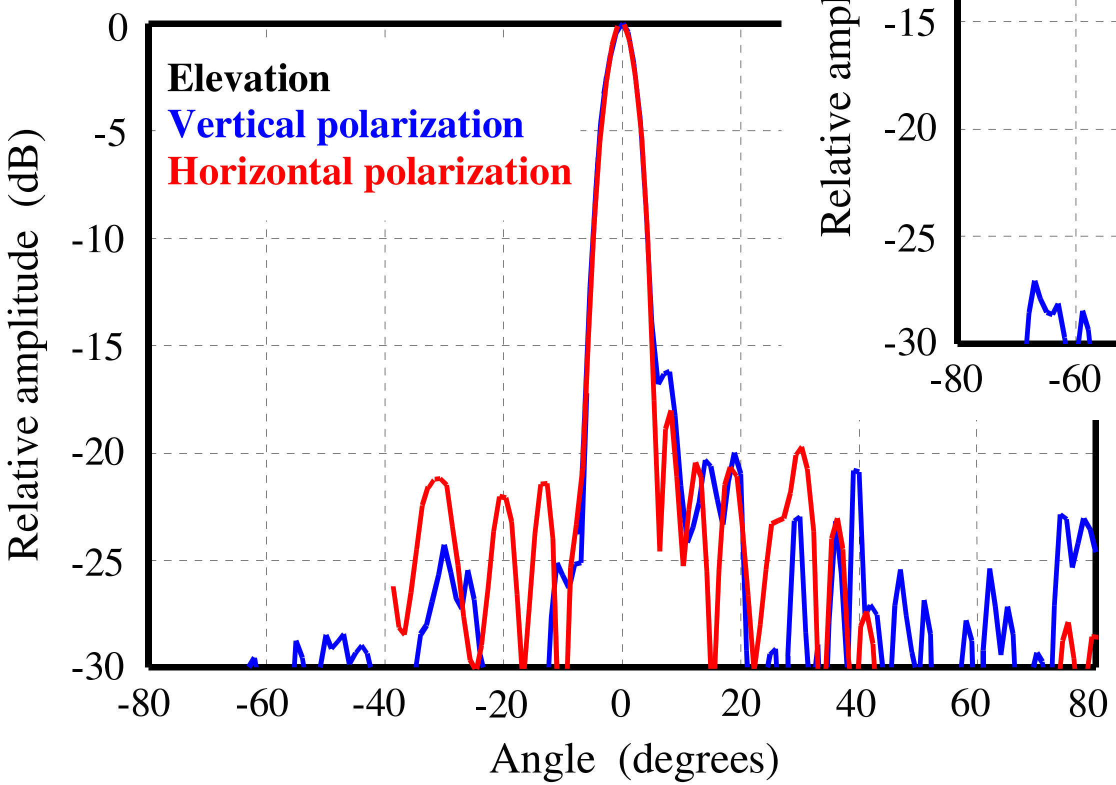
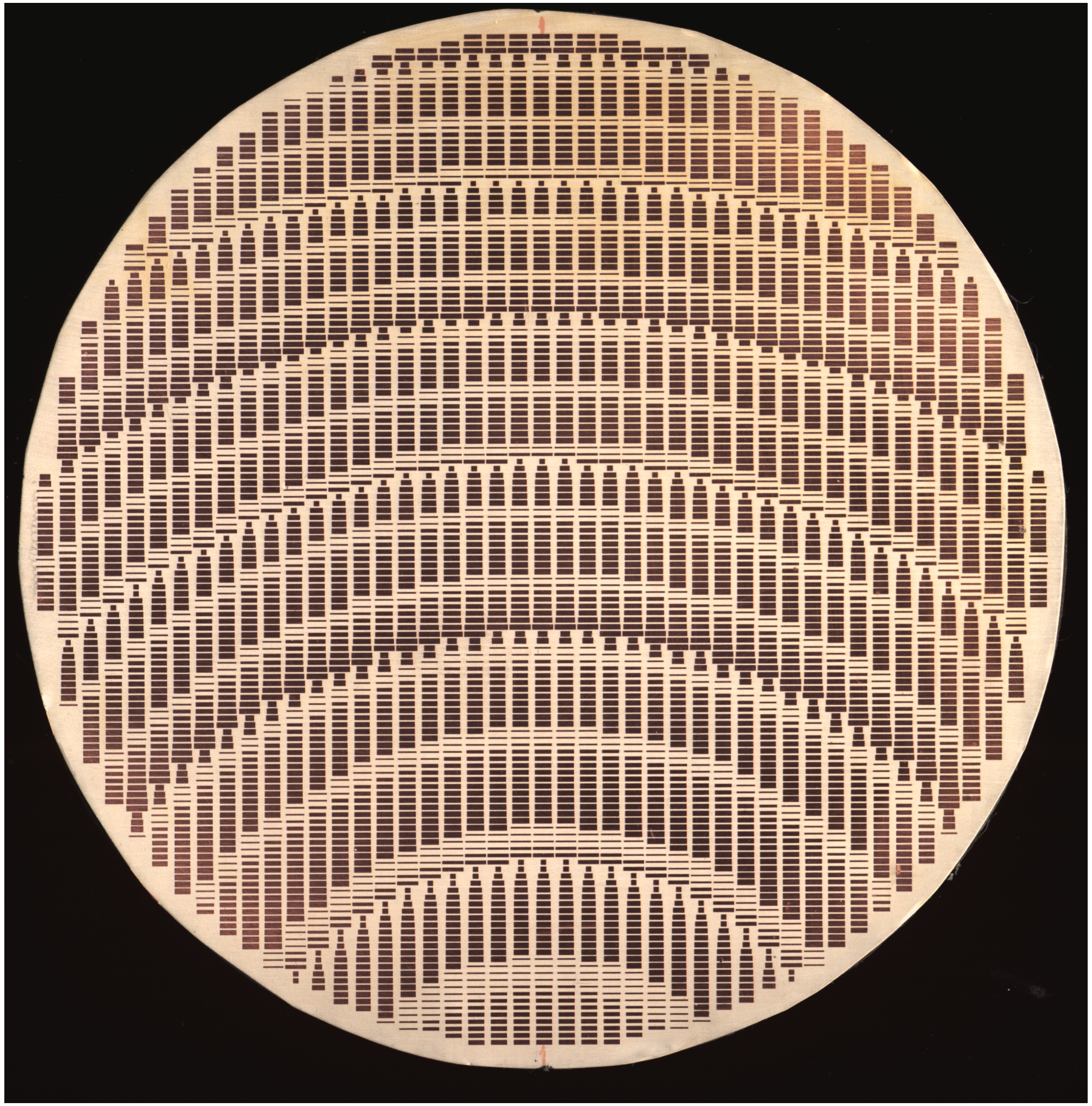
Substrate: h = 0.76 mm
ε_r = 2.5
Frequency: f = 20 GHz

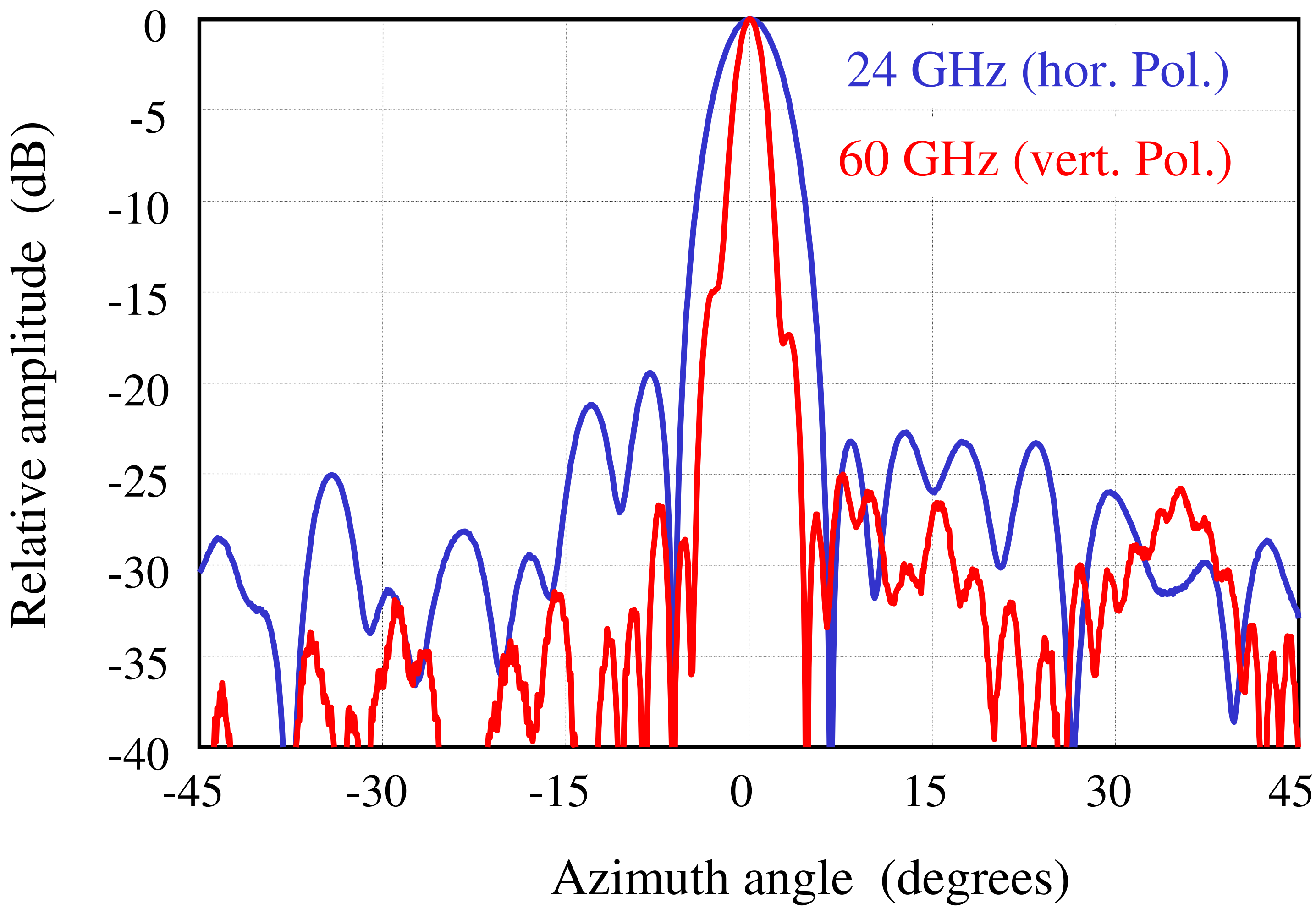




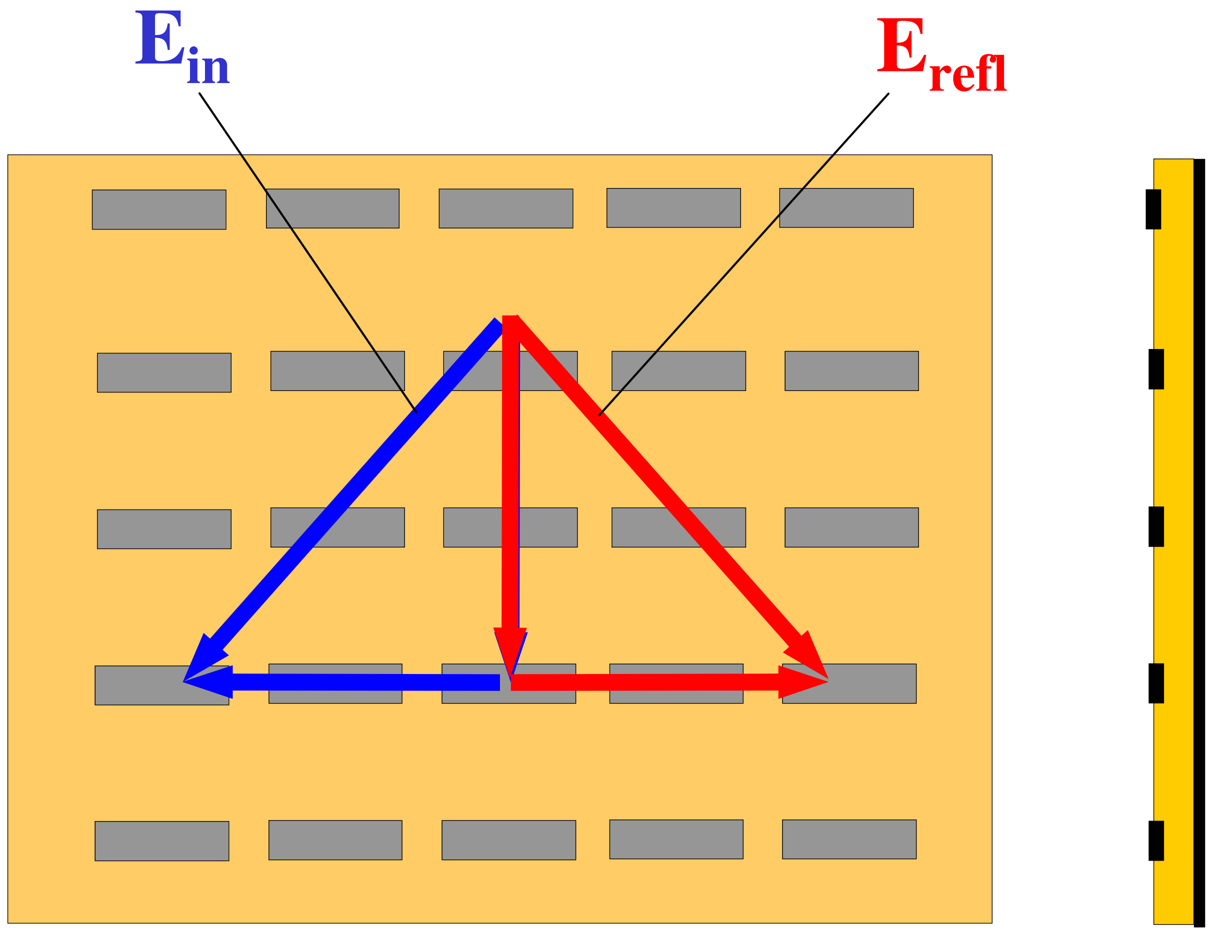
Dual frequency planar reflector antenna



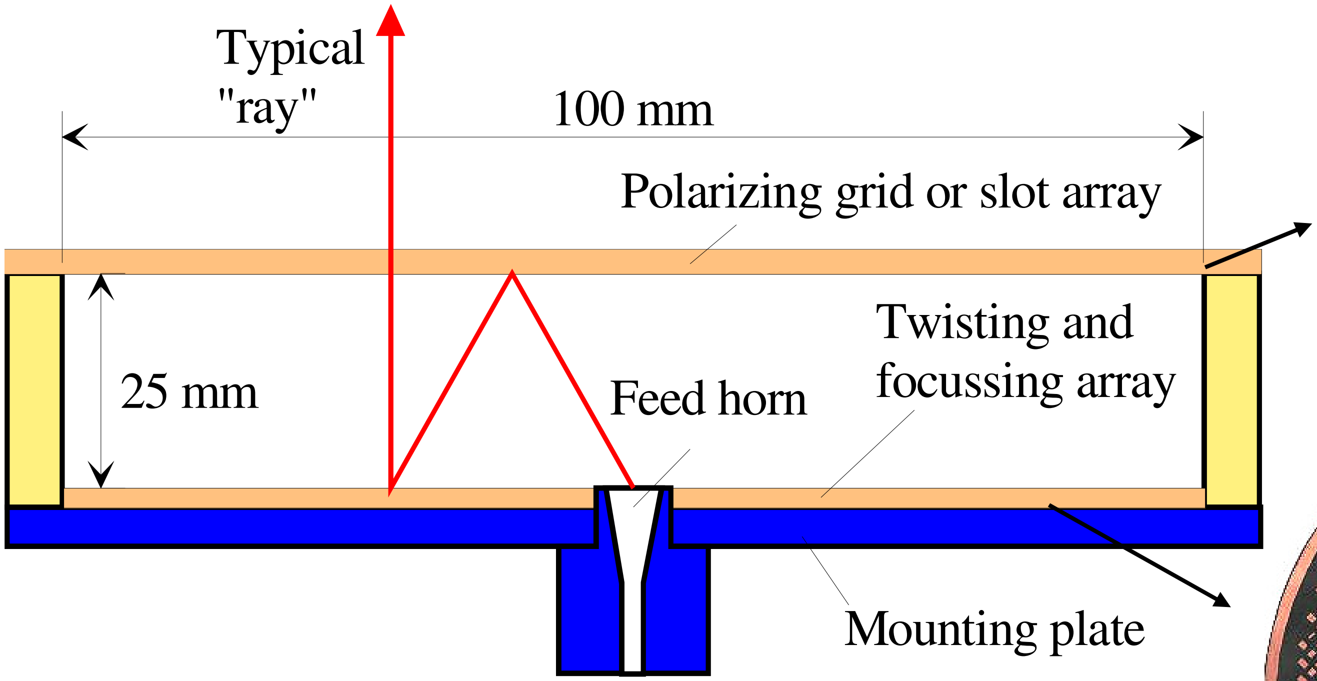
Azimuth radiation diagrams for dual frequency planar reflector antenna

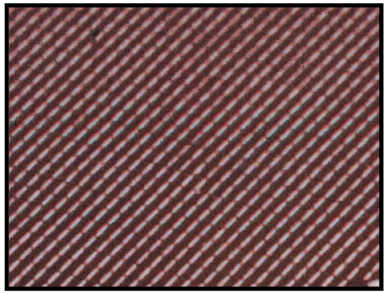


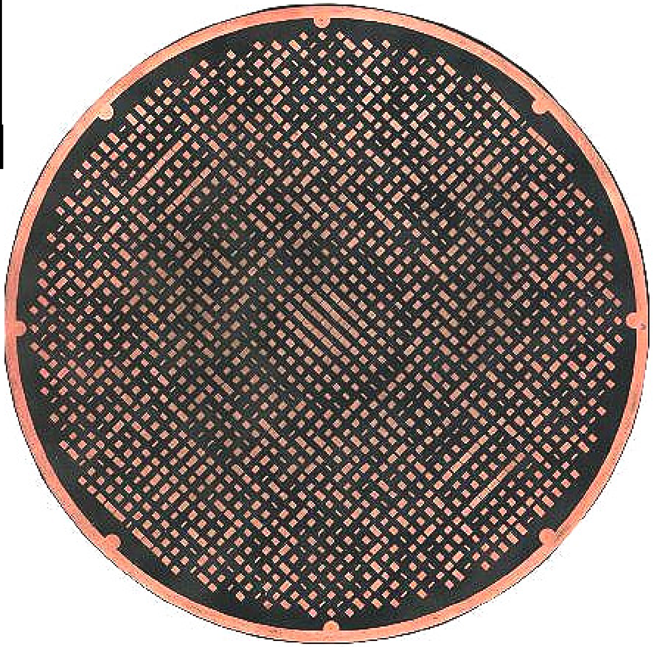
Principle of twist polarizer function



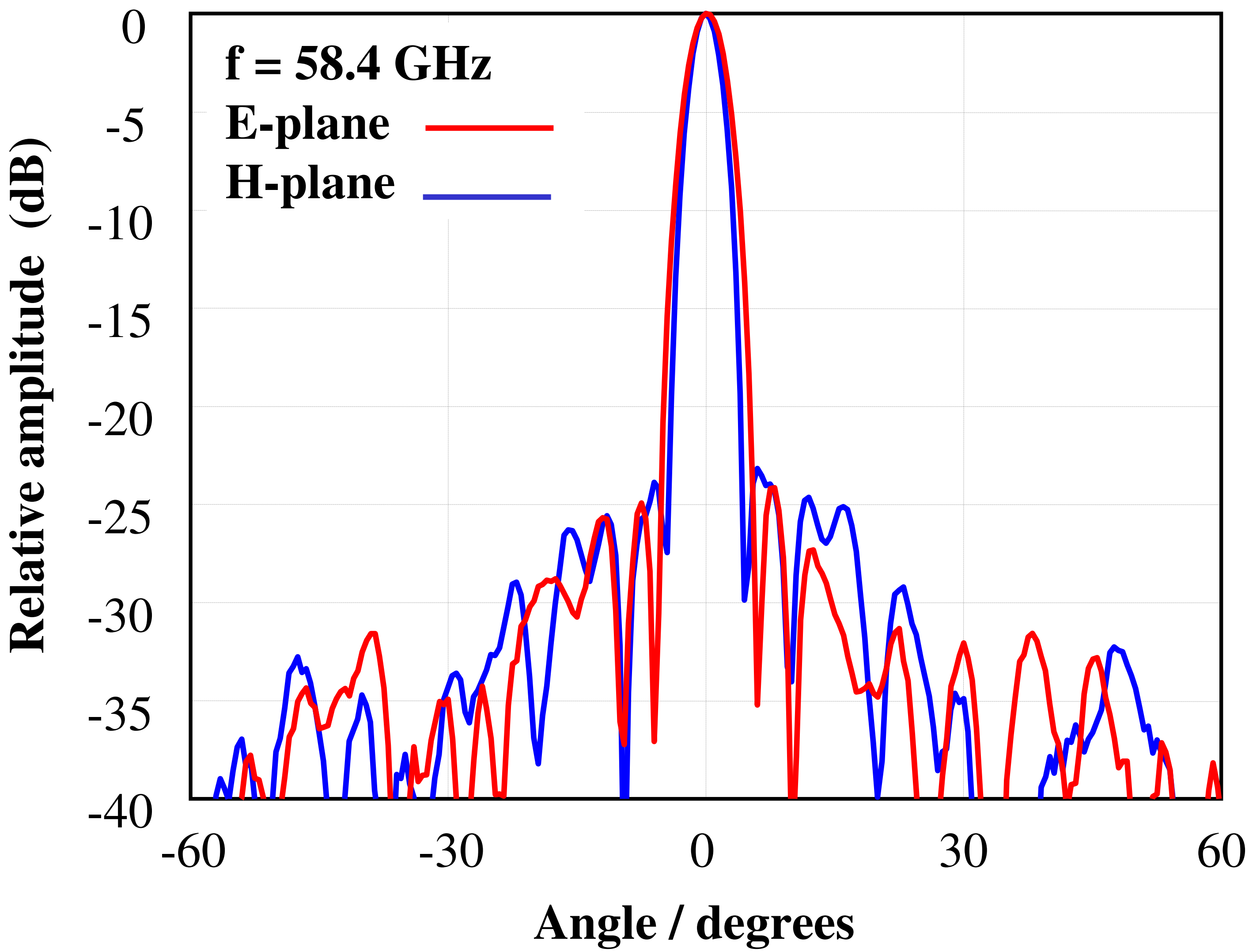
Printed and folded reflector antenna (77 GHz)



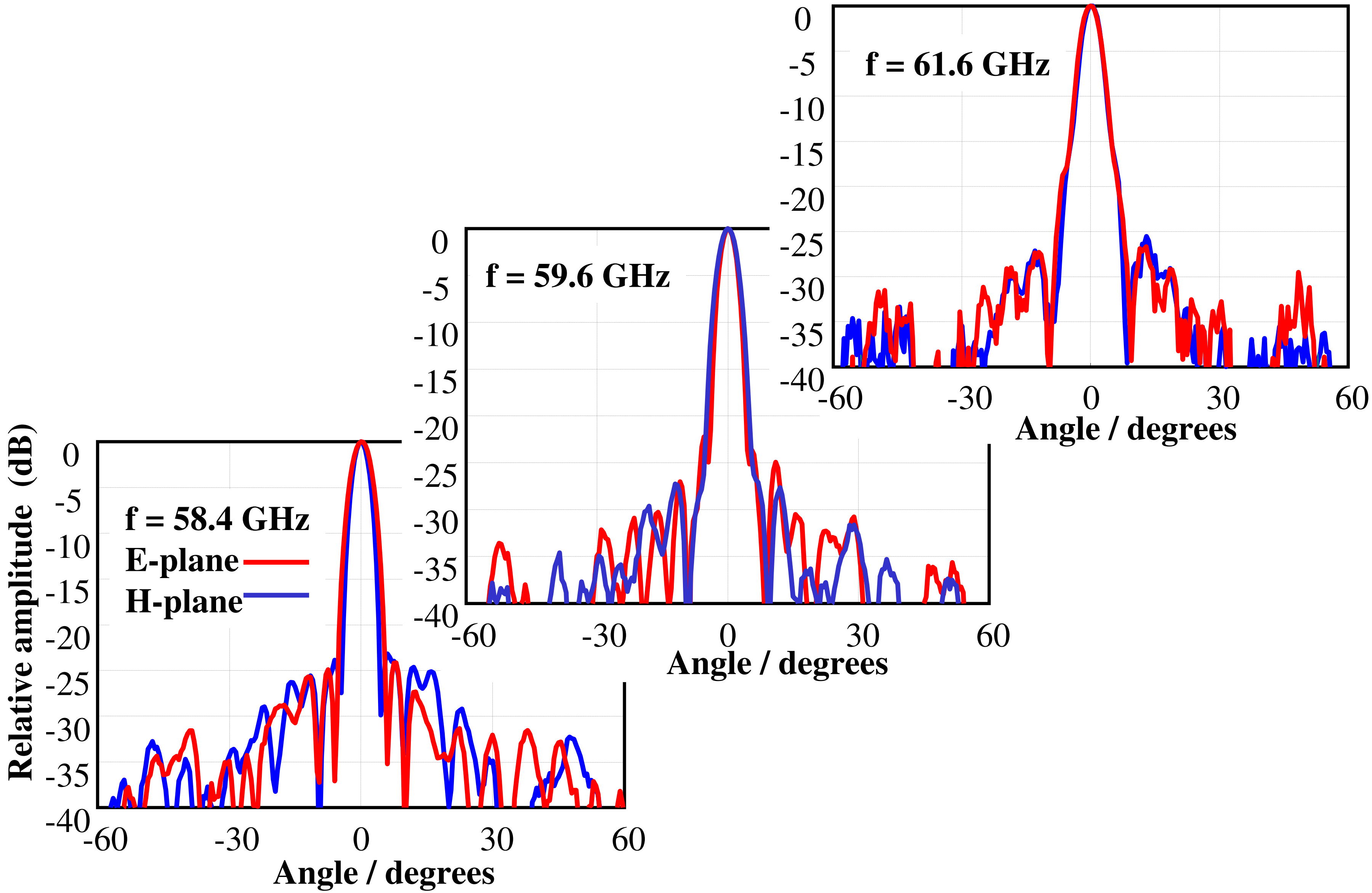




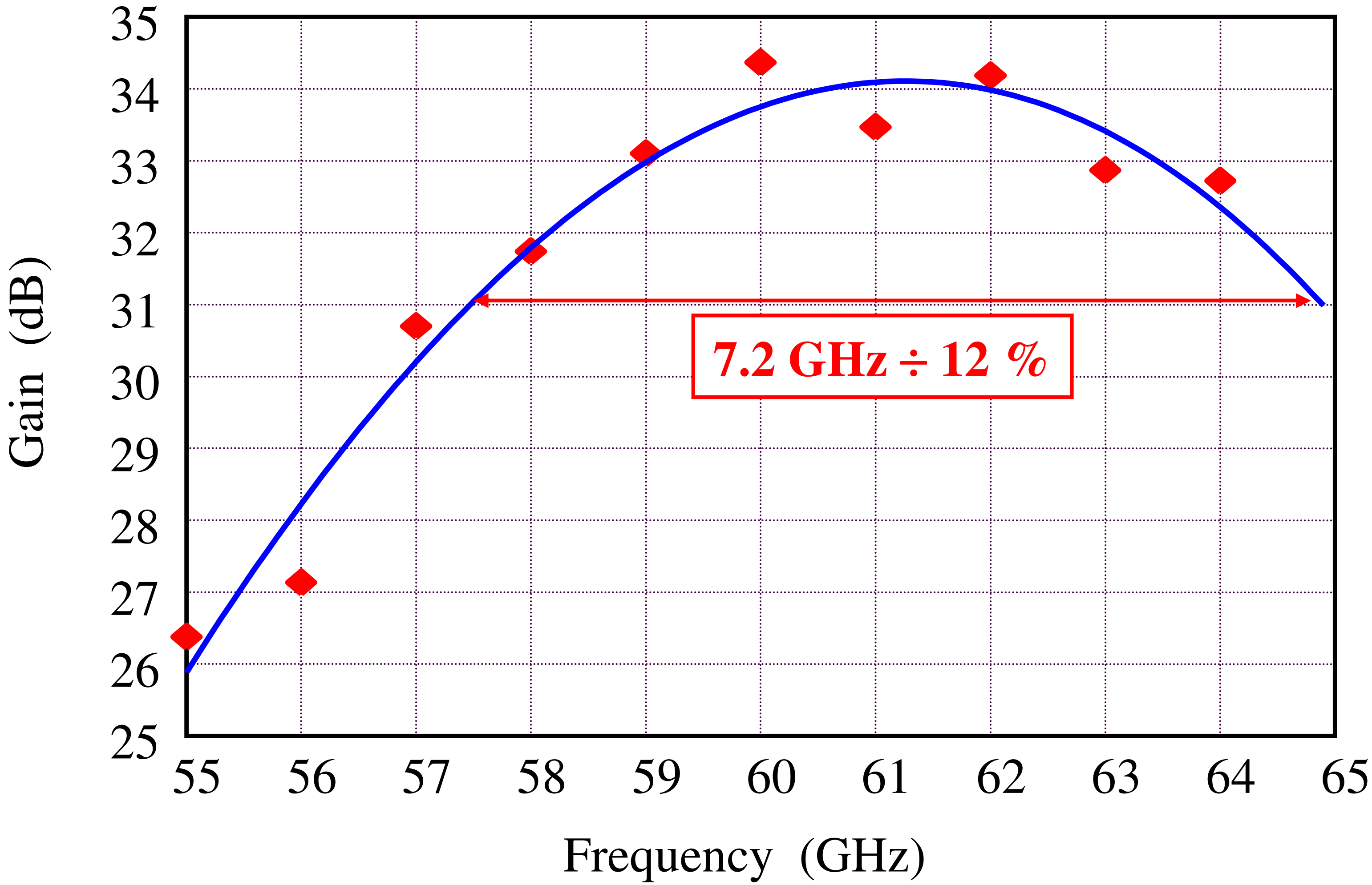
Radiation diagram of 60 GHz folded reflector antenna



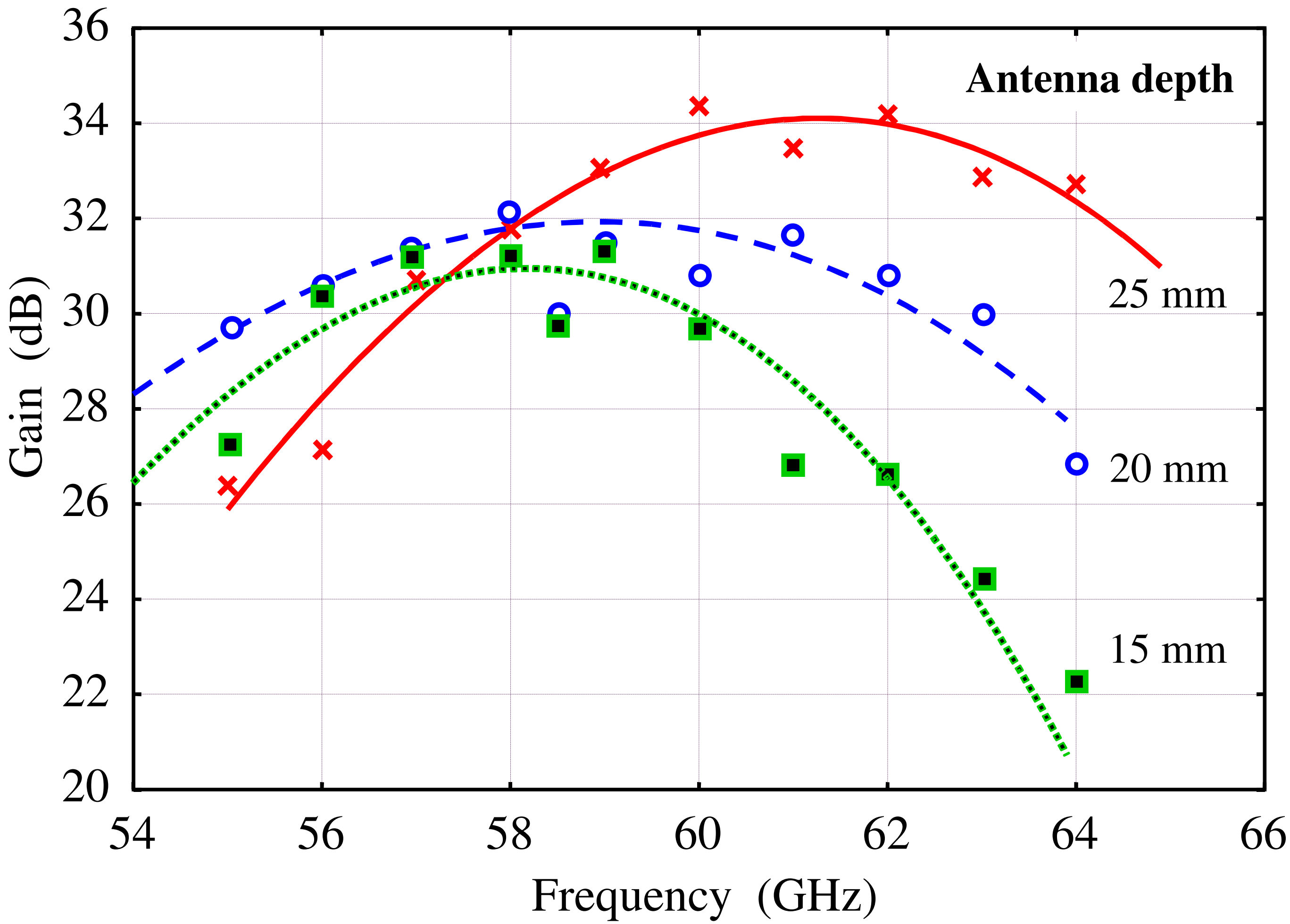
Radiation diagrams of 60 GHz folded reflector antenna for three different frequencies



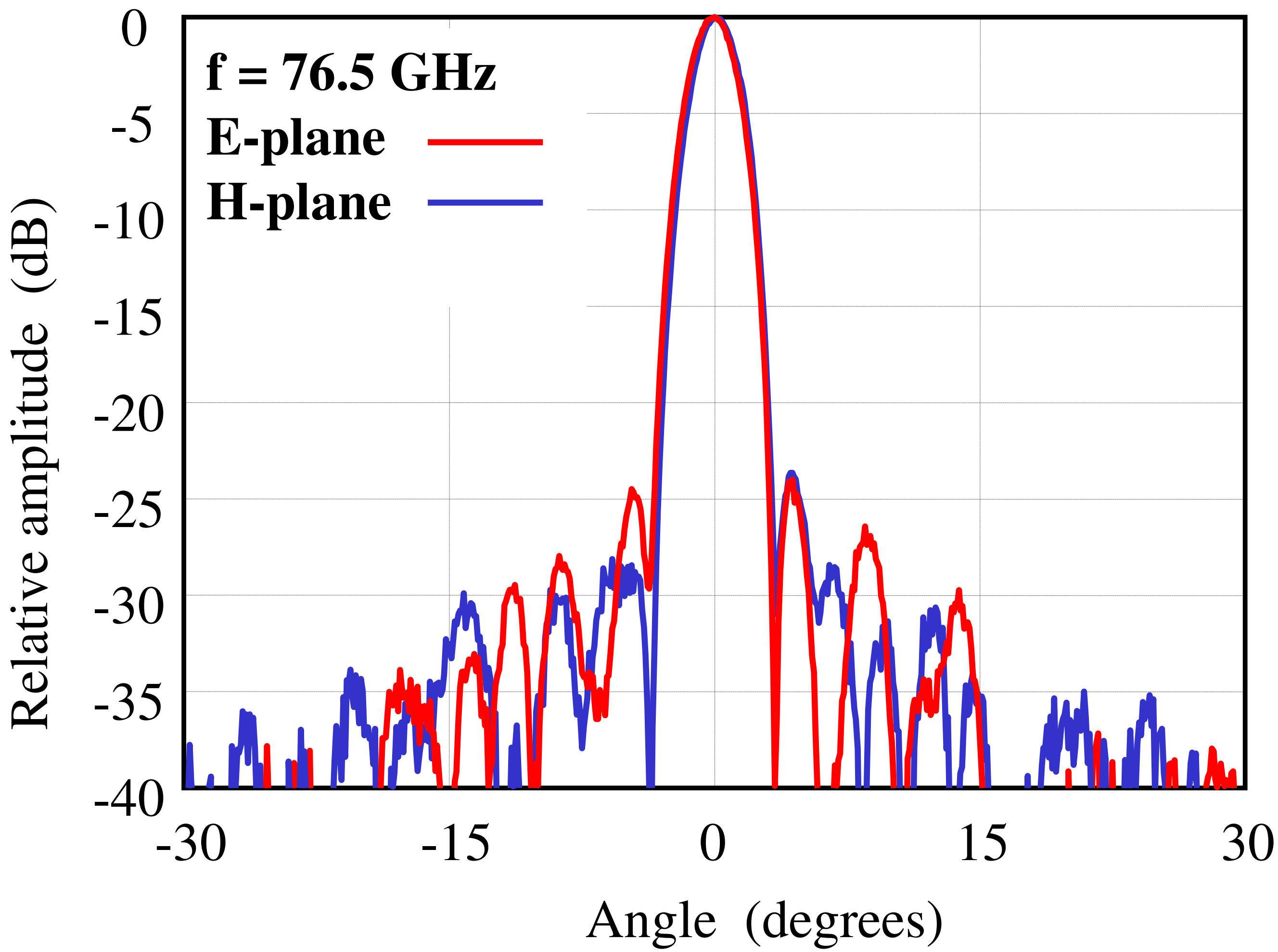
Gain of the 60 GHz antenna as a function of frequency



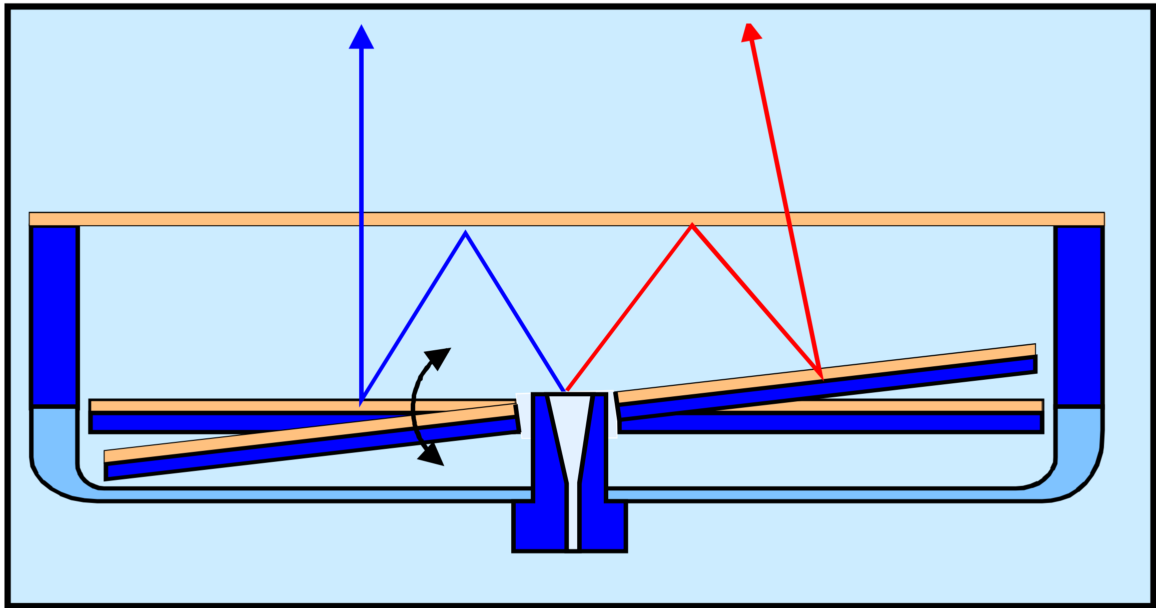
Measured gain of 60 GHz folded reflector antennas with different depths

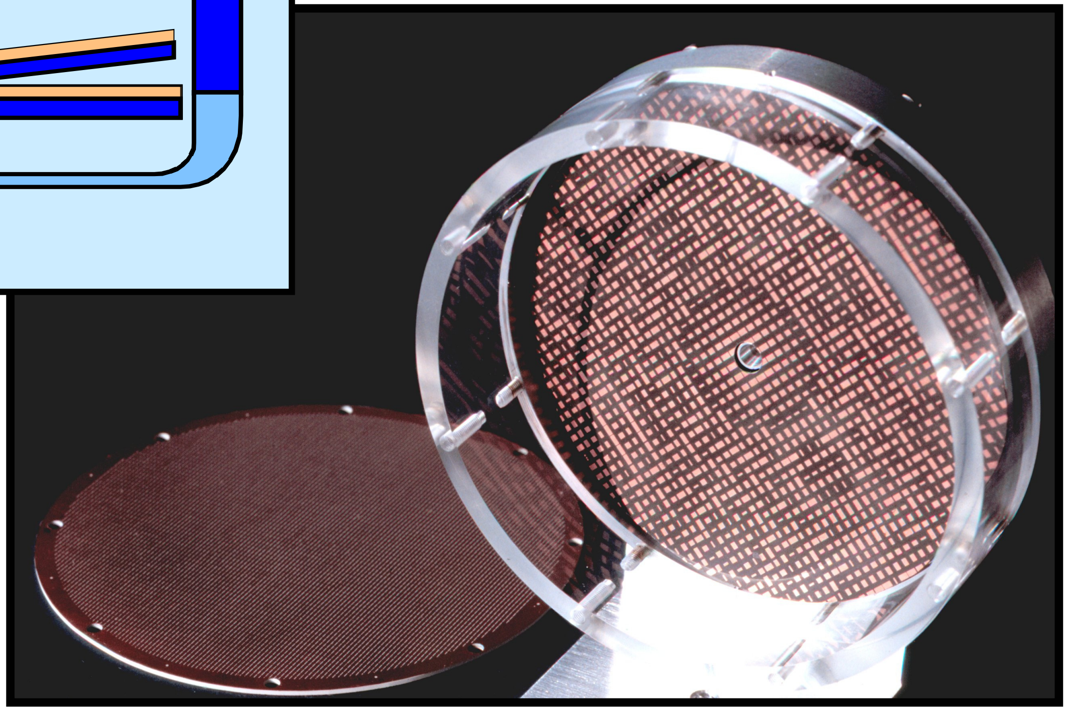


Radiation diagram of 76.5 GHz folded reflector antenna



Cross section and photograph of scanning antenna





Radiation diagrams of 76.5 GHz folded reflector antenna with different scan angles

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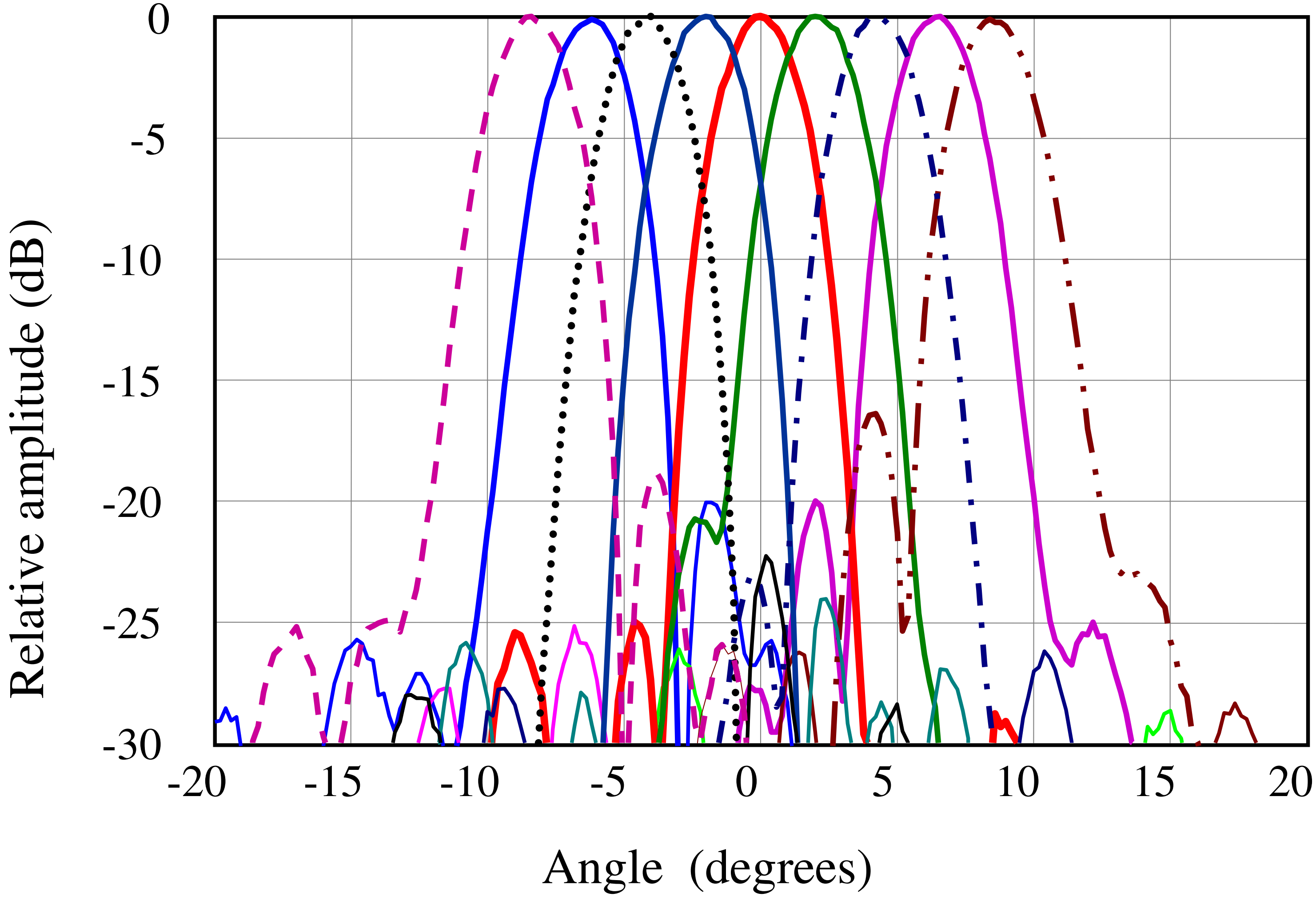
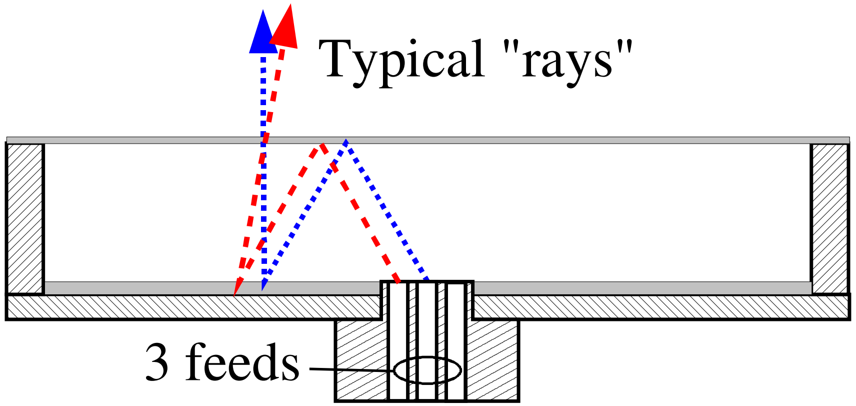
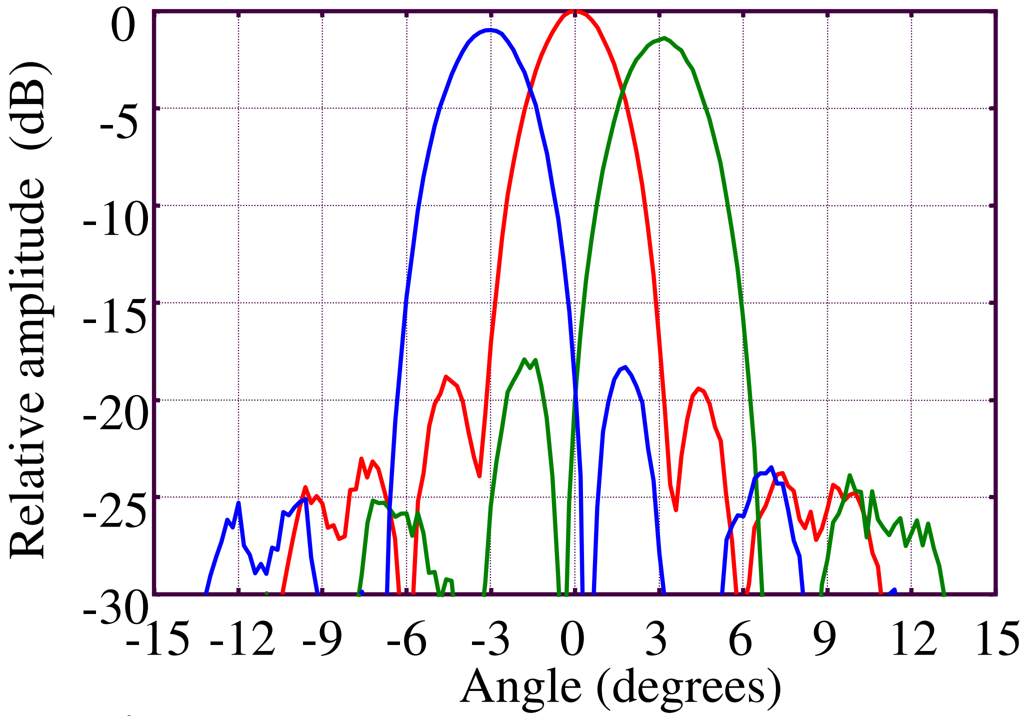
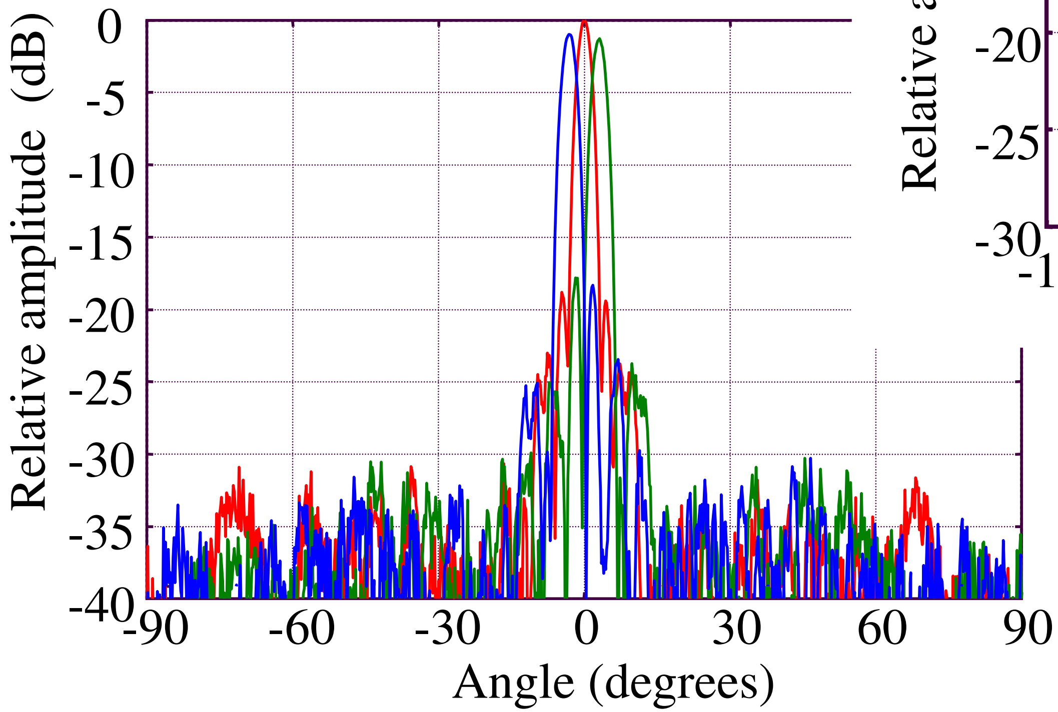


Planar folded reflector antenna with three feed points







- 76.5 GHz
- diameter 90 mm
- height 24 mm

Entwurf einer Antenne mit großem Schwenkbereich

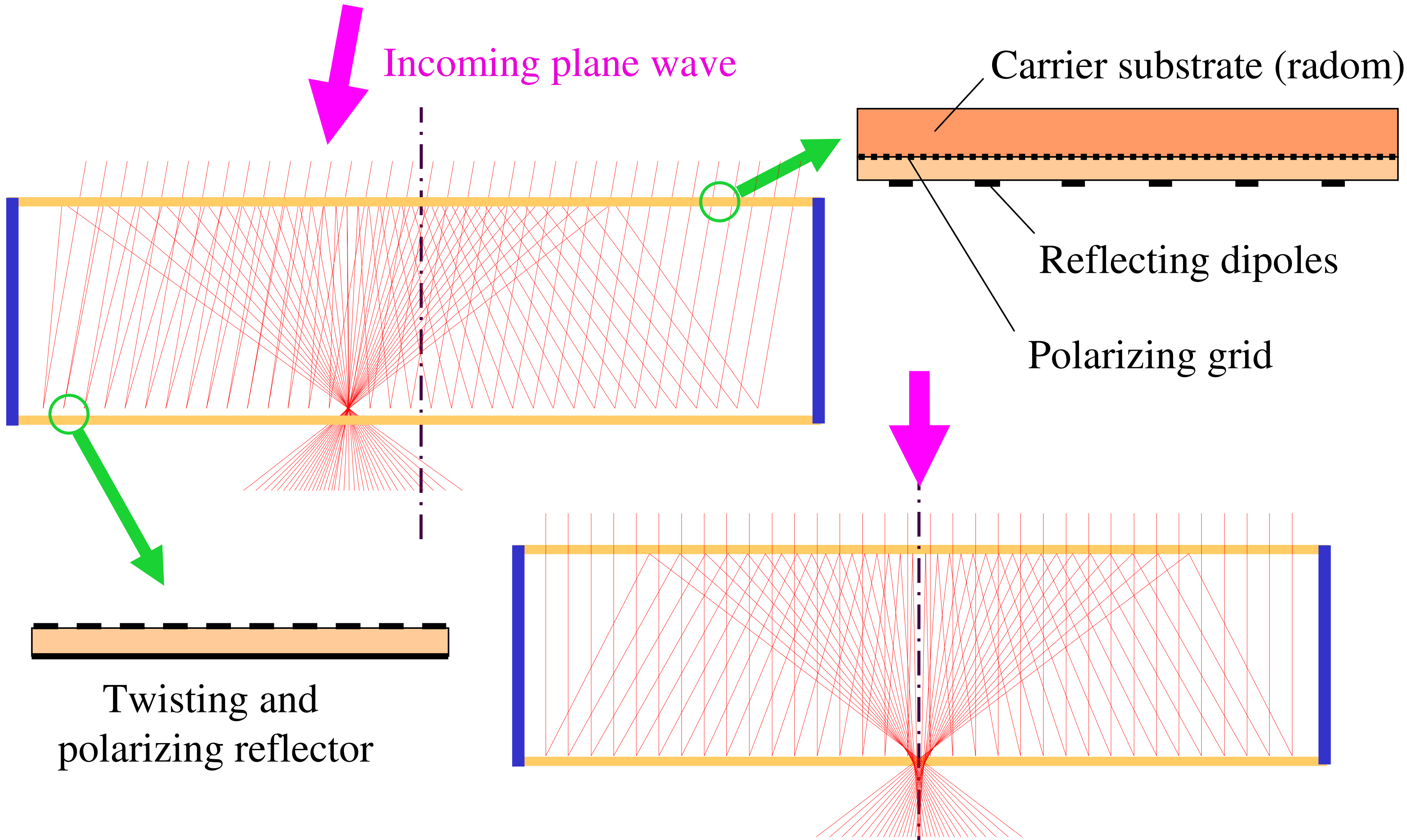
Reflektor-Antennen mit kurzer Brennweite (f/d ≈ 0.5) haben schlechte Schwenkeigenschaften

Linsen: Bifokale Linsenanordnungen
(Beide Linsen müssen geformt sein)

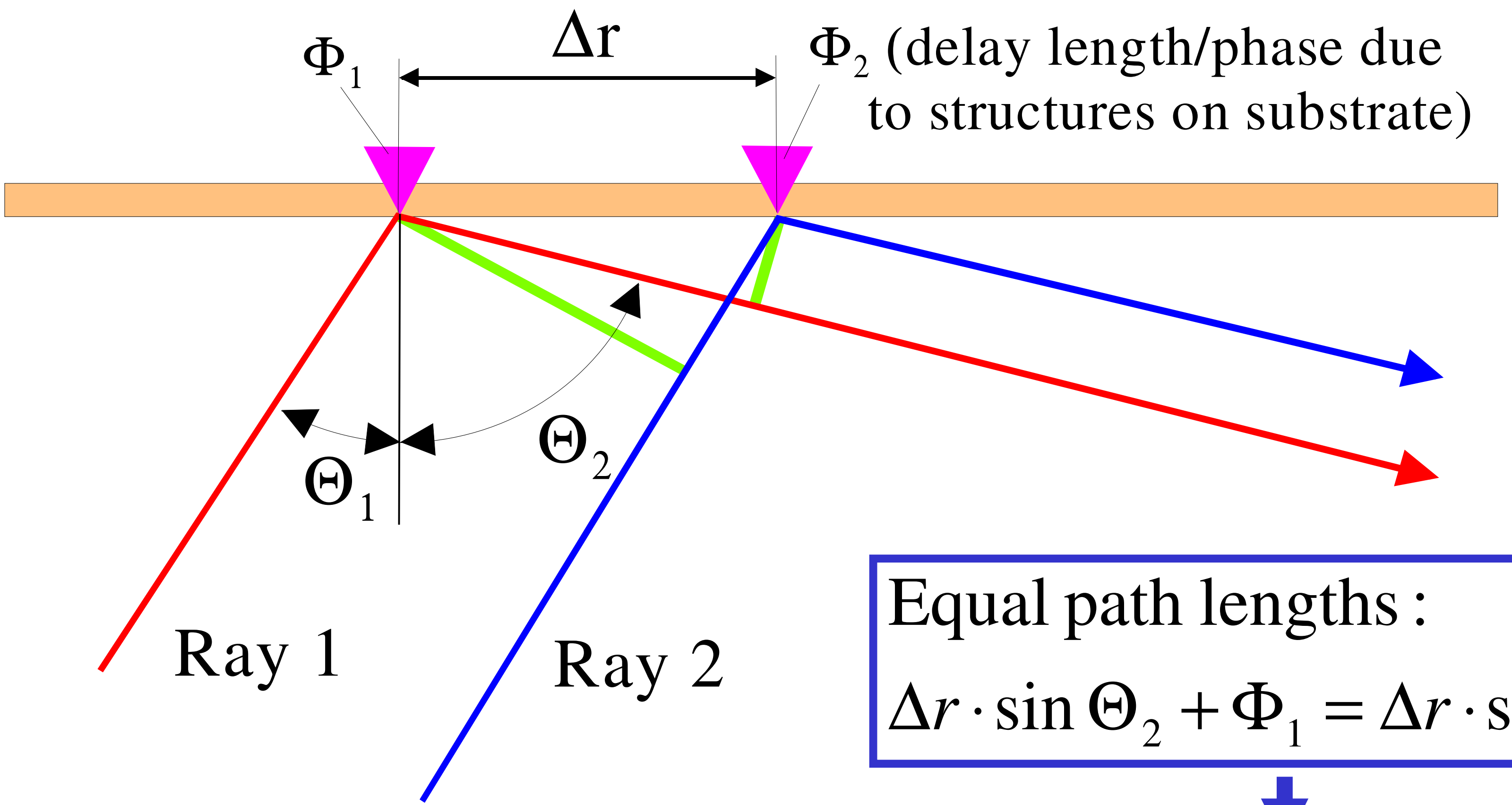
Reflektoren: Anordnungen mit zwei (geformten) Reflektoren

Hier: Antenne ist auf der Basis einer planaren und gefalteten Reflektorantenne aufgebaut.

Rays and basic setup



Calculation of reflection performance

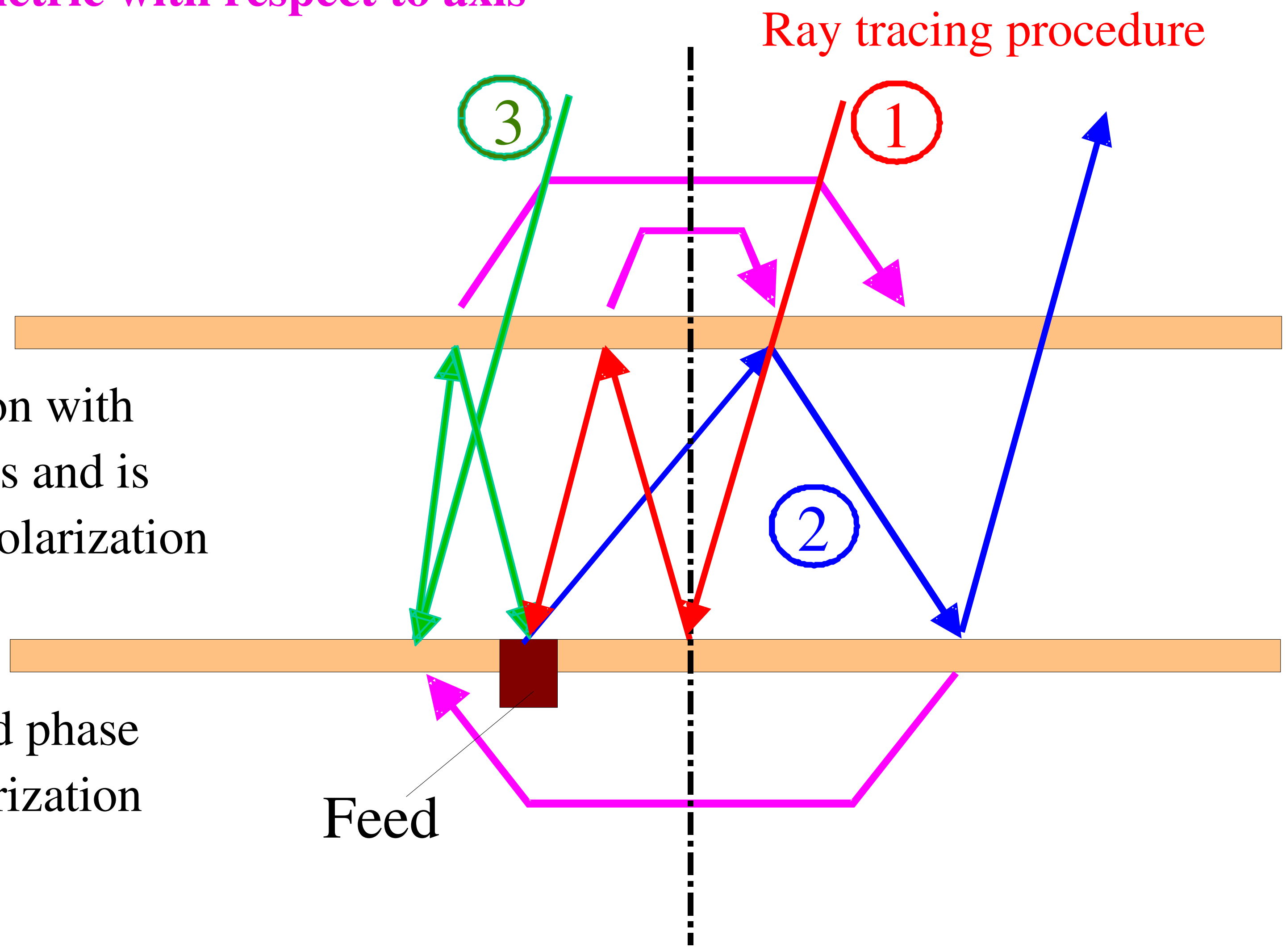


Equal path lengths:

$$\Delta r \cdot \sin\Theta_2 + \Phi_1 = \Delta r \cdot \sin\Theta_1 + \Phi_2$$

$$\sin\Theta_2 - \sin\Theta_1 = \lim_{\Delta r \to 0}\left(\frac{\Phi_2 - \Phi_1}{\Delta r}\right) = \frac{\partial \Phi}{\partial r}$$

Antenna is symmetric with respect to axis

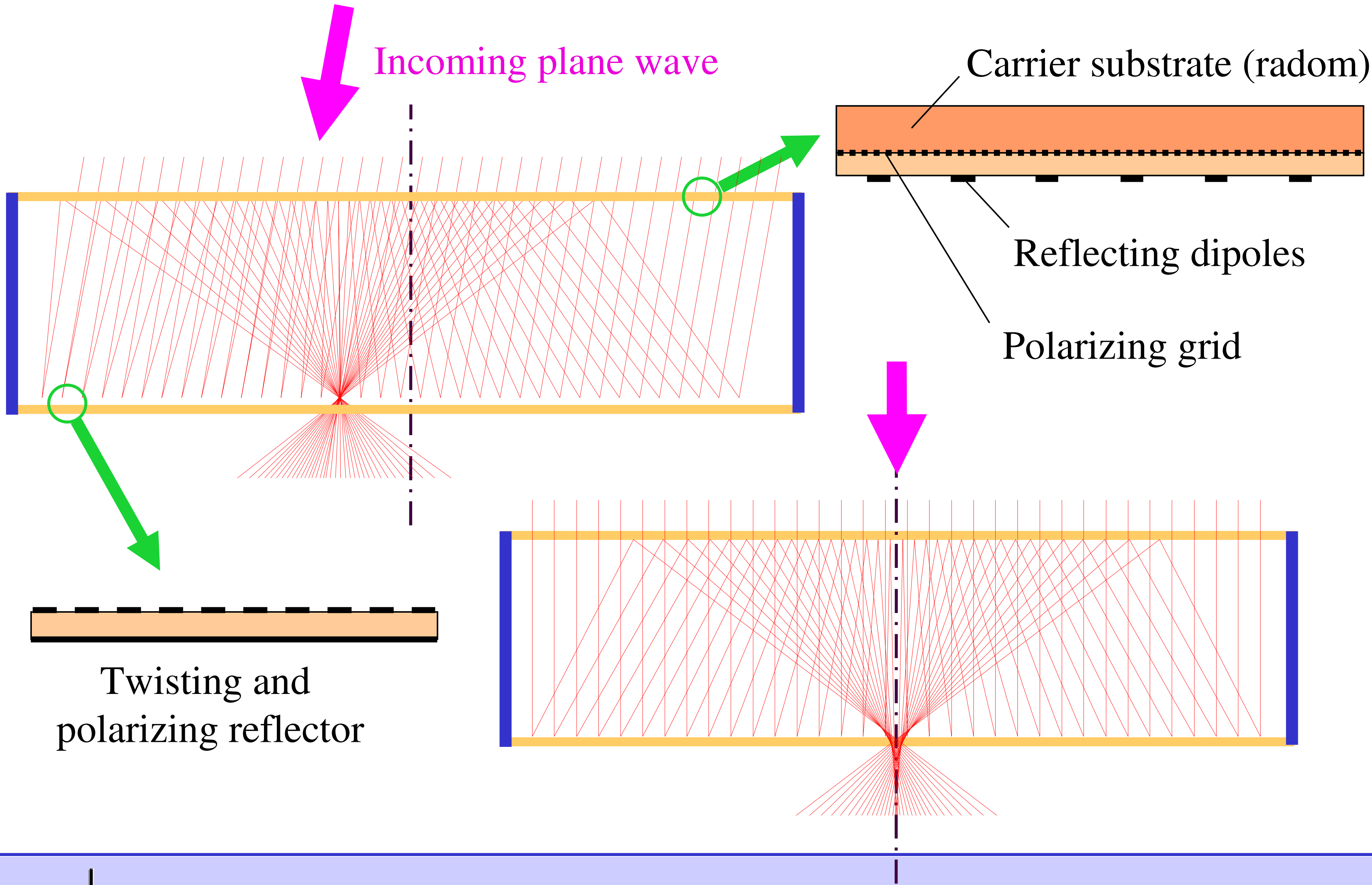


Top substrate
reflects one polarization with controlled phase angles and is transparent for other polarization

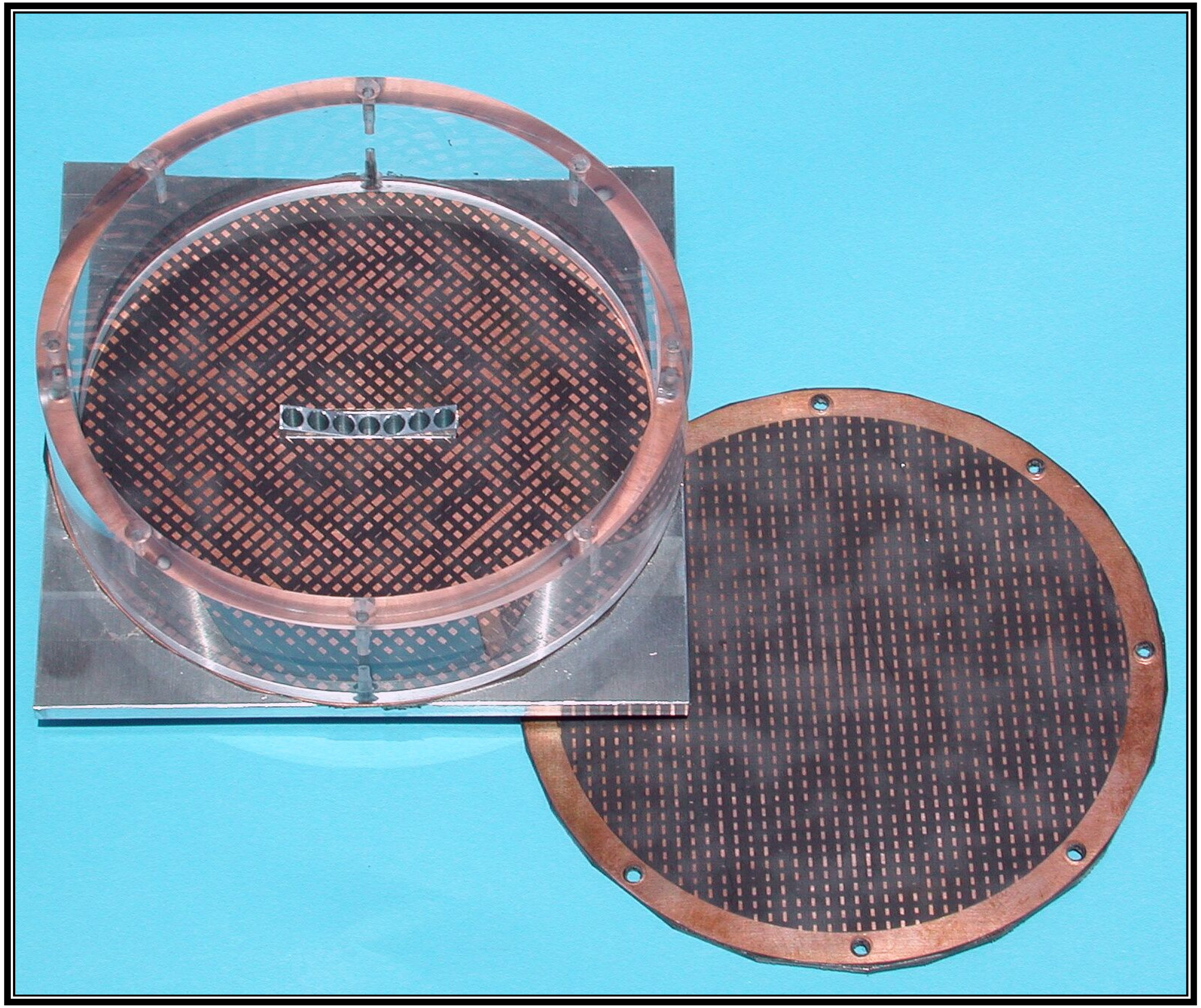
Bottom substrate
reflects with controlled phase angles and twists polarization

- Berechnung und Kombination von zwei Datensätzen (dΦ/dr) durch "Ray-Tracing" für beide Substrate
- Approximation der Daten durch ein Polynom
- Integration der Polynome $\Rightarrow$ Phasenverteilung auf beiden Reflektoren
- Optimierung der Polynomkoeffizienten bezüglich
  - geschwenktem Strahl
  - senkrechtem Strahl
- Überprüfung des Designs durch Berechung des Strahlenverlaufs und des Fernfelds (dadurch auch beste Feedposition bei einem bestimmten Schwenkwinkel)
- Auswahl der Dipolabmessungen aus vorberechneten Daten

Rays and basic setup



Photograph of of bifocal reflector antenna (± 13.5° scan range)



E- and H-plane radiation diagram of bifocal antenna at 76.5 GHz

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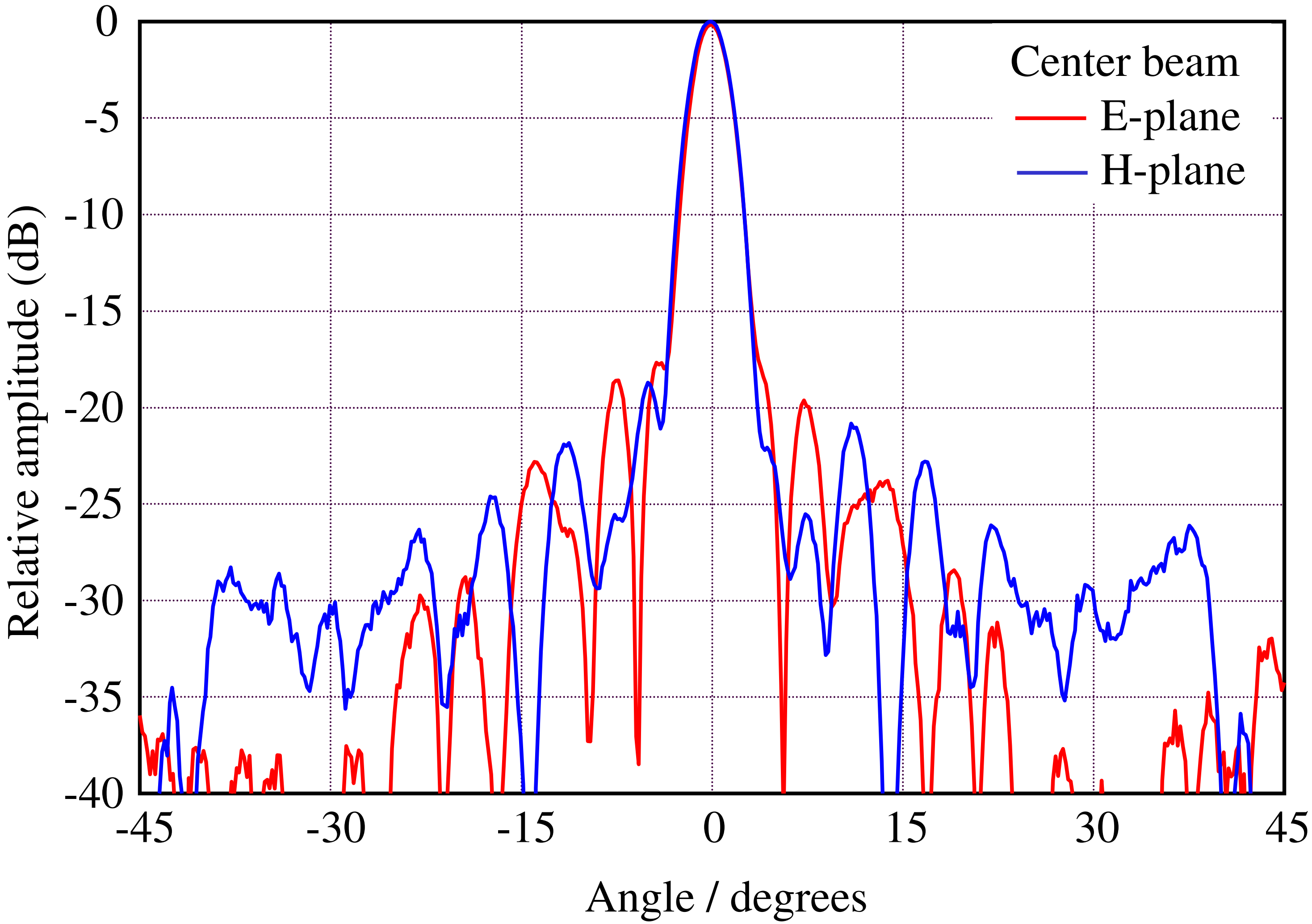
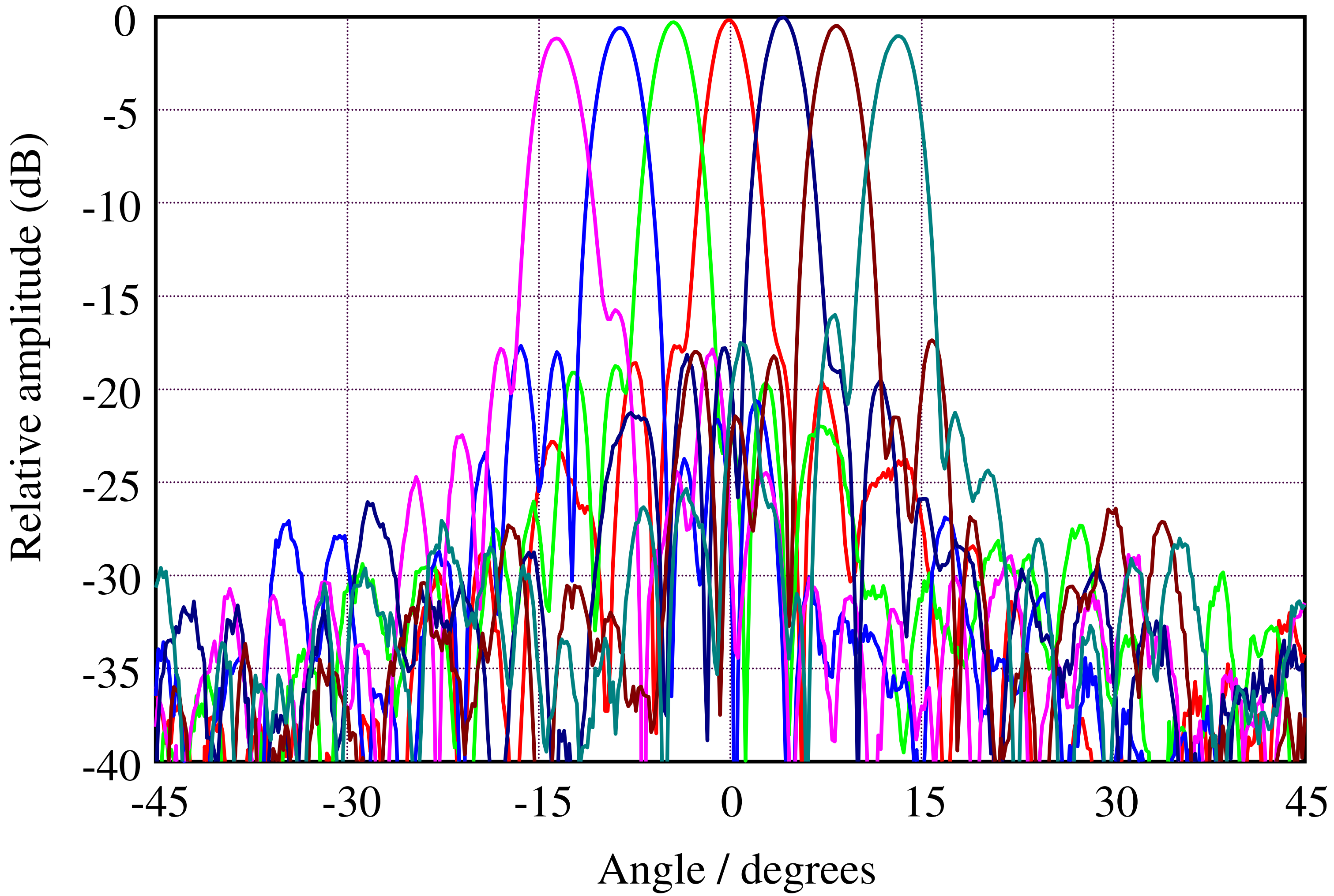
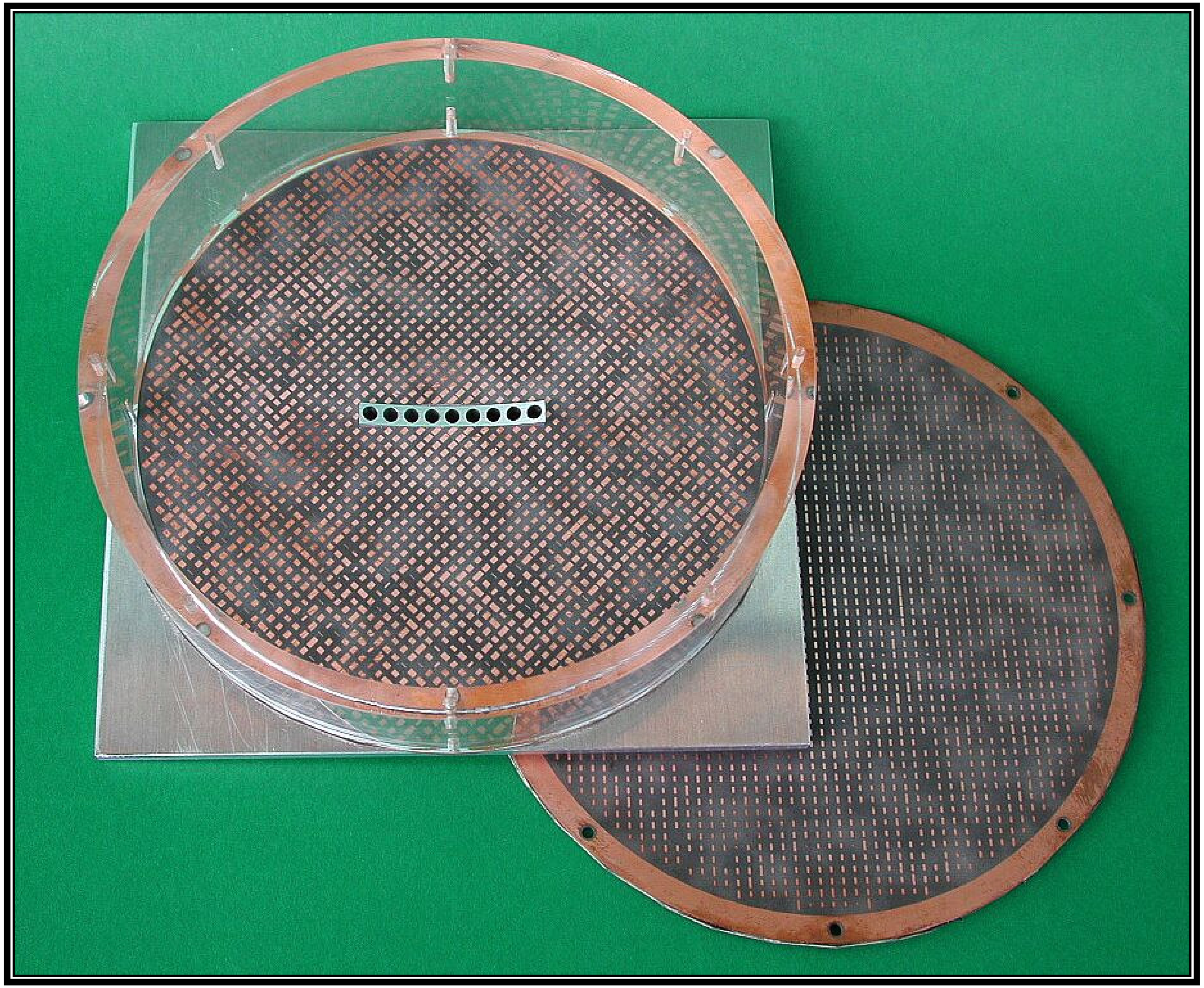


E-plane radiation diagram of bifocal antenna at 76.5 GHz



Photograph of bifocal reflector antenna (± 30° scan range)



E-plane radiation characteristics of wide angle bifocal reflector antenna (76.5 GHz)

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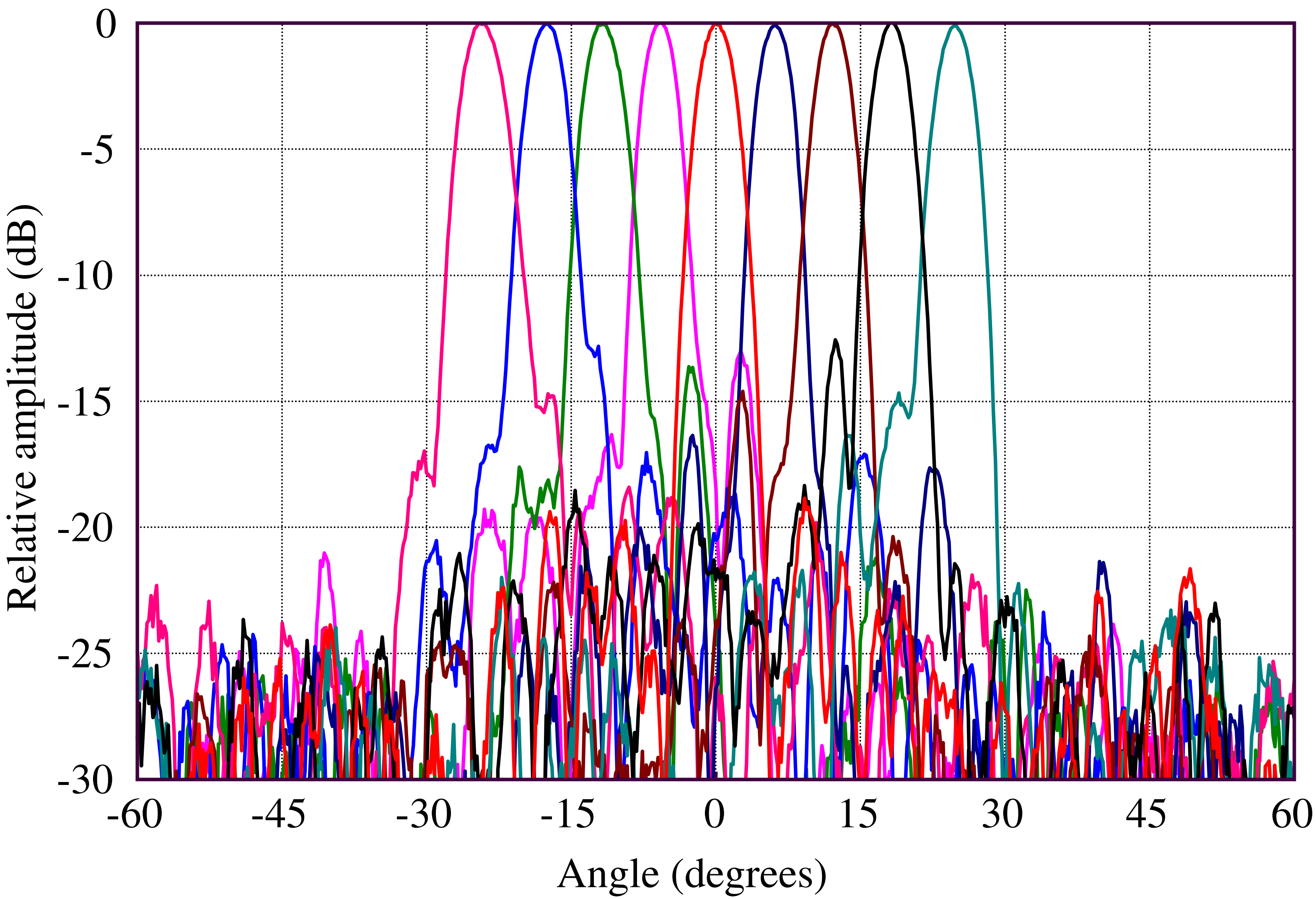
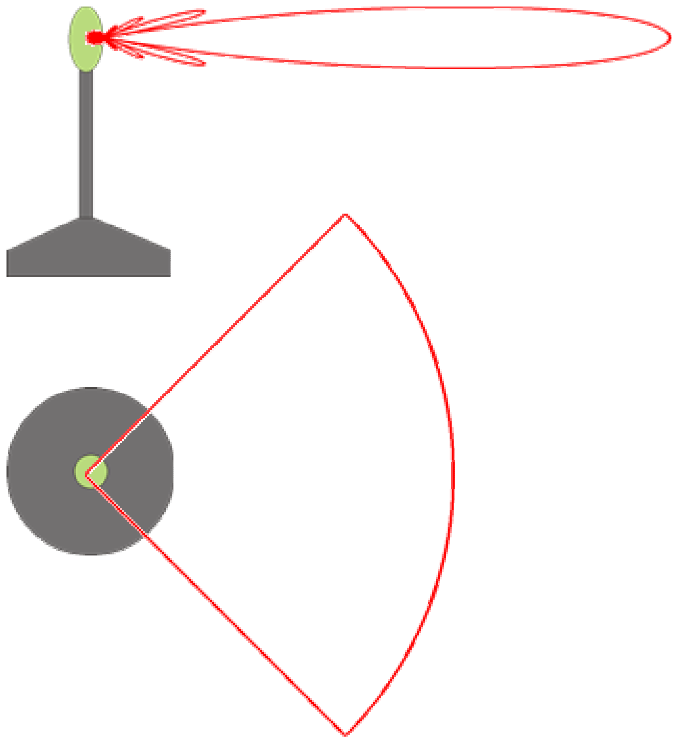
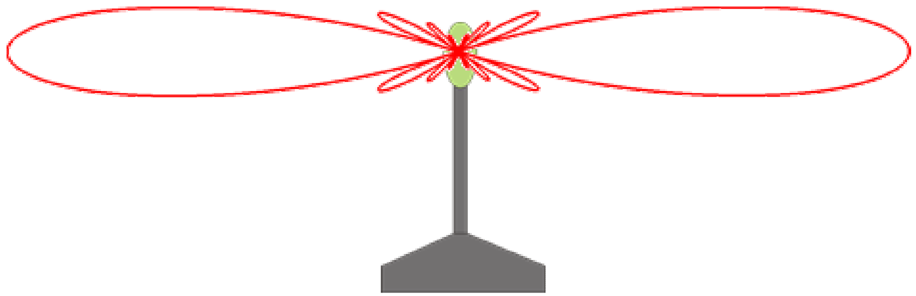


MM-Wave Antennas for Point-to-Point/Multipoint Applications

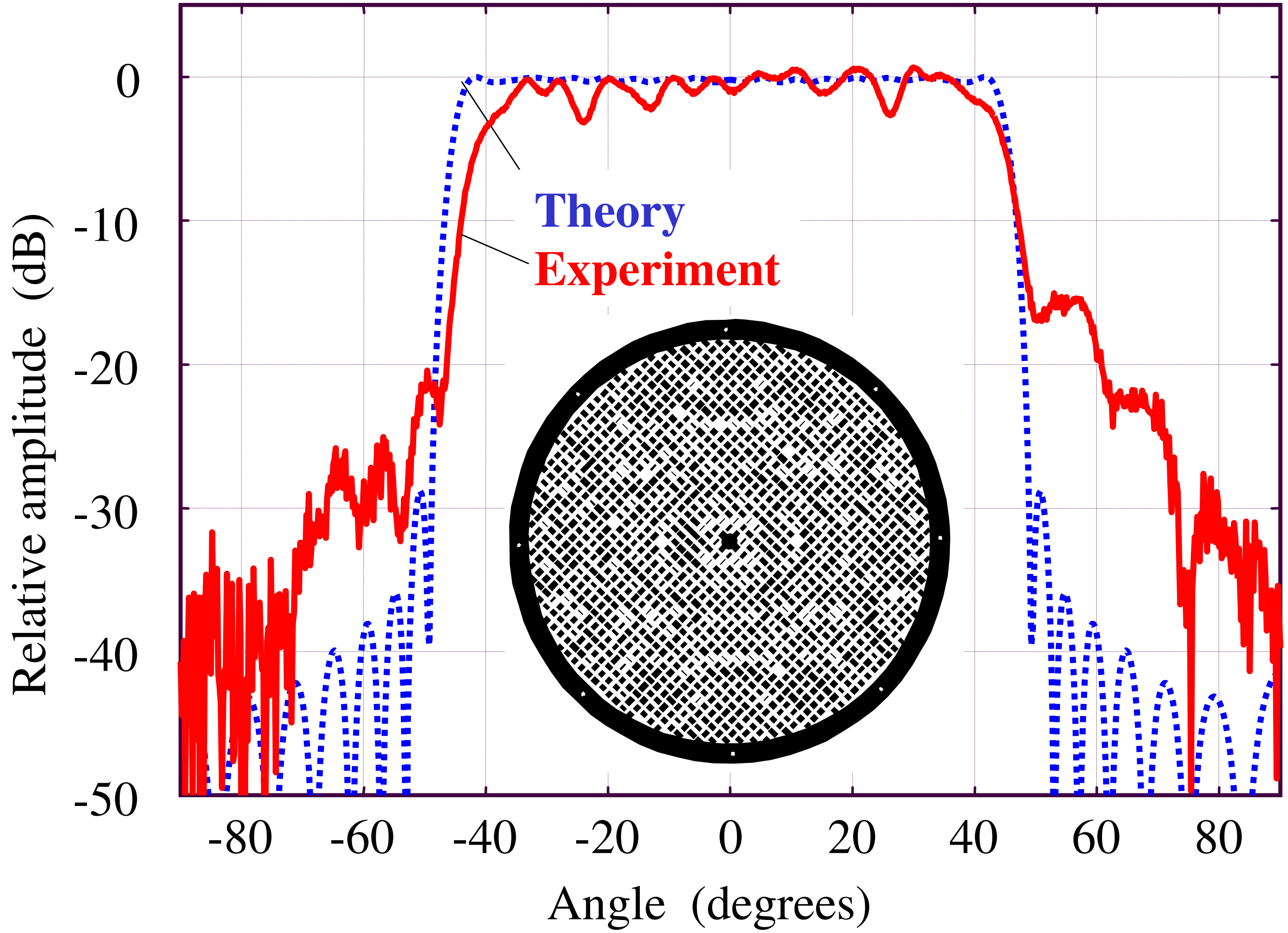
Sector Antenna



Omnidiectional Antenna



Reflector layout and sector diagram of a folded reflector sector antenna (60 GHz)



Elevation diagram of a folded reflector sector antenna (60 GHz)

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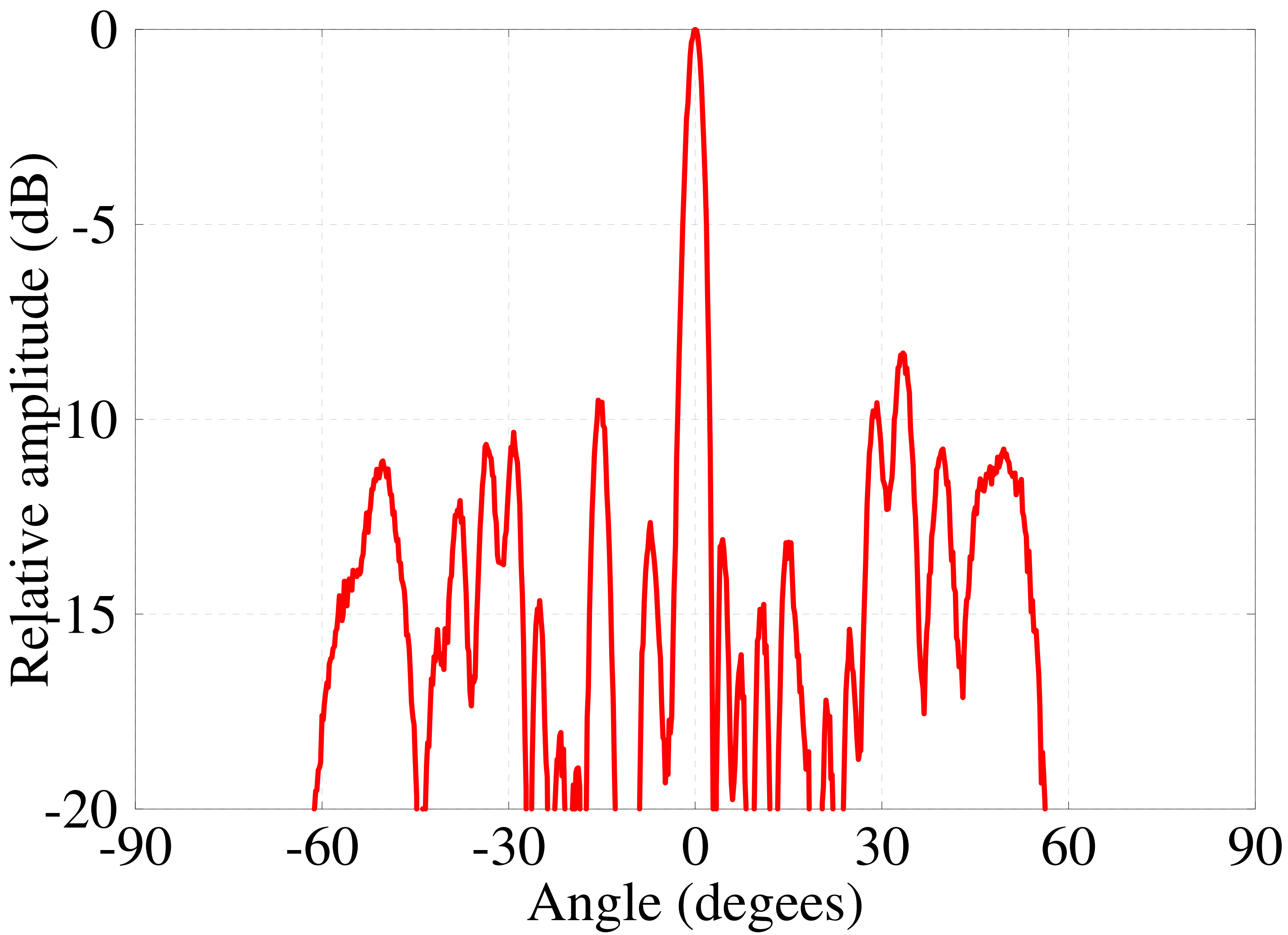
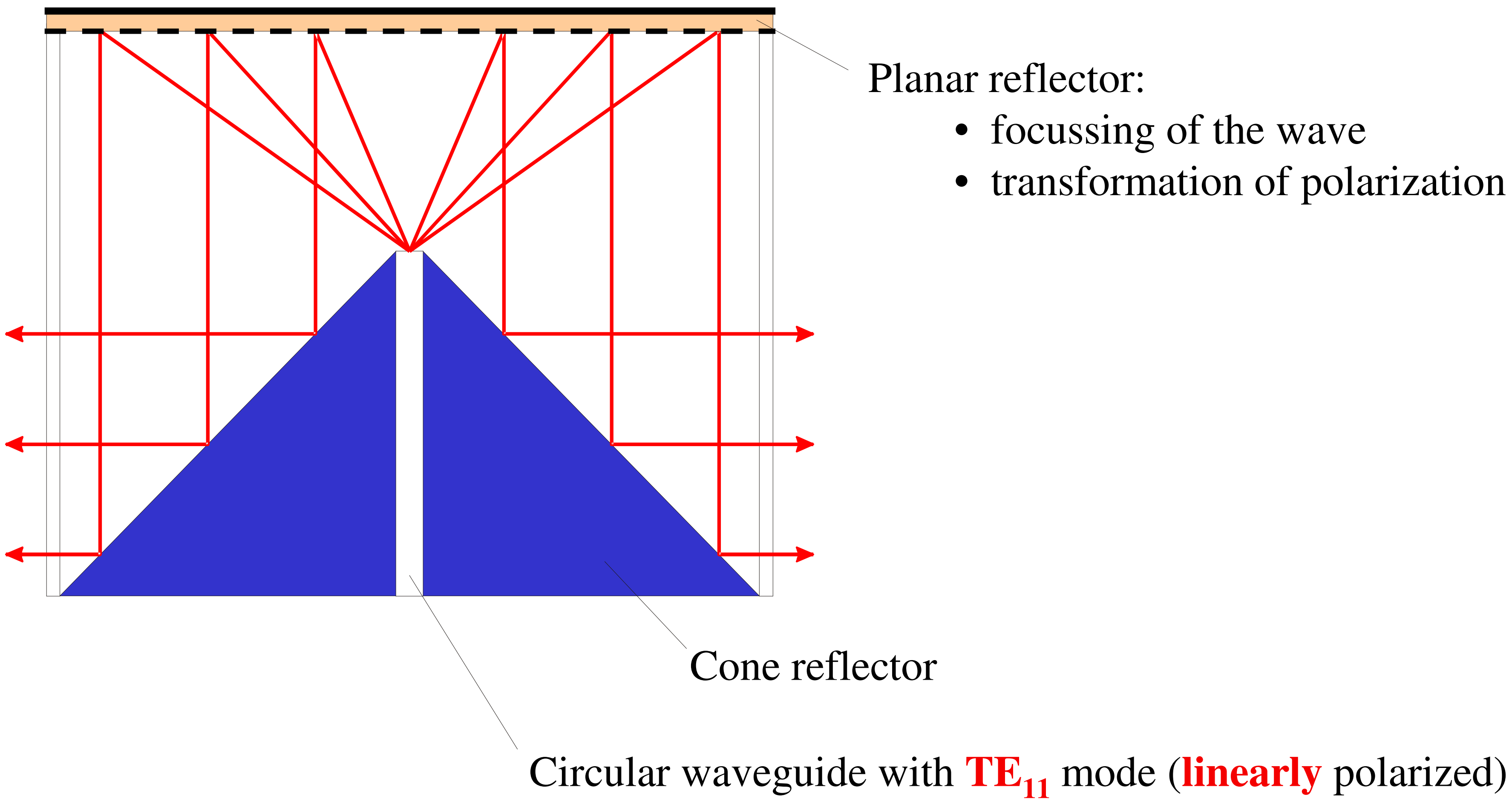
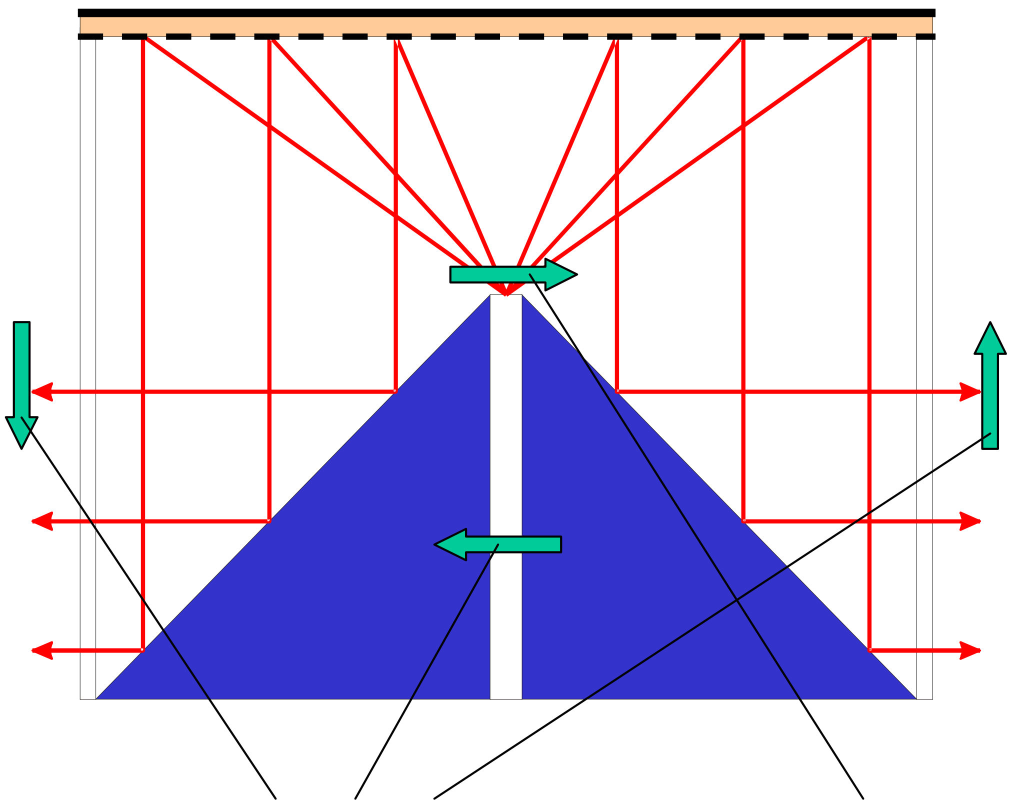


Basic principle of an omnidirectional antenna with planar reflector

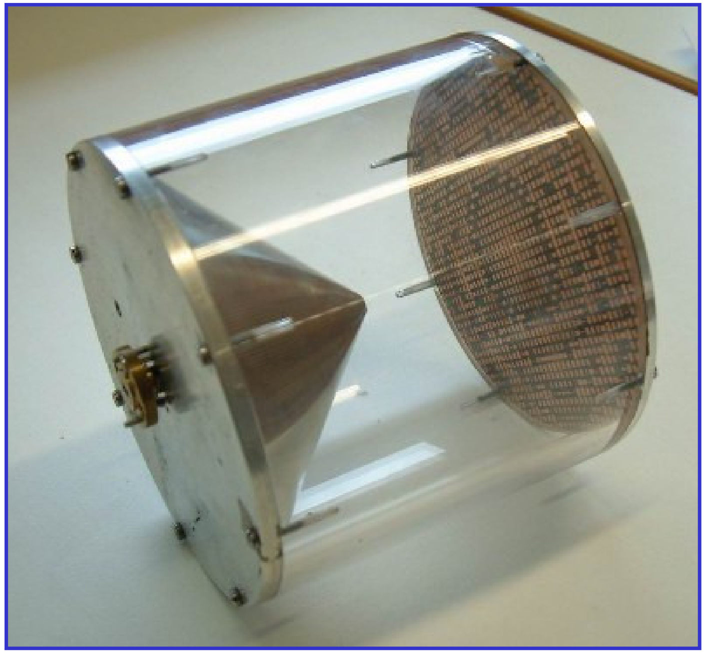


Omnidirectional Antenna: Change in Polarization



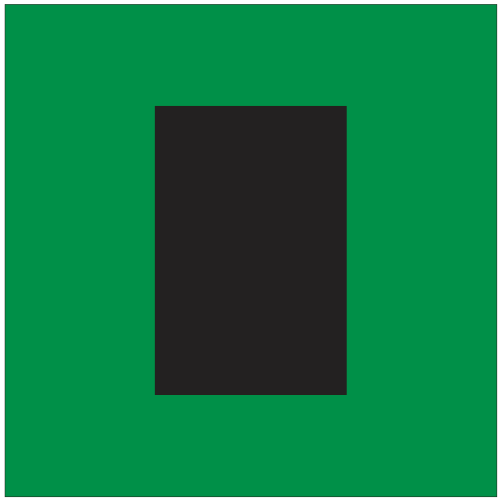
electric field vector
after reflection

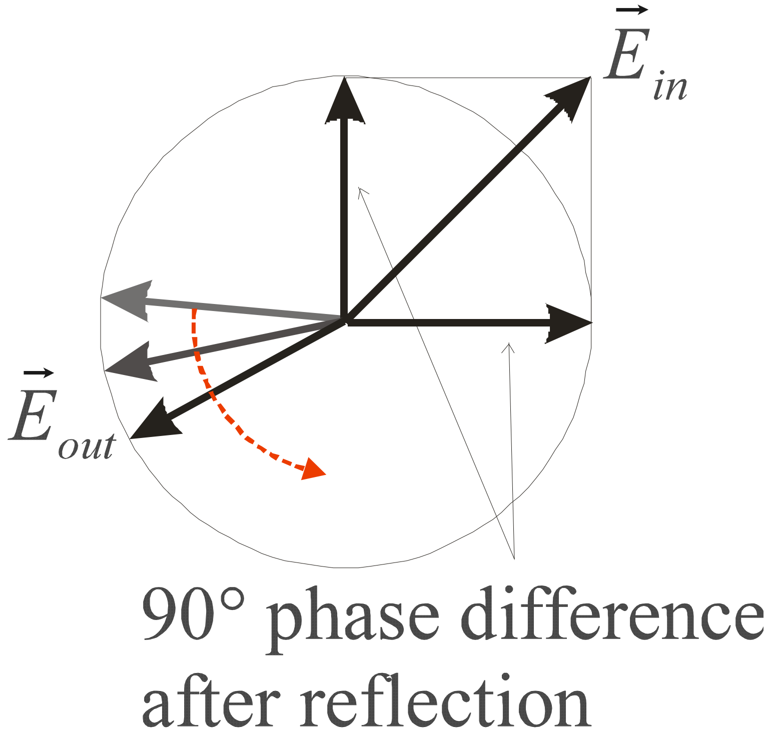
electric field vector
in the feed apertur
(fundamental TE_{11}-mode)



Omnidirectional Antenna: Polarization Transformation

linear polarization ➡ circular polarization





Radiation diagrams of an omnidirectional antenna with circular polarization (60 GHz)

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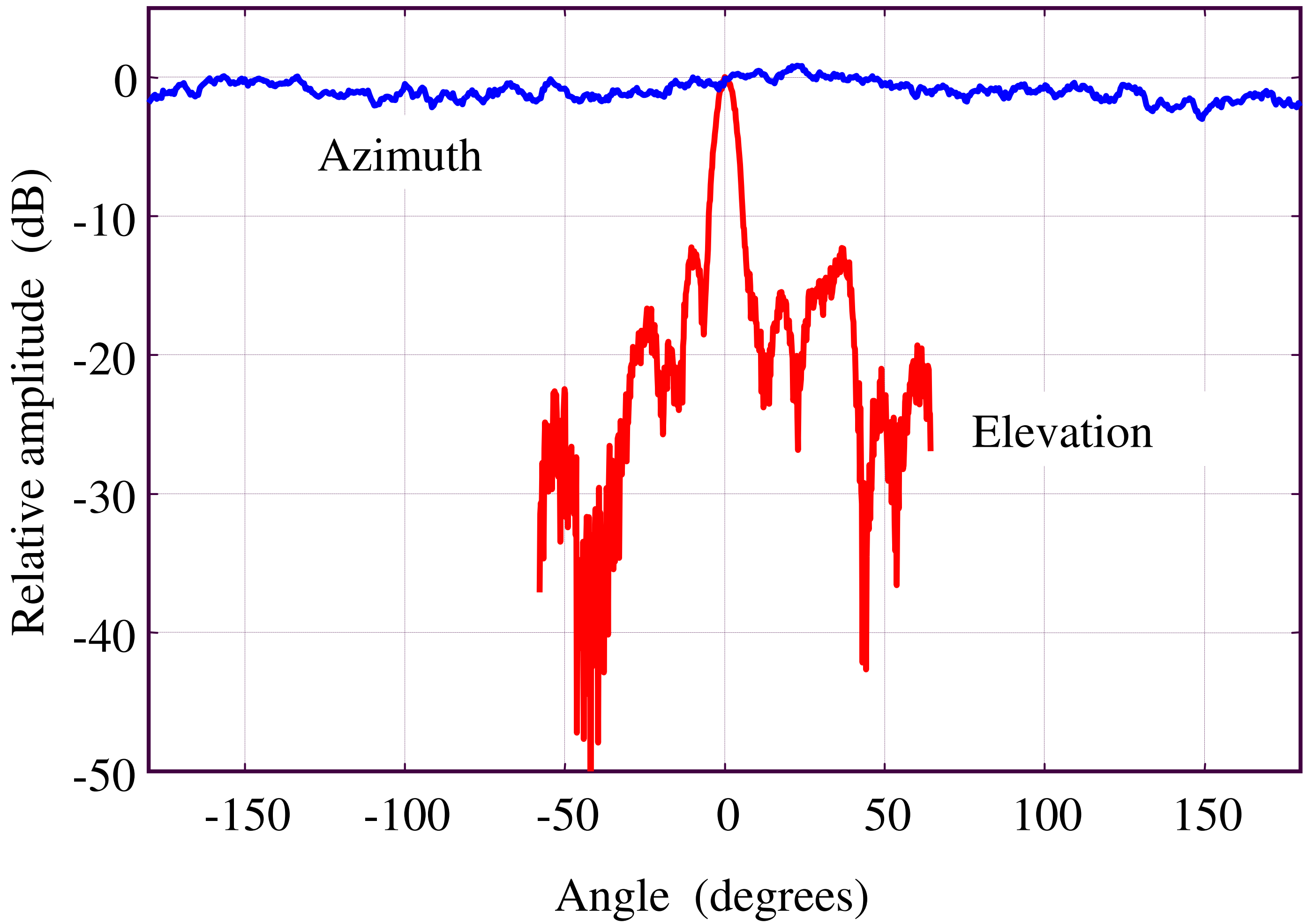

Omnidirectional Antenna: Polarization Transformation

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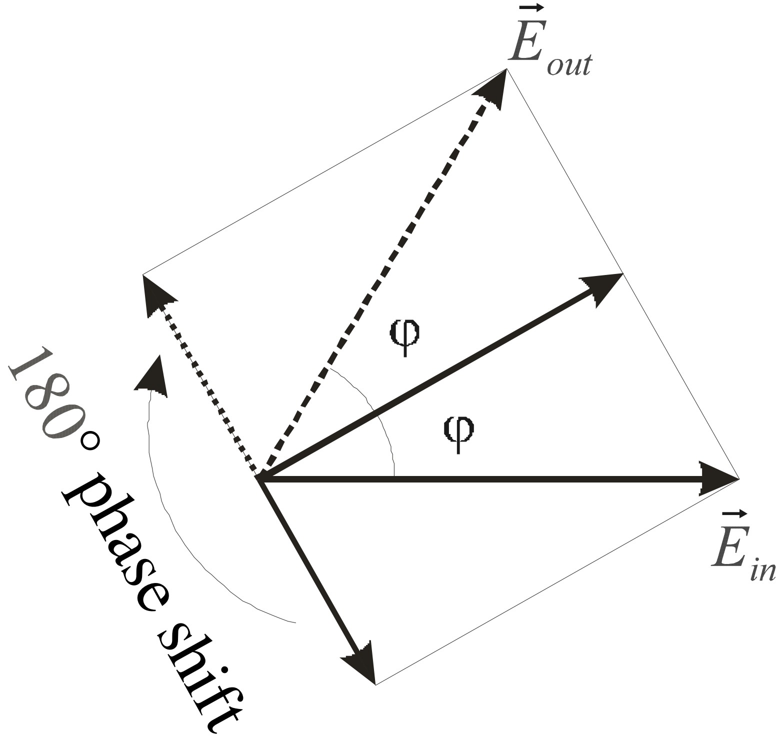
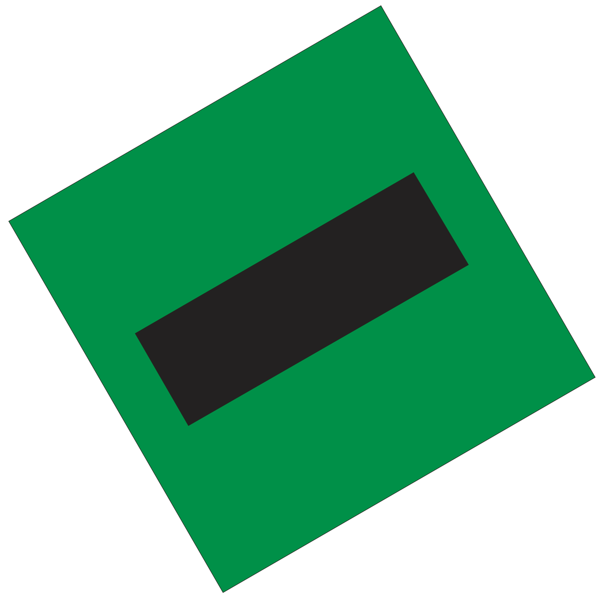
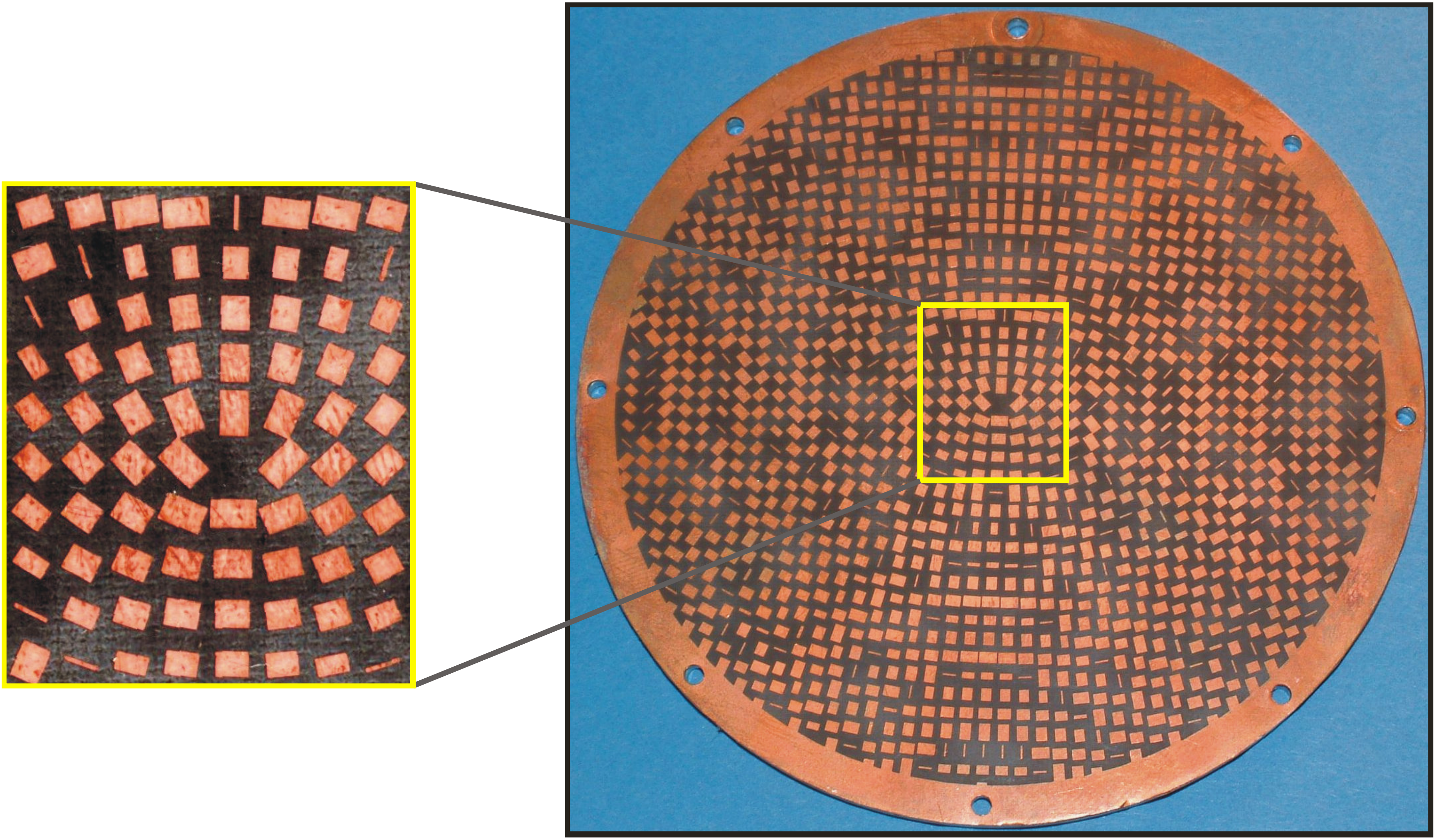
linear polarization → linear polarization rotated by 2φ





Layout of an omnidirectional antenna with linear polarization (60 GHz)



Radiation diagrams of an omnidirectional antenna with linear polarization (60 GHz)

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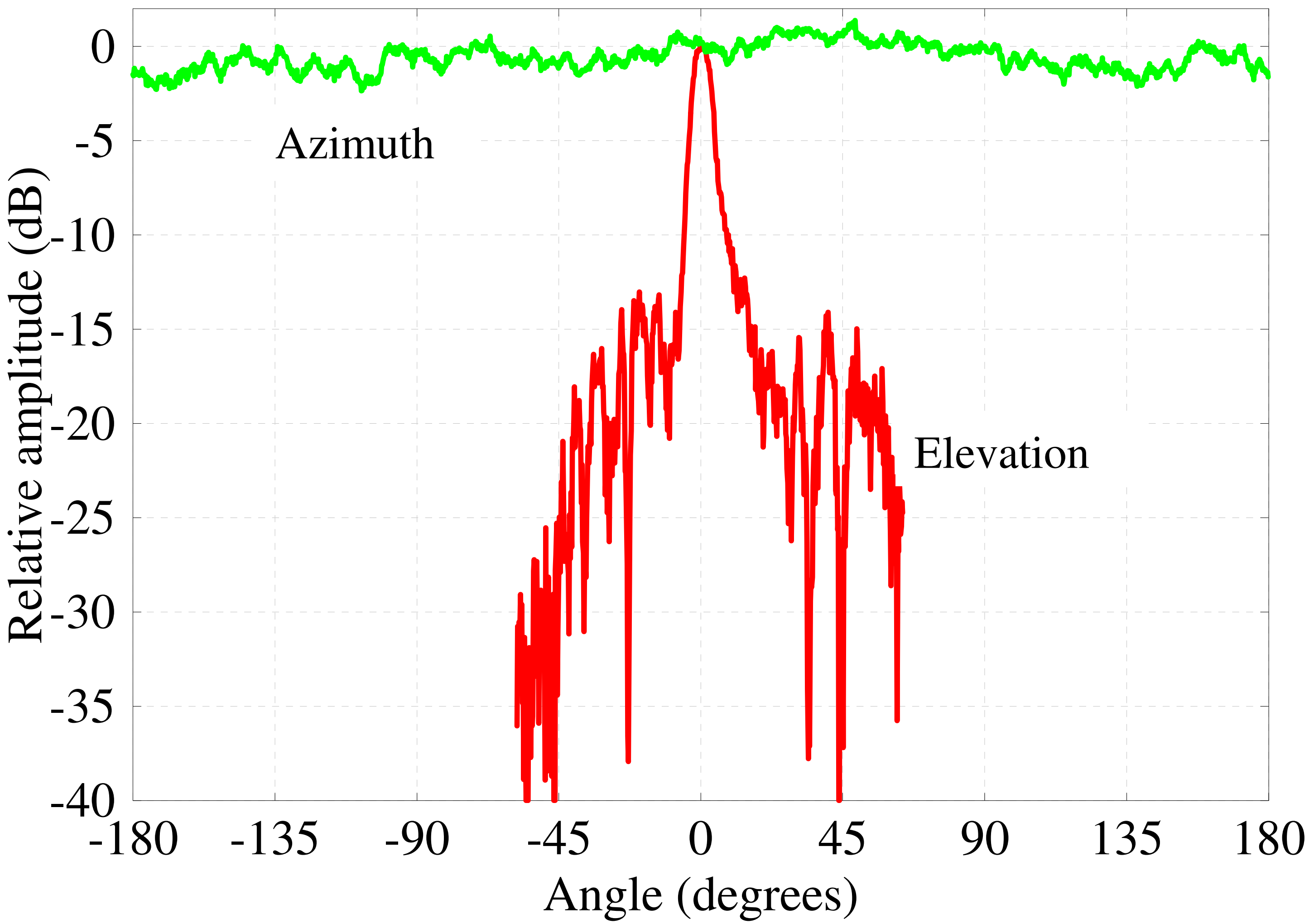

Zusammenfassung

Reflektionsarrays, die in einer gefalteten Struktur aufgebaut werden können
- weisen geringe Verluste auf
- haben eine geringe Bautiefe
- sind potenzielle Low-Cost-Antennen

und sind anwendbar in der
- Kommunikation (z.B. Funknetzwerken, Point-to-Point/Multipoint-Verbindungen)
- Sensorik (z.B. Kfz-Radar)

Danksagung:
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