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FCC Calculated Safety Distances for Human Exposure for SCANTER 2000 Series

Record of Changes

ECO	Description	Rev	Date
	Released	A	See front page

Contents

1 Introduction

1.1 Purpose

The purpose of this document is to substantiate that the safety distances calculated in TERMA document number 924000-RC [1] are sufficient to comply with the FCC Guidelines for human exposure to electromagnetic fields.

1.2 Scope

FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields applied to TERMA Radar systems.

1.3 Application

Certification of SCANTER 2202 and 2602 Series radar transceivers.

Certification is limited to configuration with an 80 W peak power output.

Equipment to be certified:

Commercial Name	Terma Part Number	Application
SCANTER 2202	902202-xxx	VTS, CS, OLC/ADLS
SCANTER 2602	902602-xxx	Naval

2 References

Ref.	Title
[1]	Terma document number 924000-RC Rev H, “Power Density in Proximity to SCANTER Antennas with SCANTER 4000/5000/6000 Series Transceivers”
[2]	“ICNIRP. Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)”. Health Phys 118(5):483-524; 2020.
[3]	“Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields”, OET Bulletin 65, Edition 97-01, August 1997
[4]	Code of Federal Regulations (CFR): Title 47. Telecommunication § 1.1310

3 Definitions

Term	Definition
CFR	Code of Federal Regulations
CS	Coastal Surveillance
ADLS	Aircraft Detection Lighting System
FCC	Federal Communications Commission
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MPE	Maximum Permissible Exposure
OET	Office of Engineering and Technology

Term	Definition
OLC	Obstruction Light Control
VTS	Vessel Traffic Services

4 Calculations

4.1 Preface

In TERMA document 924000-RC, the safety distances for all combinations of SCANTER 2202/2602 radar systems and antennas from TERMA is given to be a minimum of 5 meters in the horizontal plane and/or +/- 1 meter in the vertical plane. Distances exceeding these will result in exposure below the recommended maximum limit of 10 W/m^2 given by ICNIRP [2].

In the following, the safety distances are assessed according to the methods of OET Bulletin 65 [3], showing that using the approximate formulas of OET-65 at a distance of 5 meters results in power densities below the FCC limits [4].

All the SCANTER 2202/2602 series radar systems can be configured to operate within the frequency band of 9.0 to 9.5 GHz. The maximum permissible exposure (MPE) limit at this frequency band is 1.0 mW/cm^2 = 10 W/m^2 averaged over a time period of 30 minutes according to CFR 47 § 1.1310 [4].

The antennas used are all aperture horn antennas with continuous mechanical rotation in the horizontal plane. The rotation rate is between 6 and 60 revolutions per minute, i.e. at least 180 rotations during a 30 minutes interval. Significant human exposure to radio frequency fields from the radar system is limited to the period in which the beam sweeps past a person, hence the mechanical rotation will reduce the average exposure over a 30 minutes interval. The reduction in exposure due to the rotation of the antenna is an inherent property of the radar system as described in OET Bulletin 65 [3] page 74. In the following, this will be referred to as an antenna duty cycle, since the effect is similar to that of a duty cycle in a transmitter.

4.2 Equations used for calculations

In the following, the equations from OET-65 are used to find the time-averaged near-field power density for a system consisting of a SCANTER 2602 transceiver with a 7' Compact antenna with fan-beam elevation pattern. The smallest physical antenna is chosen, as this results in the highest power density at short range. The transceiver parameters are given in Table 5-1, and the antenna parameters are given in Table 5-2.

The extent of the near-field region can be calculated using equation (12) from OET Bulletin 65, page 27

$$R_{NF} = \frac{D^2}{4\lambda}$$

The length of the antenna (*D*) is 2.16 meters, the wavelength at the lowest frequency of interest (9.0GHz) is 0.0333 meters and the extent of the near-field range is

$$R_{NF} = \frac{(2.16\,m)^2}{4 \times 0.0333\,m} = 35.0\,m$$

OET Bulletin 65, Edition 97-01 page 11, describes that exposure can be averaged over 30 minutes for exposure to the general public. Transmitter duty cycle is therefore included in the calculation of the transmitter power. The peak power is 80 W

$$P_{Peak} = 80\ W$$

For all transceiver variants, the maximum transmitter duty cycle is

$$DutyCycle = 20\% = 0.2$$

This results in a maximum average RF power of

$$P_{Avg} = P_{Peak} \times DutyCycle$$

For the specific system

$$P_{Avg} = 80\ W\ \times 0.2 = 16\ W$$

OET Bulletin 65, Edition 97-01 page 28 describes aperture efficiency as the ratio of the effective aperture area to the physical area. The aperture efficiency for rectangular aperture horn antennas is therefore estimated as

$$\eta = \frac{\left(\frac{G\lambda^2}{4\pi}\right)}{D \times H}$$

Here *G* is the linear power gain, *D* is the length of the antenna aperture and *H* is the height. The linear gain *G* is estimated from the logarithmic gain (G_{Log}) as

$$G = 10^{0.1G_{Log}}$$

For a gain of G_{Log}= 31 dBi, this results in

$$G = 10^{0.1\times31}\ = 1259.0$$

Inserting this value results in an aperture efficiency of

$$\eta = \frac{\left(\frac{1259.0\ \times (0.0333m)^2}{4\pi}\right)}{2.16m \times 0.15m} = 0.343$$

Within the nearfield, the maximum average power density is (from OET Bulletin 65, page 28, equation 13) given by

$$S_{nf} = \frac{16\eta P_{Avg}}{\pi D^2} \times AntennaDutyCycle$$

Although the above formula is strictly speaking only applicable for circular antennas, it is used as it has been verified that results are close to those obtained using full-wave simulations. Within the near-field, the antenna duty cycle is given by the fraction of time that a person is exposed to the beam relative to the total rotation time within a single rotation period.

$$AntennaDutyCycle = \frac{T_{in-beam}}{T_{in-beam} + T_{out-of-beam}}$$

Beam divergence is considered negligible as only the near-field region is considered. Hence, the beam width is the physical width of the antenna. At a distance of *R* meters, the time spent in the beam is

$$T_{in-beam} = \frac{\theta}{2\pi} \times T_{rot}$$

Where θ is the angle spanned by the beam at a distance of *R*. The time spent outside the beam is

$$T_{out-of-beam} = \left(\frac{2\pi - \theta}{2\pi}\right) \times T_{rot}$$

Inserting these times in the equation for the antenna duty cycle, it results in

$$AntennaDutyCycle = \frac{\theta}{2\pi}$$

The angle spanned by the beam is (see Figure 1)

$$\theta = 2\mathrm{asin}\left(\frac{D}{2R}\right)$$

At a range of 5 meters the angle spanned by the beam is

$$\theta = 2\,\mathrm{asin}\left(\frac{2.16\,m}{2 \times 5\,m}\right) = 0.435\,rad$$

The antenna duty cycle is

$$AntennaDutyCycle = \frac{0.435\,rad}{2\pi} = 0.069$$

The near-field power density at a range of 5 meters in the highest field region becomes

$$S_{nf} = \frac{16\eta P_{Avg}}{\pi D^2} \times AntennaDutyCycle = \frac{16 \times 0.343 \times 16W}{\pi \times (2.16m)^2} \times 0.069 = 0.413\ W/m^2$$

Comparing with the maximum permissible exposure (MPE) limit at this frequency of 10 W/m^2, the near-field power density can be seen to be significantly lower than the limit value at the stated safety distance of 5 meters. The calculations are summarized in Table 5-3 for the different combination of 2202/2602 transceivers and antenna variants.

In the case of a non-rotating antenna due to motor failure, the antenna duty cycle will become 100% and the near-field power density of the example system will be

$$S_{nf} = \frac{16\eta P_{Avg}}{\pi D^2} \times AntennaDutyCycle = \frac{16 \times 0.343 \times 16W}{\pi \times (2.16m)^2} \times 1.0 = 6.0\,W/m^2$$

This is still significantly lower than the maximum permissible exposure limit of 10 W/m^2.

5 Conclusion

In conclusion, the safety distances given in TERMA document 924000-RC of 5 meters from the antenna is more than sufficient to ensure that the exposure to radio-frequency fields is below the MPE limit of 10 W/m^2 from CFR 47 § 1.1310 when using the calculational methods of OET Bulletin 65 for all combinations of SCANTER 2202/2602 transceivers and SCANTER Compact and 18' High Gain antennas.

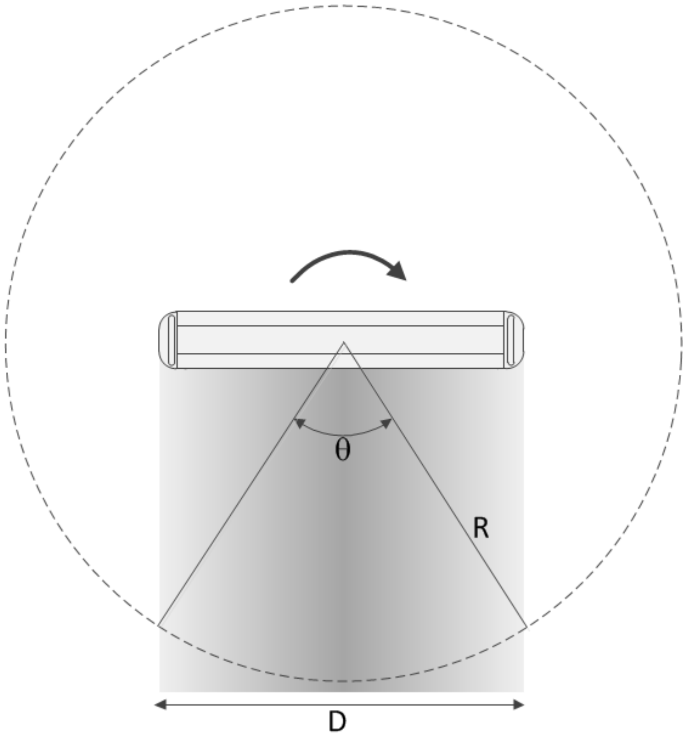

Figure 5-1 Top-view figure showing the antenna and the rotational direction. The beam is shown in gray, with a width D equivalent to the antenna width and spanning an angle Θ at a distance of R meters.

Table 5-1 Transceiver parameters

Transceiver	Peak power [W]	Transmitter duty cycle
2202 and 2602	80	0.2

Table 5-2 Antenna parameters

Antenna	Width [m]	Height [m]	Gain [dBi]	Beam width [deg]	Gain linear	Effective area [m^2]	Physical area (m^2)	Aperture efficiency (η)
HighGain 21', Fan-beam	6.25	0.26	38.00	0.36	6309.57	0.56	1.61	0.35
HighGain 18', Fan-beam	5.39	0.26	37.00	0.42	5011.87	0.44	1.39	0.32
Compact 18' Fan-beam	5.69	0.15	35.00	0.42	3162.28	0.28	0.85	0.33
Compact 12' Fan-beam	3.94	0.15	34.00	0.60	2511.89	0.22	0.59	0.38
Compact 12' Csc2	3.94	0.15	32.50	0.60	1778.28	0.16	0.59	0.27
Compact 9' Fan-beam	2.71	0.15	32.00	0.82	1584.89	0.14	0.40	0.35
Compact 9' Csc2	2.71	0.15	30.50	0.82	1122.02	0.10	0.40	0.25
Compact 7' Fan-beam	2.16	0.15	31.00	1.10	1258.93	0.11	0.32	0.34

Table 5-3 Near-field power density (far-right column) at 5 meters distance

Transceiver	Peak power [W]	Transmitter duty cycle	Antenna	Antenna duty cycle @ 5m	S_nf @ 5m [W/m^2]
2202 / 2602	80	0.20	HighGain 21', Fan-beam	0.21	0.16
	80	0.20	HighGain 18', Fan-beam	0.18	0.16
	80	0.20	Compact 18' Fan-beam	0.19	0.16
	80	0.20	Compact 12' Fan-beam	0.13	0.26
	80	0.20	Compact 12' Csc2	0.13	0.18
	80	0.20	Compact 9' Fan-beam	0.09	0.34
	80	0.20	Compact 9' Csc2	0.09	0.24
	80	0.20	Compact 7' Fan-beam	0.07	0.42