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Accredited testing laboratory

DAR registration number:
TTI-P-G 166/98

Test report no.	**: 2-2387-2-1/01**
Type identification	**: Point-to-Multipoint Systems in the frequency range of 24.5 to 29.5 GHz**
Test specification	**: R&TTE Art. 3.1a – EMF effect on health**

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1 General Information

1.1 Notes

The test results of this test report relate exclusively to the test item specified in 1.5. The CETECOM ICT Services GmbH does not assume responsibility for any conclusions and generalisations drawn from the test results with regard to other specimens or samples of the type of the equipment represented by the test item. The test report may only be reproduced or published in full. Reproduction or publication of extracts from the report requires the prior written approval of the CETECOM ICT Services GmbH.

Technical responsibility for area of testing:

Thomas Vogler		**June 21, 2001**
Name	Signature	Date

1.2 Testing laboratory

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State of accreditation: the test laboratory antenna tests are accredited according to DIN EN 45001.
TTI-P-G 166/98 18. September 1998

Test location, if different from CETECOM ICT Services GmbH

Name:
Street:
Town:
Country:
Phone:
Fax:

1.3 Details of applicant

Name: Netro Corporation

Street: 3860 N. 1st Street
Town: San Jose, CA 95134-1702
Country: USA

Contact: Mr. Jas Dhaliwal
Telephone: +1-408-216-1562

1.4 Application details

Date of receipt of application: June 15, 2001

1.5 Test item

Type identification:	**Point-to-Multipoint Systems in the frequency range of 24.5 to 29.5 GHz**

Manufacturer:

Name:	Netro Corporation
Street:	3860 N. 1^{st} Street
Town:	San Jose, CA 95134-1702
Country:	USA

1.5.1 Test specification(s)

R&TTE Art. 3.1a – EMF effect on health

2 Evaluating compliance with requirements for human exposure to EMFs

2.1 Introduction

The ´Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE-Directive)´ determines essential requirements in its article 3. These essential requirements are valid for all radio equipment and telecommunications terminal equipment. For such equipment the conformity to the essential requirements has to be demonstrated. In order to perform the conformity assessment harmonized standards can be used (article 5). The document identifier of these standards are published on the ´Official Journal of the European Community´. Not all essential requirements respectively radio and telecommunications terminal products or their purpose of use are covered by harmonized standards yet. In case of harmonized standards are not available the following ETSI document can be used to identify corresponding documents and technical specifications:
´EG 201 450: ETSI Guidance on the identification of Harmonized Standards and/or other technical specifications for Radio and Telecommunications Terminal Equipment (R&TTE) covering requirements under article 3.1 of Directive 1999/5/EC´.
One of the R&TTE essential requirements is ´the protection of the health and the safety of the user and any other person´ (article 3.1(a)). This includes the protection against human exposure to radiofrequency electromagnic fields (EMF). There is no harmonized standard under R&TTE-Directive for EMF effect on health available yet. However the ETSI Guidance mentioned above refers to the ´Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), 1999/519/EC´ which for its part refers to the ICNIRP Guidelines.
The exposure limits of the ICNIRP Guidelines are comparable to those given in some other available documents, e.g. FCC CFR 47. So for the purpose of demontration of conformity to this essential requirement international accepted limits can be determined. But the mentioned documents do not describe any practical way to find out the exposure values of the equipment under test which shall be compared to these limits.
That´s why in this assessment report the following national standards were used to show that the real exposure levels satisfy the essential requirements under R&TTE article 3.1(a):

- FCC OET Bullet No. 65, Edition 97-01, August 1997
  ´Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic fields´
- DIN VDE 0848-1, August 2000
  ´Sicherheit in elektrischen, magnetischen und elektromagnetischen Feldern´
  ´Teil 1: Definitionen, Meß- und Berechnungsverfahren´

Remark: Some other documents are available describing similar methods.

2.2 RF EMF Exposure Limits

In April 1998, ICNIRP (International Commission on Non-Ionizing Radiation Protection) published its ´Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)´. As shown in Table 2.2-1, the guidelines (Tables 6 and 7) specify the ´Reference levels on power density for occupational exposure and general public exposure to time-varying electric and magnetic fields (unperturbed rms values)´ between 2 and 300 GHz.

Table 2.2-1: ICNIRP Reference levels within the frequency range 2-300 GHz

Frequency range	Exposure characteristics	Equivalent plane wave power density S_{eq} (W/m^2)	Average time period (min)
2 – 10 GHz	occupational	50	6
	general public	10	6
10 – 300 GHz	occupational	50	$68/f^{1.05}$ (f in GHz)
	general public	10	$68/f^{1.05}$ (f in GHz)

Note: For pulsed signals it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width, does not exceed 1000 times the S_{eq} exposure levels given in the table.

Note: Within the frequency range the 10 – 300 GHz the basic restrictions are identical to the reference levels.
Remarks to the definition of basic restrictions:
1. Power densities are to be averaged over any 20 cm^2 of exposed area and any $68/f^{1.05}$ minute period (where f is in GHz) to compensate for progressively shorter penetration depth as the frequency increases.
2. Spatial maximum power densities, averaged over 1 cm^2, should not exceed 20 times the values above.

Compared to the ICNIRP restrictions, FCC CFR 47 specifies the Maximum Permissible Exposure (MPE) levels for occupational/controlled environment and general public/uncontrolled environment, as shown in Table 2.2-2.

Table 2.2-2: FCC MPE limits within the frequency range 1.5-100 GHz

Frequency range	Exposure characteristics	Equivalent plane wave power density S_{eq} (W/m^2)	Average time period (min)
1.5 –100 GHz	occupational	50	6
	general public	10	30

Quite a few other documents specify or refer to exposure limits comparable to those given above, e.g.:

- 1999/519/EC: Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)
- WHO: Environmental Health Criteria 137: ´Electromagnetic Fields (300 Hz to 300 GHz)´
- ANSI/IEEE C95.1, 1999:
  ´IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz´
- BRD, Bundesimmissionsschutzgesetz, 26. BImSchV Verordnung über elektromagnetische Felder
- Bundesamt für Umwelt, Wald und Landwirtschaft (BUWAL), Bern/Schweiz
  Schriftenreihe Umwelt Nr. 164, Luft, Mai 1992
  ´Messung nichtionisierender elektromagnetischer Strahlung, 1. Teil: Frequenzbereich 100 kHz bis 300 GHz´
- DIN VDE 0848-2, Entwurf, Oktober 1991:
  ´Sicherheit in elektrischen, magnetischen und elektromagnetischen Feldern, ´Teil 2: Schutz von Personen im Frequenzbereich von 30 kHz bis 300 GHz´
- ENV 50166-2, January 1995 (withdrawed in December 1999 by CENELEC)
  ´Human Exposure to Electromagnetic Fields (10 kHz – 300 GHz)´

2.3 Equipment Under Test: relevant technical parameters

Table 2.3-1 shows the technical parameters of the equipment under test which are relevant for the assessment of safety distances.

Table 2.3-1: Technical parameters of equipment under test

(example , for the complete set of data see annex 1)

a)	antenna type	lens horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.150	m	worst case
d)	antenna aperture length	L	0.150	m	worst case
e)	antenna aperture area	A	0.150	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	Gmax	31.5	dBi	= 1413
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	5.85	°	worst case
m)	transmit frequency range	f	24.5 – 26.5	GHz	
n)	wavelength at 24.5 GHz	?	0,012	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0,00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	Kmod	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

2.4 Analytic-practical assessment (prediction method) of safety distances on aperture antennas

Following documents are used to assess the safety distances:

- FCC OET Bullet No. 65, Edition 97-01, August 1997
  ´Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic fields´
- DIN VDE 0848-1, August 2000
  ´Sicherheit in elektrischen, magnetischen und elektromagnetischen Feldern´
  ´Teil 1: Definitionen, Meß- und Berechnungsverfahren´

In these documents analytical methods are demonstrated in order to appraisingly calculate the distances from the source of electromagnetic radiation in which the exposure limits are reached. As shown in Table 2.4-1 four exposure regions are defined. Unfortunately the definition of the dimension of these regions are slightly different. Therefore Table 2.4-1 shows both definitions.

Table 2.4-1: Exposure regions

Exposure region		Distance to antenna aperture and density of power flux definition acc. to			
		FCC OET Bullet No. 65		DIN VDE 0848-1	
A	**antenna surface** (reactive near-field)	directly in front of the antenna	$S_{surface} = \frac{4P_t}{A}$	upto 0.5...3*λ	$S_{surface} = \frac{4P_t}{A}$
B	**near-field region** (radiated near-field, Fresnel region, ´Hertzscher Schlauch´)	$R_{nf} = \frac{D^2}{4l}$	$S_{nf} = \frac{4hP_t}{A}$	$R_{nf} = \frac{A}{2l}$	$S_{nf} = \frac{4P_t}{A}$
C	**transition region**	$R_{nf} \leq R \leq R_{ff}$	$S_t = \frac{4hP_t R_{nf}}{AR}$	$R_{nf} \leq R \leq R_{ff}$	$S_t = \frac{P_t G}{4pR^2}$
D	**far-field region** (Fraunhofer region, Rayleigh-Distance)	$R_{ff} = \frac{0.6D^2}{l}$	$S_{ff} = \frac{P_t G}{4pR^2}$	$R_{ff} = \frac{2D^2}{l}$	$S_{ff} = \frac{P_t G}{4pR^2}$

where:
$S_{surface}$ = maximum power density at the antenna surface in W/m^2
S_{nf} = maximum near-field power density in W/m^2
S_t = power density in the transition region in W/m^2
S_{ff} = power density (on axis) in W/m^2
R_{nf} = extent of near-field in m
R_{ff} = distance to beginning of near field in m
R = distance to the point of interest in m
P_t = power fed to the antenna feed horn in W
A = physical (geometrical) area of the aperture antenna in m^2
D = maximum dimension of antenna (diameter if circular) in m
G = power gain factor in the direction of interest relative to an isotropic radiator
λ = wavelengths in m
η = aperture efficiency (typically 0.5-0.75 for circular apertures)

By use of Table 2.4-1 the distance r_1 in boresight direction (see Figure 1) in which the exposure limit is reached and its exposure region can be ascertained.

Table 2.4-2: Calculation of power feeding the antenna feed horn P_t

kind of correction factor	symbol	equation	unit
loss between transmitter output and antenna input	a_{dB}	$P_{t'} = P * 10^{\frac{a_{dB}}{10}}$	W
modulation scheme (acc. to DIN VDE 0848-1, Table 2)	k_{mod}	$P_{t''} = P_{t'} * k_{\mathrm{mod}}$	W
average factor for bursted or pulsed signals	k_{avg}	$P_t = P_{t''} * k_{avg}$	W

Table 2.4-3: Reasonable approximation of h **(if unknown):**

circular apertures: $h = G(\frac{l}{pD})^2$ **non-circular apertures:** $h = G(\frac{l^2}{4pA})$	where: η = aperture efficiency (typically 0.5-0.75 for circular apertures) G = gain factor in the direction of interest relative to an isotropic radiator λ = wavelengths in m D = maximum dimension of antenna (diameter if circular) in m A = physical (geometrical) area of the aperture antenna in m^2

Spurious emissions and harmonics: **According to ENV 50166-2, ´Human Exposure to Electromagnetic Fields (10 kHz – 300 GHz)´, section 4.2.1.3 and 5.3.1, there is no need to consider spurious emissions or harmonics with levels at least 10 dB below the main signal level. The fulfillment of this condition is taken possession of the requirements regarding the effective use of the rf-spectrum.**

Valuation of sidelobes:

<u>Sidelobes ≤ ca. 60°</u>:

For practical reasons each antenna sidelobe is considered as an ideal single aperture radiator with an aperture efficiency 1, a direction factor which is equal to the sidelobe gain and a spatial orientation of its ´main beam´ at the same angle of the sidelobe relative to boresight of the antenna under consideration.

With

$$G_{i(f)} = \frac{4p * A'}{l^2} \qquad 60° \leq |\phi|$$

the effective aperture of this single radiation element results to:

$$A' = \frac{G_{i(f)} * l^2}{4p}$$

For simplification circular aperture area is assumed, so the aperture diameter results to:

$$d = \sqrt{\frac{4A'}{p}}$$

Remark: This is a conservative approach on which only the part of vector is interesting which is orthogonal to boresight.

Where: $G_{i(\phi)}$ = antenna gain as a function of ϕ_{az} respectively ϕ_{el}
A´ = aperture area of single virtual radiation element
d = aperture diameter of single virtual radiation element

This diameter d used with the equation of the Rayleigh distance comes to the fact that it´s possible to use the simple far-field conditions just for very short distances.

For the antenna under consideration the most critical sidelobes according to the azimuth- and elevation antenna pattern were examined. So it´s possible to define safety distances r_3 and r_4 shown in Figure 1.

Sidelobes > 60°:
In an angular region $60° < |\phi| < 180°$, the antenna radiation pattern is well below the isotropic radiator level and dominated by feed spill-over and diffraction effects. Because these effects are generated by local parts of the antenna geometry the transition between near-field and far-field region from these local parts is 5...10 λ. This distance is very small compared to the antenna geometry. For practical reasons it is feasible to define a safety distance, which corresponds to the distances r_3 or r_4 whichever is larger.

$$r_5 = \max (r_3 ; r_4) \qquad 60° < |\phi| < 180°$$

Consideration of antenna installation height, antenna main beam width and min. elevation angle:

When the antenna is aligned at its boresight direction away from ground the safety distance can be reduced to:

$$r_2 = \frac{H-(h-\frac{r_4}{\cos(a_{el})})}{\tan(a_{el}-\frac{f_{3dB}}{2})} \qquad \text{for divident } \leq 0 \text{ then: } r_2 = 0$$

Where:
- r_1 = safety distance without consideration of elevation at operation site in m (safety distance in boresight direction)
- r_2 = safety distance with consideration of elevation at operation site in m
- r_4 = see Figure 1
- h = antenna installation height in m (= distance between the geometrical centre of main reflector and passable environment ground level)
- H = safety height of 3 m
- α_{el} = minimum elevation angle within the geographical operation area of the tranmitter (e.g. for satellite earth station this angle results from coordinates of the operation site (longitude and latitude) and the satellite position)
- ϕ_{3dB} = 3 dB – main beam width

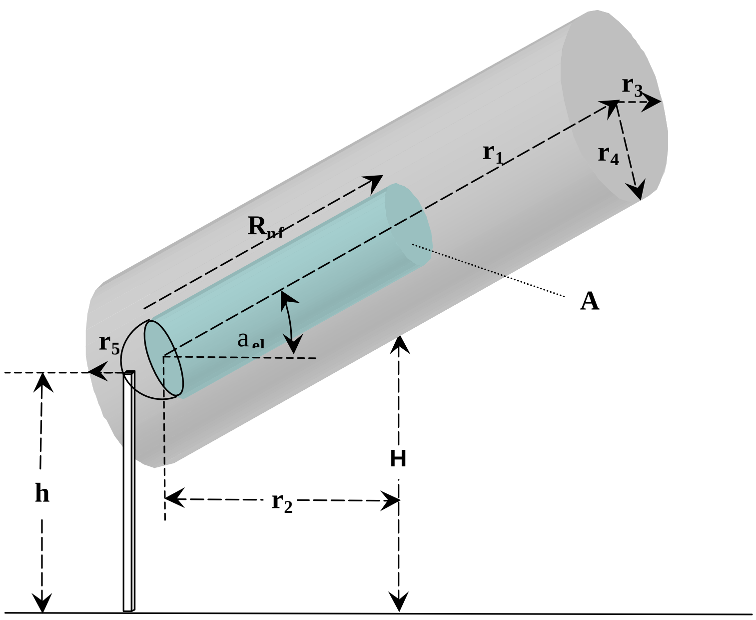

Figure 1

2.5 Results

General description

Type of test item : Digital Microwave Fixed Link
Type identification : Netro AirStar (equipped with antennas given below)

Antenna system(s):

No.	Description	Manufacturer	Type	Transmit gain dBi (max.)	Polarization	CETECOM Test Report no. respectively other documents
1	90° BRU antenna 24.5 – 26.5 GHz	Victory Inc., Taiwan	12303-0001 (V) 12303-0006 (H)	15.0	linear-orth., single pol.	2-2387-1-2/01 2-2387-1-1/01
2	30° BRU antenna 24.5 – 26.5 GHz	Victory Inc., Taiwan	12303-0004 (V)	18.5	linear-orth., single pol.	2-2387-1-5/01
3	90° BRU antenna 27.5 – 29.5 GHz	Victory Inc., Taiwan	16623-0001 (V) 16623-0011 (H)	15.0	linear-orth., single pol.	2-2387-1-4/01 2-2387-1-3/01
4	30° BRU antenna 27.5 – 29.5 GHz	Victory Inc., Taiwan	16623-0002 (V)	20.5	linear-orth., single pol.	2-2387-1-6/01
5	SRU antenna 125 mm 24.5 – 26.5 GHz	Victory Inc., Taiwan	12706-0001 (H)	30.5	linear-orth., single pol.	2-1758-1-5/99
6	SRU antenna 150 mm 24.5 – 26.5 GHz	Victory Inc., Taiwan	12706-0003 (H)	31.5	linear-orth., single pol.	2-1758-1-4/99
7	SRU antenna 125 mm 27.5 – 29.5 GHz	Victory Inc., Taiwan	16980-0007 (H) 16980-0008 (V)	30.5	linear-orth., single pol.	2-2387-1-7/01 2-2387-1-8/01

Technical Data

Transmit frequency range(s) : 24.5 – 26.5, 27,5 – 29.5 GHz
Transmitter power max. : +19 dBm

General result

According to the results stated in following tables it is necessary to label the systems given under ´Type identification´ with a safety distance because the exposure limit value of 10 W/m^2 is reached.

For BRU sytems the ‚worst case distance‘ of the examined antennas is about : **0.3 m**

For SRU systems the ‚worst case distance‘ of the examined antennas is about : **1.0 m**

Annex 1 Overview

Annex 1.1 Technical parameters of equipment under test (BRU)

Annex 1.1.1 BRU 90° sector horn antenna 24.5 – 26.5 GHz

Technical parameters of equipment under test

a)	antenna type	sector horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.03	m	worst case
d)	antenna aperture length	L	0.09	m	worst case
e)	antenna aperture area	A	0.003	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geoprahical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	15.0	dBi	= 31.62
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	90.00	°	worst case
m)	transmit frequency range	f	24.5 – 26.5	GHz	
n)	wavelength at 26.5 GHz	?	0,012	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0.00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	0.13	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	117.68	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.07	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.11	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	15.70	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	117.68	W/m²
region D: dimension (acc.to FCC)	R_{ff}	0.18	m
region D: dimension (acc.to DIN VDE)	R_{ff}	0.59	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	6.42	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	0.58	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	A	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	B	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0367	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.1103	m
general public exposure limit is reached within region (acc. to FCC)	-/-	C	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.1154**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.1414**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0152	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0154	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0451	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0453	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0451	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0453	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m

Annex 1.1.2 BRU 30° sector horn antenna 24.5 – 26.5 GHz

Technical parameters of equipment under test

a)	antenna type	sector horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.03	m	worst case
d)	antenna aperture length	L	0.09	m	worst case
e)	antenna aperture area	A	0.003	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	18.5	dBi	= 70.79
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	30.00	°	worst case
m)	transmit frequency range	f	24.5 – 26.5	GHz	
n)	wavelength at 24.5 GHz	?	0.012	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0.00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	0.31	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	117.68	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.04	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.11	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	36.82	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	117.68	W/m²
region D: dimension (acc.to FCC)	R_{ff}	0.10	m
region D: dimension (acc.to DIN VDE)	R_{ff}	0.33	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	45.45	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	4.09	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	A	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	B	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0367	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.1103	m
general public exposure limit is reached within region (acc. to FCC)	-/-	D	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.2115**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.2115**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0152	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0155	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0452	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0455	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0452	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0455	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m

Annex 1.1.3 BRU 90° sector horn antenna 27.5 – 29.5 GHz

Technical parameters of equipment under test

a)	antenna type	sector horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.03	m	worst case
d)	antenna aperture length	L	0.09	m	worst case
e)	antenna aperture area	A	0.003	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	15.0	dBi	= 31, 62
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	90.00	°	worst case
m)	transmit frequency range	f	27.5 – 29.5	GHz	
n)	wavelength at 27.5 GHz	?	0.011	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0.00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	0.11	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	117.68	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.08	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.12	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	12.46	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	117.68	W/m²
region D: dimension (acc.to FCC)	R_{ff}	0.20	m
region D: dimension (acc.to DIN VDE)	R_{ff}	0.66	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	5.10	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	0.46	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	A	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	B	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0327	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.1238	m
general public exposure limit is reached within region (acc. to FCC)	-/-	C	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.1028**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.1414**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0152	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0154	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0451	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0453	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0451	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0453	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m

Annex 1.1.4 BRU 30° sector horn antenna 27.5 – 29.5 GHz

Technical parameters of equipment under test

a)	antenna type	sector horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.03	m	worst case
d)	antenna aperture length	L	0.09	m	worst case
e)	antenna aperture area	A	0.003	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	20.5	dBi	= 112.20
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	30.00	°	worst case
m)	transmit frequency range	f	27.5 – 29.5	GHz	
n)	wavelength at 27.5 GHz	?	0.011	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0.00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	0.38	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	117.68	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.08	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.12	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	44.23	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	117.68	W/m²
region D: dimension (acc.to FCC)	R_{ff}	0.20	m
region D: dimension (acc.to DIN VDE)	R_{ff}	0.66	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	18.09	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	1.63	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	A	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	B	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0327	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.1238	m
general public exposure limit is reached within region (acc. to FCC)	-/-	D	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.2663**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.2663**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0153	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0157	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0453	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0456	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0453	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0456	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m

Annex 1.2 Technical parameters of equipment under test (SRU)

Annex 1.2.1 SRU 125mm lens horn antenna 24.5 – 26.5 GHz

Technical parameters of equipment under test

a)	antenna type	lens horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.125	m	worst case
d)	antenna aperture length	L	0.125	m	worst case
e)	antenna aperture area	A	0.125	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	30.5	dBi	= 1122
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	6.86	°	worst case
m)	transmit frequency range	f	24.5 – 26.5	GHz	
n)	wavelength at 24.5 GHz	?	0,012	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0.00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	1.09	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	25.89	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.32	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.50	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	28.24	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	25.89	W/m²
region D: dimension (acc.to FCC)	R_{ff}	0.77	m
region D: dimension (acc.to DIN VDE)	R_{ff}	2.55	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	12.10	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	1.09	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	none	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	none	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0000	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.0000	m
general public exposure limit is reached within region (acc. to FCC)	-/-	D	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.8422**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.8422**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0635	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0647	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0634	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0645	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0635	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0647	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m

Annex 1.2.2 SRU 150mm lens horn antenna 24.5 – 26.5 GHz

Technical parameters of equipment under test

a)	antenna type	lens horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.150	m	worst case
d)	antenna aperture length	L	0.150	m	worst case
e)	antenna aperture area	A	0.150	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	31.5	dBi	= 1413
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	5.85	°	worst case
m)	transmit frequency range	f	24.5 – 26.5	GHz	
n)	wavelength at 24.5 GHz	?	0,012	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0,00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	0.95	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	17.98	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.46	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.72	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	17.15	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	17.98	W/m²
region D: dimension (acc.to FCC)	R_{ff}	1.10	m
region D: dimension (acc.to DIN VDE)	R_{ff}	3.68	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	7.35	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	0.66	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	none	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	none	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0000	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.0000	m
general public exposure limit is reached within region (acc. to FCC)	-/-	C	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.7877**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.9449**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0761	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0774	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0760	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0772	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0761	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0774	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m

Annex 1.2.3 SRU 125mm lens horn antenna 27.5 – 29.5 GHz

Technical parameters of equipment under test

a)	antenna type	lens horn			
b)	antenna aperture diameter	D			
c)	antenna aperture width	W	0.125	m	worst case
d)	antenna aperture length	L	0.125	m	worst case
e)	antenna aperture area	A	0.125	m²	worst case
f)	minimum antenna installation heigt (height of reflector centre above ground)	h	-	m	
g)	minimum elevation angle at geopraphical area within the system shall operate respectely	α_{el}	-	°	
h)	antenna gain (worst case)	G_{max}	30.5	dBi	= 1122
i)	antenna azimuth pattern	$Gi_{(F)az}$	available	dB,dBi	see above
j)	antenna elevation pattern	$Gi_{(F)el}$	available	dB,dBi	see above
k)	antenna aperture efficiency	?	see results	1	
l)	3 dB - antenna main beam width	F_{3dB}	6.68	°	worst case
m)	transmit frequency range	f	27.5 – 29.5	GHz	
n)	wavelength at 27.5 GHz	?	0.011	m	
o)	effective transmitter output power	P	19	dBm	= 80 mW
p)	loss between transmitter and antenna feed horn	a_{dB}	0.00	dB	= 1
q)	polarisation	p	linear		
r)	kind of modulation (modulation scheme)	K_{mod}	16QAM	1	
s)	burst rate	r	-	1/ms	
t)	burst width	w	-	ms	maximum
u)	transmission duty cycle	d	100	%	maximum

Results

result of calculation	**smbol**	**quantity**	**unit**
modulation scheme	k_{mod}	1.00	1
average factor for bursted or pulsed signals	k_{avg}	1.00	1
transmit power fed to antenna	P_t	0.08	W
circular apertures efficiency	η	0.87	1
region A: density of power flux (acc.to FCC and DIN VDE)	$S_{surface}$	25.89	W/m²
region B: dimension (acc.to FCC)	R_{nf}	0.36	m
region B: dimension (acc.to DIN VDE)	R_{nf}	0.56	m
region B: density of power flux to Rnf (acc.to FCC)	S_{nf}	22.42	W/m²
region B: density of power flux to Rnf (acc.to DIN VDE)	S_{nf}	25.89	W/m²
region D: dimension (acc.to FCC)	R_{ff}	0.86	m
region D: dimension (acc.to DIN VDE)	R_{ff}	2.86	m
region D: density of power flux @Rff (acc. to FCC)	S_{ff}	9.60	W/m²
region D: density of power flux @Rff (acc. to DIN VDE)	S_{ff}	0.86	W/m²
occupational exposure limit is reached within region (acc. to FCC)	-/-	none	
occupational exposure limit is reached within region (acc. to DIN VDE)	-/-	none	
occupational exposure limit is reached at a distance of (acc. to FCC)	r_1	0.0000	m
occupational exposure limit is reached at a distance of (acc. to DIN VDE)	r_1	0.0000	m
general public exposure limit is reached within region (acc. to FCC)	-/-	C	
general public exposure limit is reached within region (acc. to DIN VDE)	-/-	C	
general public exposure limit is reached at a distance of (acc. to FCC)	$\mathbf{r_1}$	**0.8027**	**m**
general public exposure limit is reached at a distance of (acc. to DIN VDE)	$\mathbf{r_1}$	**0.8422**	**m**
safety distance r3 (see fig.1) occupational exp.limit only, at least W/2	r_3	0.0635	m
safety distance r3 (see fig.1) general public exp.limit only, at least W/2	r_3	0.0647	m
safety distance r4 (see fig.1) occupational exp.limit only, at least L/2	r_4	0.0634	m
safety distance r4 (see fig.1) general public exp.limit only, at least L/2	r_4	0.0645	m
safety distance r5 (see fig.1) occupational exposure limit only	r_5	0.0635	m
safety distance r5 (see fig.1) general public exposure limit only	r_5	0.0647	m
safety distance r2 (see.fig1) occupational exposure limit	r_2	n.a.	m
safety distance r2 (see.fig1) general public exposure limit	r_2	n.a.	m