A.1 Introduction

Base Transceiver Station (BTS) emit RF radiation (Radiation Hazard). Although there is no scientific evidence of possible health risks to persons living near to base stations some recommendations are giving below for the installation and operation of base station transceivers. Operators of base station transceivers are required to obey the local regulation for erecting base station transceivers.

The Federal Communications Commission (FCC), are imposing MPE (maximum permissible exposure) limits. FCC CFR part 1, subpart I, section 1.1307 requires operator to perform a Environmental Assessment (EA). Equipment listed in the table 1 of before mentioned part is subjected to routine environmental evaluation. For facilities and operations licensed under part 27, licensees and manufacturer are required to ensure that their facility and equipment comply with IEEE C95.1-1999.

The objective of the Environmental Evaluation is to ensure that human exposure to RF energy does not go beyond the maximum permissible levels stated in the standard. Therefore certain sites do not require an evaluation by nature of its design. It could be that the antennas are placed high enough thereby resulting in extremely low RF fields by the time it reaches areas that would be accessible to people. Environmental evaluations are required, for Wireless Communications Service, Part 27: Wireless Communications Service (Subpart C) if:

- Non-building mounted antennas: height of radiation center < 10m above ground level **and** total power of all channels > 1000 W ERP (1640 W EIRP)
- Building-mounted antennas: total power of all channels > 1000 W ERP (1640 W EIRP)

A.2 Maximum Permissible Exposure (MPE)

Maximum permissible exposure (MPE) refers to the RF energy that is acceptable for human exposure, given the scientific research to date. It is broken down into two categories, Controlled and Uncontrolled. Controlled limits are used for persons such as installers and designers that are in control of the hazard and exposed to energy for limited amounts of time per day. Occupational/controlled limits apply in situations in which are persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where ccupational/controlled limits apply provided he or she is made aware of the potential for exposure.

Uncontrolled limits are used for general public. General population/uncontrolled exposure apply in situations is which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or can not exercise control over their exposure. The exposure levels can be expressed in terms of power density, electric field strength, or magnetic field strength, as averaged over 30 minutes for the general public and 6 minutes for trained personnel. The exposure criterion is frequency dependent, and a chart covering the range from 3 kHz to 100 GHz can be found in NCRP No.86 (references IEEE C95.1-1999). Below are the limits.

Limits for Occupational/Controlled Exposure			
Frequency Range (MHz)	**Electric Field Strength (E) (V/m)**	**Magnetic Field Strength (H) (A/m)**	**Power Density (S) (mW/cm^2)**
0.003-0.1	614	163	(100)*
0.1-3.0	614	16.3/f	(100)*
3.0-30	1842/f	16.3/f	($900/f^2$)*
30-100	61.4	16.3/f	1.0
100-300	61.4	0.163	1.0
300-3000	--	--	f/300
3000-15,000	--	--	10
15,000-100,000	--	--	10

Limits for General Population/Uncontrolled Exposure			
Frequency Range (MHz)	**Electric Field Strength (E) (V/m)**	**Magnetic Field Strength (H) (A/m)**	**Power Density (S) (mW/cm^2)**
0.003-0.1	614	163	(100)*
0.1-1.34	614	16.3/f	(100)*
1.34-3.0	823.8/f	16.3/f	($180/f^2$)*
3.0-30	823.8/f	16.3/f	(($180/f^2$)*
30-100	27.5	$158.3 / f^{1.668}$	0.2
100-300	27.5	0.0729	0.2
300-3000	--	--	f/1500
3000-15,000	--	--	f/1500
15,000-100,000	--	--	10

Power density S [mW/cm^2] for controlled area at 2110 MHz

$$S = \frac{f\,(MHz)}{300} = \frac{2110}{300} = 7.03 \text{ mW/cm}^2$$

Power density S [mW/cm^2] for uncontrolled area at 2110 MHz

$$S = \frac{f\,(MHz)}{1500} = \frac{2110}{1500} = 1.41 \text{ mW/cm}^2$$

A.3 Calculation of the Safe Distance

Calculations can be made on a site by site basis to ensure the power density is below the limits given above, or guidelines can be done beforehand to ensure the minimum distances from the antenna is maintained through the site planning. The calculations are based on FCC OET 65 Appendix B.

A.4 Prediction of the Exposure to Electromagnetic Fields

Below method describes a theoretical approach to calculate possible exposure to electromagnetic radiation around a base station transceiver antenna. Precise statements are basically only possible either with measurements or complex calculations considering the complexity of the environment (e.g. soil conditions, near buildings and other obstacles) which causes reflections, scattering of electromagnetic fields.

The maximum output power (given in EIRP) of a base station is usually limited by license conditions of the network operator.

A rough estimation of the expected exposure in power flux density on a given point can be made with the following equation. The calculations are based on FCC OET 65 Appendix B.

$$S = \frac{P(W) * G_{numeric}}{4 * r^2(m) * \pi}$$

Whereas:

P = Maximum output power in W of the site

$G_{numeric}$ = Numeric gain of the antenna relative to isotropic antenna

R = distance between the antenna and the point of exposure in meters

A.5 Calculation of the Safe Distance

Calculations can be made on a site by site basis to ensure the power density is below the limits given above, or guidelines can be done before hand to ensure the minimum distances from the antenna is maintained through the site planning.

$$r = \sqrt{\frac{1.64 * G_d * Pt}{4\pi S}}$$

Whereas:

r = distance from the antenna [m]

G_d = Antenna gain relative to half wave dipole

Pt = Power at the antenna terminals [W]

S = power density [W/m^2] see also MPE Limits

Note: 1mW/cm^2 = 10W/m^2

For the base station RRU3801C-40W up to six types of antennas can be installed for different network configurations. For below calculation the worst case is considered. The configuration of the 2100 MHz AWS system consist two channels (carriers) per sector. The antenna consists of a strong directional characteristic.

$$r = \sqrt{\frac{G_{numeric} * Pt}{4\pi S}}$$

It is important to note that reflections from the ground and nearby fences increase power density at a given point by 4 timers. This would therefore require increasing the safe distance by a factor 2. So, the equation is modified as;

$$r = \sqrt{\frac{G_{numeric} * Pt}{\pi S}}$$

<u>Calculation:</u>

Base station configuration:

For the Maximum rating antenna output power is 40W.
For 1Channel (carrier) is 40W.
For 2 Channels (carrier), each sector is 20W, totally is 40W.
Antenna type: Kathrein 741990: Gain 18 dBi, G numeric = 63.1
Cable loss is 1.25 dB (1.34) per 20 m cable.

Total input power: 46 dBm – 1.25 dB = 44.75 dBm (29.9 W)

Limits: S= 7.03 mW/cm^2 = 70.3 W/m^2 for controlled exposure
S= 1.41 mW/cm^2 = 14.1 W/m^2 for uncontrolled exposure

Safe distance: r = 2.9 m for controlled exposure
r = 6.5 m for uncontrolled exposure

A.6 Location of Base station antennas

Base stations antennas, the source of the radiation, are usually mounted on freestanding towers, with a height up to 30 m or on a tower on the top of buildings or in less case to the side of the building. Generally the height of the antenna position does not fall below 10 m. The power usually is focused into a horizontal main beam and slightly downward tilted. The remaining power goes into the weaker beams on both side of the main beam. The main beam however does not reach ground level until the distance from the antenna position is around 50 – 200 m.
The highest level of emission would be expected in close vicinity of the antenna and in line of sight to the antenna.

A.6.1 Exclusions Zones:

1. The antenna location should be designed so that the public cannot access areas where the RF radiation exceeds the exposure levels as described above.
2. If there are areas accessible to workers where RF radiation exceeds the levels as described above make sure that workers know where these areas are, and that they can (and do) power-down (or shut down) the transmitters when entering these areas. Such areas may not exist; but if they do, they will be confined to areas within 10 m of the antennas.
3. Each Exclusion zone should be defined by a physical barrier and by a easy recognizable sign warning the public or workers that inside the exclusion zone the RF radiation might exceed exposure limits.

A.6.2 Guidelines on arranging antenna sites:

1. For roof-mounted antennas, elevate the transmitting antennas above the height of people who may have to be on the roof.
2. For roof-mounted antennas, keep the transmitting antennas away from the areas where people are most likely to be (e.g., roof access points, telephone service points, HVAC equipment).
3. For roof-mounted directional antennas, place the antennas near the periphery and point them away from the building.

4. Consider the trade off between large aperture antennas (lower maximum RF) and small aperture antennas (lower visual impact).
5. Take special precautions to keep higher-power antennas away from accessible areas.
6. Keep antennas at a site as for apart as possible; although this may run contrary to local zoning requirements.
7. Take special precautions when designing "co-location" sites, where multiple antennas owned by different operators are on the same structure. This applies particularly to sites that include high-power broadcast (FM/TV) antennas and for example co-sitting of GSM and CDMA antennas. Local zoning often favors co-location, but co-location can provide "challenging" RF safety problems.
8. Take special precautions for antenna sites near hospital and schools.