Code 6 untangled
Banff, September 20th 2017

What is Code 6 and why is it important?

- Code 6 is the name of the set of limits not to be exceeded for non-ionizing radiations
- The radio-frequencies belong to the non-ionizing radiations
- Over these limits, they become a health hazard
- It’s also important to make the calculation to reassure the public of the safety of the installations
  - What you don’t know is always scarier

What is Code 6?

Limits are set for

- Power Density i.e. amount of Watts per square meter (surface)
- Electric Field Strength per meter (V/m)
- Magnetic Field Strength per meter (A/m)
- Contact current (mA)

- There are 2 levels of limits:
  - Controlled Environments
    - Well characterized environment accessible to RF workers who are aware of the radio environment
  - Uncontrolled Environments
    - The opposite of Controlled Environment

What is Code 6?

- Controlled Environments
  - Is of interest to workers health and safety organizations
- Uncontrolled Environments
  - Is of interest to Industry Canada
  - They insure that radio operators protect the public and respect the limits set by Health Canada

Who has to file code 6 analysis and when?

- Who?
  - All the carriers (owners of spectrum licenses)
    - This includes license holders of 3.65GHz spectrum
- When?
  - When installing a new licensed antenna system or modifying one
    - http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09945.html
  - On a yearly basis as per the new rules, calculations for 10% of the sites
    - This year's deadline is September 30th

What has to be reported yearly?

- On a yearly basis as per the new rules, calculations for 10% of the sites where there are licensed equipment
  - The sites have to be in the following categories:
    - rooftops,
    - Towers less than 10m, towers from 10 to 15, towers from 15 to 25, towers from 25 to 50, towers from above 50m
    - If there are not enough towers to fill in all the categories, then operators should start filling from the lowest towers:
      - All their installations below 10m, all their installations from 10 to 15m, etc.
- Along with 10% mentioned above, the operator has to report 2 worst cases with all the potential frequencies he and other operators are licensed for and are not yet installed.

>Approach to calculations

What is the non-exemption zone

- The non-exemption zone is the volume around an antenna that is either:
  - Closer than the far field beginning
  - In less than 50% of the Code 6 Power Density Limit
  - Non-exemption refers to exemption to provide measurements and potentially restrict access to the area
- To simplify calculations, if very relaxed and generic parameters are used and the limit of the zone does not reach the area accessible by the public, then the site passes.

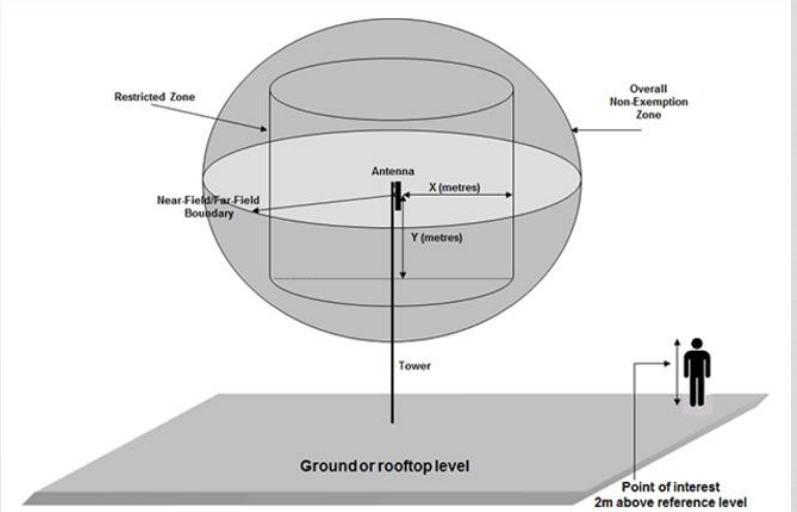
What are the required calculations?

- Therefore 2 main calculations to be done:
  - 1- Reach of the Beginning of the Far Field
  - 2- % of the Code 6 Power Density Limit

Far Field Calculations

- Beginning of the Far field is represented as a sphere around the antenna
- The far field is dependant on the antenna aperture and the wave length
- The far field of typical WISP antenna is very close
  - Ex. Far field of a 900MHz 1.6m omni antenna is 3.84m (13ft),
  - Ex. Far field of a 5.8GHz antenna with an aperture of 0.45m is 1.69m
- A person (2m height) has to be outside of this area

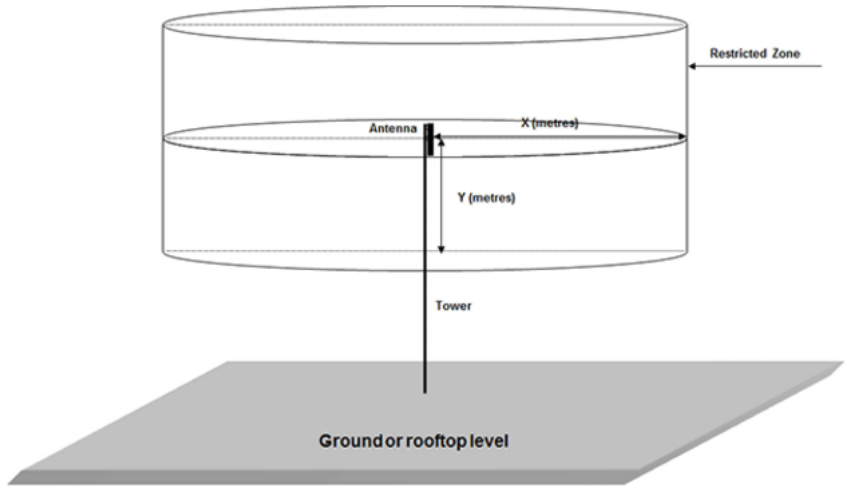
Figure 4 — If the restricted zone is in the near-field, the near-field/far-field boundary becomes the new overall non-exemption zone



Power limit calculations

- Power limits are calculated by using:
  - Power of each of the stations
  - Free space attenuation
  - Ground reflection (60% of the incident power)
  - Antenna pattern
  - Vertical antenna pattern approximation (cosine^3)
  - The limit for this type of calculation is 50% of the Code 6 limit
- It can be approximately represented by a cylinder around the transmitters

Figure 2 — Graphical representation of the restricted zone around an antenna



Power limit calculations (from ISED NT-261)

- Power limits Equation: Free space modified

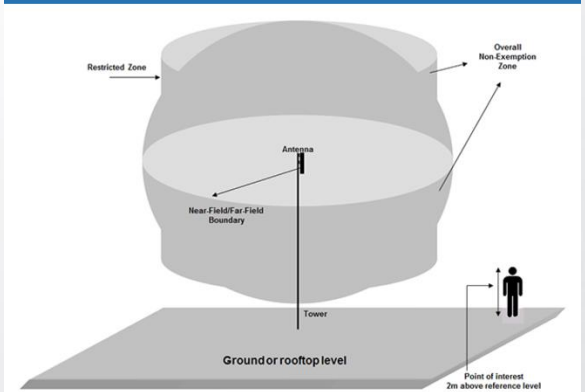
$$W_M = \frac{2.56 P_T G}{4\pi r^2} = \frac{2.56 EIRP}{4\pi r^2} = \frac{2.56 EIRP_{max} G_v(\beta) G_h(\theta)}{4\pi r^2}$$

W_M is the modified free-space power density (W/m^2),
P_T is the transmitter power fed into the antenna (W),
G is the numeric gain of the antenna with respect to an isotropic source,
EIRP is the effective isotropic radiated power from the antenna (W),
$EIRP_{max}$ is the effective isotropic radiated power with the maximum antenna gain (W),
β is the vertical angle of interest or the vertical discrimination angle (see Figure A2 below),
β is equal to (α – mechanical tilt – electrical tilt) where α is the vertical depression angle (°) (see Figure A2),
θ is the horizontal discrimination angle from the antenna main beam (°) (see Figure A2),
$G_v(\beta)$ is the normalized numerical vertical antenna gain for the angle of interest ($0 \leq G_v(\beta) \leq 1$),
$G_h(\theta)$ is the normalized numerical horizontal antenna gain ($0 \leq G_h(\theta) \leq 1$), and
r is the distance from the centre of radiation of the antenna to the test point (m).

Examples of Power limit calculations

- The power density of WISP installations do not have a big reach. For example:
  - A 900MHz, 8dBi antenna gain and 50dBm located at 6m height would have it's 50% power density limit at 5.8m from the tower
    - At a lower power, for example 30 dBm, it's density limit would be within it's far field limit

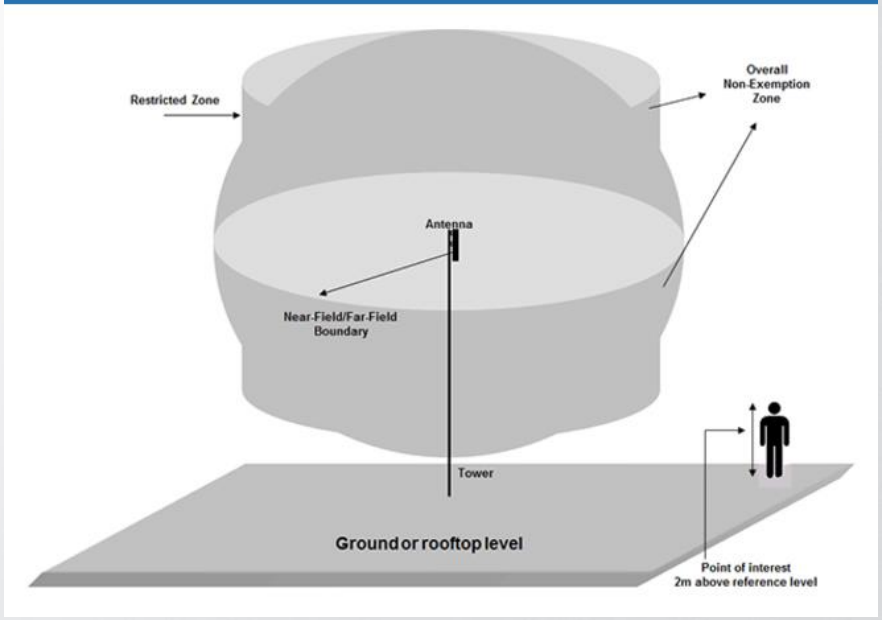
Figure 6 — The overall non-exemption zone is the combination of the sphere and cylinder



Non-exemption Zone

- The zone inside the sphere and cylinder is a restricted zone
  - It's a zone that can't be accessed by the public
- If that zone does not reach the ground for a tower, then there are no Code 6 issues

Figure 6 — The overall non-exemption zone is the combination of the sphere and cylinder



How do we calculate if a site passes or fails?

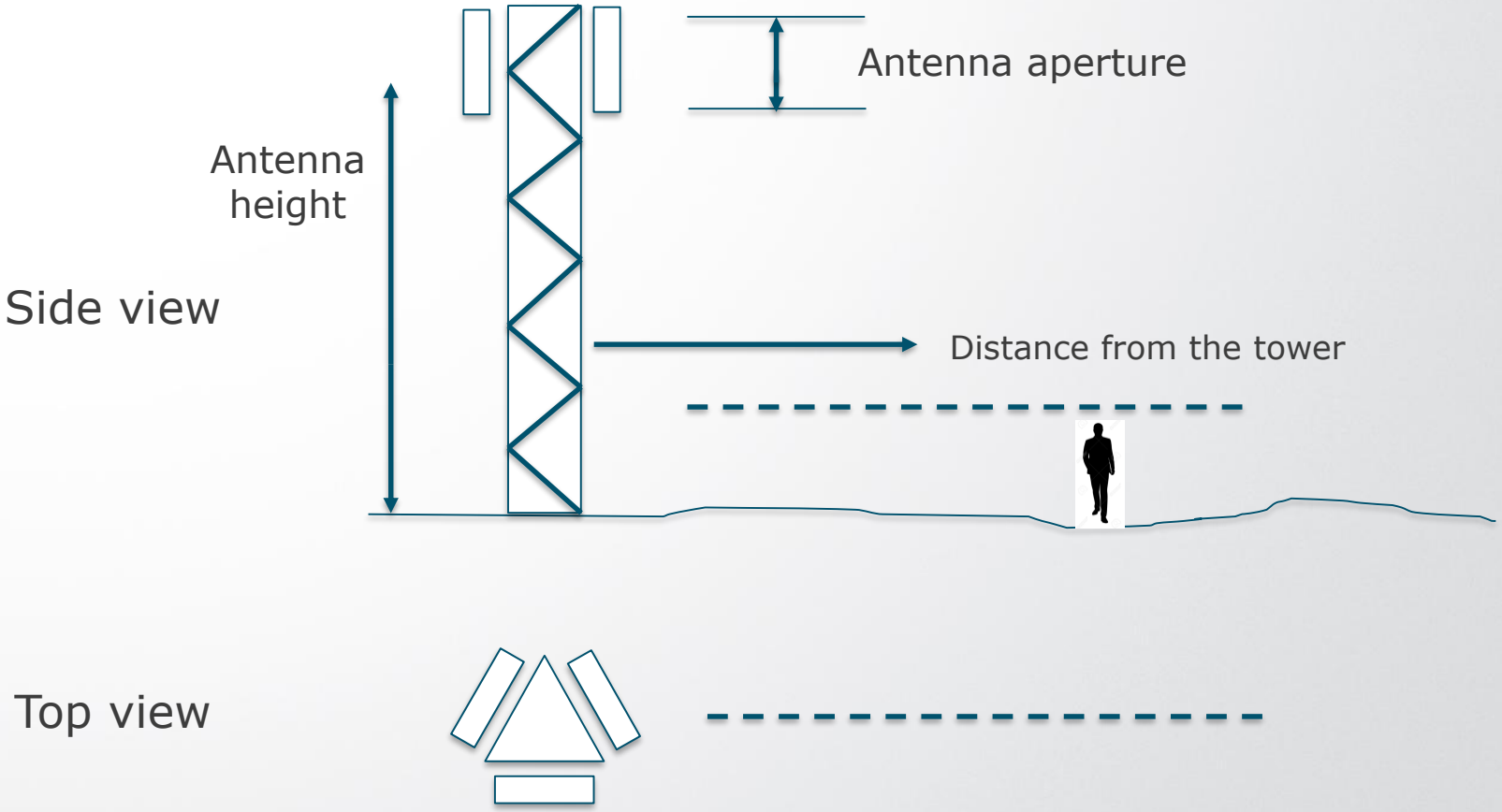
- Calculating power limit distances is not practical
- Instead, we calculate the contribution of each transmitter to the power density at a critical distance
  - We calculate the % of the contribution of each transmitter
  - We add the % of each contributor
  - The total has to be below 50% of the Code 6 Power Density limit

>Spreadsheet calculator

Spreadsheet

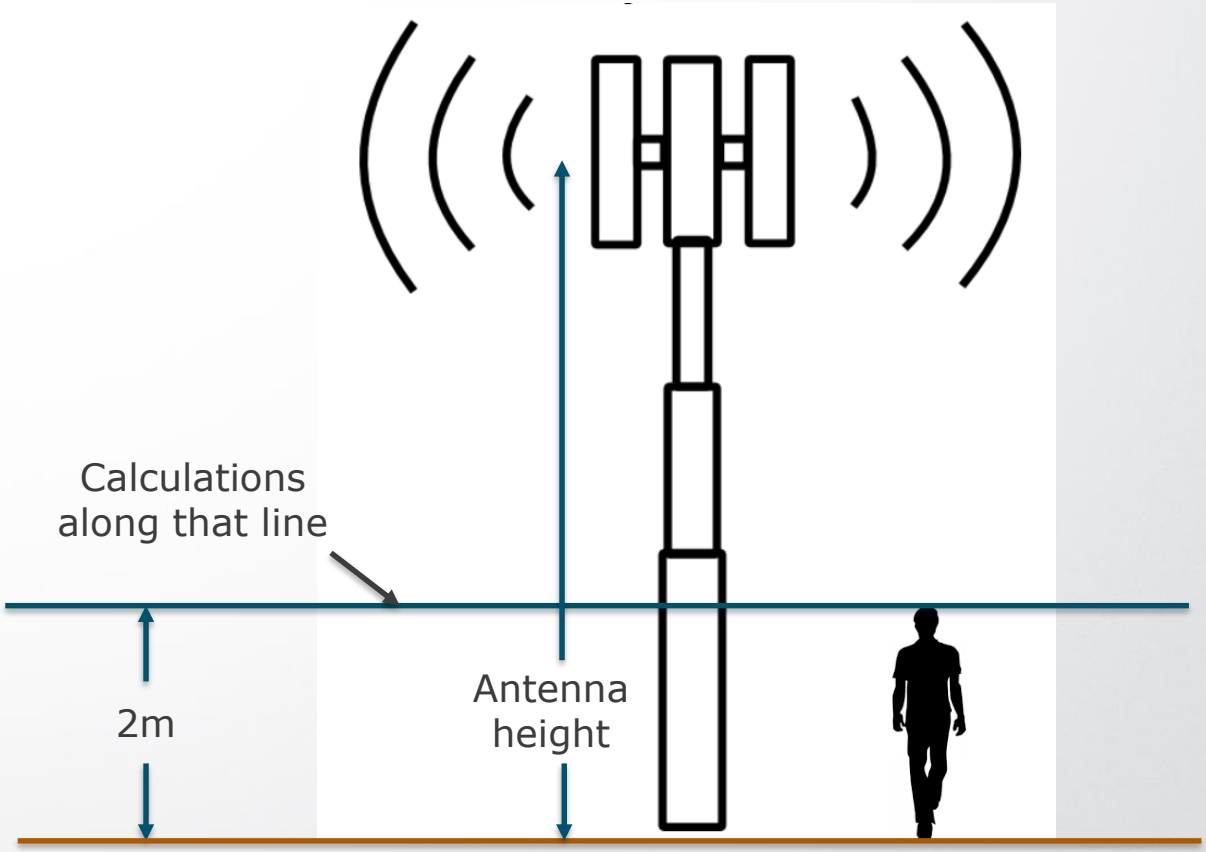
- Built on the NT-261 ISED model
- Built only for the tower cases
  - Could be applied to rooftops but calculations are over estimated and more explanations have to be given in the analysis
- Calculates the worst case along a radial at a height of 2m above the ground of the combined effect of all the transmitters
- Identifies the worst case and reports it
- Possibility to include up to 15 transmitters
  - Why that many?
    - One cellular operator in Canada typically has:
      - 3 sectors (3 transmitters)
      - 800MHz, 1900MHz, 700MHz and now 2100MHz (and sometimes multiple transmitters in each band)
      - A total of 12 transmitters
    - More than 15 is a very complex site and needs to be analyzed with more caution

Spreadsheet calculator diagram



Spreadsheet

- NOT built for:
  - Cases of towers in close proximity of each other
    - specially with high power broadcasting stations
  - Cases below 54MHz


Calculations
along that line
2m
Antenna
height

Near Field/Far Field Limit Calculator

Near Field Limit/Far Field start

Nb	Description of transmitter	Frequency (MHz)	Antenna Aperture (lenght) (m)	Antenna Far Field beginning at (m)
1	My tx1	900	1.6	3.84
2	My 3650 MHz system	3650	0.75	3.421875
3				
4				
5				
6				
7				
8				
9				
#				
#				
#				
#				
#				
#				

% of Limit of Code 6 example

Nb	Description of transmitter	Frequency (MHz)	Transmitter power (dBm)	Antenna Gain (dBi)	Antenna Down Tilt (elec + Mech, deg.)	Antenna height(m)		Density of power MAX (W/m2)	% of Code 6
1	My Tx1	900	33	11	3	20		0.005	0.17
2	My 3650	3650	43	16	3	15		0.323	4.53
3	3650 sector2	3650	43	16	3	15		0.323	4.53
4	3650 sector 3	3650	43	16	3	15		0.323	4.53
5	My Tx 2400	2400	30	15	3	10		0.027	0.50
6								0.000	0.00
7								0.000	0.00
8								0.000	0.00
9								0.000	0.00
10								0.000	0.00
11								0.000	0.00
12								0.000	0.00
13								0.000	0.00
14								0.000	0.00
15								0.000	0.00
Total % of Code 6 limit									14.26
								Result:	PASS

% of Limit of Code 6 Calculations