MCMC MTSFB TC G032:2021

TECHNICAL CODE

PREDICTION AND MEASUREMENT OF RF EMF EXPOSURE FROM BASE STATION

Developed by

Malaysian Technical Standards Forum Bhd

Registered by

MCMC

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MCMC MTSFB TC G032:2021

Development of technical codes

The Communications and Multimedia Act 1998 (‘the Act’) provides for Technical Standards Forum designated under section 184 of the Act or the Malaysian Communications and Multimedia Commission (‘the Commission’) to prepare a technical code. The technical code prepared pursuant to section 185 of the Act shall consist of, at least, the requirement for network interoperability and the promotion of safety of network facilities.

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Foreword

This technical code for Prediction and Measurement of RF EMF Exposure from Base Station (‘this Technical Code’) was developed pursuant to section 95 and section 185 of the Act 588 by the Malaysian Technical Standards Forum Bhd (MTSFB) via its International Mobile Telecommunications and Future Networks Working Group.

This Technical Code shall continue to be valid and effective from the date of its registration until it is replaced or revoked.

PREDICTION AND MEASUREMENT OF RF EMF EXPOSURE FROM BASE STATION

1. Scope

This Technical Code provides prediction and measurement methods for the determination of Radio Frequency (RF) field strength and power density in the vicinity of International Mobile Telecommunications (IMT) Base Station (BS) for the purpose of evaluating Electromagnetic Field (EMF) exposure to human.

The method of evaluating EMF exposure for EMF Compliance Assessment shall be as specified in the **Commission Determination on the Mandatory Standard for Electromagnetic Field Emission from Radiocommunications Infrastructure*, Determination No. 5 of 2021** ('Mandatory Standard').

2. Normative reference

The following normative reference is indispensables for the application of this document. For dated reference, only the edition cited applies. For undated reference, the latest edition of the normative reference (including any amendment) applies.

MCMC Determination No. 5 of 2021, *Commission determination on the mandatory standard for electromagnetic field emission from radiocommunications infrastructure.*

Recommendation ITU-T K.100 (07/2019), *Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service*

Recommendation ITU-T K.70 (01/2018), *Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations*

Recommendation ITU-T K.61 (01/2018), *Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations*

Recommendation ITU-T K.52 (01/2018), *Guidance on complying with limits for human exposure to electromagnetic fields*

IEC 62232:2019, *Determination of RF field strength, power density and Specific Energy Absorption Rate (SAR) in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*

ICNIRP Guidelines, Health Phys. 118(5):483–524; 2020; *Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)*

3. Abbreviations

For the purposes of this Technical Code, the following abbreviations apply.

5G	Fifth Generation
5G NR	5G New Radio
AF	Antenna Factor
AMS	Antenna Mounting Structure
BCCH	Broadcast Control Channel

BS	Base Station
CF	Calibration Factor
CPICH	Common Pilot Channel
DL	Downlink
DR	Domestic Roaming
E-field	Electric field
EIRP	Equivalent Isotropic Radiated Power
EMF	Electromagnetic Fields
FDTD	Finite-Difference Time-Domain
FF	Far-field
H-field	Magnetic field
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IMT	International Mobile Telecommunications
ITU	International Telecommunication Union
MIMO	Multiple-Input and Multiple-Output
MOCN	Multi-Operator Core Network
MOM	Method of Moments
MR	Multiple-Region
MR-FDTD	Multiple-Region Finite-Difference Time
MVNO	Mobile Virtual Network Operator
NEC	Numeric Electromagnetic Code
NF	Near-field
NR	New Radio
NSA	Non-Standalone
PBCH	Physical Broadcast Channel
POI	Point of Investigation
PSS	Primary Synchronisation Signal
RCI	Radiocommunications Infrastructure
RE	Resource Element
RF	Radio Frequency
rms	root mean square
RS	Reference Signal
SAR	Specific Energy Absorption Rate
SCS	Sub-Carrier Spacing
SI	International System of Units
SINR	Signal-To-Interference-Plus-Noise Ratio
SSB	Synchronisation Signal Block

SSS	Secondary Synchronisation Signal
TDD	Time Division Duplex
TSSR	Technical Survey Specification Report
UEEUT	User Equipment
UL	Uplink
WHO	World Health Organisation

4. Terms and definitions

For the purposes of this Technical Code, the following terms and definitions apply.

4.1 Antenna Factor (AF)

Ratio of the electromagnetic field strength incident upon an antenna to the voltage that is produced across a specified impedance (e.g. 50 Ω) terminating the line connection of the antenna.

4.2 Averaging time

Appropriate time over which exposure is averaged for purposes of determining compliance.

4.3 Base Station (BS)

Fixed equipment including the radio transmitter and associated antenna(s) as used in wireless telecommunications networks.

4.4 Compliance zone

In the compliance zone, potential exposure to EMF is below the applicable limits for both controlled/occupational exposure and uncontrolled/general public exposure.

4.5 Directivity

Ratio of the radiation intensity produced by an antenna in a given direction to the value of the radiation intensities averaged across all directions in space.

4.6 Electric field (E-field) strength

Vector field quantity, E which exerts on any charged particle at rest a force, F equal to the product of E and the electric charge, Q of the particle.

4.7 Electromagnetic Field (EMF)

It refers to the RF EMF which is part of electromagnetic spectrum comprising the frequency range from 100 kHz to 300 GHz.

4.8 Equivalent Isotropic Radiated Power (EIRP)

Product of the RF input power to an antenna and the absolute gain of the antenna in a given direction relative to an isotropic radiator.

4.9 Exceedance zone

In the exceedance zone, potential exposure to EMF exceeds the applicable limits for both controlled/occupational exposure and uncontrolled/general public exposure.

4.10 Exclusion zone

Area around an antenna or antennas where the RF field values emanating from the antennas exceed the International Commission on Non-Ionizing Radiation Protection (ICNIRP) public guidelines (public exclusion zone) or the ICNIRP occupational guidelines (occupational exclusion zone).

4.11 Far-field (FF) region

Region of the field of an antenna where the radial field distribution is essentially dependent inversely on the distance from the antenna. In this region, the field has a predominantly plane-wave character, i.e. locally uniform distribution of electric field and magnetic field in planes transverse to the direction of propagation.

4.12 Magnetic field (H-field) strength

Vector quantity obtained at a given point by subtracting the magnetisation, M from the magnetic flux density, B divided by the magnetic constant, μ_0.

4.13 Near-field (NF) region

Region generally in 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 (NF) region is further subdivided into the reactive NF region, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating NF region where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complex in structure.

4.14 Occupational zone

In the occupational zone, potential exposure to EMF is below the applicable limits for controlled/occupational exposure but exceeds the applicable limits for uncontrolled/general public exposure.

4.15 Shared sites

Multiple services or systems on the same or different radiocommunications infrastructure within a particular location.

5. Exposure limits

All service providers have to individually and jointly comply with the EMF exposure limits for general public and occupational workers according to the Mandatory Standard. Basic restriction and reference level units are shown in Table 1.

Table 1. Quantities and corresponding SI units used

Quantity	Symbol	Unit
Incident power density	S_{inc}	Watt per square meter, W m^{-2}
Incident electric field strength	E_{inc}	Volt per meter, V m^{-1}
Induced magnetic field strength	H_{ind}	Ampere per meter, A m^{-1}
Incident magnetic field strength	H_{inc}	Ampere per meter, A m^{-1}
Specific energy absorption rate	*SAR*	Watt per kilogram, W kg^{-1}
Electric current	*I*	Ampere, A
Frequency	*f*	Hertz, Hz
Time	*t*	Second, s

For convenience, the limit of EMF exposure from a BS for public and occupational workers are as in Table 2. In the event of any inconsistency with the Mandatory Standard, the limits specified by the Mandatory Standard shall prevail.

The averaging and integrating time of the relevant exposure quantities are specified to determine whether personal exposure level is compliant with the guidelines. The averaging time is not necessarily the same as the measurement time needed to estimate field strengths or other exposure quantities.

Table 2. Reference levels for exposure from 100 kHz to 300 GHz (unperturbed root means square (rms) values)

Exposure scenario	Frequency range	Incident E-field strength, E_{inc} (V m^{-1})	Incident H-field strength, H_{inc} (A m^{-1})	Incident power density, S_{inc} (W m^{-2})
Occupational workers	0.1 MHz - 30 MHz	$660/f_M^{0.7}$	$4.9/f_M$	N/A
	> 30 MHz - 400 MHz	61	0.16	10
	> 400 MHz - 2 000 MHz	$3\ f_M^{0.5}$	$0.008\ f_M^{0.5}$	$f_M/40$
	> 2 GHz - 300 GHz	N/A	N/A	50
Public	0.1 MHz - 30 MHz	$300/f_M^{0.7}$	$2.2/f_M$	N/A
	> 30 MHz - 400 MHz	27.7	0.073	2
	> 400 MHz - 2 000 MHz	$1.375\ f_M^{0.5}$	$0.0037\ f_M^{0.5}$	$f_M/200$
	> 2 GHz - 300 GHz	N/A	N/A	10

NOTES:

1. N/A signifies not applicable and does not need to be taken into account when determining compliance.
2. f_M is frequency in MHz.
3. S_{inc}, E_{inc}, and H_{inc} are to be averaged over 30 min, over the whole-body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values.
4. For frequencies of 100 kHz to 30 MHz, regardless of the FF/NF zone distinctions, compliance is demonstrated if neither E_{inc} or H_{inc} exceeds the above reference level values.

Table 2. Reference levels for exposure from 100 kHz to 300 GHz (unperturbed root means square (rms) values) *(continued)*

5. For frequencies of > 30 MHz to 2 GHz: a. within the FF zone: compliance is demonstrated if either S_{inc}, E_{inc} or H_{inc}, does not exceed the above reference level values (only one is required); S_{eq} may be substituted for S_{inc}; b. within the radiative NF zone, compliance is demonstrated if either S_{inc}, or both E_{inc} and H_{inc}, does not exceed the above reference level values; and c. within the reactive NF zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance, and so basic restrictions must be assessed. 6. For frequencies of > 2 GHz to 300 GHz: a. within the FF zone: compliance is demonstrated if S_{inc} does not exceed the above reference level values; S_{eq} may be substituted for S_{inc}; b. within the radiative NF zone, compliance is demonstrated if S_{inc} does not exceed the above reference level values; and c. within the reactive NF zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.

Exposure limits for EMF workers are higher than for the general public because workers are adults who are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. Anyone who is not at work would be regarded as a member of the public and the public exposure limits apply.

6. Shared sites

BS shared site can be divided into the following categories:

a) tower/pole BS;

Multiple service providers or systems installed within a tower or pole. The tower or pole may be in the form of steel mono leg, 3-legged, 4-legged (Figure 1(a)), guyed wire or in other shape or material specifically built for communication purpose.

b) dual-function BS; and

Multiple service providers or systems installed within an infrastructure meant for certain usage other than communication. The infrastructure may be in form of minaret, street light pole, water tank (Figure 1(b)), advertising board (Figure 1(c)), etc.

c) rooftop BS.

Multiple service providers or systems installed within rooftop (Figure 1(d)) or wall with 60 m to 100 m vicinity radius (depending on the site scenario and location). The building may be a single, double or multi-storey with any size or shape.

Figure 1 shows the examples of shared site.

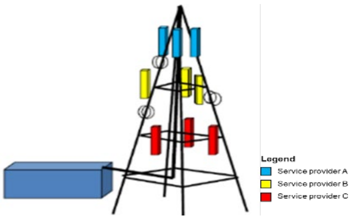


Figure 1a. 4-legged tower

Figure 1b. Water tank

Figure 1c. Billboard

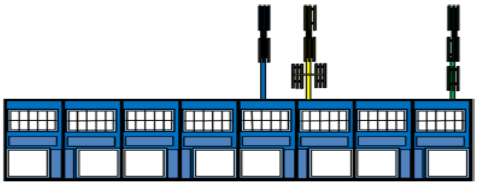


Figure 1d. Rooftop

Figure 1. Illustration of shared sites

6.1 Determination of Radio Frequency (RF) owner at shared site

In view of the existence of multiple service providers at 1 BS, RF owner shall be appointed to ease EMF compliance activities, such as generating and submitting the latest EMF compliance report. Nevertheless, the compliance with EMF exposure limit is the responsibility of all sharing parties, whereby any non-compliance should be resolved amicably.

6.2 Principles of determining RF owner for a shared site

The RF owner for each shared site should be decided by the relevant service providers that share the same BS. The list below stipulates the principles of determining the RF owner for a shared site depending on the ownership of the BS:

a) BS owned by network facilities provider that provides network service; and

BS structure owner is designated as the RF owner. The role will be relinquished to subsequent service provider that comes on board. Ownership will also change to the service provider who performs upgrade with additional antennas or transmitters. However, the BS structure owner has the responsibility to inform all existing service providers that are currently operated at the BS if any new tenant came in or change in transmitter or antenna. This is to allow the current RF owner to handover the responsibility to the new RF owner.

b) BS not owned by the network service provider.

The first comer is designated as the RF owner. The role will be relinquished to subsequent service provider that comes on board. Ownership will also change to the service provider who performs upgrade with additional antennas or transmitters. However, the BS structure owner has the responsibility to inform all existing service providers that are currently operating at the BS if any new tenant came in or change in transmitter or antenna. This is to allow the current RF owner to handover the responsibility to the new RF owner.

NOTES:

1. While the principles highlighted above are more applicable to new BS that is on-air subsequent to the issuance date of this document, it is encouraged for relevant service providers to deliberate on the RF ownership amicably for existing sites that are on-air prior to this.

2. The candidate for RF owner shall be from the service providers that operate the spectrum assigned to it to provide network service. MVNO, DR partner, MOCN sharer or any form in similar nature which does not operate the BS/spectrum are excluded.

3. The role will be relinquished to the previous RF owner should the current RF owner left the site.

7. Exclusion zone

The methods for determining the exclusion zone shall be in accordance with the calculations as described in the ITU-T K.100 and IEC 62232.

7.1 Theoretical calculation for single base station

The theoretical calculation for determining the exclusion zone is derived from NF and FF zone formula.

7.1.1 NF zone

The NF zone formula is used to estimate the power density for distance less than the FF zone distance.

The formula is shown as below

$$S_m = \frac{4PE}{A}$$

where,

S_m	the maximum power density, in watts per square meter, *W/m²*;
E	antenna efficiency (in number 0 to 1);
P	the power output of the system; and
A	the physical aperture area, in square meter, m^2.

7.1.2 FF zone

The FF zone formula is used to estimate the incident power density for FF zone distance.

The formula is shown as below:

$$S_{inc} = \frac{PG_{\theta,\varphi}}{(4\pi d^2)}$$

where,

S_{inc}	the incident power density;
P	transmitted power;
$G_{\theta,\varphi}$	gain of the antenna in the direction ($\theta,\boldsymbol{\varphi}$); and
d	distance from the antenna to the evaluation point.

The associated incident electric field strength, E_{inc}, and incident magnetic field strength, H_{inc}, can be evaluated as follows:

$$E_{inc} = \sqrt{\frac{30PG_{\theta,\varphi}}{d}}$$

$$H_{inc} = \frac{E}{\eta_0}$$

where, $\eta_0 \approx 377\ \Omega$.

If the power density is evaluated in the direction of maximum antenna gain, the formula is as follows:

$$S_{inc} = \frac{EIRP}{(4\pi d^2)}$$

where, Equivalent Isotropic Radiated Power (EIRP) is $PG_{\theta,\varphi}$.

The equation is re-arranged to calculate the minimum safe distance from the antenna, d_{min} or also known as exclusion zone distance as follows:

$$d_{min} = \sqrt{\frac{EIRP}{4\pi S_{inc}}}$$

7.2 Typical exclusion zone distances for BS

Based on the method described in section 7.1.2, the typical exclusion zone distances for IMT bands BS are shown in Table 3. The exclusion zones are calculated for downlink frequency bands to reflect the frequencies transmitted from BS.

Table 3. Typical exclusion zone distances of IMT bands base station based on EIRP calculation

Downlink frequency (MHz)	Transmit power at antenna/ EIRP (dBm)	Transmit power at antenna/ EIRP (Watt)	ICNIRP limit for public, S_{inc} (W/sq m)	ICNIRP limit for occupational exposure, S_{inc} (W/sq m)	Exclusion zone distance for public (m)	Exclusion zone distance for workers (m)
2 110 - 2 170	50	100	10	50	0.89	0.40
1 930 - 1 990	50	100	10	48	0.89	0.40
1 805 - 1 880	50	100	9	45	0.94	0.42
869 - 894	50	100	4	22	1.41	0.60
2 620 - 2 690	50	100	10	50	0.89	0.40
925 - 960	50	100	5	23	1.26	0.59
729 - 746	50	100	4	18	1.41	0.66
758 - 768	50	100	4	19	1.41	0.65
860 - 875	50	100	4	22	1.41	0.60
791 - 821	50	100	4	20	1.41	0.63
1 930 - 1 995	50	100	10	48	0.89	0.41
758 - 803	50	100	4	19	1.41	0.65
717 - 728	50	100	4	18	1.41	0.66

Table 3. Typical exclusion zone distances of IMT bands base station based on EIRP calculation *(continued)*

Downlink frequency (MHz)	Transmit power at antenna/ EIRP (dBm)	Transmit power at antenna/ EIRP (Watt)	ICNIRP limit for public, S_{inc} (W/sq m)	ICNIRP limit for occupational exposure, S_{inc} (W/sq m)	Exclusion zone distance for public (m)	Exclusion zone distance for workers (m)
2 350 - 2 360	50	100	10	50	0.89	0.40
2 010 - 2 360	50	100	10	50	0.89	0.40
2 570 - 2 620	50	100	10	50	0.89	0.40
1 880 - 1 920	50	100	9	47	0.94	0.41
2 300 - 2 400	50	100	10	50	0.89	0.40
2 496 - 2 690	50	100	10	50	0.89	0.40
3 550 - 3 700	50	100	10	50	0.89	0.40
1 432 - 1 517	50	100	7	36	1.07	0.47
1 427 - 1 432	50	100	7	36	1.07	0.47
2 110 - 2 200	50	100	10	50	0.89	0.40
2 110 - 2 200	50	100	10	50	0.89	0.40
1 995 - 2 020	50	100	10	50	0.89	0.40
617 - 652	50	100	3	15	1.63	0.73
1 475 - 1 518	50	100	7	37	1.07	0.46
1 432 - 1 517	50	100	7	36	1.07	0.47
1 427 - 1 432	50	100	7	36	1.07	0.47
3 300 - 4 200	50	100	10	50	0.89	0.40
3 300 - 3 800	50	100	10	50	0.89	0.40
3 300 - 4 200	50	100	10	50	0.89	0.40
4 400 - 5 000	50	100	10	50	0.89	0.40
2 496 - 2 690	50	100	10	50	0.89	0.40

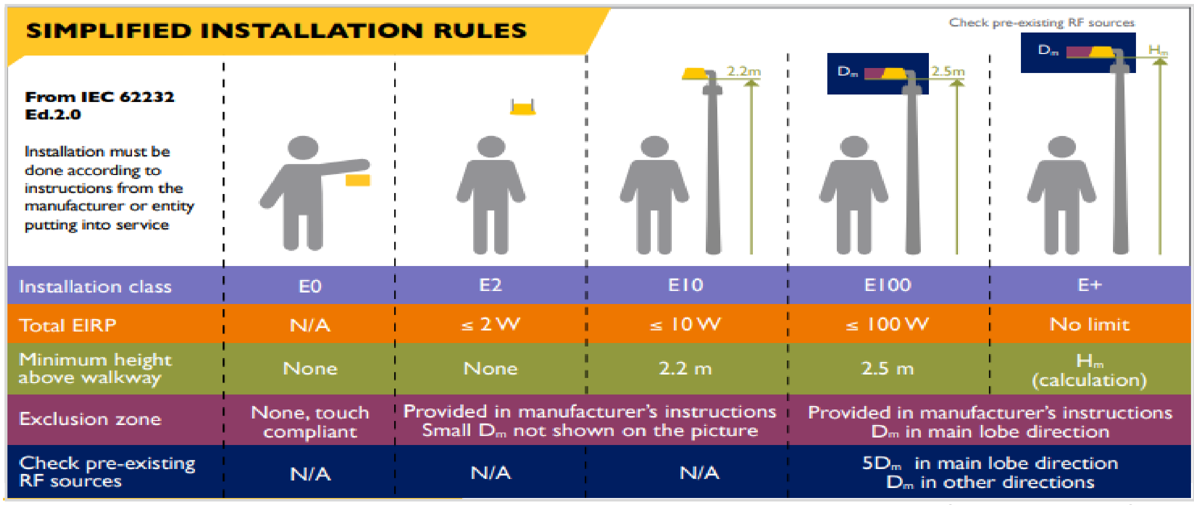
Table 3. Typical exclusion zone distances of IMT bands base station based on EIRP calculation *(continued)*

Downlink frequency (MHz)	Transmit power at antenna/ EIRP (dBm)	Transmit power at antenna/ EIRP (Watt)	ICNIRP limit for public, S_{inc} (W/sq m)	ICNIRP limit for occupational exposure, S_{inc} (W/sq m)	Exclusion zone distance for public (m)	Exclusion zone distance for workers (m)
1 427 - 1 432	50	100	7	36	1.07	0.47
1 432 - 1 517	50	100	7	36	1.07	0.47
1 427 - 1 432	50	100	7	36	1.07	0.47
1 432 - 1 517	50	100	7	36	1.07	0.47
26 500 - 29 500	50	100	10	50	0.89	0.40
24 250 - 27 500	50	100	10	50	0.89	0.40
37 000 - 40 000	50	100	10	50	0.89	0.40
27 500 - 28 350	50	100	10	50	0.89	0.40

It shall be noted that the distances in Table 3 are only examples based on practical EIRP and antenna data, and that the proper usage of the formula shall be ensured in calculating the correct exclusion zone distances that must be based on the actual BS specifications.

The EIRP values used in Table 3 are based on the recommendations described in ITU-T K. Sup 16 and IEC 62232. These recommendations assume a macro cell condition, where the antenna height is more than 2.5 m, hence the 100 W EIRP is applied.

However, in real condition, the simplified installation rules in Figure 2 and further examples of simple EMF exposure evaluation for various situations shall be referred to ITU-T K.52.



(Source: ITU-T K Sup 9)

Figure 2. Simplified installation rules and total EIRP determination

The maximum EIRP transmissions for mobile cellular and IMT systems in Malaysia are specified in Table 4.

Table 4. Maximum EIRP limits for mobile cellular and IMT systems in Malaysia

Frequency band (MHz)	Maximum EIRP for base station in-block transmission
824 - 834	61 dBm
869 - 879	61 dBm
880 - 915	61 dBm
925 - 960	61 dBm
1 710 - 1 785	61 dBm/5 MHz
1 805 - 1 880	61 dBm/5 MHz
1 915 - 1 980	65 dBm/5 MHz
2 010 - 2 025	65 dBm/5 MHz
2 110 - 2 170	65 dBm/5 MHz
2 500 - 2 690	61 dBm/5 MHz

Based on Table 4, the maximum exclusion zone distances calculated from the maximum EIRP transmission limits at the centre frequency of each band are shown in Table 5.

Table 5. Maximum exclusion zone distances of typical cellular sites

Frequency band (MHz)	Transmit power at antenna/ EIRP (dBm)	Transmit power at antenna/EIRP (W)	ICNIRP limit for public (W/sq m)	ICNIRP limit for occupational exposure, S_{inc} (W/sq m)	Exclusion zone distance for public, S_{inc} (m)	Exclusion zone distance for workers (m)
869 - 879	61	1,259	4	22	5.0	2.10
925 - 960	61	1,259	5	23	4.5	2.10
1 805 - 1 880	61	1,259	9	46	3.3	1.48
2 010 - 2 025	65	3,162	10	50	5.0	2.24
2 110 - 2 170	65	3,162	10	50	5.0	2.24
2 500 - 2 690	61	1,259	10	50	3.2	1.42

It shall be noted that the distances in Table 5 are only examples based on maximum EIRP and practical antenna data, and that the proper usage of the formulas shall be ensured in calculating the correct exclusion zone distances that shall be based on the actual BS specifications.

8. Prediction methods for EMF exposure

This section describes the calculation and computation methods to evaluate EMF exposure. The selection of numerical methods suitable for EMF exposure prediction in various situations are provided in ITU-T K.61 and IEC 62232.

The evaluation procedure is divided into:

a) evaluation by calculation for single transmitter BS; and

b) evaluation by advanced computation using a simulation software for complex BS (where there are 2 or more antennas/transmitters).

In the event of any configuration changes on the BS, the EMF exposure should be re-evaluated with the updated configuration parameters.

8.1 Evaluation by calculation

In the case of a single transmitter BS (including 3 sectors/panels for coverage in all directions), the basic calculation of EMF exposure is as stipulated in Clause 7. The evaluation of the EMF exposure is to be made at various publicly accessible points in the environment surrounding the BS. The EMF exposure calculation report shall consist of the data and technical parameters as shown in Table 6.

Table 6. EMF exposure calculation information

Type	Descriptions
BS information	a) BS ID; b) BS address; c) Global Positioning System (GPS) coordinate; and d) date of commission.
Technical parameters	a) BS type - Tower/pole, dual function or rooftop; b) BS height in meter; c) electrical tilt and mechanical tilt in degree; d) antenna transmit gain in dB; e) antenna vertical bandwidth beam in degree; f) antenna side lobe attenuation in dB; g) antenna type, model and manufacturer; and h) transmitter power output in Watt.
Other technical parameters	Uncertainty estimation analysis, consist of: a) cable, connector and combiner loss in dB; b) scattering from nearby object and ground in dB; c) mismatch between antenna and its feed in dB; and d) antenna radiation pattern data.
Calculation tool information	a) version, model and manufacturer (if any); b) operator name and designation; and c) date and time of calculation report.

8.2 Evaluation by advanced computation

Advanced computational electromagnetic mapping using a simulation software is required for complex sites where there are 2 or more transmitters or antennas. The simulation results are to be presented in the form of field strength or power densities that are calculated according to the plane of interest, and expressed in terms of numerical values and percentage of the exposure limit. Based on the simulated results, it is required for the EMF measurements to be performed if the power density values are found to exceed the stipulated exposure limit.

8.2.1 Advanced computation methods

For complex scattering environment, exclusion zones for multiple antennas in close proximity are drawn by software simulation based on methodologies as proposed in IEC 62232, ITU-T K.52 and ITU-T K.61.

There are several methods for determining compliance with exposure limits:

a) Finite-Difference Time-Domain (FDTD);

b) Multiple-Region Finite-Difference Time-Domain (MR/FDTD);

c) ray tracing model;

d) hybrid ray tracing/FDTD methods; and

e) NF antenna models such as Method of Moments (MOM) and the Numeric Electromagnetic Code (NEC).

The guidance in selecting appropriate computation methods to assess compliance with EMF levels is shown in Table 7, which shall depend on the following factors:

a) the field zone where the exposure evaluation is required;

b) the quantities being evaluated; and

c) the topology of the environment where the exposure occurs.

Table 7. Selection of numerical techniques

Field zone	Topology	Evaluated quantity	Suitable numerical technique
NF	Open	Field	FDTD, MOM
NF	Closed, multiple scatterers	Field	FDTD, MOM
FF	Open	Field	Ray tracing, MOM
FF	Multiple scatterers (complex urban environment)	Field	Ray tracing
NOTE: More detailed information on numerical techniques can be found in IEC 62232.			

8.2.2 Software estimation of uncertainty

Every method requires uncertainty analysis report to be included with the simulation report. Detailed information can be found in IEC 62232 and ITU-T K.100. The software estimation of uncertainty involves 4 tasks:

a) identification of all sources of uncertainty that may reasonably be expected to cause significant variation or uncertainty in the evaluation;

b) for each source of uncertainty, an estimation of the probability distribution type and parameter;

c) specification of how the sources of uncertainty are combined to provide a total uncertainty value (a mathematical model which defines how the influence quantities are combined or added); and

d) determine the best estimate of the evaluation and expanded uncertainty for a 95 % confidence interval.

8.2.3 Validation of EMF simulation report

The simulation software shall be validated with reference example stated in IEC 62232 depending on the choice of computational method used. If the maximum deviation from the reference results is within ± 3 dB, the simulation package has passed the validation. The validation report of the software algorithm for each version and model shall be registered to MCMC. The latest simulation software validation registration is required for the updated version or/and model.

Simulation software operator shall be trained and training certificate shall be provided for verification purpose. Software operator name and designation shall be available in simulation report. A simulation software (EMF estimator) as described in ITU-T K.70 should be used.

8.2.4 Exclusion zone indicators

The simulation report shall provide clear information on zoning as defined in ITU K.52 that classifies potential exposure to EMF as belonging to one of the three following zones; compliance zone, occupational zone and exceedance zone.

In the examples shown in Figure 3, the red zone indicates the exceedance zone, where no person is allowed into this area without following the appropriate shut-down, power-down or safe pass-through procedures. The yellow zone indicates the occupational zone, where only the RF trained personnel are allowed, on the condition that they follow the relevant site access procedures. The area outside the yellow zone (white zone) is open for public access.

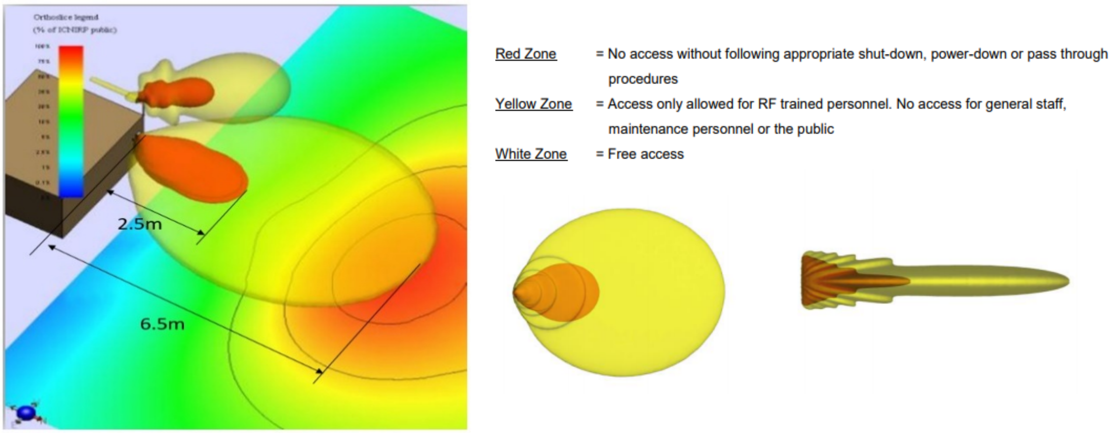


Figure 3. An example of simulated exclusion zone

The examples of simulation models illustrating the exclusion zones for various antenna structures are shown in Figure 4.

Tower/mast | **Building rooftop** | **Oil and gas platform**

Figure 4. Examples of computed exclusion zone in simulation tool based on real antenna structures

8.2.5 EMF simulation report

The simulation report should include the following data and technical parameters as elaborated and explained in Annex A:

a) base station information;

b) Radiocommunications Infrastructure (RCI) technical parameters;

c) other technical parameters for uncertainty estimation analysis

d) cut-plane figures;

e) simulation software information; and

f) blueprint to scale.

The computations and assessments of the exposure level shall consider the following conditions:

a) the maximum emission conditions (e.g. maximum EIRP, gain and beamwidth of the antenna system;

b) the simultaneous presence of several EMF sources, even at different frequencies; and

c) various characteristics of the installation, such as the antenna location, antenna height, beam direction, beam tilt.

Sample of the EMF compliance report (simulation) is shown in Annex C.

9. On-site measurement for EMF exposure

On-site measurement shall be performed to analyse and confirm the actual EMF exposure at site and its surrounding areas. The measurement shall comply with the EMF exposure limits as stated in the Mandatory Standard. This clause specifies the techniques and instrumentation for the on-site EMF measurement.

9.1 In-situ EMF measurement

In-situ measurement is a measurement of the RF exposure level in the vicinity of the BS. Measurement or evaluation shall be made in the areas, which are known to be accessible by public and workers, and shall be performed at one location or area, known as the measurement area. The in-situ measurement method shall be in accordance to the IEC 62332.

9.1.1 NF measurement

NF measurement is conducted to determine the EMF exposure level for workers. For NF measurement, both E-field and H-field intensities shall be measured and compared to the EMF exposure limits as specified in the Mandatory Standard.

9.1.2 FF measurement

FF measurement is conducted to determine the EMF exposure for the public. For FF measurement, only electric field strength (E-field) or power density shall be measured and compared to the EMF exposure limits, and shall be in accordance to the Mandatory Standard.

FF region can be determined by the following formula:

$$FF = \frac{2D^2}{\lambda}$$

where,

FF	the distance which indicates the beginning of the FF region;
D	the biggest dimension of the antenna in metre, m; and
λ	wavelength of the transmitted radiation in metre, m.

a) However, for the onset of the FF zone, the maximum phase difference of the electromagnetic waves coming from different points on the antenna is 22.5º. For estimating the field strength (worst case scenario), a realistic practical distance from a large antenna (parabolic) at the FF zone begins at:

$$FF = \frac{0.5D^2}{\lambda}$$

b) For small antenna size (e.g. rod/dipole), the FF can be determined using the following formula.

$$FF = \frac{\lambda}{2\pi}$$

The NF and FF regions are illustrated in Figure 5.

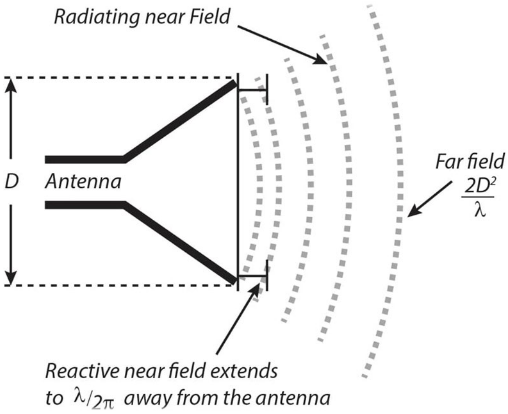


Figure 5. NF and FF regions

9.1.3 Measurement instrumentations

Measurement shall be performed using the most appropriate measuring equipment to obtain the information of transmit electromagnetic fields emitted on-site. According to the ITU-T K.61, there are several considerations in selecting the measurement devices as follows:

a) frequency range

There are 2 frequency ranges, which are the broadband and narrowband frequency range. Broadband devices will measure the overall frequency available around the site. This measurement will not indicate the individual frequency spectrum, but this is very appropriate for measurement at the public area, to show the overall EMF emission as indication of the public exposure. Measurement devices are generally antennas with big frequency range. Narrowband measurement devices are generally antennas with flat antenna factors over a limited spectrum ranges and can be used for selective frequency measurement.

b) antenna directivity

The antenna response maybe isotropic or directional. For the isotropic devices, the response is expected to be dependent of the direction on the incident EMF. Directional devices are generally polarised and have an axial symmetry in the radiation pattern.

c) quantity measured

The majority of the devices measure either the electric field or the magnetic field. In the FF region, measurement devices for the electric field component are preferred. The equivalent power density within the FF region is obtained from the measured field by calculation shown in Table 1 of the ITU-T K.61, which is based on the following equation.

$$Power\ density, S = \frac{E^2}{Z_0} = Z_0 \cdot H^2$$

where,

E	Electric field
Z_0	Intrinsic impedance
H	Magnetic field

d) device selection

The selection for EMF measurement devices is determined by some factors, for instance:

i) The equipment and device shall comply the following recommendation:

1) The device shall measure electric field (V/m), magnetic field (A/m) and power density (μWatts/cm^2) and comply to the existing standard by ICNIRP; and

2) The equipment should be suitable for the frequency range; i.e. narrowband or broadband measurement to comply to the characteristics of EMF source.

ii) For NF measurement, the EMF personal monitor is required.

iii) The number and the characteristics of EMF sources (which meet the measurement objective).

iv) Equipment or device shall be calibrated and has valid calibration certificate.

v) The field region (i.e. reactive NF, radiating NF or FF) in which the measurement is made.

The accuracy of measurement results depends on the measurement procedures as well on the characteristics of the measurement instrument used. An expanded measurement uncertainty with a 95 % confidence interval less than or equal to 4 dB is deemed sufficient to show compliance.

9.1.4 Calibration requirements

Calibration is very important to ensure the reliability of the equipment used. The objective of the calibration is to minimise any measurement uncertainty by ensuring the accuracy of the test equipment by quantifying and controlling errors within measurement processes to an acceptable level. The calibration requirements shall comply to the ITU-T K.61 and IEC 62232.

a) Calibration Factor (CF)

For the broadband probes, the CF is defined by the following formula:

$$CF = \frac{E_{ref}}{E_{meas}}$$

It is the ratio between the expected electric field reference field strength, E_{ref} and the measured value, E_{meas} displayed on the dedicated receiver unit. This factor is mainly a function of frequency and in the presence of non-linearity error or field strength. The CF is determined as a frequency function. For each frequency, the CF value shall be known with uncertainty less than 1 dB. Errors due to frequency interpolation are included in the tolerable uncertainty on CF.

b) Antenna Factor (AF)

The AF is defined for antennas and frequency selective probe as the ratio of the following formula:

$$AF = \frac{E_{ref}}{V}\,[m^{-1}]$$

where,

E_{ref}	the E-field strength on the probe; and
V	the voltage measured on the spectrum analyser.

This factor is primarily function of frequency but, in presence of non-linearity errors, it may depend on field strength too. The AF is determined as a frequency function. For each frequency, the AF value shall be known with an expanded uncertainty (i.e. 95 % statistical confidence) of less than 2 dB. The maximum tolerable uncertainty includes the error due the frequency interpolation.

c) isotropy

An isotropic probe is needed for compliance measurement of EMF emission. The isotropic response is usually achieved by a three-axial antenna system, where the three axes are arranged to be orthogonal. The deviation from an ideal isotropic response is called isotropic error and in general it is a function of the incident wave direction. It can be evaluated by measuring the difference from a cosine response of each axis if they are spatially identified and a signal from each axis is available or by checking the whole probe response (if it is not possible to clearly define the position of each axis or a single axis signal is not available). The mean deviation from the isotropic response should be less than 1 dB.

d) linearity

A linear response versus the field amplitude is required; a linearity error would mean that the antenna and the calibration factors are functions of the test field strength. Thus, the linearity test should be the starting point of the whole characterisation process of the probe.

9.1.5 Probe selection

General consideration in probe selection is the frequency range. It can be a broadband probe or a narrowband probe. This depends on the EMF sources intended to be measured (single source and multiple EMF sources). Broadband measurement will provide one set of field strength measurement for all frequency range and sources at the measurement area while narrowband measurement will require separate sets of field strength values of each source and frequencies at the measurement area. The choice of the measurement type depends on the objective of the in-situ evaluation as stated in the IEC 62232.

The dimension of probe sensor should be less than a wavelength at the highest operating frequency. According to ITU-T K.61, a non-directional probe is preferred in conducting EMF measurement.

9.1.6 Measurement method

The details of the measurement method in accordance to IEC 62232, ITU-T K.61 and ITU-T K.100 are as follows:

a) measurements shall be conducted by personnel with specific training on EMF instrumentations and techniques;

b) visual inspection shall be conducted before the measurement start;

c) physical condition of the EMF source at the site must be recorded (number of antenna, height of the structure, type of the antenna) and photo of the site must be taken for record on the day of the measurement;

d) the parameters that shall be considered during the assessment are as follows:

    i) frequency range;

    ii) type of antenna;

    iii) transmitting power;

iv) dimension of the antenna; and

v) distance.

e) identification of RF source and measurement points;

f) the locations of measurement selected shall be based on the worst-case situation (nearest accessible location facing the antenna beam) and popular public places (residential area, playground, bus stops).

Distance from the EMF source to the measurement point must be recorded as reference. The NF or FF region shall be determined before selecting the measurement point. EMF measurement shall be conducted at various location points and should be mapped with the exact location (with longitude and latitude coordinate). This process is called EMF mapping and through this, we can see the EMF exposure level variations over the distance and at the selected measurement points. The layout plan must be sketched for any measurement conducted in the building;

g) EMF measurement instruments shall match with the EMF sources frequency range and suit to FF or NF region which appropriate equipment and probes shall be selected based on the intended frequency range;

h) the measurement shall be carried out at 1.5 m to 2 m from the ground/floor which the measurement probe should be mounted on a wooden tripod;

i) inspection or measurement point shall be selected at least 3 probe lengths or 0.2 m away from any conducting or reflecting objects;

j) for each point, measurement shall be taken for 6 min by using broadband and selective spectrum analyser with root mean square (rms) detector using appropriate probe (according to frequency used by each telco service); and

k) results shall be recorded in power density (μWatts/cm^2) to represent the EMF exposure.

Measurement for shared site shall consider the number of RF sources available at the site. Information on the individual frequency of the RF source used by each service provider shall be obtained before the measurement. Broadband measurement is required to determine the total electromagnetic field around the site. Individual frequency measurement using the selective spectrum analyser can be conducted if needed. The EMF exposure calculation for the shared sites shall be determined by using the lowest frequency used by the shared service provider as a consideration of the worst-case scenario.

The EMF should be assessed by using the narrowband method in order to capture every frequency range used by the network service provider. The measurement should assess the maximum emission from the RCI. As different frequency with different information needs to be assessed individually, the assessment shall be measured using the extrapolation method. The system used by the RCI shall be identified whether they use 2G, 3G or 4G. The broadcast control channel (BCCH) is the essential channel for 2G, common pilot channels (CPICH) for 3G and reference signal (RS) for 4G need to be measured and extrapolated accordingly in order to determine the maximum EMF exposure emitted by the system. The worst-case EMF exposure scenario should be calculated by using the extrapolation factor for each measurement point.

9.1.7 Extrapolation factor analysis

The details of the extrapolation method in accordance to IEC 62232 and ITU-T K.100 are as follows:

a) Extrapolation analysis is done by using spectrum analyser (selective narrowband measurement) with capability of decoding 3G/4G signal.

b) The service provided shall be identified whether 2G, 3G or 4G.

c) The frequency used shall be identified.

d) For 2G, as the BCCH is always sending constant signal all the time and independent from the traffic signals that fluctuate, BCCH shall be measured for 2G system. The BCCH shall then be extrapolated to the maximum channels.

e) For 3G, the constant signal to be measured is CPICH. This signal needs to be decoded from the 3G spectrum and extrapolated accordingly.

f) For 4G, the constant signal required to be measured is Reference Signal (RS). It requires to be extrapolated to the maximum.

g) The azimuth of the antenna shall be identified to determine the measurement point.

h) The information of each RCI should be obtained from the Technical Survey Specification Report (TSSR).

i) During the measurement, antenna sweeping or point raster can be used.

9.1.8 Measurement report

A sample of measurement report is as per Annex D. A measurement report shall consist of the following information:

a) introduction;

b) objective;

c) scope of the measurement;

d) description of survey site and radiation source;

e) safety guideline and exposure limit;

f) standard measurement equipment;

g) method of measurement;

h) extrapolation factor analysis;

i) results and discussion;

j) conclusion;

k) attachment; and

l) report verification.

9.2 5G New Radio (NR) base station EMF measurement

In 5G New Radio (NR), the signalling and data signals transmit on different beam. Even if the beam width of signalling and data beam are different, a good correlation (constant factor) between signalling and data is in the range of directions, where half power beam width of signalling and data overlap. Towards the maximum angles of the beams, high differences up to 30 dB or more occur between signalling and data field strength. This may result in an underestimation of the maximum field strength, if only the signalling is measured. There are many different modes for the signalling pattern and beam width. The exact mode must be known for any correlation, which should be provided by the network provider.

The assessment method should consider for the maximum emission approach rather than just the current emission approach for 5G on-site EMF measurement. The measurement needs to identify and decode carriers and beams of the 5G site. Estimation/calculation of the worst-case EMF exposure at the 5G site shall be made using extrapolation factor. To evaluate the exposure level for maximum traffic conditions by extrapolation, it is important that the transmitted power of the received signal or channel is not dependent on the amount of traffic. The measurement should be made using a known antenna (where antenna factor is available). A quick survey at the BS should be made to ensure no emissions from other transmitters in the area.

The method described in this section is based on the guidelines stated in the IEC 62232, in which the radiation pattern and the power per Resource Element (RE) for the Synchronisation Signal Block (SSB) are the same as the traffic channels (or any other signal transmitted by the BS). Otherwise, an additional extrapolation factor should be considered in the extrapolation to account for the possible difference in the antenna gain and power. Considerations which should be made for 5G NR EMF measurement are discussed in the following sub-sections.

9.2.1 Beam/gain offset between Synchronisation Signal Block (SSB) and data beams

The 5G NR UE specific beams have a much lower beam width and/or more power as compared to SSB beams to further increase the SINR. The corresponding data either to be measured with the RF scanner or to be requested from the network operators or network vendors. Figure 6 illustrates the multi-beam signals transmitting from the 5G NR base station antenna.

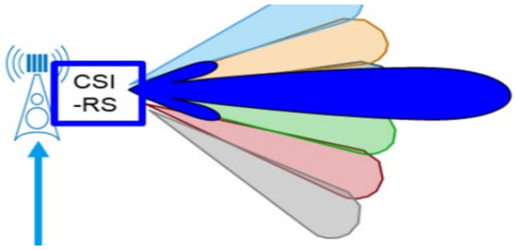


Figure 6. Multi-beam signal from the same antenna sector in 5G NR

9.2.2 Uplink (UL) and Downlink (DL) relation factor

In the case of TDD, the relation between Uplink (UL) and Downlink (DL) significantly affects the radiated power by the 5G NR base station. In the case, if more slots are reserved for UL, the radiated power decreases. The relation factor depends on the network configuration, which may be requested from the network operators. An exception is the 5G NSA networks, where the 5G NR carrier may be used for DL only. An example of Uplink (DL) and Downlink (DL) sequences in the 5G NR TDD network is shown in Figure 7.

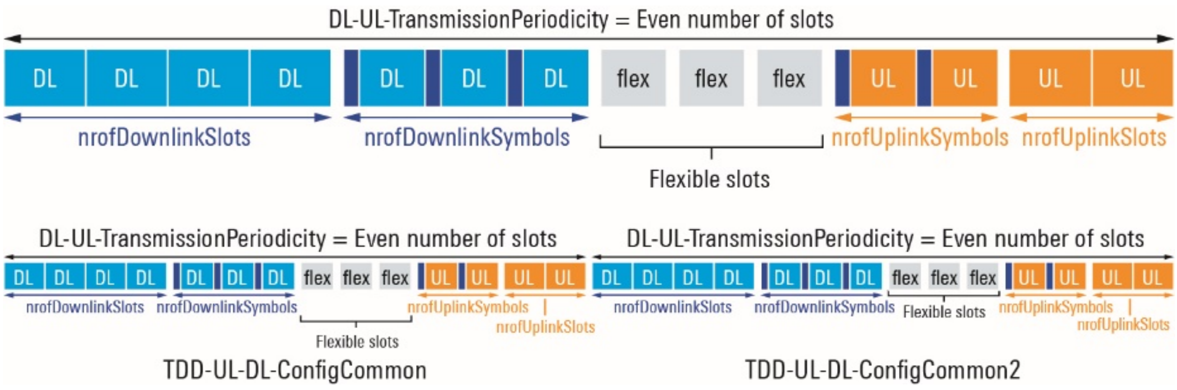


Figure 7. Example of UL/DL sequence in 5G NR TDD standalone network

9.2.3 Projection of synchronisation signal block power on the total 5G NR carrier spectrum

5G NR SSBs only have a bandwidth of 3.6 MHz to 7.2 MHz depending on the subcarrier spacing. The total bandwidth of 5G NR carrier can be up to 400 MHz. An extrapolation factor is then required, which can be requested from the operators or to be determined by using a mobile phone with an active subscription for the 5G NR network. In the 5G NR carrier, the SSB is the only “always on” signal. Since the 5G is packet switch, the total carrier power is only measurable during the time when it is at maximum active traffic. The illustration of the SSB block within the 5G carrier is shown in Figure 8.

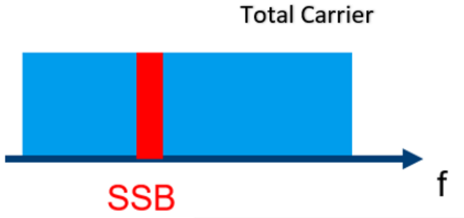


Figure 8. Illustration of the SSB from the total 5G NR carrier spectrum

9.2.4 Maximum 5G NR exposure evaluation

An evaluation method based on extrapolation is needed to assess the maximum exposure level from 5G NR BS using the Secondary Synchronisation Signal (SSS), Primary Synchronisation Signal (PSS) and Physical Broadcast Channel (PBCH), all of which form the signal SSB. The extrapolation is possible by decoding of the SSS to extrapolate the maximum exposure for each cell ID separately.

5G NR uses beamforming to overcome the path loss at higher frequencies. Intelligent antenna arrays create very narrow but high-gain beams to focus the power on a certain area to increase SINR and received power. This can create field strength hotspots in the very narrow main lobes of the beams. Figure 8 shows the different SSB beams transmitting from the same antenna sector of the 5G NR base stations.

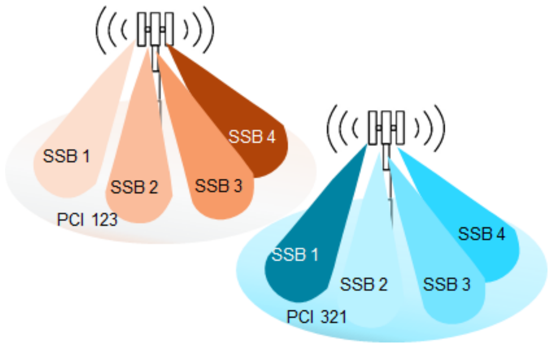


Figure 8. Multiple SSBs beam from same antenna sector

9.2.5 Method of 5G EMF measurement using dedicated 5G NR decoder/scanner

The maximum exposure from the 5G NR BS can be determined by measuring the SSB EMF and extrapolate to full bandwidth and consider the maximum gain as compensation factor. The measurements require that the system bandwidth and centre frequency of the target 5G NR carrier is set. The maximum electric field strength (V m-1), E_{asmt}, is defined by the following equation:

$$E_{asmt} = E_{SSB} \text{ x } \sqrt{F_{extSSB}} = E_{SSB} \text{ x } \sqrt{F_{BW} \times F_{PR} \times F_{TDC}}$$

where,

E_{asmt}	the extrapolated electrical field strength, V m^{-1};
E_{SSB}	the field level, V m^{-1} per RE of the SSB;
F_{TDC}	the technology duty cycle;
F_{PR}	the power reduction if the actual maximum approach is used, otherwise it is set to 1;
F_{BW}	the total number of subcarriers within the carrier bandwidth; and
F_{extSSB}	the extrapolation factor for the SSB.

Figure 9 illustrates the test setup to measure the 5G EMF using a dedicated 5G NR decoder/scanner.

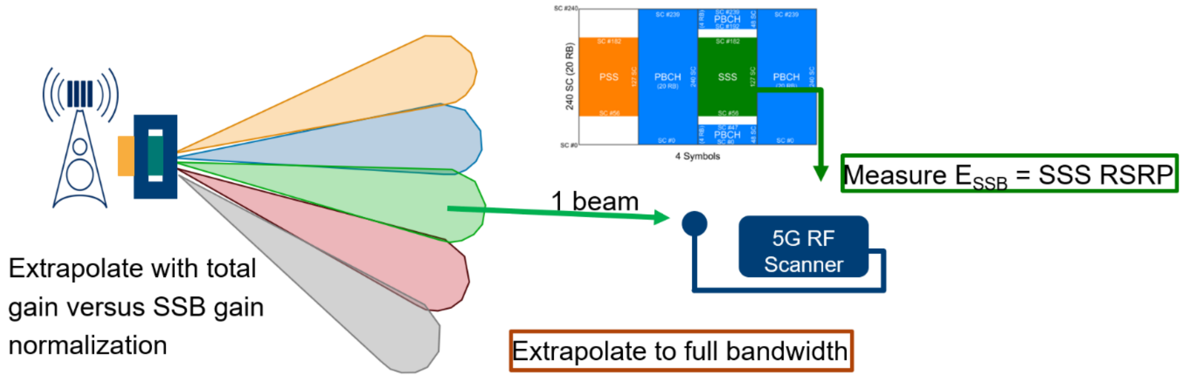


Figure 9. Measurement of the 5G NR base station antenna SSB E-field and the extrapolation method

When the power allocated to any subcarrier is the same, F_{BW} corresponds to the number of resource elements for the system bandwidth of the target BS, the technology duty cycle and a power reduction factor. The extrapolation factor, F_{BW} for each system bandwidth is shown in Table 9 for sub-6 GHz and Table 10 for mm-Wave, assuming that all subcarriers are transmitted with the same power level.

Table 9. F_{BW} for each combination of BS channel bandwidth and SSB Subcarrier Spacing (SCS) for sub 6 GHz signals

SCS (kHZ)	Bandwidth (MHz)												
	5	10	15	20	25	30	40	50	60	70	80	90	100
15	300	624	948	1,272	1,596	1,920	2,592	3,240	N/A	N/A	N/A	N/A	N/A
30	132	288	456	612	780	936	1,272	1,596	1,944	2,268	2,604	2,940	3,276
60	N/A	132	216	288	372	456	612	780	948	1,116	1,284	1,452	1,620

Table 10. F_{BW} for each combination of BS channel bandwidth and SSB subcarrier spacing (SCS) for mm-Wave signals

SCS (kHz)	Bandwidth (MHz)			
	50	100	200	400
60	792	1,584	3,168	N/A
120	384	792	1,584	3,168

In order to distinguish between the contribution of different cells, E_{SSB} should correspond to the field strength per RE of the decoded SSB. Figure 10 shows the setup to measure the total sum of the SSB beams electric field.

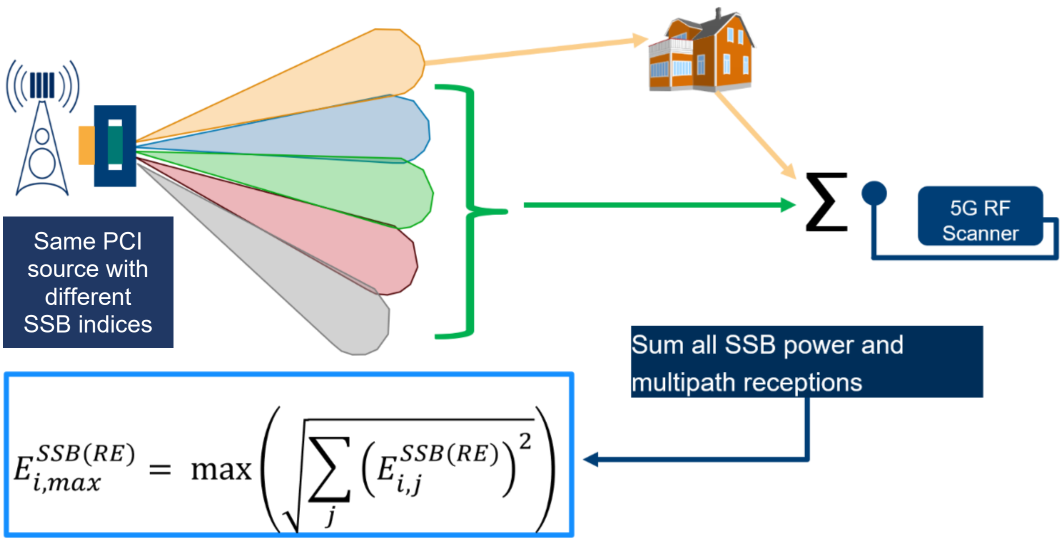


Figure 10. Total sum up measurement for all SSBs beams electric field

In general, the EMF measurement method for 5G NR can be summarised into 5 steps:

a) 5G NR signal scan overview to identify the channels;

b) identification of the reference frequency position of the SSB, which contains the 5G NR always on signals, SCS of the SSB and the channel bandwidth of the signal under test;

c) measurement of the electric field strength per RE of the SSB;

d) measurement of the time averaged instantaneous exposure level; and

e) extrapolation of the electric field strength per RE to the (theoretical) maximum electric field level, based on a fully occupied 5G NR channel.

9.2.6 Massive MIMO beamforming

In 5G, different signals can be transmitted on multiple beams. The power, gain, steering direction, beam shape and polarisation plane of the different beams may vary over time. By measuring the signal SSBs, 2 EIRP envelopes shall be known for implementing the corresponding extrapolation methods. In general, these 2 EIRP envelopes are functions of the azimuth, ϕ and elevation angle, θ and depend on the configuration of the cell:

a) the first EIRP envelope is the EIRP envelope of the SSB. It is defined as the maximum EIRP due to the broadcast signal for all beams which are used to transmit the broadcast signal. For the EIRP envelope of the broadcast signal it is assumed that all resource elements of the complete resource grid transmit the same power as a resource element which is indeed transmitting a part of the broadcast signal; and

b) the second EIRP envelope is the EIRP envelope of all signals. It is defined as the maximum EIRP due to all signals for all beams which may be used to transmit all signal types. This EIRP envelope describes the configured maximum EIRP as a function of the azimuth and elevation angle.

The ratio of the EIRP envelope of all traffic beams to the EIRP envelope of the broadcast signal at a given azimuth and elevation angle is the extrapolation factor $F_{ExtBeam}$ at this azimuth and elevation angle.

From IEC 62232, if azimuth and elevation direction from the BS to the Point of Investigation (POI) is known and the received power of the reflected waves is not dominant, the extrapolation factor for 5G massive MIMO corresponding to the ratio of the EIRP envelope of all traffic beams to the EIRP envelope of the SSB signal ($F_{ExtBeam}$) can be applied as the following:

a) $F_{ExtBeam}$ is selected as the value for that particular azimuth and elevation;

b) for high gradients of $F_{ExtBeam}$ the uncertainty of the current azimuth and elevation position shall be taken into account for the total assessment uncertainty; and

c) if the spatial maximum of the broadcast signal in a certain volume around a nominal azimuth and elevation position is used as the base for the extrapolation process the minimum extrapolation factor $F_{ExtBeam}$ inside this volume should be used to avoid overestimation.

If the radiation pattern of the SSB is different from that of other signals transmitted by the antenna, the extrapolation factor shall take into account for the possible difference in the antenna gain, in order to ensure that maximum possible field strength is obtained. Based on IEC 62232, the maximum electric field strength (V m^{-1}), E_{max}, is defined by equation below.

$$E_{asmt} = E_{SSB} \text{ x } \sqrt{F_{ExtBeam} \times F_{BW} \times F_{PR} \times F_{TDC}}$$

where,

E_{asmt}	the extrapolated E-field strength;
E_{SSB}	the E-field level of the measured SSB beam;
$F_{ExtBeam}$	the extrapolation factor corresponding to the ratio of the EIRP envelope of all traffic beams to the EIRP envelope of the broadcast signal at the direction to the measurement location;
F_{TDC}	the technology duty cycle;

F_{PR} the power reduction if the actual maximum approach is used, otherwise it is set to 1; and

F_{BW} the total number of subcarriers within the carrier bandwidth.

Figure 11 illustrates the test flow to measure the 5G EMF of a massive MIMO 5G NR base station.

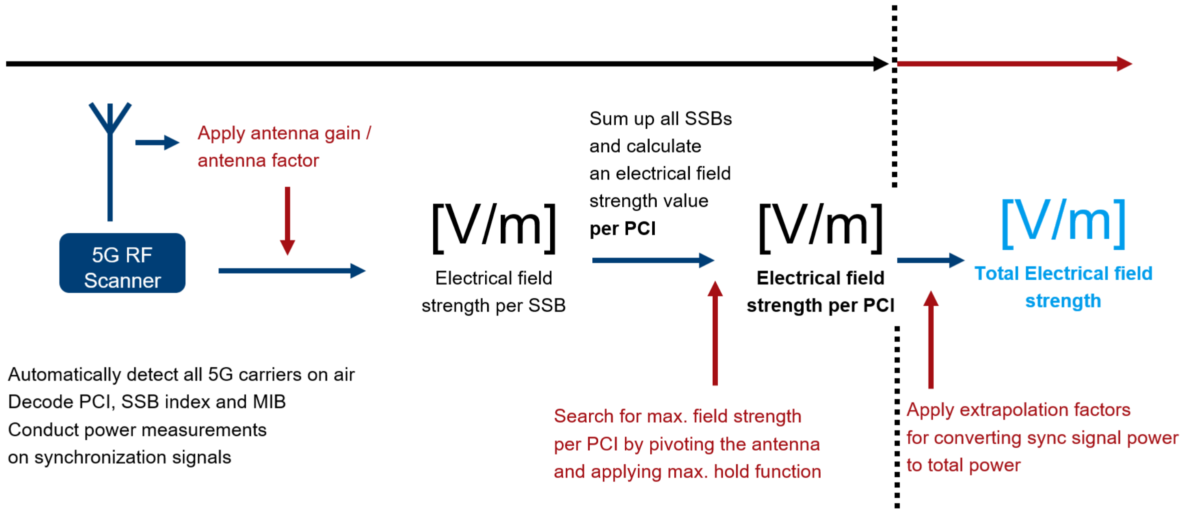


Figure 11. The process flow of the 5G EMF base station measurement and maximum exposure extrapolation with massive MIMO consideration

Annex A
(normative)

Technical requirements in EMF compliance report (simulation)

The following data and technical details should be included in the EMF simulation report:

a) base station information

i) RCI ID;

ii) RCI address;

iii) GPS coordinate;

iv) RCI type (e.g. 3 legged, 4 legged, billboard, minaret, mini monopole for rooftop, monopole/monopole tree, streetlight/lamp pole, wall mounted/tripod for rooftop and water tank);

v) geographical classification (e.g. dense urban/urban/sub-urban/rural);

vi) date of commission;

vii) RCI owner;

viii) RF owner;

ix) service providers;

x) frequency available/maximum limit; and

xi) simulation software.

b) RCI technical parameters

i) RCI height in meter;

ii) electrical tilt and mechanical tilt in degree;

iii) antenna transmit gain in dBi;

iv) antenna vertical bandwidth beam in degree;

v) antenna side lobe attenuation in dB;

vi) antenna type, model and make;

vii) antenna GPS position;

viii) transmitter power output in Watt;

ix) frequency of operation; and

x) system type (e.g. 2G/3G/4G/5G).

c) other technical parameters for uncertainty estimation analysis

   i) cable, connector and combiner loss in dB;

   ii) scattering from nearby objects and ground in dB;

   iii) mismatch between antenna and its feed in dB; and

   iv) antenna radiation pattern data.

d) cut-plane figures as described in Table A.1 and Figure A.1

   i) orthoslice at ground level;

   ii) orthoslice at rooftop level; and

   iii) exclusion zone crossover with adjacent building.

Table A.1. The description of the required cut-plane figures

Cut-plane type	Description
Orthoslice at ground level	Horizontal plane 2 m above ground level in term of power density or emission percentage against exposure limits. Legend with logarithmic rainbow colour scale shall be marked clearly.
Orthoslice at rooftop level (not applicable for tower BS)	Horizontal plane 2 m above rooftop level in term of power density or emission percentage against exposure limits. Legend with logarithmic rainbow colour scale shall be marked clearly.
Exclusion zone crossover with adjacent building:	At antenna height level to analyse the crossover within adjacent nearby building in close vicinity, in term of power density or emission percentage against exposure limits. Legend with logarithmic rainbow colour scale shall be marked clearly.
NOTE: Public, occupational, and exceedance exposure limits shall be marked clearly.	

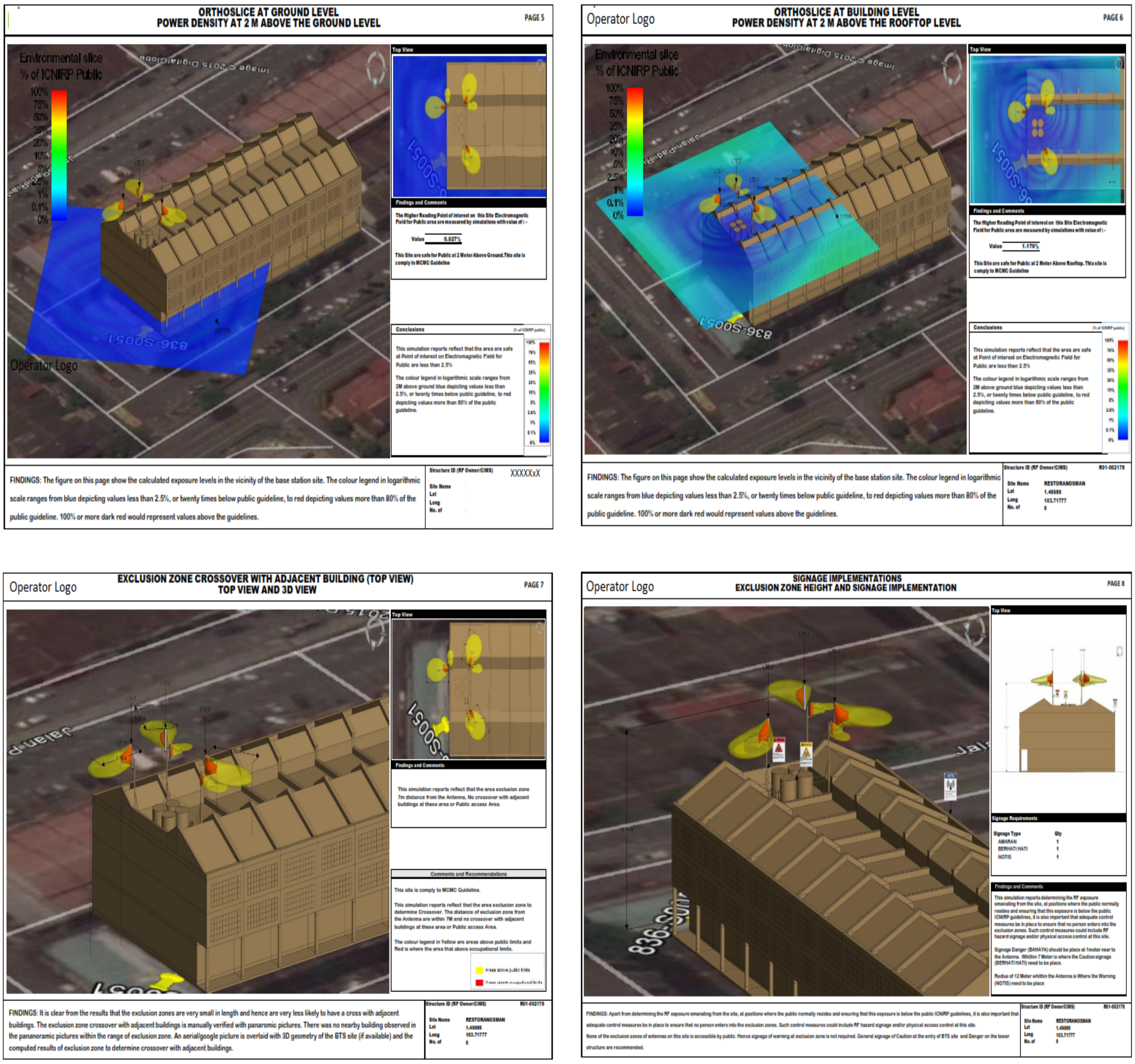


Figure A.1. Orthoslice method

e) simulation software information

i) simulation software's version, model and manufacturer;

ii) simulation software operator's Name and designation; and

iii) date and time of simulation report.

f) blueprint to scale as shown in Figure A.2.

i) simulation must be based on actual size of the building and area;

ii) the actual size of blueprints and aerial pictures in any format (JPEG, PDF, PNG and BMP) must be imported

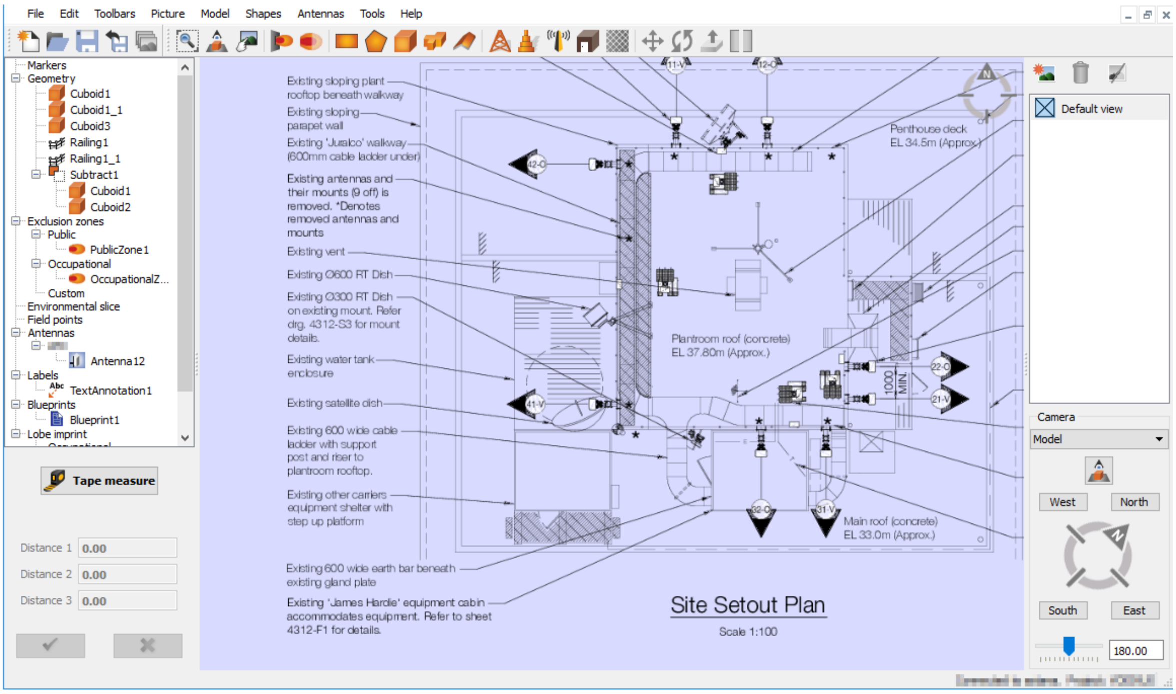


Figure A.2. Blueprint sample

Annex B
(normative)

Technical requirements in EMF compliance report (measurement)

The following data and technical details should be included in the EMF measurement report:

a) base station information

i) RCI ID;

ii) RCI address;

iii) GPS coordinate;

iv) RCI type (e.g. 3 legged, 4 legged, billboard, minaret, mini monopole for rooftop, monopole/monopole tree, streetlight/lamp pole, wall mounted/tripod for rooftop and water tank);

v) geographical classification (e.g. dense urban/urban/sub-urban/rural);

vi) date of commission;

vii) RCI owner;

viii) RF owner;

ix) service providers;

x) frequency available/maximum limit; and

xi) measurement equipment.

b) RCI technical parameters

i) RCI height in meter;

ii) electrical tilt and mechanical tilt in degree;

iii) antenna transmit gain in dBi;

iv) antenna vertical bandwidth beam in degree;

v) antenna side lobe attenuation in dB;

vi) antenna type, model and make;

i) antenna GPS position;

ii) transmitter power output in Watt;

iii) frequency of operation; and

iv) system type (e.g. 2G/3G/4G/5G).

c) measurement assessment

    i) measurement site;

    ii) measurement points; and

    iii) measurement data.

d) measurement equipment information

    i) measurement equipment model and manufacturer;

    ii) frequency range and calibration date;

    iii) measurement equipment operator’s name and designation; and

    iv) date and time of measurement report.

e) extrapolation factor analysis

    i) centre frequency of measured signal [MHz];

    ii) name of service provider;

    iii) limit according to Mandatory Standard for general public;

    iv) measured field strength of BCCH (2G), CPICH (3G) or RS (4G) signals [dBμV/m];

    v) uncertainty value;

    vi) extrapolation factor;

    vii) extrapolated value [dBμV/m];

    viii) conversion of extrapolated value from dBμV/m to V/m;

    ix) percentage of extrapolated value to the limit according to Mandatory Standard;

    x) conversion of extrapolated value from V/m to mW/m^2; and

    xi) summation of all signal values.

f) blueprint to scale as shown in Figure B.2.

    iii) simulation must be based on actual size of the building and area; and

    iv) the actual size of blueprints and aerial pictures in any format (JPEG, PDF, PNG and BMP) must be imported.

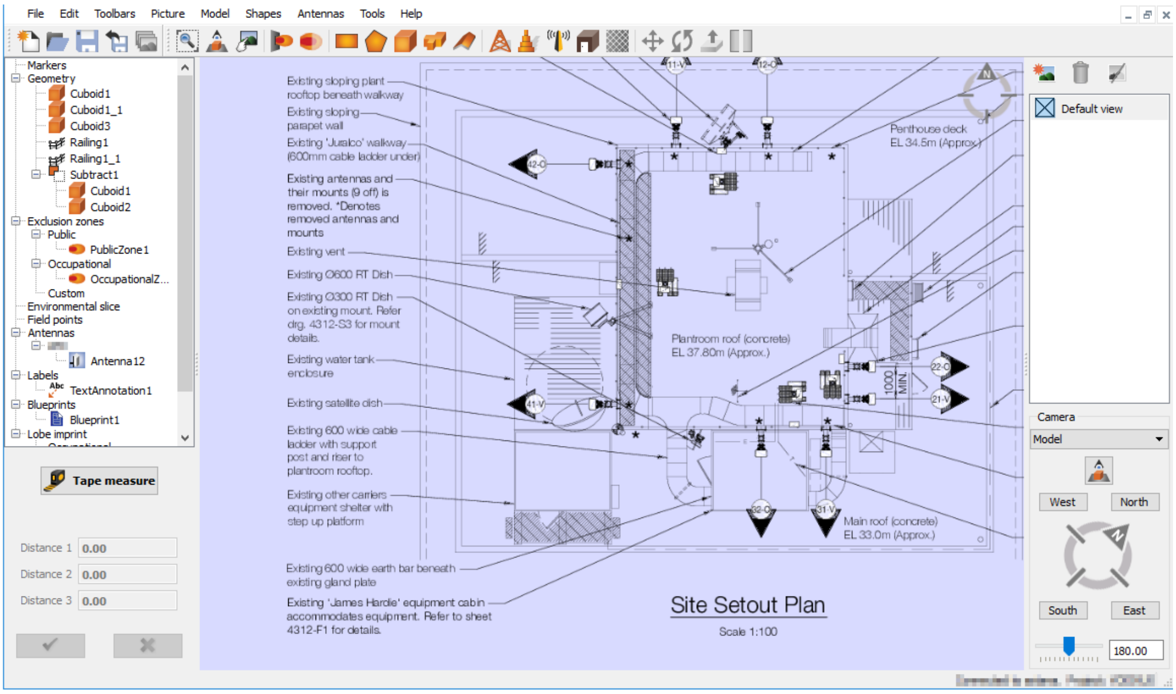


Figure B.2. Blueprint sample

Annex C
(informative)

EMF compliance report (simulation) sample

The EMF compliance report (simulation) sample is as follows.

EMF COMPLIANCE REPORT (SIMULATION)

SAMPLE

Report ID: **R04-000900/S/2021/1**

Compliance Method	Simulation Measurement
RCI ID	R04-000900
RF Owner	Telco A Sdn Bhd
RCI Address	42, Jalan Tun Sri Lanang, Kampung Durian Daun, 75100 Melaka.

RF Owner

Company Logo	Company Name and Address
	Telco A Sdn Bhd, Ground Floor, Block A, Shaftsbury Square, 63000 Cyberjaya, Malaysia.

Revision History

Issue No.	Issue Date	Validation Date	Reason for Amendment
1.0	17 August 2021	25 August 2021	Original

R04-000900/S/2021/1

TABLE OF CONTENT

SAMPLE

R04-000900/S/2021/1

1. EMF SIMULATION REPORT APPROVAL

This radio frequency electromagnetic field (RF EMF) simulation assessment has been performed in accordance with the Malaysian Communications and Multimedia Commission (MCMC) Mandatory Standard for Electromagnetic Field Emission from Radiocommunications Infrastructure ('MS EMF') and Malaysian Technical Standard Forum Bhd. (MTSFB) Technical Codes on EMF ('TC on EMF'):

- MCMC MTSFB TC G032:2021 - Prediction and Measurement of EMF Exposure from Base Station; or
- MCMC MTSFB TC G033:2021 - Prediction and Measurement of EMF Exposure from Terrestrial Radio and Television Broadcast Transmitter Station.

The assessment were conducted based on technical information provided by the client in the Technical Site Survey Report (TSSR) document.

Performed by:

Name	Address
Ultimate Communications Sdn. Bhd.	Unit 543, Jalan 51A/243, 46100 Petaling Jaya, Selangor Darul Ehsan, Malaysia.

Prepared by:

Name & Position	Date	Sign
Mohd Fadli Ahmad System Engineer	10 August 2021	Fadli

[To be completed by personnel who conducted simulation and prepared report]

Approved by:

Name & Position	Date	Sign
Alan Tan Technical Director	10 August 2021	Alan T.

[To be completed by company representative who approved the simulation result]

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SAMPLE

R04-000900/S/2021/1

2. SUMMARY OF SIMULATION ASSESSMENT

[To provide the objective, summarised data and result of compliance to MS EMF based on assessment results and findings.]

The purpose of this assessment was to determine whether the RF EMF strength at this site was in compliance with the MS EMF for the general public. This assessment was done in accordance to the TC on EMF.

The highest RF EMF reading point of interest in public area were simulated with the technical parameters stated in Section 3.

Site Information

Report ID	R04-000900/S/2021/1		
RCI ID / Name	R04-000900 / Durian Daun		
GPS Coordinate	Lat 2.20458°, Long 102.25322°		
RCI Type	Mini Monopole (Rooftop)		
Geographical Classification	Rural		
Date of Commission	10 September 2013		
RCI Owner	Telco A Sdn Bhd		
RF Owner	Telco A Sdn Bhd		
Service Providers	Telco A 900MHz - 2G/3G 1800MHz - 2G	Telco B 1800MHz - 4G 2100MHz - 3G 2600MHz - 4G	Telco C 1800MHz - 4G 2100MHz - 3G 2600MHz - 4G
Frequency Available / Maximum Limit	900MHz/41 Vm^{-1}, 1800MHz/58 Vm^{-1}, 2100MHz/61 Vm^{-1}		
Simulation Software	IXUS EMF Compliance Software		

Simulation Result (Orthoslice) Power Density:

Level	Simulation Value		Compliance Status
2m above ground	6.57%	2.69 V/m	PASS
2m above rooftop	57.49%	23.57 V/m	PASS

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SAMPLE

R04-000900/S/2021/1

The simulation result at 2m above ground indicated that the highest point for RF EMF emission at public area was 2.69V/m or at 6.57% of the limit.

In comparison to the allowable exposure limit of 41V/m, this *value was well below the exposure limits* recommended by the MS EMF for the general public.

The actual RF EMF exposure levels will generally be significantly less than the simulated values, due to automatic power control used by cellular base stations as well as reduction in exposure levels due to environmental factors such as the presence of buildings, trees and other objects. The simulated values were aimed towards the analytic of **worst-case scenario** for the peak traffic conditions.

RESULT OF ASSESSMENT	**2.69V/m , 6.57%**
COMPLIANCE TO MS EMF	**PASS**

SAMPLE

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3. TECHNICAL REQUIREMENTS

[Refer to TC on EMF for the technical requirements for simulation. Include the data for all service providers at the same site.]

3.1 TECHNICAL PARAMETERS

ITEM	UNITS	TELCO A			TELCO A			TELCO A		
BUILDING HEIGHT AGL	(m)	22	22	22	22	22	22	22	22	22
RCI HEIGHT (GBT) AGL	(m)	7	7	7	7	7	7	7	7	7
RTT / GBT		Rooftop			Rooftop			Rooftop		
ANTENNA HEIGHT AGL	(m)	27	27	27	27	27	27	27	27	27
SYSTEM TYPE		3G	3G	3G	2G	2G	2G	2G	2G	2G
FREQUENCY OF OPERATION	(MHz)	900			1800			900		
MAKE AND MODEL OF ANTENNA	Ant-1	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
	Ant-2	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
	Ant-3	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
ANTENNA GAIN	(dBi)	2	2	2	2	2	2	2	2	2
ELECTRICAL TILT	(Deg)	7	7	7	7	7	7	7	7	7
MECHANICAL / TOTAL TILT	(Deg)	3	3	3	3	3	3	3	3	3
AZIMUTH	(Deg)	120	230	320	120	230	320	120	230	320
TX POWER	(Watts)	80	80	80	80	80	80	80	80	80

SAMPLE

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ITEM	UNITS	TELCO B			TELCO B			TELCO B		
BUILDING HEIGHT AGL	(m)	22	22	22	22	22	22	22	22	22
RCI HEIGHT (GBT) AGL	(m)	7	7	7	7	7	7	7	7	7
RTT / GBT		Rooftop			Rooftop			Rooftop		
ANTENNA HEIGHT AGL	(m)	27	27	27	27	27	27	27	27	27
SYSTEM TYPE		LTE	LTE	LTE	LTE	LTE	LTE	3G	3G	3G
FREQUENCY OF OPERATION	(MHz)	2600			1800			2100		
MAKE AND MODEL OF ANTENNA	Ant-1	Agisson ATR451607			Agisson ATR451606			Agisson ATR451607		
	Ant-2	Agisson ATR451607			Agisson ATR451606			Agisson ATR451607		
	Ant-3	Agisson ATR451607			Agisson ATR451606			Agisson ATR451607		
ANTENNA GAIN	(dBi)	3	3	3	3	3	3	3	3	3
ELECTRICAL TILT	(Deg)	7	7	7	7	7	7	7	7	7
MECHANICAL / TOTAL TILT	(Deg)	3	3	3	3	3	3	3	3	3
AZIMUTH	(Deg)	120	230	320	120	230	320	120	230	320
TX POWER	(Watts)	80	80	80	80	80	80	80	80	80

ITEM	UNITS	TELCO C			TELCO C			TELCO C		
BUILDING HEIGHT AGL	(m)	22	22	22	22	22	22	22	22	22
RCI HEIGHT (GBT) AGL	(m)	7	7	7	7	7	7	7	7	7
RTT / GBT		Rooftop			Rooftop			Rooftop		
ANTENNA HEIGHT AGL	(m)	27	27	27	27	27	27	27	27	27
SYSTEM TYPE		LTE	LTE	LTE	LTE	LTE	LTE	3G	3G	3G
FREQUENCY OF OPERATION	(MHz)	2600			1800			2100		
MAKE AND MODEL OF ANTENNA	Ant-1	Agisson ATR451607			Agisson ATR451606			Agisson ATR451607		
	Ant-2	Agisson ATR451607			Agisson ATR451606			Agisson ATR451607		
	Ant-3	Agisson ATR451607			Agisson ATR451606			Agisson ATR451607		
ANTENNA GAIN	(dBi)	3	3	3	3	3	3	3	3	3
ELECTRICAL TILT	(Deg)	7	7	7	7	7	7	7	7	7
MECHANICAL / TOTAL TILT	(Deg)	3	3	3	3	3	3	3	3	3
AZIMUTH	(Deg)	120	230	320	120	230	320	120	230	320
TX POWER	(Watts)	80	80	80	80	80	80	80	80	80

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SAMPLE

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3.2 BLUEPRINT TO SCALE

[To provide the actual size of blueprints of the structure and aerial pictures of site in any format (JPEG, PDF, PNG and BMP).]

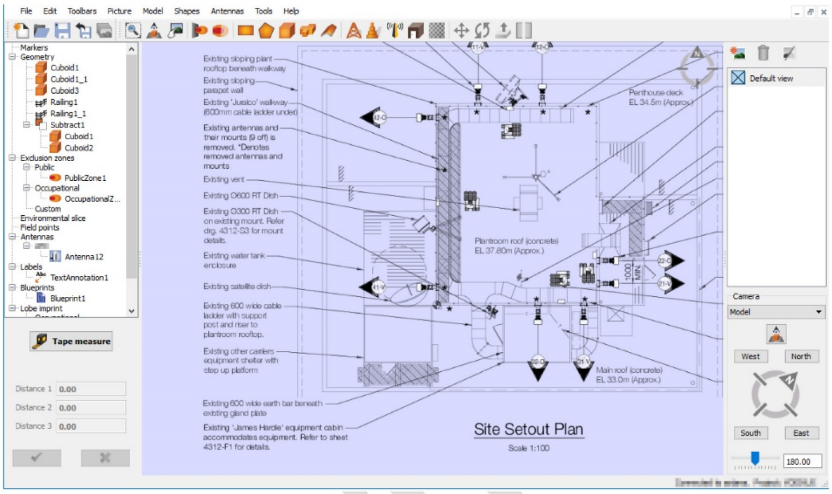

Figure 1: Blueprint of Structure

The site is located at **LAT 2.20458° LONG 102.25322°** shown in Figure 2.

Figure 2: Site location (Top View)

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4. UNCERTAINTY ESTIMATION ANALYSIS

[To identify all sources of uncertainty that may reasonably be expected to cause significant variation or uncertainty in the evaluation. Refer to TC on EMF. Table below is a sample template.]

Source of uncertainty	Unit	Prob. distrib. type	Uncertainty or semi span a	Divisor d	Sens. couff. c	Standard uncertainty $u=a/d$	Corr. fact t	c^2u^2
System								
Variation in the power of the RF transmitter from its nominal level	dB	rect.			1			
Cable/connector losses	dB	normal			1			
Mismatch between antenna and its feed	dB	U			1			
Antenna radiation pattern data (NOTE 2)	dB	normal			1			
Antenna positioning, mounting & support structure	dB	rect.			1			
Technique Uncertainties								
Inherent uncertainties associated with the approximate numerical model used to represent the antenna	dB	rect.			1			
Null-filling of antenna patterns (if applied)	dB	Depends on algoritm			1			
Environmental Uncertainties								
Scattering from nearby objects and the ground	dB	rect.			1			
Uncertainty in using electric field strength evaluations to estimate magnetic field strength or vice versa	dB	rect.			1			
Combined correction factor, $t_C = \sum_{i=1}^{N} t_i$								N/A
Combined standard uncertainty, $u_C = \sqrt{\sum_{i=1}^{N} (c_i^2 u_i^2)}$								
Expanded uncertainty, $U=k \times u_C$								

Note 1: The value of divisor d for normal probability distribution is for 95% confidence.

Note 2: The normalized radiation pattern uncertainty can be different inside the HPBW (very small); outside the main beam (larger); and in the side lobes.

SAMPLE

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5. SIMULATION ASSESSMENT

[Refer to Section 8 in TC on EMF for the simulation assessment methodology.]

5.1 SIMULATION RESULT OF ORTHOSLICE AT 2M ABOVE GROUND LEVEL (3D ELEVATION)

[To provide simulation data on whether the area is safe in Places of Interest in the Electromagnetic Field for General Public at 2m above ground level and the radiation emitted to the adjacent building, if any. Examples below in Figures 3-5.]

In this section, orthoslice at 2m above ground level were simulated.

i. Figures 3 and 4 showed the simulation data that reflected the area is safe in Places of Interest in the Electromagnetic Field for General Public. The simulation value with the highest point is 6.57% of the limit for public.

Description	Value %	Value V/m
The highest point of 2 meter above ground level	6.57	2.69

ii. Figure 5 is the top view simulation, showing no radiation emitted to the adjacent building.

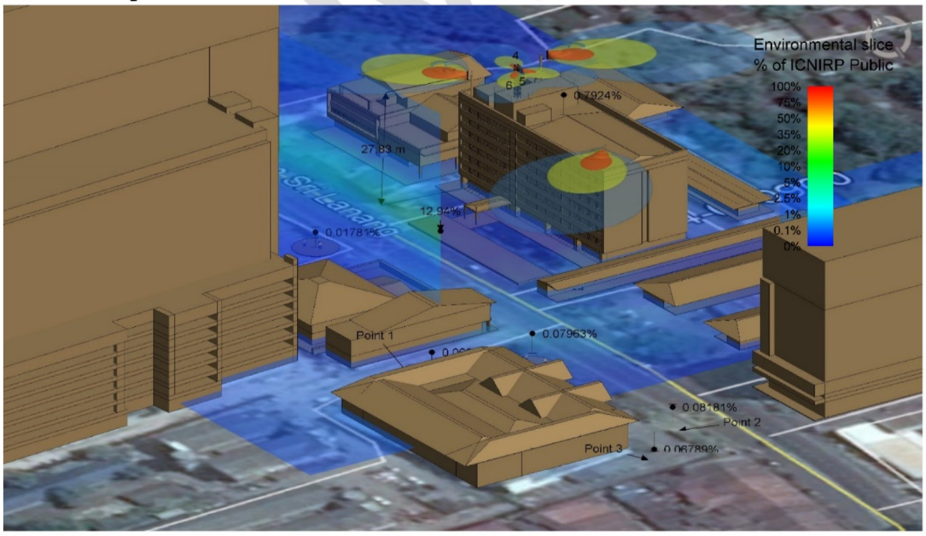

Figure 3: Power density at 2m above the ground level (3D Overview North or South View Elevation)

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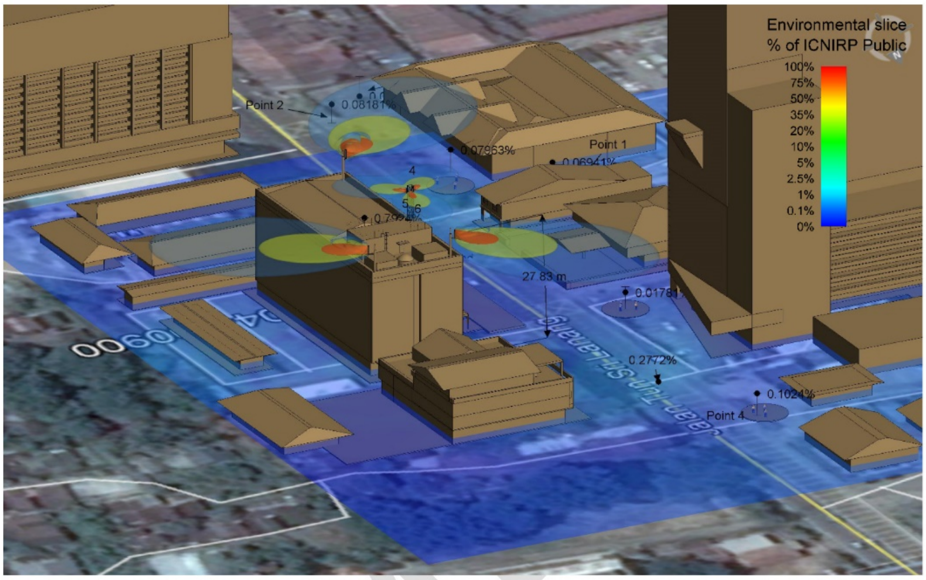

Figure 4: Power density at 2m above the ground level (3D Overview Top View Elevation)

Figure 5: Power density at 2m above the ground level (Top View 2D Elevation)

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5.2 SIMULATION RESULT OF ORTHOSLICE AT 2M ABOVE ROOF TOP (3D ELEVATION)

[To provide simulation data on whether the area is safe in Places of Interest in the Electromagnetic Field for General Public at 2m above roof top level and the radiation emitted to the adjacent building, if any. Examples below in Figures 6-8.]

In this section, orthoslice at 2 meters above roof top level were simulated.

i. Figures 6 and 7 showed that the highest simulated emission reading was 57.49% of the limit. The exposure rate was still below the permissible limit for public, but it was recommended that only qualified workers were allowed to enter the building's roof top.

ii. Figure 8 showed the simulation for the top view of the radiation exposure to several adjacent buildings.

Description	Value %	Value V/m
The highest point of 2 meter above roof top	57.49	23.57

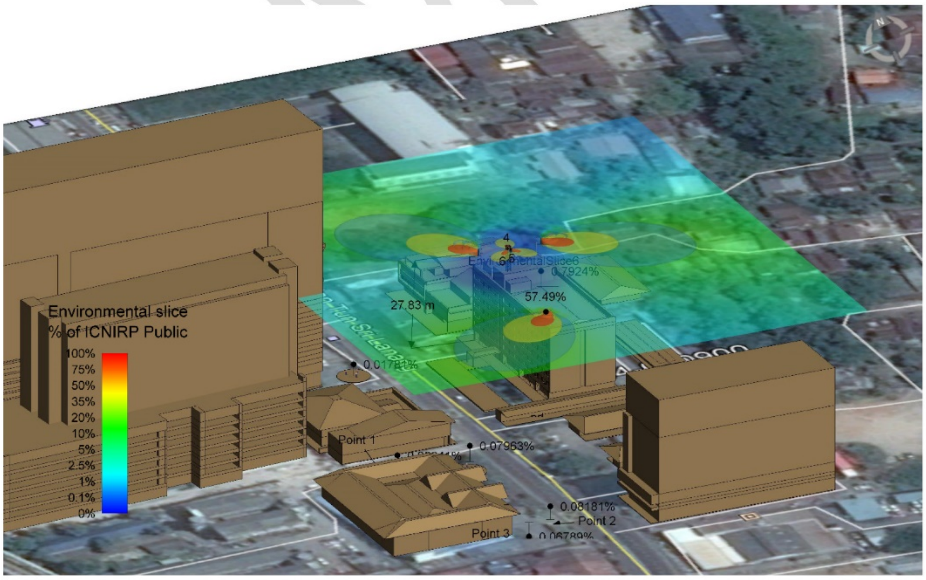

Figure 6: Orthoslice at 2m above roof top (North 3D View Elevation)

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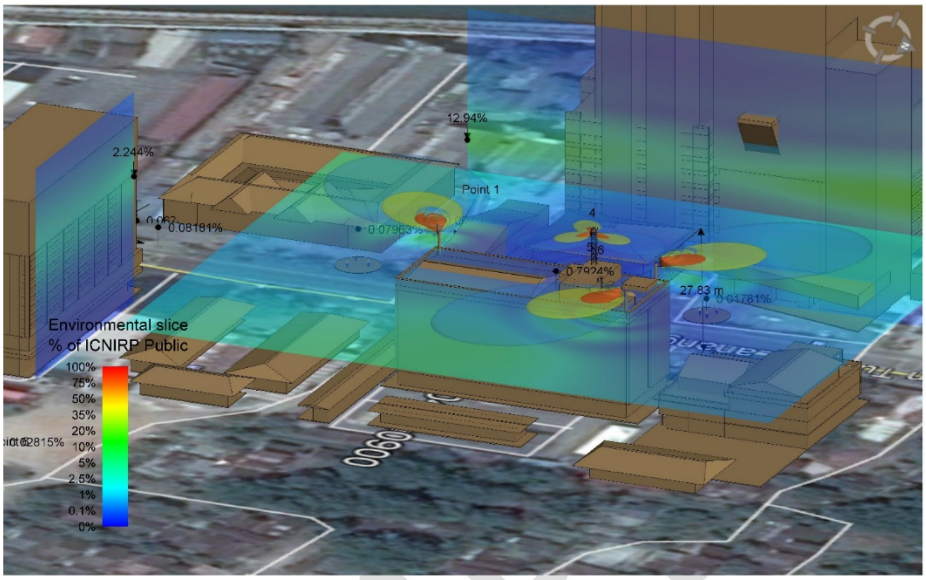

Figure 7: Orthoslice vertical & horizontal at 2m above roof top (South 3D View Elevation)

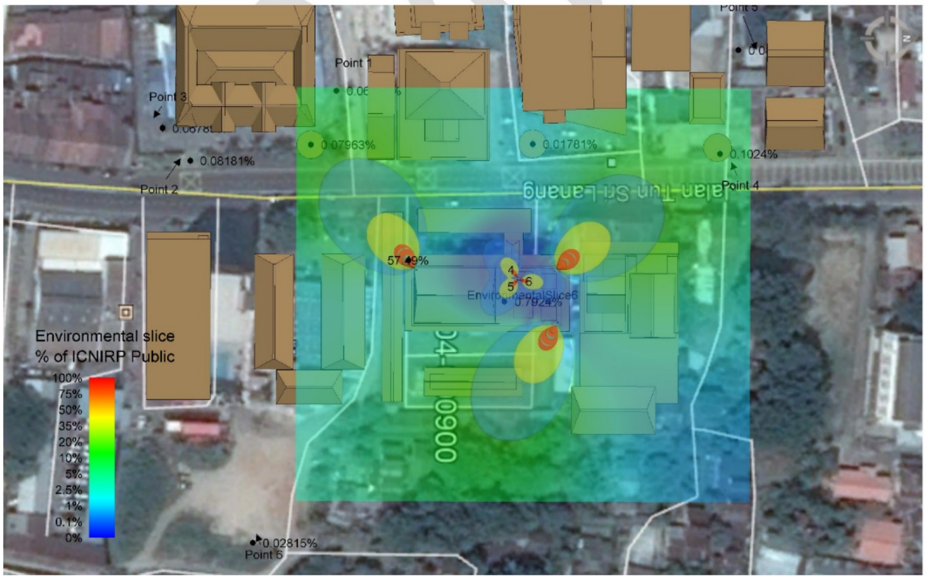

Figure 8: Power density at 2m above roof top (Top View)

5.3 SIMULATION RESULT OF EXCLUSION ZONE WITH ADJACENT BUILDING (3D ELEVATION)

[To provide simulation and lope imprint data on the exclusion zone with adjacent buildings (3D Elevations) below antenna, including the distance (meter) for Near Field and Far Field. Refer to Section 7 in TC on EMF. Examples below in Figures 9-11.]

Near Fields (Fresnel) Exclusion Zone		Far Fields Region (Fraunhofer)
Reactive Region	Radiation Region	
9.52 meters	22.89 meters	Above 23 meter

i. In Figures 9 and 10, the simulated data showed the distance of 2 regions, near field and far fields between the antennas to the adjacent Building. The simulated distance were 23 meters Near Field consist of Reactive & Radiating Region (Near Field) where the distance setting of this antenna beam should not be facing towards adjacent buildings within **23 meters.**

ii. Figure 11 is a top view simulated data showing the Far Field distances of the antennas to the adjacent building. Far Fields distance started from 23 meters from the antenna.

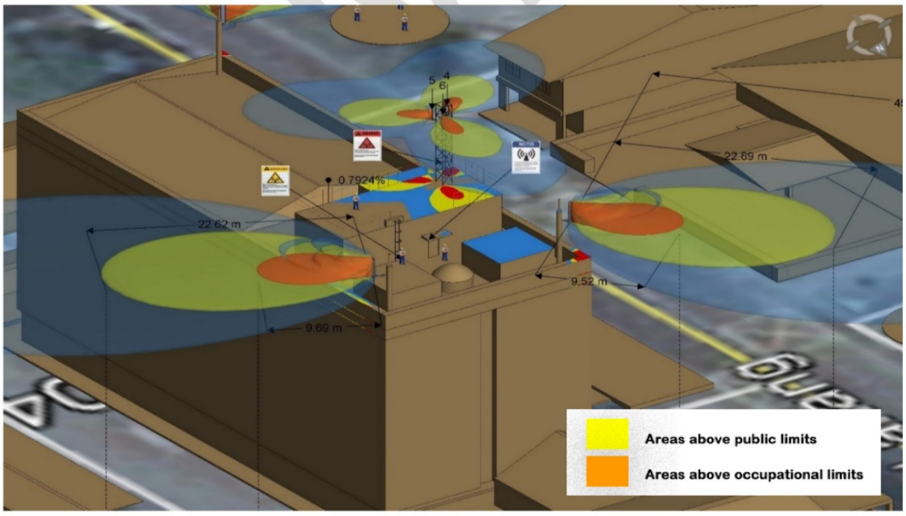

Figure 9: Zoom in view on the exclusion zone lope imprint the limit for public and occupational in 3d elevations for tower/rooftop/dual-function

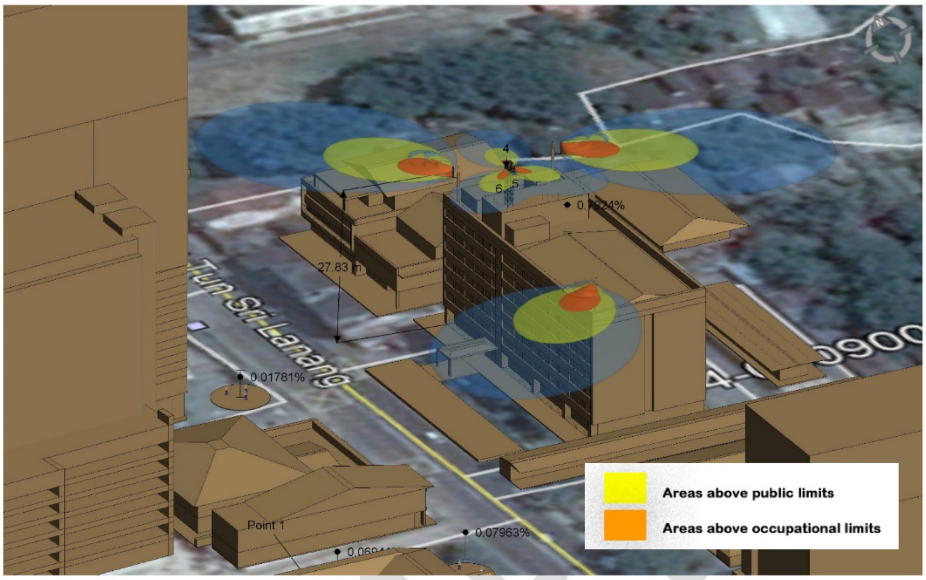

Figure 10: Exclusion zone with adjacent building near fields and far fields (3D View Elevation)

Figure 11: Exclusion zone with adjacent building near fields and far fields (2D Top View)

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5.4 SIMULATION RESULT FOR SIGNAGE PLACEMENTS

[To provide simulation on the placement of 3 types of signage, including the distance (meter). Refer to Section 7 in TC on EMF. Examples below in Figures 12 and 13.]

Base on the simulated data, there should be 3 types of signage to be displayed at designated area as shown in Figures 12 and 13.

Signage Type	Description	Distance from the Antenna
WARNING	Near Field-Reactive Region	6 meters from the antenna
CAUTION	Near Field - Radiating Region	22.62 meters from the antenna
NOTICE	Far field	Signage must be placed at the entrance on the Base station area.

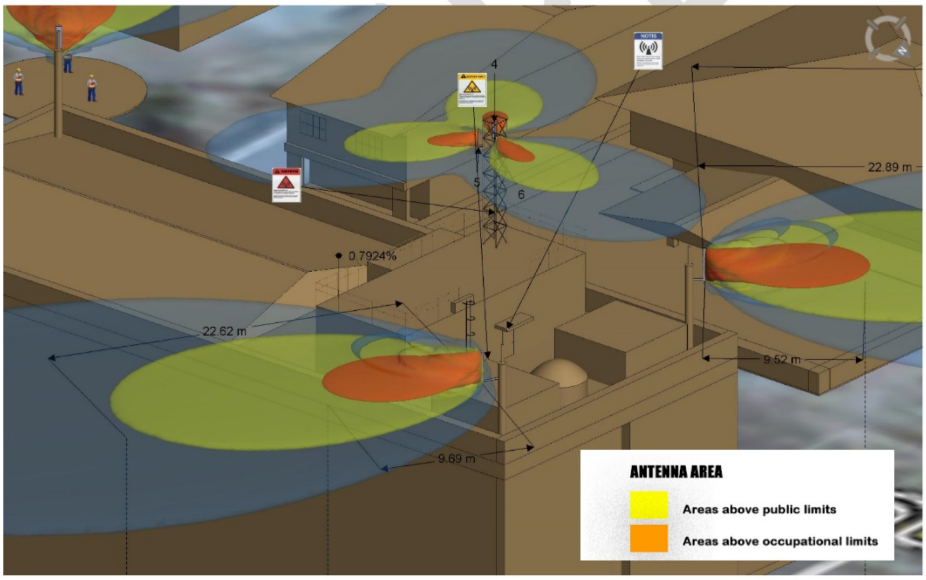

Figure 12: Zoom in View on the Exclusion Zone for Signage placement in 3D Elevations

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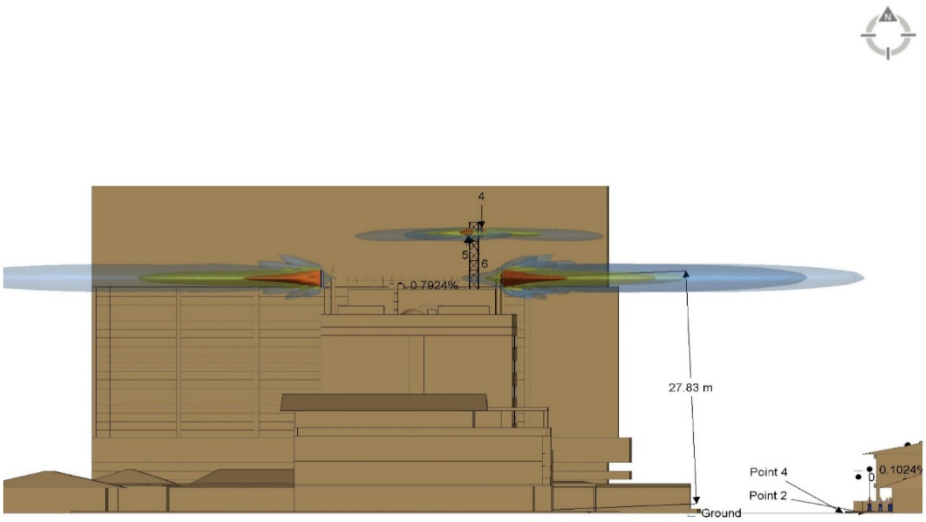


Figure 13: Signage placement in side view Elevations

5.5 SIMULATION SOFTWARE

[To provide information on the software used for this simulation.]

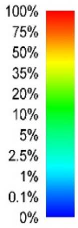
Model & Version	IXUS EMF Compliance Software
Manufacturer	Alphawave Mobile Network Products
Operator Name & Designation	Mohd Fadli Ahmad, System Engineer
Simulation Date / Time	10 August 2021 / 3.40 PM

The algorithms implemented and used in IXUS are an implementation of the ray tracing synthetic model as detailed in ITU-T K.61, CENELEC 50383, and IEC62232.

Numerical modelling assessments in IXUS Modeller include the combined exposure from multi-band and multi-operator transmissions as specified in the EU directive. IXUS Modeller calculates the occupational and public exclusion zones established by ICNIRP.

SAMPLE

6. CONCLUSION

Environmental Slice % of MS EMF Exposure Limit for Public 	The scale for Environmental Slice % of MS EMF Exposure Limit for Public describes the value of the simulation performed, where 100% is the value of a predefined standard level of MS EMF. Exposure limit used for this simulation was **41 V/m**. **Current Value of Simulated Data:** 2m above ground = **2.69 V/m (6.57%)** The simulated value was less than 7%, and referring to the scale it was in the green area. 2m above rooftop = **23.57 V/m (57.49%)** The simulated value was less than 60%, and referring to the scale it was in the orange area. The exposure rate is still below the permissible limit for public. However, due to the high value, it was recommended that area on the building's roof top is not safe for the public and only qualified workers were allowed to enter.

In conclusion, the simulation assessment has confirmed that the electric field strength simulated at this site was well below the RF EMF exposure limits recommended by the MS EMF for the general public.

This was in compliance with MS EMF exposure for the general public.

Based on the findings of the simulated data, we strongly believe that the presence of the RF EMF emitted by the antennas installed on the telecommunication structure at this site, with its current load and the background condition, would not lead to any significant radiation exposure received by members of the public living or working in this area.

SAMPLE

R04-000900/S/2021/1

7. CERTIFICATE OF COMPLIANCE

KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI

NUKLEAR MALAYSIA

MALAYSIAN NUCLEAR AGENCY (NUKLEAR MALAYSIA)
Ministry of Science, Technology and Innovation
Bangi, 43000 Kajang, Selangor

Certificate of Radio Frequency (RF) Radiation Safety Assessment
[Certificate Reference Number : CISSPT_XXXX]

Title	EMF SIMULATION AND ASSESSMENT
Conducted by	EMF SIMULATION SDN BHD
Location	42, Jalan Tun Sri Lanang, Kampung Durian Daun, 75100 Melaka.
Coordinate	L[illegible] 2.20458 [illegible] [illegible]02.253[illegible]
Simulation Date	10^{th} Aug 2021
Report number	R04-000900/S/2021/1
Results	PASS

SAMPLE

Field strength / Measurement range	Highest RF radiation level ($\mu W/cm^2$)	Permissible exposure limit ($\mu W/cm^2$)	Comparison with permissible exposure limit (%) *
Broadband (100kHz – 6 GHz)			

Malaysian Communications And Multimedia Commission (MCMC) Mandatory Standard for Electromagnetic Field Emission from Radiocommunications Instructructure, Determination No 1 of 2010 (Communication and Multimedia Act 1998)
International Commission on Non Ionising Radiation Protection (ICNIRP)

The Radio Frequency (RF) radiation emitted from the antenna(s) of this telecommunication structure complies with the permissible exposure limits issued by the MCMC and ICNIRP.
The results are valid only to the current specification and configuration of the antenna(s).
Reassessment will be required if there are any changes to the current antenna(s) structure.

Verified by:

....

Radiation Health and Safety Division.
Malaysian Nuclear Agency (Nuklear Malaysia)

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Annex D
(informative)

EMF compliance report (measurement) sample

The EMF compliance report (measurement) sample is as follows.

EMF COMPLIANCE REPORT (MEASUREMENT)

SAMPLE

Report ID: **D14-005660/M/2021/1**

Compliance Method	On-site Measurement
RCI ID	D14-005660
RF Owner	Telco A Sdn Bhd
RCI Address	Lot 13270, Jalan Segambut, Mukim Batu, Kuala Lumpur, Malaysia.

RF Owner

Company Logo	Company Name and Address
	Telco A Sdn Bhd, Ground Floor, Block A, Shaftsbury Square, 63000 Cyberjaya, Malaysia.

Revision History

Issue No.	Issue Date	Validation Date	Reason for Amendment
1.0	17 August 2021	25 August 2021	Original

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D14-005660/M/2021/1

1. EMF MEASUREMENT REPORT APPROVAL

This radio frequency electromagnetic field (RF EMF) measurement assessment has been performed in accordance with the Malaysian Communications and Multimedia Commission (MCMC) Mandatory Standard for Electromagnetic Field Emission from Radiocommunications Infrastructure ('MS EMF') and Malaysian Technical Standard Forum Bhd. (MTSFB) Technical Codes on EMF ('TC on EMF'):

- MCMC MTSFB TC G032:2021 - Prediction and Measurement of EMF Exposure from Base Station; or
- MCMC MTSFB TC G033:2021 - Prediction and Measurement of EMF Exposure from Terrestrial Radio and Television Broadcast Transmitter Station.

The assessment were conducted based on technical information provided by the client in the Technical Site Survey Report (TSSR) document.

Performed by:

Company Name	Address
Ultimate Communications Sdn. Bhd.	Unit 543, Jalan 51A/243, 46100 Petaling Jaya, Selangor Darul Ehsan, Malaysia.

Prepared by:

Name & Position	Date	Signature
Ahmad Shahir System Engineer	10 August 2021	A Shahir

[To be completed by personnel who conducted simulation and prepared report.]

Approved by:

Name & Position	Date	Signature
Alan Tan Manager	17 August 2021	Alan T.

[To be completed by company representative who approved the measurement result.]

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2. SUMMARY OF MEASUREMENT ASSESSMENT

[To provide the objective, summarised data and result of compliance to MS EMF based on assessment results and findings.]

The purpose of this assessment was to determine whether the electromagnetic field strength at this site was in compliance with the MS EMF for the general public. This assessment was done in accordance to the TC on EMF.

The scope of this assessment covers the on-site measurement of electromagnetic fields emitted by radiation sources in the 900 MHz – 2.6 GHz frequencies used by mobile service providers in Malaysia. The site under assessment is shown below.

Site Information

Report ID	D14-005660/M/2021/1	
RCI ID / Name	D14-005660 / Jalan Segambut	
GPS Coordinate	Lat 3.18484414°, Long 101.6691854°	
RCI Type	Lamp Pole	
Geographical Classification	Urban	
Date of Commission	10 September 2017	
RCI Owner	Telco A Sdn. Bhd.	
RF Owner	Telco A Sdn. Bhd.	
Service Providers	Telco A 900MHz - 2G/4G 1800MHz - 4G	Telco B 900MHz - 2G/4G 1800MHz - 4G
Frequency Available / Maximum Limit	900MHz/41 Vm^{-1}, 1800MHz/58 Vm^{-1}	
Measurement Equipment	Narda SRM-3006, Antenna-3502/01	

A total of 5 test points were selected for assessment in the areas surrounding the antenna structure. Based on measured data obtained during this assessment, the electrical field strength was found to be *well below the EMF exposure limits of 41V/m*. This is in compliance with MS EMF on EMF exposure for the general public.

RESULT OF ASSESSMENT	**3.04V/m , 7.34%**
COMPLIANCE TO MS EMF	**PASS**

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3. TECHNICAL REQUIREMENTS

[Refer to TC on EMF for the technical requirements for measurement. Include the data for all service providers at the same site.]

3.1 TECHNICAL PARAMETERS

ITEM	UNITS	TELCO A			TELCO A			TELCO A		
BUILDING HEIGHT AGL	(m)	22	22	22	22	22	22	22	22	22
RCI HEIGHT (GBT) AGL	(m)	7	7	7	7	7	7	7	7	7
RTT / GBT		Lamp Pole			Lamp Pole			Lamp Pole		
ANTENNA HEIGHT AGL	(m)	27	27	27	27	27	27	27	27	27
SYSTEM TYPE		4G	4G	4G	4G	4G	4G	2G	2G	2G
FREQUENCY OF OPERATION	(MHz)	900			1800			900		
MAKE AND MODEL OF ANTENNA	Ant-1	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
	Ant-2	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
	Ant-3	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
ANTENNA GAIN	(dBi)	2	2	2	2	2	2	2	2	2
ELECTRICAL TILT	(Deg)	7	7	7	7	7	7	7	7	7
MECHANICAL / TOTAL TILT	(Deg)	3	3	3	3	3	3	3	3	3
AZIMUTH	(Deg)	120	230	320	120	230	320	120	230	320
TX POWER	(Watts)	80	80	80	80	80	80	80	80	80

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ITEM	UNITS	TELCO B			TELCO B			TELCO B		
BUILDING HEIGHT AGL	(m)	22	22	22	22	22	22	22	22	22
RCI HEIGHT (GBT) AGL	(m)	7	7	7	7	7	7	7	7	7
RTT / GBT		Lamp Pole			Lamp Pole			Lamp Pole		
ANTENNA HEIGHT AGL	(m)	27	27	27	27	27	27	27	27	27
SYSTEM TYPE		4G	4G	4G	4G	4G	4G	2G	2G	2G
FREQUENCY OF OPERATION	(MHz)	900			1800			900		
MAKE AND MODEL OF ANTENNA	Ant-1	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
	Ant-2	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
	Ant-3	Agisson ATR451606			Agisson ATR451606			Agisson ATR451606		
ANTENNA GAIN	(dBi)	2	2	2	2	2	2	2	2	2
ELECTRICAL TILT	(Deg)	7	7	7	7	7	7	7	7	7
MECHANICAL / TOTAL TILT	(Deg)	3	3	3	3	3	3	3	3	3
AZIMUTH	(Deg)	120	230	320	120	230	320	120	230	320
TX POWER	(Watts)	80	80	80	80	80	80	80	80	80

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3.2 BLUEPRINT TO SCALE

[To provide the actual size of blueprints and aerial pictures in any format (JPEG, PDF, PNG and BMP).]

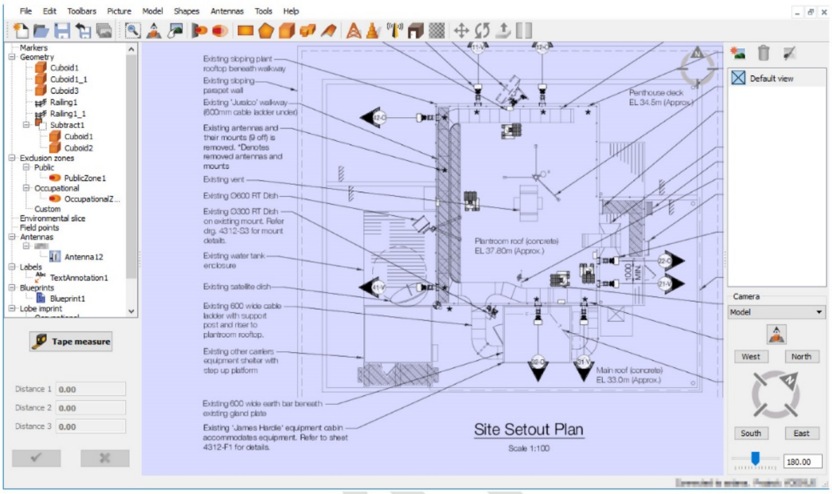

Figure 1: Blueprint of Structure

The site is located at **LAT 3.18484414°, LONG 101.6691854°** shown in Figure 12.

Figure 2: Site location (Top View)

4 MEASUREMENT ASSESSMENT

[Refer to Section 9 in TC on EMF for the measurement assessment methodology]

4.1 MEASUREMENT SITE

[To provide details on measurement site. Example below in Figure 3.]

The site involved in this assessment was located at Lot 13720, Jalan Segambut, Mukim Batu, Kuala Lumpur, next to Condominium Savio at Ria Dutamas in the middle of a busy area with combination of residential, shops and school.

The Structure ID for this structure was D14-005660.

The radiation source for this assessment were the telecommunication antennas installed on a lamp pole structure as shown in Figure 1 below.

Figure 3: Measurement Site Picture and Radiation Source.

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4.2 MEASUREMENT POINTS

[To provide the details on measurement points. The number of measurement points depends on the location selected and shall be based on the worst-case situation (nearest accessible location facing the antenna beam and public area). Recommended measurement points were 5 or more. Examples below in Figures 4 and 5.]

A total of 5 test points were selected for measurements. They were all outdoor locations in areas surrounding the antenna structure where the public go about their daily lives, such as schools, shop lots, residential homes, pedestrian bridge, and etc. Refer to Figure 4 below.

Figure 4: Measurement Points

Test Points	Coordinates (Lat, Long)	Location	Level
1 – S01	3.184417, 101.669354	Residential - Behind Savio Condo	Ground
2 – S02	3.1851267, 101.6695605	Shoplot - Ho Leong Tractor	Ground
3 – S03	3.185563, 101.669029	Shoplot - Home Deco	Ground
4 – S04	3.185437, 101.669582	School - SRJK Khai Chee	Ground
5 – S05	3.185370, 101.669711	Pedestrian Crossing - Jejantas	Ground

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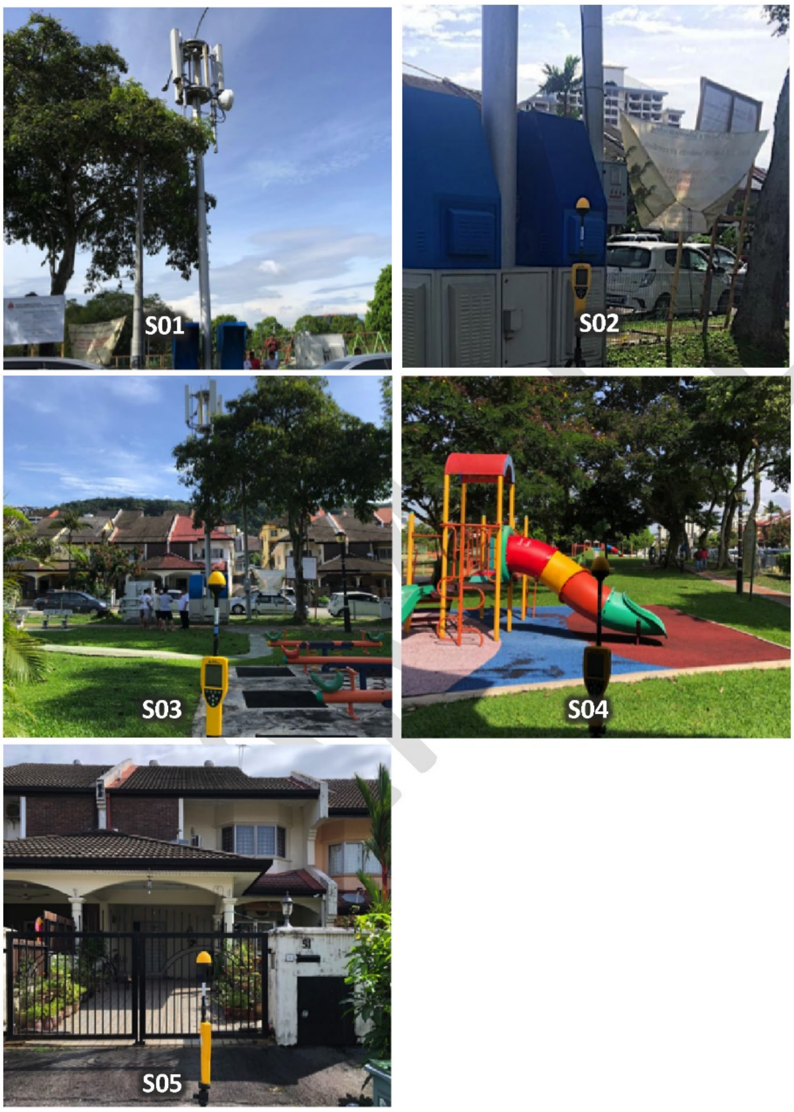

Figure 5: Site Pictures of Measurement Points

4.3 MEASUREMENT DATA

[To provide details on the results and findings of measurement assessment. Example below in Table 1.]

During assessment, the electric field (E) at each test point was measured, recorded and compared to the worst case MS EMF limit of 41V/m as the Pass/Fail Criteria for the general public.

Table 1 below showed a summary of Electric Field Exposure Levels measured relative to the MS EMF safety limit for the general public.

Test Points	Electric Field (V/m)	ICNIRP Limit (V/m)	Percent Of Limit (%)	Result
1 – S01	1.24	41	3.02	Pass
2 – S02	2.07	41	5.04	Pass
3 – S03	0.93	41	2.27	Pass
4 – S04	2.25	41	5.49	Pass
5 – S05	**3.01**	**41**	**7.34**	**Pass**

Table 1: Summary of Electric Field Levels (V/m) Measured On-site.

The highest Electric Field measured in this assessment was found to be at **Test Point S05**, **showing 3.01V/m or 7.34% of the limit.**

In comparison to the allowable exposure limit of 41V/m, this *value was well below the exposure limits* recommended by the MS EMF for the general public.

4.4 MEASUREMENT EQUIPMENT

[To provide details on the equipment used for measurement assessment; including model, frequency range and calibration information. Examples below in Table 2 and Figure 6.]

Measurements were taken using calibrated and specialized equipment designed specifically for broadband electromagnetic field test and measurement. It was conducted on 10 August 2021 by our System Engineer, Ahmad Shahir.

Refer to equipment list below.

Equipment	Frequency Range	Calibration Due Date
Narda SRM-3006, Antenna-3502/01	100kHz – 6GHz	5th July, 2022

Table 2: Equipment Used and Calibration Information.

Figure 6: Equipment Used for Testing.

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5. EXTRAPOLATION FACTOR ANALYSIS

[To provide estimation/calculation of the worst-case EMF exposure at the site using extrapolation factor. Refer to TC on EMF. Table below is a sample data.]

1	2	3	4	5	6	7	8	9	10	11
f (MHz)/Code(UMTS)/ Cell-ID+no of MIMO path (LTE)	Service Provider	Limit (V/m)	E (Meas.) (dBµV/m)	Meas. Uncert (dB)	Max. Immission Factor	Emax (dBµV/m)	Emax (V/m)	Emax limit (%)	Smax (mW/m²)	Service Type
Point No.	S01									
939.0	Telco A	41.7	105.1	0.0	2.0	108.1	0.25	0.61	0.17	GSM-900
944.6	Telco A	41.7	130.8	0.0	2.0	133.8	4.90	11.76	63.78	GSM-900
953.8	Telco B	41.7	118.8	0.0	2.0	121.8	1.23	2.95	4.02	GSM-900
936.8	Telco B	41.7	116.4	0.0	4.0	122.4	1.32	3.17	4.63	GSM-900
946.6	Telco B	41.7	105.3	0.0	4.0	111.3	0.37	0.88	0.36	GSM-900
948.6	Telco B	41.7	113.9	0.0	4.0	119.9	0.99	2.38	2.60	GSM-900
1860.0	Telco B	58.4	109.9	0.0	4.0	115.8	0.62	1.06	1.01	GSM-1800
1863.8	Telco A	58.4	105.4	0.0	4.0	111.4	0.37	0.64	0.37	GSM-1800
1864.6	Telco A	58.4	116.4	0.0	4.0	122.4	1.32	2.26	4.63	GSM-1800
2132.6/23	Telco A	61.0	103.4	0.0	20.0	116.4	0.66	1.08	1.16	UMTS
2132.6/301	Telco A	61.0	117.3	0.0	20.0	130.3	3.28	5.37	28.49	UMTS
2132.6/413	Telco B	61.0	101.0	0.0	20.0	114.0	0.50	0.82	0.67	UMTS
2167.2/154	Telco B	61.0	121.8	0.0	20.0	134.8	5.50	9.02	80.30	UMTS
2167.2/157	Telco A	61.0	100.5	0.0	20.0	113.5	0.47	0.78	0.60	UMTS
2167.2/159	Telco A	61.0	102.7	0.0	20.0	115.7	0.61	1.00	0.99	UMTS
816.0/131-0	Telco A	39.2	100.5	0.0	600.0	128.3	2.59	6.62	17.86	LTE-800
816.0/131-1	Telco A	39.2	100.1	0.0	600.0	127.9	2.48	6.32	16.29	LTE-800
816.0/132-0	Telco B	39.2	105.6	0.0	600.0	133.4	4.67	11.91	57.78	LTE-800
816.0/132-1	Telco B	39.2	105.0	0.0	600.0	132.8	4.36	11.11	50.33	LTE-800
816.0/133-0	Telco A	39.2	84.1	0.0	600.0	111.9	0.39	1.00	0.41	LTE-800
816.0/133-1	Telco A	39.2	84.3	0.0	600.0	112.1	0.40	1.03	0.43	LTE-800
						Sum	11.3	25.2	336.88	

Total summation of extrapolated values over all operators are highlighted in the table. The values represented the worst-case EMF exposure scenario.

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6. CONCLUSION

In conclusion, this assessment has confirmed that the electric field strength measured at this site was well below the EMF exposure limits.

This was in compliance with MS EMF exposure for the general public.

Based on the findings of this on-site measurement assessment, we strongly believe that the presence of the RF EMF emitted by the antennas installed on the telecommunication structure at this site, with its current load and the background condition, would not lead to any significant radiation exposure received by members of the public living or working in this area.

Re-assessment must be performed if there is any modification of the equipment.

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7. CERTIFICATE OF COMPLIANCE

KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI

NUKLEAR MALAYSIA

MALAYSIAN NUCLEAR AGENCY (NUKLEAR MALAYSIA)
Ministry of Science, Technology and Innovation
Bangi, 43000 Kajang, Selangor

Certificate of Radio Frequency (RF) Radiation Safety Assessment

[Certificate Reference Number : CISSPT_XXXX]

Title	EMF MEASUREMENT AND ASSESSMENT
Conducted by	ASEAN SAINTIFIK SDN BHD
Location	Lot 13270, Jalan Segambut, Mukim Batu, Kuala Lumpur.
Coordinate	Lat 3.18484414 Long 101.6691854
Measurement Date	[illegible]th Aug 2021
Report number	D14-005660/M/2021/1
Results	PASS

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Field strength / Measurement range	Highest RF radiation level ($\mu W/cm^2$)	Permissible exposure limit ($\mu W/cm^2$)	Comparison with permissible exposure limit (%) *
Broadband (100kHz – 6 GHz)			

****Malaysian Communications And Multimedia Commission (MCMC) Mandatory Standard for Electromagnetic Field Emission from Radiocommunications Instructructure, Determination No 1 of 2010 (Communication and Multimedia Act 1998)***

****International Commission on Non Ionising Radiation Protection (ICNIRP)***

The Radio Frequency (RF) radiation emitted from the antenna(s) of this telecommunication structure complies with the permissible exposure limits issued by the MCMC and ICNIRP.
The results are valid only to the current specification and configuration of the antenna(s).
Reassessment will be required if there are any changes to the current antenna(s) structure.

Verified by:

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Radiation Health and Safety Division.
Malaysian Nuclear Agency (Nuklear Malaysia)

Bibliography

[1] MCMC SRSP 504, 21 June 2017; *Requirements for mobile cellular systems and International Mobile Telecommunications (IMT) systems operating in the frequency bands 824 MHz to 834 MHz paired with 869 MHz to 879 MHz and 880 MHz to 915 MHz paired with 925 MHz to 960 MHz*

[2] MCMC SRSP MS 2100, 3 May 2018; *Requirements for international mobile telecommunications systems operating in the frequency bands of 1 915 MHz to 1 980 MHz, 2 010 MHz to 2 025 MHz, and 2 110 MHz to 2 170 MHz*

[3] MCMC SRSP 508, 21 June 2017; *Requirements for mobile cellular systems and International Mobile Telecommunications (IMT) systems operating in the frequency band 1 710 MHz to 1 785 MHz paired with 1 805 MHz to 1 880 MHz*

[4] SKMM SRSP-523 IMT, 28 November 2012; *Requirements for International Mobile Telecommunications (IMT) systems operating in the frequency band 2 500 MHz to 2 690 MHz*

[5] MTSFB 004: 2005; *Technical standard on RF emission control of cellular radio sites*

[6] MS 739:1981: *Specification for Hot–Dip Galvanized Coatings on Iron Threaded Fasteners*

[7] MS 740:1981: *Specification for Hot– Dip Galvanized Coatings on Iron and Steel Articles*

[8] ITU-T K.91(11,2019); *Protection against interference, guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields*

[9] ITU-T K. Sup 9 (05/2019), *5G technology and human exposure to radiofrequency electromagnetic fields*

[10] ICNIRP Statement, Health Phys. 118(5):477–482; 2020; *Principles for non-ionizing radiation protection*

[11] IEEE Std. C95.1-2019/Cor 1-2019; *IEEE standard for safety levels with respect to human exposure to electric, magnetic, and electromagnetic fields, 0 Hz to 300 GHz*

[12] The electromagnetic spectrum of non-Ionizing radiation
https://www.cdc.gov/nceh/radiation/nonionizing_radiation.html

[13] Electromagnetic fields and public health
https://www.who.int/peh-emf/publications/facts/fs304/en/

Acknowledgements

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