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Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations

Recommendation ITU-T K.70

ITU-T

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Summary

Recommendation ITU-T K.70 defines techniques which may be used by telecommunication operators to evaluate the cumulative (total) exposure ratio in the vicinity of transmitting antennas and to identify the main source of radiation. It offers guidance on mitigation methods which allow reduction of radiation level in order to comply with exposure limits. It also provides guidance on procedures necessary in the environment (on site) in which, in most cases, there is a simultaneous exposure to multiple frequencies from many different sources. Radiating sources may belong to many operators and may represent different radiocommunication services (e.g., cellular systems, trunking systems, broadcasting, radio relays, wireless access, etc.).

This Recommendation includes an electronic attachment with an EMF-estimator software that implements the methodology it describes.

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Electronic attachment: EMF software estimator described in Appendix I

Recommendation ITU-T K.70

Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations

1 Scope

This Recommendation¹ provides guidance on mitigation techniques for limiting the exposure from radiocommunication installations, especially in the multiple sources environment. This guidance presents methods for field strength distribution evaluation, cumulative exposure ratio evaluation, identification of the main source of radiation, and offers mitigation techniques – methods for reducing the levels of electromagnetic fields during simultaneous exposure in the multiple sources environment.

In this Recommendation, the following reference limits are used: electric field strength, magnetic field strength and power density. Since compliance with the reference limits guarantees the compliance with basic restrictions, this is a conservative approach. In the far-field region the use of the reference levels gives results which are very close to real radiation levels. In the near-field region the obtained results will overestimate or underestimate real radiation levels. Moreover, this Recommendation deals with reference levels calculated in free space, so EMF influence on human tissues or human body is not considered.

This Recommendation also gives guidance on identifying those areas in which the highest radiation levels should be expected. This piece of information may be helpful to define the area for measurements.

The guidance given in this Recommendation applies to any exposure limits; however, in the examples of calculations, the ICNIRP exposure limits are taken.

A software EMF-estimator (see Appendix I) is attached to this Recommendation in order to support its application. The software implements the methodology described in this Recommendation and gives the possibility to calculate the cumulative exposure for the reference levels. It also contains the library of the radiation patterns of transmitting antennas for a wide range of radiocommunication and broadcast services. The EMF-estimator is not appropriate for the equipment certification in order to put it on the market.

This Recommendation is intended for use when considering the EMFs in areas around transmitting stations, e.g., around transmitting antennas in their places of installation.

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 (2017), *Guidance on complying with limits for human exposure to electromagnetic fields*.

¹ This Recommendation includes an electronic attachment with an EMF-estimator software that implements the methodology described.

- [ITU-T K.61] Recommendation ITU-T K.61 (2017), *Guidance to measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations.*
- [ITU-R BS.80-3] Recommendation ITU-R BS.80-3 (1990), *Transmitting antennas in HF broadcasting.*
- [ITU-R BS 705-1] Recommendation ITU-R BS.705-1 (1995), *HF transmitting and receiving antennas characteristics and diagrams.*
- [ITU-R BS.1195] Recommendation ITU-R BS.1195 (1995), *Transmitting antenna characteristics at VHF and UHF.*
- [ITU-R BS.1386-1] Recommendation ITU-R BS.1386-1 (2001), *LF and MF transmitting antennas characteristics and diagrams.*
- [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.*
- [ITU-R F.1245-1] Recommendation ITU-R F.1245-1 (2000), *Mathematical model of related radiation patterns for line-of-sight point-to-point radio-relay system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz.*
- [ITU-R F.1336-1] Recommendation ITU-R F.1336-1 (2007), *Reference radiation patterns of omnidirectional, sectoral and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz.*
- [IEC/EN 62311] IEC/CENELEC 62311:2007, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz-300 Hz).*
- [IEC 62232] IEC 62232:2017, *Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.*

3 Terms and definitions

This Recommendation defines the following terms:

3.1 antenna: 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).

3.2 antenna gain: The antenna gain $G_i(\theta, \phi)$ 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:

$$G_i(\theta, \phi) = \frac{4\pi}{P_{in}} \cdot \frac{dP_r}{d\Omega} \quad (3-1)$$

where:

θ, ϕ are the angles in a polar coordinate system

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

P_{in} is the total input power

Ω 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.

3.3 basic restrictions: 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).

3.4 compliance distance: Minimum distance from the antenna to the point of investigation where the field level is deemed to be compliant to the limits.

3.5 controlled/occupational exposure: Controlled/occupational exposure applies to situations where 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. Occupational/controlled 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 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.

3.6 directivity: Is the ratio of the power radiated per unit solid angle over the average power radiated per unit solid angle.

3.7 equivalent isotropically radiated power (eirp): The eirp is the product of the power supplied to the antenna and the maximum antenna gain relative to an isotropic antenna.

3.8 equivalent radiated power (ERP): The ERP is the product of the power supplied to the antenna and the maximum antenna gain relative to a half-wave dipole.

3.9 exposure: 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.

3.10 exposure level: Value given in the appropriate quantity used when to express the degree of exposure of a person to electromagnetic fields or contact currents.

3.11 exposure limits: 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.

3.12 far-field region: 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.

3.13 general population/uncontrolled exposure: 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.

3.14 general public: All non-workers (see definition of workers in clause 3.27) are defined as the general public.

3.15 intentional radiation: Electromagnetic fields radiated through the transmitting antenna even in directions which are not needed (for example to the back of the parabolic microwave antenna).

3.16 near-field region: The near-field region exists in the proximity of 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 which 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.

3.17 power density; power flux-density (S): 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 mainly used as equivalent plane wave power density, which is true in the far-field region.

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, $Z_0 = 377 \Omega$. In particular,

$$S_{eq} = \frac{E^2}{Z_0} = Z_0 H^2 = EH \quad (3-2)$$

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 .

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

3.19 radio frequency (RF): Any frequency at which electromagnetic radiation is useful for telecommunication.

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

3.20 reference levels: 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.

3.21 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:

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

3.22 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.

3.23 specific absorption rate (SAR): The time derivative of the incremental energy (dW) absorbed by (dissipated in) an incremental mass (dm) contained in a volume element (dV) of a given mass density (ρ_m).

3.24 transmitter: A transmitter is an electronic device to generate the radio-frequency electromagnetic field for the purpose of communication. Transmitter output is connected via a feeding line to the transmitting antenna which is the real source of the intentional electromagnetic radiation.

3.25 unintentional radiation: Electromagnetic fields radiated unintentionally, for example through the transmitter enclosure or feeding line.

3.26 wavelength (λ): The wavelength of an electromagnetic wave is related to frequency (f) and velocity (v) of an electromagnetic wave by the following expression:

$$\lambda = \frac{v}{f} \quad (3-3)$$

In free space the velocity is equal to the speed of light (c) which is approximately 3×10^8 m/s.

3.27 workers: Any person employed by an employer, including trainees and apprentices but excluding domestic servants.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

a.t.l.	above the terrain level
AM	Amplitude Modulation
ATSC	Advanced Television Systems Committee
CDMA	Code Division Multiple Access
CT-3	Cordless Telephony type 3
DECT	Digital Enhanced Cordless Telecommunications
DRM	Digital Radio Mondiale
DVB-T	Digital Video Broadcasting – Terrestrial
EIRP	Equivalent Isotropically Radiated Power
EMF	Electromagnetic Field
ERP	Equivalent Radiated Power
FM	Frequency Modulation
GSM	Global System for Mobile communications
HRP	Horizontal Radiation Pattern
IBOC	In Band On Channel
IS95	Interim Standard 95
MMDS	Multipoint Microwave Distribution System
NADC	North American Digital Cellular
PHS	Personal Handy phone System
T-DAB	Terrestrial Digital Audio Broadcasting
TETRA	Terrestrial Trunked Radio
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunication System
VHF	Very High Frequency
VRP	Vertical Radiation Pattern
WCDMA	Wideband CDMA

5 Evaluation of exposure levels

Basic restrictions on exposure to EMFs are based directly on established health effects. In many cases it is difficult to calculate them in real situations. Reference levels for human exposure to electric, magnetic and electromagnetic fields are derived from the basic restrictions using the realistic worst-case assumption about exposure. If the reference limits are met, then the basic restrictions will also be met; if reference levels are exceeded, that does not necessarily mean that the basic restrictions are exceeded. It means that the demand for the compliance with the reference levels is a conservative approach.

In this Recommendation, the compliance with the reference levels: electric field strength, magnetic field strength and power density is considered. According to [IEC 62232], the calculation of the reference levels is recognized as the reference method in the far-field region as well as the alternative method in the radiating near-field region. So the reactive near field is the only region in which the methodology used in this Recommendation has not enough accuracy and in which this methodology should not be applied.

The real source of intentional EMF is the transmitting antenna – not the transmitter itself, because the transmitting antenna is the main source that determines EMF distribution in the vicinity of a transmitting station. The EMF distribution does not depend on the type of the transmitter used if the same type of a signal and the same output power is applied to the input of the antenna (more exactly, the input of the feeding system). In most cases the distance between a transmitter and a transmitting antenna is rather big (around 30 m to 100 m in radiocommunication and around 200 m to 1500 m in broadcasting). The radiation emitted by the transmitter enclosure is unintentional radiation and is not considered in this Recommendation. The radiation emitted by the transmitting antenna is the intentional radiation which is most important from the point of view of the exposure assessment and determines radiation levels in areas accessible to people.

The most important step in the exposure assessment is the evaluation of radiation levels in the considered area. In typical transmitting and base stations, many operating frequencies are used, so the cumulative exposure assessment is required. Depending on the accessible data, models and methods used for the evaluation, the results have a lower or higher accuracy. In general, more detailed information concerning the radiation sources and more sophisticated methods and models lead to higher accuracy. In some cases, the accuracy of the evaluation is limited because of the lack of appropriate data concerning transmitting equipment (antennas). More detailed information concerning the influence of the radiation patterns of the transmitting antenna are provided in Annex A.

There are many methods of calculating the reference levels and then the cumulative exposure in the vicinity of transmitting stations [IEC 62232], [b-EN 50413], [IEC/EN 62311], [b-IEEE 1597.1], [ITU-R BS.1698], [ITU-T K.52] and [ITU-T K.61]. Depending on the method used and accessible data concerning radiating sources (antennas) and depending on the needs and required accuracy, in general three approach levels may be applied and may be efficient in cases met in practice. Most important features and applicability of these methods are described below.

5.1 Full-wave methods

The highest accuracy of calculation of the reference levels will be achieved by the numerical modelling using one of the full-wave methods based on solving Maxwell's equations in frequency or time domain [IEC 62232], [b-EN 50413], [IEC/EN 62311], [b-IEEE 1597.1], [ITU-R BS.1698] and [ITU-T K.61]. It includes the method of moments (MoM), finite-difference time domain (FDTD) and many others. Such methods of calculation may be used for any region of the EMF. They use detailed-segmented models of systems – the more detailed-segmented model is used, the better accuracy of the evaluated field distribution is achieved.

A typical transmitting station or base station consists of many transmitting antennas. The area required for consideration is usually big and inhomogeneous. In such a case, the method of moments (MoM) is more effective than other methods.

The application of numerical modelling, as described above, requires appropriate software, experience in electromagnetics and very detailed input data. There are many commercial packages available. In some cases, there are limitations concerning the number of unknowns (the number of segments) which may be used in calculations. The accuracy of the results of calculations strongly depends on the exactness and the range of accessible data concerning a transmitting antenna, which includes antenna geometry and its feeding arrangement. Many antennas (broadcasting antenna systems, cellular panels, etc.) contain a huge number of active radiating elements (up to 256) which

are fed with different amplitudes and phases. Without such information, the calculation is impossible or may be used for a general assessment only. In many cases (for example, for the GSM panels which also consist of many dipoles), it is very difficult to obtain the required data – it is manufacturer know-how.

The methods such as MoM give also the possibility to take into account all other objects which have an influence on the radiation level as secondary sources causing reflections (for example, facings made of metallic elements, antenna towers and antenna supporting structures, ground, etc.).

In general, numerical modelling methods provide a good opportunity to take into account almost all substantial factors influencing radiation, but they are useful in rather simple cases only, or for reactive near-field regions in which other methods are not sufficiently accurate. It happens so because it is very difficult to collect all the data needed. Additionally, sophisticated software and experience in electromagnetics are required, together with huge computer resources.

5.2 Synthetic model

In the synthetic model [IEC 62232], [b-EN 50413] each antenna is considered to be a set of elementary sources which have identical parameters. Such an approach is natural, for example, for broadcast antennas which usually contain sets (up to 64) of identical panels operating as one transmitting antenna [ITU-R BS.1195]. In the case of GSM panels (or similar antennas), they can be divided into "patches" (usually containing one dipole with a screen) and each of them may be considered as a separate radiating source. This model may be employed for distances beyond the near-field distance calculated with respect to the maximum size of an elementary radiating source (patch in GSM, panel in broadcasting). The model leads to very accurate results, but the accuracy is lower than in numerical modelling because the coupling between radiating sources is neglected. In many cases (for example, for all the broadcasting antennas) this assumption is well fulfilled.

A disadvantage of this model is that exact information concerning the feeding arrangements of the system containing many radiating sources is required.

5.3 Point source model

The point source model is a simple but very effective model which may be used in calculating the reference levels [IEC 62232], [b-EN 50413], [IEC/EN 62311], [ITU-R BS.1698] and [ITU-T K.52]. It is assumed that the transmitting antenna is represented only by one point source, situated in the antenna electric centre and having a radiation pattern of the considered transmitting antenna. The accuracy of this model depends on the field region and on the antenna gain. The boundaries of the field regions are defined according to slightly different criteria which can be found in [IEC 62232], [b-EN 50413], [IEC/EN 62311], [ITU-R BS.1698], [ITU-T K.52] and [ITU-T K.61]. This model is fully applicable in the far-field region. Further information on the point source method and its domain of application are developed in Annex B.

A disadvantage of this model is in the immediate vicinity of the antenna, where the dimension of the antenna needs to be taken into account in the exposure assessment.

5.4 Influence of the reflections

The radiation patterns (see Annex A) are provided for free space conditions. A reflection from the ground or from other structures, such as buildings or fencing (especially metallic objects), may lead to an increase in the value of the reference level. In a conservative approach, reflections from the ground can be taken into account as in Appendix II to [ITU-T K.52]. In typical cases, where an observation point is located up to a few metres above the terrain level, the electric field strength is multiplied by the factor 1.6 and it means that corresponding power density is multiplied by the factor 2.56.

Reflections from other structures are discussed in [IEC 62232]. These can be modelled using calculation tools such as Ray Tracing. It should be noted that in a complex environment, with many

reflections, only the one with the highest multiplication factor should be considered. In practice, a generic multiplication factor is 1.6 for the electric field strength which corresponds to 2.56 for the power density.

5.5 Uncertainty

When performing the calculation, the uncertainty of the result has to be specified. The calculation of uncertainty with a 95% confidence interval should be done according to [IEC 62232], [b-EN 50413] and [b-JCGM 100]. The target expanded uncertainty is 4 dB or below, which is considered industry best practice. The expanded uncertainty for the RF exposure evaluation used for the compliance assessment should not exceed 6 dB. If the calculation uncertainty exceeds 6 dB, the limit values should be reduced, see clause 7.1.2 of [ITU-T K.61].

6 The eirp and other parameters for the radiocommunication transmitting stations

The transmitters used in radiocommunication produce electromagnetic waves which, by feeding lines, are delivered to the transmitting antennas and radiated into the environment. The best situation is when the calculation is based on the exact information concerning the radiating sources (the ERP, radiation patterns, etc.). In many cases, it is very difficult to obtain such information. Therefore, the general data concerning the transmitting system under consideration may be helpful. General characteristics of the intentional radiation sources (transmitters and transmitting antennas) such as: transmitter power, transmitting antenna radiation patterns, antenna gain, antenna height and eirp are presented in Appendix II. Appendix II contains information concerning typical systems used in radiocommunication and broadcasting. The calculations based on limited data give only a general view on exposure levels in a considered site.

7 Evaluation of the cumulative exposure ratio in multiple sources environment

In most cases, a typical transmitting station contains many transmitting systems operating on many frequencies. In this case, in the area around the antenna tower, the electromagnetic field has a complex structure with many components of different frequencies and different field strengths, varying from point to point. For example, a typical cellular base station contains transmitting antennas of two frequency ranges (e.g., 900 MHz and 1800 MHz), operating on many radio carriers and is frequently shared by several operators, which involves the presence of additional transmitting antennas and radio carriers. The cellular base stations are often mounted on broadcast antenna towers which usually contain transmitting equipment for the FM, VHF and UHF bands. In such multiple sources environments, the human body is exposed to radiation emitted simultaneously by all the radiating sources.

The exposure assessment in the multiple sources environment, according to the existing standards [IEC 62232], [IEC/EN 62311] and [ITU-T K.52], requires the calculation of the cumulative exposure W (in some standards called also the total exposure ratio). All the operating frequencies must be considered in a weighted sum, where each individual source is pre-rated according to the limit applicable to its frequency.

For the frequency range above 100 kHz, in which the thermal effect is dominating the cumulative exposure, the coefficient W_t has the form (for the electric field strength) shown in equation 7-1:

$$W_t = \sum_{i=100\text{kHz}}^{300\text{GHz}} \left(\frac{E_i}{E_{l,i}} \right)^2 \leq 1 \quad (7-1)$$

where:

E_i is the electric field strength at frequency i

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

For the induced current density and electrical stimulation effect, relevant up to 10 MHz, and electric field strength as the reference level, the coefficient W_e has the form shown in equation 7-2:

$$W_e = \sum_{i=1\text{Hz}}^{10\text{MHz}} \frac{E_i}{E_{l,i}} \leq 1 \quad (7-2)$$

For compliance with the regulations, both coefficients W of the cumulative exposure should be less than 1. For the radiocommunication and broadcasting transmitting stations, the condition (7-1) is much more restrictive than the condition 7-2. The conditions concerning electrical stimulation effects are important at very short distances from the transmitting antenna, usually with no access for people.

Equations 7-1 and 7-2 show that the exposure assessment in the multiple sources environment requires the prediction of the electric field strength for each operating frequency. Such prediction, including calculation of the coefficients W , can be done using methods described in clause 5.

8 Identification of the main source of radiation

In the multiple sources environment, at each observation point, the components radiated from all transmitting antennas are present. In most cases, only one component is dominant and has the biggest influence on the total exposure level. Identification of the dominant radiation source is indispensable to consider the possibility of reducing the radiation level.

The main source of radiation may be identified by the calculation of the coefficient W_t (using equation 7-1) in the points of investigation regularly distributed in the area accessible to people. All the points should be at the same height (for example, 1.5 m a.t.l.) with respect to the ground level, uniformly distributed along a line from the antenna tower to the maximum distance considered, usually hundreds of metres up to 3 km for the high power transmitting stations. The azimuth angle for such calculation should be on the common maximum of the HRP of all antennas. If, for different antennas, the maxima are at different azimuth angles, then the calculations may be required for all the respective azimuths.

The calculations of the equivalent plane-wave power density should be done with a sufficiently low step. The guidance may be found in [IEC/EN 62311], [ITU-T K.61], and it is identical as for measurements. Since it does not matter on how many lines the calculations are performed, they should be done at least at three heights in the publicly accessible area. According to [IEC 62232], [IEC/EN 62311], [ITU-T K.61], these heights should be 1.1 m, 1.5 m and 1.7 m.

Such calculations done for each operating frequency separately allow to evaluate the cumulative exposure ratio and to make a graph presented in Figure 8-1.

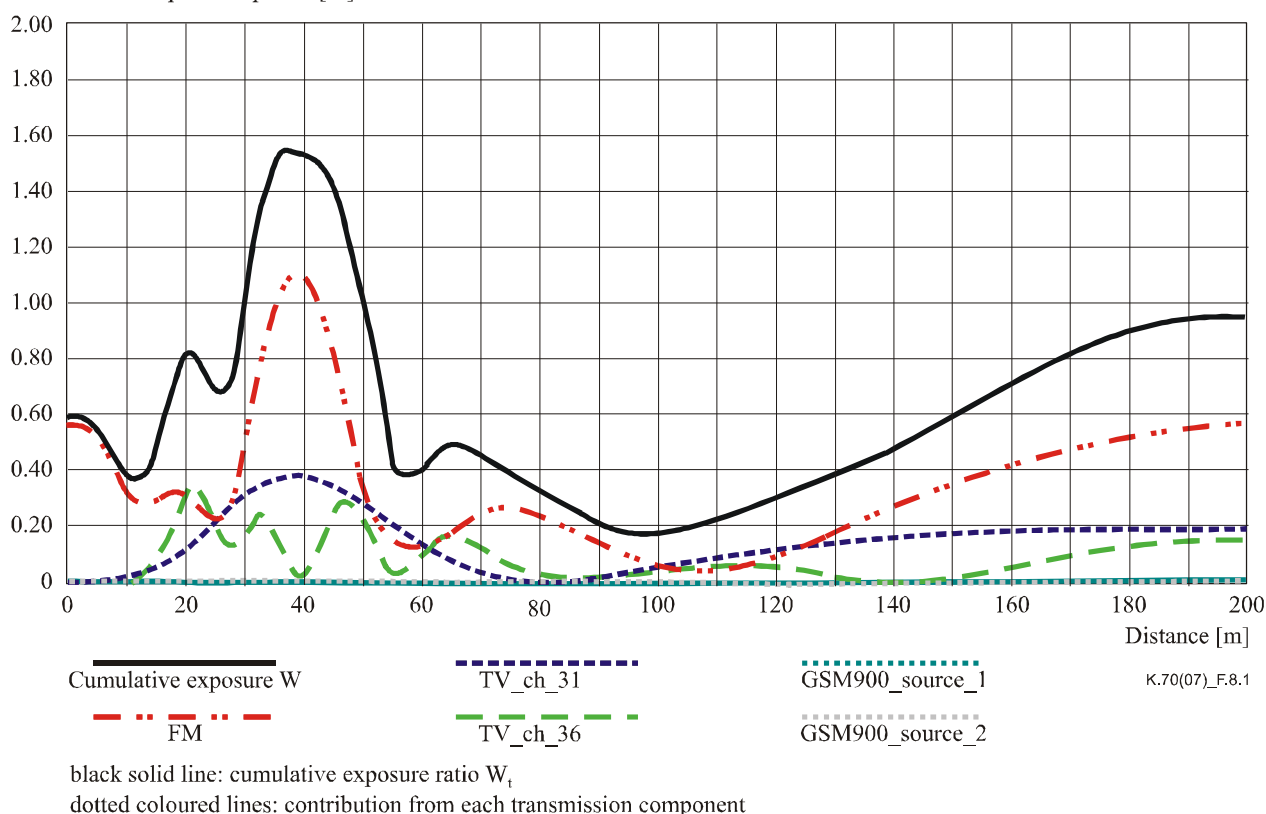


Figure 8-1 – Example of the coefficient W_t distribution as a function of distance for a transmitting site with FM, TV and GSM 900 systems

It can be seen that the procedure proposed provides an opportunity to identify easily the main source of radiation, which may be different for different observation points. In the example considered, the FM emission has the biggest contribution to the cumulative exposure, so it is the main source of radiation for this transmitting station. It can also be seen that the contribution from the GSM 900 base station is very small. This is a typical situation, where GSM or other radiocommunication transmitting systems coexist with broadcasting. A reduction of the exposure level should be done in such a way that it affects sufficiently the whole area in which the radiation limits are exceeded.

9 Compliance distances

Taking into account the exposure limits given in [b-ICNIRP], it is possible to calculate distances to the transmitting antennas at which exposure limits are achieved. Such distances are different for different types of transmitting antennas. Compliance distances are also different for the general public and for the occupational exposure because of different limits for these two types of exposure.

Compliance distances may be evaluated in many ways, depending on the accuracy required and on the data available (see clause 5). It should be always assured that for distances greater than the compliance distance, the radiation level is under the limit. It means that if a lower amount of data concerning a radiating source is available, then the higher overestimation of the compliance distances is required.

In the first approach, the point source model with an isotropic antenna (which means that radiation pattern is assumed $f(\theta, \phi) = 1$) is used. The approach may be used in all cases, but it gives the highest overestimation. Annex C contains the expressions on which the calculation of the compliance distances (performed in such a way) is based. The level of overestimation depends on the directivity of the transmitting antenna and on the direction of the point of investigation in relation to the transmitting antenna. For an isotropic antenna or for a directional antenna, but at the direction with