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Exposure levels in close proximity of radiocommunication antennas

Recommendation ITU-T K.122

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Exposure levels in close proximity of radiocommunication antennas

Summary

The guidance concerning the exposure levels in close proximity to transmitting antennas is important for safety of the radiocommunication staff operating in such areas.

Recommendation ITU-T K.122 gives information concerning the electric field strength levels that can be expected in close proximity to the broadcasting and radiocommunication antennas so that a comparison with the exposure limits is possible. This is important for maintenance personnel and in some cases also for the general public. In the case of workers it is recommended that affected personnel should be trained by expert staff so that they are able to assess the exposure levels in close proximity of radiocommunication antennas.

There are many possible configurations of transmitting antennas. In this Recommendation the most typical ones are presented, in order to give general information about exposure levels that can be expected during the operation of radiocommunication systems.

History

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Keywords

Exposure level, maintenance, occupational exposure, radiocommunication antenna.

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Introduction

This Recommendation provides information on the electric field strength levels that could be expected in close proximity to broadcasting and radiocommunication antennas so that a comparison with the exposure limits is possible. This is important for maintenance personnel and in some cases also for the general public.

This Recommendation presents examples of the results of calculations done for typical conditions of operation of radio equipment in areas accessible by maintenance personnel or in some cases for the general public. This Recommendation also gives guidance on how to recalculate these levels for user-specific configurations.

The results presented in this Recommendation have been obtained using the following calculation methods: method of moments (MoM) or hybrid methods multilevel fast multipole method (MLFMM) and physical optics with MoM (PO/MoM). All these methods are full-wave methods so they allow for calculations even in the reactive part of the near-field region.

Recommendation ITU-T K.122

Exposure levels in close proximity of radiocommunication antennas

1 Scope

In this Recommendation the level of electric field strength is simulated in the vicinity of transmitting antennas of the:

- FM high-power antenna system with horizontal polarization
- FM high-power antenna system with vertical polarization
- UHF TV high-power antenna system with horizontal polarization
- mobile communication dual-band 900 /1 800MHz antenna panel (+45°/−45° polarization)
- micro-cell ceiling-mounted antenna
- fixed point-to-point 22.4 GHz antenna
- fixed point-to-point 75 GHz antenna.

There are many possible configurations of transmitting antennas. In this Recommendation most typical ones are presented in order to give information about exposure levels that may be expected during the operation of radiocommunication systems. It is also recommended, if the exposure level is close to the limit, to confirm results by measurements using the procedures defined in [ITU-T K.61] and [IEC 62232].

NOTE – In addition to the field levels provided in this Recommendation, guidelines about how to manage workers' exposure in the vicinity of base stations can be found in [ETSI 101870], [b-EN 50499] and [IEC 62232].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.52] Recommendation ITU-T K.52 (2004), *Guidance on complying with limits for human exposure to electromagnetic fields.*

[ITU-T K.61] Recommendation ITU-T K.61 (2003), *Guidance to measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations.*

[ITU-T K.70] Recommendation ITU-T K.70 (2007), *Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations.*

[ITU-T K.91] Recommendation ITU-T K.91 (2012), *Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields.*

[ITU-R BS.1195] Recommendation ITU-R BS.1195 (1995), *Transmitting antenna characteristics at VHF and UHF.*

[ITU-R BS.1698] Recommendation ITU-R BS.1698 (2005), *Evaluating fields from terrestrial broadcasting transmitting systems operating in any frequency band for assessing exposure to non-ionizing radiation.*

[ICNIRP] ICNIRP (1998), *ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz),* Health Physics, Vol. 74, No. 4; pp. 494-522.

[IEC 62232] IEC 62232 (2011), *Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.*

[IEEE C95.1] IEEE C95.1-2005, *Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.* <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=1626482&contentType=Standards&refinements%3D4294965216%2C4293621946%26queryText%3DIEEE+C95.1>

[IEEE C95.7] IEEE C95.7-2005, *Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz.* <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?tp=&arnumber=1611107&contentType=Standards&queryText%3DRecommended+Practice+for+Radio+Frequency+Safety+Programs%2C+3+kHz+to+300+GHz>

[ISO/IEC 98-3] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).* <http://www.iso.org/iso/catalogue_detail.htm?csnumber=50461>

[ETSI 101870] ETSI TR 101 870 V1.1.1 (2001-11), *Fixed radio transmitter sites; Exposure to non-ionising electromagnetic fields; Guidelines for working conditions.*

[ETSI 102457] ETSI TR 102 457 V1.1.1 (2006-08), *Transmission and Multiplexing (TM); Study on the electromagnetic radiated field in fixed radio systems for environmental issues.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 antenna [ITU-T K.70]: Device that serves as a transducer between a guided wave (e.g., coaxial cable) and a free space wave, or vice versa. It can be used to emit or receive a radio signal. In this Recommendation the term antenna is used only for emitting antenna(s).

3.1.2 antenna gain [ITU-T K.70]: The antenna gain $G(\theta, \phi)$ is the ratio of power radiated per unit solid angle multiplied by 4π to the total input power. The gain is frequently expressed in decibels with respect to an isotropic antenna (dBi). The formula defining the gain is:

$$G_i(\theta,\phi)=\eta\frac{4\pi}{P_{in}}\frac{dP_r}{d\Omega}$$

where:

θ, ϕ are the angles in polar coordinates system

η is the antenna efficiency due to dissipative losses

P_r is the radiated power in the (θ, ϕ) direction

P_{in} is the total input power

$d\Omega$ an elementary solid angle in the direction of observation.

NOTE – In manufacturers' catalogues the antenna gain is understood as a maximum value of the antenna gain. Gain does not include losses arising from impedance and polarization mismatches. If an antenna is without dissipative loss then its gain is equal to its directivity $D(\theta, \phi)$.

3.1.3 average (temporal) power (P_{avg}) [ITU-T K.52]: The time-averaged rate of energy transfer defined by:

$$P_{avg} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} P(t) dt$$

where:

P(t) is the instantaneous power,

t_1 and t_2 are the start and stop time of the exposure.

3.1.4 basic restrictions [ITU-T K.70]: Restrictions on exposure to time-varying electric, magnetic and electromagnetic fields that are based directly on established health effects. Depending upon the frequency of the field, the physical quantities used to specify these restrictions are: current density (*J*), specific absorption rate (SAR) and power density (*S*).

3.1.5 compliance distance [ITU-T K.70]: Minimum distance from the antenna to the point of investigation where the field level is deemed to be compliant with the limits.

3.1.6 controlled/occupational exposure [ITU-T K.70]: Controlled/occupational exposure applies to situations where the persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Controlled/occupational exposure also applies to the cases where the exposure is of transient nature as a result of incidental passage through a location where the exposure limits may be above the general population/uncontrolled environment limits, as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

3.1.7 directivity [ITU-T K.70]: Is the ratio of the power radiated per unit solid angle over the average power radiated per unit solid angle.

3.1.8 equivalent isotropically radiated power (eirp) [ITU-T K.70]: The EIRP is the product of the power supplied to the antenna and the maximum antenna gain relative to an isotropic antenna.

3.1.9 equivalent radiated power (ERP) [ITU-T K.70]: The ERP is the product of the power supplied to the antenna and the maximum antenna gain relative to a half-wave dipole antenna.

3.1.10 exposure [ITU-T K.52]: Exposure occurs wherever a person is subjected to electric, magnetic or electromagnetic fields or to contact currents other than those originating from physiological processes in the body or other natural phenomena.

3.1.11 exposure level [ITU-T K.52]: Exposure level is the value of the quantity used when a person is exposed to electromagnetic fields or contact currents.

3.1.12 exposure limits [ITU-T K.70]: Values of the basic restrictions or reference levels acknowledged, according to obligatory regulations, as the limits for the permissible maximum level of the human exposure to the electromagnetic fields.

3.1.13 far-field region [ITU-T K.52]: That region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. In the far-field region, the field has predominantly plane-wave character, i.e., locally uniform distribution of electric field strength and magnetic field strength in planes transverse to the direction of propagation.

3.1.14 general population/uncontrolled exposure [ITU-T K.52]: General population/uncontrolled exposure applies to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure.

3.1.15 general public [ITU-T K.52]: All non-workers (see definition of workers in clause 3.1.29) are defined as the general public.

NOTE – General public exposure – RF exposure of persons who have not received any form of RF safety awareness information or training. Typically, general public exposure occurs in uncontrolled environments and includes individuals of all ages and varying health status, including children, pregnant women, individuals with impaired thermoregulatory systems, individuals equipped with electronic medical devices, and persons using medications that may result in poor thermoregulatory system performance [IEEE C95.7].

3.1.16 intentional emitter [ITU-T K.52]: Intentional emitter is a device that intentionally generates and emits electromagnetic energy by radiation or by induction.

3.1.17 intentional radiation [ITU-T K.70]: Electromagnetic fields radiated through the transmitting antenna even in directions which are not needed (for example to the back of the parabolic microwave antenna).

3.1.18 near-field region [ITU-T K.52]: The near-field region exists in the proximity to an antenna or other radiating structure in which the electric and magnetic fields do not have a substantially plane-wave character but vary considerably from point to point. The near-field region is further subdivided into the reactive near-field region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating near-field region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complicated in structure.

NOTE – For many antennas, the outer boundary of the reactive near-field is taken to exist at a distance of one wavelength from the antenna surface.

3.1.19 power density (S) [ITU-T K.52]: Power flux-density is the power per unit area normal to the direction of electromagnetic wave propagation, usually expressed in units of watts per square metre (W/m^2). In this Recommendation, this term is commonly used to refer to equivalent plane wave power density, see clause 3.1.32.

NOTE – For plane waves, power flux-density, electric field strength (*E*), and magnetic field strength (*H*) are related by the intrinsic impedance of free space, $Z_0 \approx 377$ or $120\,\pi\,\Omega$. In particular,

$$S_{eq} = \frac{E^2}{Z_0} = Z_0 H^2 = EH$$

where *E* and *H* are expressed in units of V/m and A/m, respectively, and *S* in units of W/m^2. Although many survey instruments indicate power density units, the actual quantities measured are *E* or *H*.

3.1.20 power density, average (temporal) [ITU-T K.52]: The average power density is equal to the instantaneous power density integrated over a source repetition period.

NOTE – This averaging is not to be confused with the measurement averaging time.

3.1.21 power density, peak [ITU-T K.52]: The peak power density is the maximum instantaneous power density occurring when power is transmitted.

3.1.22 power density, plane-wave equivalent (S_{eq}) [ITU-T K.52]: The equivalent plane-wave power density is a commonly used term associated with any electric or magnetic field, that is equal in magnitude to the power flux-density of a plane wave having the same electric (E) or magnetic (H) field strength.

3.1.23 radio frequency (RF) [ITU-T K.70]: Any frequency at which electromagnetic radiation is useful for telecommunication.

NOTE – In this Recommendation, radiofrequency refers to the frequency range of 9 kHz – 300 GHz allocated by ITU-R Radio Regulations.

3.1.24 reference levels [ITU-T K.70]: Reference levels are provided for the purpose of comparison with exposure quantities in air. The reference levels are expressed as electric field strength (E), magnetic field strength (H) and power density (S) values. In this Recommendation the reference levels are used for the exposure assessment.

3.1.25 relative field pattern (radiation pattern): The relative field pattern $f(\theta,\phi)$ is defined in this Recommendation as the ratio of the absolute value of the field strength (arbitrarily taken to be the electric field) to the absolute value of the maximum field strength. It is related to the relative numeric gain (see clause 3.22) as follows:

$$f(\theta, \phi) = \sqrt{F(\theta, \phi)}$$

3.1.26 relative numeric gain (normalized antenna gain): The relative numeric gain $F(\theta,\phi)$ is the ratio of the antenna gain at each angle to the maximum antenna gain. It is a value ranging from 0 to 1. It is also called antenna pattern.

3.1.27 transmitter [ITU-T K.70]: Is an electronic device used to intentionally generate radio frequency electromagnetic energy for the purpose of communication (in contrast to the definition for intentional emitter in clause 3.1.23). The transmitter output is connected via a feeding line to the transmitting antenna which is the real source of the intentional electromagnetic radiation.

3.1.28 wavelength (λ) [ITU-T K.52]: The wavelength of an electromagnetic wave is related to frequency (f) and propagation velocity (v) of an electromagnetic wave by the following expression:

$$\lambda = \frac{v}{f}$$

In free space the propagation velocity is equal to the speed of light (c) which is approximately 3×10^8 m/s. In body tissue the propagation velocity is reduced by the square root of the relative dielectric constant so that wavelength in tissue is typically 7 times shorter than in free space.

3.1.29 workers [ITU-T K.70]: Any person employed by an employer, including trainees and apprentices but excluding domestic servants (see clause 3.1.9).

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BS	Base Station
EIRP	Equivalent Isotropically Radiated Power
EM	Electromagnetic
EMF	Electromagnetic Field
ERP	Equivalent Radiated Power
FM	Frequency Modulation
FPP	Fixed Point-to-Point
GSM	Global System for Mobile communications
HRP	Horizontal Radiation Pattern
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MLFMM	Multilevel Fast Multipole Method
MoM	Method of Moments
PO/MoM	Physical Optics with MoM
RF	Radio Frequency
rms	Root Mean Square
RSS	Root Sum Square
UHF	Ultra High Frequency
VHF	Very High Frequency
VRP	Vertical Radiation Pattern

5 Conventions

None.

6 FM broadcasting antenna with horizontal polarization

Typical FM antennas are mounted using FM two-dipole panels whose number depends on the needs – mainly the require radiated power ERP, number of channels (operating frequencies) that have to be handled and the shape of the horizontal radiation pattern HRP. High-power, omnidirectional FM transmitting antennas usually consist of 6 to 8 bays, each of them with 3 faces that require 18 FM panels (6x3) or 24 panels (8x3). Supporting structure for such antenna systems is the antenna tower, usually with a triangular cross-section. The size of the triangle side is around 3 m so that inside the antenna tower there is enough space for communication. Thus it is important to have knowledge about the level of the electric field strength inside the antenna tower at the height of the FM antenna system.

In Figures 6-1 to 6-3 a configuration is presented of the FM high-power 6 bays 3 faces antenna with ADB4510 (Tesla) two-dipole panels with horizontal polarization mounted on the triangle antenna tower ((6x3)ADB4510).

In Figures 6-4 to 6-12 the results of calculations of the electric field strength are presented for the antenna fed with different frequency (lower, medium and upper for FM frequency band) and with input power (P_{input}) required to achieve a typical maximum ERP = 120 kW. The tower side size is 2.7 m. The results of calculations done for the area inside the antenna tower are presented in two scales: in the scale close to the maximum values and in the scale with maximum value equal to the corresponding occupational exposure limits.

The area inside the antenna tower is accessible for maintenance activity or for communication with antenna systems located at the biggest heights. The area of calculation is usually of a square shape, thus for the antenna tower with a triangular cross-section (typical of an FM antenna tower), the presented results extend beyond the internal region of the tower.

Calculations have been done using MoM for a vertical rectangle of 2.22 m width and 20.3 m height with a step of 5 mm (width) and 20 mm (height); and for a horizontal rectangle of 2.22 m (length) and 2.56 m (width) with 5 mm step. About 16 minutes of CPU time were required for the calculations.

The field strength levels are much higher in the areas outside the antenna tower (in the directions of radiation) but in these areas the presence of maintenance personnel is very rarely required, and if it is all the transmitters feeding the antenna should be switched off.

The maximum value of the electric field strength (inside the antenna tower) is: 426 V/m (f = 88 MHz), 312 V/m (f = 98 MHz) and 307 V/m (f = 108 MHz).

It should be noted that the typical broadcasting antenna system is operating on many (up to 6) frequencies, thus the total exposure level can be adequately higher.

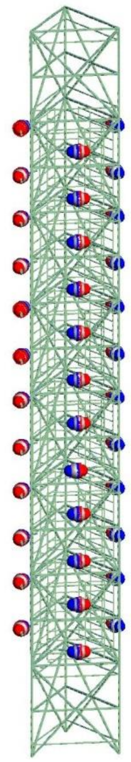

Figure 6-1 – General view of the FM antenna mounted on a triangle antenna tower

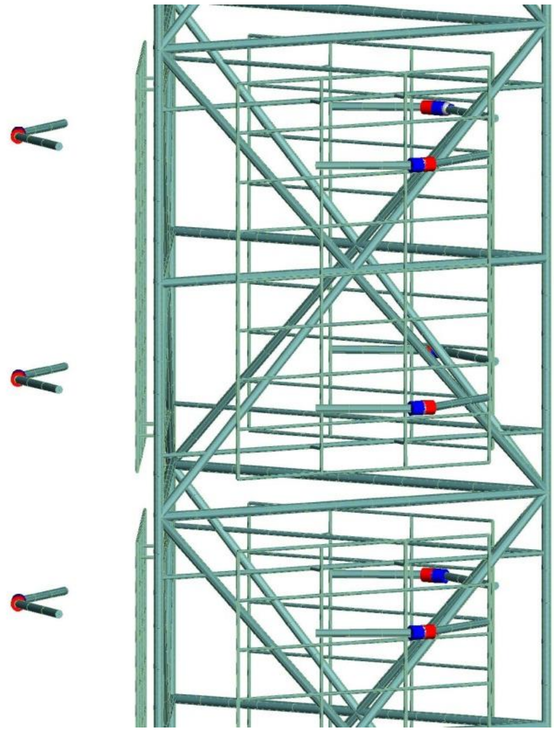

Figure 6-2 – Enlarged part of the FM antenna mounted on a triangle antenna tower

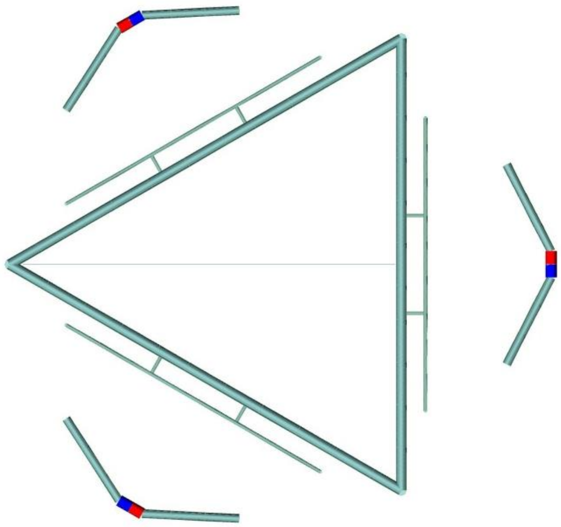

Figure 6-3 – Top view of the considered FM antenna

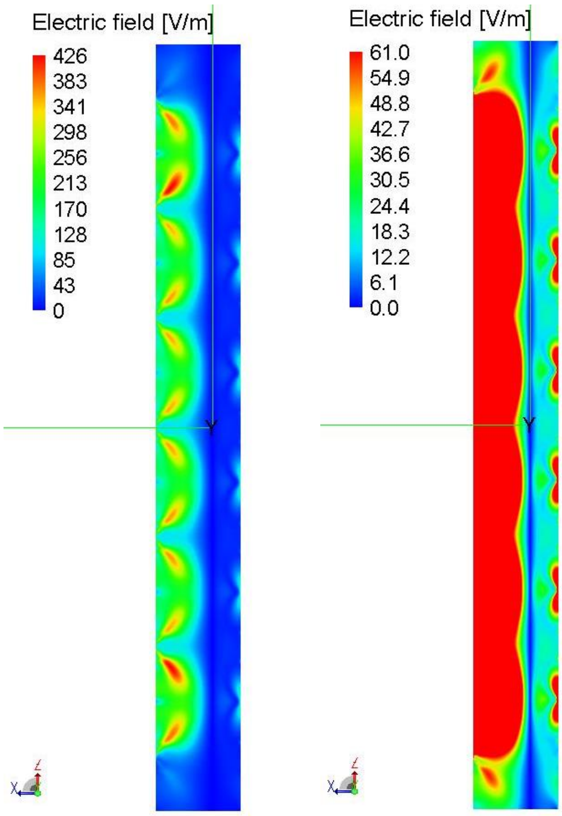

Figure 6-4 – Electric field strength distribution, vertical cross-section, *f* = 88 MHz, ERP = 120 kW, attenuation = 1.18 dB, P_{input} = 18.8 kW, occupational exposure limit: 61 V/m

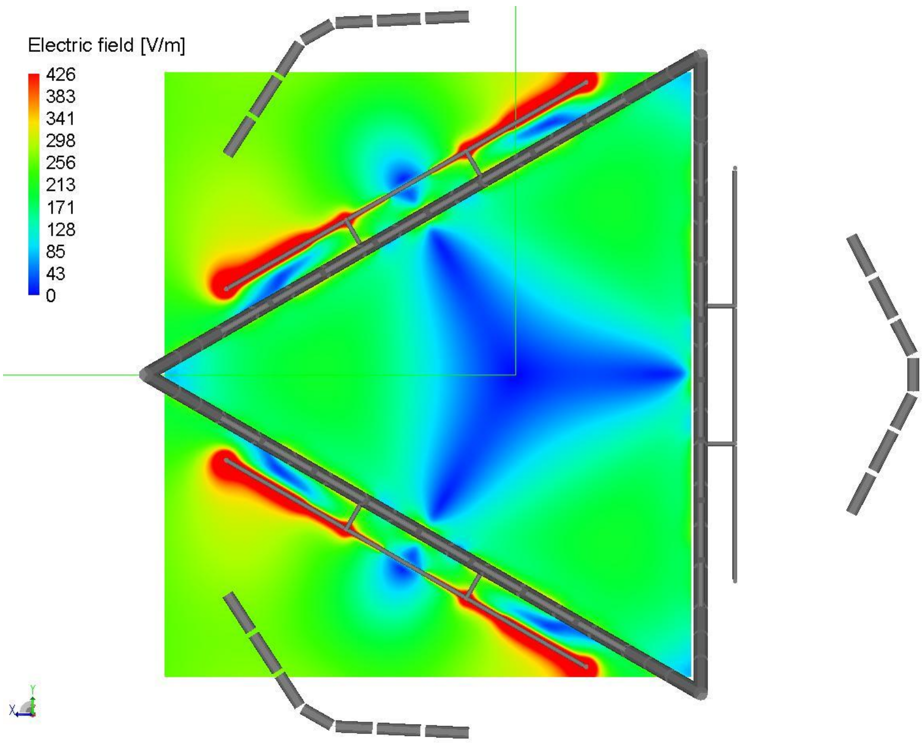

Figure 6-5 – Electric field strength distribution, horizontal cross-section, *f* = 88 MHz, P_{input} = 18.8 kW, attenuation = 1.18 dB, ERP = 120 kW

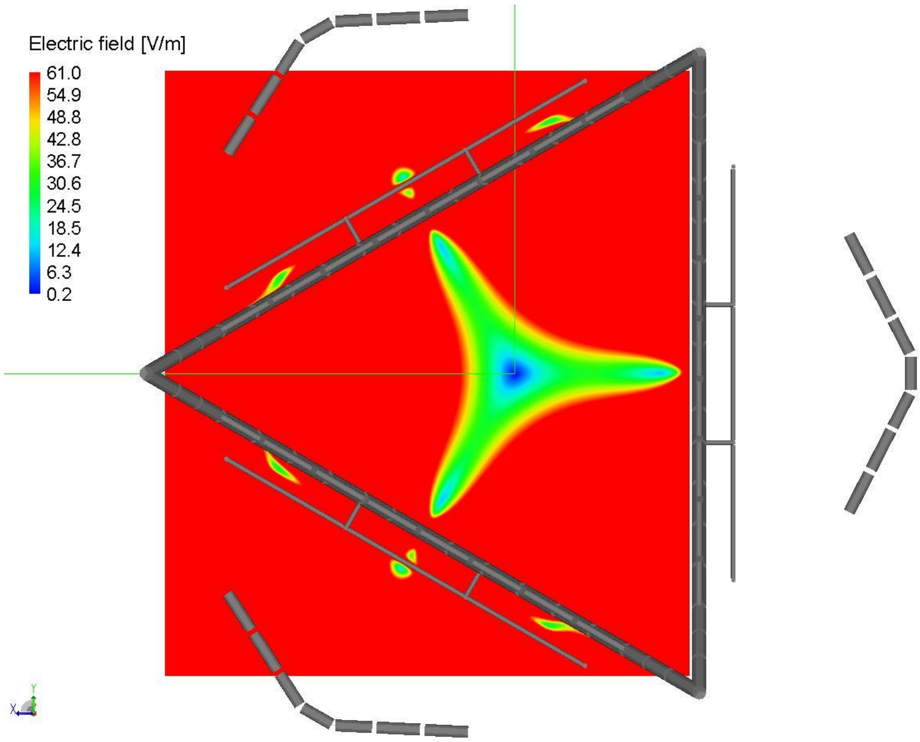

Figure 6-6 – Electric field strength distribution, horizontal cross-section, *f* = 88 MHz, ERP = 120 kW, P_{input} = 18.8 kW, attenuation = 1.18 dB, rescaled to occupational exposure limit 61 V/m

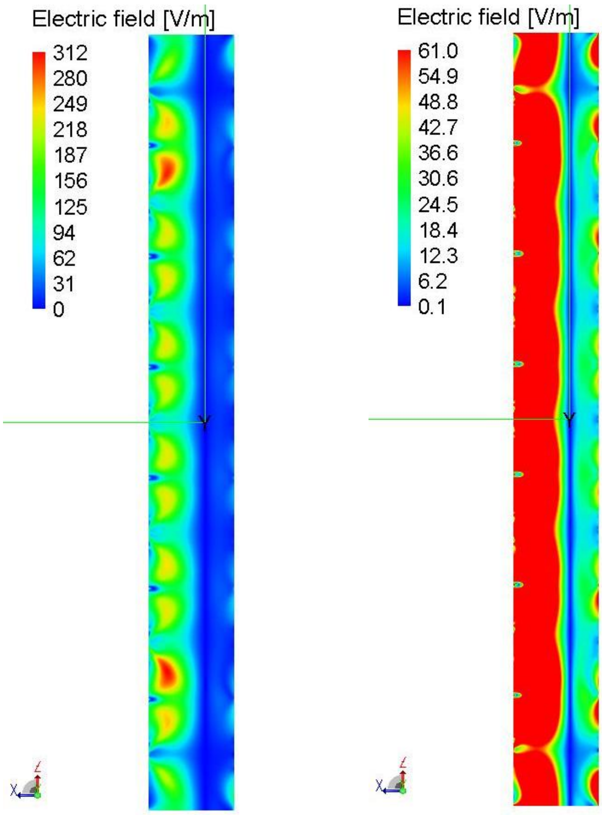

Figure 6-7 – Electric field strength distribution, vertical cross-section, *f* = 98 MHz, ERP = 120 kW, P_{input} = 17.59 kW, attenuation = 1.20 dB, occupational exposure limit: 61 V/m

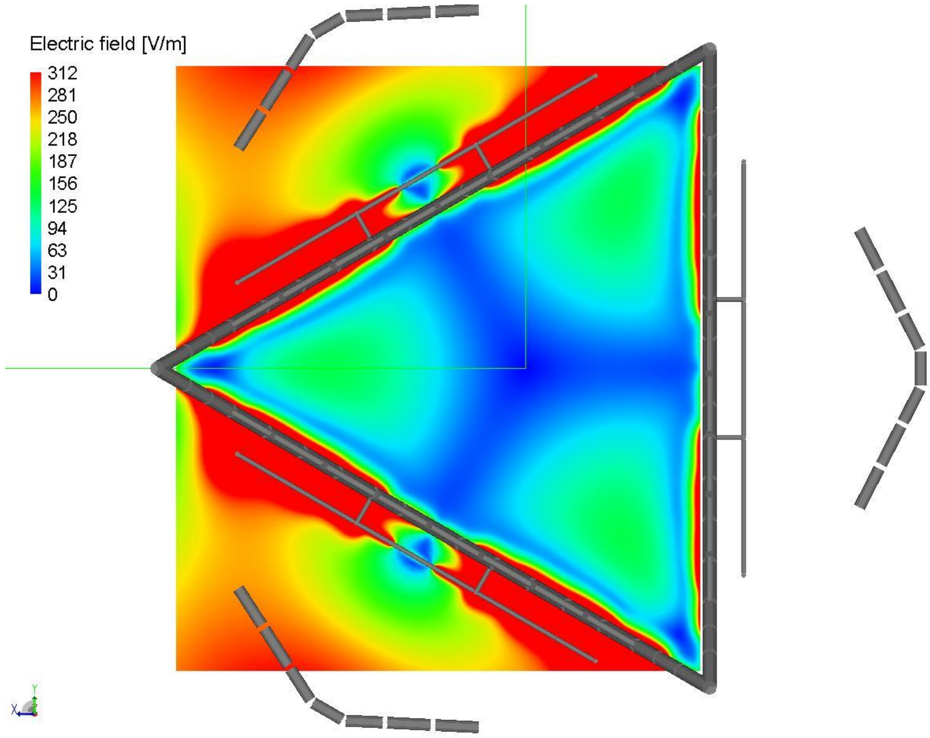

Figure 6-8 – Electric field strength distribution, horizontal cross-section, *f* = 98 MHz, P_{input} = 17.59 kW, attenuation = 1.20 dB, ERP = 120 kW

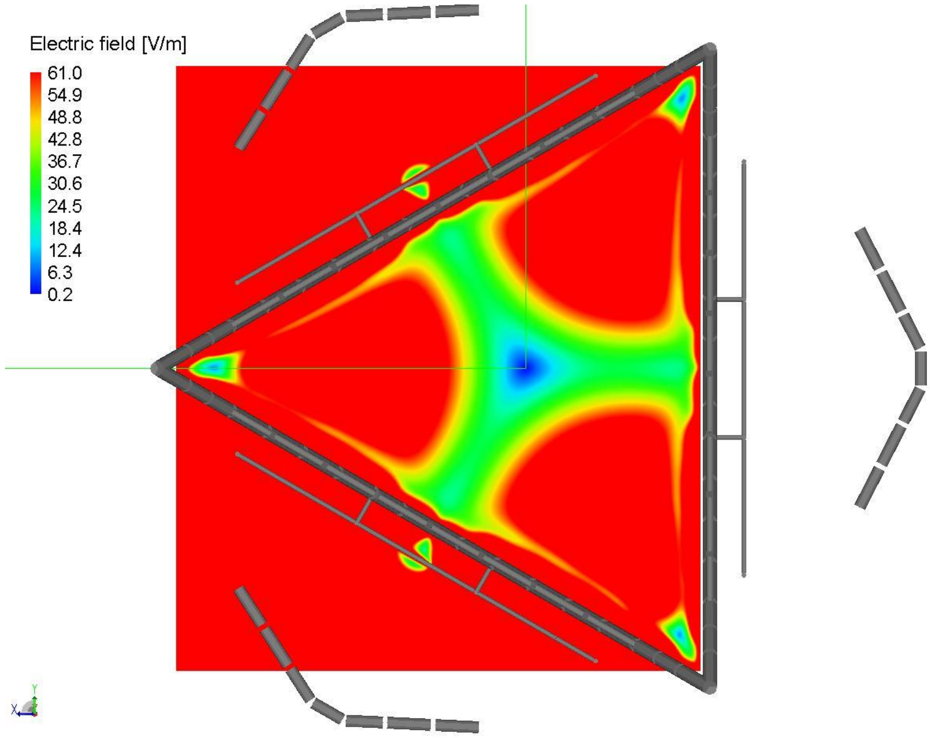

Figure 6-9 – Electric field strength distribution, horizontal cross-section, *f* = 98 MHz, ERP = 120 kW, P_{input} = 17.59 kW, attenuation = 1.20 dB, rescaled to occupational exposure limit 61 V/m

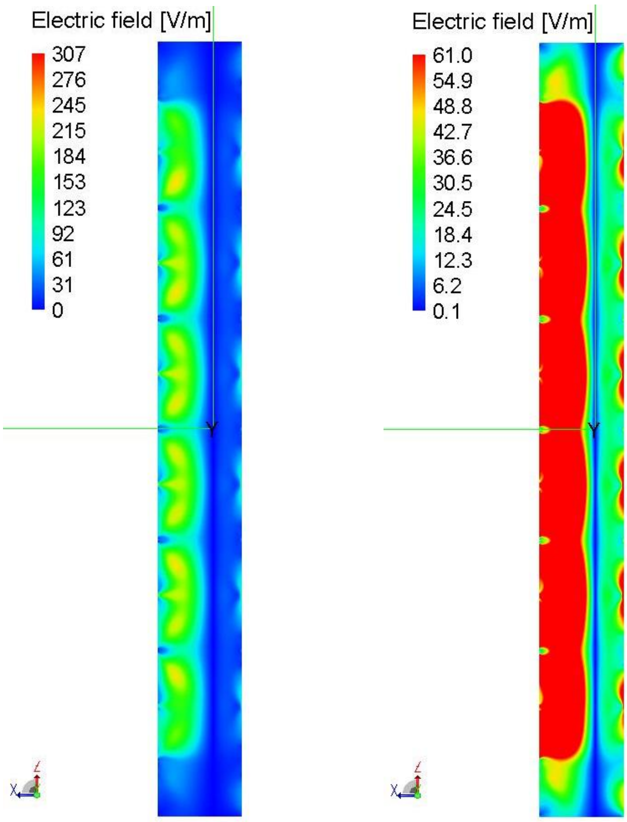

Figure 6-10 – Electric field strength distribution, vertical cross-section, *f* = 108 MHz, ERP = 120 kW, P_{input} = 15.32 kW, attenuation = 1.25 dB, occupational exposure limit: 61 V/m

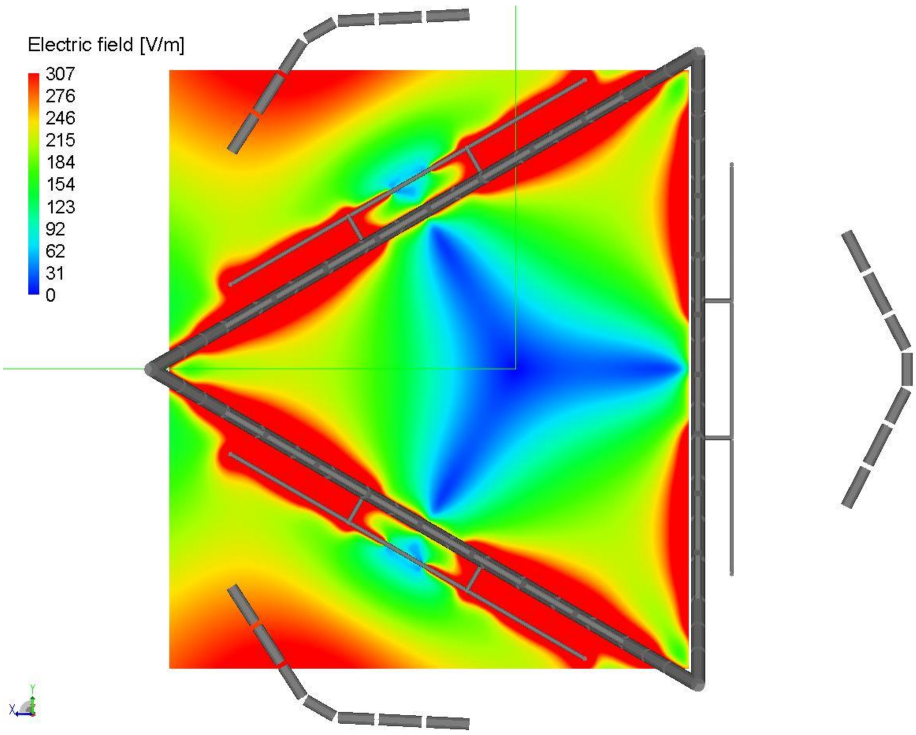

Figure 6-11 – Electric field strength distribution, horizontal cross-section, *f* = 108 MHz, P_{input} = 15.32 kW, attenuation = 1.25 dB, ERP = 120 kW

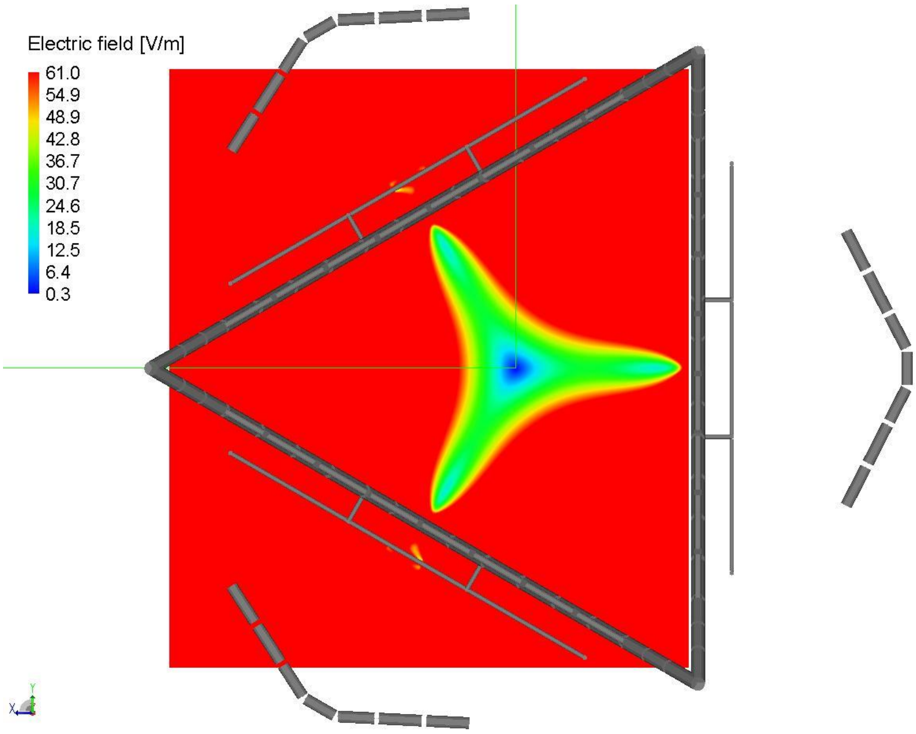

Figure 6-12 – Electric field strength distribution, horizontal cross-section, *f* = 108 MHz, ERP = 120 kW, P_{input} = 15.32 kW, attenuation = 1.25 dB, rescaled to occupational exposure limit 61 V/m

6.1 Total exposure

The total exposure takes into account exposure caused by the three frequencies that may operate simultaneously. In Figures 6-13 and 6-14 the coefficient W_t (see clause 13) for the input data used in clause 6 is presented.

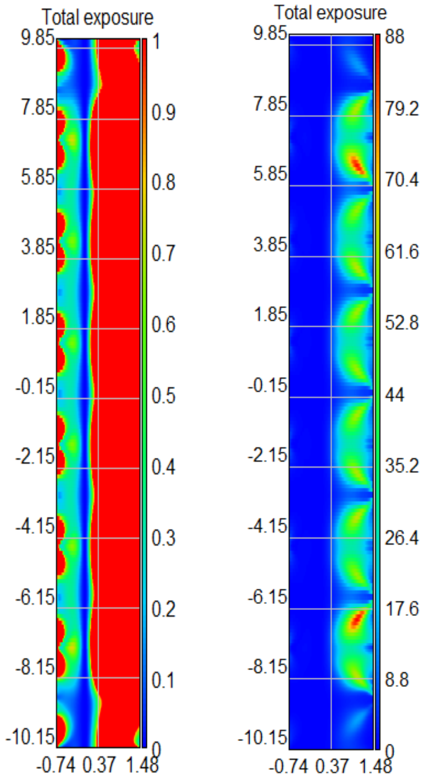

Figure 6-13 – Total exposure W_t, frequencies 88, 98 and 108 MHz, exposure limit: 61 V/m

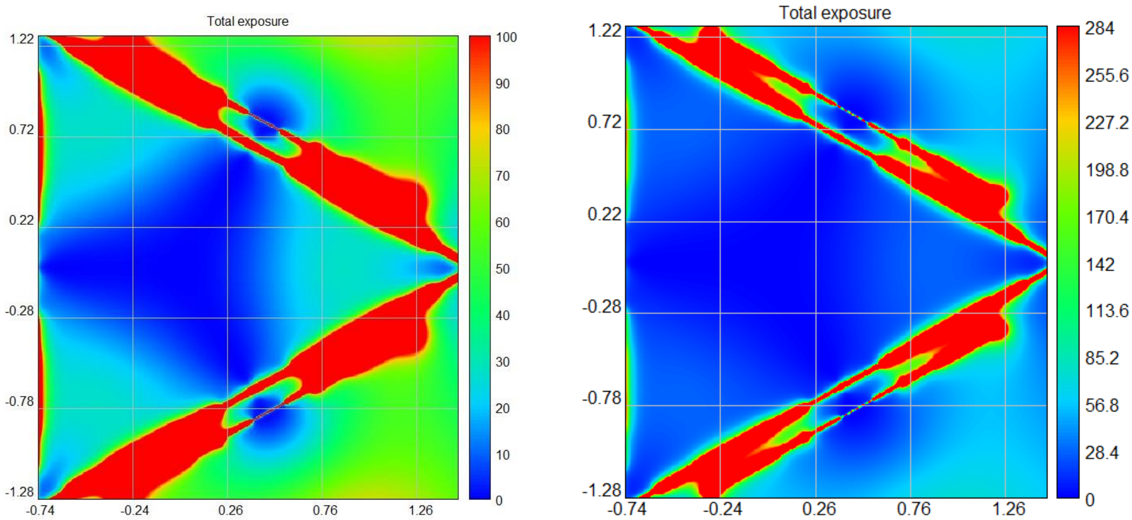

Figure 6-14 – Total exposure W_t, frequencies 88, 98 and 108 MHz, exposure limit: 61 V/m

The maximum value of the total exposure in the area inside the tower is W_t = 88 (8 800%). Additionally, in the very close proximity to the tower structure (accessible only in special cases) the maximum value is 284 (28 400%). It means that in the considered conditions the exposure level inside the antenna tower is much higher than the exposure limit for workers.

7 FM broadcasting antenna with vertical polarization

In this clause the results of calculations are presented for the FM high-power transmitting antenna with vertical polarization. The size of the side of the antenna tower is 3.2 m. All other assumptions concerning the input parameters are the same as for those in clause 6.

In Figures 7-1 to 7-11 a configuration is presented of the FM high-power 6 bays 3 faces antenna with ADB4510 (Tesla) two-dipole panels with vertical polarization mounted on the triangle antenna tower ((6x3)ADB4515).

Calculations have been done using MoM for a vertical rectangle of 2.53 m width and 20.3 m height with a step of 5 mm (width) and 25 mm (height); and for a horizontal rectangle of 2.53 m (length) and 2.91 m (width) with 5 mm step. About 23 minutes of CPU time were required for the calculations.

The maximum value of the electric field strength (inside the antenna tower) is: 544 V/m (f = 88 MHz), 368 V/m (f = 98 MHz) and 642 V/m (f = 108 MHz).

Also in this case the typical broadcasting antenna system is operating on many (up to 6) frequencies, and thus the total exposure level can be adequately higher.

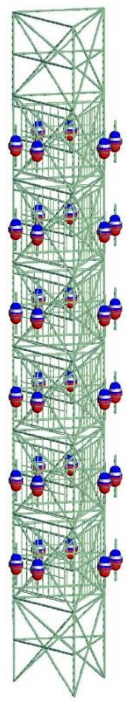

Figure 7-1 – General view of the FM antenna mounted on a triangle antenna tower

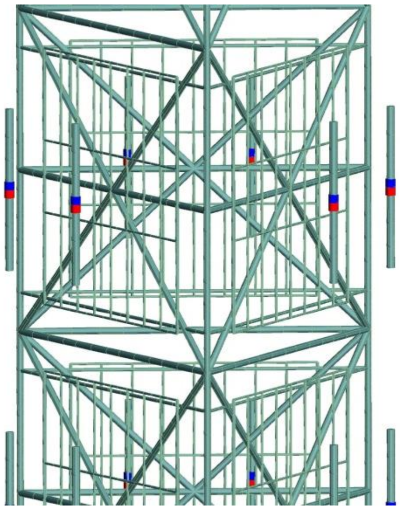

Figure 7-2 – Enlarged part of the FM antenna (6x3)ADB 4515 (Tesla) mounted on a triangle antenna tower

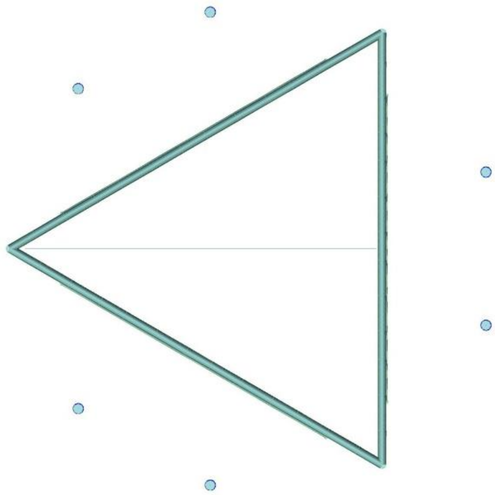

Figure 7-3 – Top view of the (6x3)ADB4515 antenna system

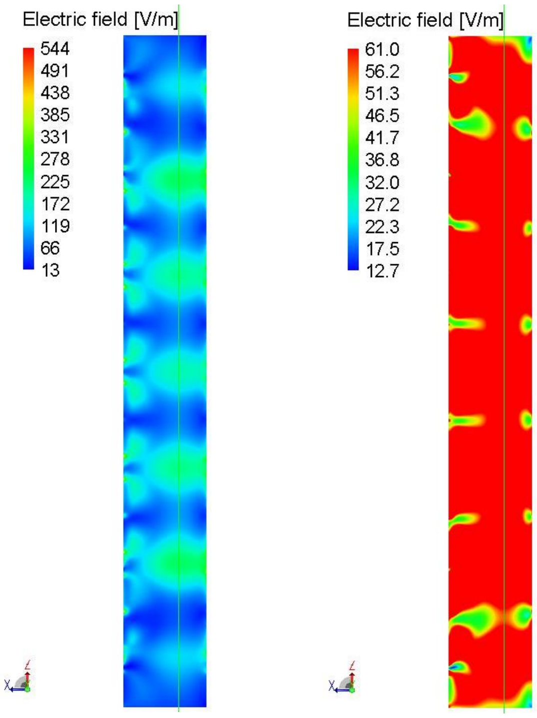

Figure 7-4 – Electric field strength distribution, vertical cross-section, *f* =88 MHz, polarization V, ERP = 120 kW, P_{input} = 22.1 kW, attenuation = 1.18 dB, occupational exposure limit: 61 V/m

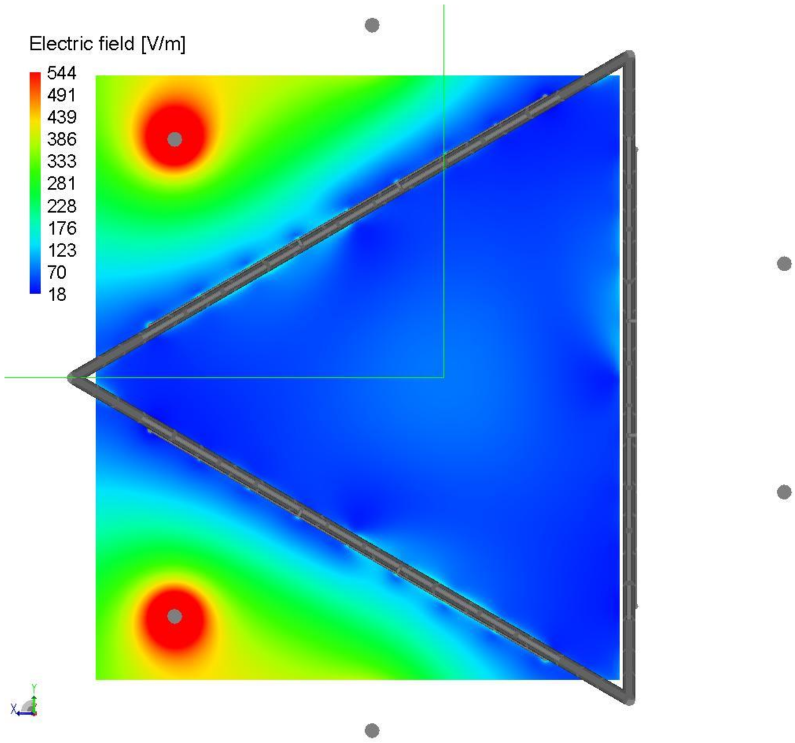

Figure 7-5 – Electric field strength distribution, horizontal cross-section, *f* =88 MHz, polarization V, ERP = 120 kW, P_{input} = 22.1 kW, attenuation = 1.18 dB, occupational exposure limit: 61 V/m

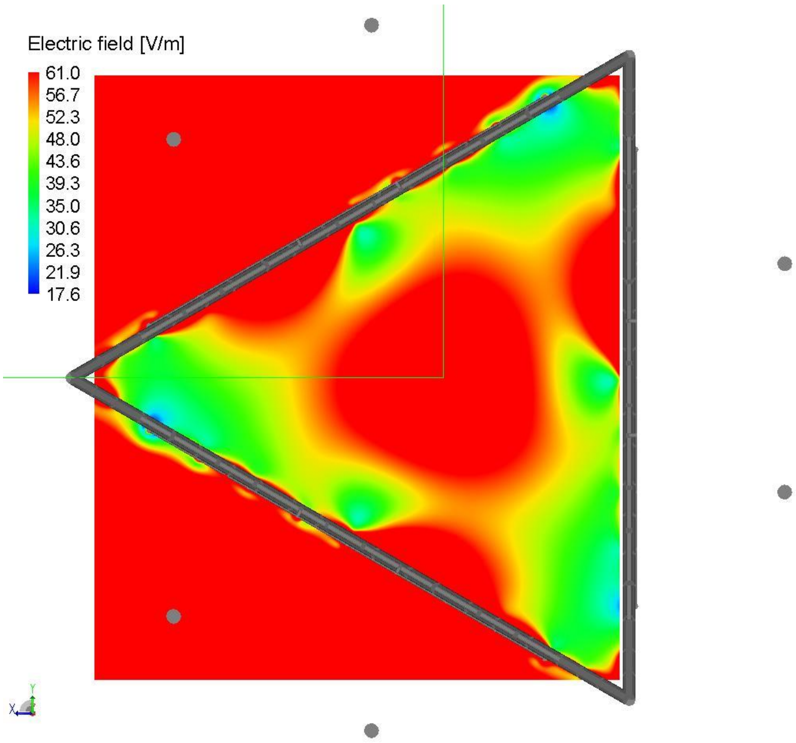

Figure 7-6 – Electric field strength distribution, horizontal cross-section, *f* =88 MHz, polarization V, ERP = 120 kW, P_{input} = 22.1 kW, attenuation = 1.18 dB, occupational exposure limit: 61 V/m

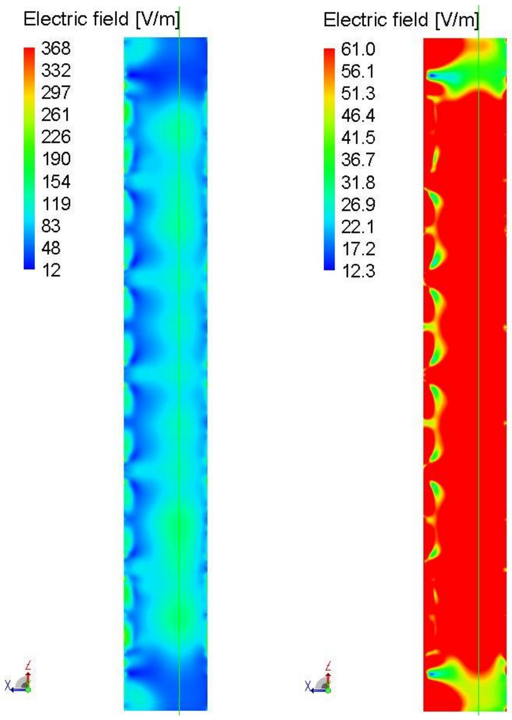

Figure 7-7 – Electric field strength distribution, vertical cross-section, *f* = 98 MHz, polarization V, ERP = 120 kW, P_{input} = 19.2kW, attenuation = 1.20 dB, occupational exposure limit: 61 V/m

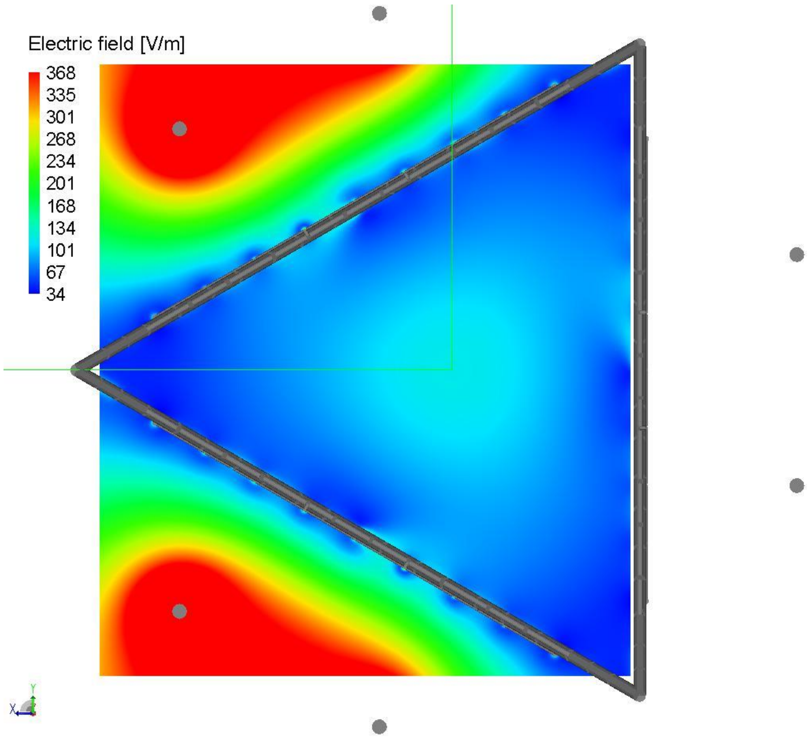

Figure 7-8 – Electric field strength distribution, horizontal cross-section, *f* = 98 MHz, polarization V, ERP = 120 kW, P_{input} = 19.2kW, attenuation = 1.20 dB, occupational exposure limit: 61 V/m

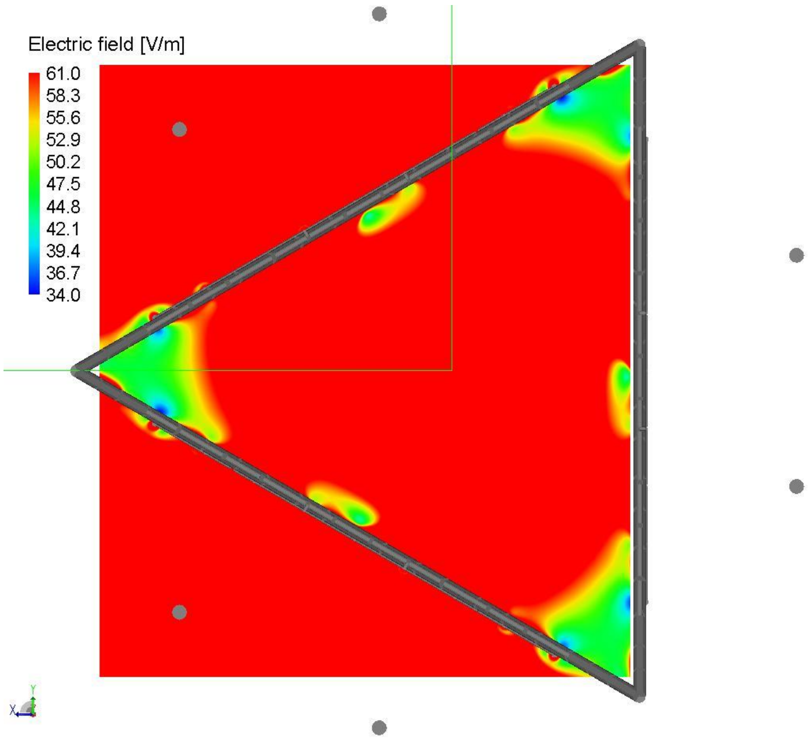

Figure 7-9 – Electric field strength distribution, horizontal cross-section, *f* = 98 MHz, polarization V, ERP = 120 kW, P_{input} = 19.2kW, attenuation = 1.20 dB, occupational exposure limit: 61 V/m

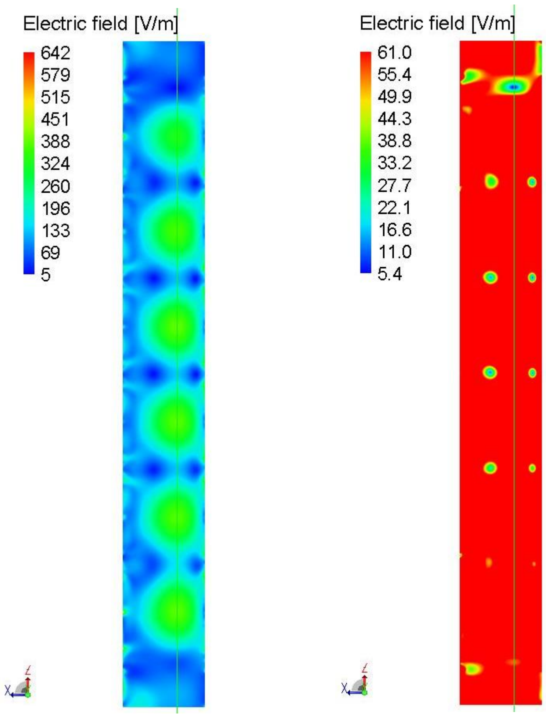

Figure 7-10 – Electric field strength distribution, vertical cross-section, *f* = 108 MHz, polarization V, ERP = 120 kW, P_{input} = 20.1 kW, attenuation = 1.25 dB, occupational exposure limit: 61 V/m

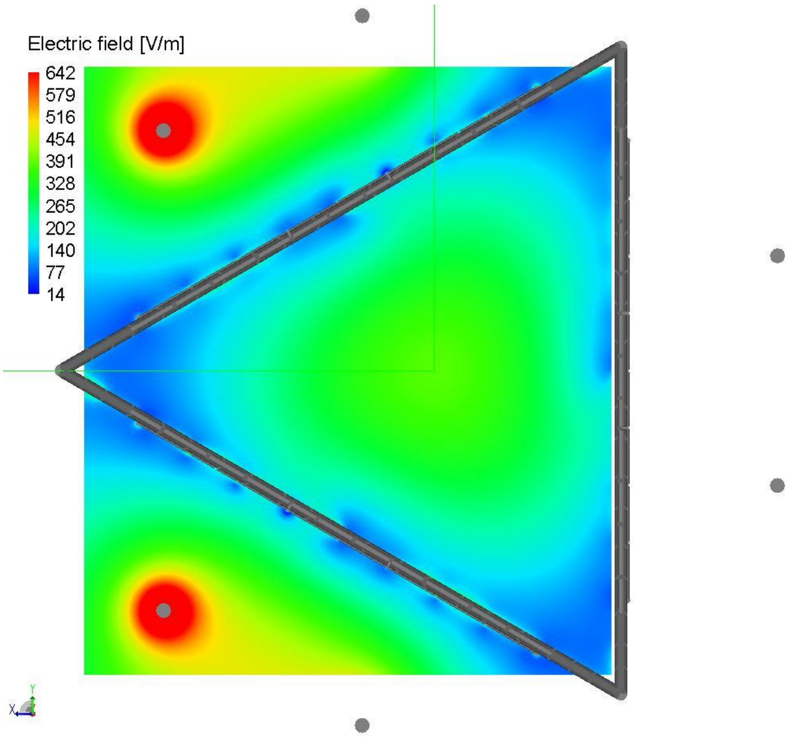

Figure 7-11 – Electric field strength distribution, horizontal cross-section, *f* = 108 MHz, polarization V, ERP = 120 kW, P_{input} = 20.1 kW, attenuation = 1.25 dB, occupational exposure limit: 61 V/m

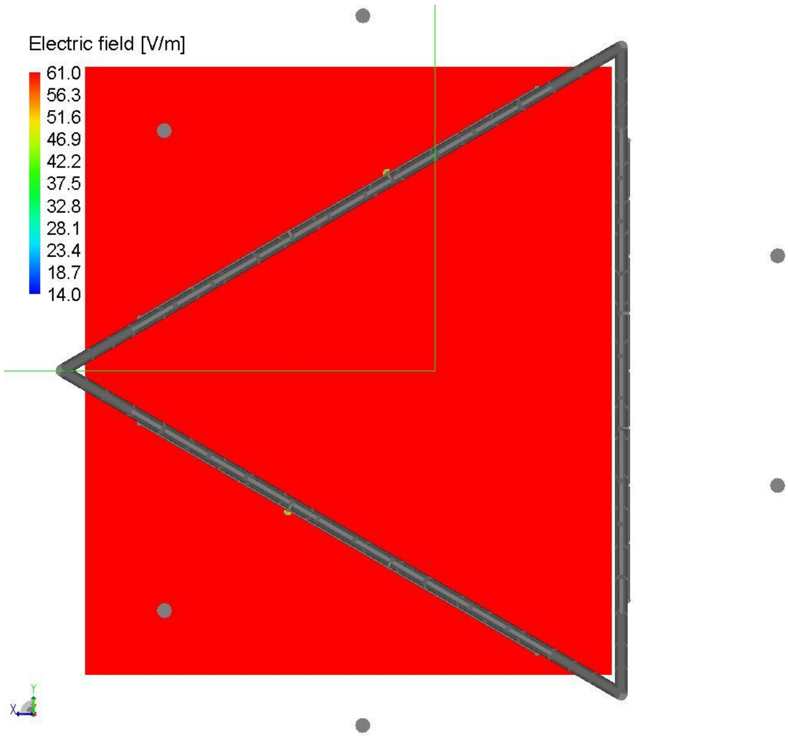

Figure 7.12 – Electric field strength distribution, horizontal cross-section, *f* = 108 MHz, polarization V, ERP = 120 kW, P_{input} = 20.1 kW, attenuation = 1.25 dB, occupational exposure limit: 61 V/m

7.1 Total exposure

The total exposure takes into account exposure caused by the three frequencies that may operate simultaneously. In Figures 7-13 to 7-14 the coefficient W_t (see clause 13) for the input data used in the cases presented above is presented.

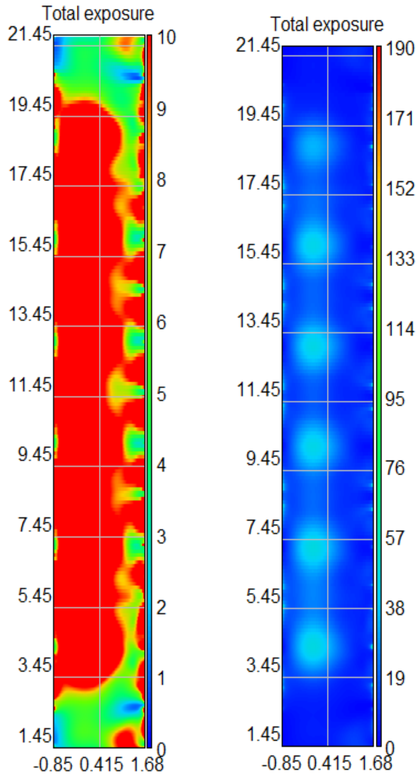

Figure 7-13 – Total exposure W_t, frequencies 88, 98 and 108 MHz, exposure limit: 61 V/m

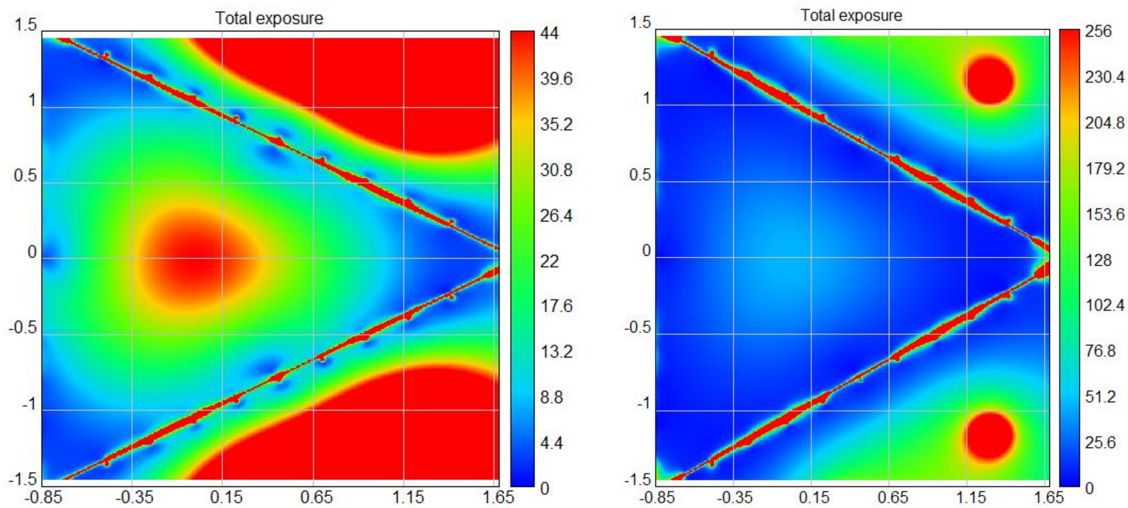

Figure 7-14 – Total exposure W_t, frequencies 88, 98 and 108 MHz, exposure limit: 61 V/m

The maximum value of the total exposure in the area inside the tower is W_t = 44 (4 400%). Additionally, in the very close proximity to the tower structure (accessible only in special cases) the maximum value is W_t = 256 (25 600%). It means that in the considered conditions the exposure level inside the antenna tower is much higher than the exposure limit for workers.

8 UHF TV/DVB-T antenna

The UHF antennas, mainly used for the transmission of analogue or digital TV signals, are usually mounted on top of an antenna tower, and such antennas have their own supporting structure. For the high-power transmitting antennas the typical configuration is 16 bays and 4 faces mounted on a square of size 0.5-0.7 m. The space inside the antenna tower is not big; however, it is usually used for communication or at least for the maintenance of the aviation obstacle lights or lighting arrestor rods.

In this clause the results of calculations for the UHF TV/DVB-T high-power transmitting antenna with horizontal polarization are presented. The transmitter output power has been assumed to achieve ERP = 100 kW. It is a typical high-power ERP for DVB-T broadcasting. For an analogue TV the typical ERP is higher and equal up to 1 000 kW.

In Figures 8-1 to 8-2 a configuration is presented of the UHF high-power 16 bays 4 faces antenna with PHP 4S (RFS) four-dipole panels mounted on the squared antenna tower ((16x4) PHP 4S).

Calculations have been done using the MLFMM method for a vertical rectangle of 0.6 m width and 19 m height with a step of 10 mm (width) and 25 mm (height), and for a horizontal square of size 0.6 m with 5 mm step. About 140 hours of CPU time were required for the calculations.

The maximum value of the electric field strength (inside antenna tower) is: 28.3 V/m (f = 474 MHz), 64.2 V/m (f = 642 MHz) and 55.1 V/m (f = 786 MHz). This value is lower than the occupational exposure limits; however, it should be noted that a typical broadcasting antenna system is operating on many (up to 6) frequencies and the total exposure level can be adequately higher.

Figure 8-1a – Antenna system (16x4)PHP 4S (RFS) on the squared supporting structure

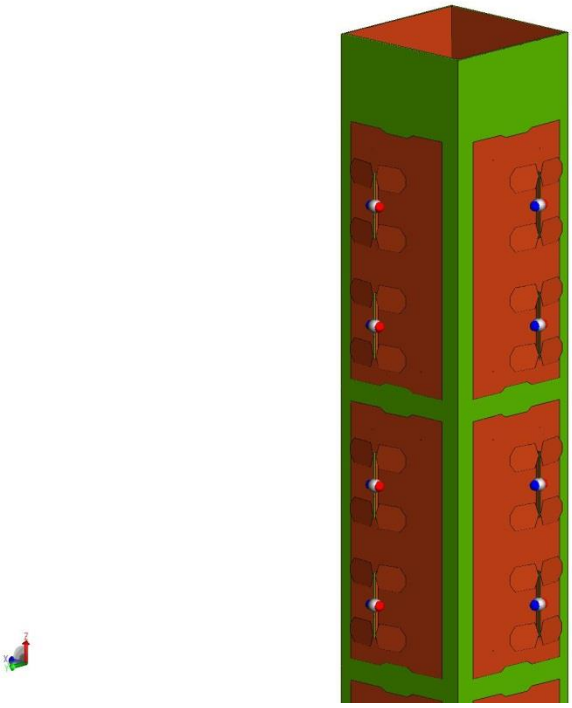

Figure 8-1b – Enlarged part of the antenna system (16x4)PHP 4S (RFS) on the squared supporting structure

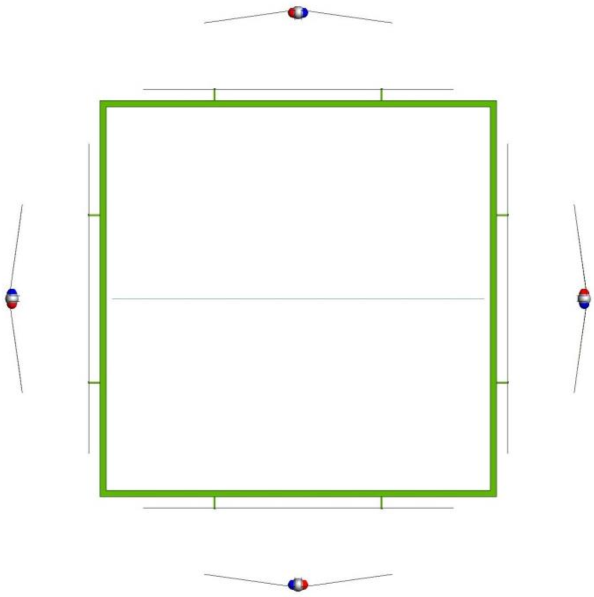

Figure 8-2 – Top view of the antenna system (16x4) PHP 4S (RFS)

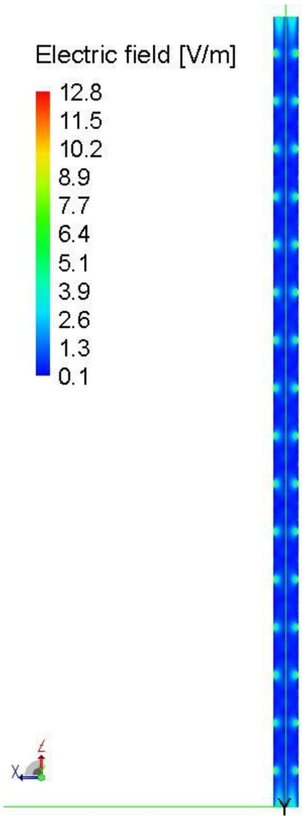

Figure 8-3 – Electric field strength distribution, vertical cross-section, *f* = 474 MHz, polarization H, ERP = 100 kW, P_{input} = 3.77 kW, attenuation = 2.02 dB, occupational exposure limit: 65.3 V/m

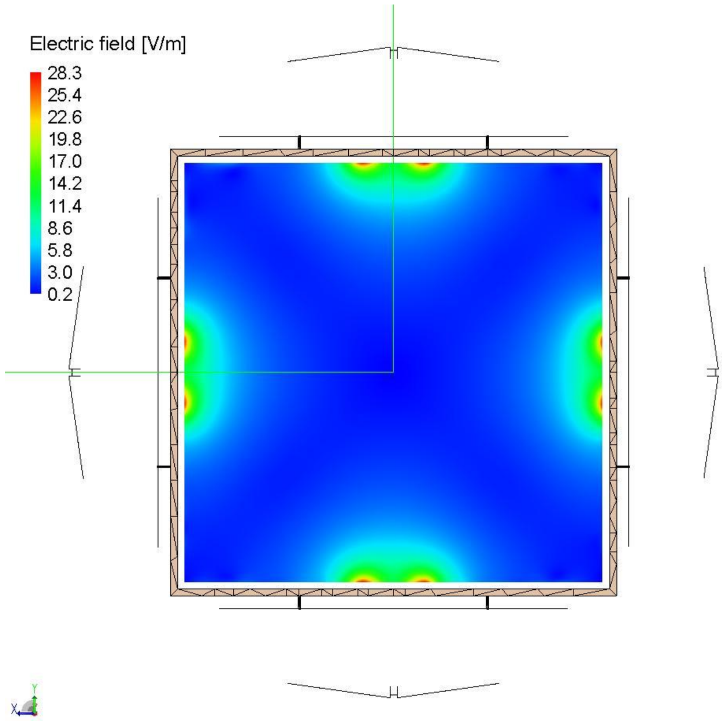

Figure 8-4 – Electric field strength distribution, horizontal cross-section at a height of the middle of the first bay (0.875 m from the bottom of the antenna system), *f* = 474 MHz, polarization H, ERP = 100 kW, P_{input} = 3.77 kW, attenuation = 2.02 dB, occupational exposure limit: 65.3 V/m

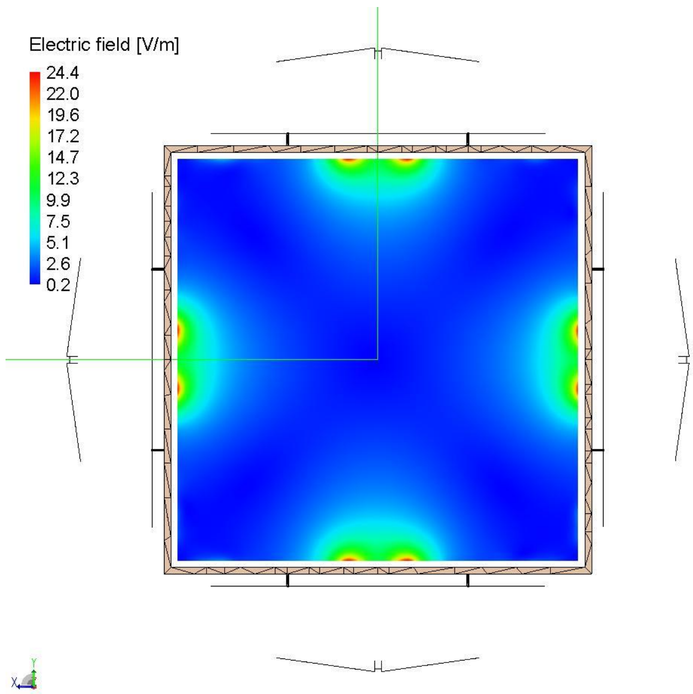

Figure 8-5 – Electric field strength distribution, horizontal cross-section at a height of the middle of the ninth bay (10.075 m from the bottom of the antenna system), *f* = 474 MHz, polarization H, ERP = 100 kW, P_{input} = 3.77 kW, attenuation = 2.02 dB, occupational exposure limit: 65.3 V/m

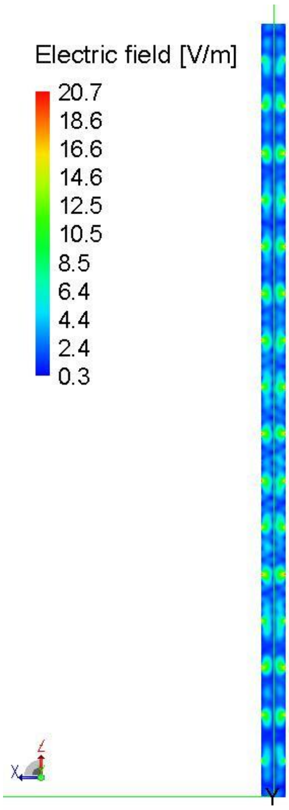

Figure 8-6 – Electric field strength distribution, vertical cross-section, *f* = 642 MHz, polarization H, ERP = 100 kW, P_{input} = 2.47 kW, attenuation = 2.31 dB, occupational exposure limit: 76.0 V/m

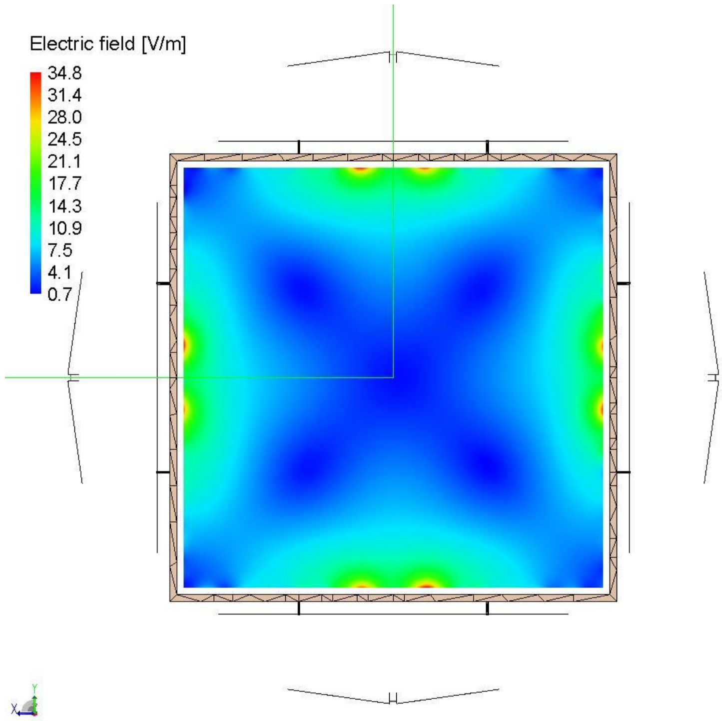

Figure 8-7 – Electric field strength distribution, horizontal cross-section at a height of the middle of the first bay (0.875 m from the bottom of the antenna system), *f* = 642 MHz, polarization H, ERP = 100 kW, P_{input} = 2.47 kW, attenuation = 2.31 dB, occupational exposure limit: 76 V/m

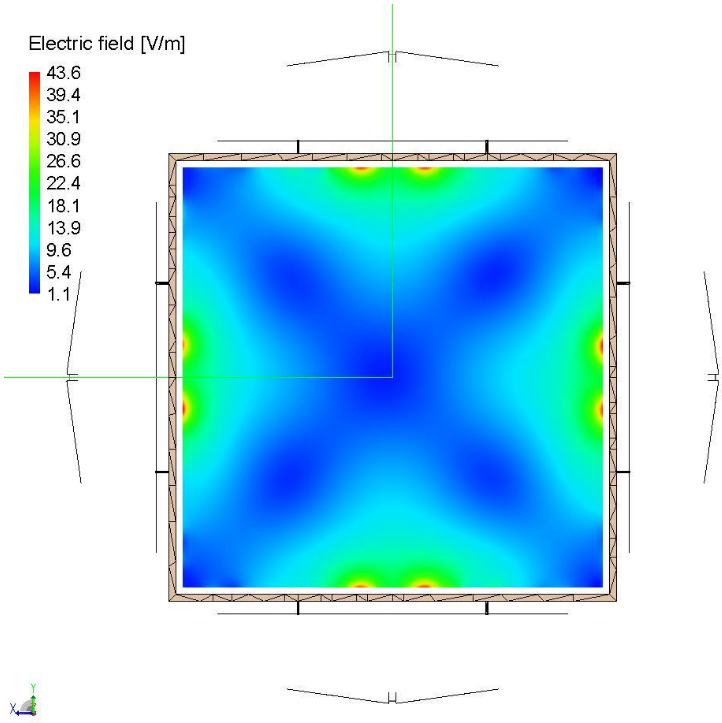

Figure 8-8 – Electric field strength distribution, horizontal cross-section at a height of the middle of the ninth bay (10.075 m from the bottom of the antenna system), *f* =642 MHz, polarization H, ERP = 100 kW, P_{input} = 2.47 kW, attenuation = 2.31 dB, occupational exposure limit: 76 V/m

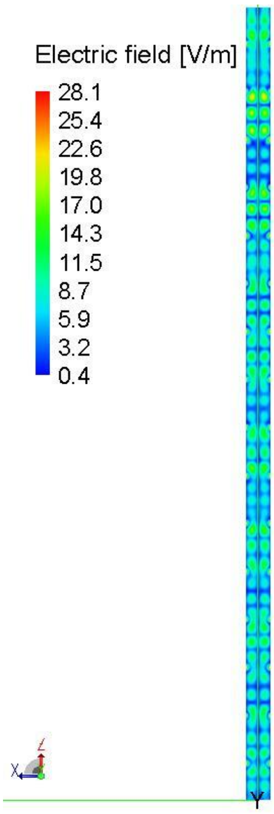

Figure 8-9 – Electric field strength distribution, vertical cross-section, *f* = 786 MHz, polarization H, ERP = 100 kW, P_{input} = 2.81 kW, attenuation = 2.54 dB, occupational exposure limit: 84.1 V/m

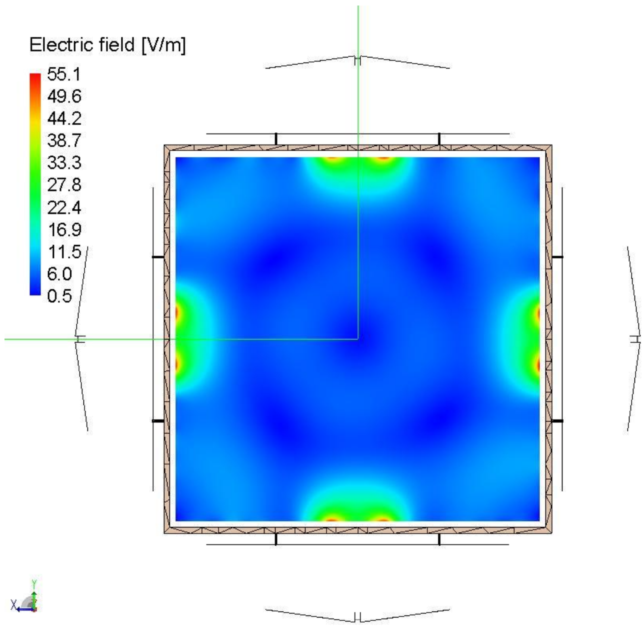

Figure 8-10 – Electric field strength distribution, horizontal cross-section at a height of the middle of the first bay (0.875 m from the bottom of the antenna system), *f* = 786 MHz, polarization H, ERP = 100 kW, P_{input} = 2.81 kW, attenuation = 2.54 dB, occupational exposure limit: 84.1 V/m

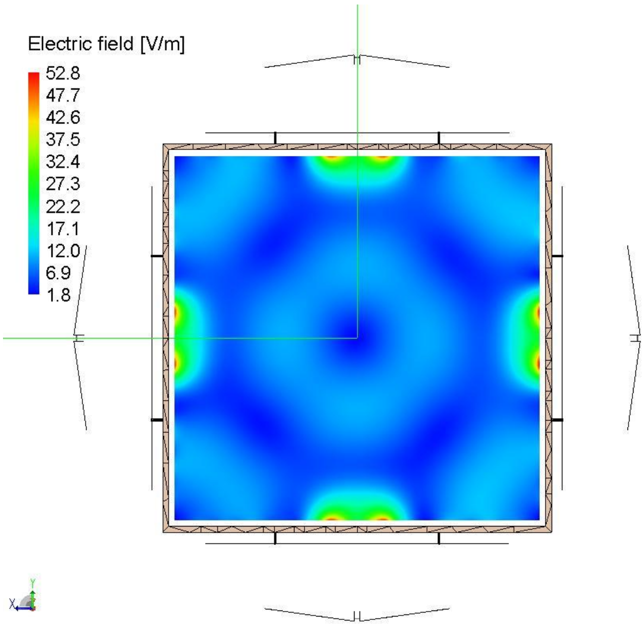

Figure 8-11 – Electric field strength distribution, horizontal cross-section at a height of the middle of the ninth bay (10.075 m from the bottom of the antenna system), *f* = 786 MHz, polarization H, ERP = 100 kW, P_{input} = 2.81 kW, attenuation = 2.54 dB, occupational exposure limit: 84.1 V/m

8.1 Total exposure

The total exposure takes into account exposure caused by the three frequencies that may operate simultaneously. In Figures 8-12 to 8-13 the coefficient W_t (see clause 13) for the input data used in clause 8 is presented.

The maximum value of the total exposure in the area inside the tower is $W_t = 0.8$ (80%). It is very close to the limit. Frequently UHF antennas are operating on more than three frequencies. So each case should be considered individually as exposure limits may be exceeded.

It should be noted that analogue UHF TV is using a much higher transmitter output power so the expected exposure levels will be higher too. The analogue TV is typically operating with a maximum ERP = 1 000 kW per channel. This is 10 times more than in the case of DVB-T systems (100 kW). So in this case each the analogue TV channel will give an electric field strength higher than DVB-T by factor of SQRT(1000kW/100kW)=SQRT(10)=3.16. Similarly, taking into account equation (13.1) the total exposure coefficient for the analogue TV will be 10 times higher than that given by a DVB-T system (as the total exposure is proportional to the power).

8.2 UHF TV system with vertical polarization

There will be no substantial difference between the exposure level inside the antenna tower if the UHF TV antenna system operates with vertical polarization and that presented in this clause, for the antenna system with horizontal polarization.

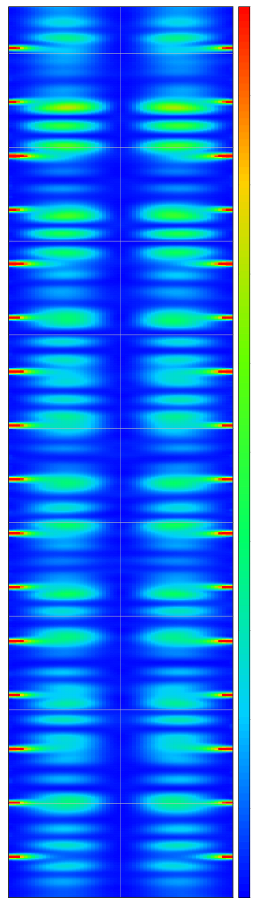

Figure 8-12 – UHF TV vertical plane, frequencies: 474 MHz, 642 MHz and 786 MHz

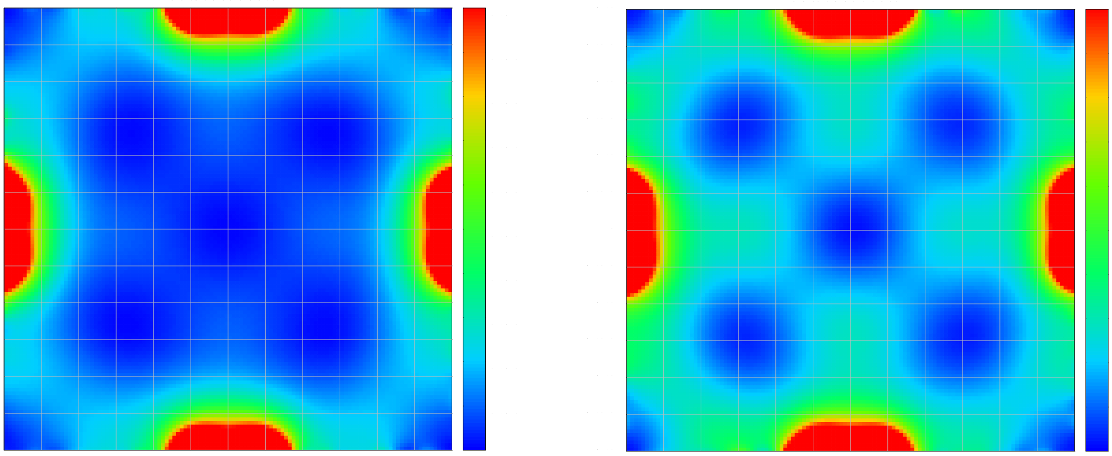

Figure 8-13 – Horizontal plane in the middle of the bay 1 (left), frequencies: 474 MHz, 642 MHz and 786 MHz and in the middle of the bay 9 (right)

9 Mobile communication dual-band 900/1 800 MHz antenna panel

Base station antennas represent the majority of transmitting antennas, which are being operated by the telecommunication operators, and that are present in the human environment. Old base station antenna panels have one transmitting antenna inside. New base station panels can cover many transmitting antennas – typically four but even up to 10 antennas, that may be used for transmitting or receiving purposes. So it is important to distinguish between base station antennas and base station antenna panels.

Base station panels are mounted typically on antenna towers (free-standing or located on roofs of buildings) but some of them are mounted on building walls. It is important to assess the level of backward radiation of such antenna panels for maintenance personnel safety reasons but also for the safety of the general public that in some cases may be present in comparatively close vicinity to such antennas. If a panel is installed on the wall of a building, the general public may be also exposed to backward radiation. However, in this case there is a wall between the area accessible to people and the antenna panel giving a certain level of screening.

It is assumed that there is no access (also for maintenance personnel) to the area close to the front of the transmitting antenna. So the main area of consideration is the exposure level in the back directions of the base station antennas.

The dual band panel 900/1 800 MHz, with polarization +45°/−45° (742 047 Kathrein), consisting of four antennas inside its cover, has been considered. The panel has a size of 0.215 m × 0.04 m × 2.55 m.

In this Recommendation three cases have been considered: exposure levels in the area back to panels in free space, and in the area back to panels but with a concrete wall or brick wall (of 30 cm thickness) just behind the panel. In Figure 9.1 the picture of the part of the panel (without its cover) and a model of the antenna panel is presented with a wall behind it.

It was assumed that transmitter power is 30 W in both frequency bands. Taking into account feeder attenuation 0.88 dB (f = 947.5 MHz) and 1.25 dB (f = 1 842.5 MHz), the radiated power EIRP is equal to 1 380 W (947.5 MHz) and 1 420 W (1 842.5 MHz).

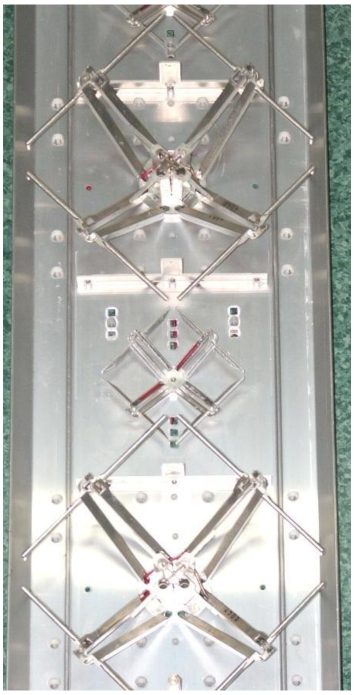

Figure 9-1a – Part of the considered antenna panel (without cover)

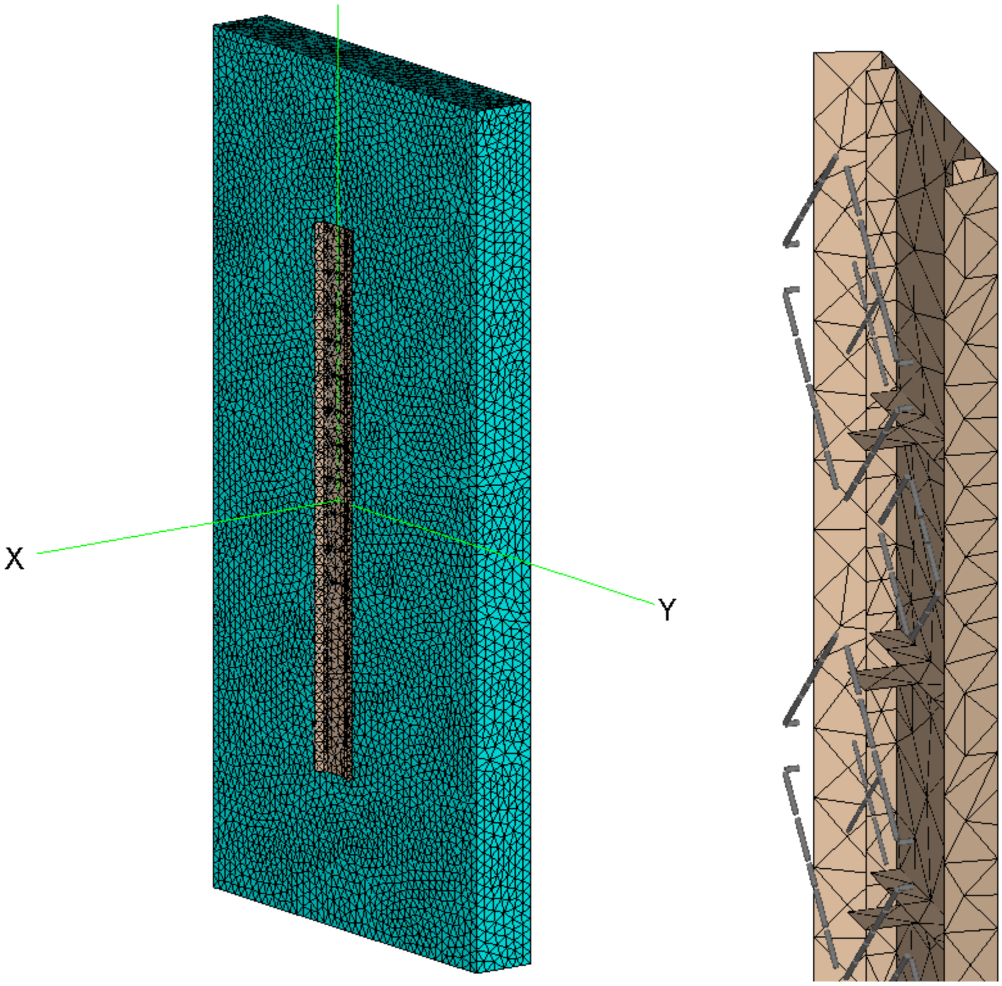

Figure 9-1b – Model of the panel with an additional wall (0.3 m thickness) – left, and enlarged part of the antenna – right

In Table 9-1 the electric parameters are presented of the concrete and brick, which have been used in the calculations.

Table 9-1 – Electrical parameters for concrete and brick walls

Material class	Relative permittivity			Conductivity			Frequency	Frequency range
	a	b	Ɛr	c	d	σ	f[GHz]	
Concrete	5.31	0	5.31	0.0326	0.8095	0.0312	0.9475	1-100GHz
Concrete	5.31	0	5.31	0.0326	0.8095	0.0535	1.8425	1-100GHz
Brick	3.75	0	3.75	0.038	0	0.038	0.9475	1-10GHz
Brick	3.75	0	3.75	0.038	0	0.038	1.8425	1-10GHz

9.1 Frequency 947.5 MHz

In Figures 9-2 and 9-3 the electric field strength distributions on a rectangular plane 0.5 m behind the panel, of the size 2 m × 4 m (perpendicular to the main direction of radiation) have been considered in three cases: the panel located in free space or placed on a concrete or brick wall of 30 cm thickness.

The required calculation time (MoM method) was 0.5 hour of CPU time (for 947.5 MHz) and about 12 hours (for 1 842.5 MHz).

The general public exposure limit for the frequency 947.5 MHz is 42.3 V/m. The maximum value of the electric field strength in the area up to 0.5 m behind the panel is 16.6 V/m (in free space), 10.0 V/m (concrete wall) and 6.8 V/m (brick wall).

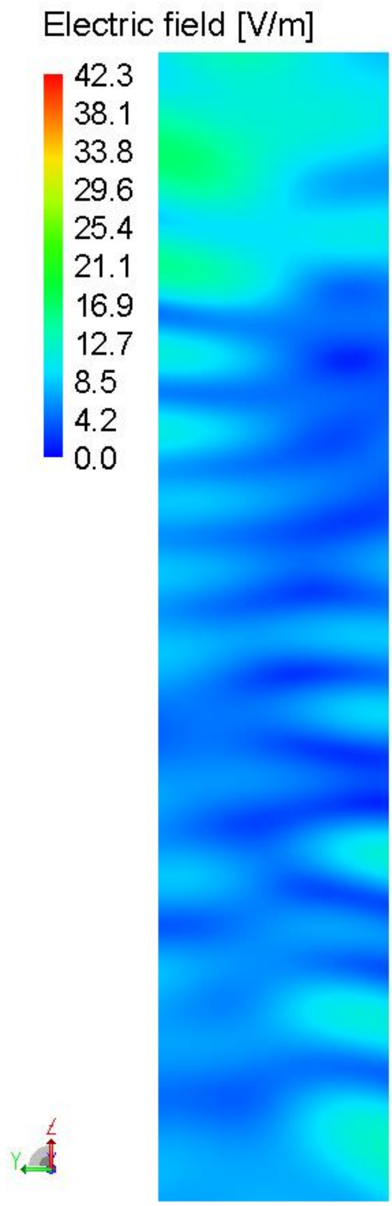

Figure 9-2 – Electric field strength distribution at a back view (3 m height and 0.6 m width) and 0.5 m behind the panel screen, without a concrete wall

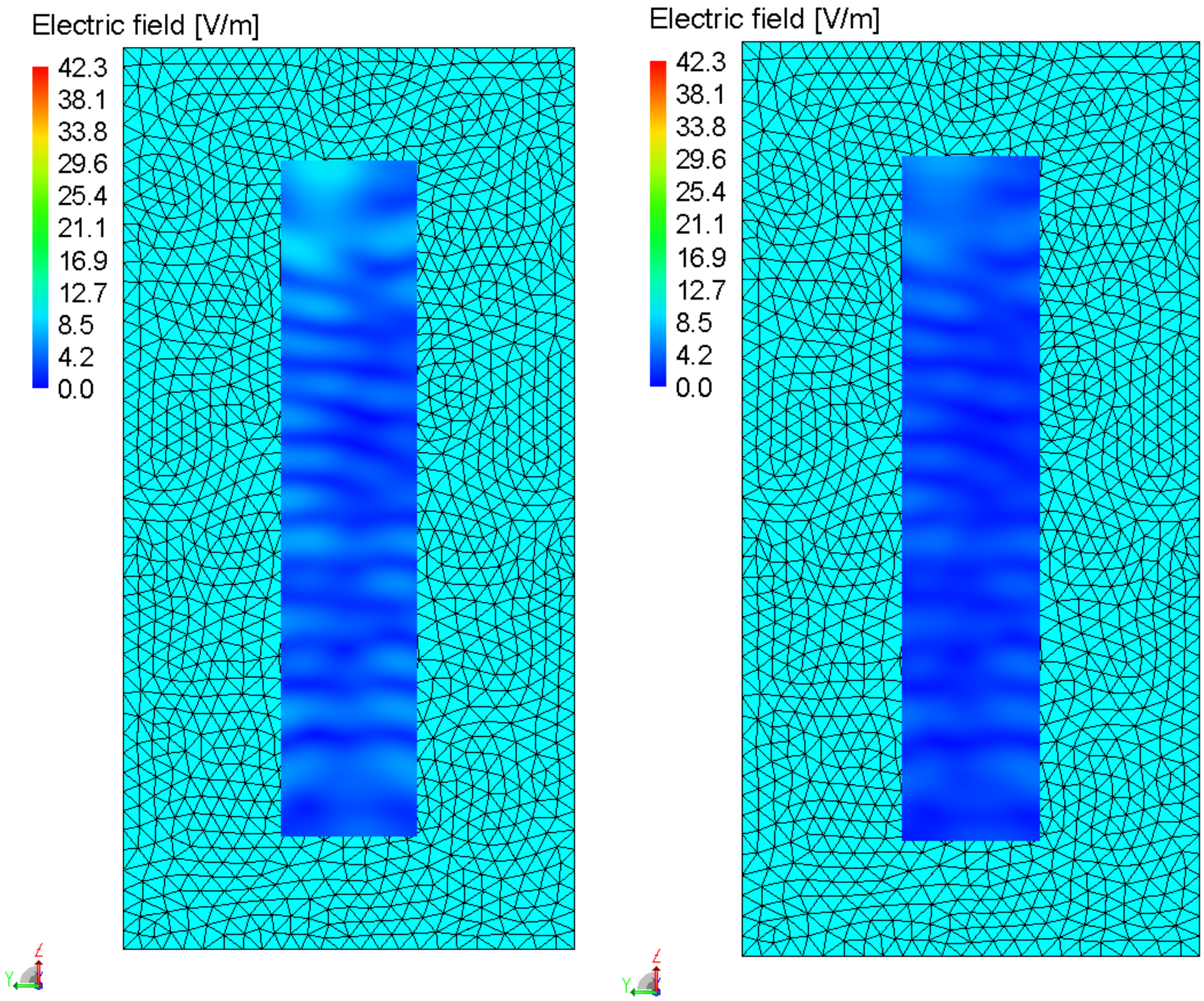

Figure 9-3 – Electric field strength distribution at a back view (3 m height and 0.6 m width) and 0.5 m behind the panel screen, with a concrete wall (on the left) and brick wall (on the right)

In Figures 9-4, 9-5 and 9-6, the electric field strength in the area 4.5 m × 4 m on a vertical plane and along the main direction of radiation is presented. It can be seen that as expected, the level of radiation to the back of the panel is much lower than in the main direction of radiation.

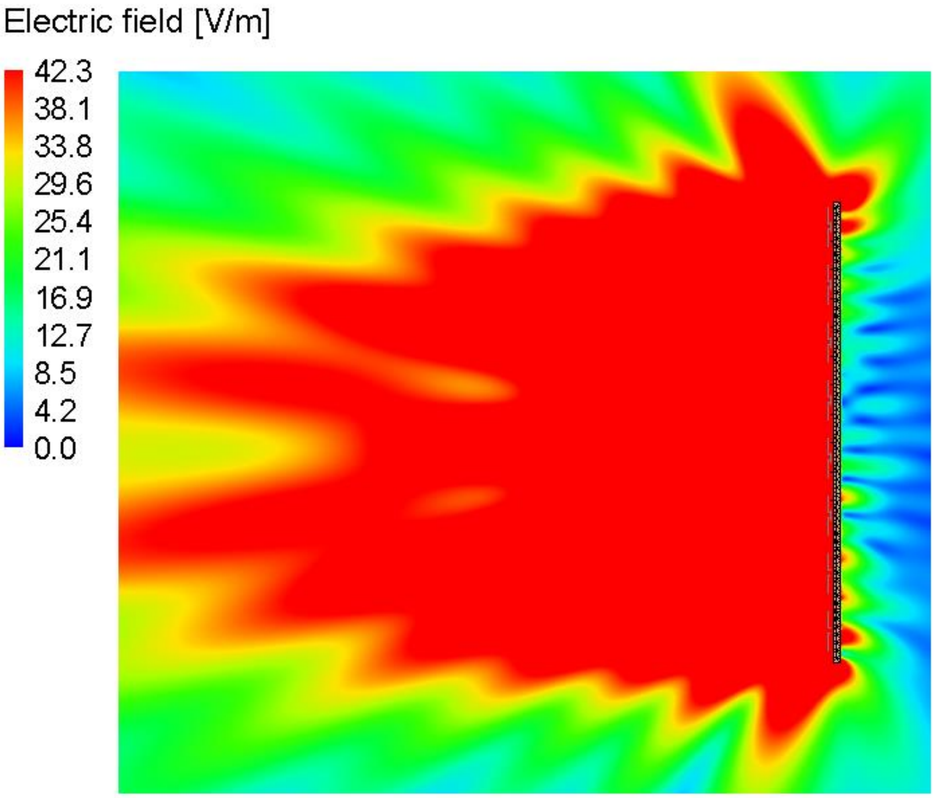

Figure 9-4 – Electric field strength distribution at a side view (4 m height, 4.5 m width), without a concrete wall, *f* = 947.5 MHz

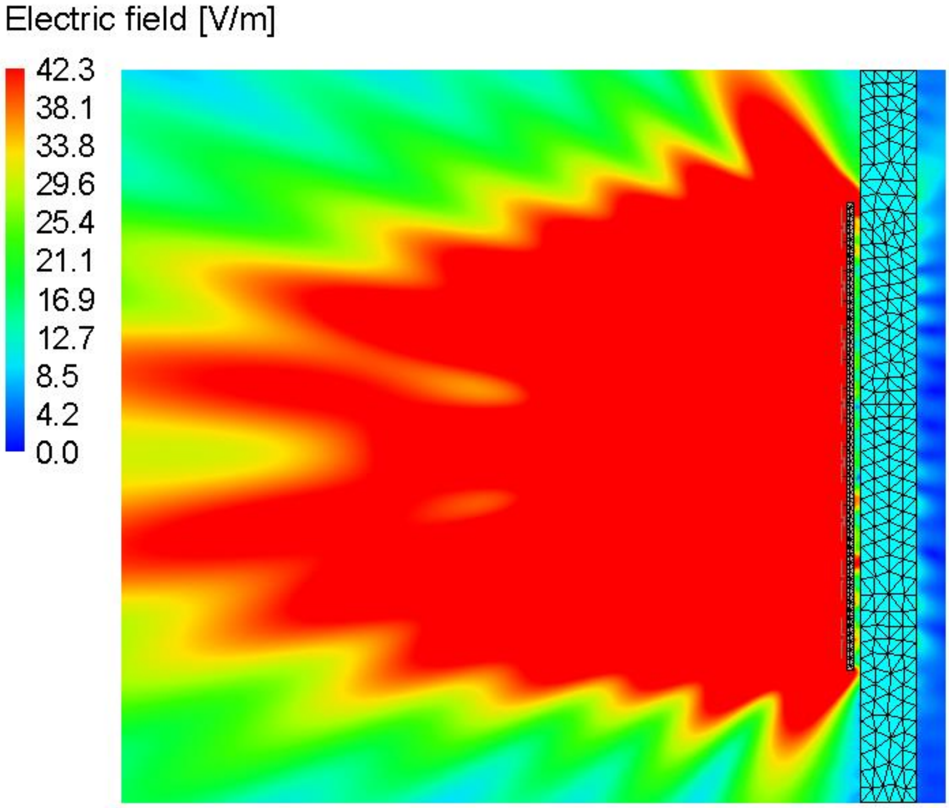

Figure 9-5 – Electric field strength distribution at a side view (4 m height, 4.5 m width), with a concrete wall, *f* = 947.5 MHz

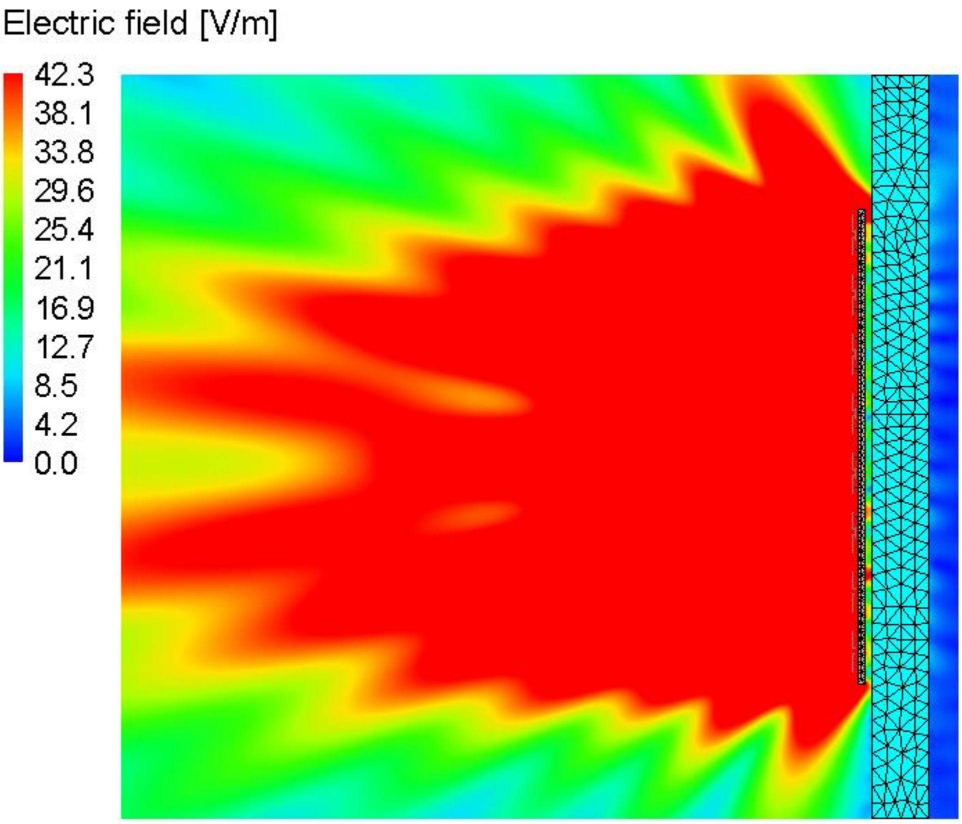

Figure 9-6 – Electric field strength distribution at a side view (4 m height, 4.5 m width), with a brick wall, *f* = 947.5 MHz

9.2 Frequency 1 842.5 MHz

In Figures 9-7 to 9-11 the results similar to those from Figures 9-1 to 9-5 are presented but they correspond to the frequency 1 842.5 MHz.

The general public exposure limit for the frequency 1 842.5 MHz is 59.0 V/m. The maximum value of the electric field strength in the area up to 0.5 m behind the panel is 12.2 V/m (in free space), 7.9 V/m (concrete wall) and 5.5 V/m (brick wall).

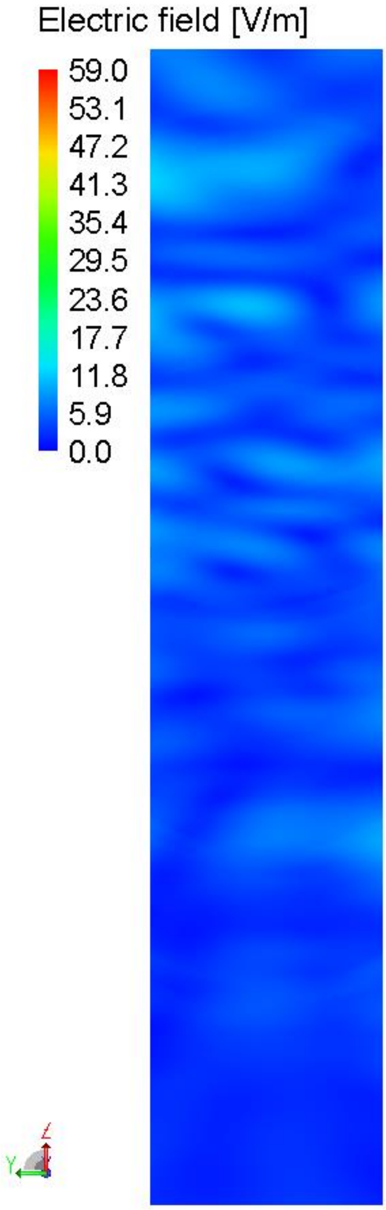

Figure 9-7 – Electric field strength distribution at a back view (3 m height and 0.6 m width) and 0.5 m behind the panel screen, without a concrete wall

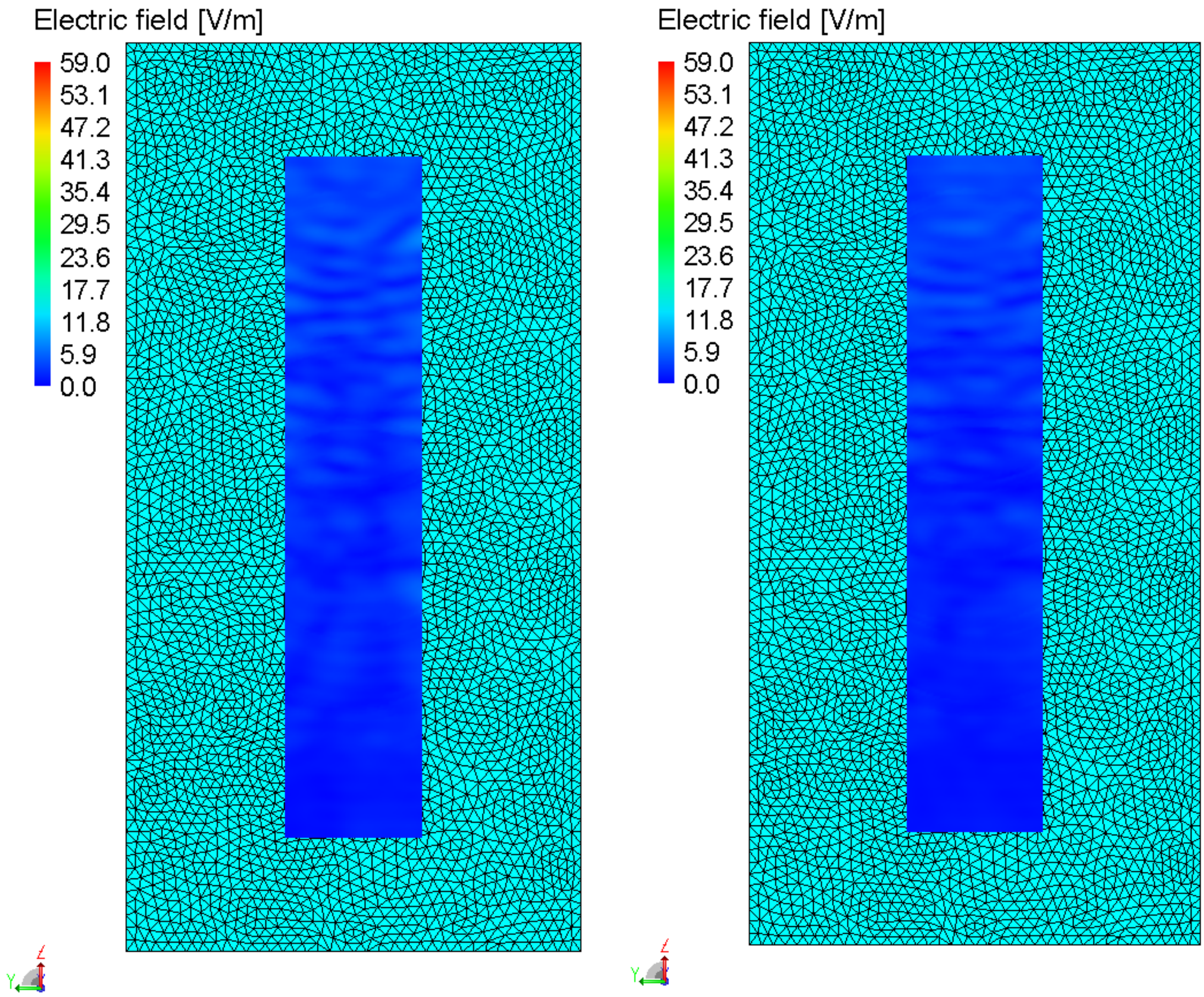

Figure 9-8 – Electric field strength distribution at a back view (3 m height and 0.6 m width) and 0.5 m behind the panel screen, with a concrete wall (on the left) and brick wall (on the right) *f* = 1 842.5 MHz

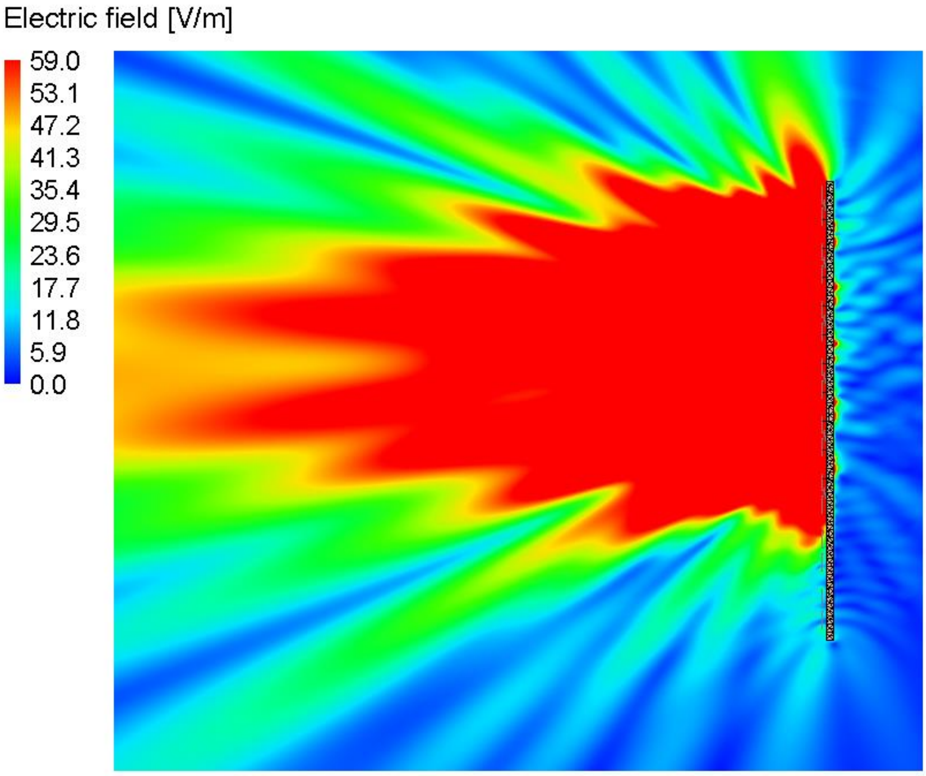

Figure 9-9 – Electric field strength distribution at a side view (4 m height, 4.5 m width), without a concrete wall. *f* = 1 842.5 MHz

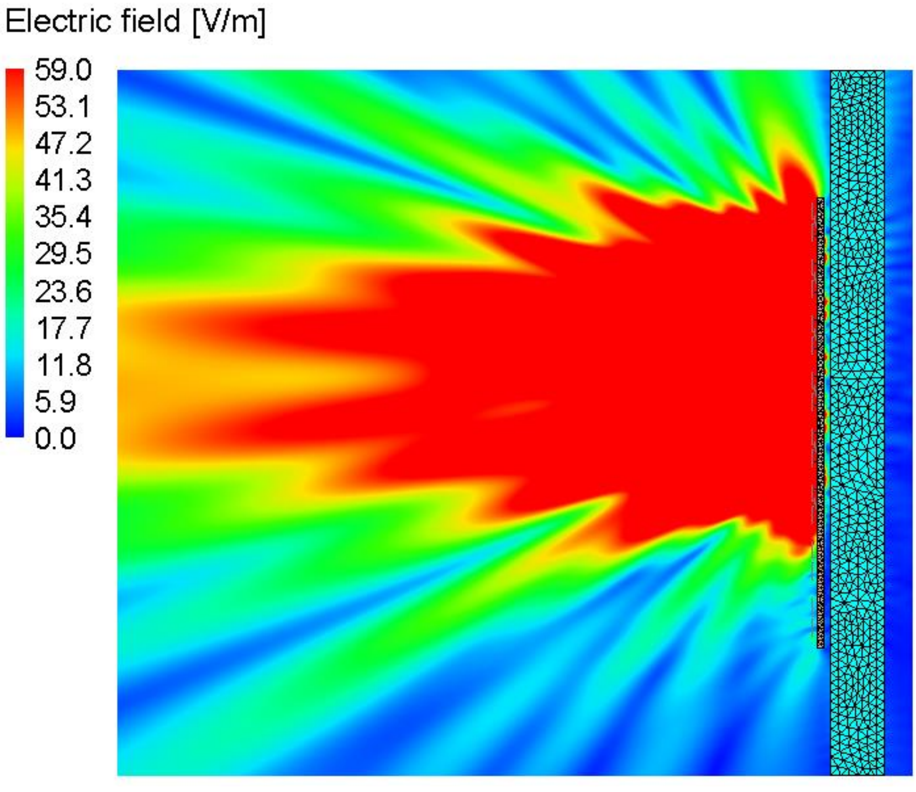

Figure 9-10 – Electric field strength distribution at a side view (4 m height, 4.5 m width), with a concrete wall. *f* = 1 842.5 MHz

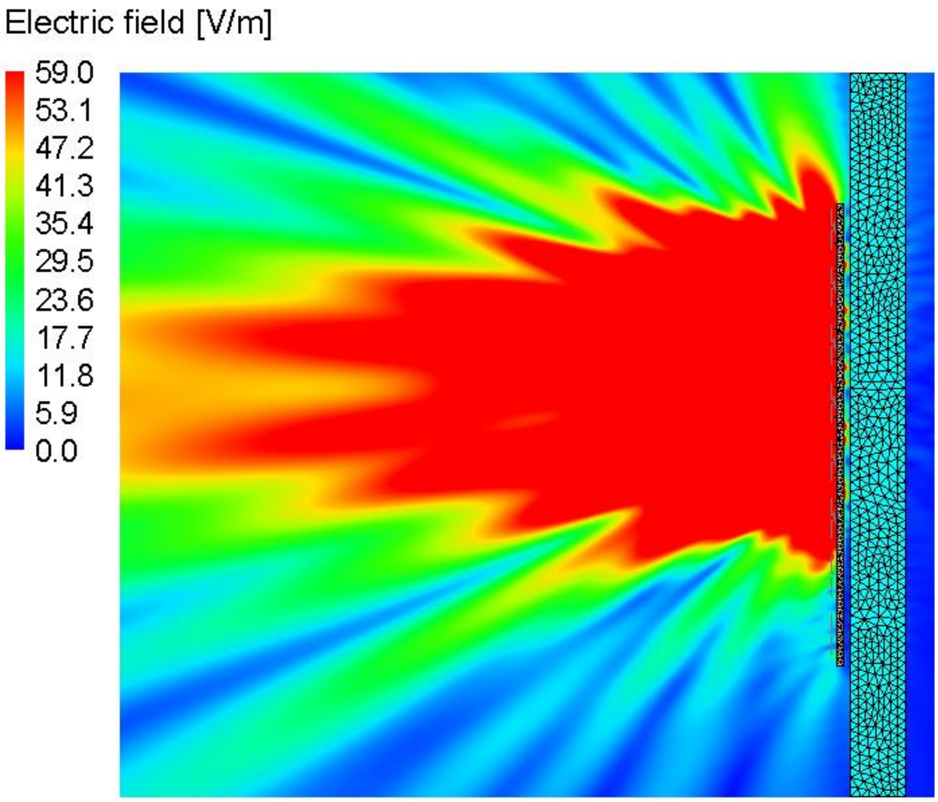

Figure 9-11 – Electric field strength distribution at a side view (4 m height, 4.5 m width), with a brick wall. *f* = 1 842.5 MHz

9.3 Total exposure in both frequency bands

The total exposure takes into account exposure caused by two frequency bands that may operate simultaneously. In Figure 9-12 the coefficient W_t (see clause 13) for the input data used in clauses 9.1 and 9.2 is presented.

The maximum value of the total exposure in the backward and side directions is W_t = 0.19 (19%) in cases without a wall on the back of the panel. This value is far below the limit. Frequently mobile antennas are operating on more than one channel per one frequency band. So each case should be considered individually as exposure limits may be exceeded.

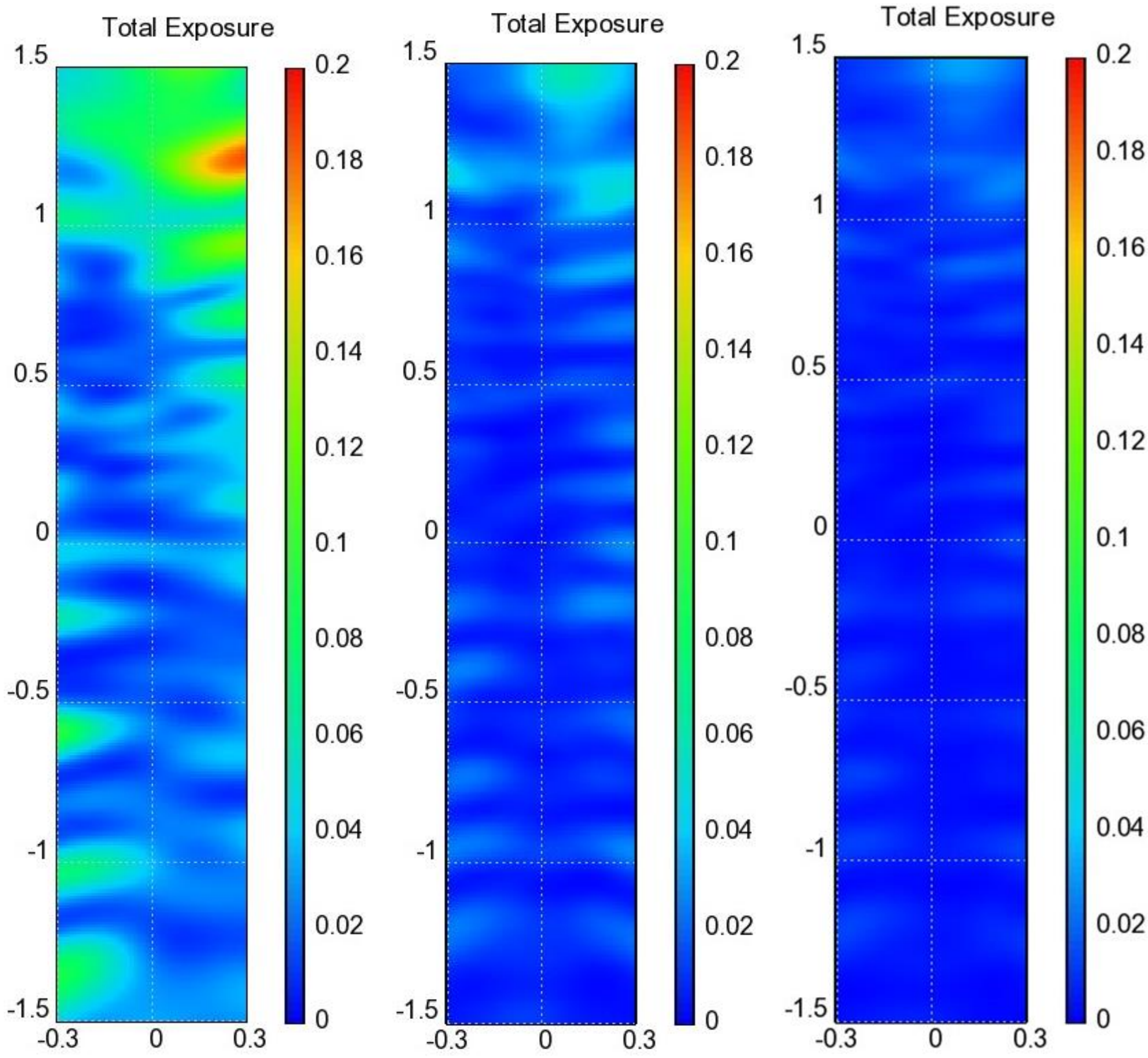

Figure 9-12 – Total exposure at a back view 0.5 m behind the panel screen, without a concrete wall

(left: max value 0.19), with a concrete wall (middle: max value 0.06) and with a brick wall (right: max value 0.03)

10 Microcell ceiling-mounted antenna

Calculations have been performed for the Kathrein 80010709 ceiling-mounted microcell antenna. Antennas may operate in three bands: 900 MHz, 1 800 and 2 100 MHz.

Figure 10-1 – Microcell ceiling-mounted antenna with (left) and without (right) antenna cover

It has been assumed that the antenna is mounted on the ceiling of the room of 2.8 m height and with one wall and floor made of concrete.

The calculations have been performed for the 2.5 m × 2.5 m vertical plane (from the ground level to 2.5 m above the ground) just below the antenna. For all the three operating frequencies the transmitter power P = 24 mW has been assumed. The related EIRP was 3.5 W (947.5 MHz), 5.7 W (1 842.5 MHz) and 6.9 W (2 140 MHz).

The required calculation time (MoM method) was 0.3 hour (for 947.5 MHz), 22.5 hours (for 1 842 MHz) and 47.7 hours (for 2 140 MHz) of CPU time.

The results of calculations show the maximum exposure level 3.8 V/m (f = 947.5 MHz), 5.3 V/m (f = 1 842.5 MHz) and 5.2 V/m (f = 2 140 V/m). If all the three antennas are radiating simultaneously than the total exposure ratio is 0.023 = 2.3%. It should be noted that the considered case is the worst one (the distance between the head of a person (2 m height) and the antenna is only 0.5 m).

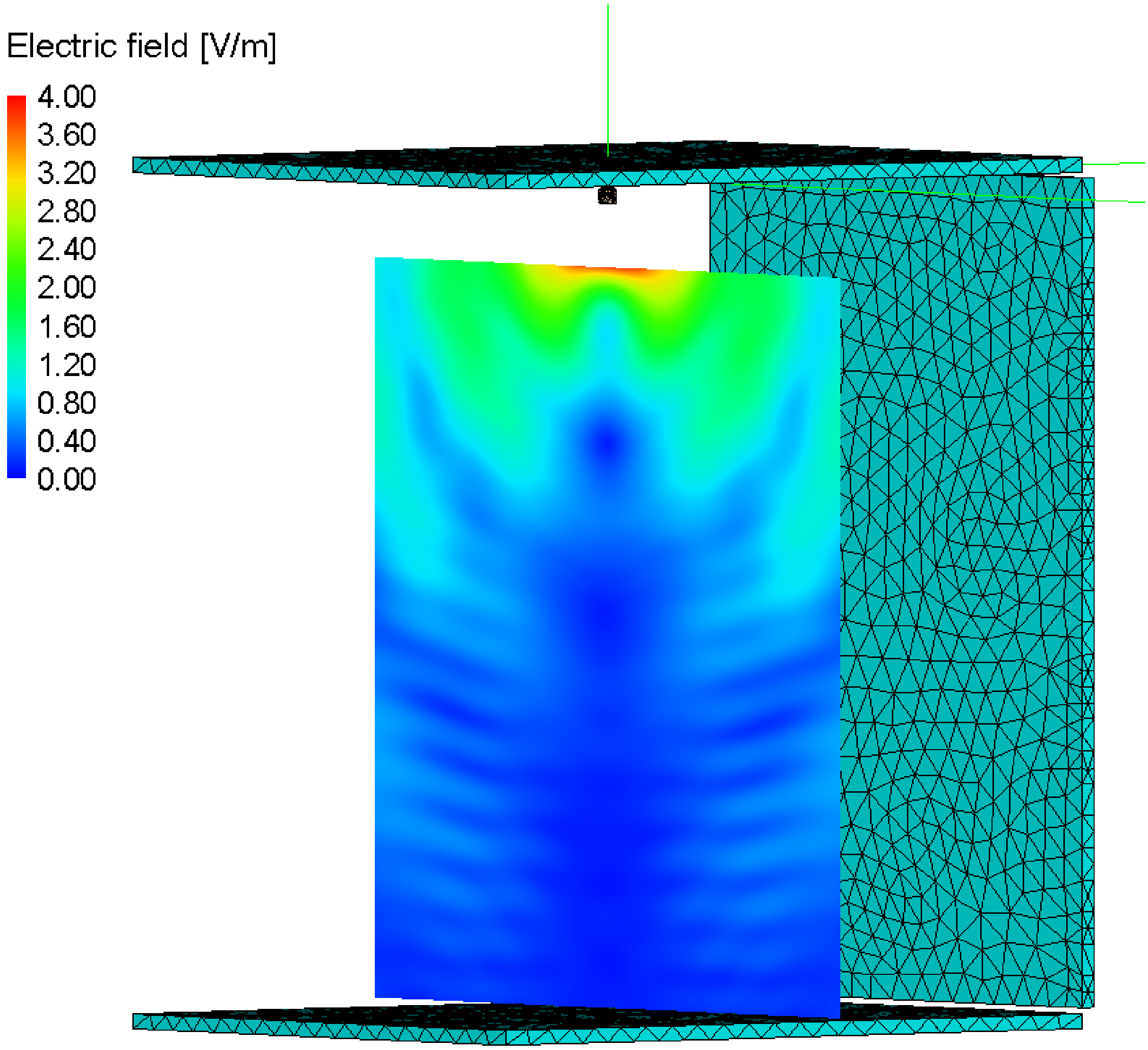

Figure 10-2 – Electric field strength distribution (general view), vertical cross-section, f = 947.5 MHz, P_{input} = 24 mW, general public exposure limit: 42.3 V/m

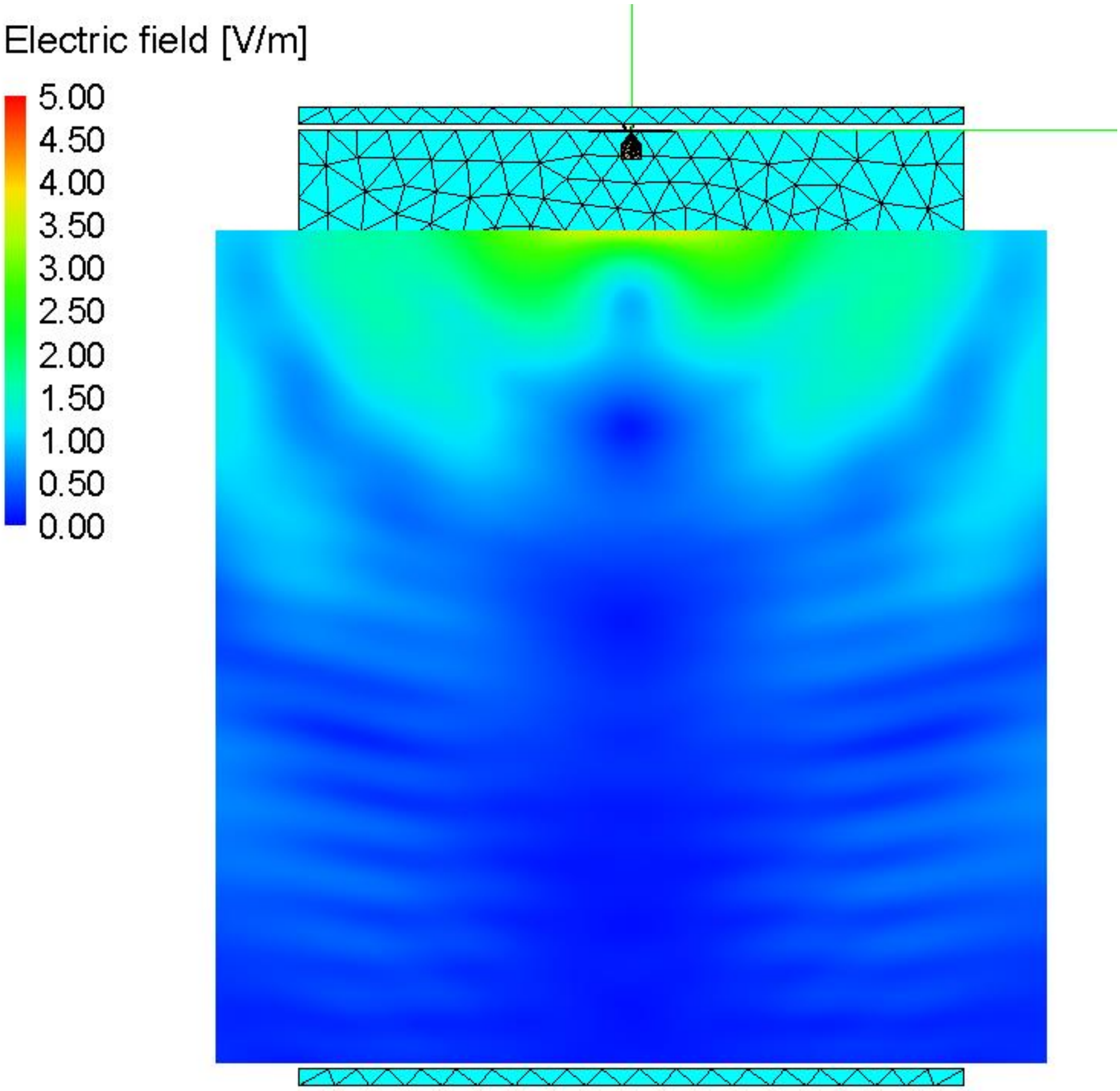

Figure 10-3 – Electric field strength distribution (front view), vertical cross-section, *f* = 947.5 MHz, P_{input} = 24 mW, general public exposure limit: 42.3 V/m

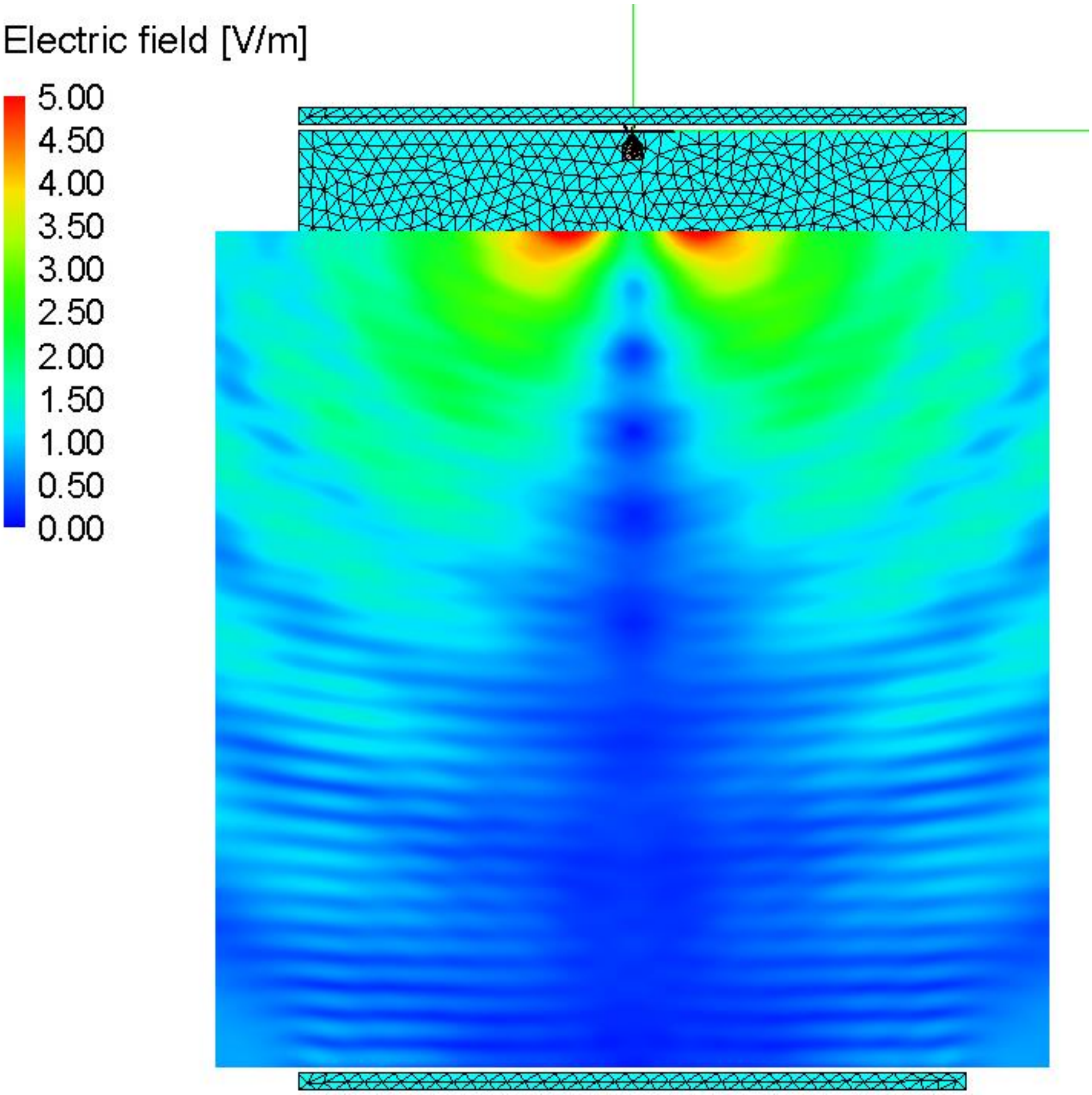

Figure 10-4 – Electric field strength distribution (front view), vertical cross-section, *f* = 1842 MHz, P_{input} = 24 mW, general public exposure limit: 59.0 V/m

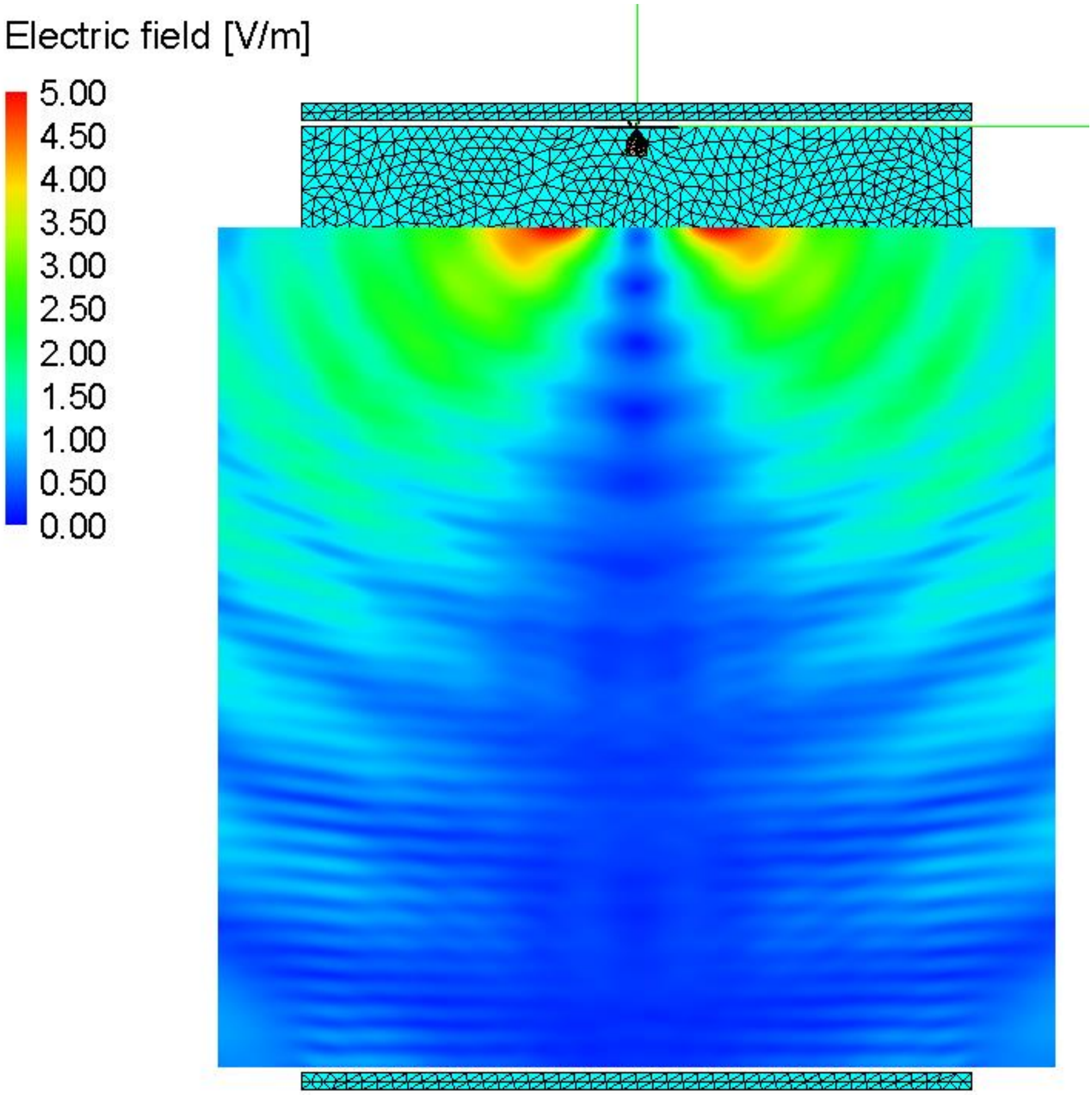

Figure 10-5 – Electric field strength distribution (front view), vertical cross-section, f = 2140 MHz, P_{input} = 24 mW, general public exposure limit: 61.0 V/m

10.1 Total exposure

The total exposure takes into account exposure caused by the three frequencies that may operate simultaneously. In Figure 10-6 the coefficient W_t (see clause 13) for the input data used in cases presented above is presented.

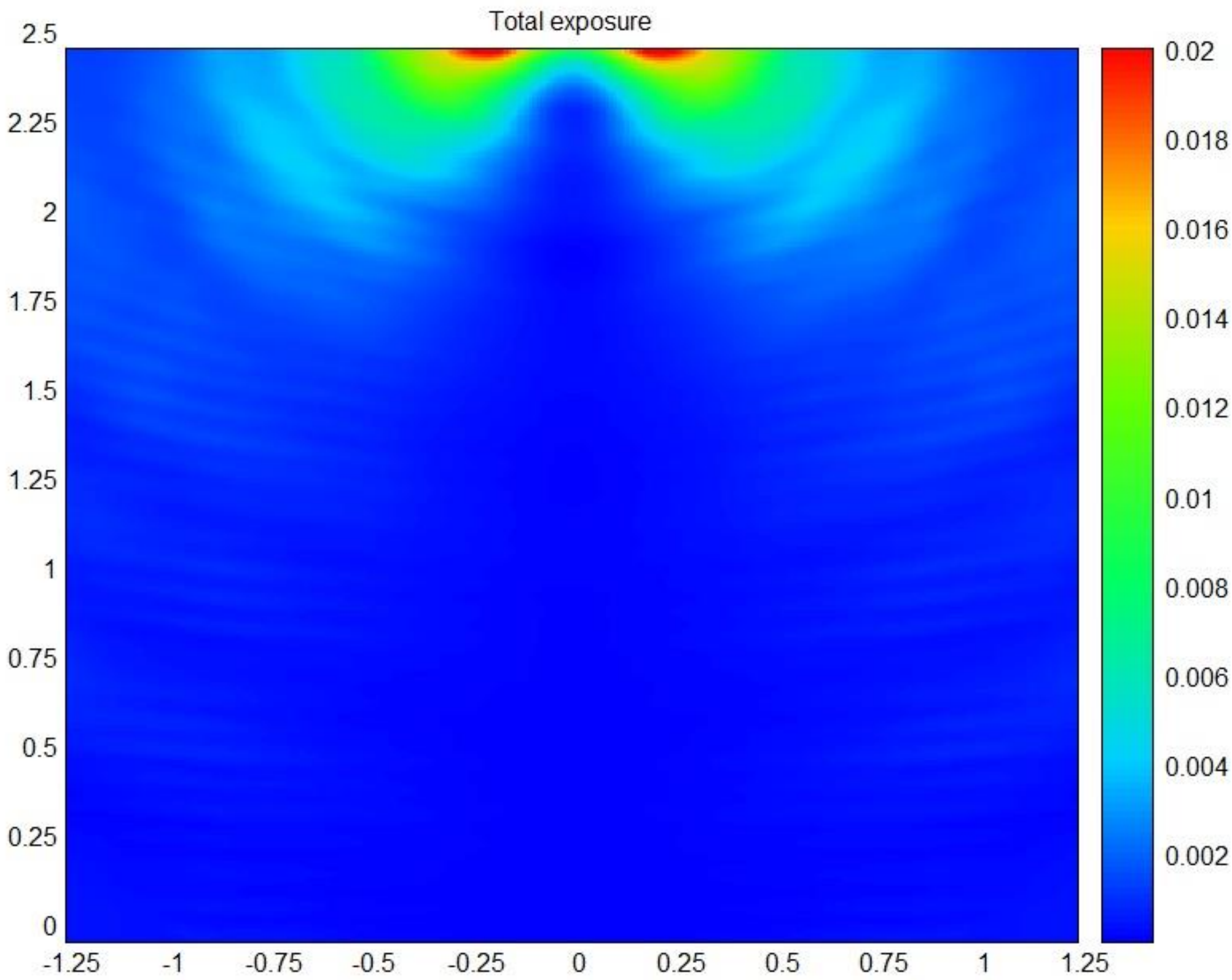

Figure 10-6 – Total exposure (front view), vertical cross-section, for simultaneous three emissions

It may be noticed that in the considered case the total exposure W_t is on the level of 0.02 (2%) so it is much lower than the allowed level of exposure of the general public. This is according to expectations as such systems are widely used in big malls, airports etc.

11 Fixed point-to-point 22.4 GHz antenna

Fixed point-to-point links use the high gain parabolic antennas (also called dish antennas). The basics of antenna physical parameters relevant for the RF exposure evaluation of dish antennas can be found in [ETSI 102457]. This ETSI technical report also reviews far-field analysis principles, as well as near-field evaluations based on simulation methods and measurements' calibration. It includes measurement and calculation results on real systems.

Usually it is not possible that a person is present in front of such antenna. It is connected with the fact that any object present in the line (more exactly Fresnel Zone) between both antennas will interrupt or at least highly disturb the connection. Thus, such antennas are mounted in such a way that the probability of any object being present between them is very small. For this reason the main part of the calculations presented below are focused on the areas on the back side of the antenna. This area is usually accessible to maintenance personnel only. Two types of parabolic antennas have been considered.

In Figure 11-1 a model of a standard parabolic antenna, with a dish of radius 15.25 cm and operating on the frequency 22.4 GHz with vertical polarization, is presented. Calculations have been performed using MoM for the area 1 m x 1 m (in horizontal and in vertical planes) with a step of 4 mm and took about 14 minutes. The results are presented in Figures 11-2 and 11-3. The maximum level of the electric field strength in the area in the back of the antenna is 5.5 V/m at a distance of 15.5 cm from the antenna.

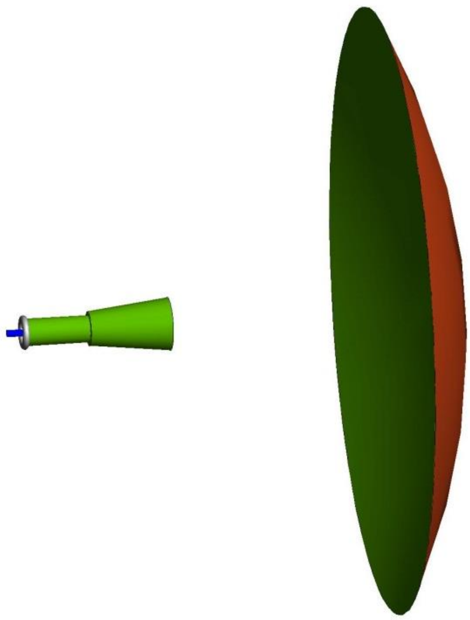

Figure 11-1 – Model of the standard parabolic antenna VHP1-220 (Andrew) with Radius = 15.25 cm

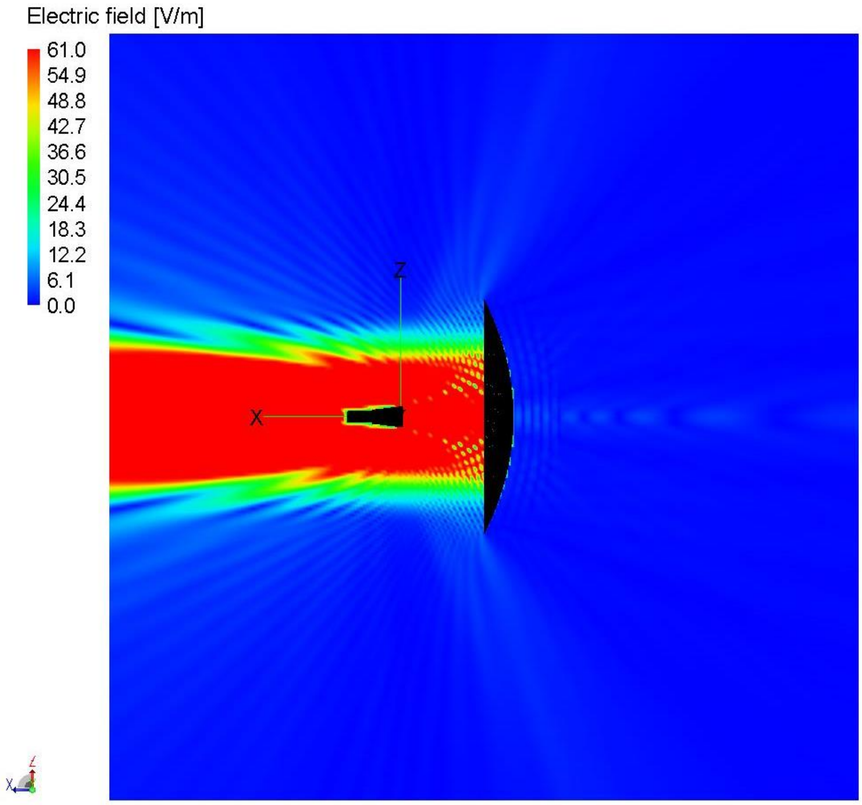

Figure 11-2 – Electric field strength distribution, vertical cross-section, *f* = 22.4 GHz, P_{input} = 0.316 W, area 1 m × 1 m, EIRP = 0.657 kW, occupational exposure limit: 137 V/m

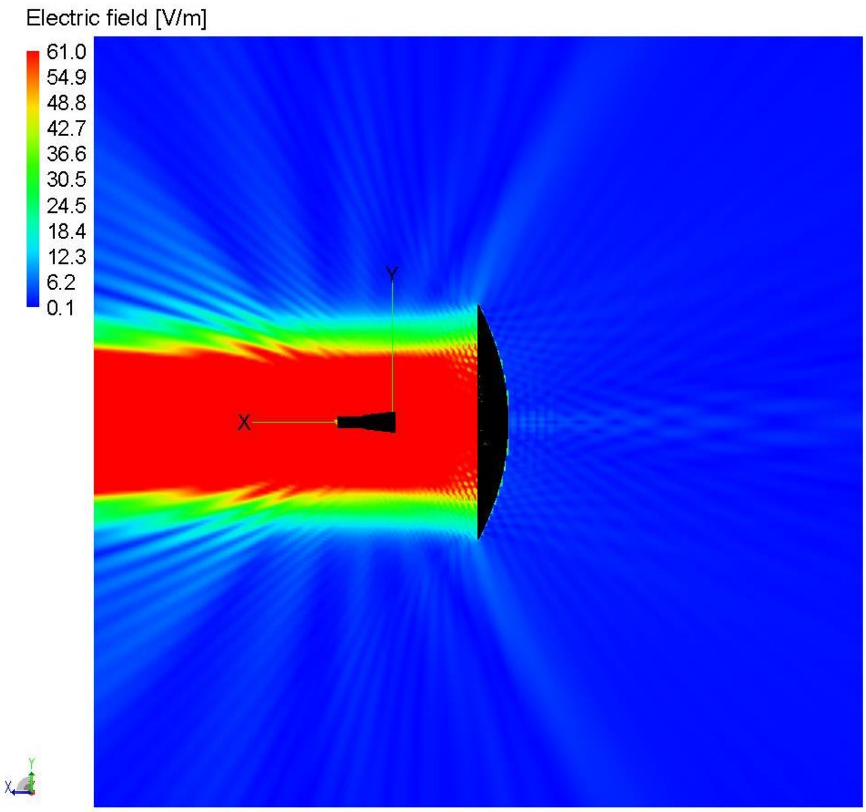

Figure 11-3 – Electric field strength distribution, horizontal cross-section, *f* = 22.4 GHz, P_{input} = 0.316 W, area 1 m × 1 m, EIRP = 0.657 kW, occupational exposure limit: 137 V/m

In Figure 11-4 a model of the high-performance parabolic antenna, with a dish of radius 15.25 cm and operating on the frequency 22.4 GHz with vertical polarization, is presented. Calculations have been performed using MLFMM for the area 1 m × 1 m (in horizontal and in vertical planes) with a step of 4 mm and took about 31 minutes. The results are presented in Figures 11-5 and 11-6. The maximum level of the electric field strength in the area in the back of the antenna is 22.7 V/m at a distance of 16.7 cm from the antenna. Calculations have been performed using MoM for the area 1 m × 1 m (in horizontal and in vertical planes) with a step of 4 mm and took about 31 minutes.

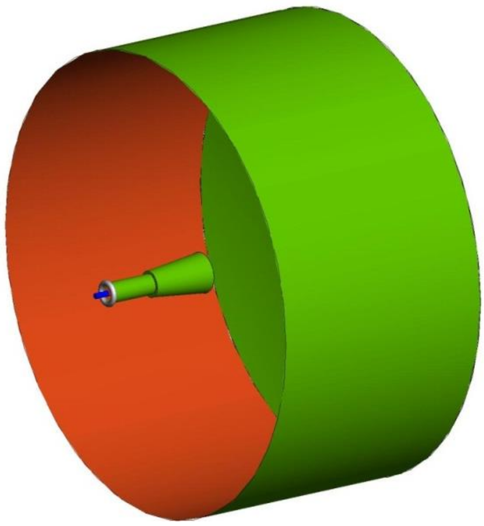

Figure 11-4 – Model of a high-performance antenna VHP1-220 (Andrew) of radius = 15.25 cm

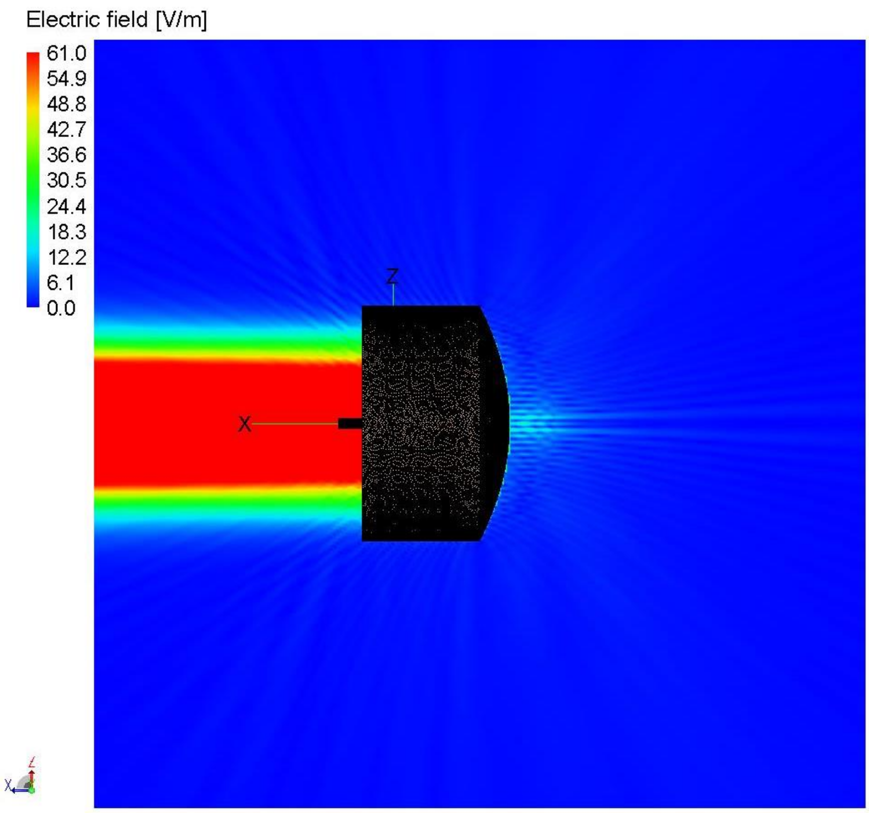

Figure 11-5 – Electric field strength distribution, vertical cross-section, *f* = 22.4 GHz, P_{input} = 0.316 W, area 1 m × 1 m, EIRP = 0.677 kW, occupational exposure limit: 137 V/m

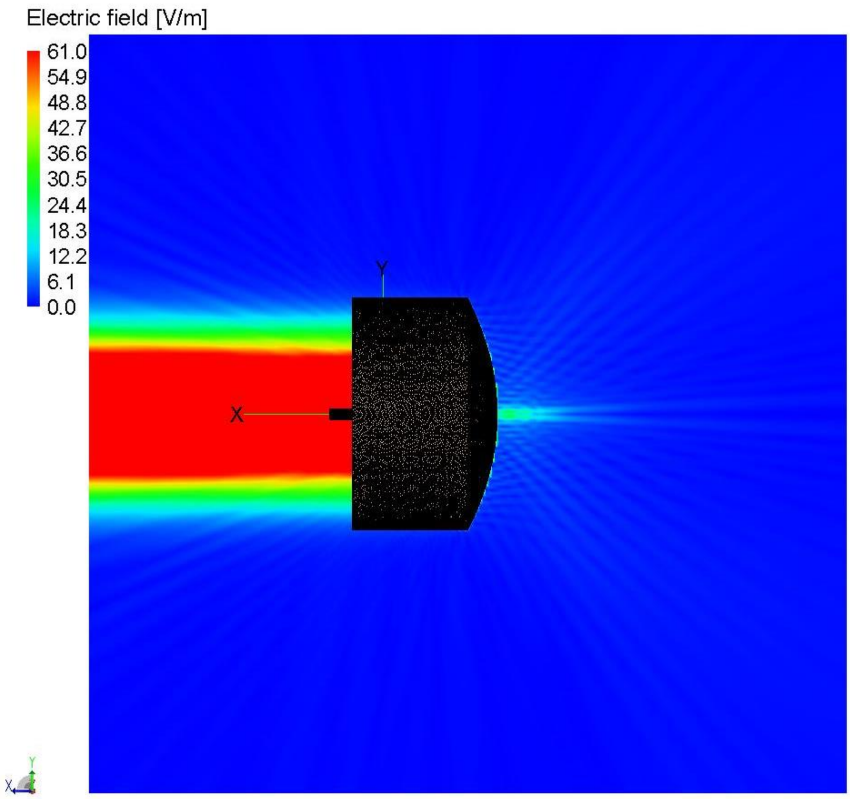

Figure 11-6 – Electric field strength distribution, horizontal cross-section, *f* = 22.4 GHz, P_{input} = 0.316 W, area 1 m × 1 m, EIRP = 0.677 kW, occupational exposure limit: 137 V/m

12 Fixed point-to-point 75 GHz antenna

In this clause the fixed point-to-point parabolic antenna VHLP200-80 (Andrew), similar to that described in clause 11, operating with vertical polarization, but operating on the frequency 75 GHz has been considered. The model of the antenna is presented in Figure 12-1. In this case the use of the PO/MoM calculation method was required. Calculation time for the area 1 m × 1 m with step of 2 mm was 2.8 hours. The results of calculations are presented in Figures 12-2 and 12-3.

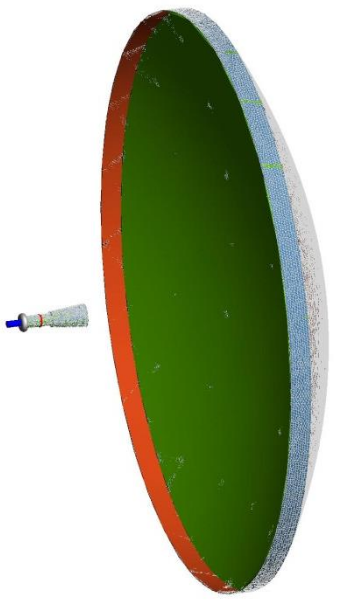

Figure 12-1 – Model of a parabolic antenna VHLP200-80 (Andrew) with Radius = 10.0 cm

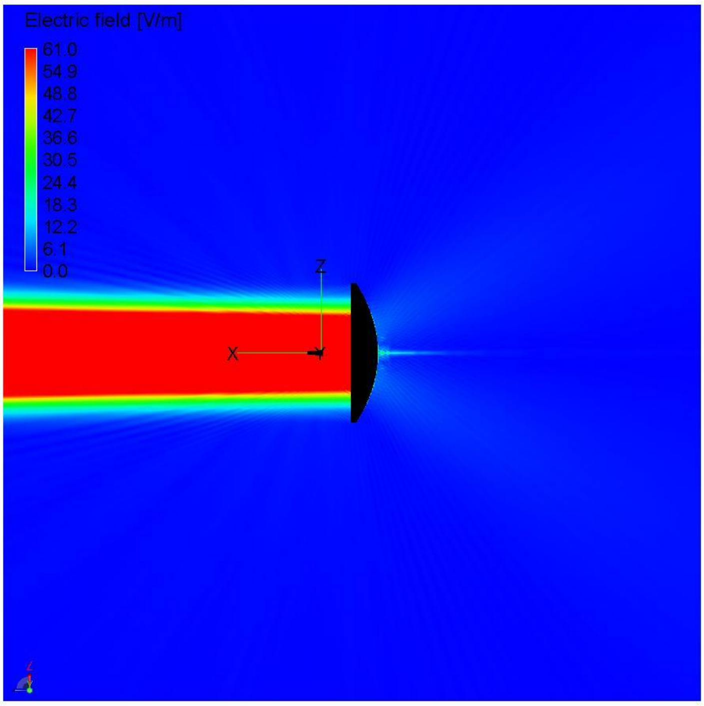

Figure 12-2 – Electric field strength distribution, vertical cross-section, *f* = 75 GHz, P_{input} = 0.316 W, area 1 m × 1 m, EIRP = 0.185 kW, occupational exposure limit: 137 V/m

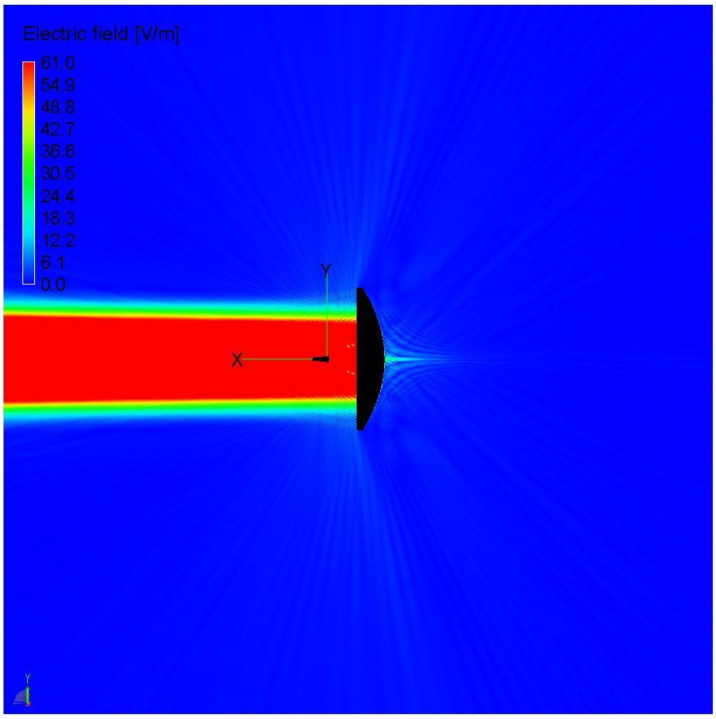

Figure 12-3 – Electric field strength distribution, horizontal cross-section, *f* = 75 GHz, P_{input} = 0.316 W, area 1 m × 1 m, EIRP = 0.185 kW, occupational exposure limit: 137 V/m

Maximum level of the electric field strength in the area in the back of the antenna is 32.6 V/m at a distance of 8.8 cm from the antenna.

13 Total exposure

In real conditions the person is exposed to three frequencies simultaneously. The total exposure [ITU-T K.70] should be calculated according to the equation below:

$$W_t = \sum_{i=100\text{kHz}}^{300\text{GHz}} \left(\frac{E_i}{E_{l,i}} \right)^2 \le 1 \qquad (13.1)$$

where:

E_i is the electric field strength at frequency i

$E_{l,i}$ is the reference limit at frequency i

For compliance with the regulations, the coefficients W_t of the total exposure should be less than 1.

14 Exposure levels for different transmitter power

The information given in previous clauses are given for certain levels of the transmitter output power feeding the transmitting antenna. In many cases the transmitter output power may differ to that presented. It is possible to estimate the expected exposure level because the exposure level and transmitter power are closely related. The electric field strength may be calculated using this equation [ITU-T K.70]:

$$S_{eq} = \frac{P \cdot G_i}{4\pi R^2} F(\phi,\theta) = \frac{P \cdot G_i}{4\pi R^2} H^2(\phi) V^2(\theta) = \frac{E^2}{Z_0} \tag{14.1}$$

where:

- S_{eq} is the equivalent plane-wave power density (W/m²) in a given direction
- R is the distance (m) from the radiation source
- P is the average power (W) of the transmitter feeding the antenna
- G_i is the maximum gain of the transmitting antenna, relative to an isotropic radiator
- $H(\phi)$ is the horizontal relative field strength radiation pattern (HRP)
- $V(\theta)$ is the vertical relative field strength radiation pattern (VRP)
- E is the rms electric field strength (V/m)
- Z_0 is the free space wave impedance = 120 $\pi \approx 377$ (Ω)

Taking into account that for any considered case R, G_i, $H(\phi)$,$V(\theta)$, Z_0 are constant values the equation may be written as:

$$E = \sqrt{Z_0 \frac{P \cdot G_i}{4\pi R^2} H^2(\phi) V^2(\theta)} = k\sqrt{P} \tag{14.2}$$

so the electric field strength is proportional to the square root of the average transmitter power feeding the antenna. The constant coefficient k is different in the different areas around the antenna (including area inside the antenna tower).

So if the calculations are done for the transmitter output power P_1 with the result of the maximum exposure level of E_1 and the real transmitter power in the considered case is P_2 then the maximum exposure level E_2 may be calculated using equation:

$$E_2 = E_1 \sqrt{\frac{P_2}{P_1}} \tag{14.3}$$

This equation allows us to convert the maximum exposure level presented in this Recommendation to the maximum exposure level adequate to the real considered cases.

15 Conclusions

For technical staff the knowledge about the expected exposure levels in the close proximity of transmitting antennas is important, especially during installation and maintenance activities. In the main beam of antennas the expected exposure level is usually very high and presence of any worker close to this area should be forbidden if transmitters are in operation. The exceptions are very low power systems that in some cases may be even inherently compliant [ITU-T K.52]. The situation is different in side and backward directions of the antennas in which radiation levels are usually much lower and may be under the exposure limit.

In this Recommendation information is included concerning the exposure levels that can be expected in backward or side directions of different types of transmitting antennas. Examples of calculations are presented in which the highest typical levels for the lowest, medium and highest operating frequencies within the system bandwidth are assumed. Moreover, a methodology is presented on how to recalculate these values if the transmitter power feeding antenna is different or if many channels are operating simultaneously.

The results presented in this Recommendation show that the exposure levels inside FM and TV antenna towers are usually much higher than occupational exposure limits. The exposure levels in the backwards direction of the mobile base station antennas and fixed point-to-point systems are usually lower than the occupational exposure limits. The microcell ceiling-mounted antennas give exposure levels which are much lower than the given limits.

The results presented in this Recommendation are obtained with the use of the full wave methods that are valid in a reactive near field. In many cases, the influence of the supporting structure has been taken into account. However, if the use of this Recommendation adjusted to a particular case shows that the expected exposure is close to the occupational exposure limits, a detailed individual analysis is required before maintenance or installation activity is allowed. In such cases control measurements are also strongly recommended.

Bibliography

[b-EN 50499] CENELEC EN 50499:2008, *Procedure for the assessment of the exposure of workers to electromagnetic fields*

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