Modularbeit Hohlleiterschlitzantenne

Hochschule München - Antennen und Wellen

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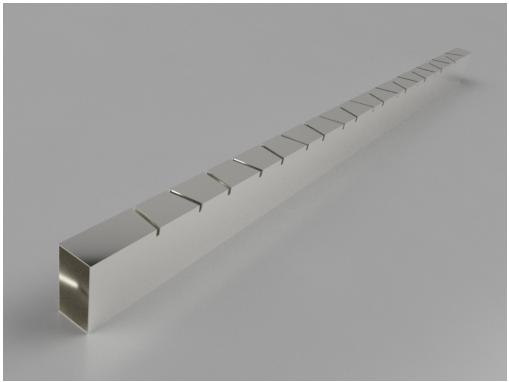
Inhaltsverzeichnis

Abbildung 1: Drehende Radarantenne[1]

Bildquelle: Wikipedia – https://en.wikipedia.org/wiki/File:Rotating_marine_radar_-_rotating_waveguide_antenna.gif

1. Antennentyp

[In-line] [resonant] [waveguide] [slot array] [with narrow-wall slots]



In-line Linear angeordnete Schlitze

Resonant Betrieb auf Resonanzfrequenz

Waveguide Hohlleiterstruktur für die Führung der Wellen

Slot array Mehrere Schlitze als Antennen-Array

Narrow-wall slots Schlitze in der schmalen Hohlleiterwand

Abbildung 2: 3D-Render des Hohlschlitzstrahlers in Fusion360

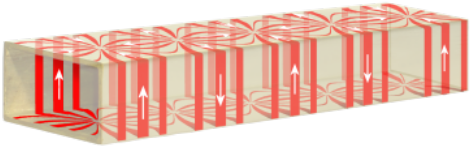


Abbildung 3: Darstellung der Wandströme einer H_{10}–Welle.

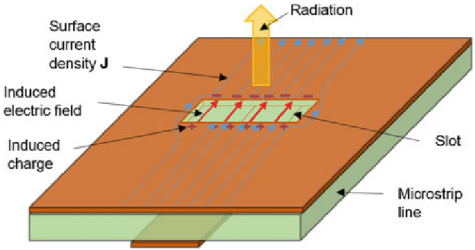


Abbildung 4: Unterbrechung von Wandströmen

Quelle Abbildung 3:
https://www.radartutorial.eu/03.linetheory/Hohlleiter.de.html

[1] Quelle Abbildung 4: Kumar, K. P. Ray: Compact Slot Array Antennas for Wireless Communications, Academic Press, 2019

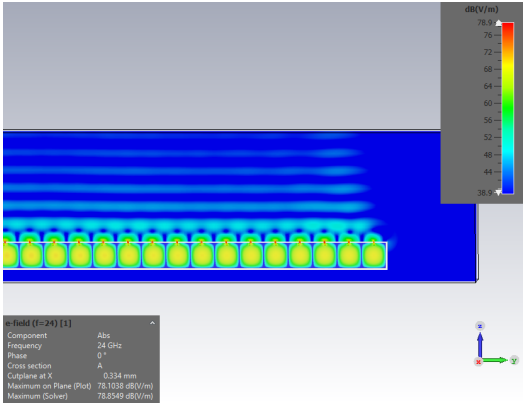


Abbildung 5: Elektrisches Nahfeld (CST Export)

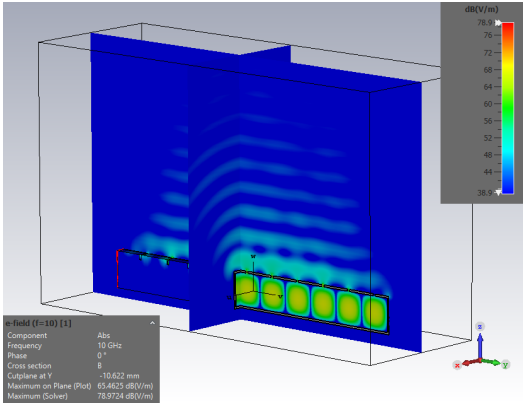


Abbildung 6: Elektrisches Nahfeld (CST Export)

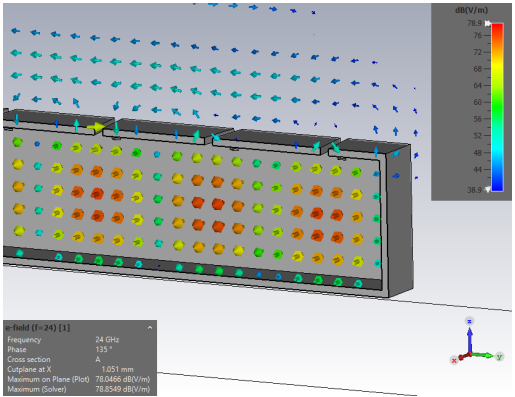


Abbildung 7: Elektrisches Nahfeld (CST Export)

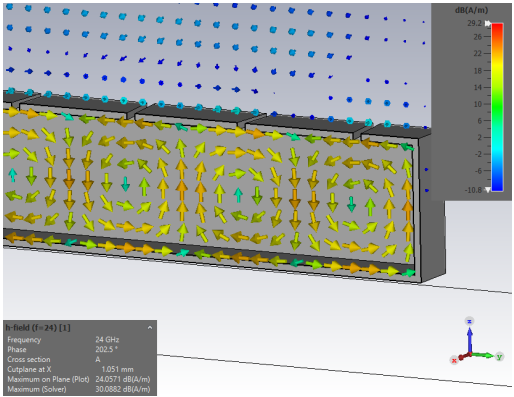


Abbildung 8: Magnetisches Nahfeld (CST Export)

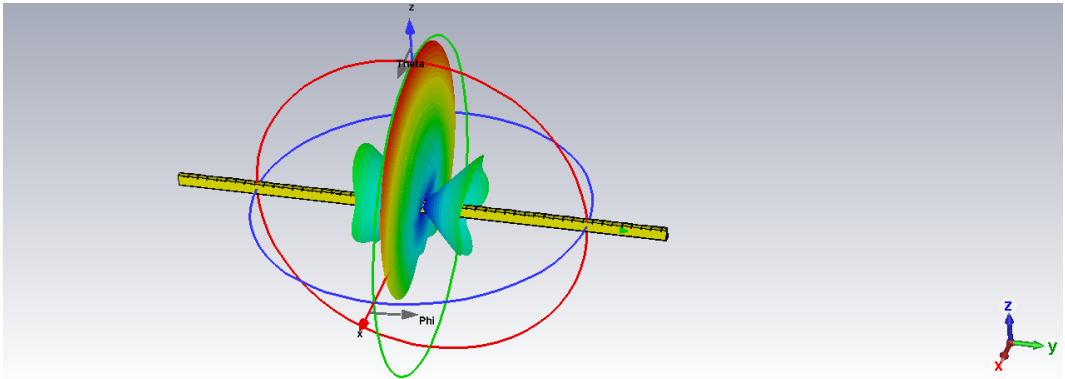


Abbildung 9: 3D-Darstellung der Richtwirkung (CST Render)

5. Fernfeld

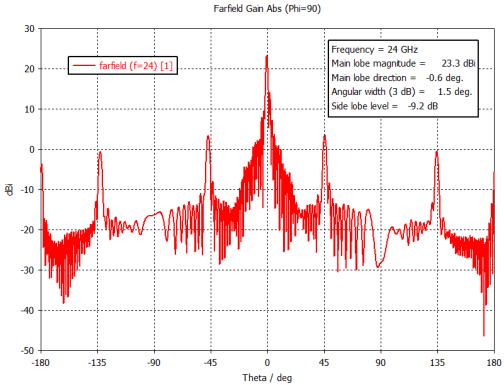


Abbildung 10: Fernfeld e-plane (CST Export)

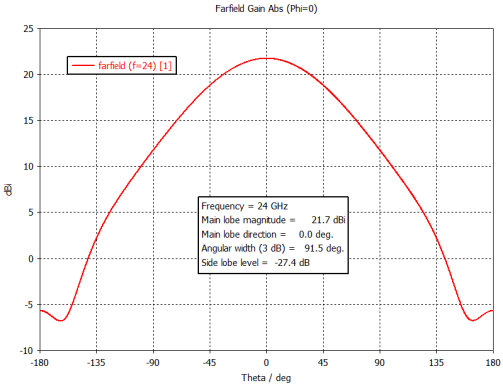


Abbildung 11: Fernfeld h-plane (CST Export)

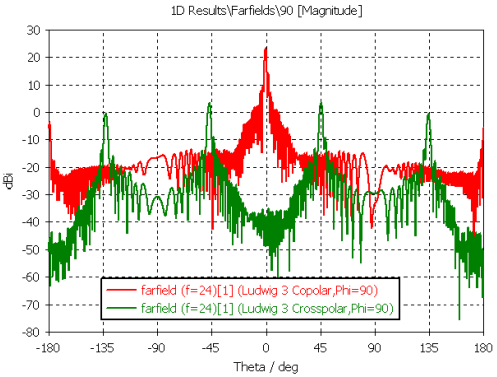


Abbildung 12: Fernfeld e-plane (CST Export)

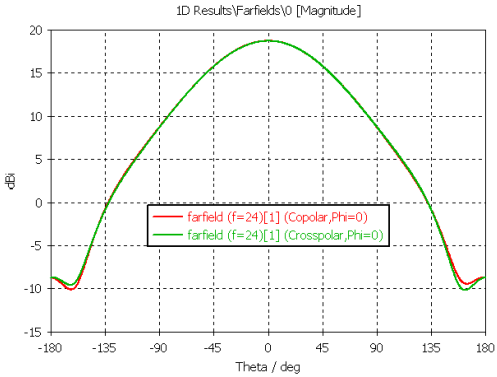


Abbildung 13: Fernfeld h-plane (CST Export)

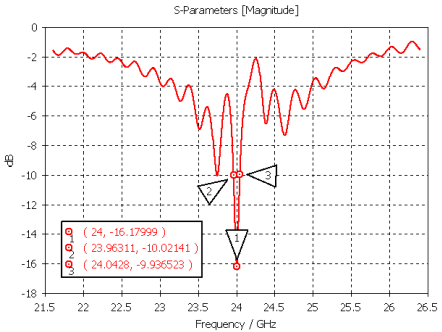


Abbildung 14: Reflexionsdämpfung (Logarithmisch)

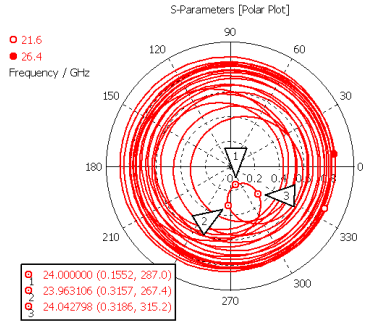


Abbildung 15: Reflexionsdämpfung (Polar)

8. Berechnungen

Größe	Allgemein	Für meine Schlitzantenne
$\mathrm{HPBW}_{\mathrm{uni}}$	$\mathrm{HPBW}_{\mathrm{uni}} \approx \frac{50{,}76^\circ}{N \cdot d/\lambda}$	$N = 50$, $d = 8{,}74\mathrm{mm}$, $\lambda = 12{,}45\mathrm{mm}$ $\Rightarrow \mathrm{HPBW} \approx 1{,}4^\circ$
HPBW Dipol	$\mathrm{HPBW}_{\mathrm{hertz}} = 90^\circ$	Gilt vertikal für jeden Schlitz (dipolähnlich)
Richtwirkung Gesamt	$D \approx \frac{41253}{\Theta_{\mathrm{min}} \cdot \Theta_{\mathrm{max}}}$	Mit $\Theta_{\mathrm{min}} \approx 1{,}4^\circ$, $\Theta_{\mathrm{max}} \approx 90^\circ$ $\Rightarrow D \approx 327$

Parameter:

N: Anzahl der Strahlerelemente, d: Abstand zwischen den Elementen, λ: Wellenlänge, HPBW: Halbwertsbreite der Hauptkeule (3 dB), D: Richtwirkung (Direktivität), $\Theta_{\mathrm{min}}, \Theta_{\mathrm{max}}$: kleinste bzw. größte 3-dB-Keulenbreite (in Grad)

9.1 Spezifikationen: Mechanisch

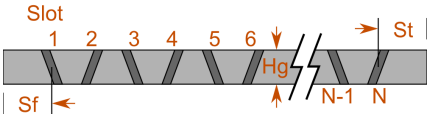


Abbildung 16: Skizze des Hohlleiters aus Antenna Magus

Tabelle 1: Mechanische Parameter

Parameter	Gewünscht	Berechnet	Generiert mit Magus
Wellenleiterbreite	-	-	8,93 mm
Wellenleiterhöhe	-	-	3,97 mm
Wellenleiterlänge	–	–	44,13 cm
Anzahl Slots	–	–	**50**
Slotbreite	–	$\lambda/20$	624,6 µm
Slotabstand	–	$\lambda \cdot \frac{7}{10}$	8,74 mm
Abstand letzer Slot	–	–	4,36 cm
Material	Silber	–	Silber

Realisierung durch Einschränkungen von Antenna Magus limitiert

9.2 Spezifikationen: Mechanisch i

Nr.	Winkel (°)	Tiefe (µm)
1	6.117	891.3
2	6.052	891.6
3	5.940	892.1
4	5.807	892.6
5	5.684	893.2
6	5.601	893.5
7	5.580	893.6
8	5.632	893.4
9	5.763	892.8
10	5.968	891.9
11	6.232	890.7
12	6.534	889.4
13	6.848	887.9
14	7.150	886.4
15	7.421	885.1
16	7.654	884.0
17	7.850	883.0

Nr.	Winkel (°)	Tiefe (µm)
18	8.018	882.1
19	8.169	881.3
20	8.312	880.6
21	8.449	879.8
22	8.578	879.2
23	8.690	878.5
24	8.774	878.1
25	8.819	877.8
26	8.819	877.8
27	8.774	878.1
28	8.690	878.5
29	8.578	879.2
30	8.449	879.8
31	8.312	880.6
32	8.169	881.3
33	8.018	882.1
34	7.850	883.0

Nr.	Winkel (°)	Tiefe (µm)
35	7.654	884.0
36	7.421	885.1
37	7.150	886.4
38	6.848	887.9
39	6.534	889.4
40	6.232	890.7
41	5.968	891.9
42	5.763	892.8
43	5.632	893.4
44	5.580	893.6
45	5.601	893.5
46	5.684	893.2
47	5.807	892.6
48	5.940	892.1
49	6.052	891.6
50	6.117	891.3

9.3 Spezifikationen: Mechanisch

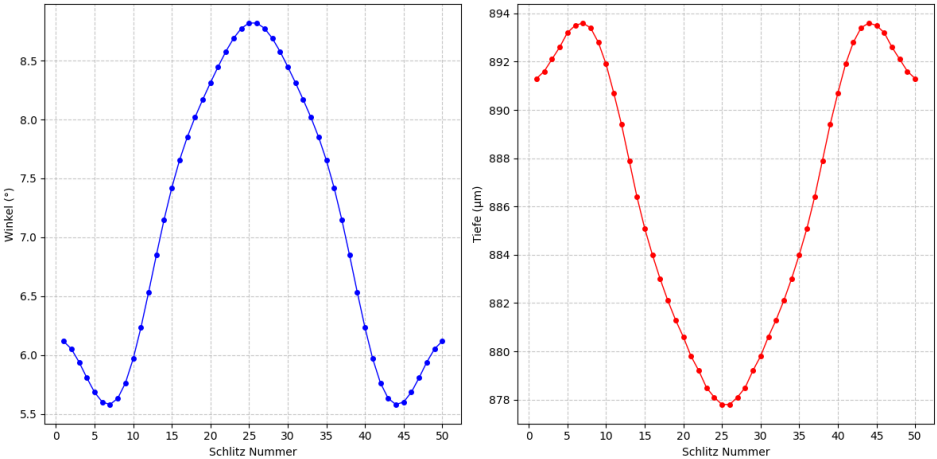


Abbildung 17: Tiefe und Winkel der Schlitze (python plots)

9. Spezifikationen: Elektrisch

Tabelle 2: Elektrische Parameter

Parameter	**Gewünscht**	**Berechnet**	**Simuliert**
Frequenz (Mittenfrequenz)	24,0 GHz	–	24,0 GHz
Maximaler Gain	–	–	23,0 dBi (e) | 22,6 dBi (h)
Realisierter Gain	–	–	22,8 dBi (e) | 22,4 dBi (h)
$HPBW_{\mathrm{hplane}}$	$\leq 1{,}0^\circ$	$1{,}4^\circ$	$1{,}6^\circ$
$HPBW_{\mathrm{eplane}}$	–	90° (Dipol)	$91{,}5^\circ$
Richtwirkung	–	327	219

Realisierung durch Einschränkungen von Antenna Magus limitiert

10. Anhang: Abkürzungen

Abkürzung	Bedeutung
HPBW	Half Power Beam Width (Halbwertsbreite)
dBi	Dezibel gegenüber Isotropstrahler
dB	Dezibel
S11	Rückflussdämpfung (Reflexionsfaktor)
GHz	Gigahertz
mm	Millimeter
µm	Mikrometer
λ	Wellenlänge (Wavelength)
f	Frequenz
E-Feld	Elektrisches Feld
H-Feld	Magnetisches Feld
CST	Computer Simulation Technology

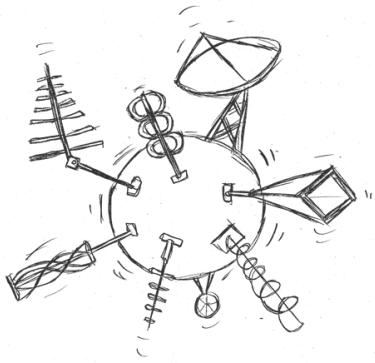
10. Anhang: Literatur i

- G. Strauß: *Antennen und Wellen*.
  Manuskript, Pasing: Hochschule Muenchen, Maerz 2022
- Kumar, K. P. Ray: *Compact Slot Array Antennas for Wireless Communications*,
  Academic Press, 2019
- Autodesk Fusion 360, Autodesk Inc., www.autodesk.com/products/fusion-360
- CST Studio Suite, Version 2023, Dassault Systèmes,
  www.3ds.com/products-services/simulia/products/cst-studio-suite
- Antenna Magus, Version 2023.2, Dassault Systèmes, www.antennamagus.com

10. Anhang: Literatur ii

Marcelo B. Perotoni, Rodrigo Enjiu: *Design und Bewertung einer Hohlleiter-Schlitzantenne (Slotted Waveguide Antenna, SWA) mit EM-Simulation*, Federal University of ABC, CST – Computer Simulation Technology AG, Oktober 2014.
https://www.researchgate.net/publication/283683848_Design_and_Analysis_of_Slotted_Waveguide_Antennas_with_EM_Simulation

AntennaMagus
Explore.Design.Deliver.



AntennaMagus

The leading antenna design tool

AntennaMagus
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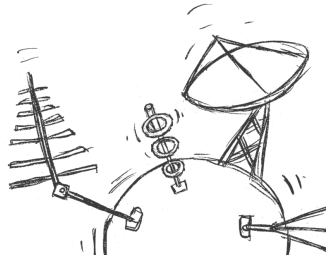
Linear resonant waveguide slot array with narrow-wall slots

Antenna 2 : Results



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Linear resonant waveguide slot array with narrow-wall slots

Antenna 2 : sketches, objectives and parameters

Antenna Structure: Antenna Parameters

Name	Description
f_0	Centre frequency
Wg	Waveguide width
Hg	Waveguide height
Sf	Distance from feed to first slot
St	Distance from last slot to termination
N	Number of slots
Ss	Slot spacing
Ws	Slot width
θ1	Slot 1 angle
θ2	Slot 2 angle

Antenna Structure: Antenna Parameters (2)

Name	Description
θ3	Slot 3 angle
θ4	Slot 4 angle
θ5	Slot 5 angle
θ6	Slot 6 angle
θ7	Slot 7 angle
θ8	Slot 8 angle
θ9	Slot 9 angle
θ10	Slot 10 angle
θ11	Slot 11 angle
θ12	Slot 12 angle

Antenna Structure: Antenna Parameters (3)

Name	Description
θ13	Slot 13 angle
θ14	Slot 14 angle
θ15	Slot 15 angle
θ16	Slot 16 angle
θ17	Slot 17 angle
θ18	Slot 18 angle
θ19	Slot 19 angle
θ20	Slot 20 angle
θ21	Slot 21 angle
θ22	Slot 22 angle

Antenna Structure: Antenna Parameters (4)

Name	Description
θ23	Slot 23 angle
θ24	Slot 24 angle
θ25	Slot 25 angle
θ26	Slot 26 angle
θ27	Slot 27 angle
θ28	Slot 28 angle
θ29	Slot 29 angle
θ30	Slot 30 angle
θ31	Slot 31 angle
θ32	Slot 32 angle

Antenna Structure: Antenna Parameters (5)

Name	Description
θ33	Slot 33 angle
θ34	Slot 34 angle
θ35	Slot 35 angle
θ36	Slot 36 angle
θ37	Slot 37 angle
θ38	Slot 38 angle
θ39	Slot 39 angle
θ40	Slot 40 angle
θ41	Slot 41 angle
θ42	Slot 42 angle

Antenna Structure: Antenna Parameters (6)

Name	Description
θ43	Slot 43 angle
θ44	Slot 44 angle
θ45	Slot 45 angle
θ46	Slot 46 angle
θ47	Slot 47 angle
θ48	Slot 48 angle
θ49	Slot 49 angle
θ50	Slot 50 angle
δ1	Slot 1 depth
δ2	Slot 2 depth

Antenna Structure: Antenna Parameters (7)

Name	Description
δ3	Slot 3 depth
δ4	Slot 4 depth
δ5	Slot 5 depth
δ6	Slot 6 depth
δ7	Slot 7 depth
δ8	Slot 8 depth
δ9	Slot 9 depth
δ10	Slot 10 depth
δ11	Slot 11 depth
δ12	Slot 12 depth

Antenna Structure: Antenna Parameters (8)

Name	Description
δ13	Slot 13 depth
δ14	Slot 14 depth
δ15	Slot 15 depth
δ16	Slot 16 depth
δ17	Slot 17 depth
δ18	Slot 18 depth
δ19	Slot 19 depth
δ20	Slot 20 depth
δ21	Slot 21 depth
δ22	Slot 22 depth

Antenna Structure: Antenna Parameters (9)

Name	Description
δ23	Slot 23 depth
δ24	Slot 24 depth
δ25	Slot 25 depth
δ26	Slot 26 depth
δ27	Slot 27 depth
δ28	Slot 28 depth
δ29	Slot 29 depth
δ30	Slot 30 depth
δ31	Slot 31 depth
δ32	Slot 32 depth

Antenna Structure: Antenna Parameters (10)

Name	Description
δ33	Slot 33 depth
δ34	Slot 34 depth
δ35	Slot 35 depth
δ36	Slot 36 depth
δ37	Slot 37 depth
δ38	Slot 38 depth
δ39	Slot 39 depth
δ40	Slot 40 depth
δ41	Slot 41 depth
δ42	Slot 42 depth

Antenna Structure: Antenna Parameters (11)

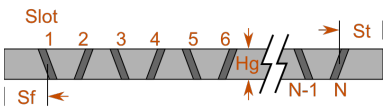
Name	Description
δ43	Slot 43 depth
δ44	Slot 44 depth
δ45	Slot 45 depth
δ46	Slot 46 depth
δ47	Slot 47 depth
δ48	Slot 48 depth
δ49	Slot 49 depth
δ50	Slot 50 depth
X	Device X-dimension
Y	Device Y-dimension

Antenna Structure: Antenna Parameters (12)

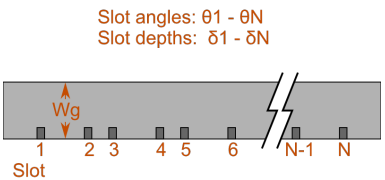
Name	Description
Z	Device Z-dimension

Sketches

Side view

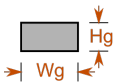


Top view

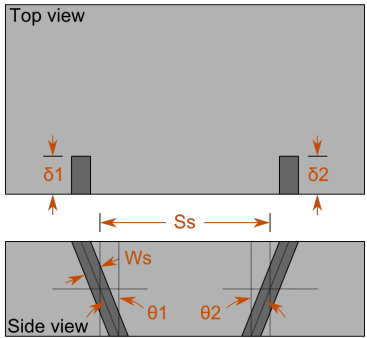


Sketches (2)

End view



Zoom view



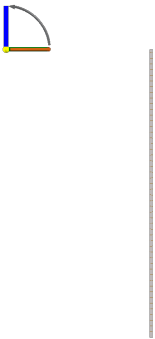
Design 9: Preview

Design 9: Front Side Preview

Design 9: Left Side Preview

Design 9: Right Side Preview

Design 9: Top Side Preview



Design 9: Bottom Side Preview

Design 9: Design Objectives

Objective Group: beamwidth

Name	Description	Value
f_0	Centre frequency	24 GHz
bw	3dB beamwidth	1.6 °
Tt	Select the taper to be used	Villeneuve

Design 9: Physical Parameters

Name	Description	Value
Wg	Waveguide width	8.930 mm
Hg	Waveguide height	3.969 mm
Sf	Distance from feed to first slot	8.739 mm
St	Distance from last slot to termination	4.369 mm
N	Number of slots	50
Ss	Slot spacing	8.739 mm
Ws	Slot width	624.6 µm
θ1	Slot 1 angle	6.117 °
θ2	Slot 2 angle	6.052 °
θ3	Slot 3 angle	5.940 °

Design 9: Physical Parameters (2)

Name	Description	Value
θ4	Slot 4 angle	5.807 °
θ5	Slot 5 angle	5.684 °
θ6	Slot 6 angle	5.601 °
θ7	Slot 7 angle	5.580 °
θ8	Slot 8 angle	5.632 °
θ9	Slot 9 angle	5.763 °
θ10	Slot 10 angle	5.968 °
θ11	Slot 11 angle	6.232 °
θ12	Slot 12 angle	6.534 °
θ13	Slot 13 angle	6.848 °

Design 9: Physical Parameters (3)

Name	Description	Value
θ14	Slot 14 angle	7.150 °
θ15	Slot 15 angle	7.421 °
θ16	Slot 16 angle	7.654 °
θ17	Slot 17 angle	7.850 °
θ18	Slot 18 angle	8.018 °
θ19	Slot 19 angle	8.169 °
θ20	Slot 20 angle	8.312 °
θ21	Slot 21 angle	8.449 °
θ22	Slot 22 angle	8.578 °
θ23	Slot 23 angle	8.690 °

Design 9: Physical Parameters (4)

Name	Description	Value
θ24	Slot 24 angle	8.774 °
θ25	Slot 25 angle	8.819 °
θ26	Slot 26 angle	8.819 °
θ27	Slot 27 angle	8.774 °
θ28	Slot 28 angle	8.690 °
θ29	Slot 29 angle	8.578 °
θ30	Slot 30 angle	8.449 °
θ31	Slot 31 angle	8.312 °
θ32	Slot 32 angle	8.169 °
θ33	Slot 33 angle	8.018 °

Design 9: Physical Parameters (5)

Name	Description	Value
θ34	Slot 34 angle	7.850 °
θ35	Slot 35 angle	7.654 °
θ36	Slot 36 angle	7.421 °
θ37	Slot 37 angle	7.150 °
θ38	Slot 38 angle	6.848 °
θ39	Slot 39 angle	6.534 °
θ40	Slot 40 angle	6.232 °
θ41	Slot 41 angle	5.968 °
θ42	Slot 42 angle	5.763 °
θ43	Slot 43 angle	5.632 °

Design 9: Physical Parameters (6)

Name	Description	Value
θ44	Slot 44 angle	5.580 °
θ45	Slot 45 angle	5.601 °
θ46	Slot 46 angle	5.684 °
θ47	Slot 47 angle	5.807 °
θ48	Slot 48 angle	5.940 °
θ49	Slot 49 angle	6.052 °
θ50	Slot 50 angle	6.117 °
δ1	Slot 1 depth	891.3 µm
δ2	Slot 2 depth	891.6 µm
δ3	Slot 3 depth	892.1 µm

Design 9: Physical Parameters (7)

Name	Description	Value
δ4	Slot 4 depth	892.6 µm
δ5	Slot 5 depth	893.2 µm
δ6	Slot 6 depth	893.5 µm
δ7	Slot 7 depth	893.6 µm
δ8	Slot 8 depth	893.4 µm
δ9	Slot 9 depth	892.8 µm
δ10	Slot 10 depth	891.9 µm
δ11	Slot 11 depth	890.7 µm
δ12	Slot 12 depth	889.4 µm
δ13	Slot 13 depth	887.9 µm

Design 9: Physical Parameters (8)

Name	Description	Value
δ14	Slot 14 depth	886.4 µm
δ15	Slot 15 depth	885.1 µm
δ16	Slot 16 depth	884.0 µm
δ17	Slot 17 depth	883.0 µm
δ18	Slot 18 depth	882.1 µm
δ19	Slot 19 depth	881.3 µm
δ20	Slot 20 depth	880.6 µm
δ21	Slot 21 depth	879.8 µm
δ22	Slot 22 depth	879.2 µm
δ23	Slot 23 depth	878.5 µm

Design 9: Physical Parameters (9)

Name	Description	Value
δ24	Slot 24 depth	878.1 µm
δ25	Slot 25 depth	877.8 µm
δ26	Slot 26 depth	877.8 µm
δ27	Slot 27 depth	878.1 µm
δ28	Slot 28 depth	878.5 µm
δ29	Slot 29 depth	879.2 µm
δ30	Slot 30 depth	879.8 µm
δ31	Slot 31 depth	880.6 µm
δ32	Slot 32 depth	881.3 µm
δ33	Slot 33 depth	882.1 µm

Design 9: Physical Parameters (10)

Name	Description	Value
δ34	Slot 34 depth	883.0 µm
δ35	Slot 35 depth	884.0 µm
δ36	Slot 36 depth	885.1 µm
δ37	Slot 37 depth	886.4 µm
δ38	Slot 38 depth	887.9 µm
δ39	Slot 39 depth	889.4 µm
δ40	Slot 40 depth	890.7 µm
δ41	Slot 41 depth	891.9 µm
δ42	Slot 42 depth	892.8 µm
δ43	Slot 43 depth	893.4 µm

Design 9: Physical Parameters (11)

Name	Description	Value
δ44	Slot 44 depth	893.6 µm
δ45	Slot 45 depth	893.5 µm
δ46	Slot 46 depth	893.2 µm
δ47	Slot 47 depth	892.6 µm
δ48	Slot 48 depth	892.1 µm
δ49	Slot 49 depth	891.6 µm
δ50	Slot 50 depth	891.3 µm

Design 9: Derived Quantities

Name	Description	Value
X	Device X-dimension	3.969 mm
Y	Device Y-dimension	441.3 mm
Z	Device Z-dimension	8.930 mm

Linear resonant waveguide slot array with narrow-wall slots

Antenna 2 : estimated performance charts

S-Reflection vs Frequency

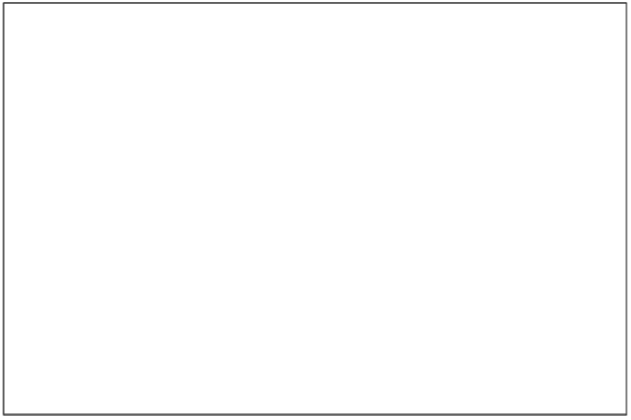
S-Parameters (reflection)

Far Field vs Angle @ f0

Gain (Total)

Far Field vs Angle @ f0

Gain (Total)

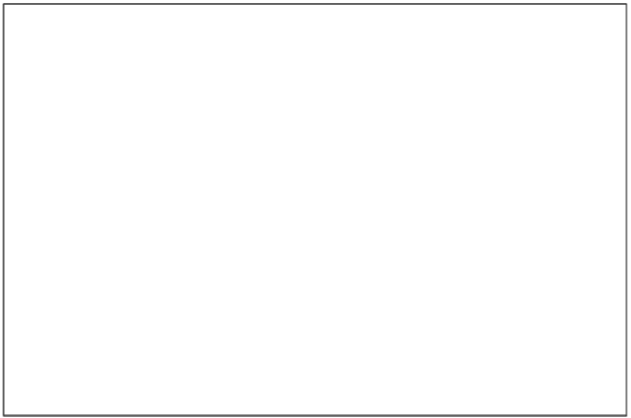


Far Field vs Angle @ f0

Gain (LHC)

Far Field vs Angle @ f0

Gain (LHC)

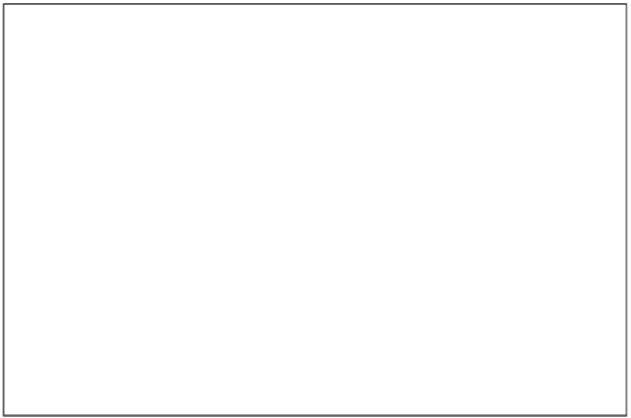


Far Field vs Angle @ f0

Gain (RHC)

Far Field vs Angle @ f0

Gain (RHC)

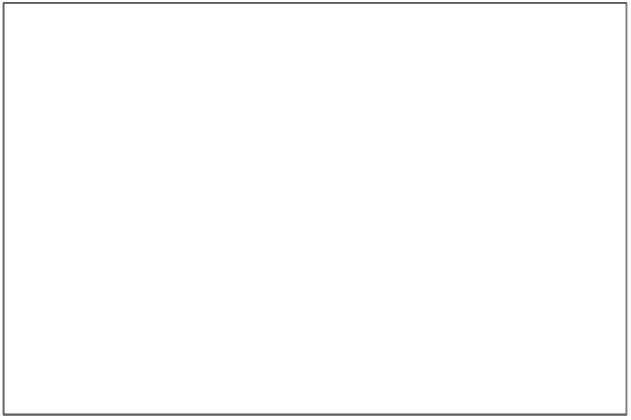


Far Field vs Angle @ f0

Gain (Horizontal)

Far Field vs Angle @ f0

Gain (Horizontal)

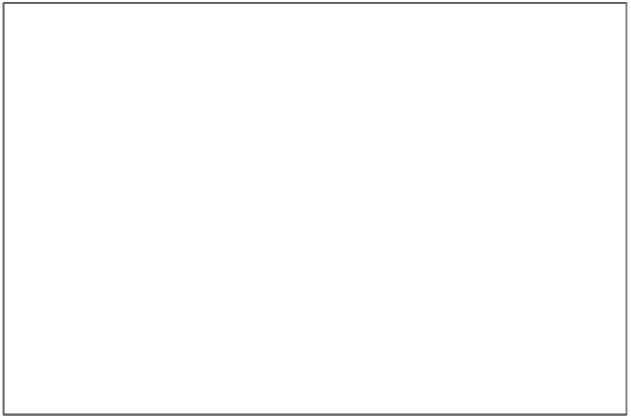


Far Field vs Angle @ f0

Gain (Vertical)

Far Field vs Angle @ f0

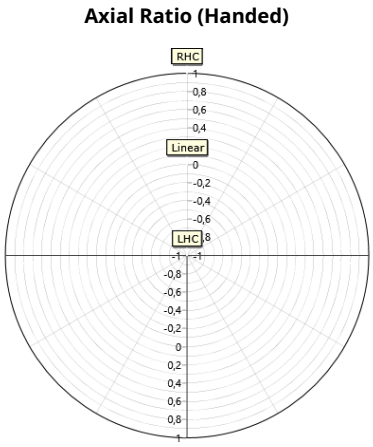
Gain (Vertical)



Far Field vs Angle @ f0

Axial Ratio (Handed)

Far Field vs Angle @ f0

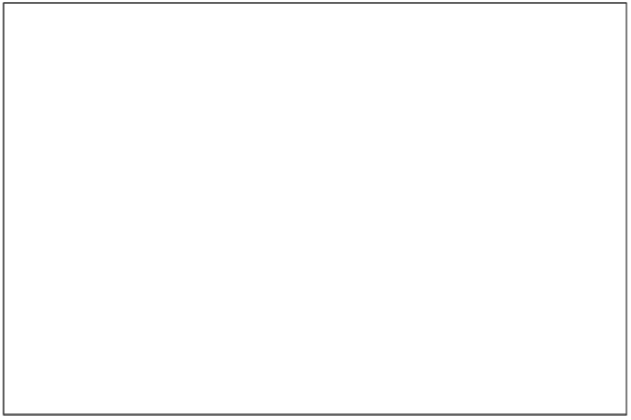


Far Field vs Angle @ f0

Axial Ratio (IEEE)

Far Field vs Angle @ f0

Axial Ratio (IEEE)

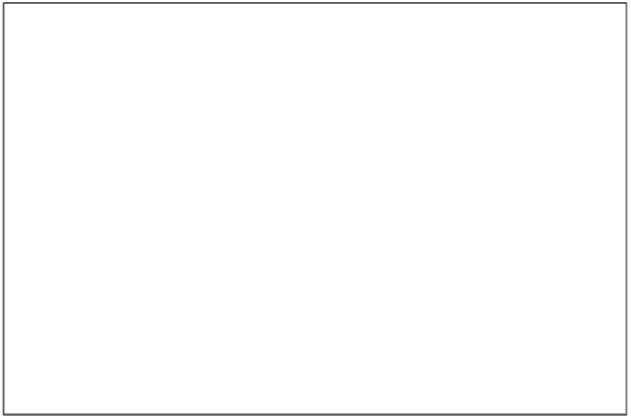


Far Field vs Angle @ f0

Ludwig III (Co)

Far Field vs Angle @ f0

Ludwig III (Co)



Far Field vs Angle @ f0

Ludwig III (Cross)

Far Field vs Angle @ f0

Ludwig III (Cross)