GSM, EMC and Health Issues

Can a mobile phone call kill you?

What are the issues

- Field strength from GSM installation must not influence neighbouring systems
- Field strength from GSM installation must not present a health and safety risk to users

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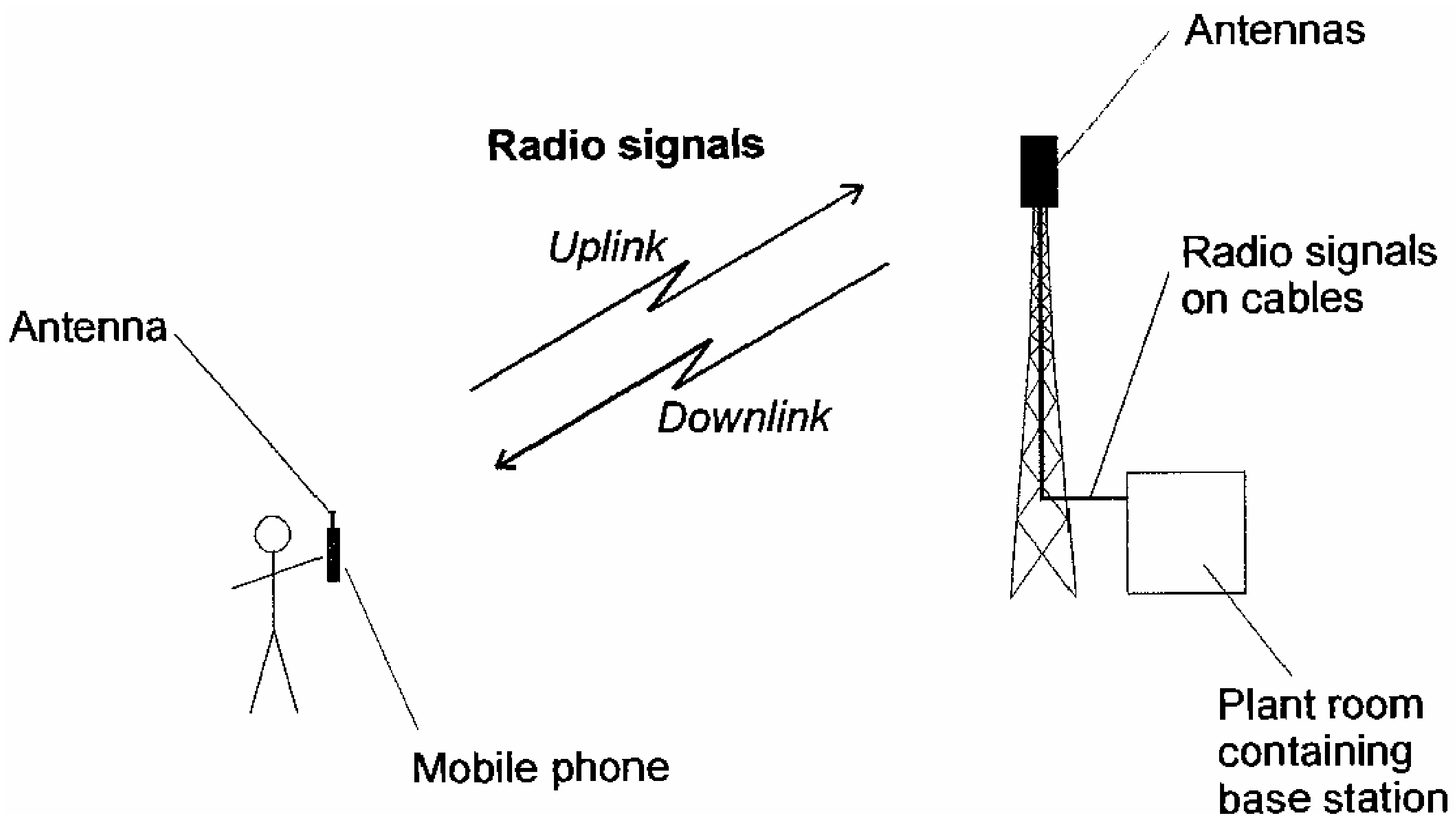

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The Source - BTS

- Base Transceiver Station (BTS)
  - Generates the air interface to the mobile.
  - It is composed of an antenna and a transceiver
  - It is the first entity within the GSM network that detects the mobile signal

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GSM - R Antenna

- Two phase dipole array on top of each antenna masts
- The array consist of 8 pairs of cross polarised dipoles housed in a metal reflector (2.3m long)
- Each array is capable of Tx and Rx through two separate channels

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GSM-R Antenna

- GSM antennas tends to be sector antennas with a typical gain of:
  - 15 – 17dBi for 900MHz
  - 16 – 18dBi for 1800MHz
- Omnidirectional antenna are also used (though less common)
  - 8 – 10dB

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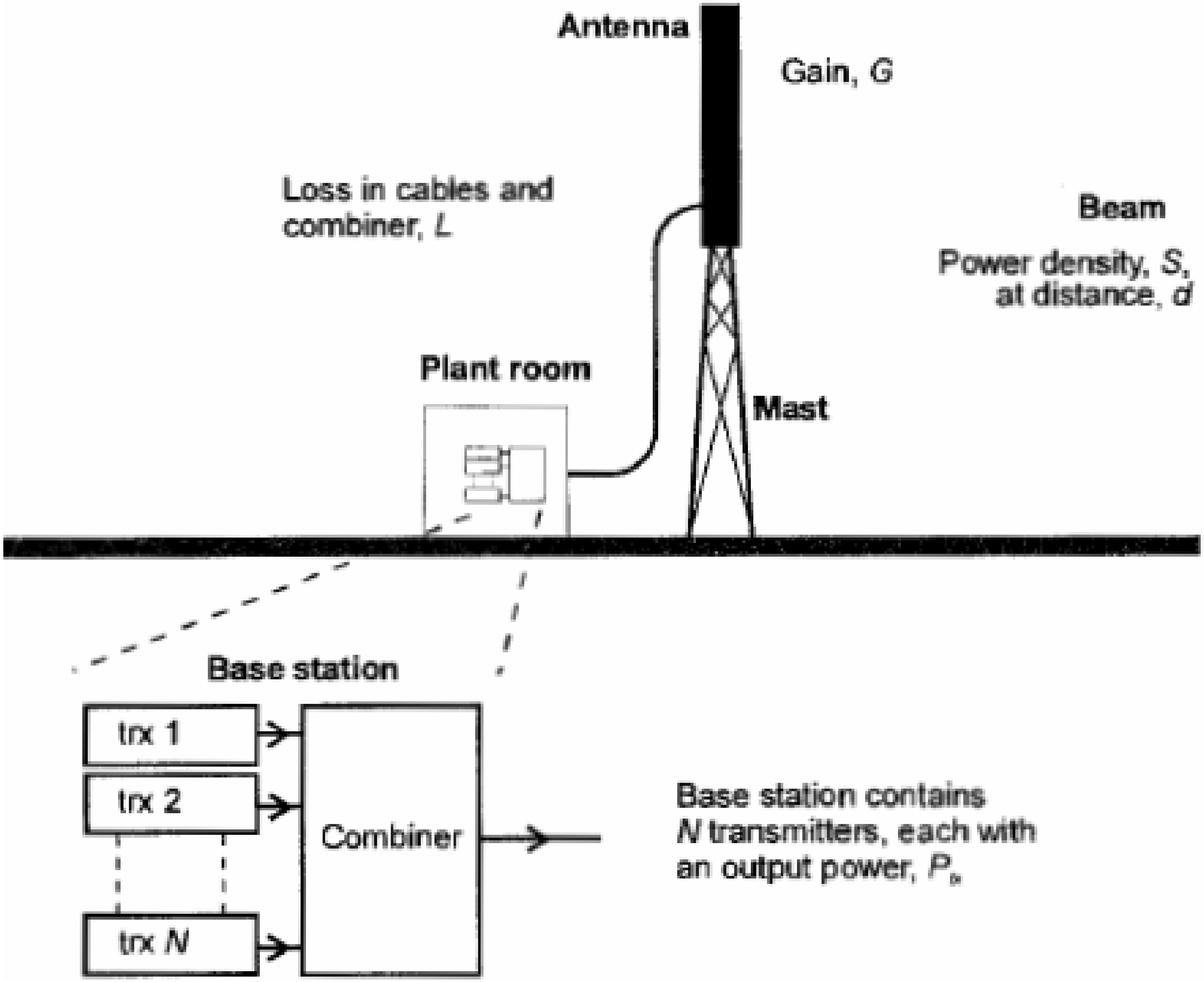

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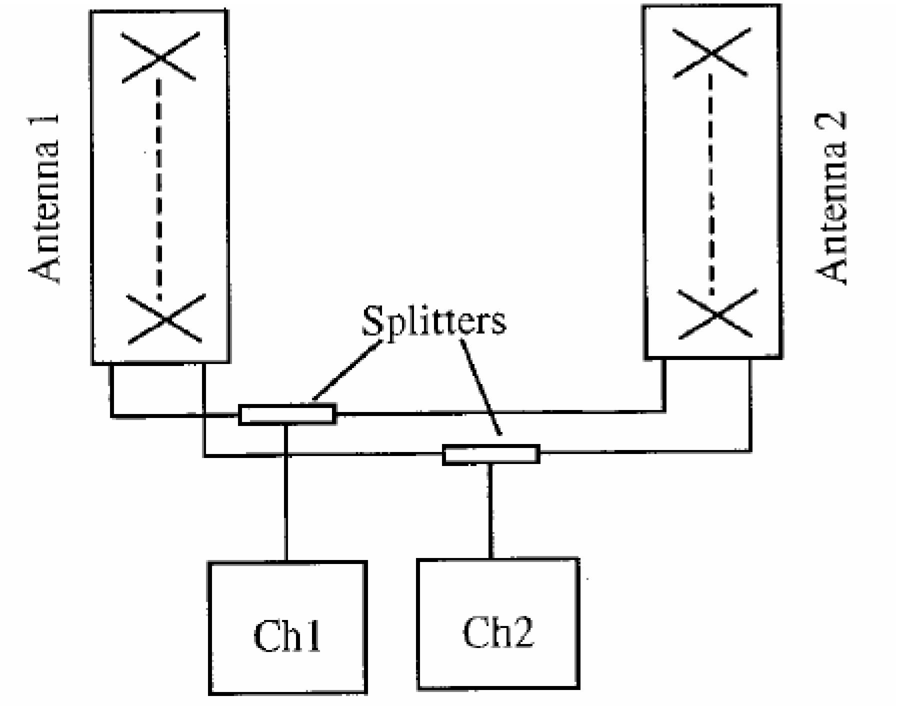
GSM - R Antenna

- The signal level is split between the two antenna by power splitters
- The antennas are highly directional



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Exclusion Distance - LOS

- In theory, either due to fault or installation error, the entire power could be fed to one antenna, effectively doubling the power to that antenna

Power, one channel	53 dBm	200W
Power, 2 channels	56 dBm	400W
Cross polar loss	58 dBm	631 W
Power splitters by passed	61 dBm	1262 W
Shared mast, two antenna	64 dBm	2524 W

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Far Field – Electric Field Strength

$$ERP = \frac{E^2 r^2}{30} \Rightarrow E = \frac{\sqrt{30ERP}}{r}$$

$$E \approx \frac{5.5\sqrt{ERP}}{r}$$

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Protection Limits for biological matters

- Limits based on heating effects on humans
- This is expressed as a derivative of the ability of the exposure to excite water molecules in tissues
- It is weighted against the ability of the thermoregulatory systems of the body to remove this heat

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Localised ICNIRP Exposure Guidelines for the general public

Whole body SAR	0.08 W/kg
Head and trunk SAR	2 W/kg
Limbs SAR	4 W/kg

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Safe distances

MHz	ICNIRP Level	dBm	m	dBm	m
876	40.7	61	4.78	64	6.76
880	40.8	61	4.77	64	6.74
915	41.6	61	4.68	64	6.62
921	41.7	61	4.67	64	6.6
925	41.8	61	4.65	64	6.58

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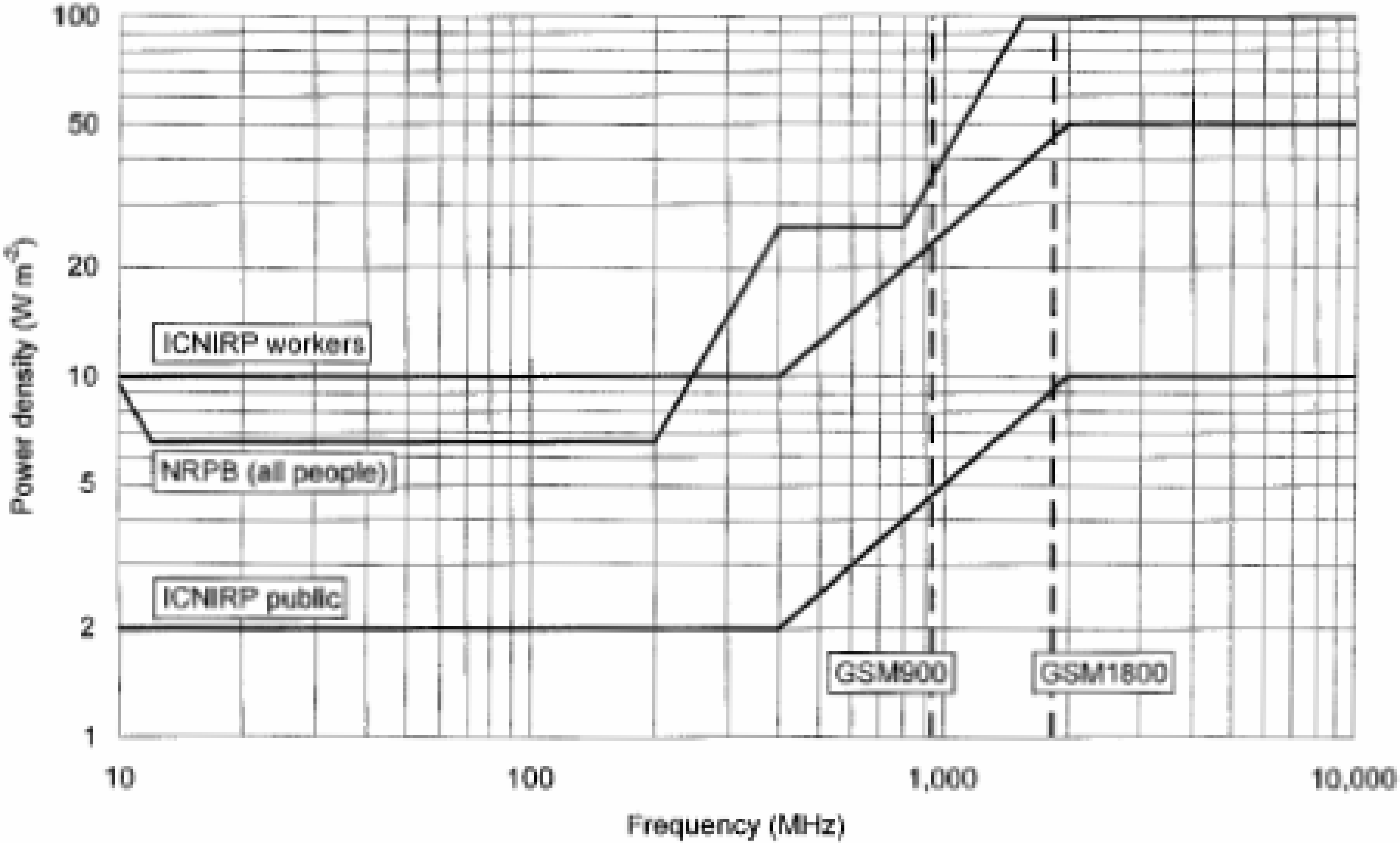

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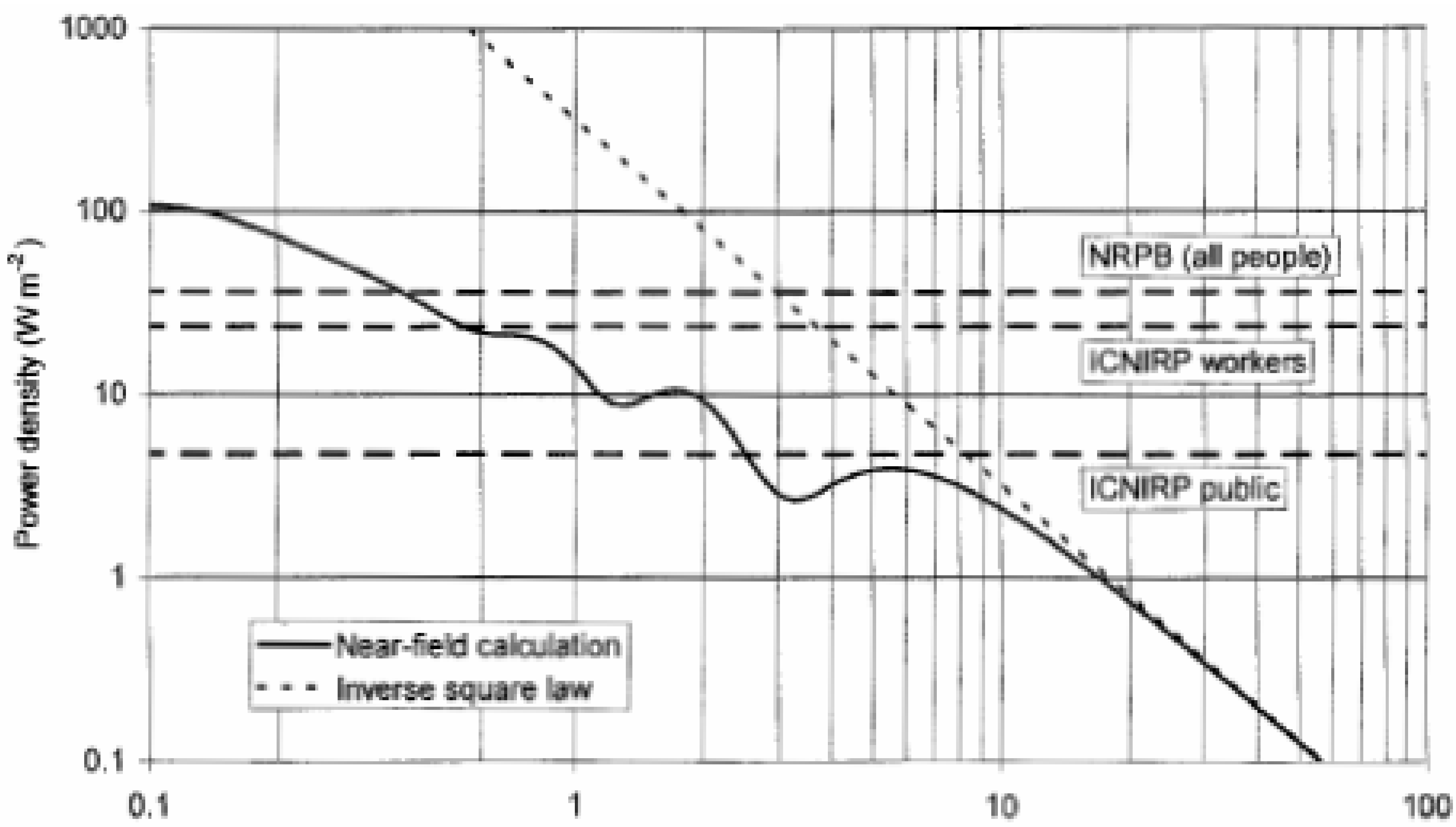

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Safe distances at 900MHz

Power	**41.25V/m**	**20V/m**	**10V/m**	**3V/m**
53 dBm	**1.88m**	3.87 m	7.75m	25.82m
56 dBm	**2.66m**	5.48 m	10.95m	36.5
58 dBm	**3.3m**	6.88 m	13.76m	45.86
61 dBm	**4.72m**	9.73m	19.46m	64.86
64 dBm	**6.67 m**	13.75 m	27.5m	91.7m

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So what should we recommend?

- Does NCC/ mobile operators allow shared mast?
  - Then an exclusion of 8m is recommended (7m plus a 1m buffer zone)
  - If not, a 6m exclusion zone is recommended (5m plus 1m buffer zone)

Remember this is the safe distance from a line of sight!!!!

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What else can we do?

- Antenna are usually mounted on masts
- Height are usually 15m above but can have them lower depending on application
- So we need to re-evaluate the risk

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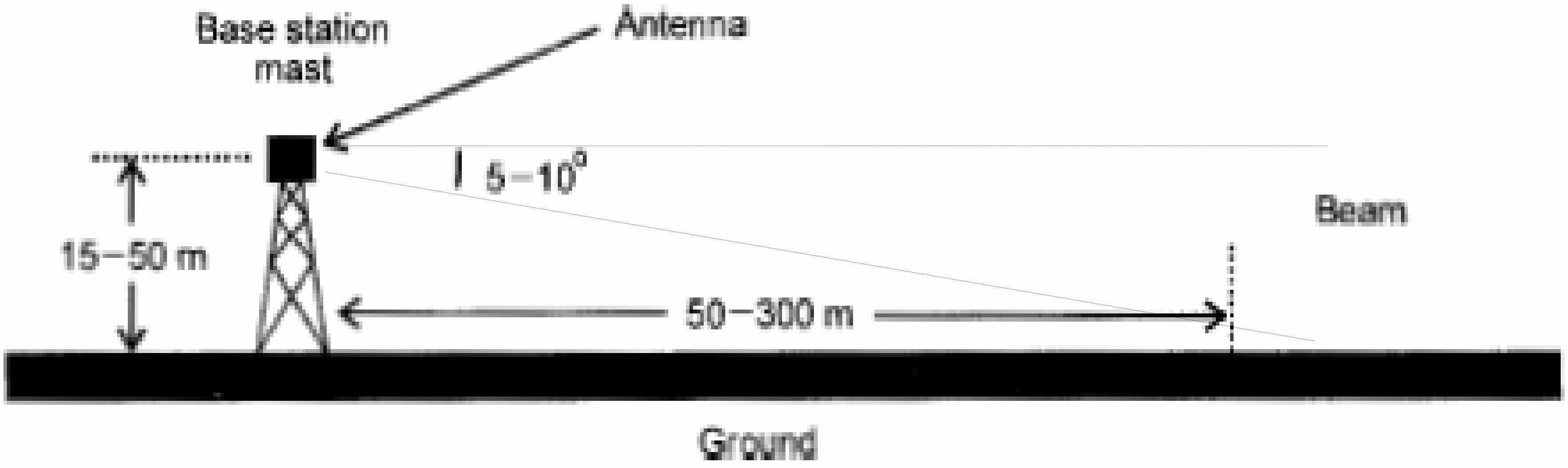

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Typical GSM Antenna Data

Horizontal Beam -3dB	$65^o \pm 3^o$
Side lobes in Horizontal	20 dB
Elevation beam with -3dB	$9.4^o \pm 0.6^o$
Electrical Tilt	$2^o \pm 0.5^o$
Side lobes in elevation	20 dB less than main beam
L by W by H	2310mm by 290mm by 210mm
Mechanical Tilt	0^o to 12^o, 1^o intervals

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Field seen at head height under normal condition

- Assume height human is 2m
- Assume antenna mast height of 15m

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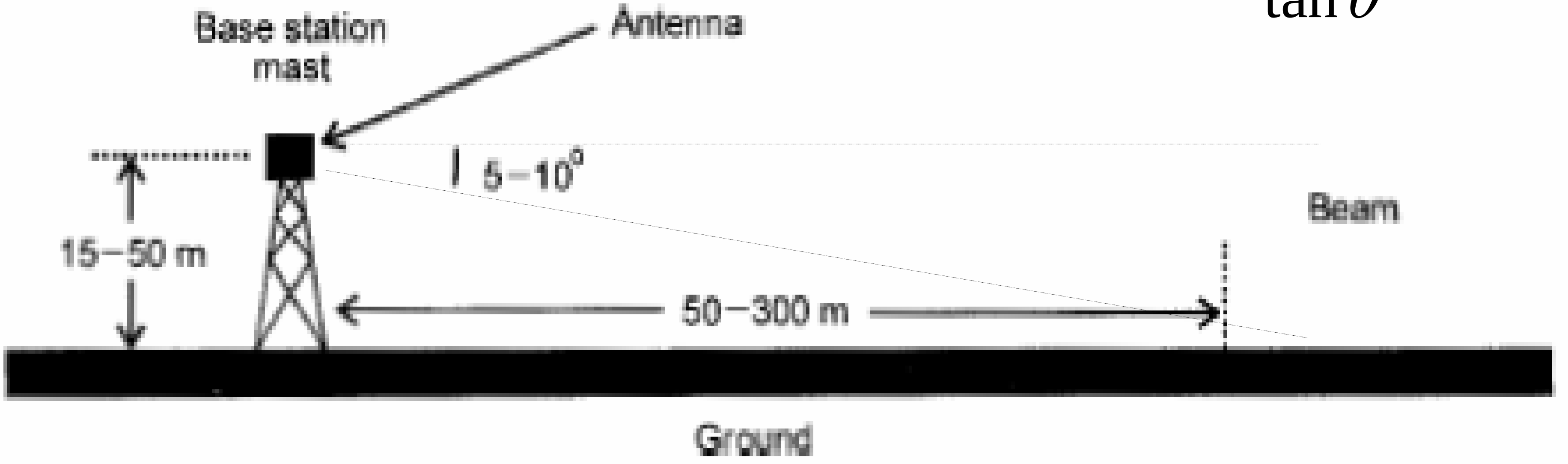
Field at Head Height

$$dis = \frac{Height}{\tan\theta}$$



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Field at Head height

53 dBm	0.78 V/m
56 dBm	0.9 V/m
58 dBm	1.38 V/m
61 dBm	1.95 V/m
64 dBm	2.75 V/m

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Tilt Angle Effect

- Antenna has mechanical tilt which
  - Helps optimise the beam and thus coverage away from the line of sight
  - Mechanical tilt may in fact affect the antenna pattern slight

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Handheld Mobile

Type	Base Station Tx	Handset Tx	Peak Handset Power	Operators (UK)
GSM900	935 -960 MHz	890 -915 MHz	2W	O2 and Vodaphone
GSM1800	1805 – 1880 MHz	1710 – 1785 MHz	1W	Orange and T- Mobile

Old mobiles may have a peak handset power of 20W

The power is reduced to 100th of the nominal value if very close to a base station

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Handheld Mobile

- The wavelength at 900 MHz is approximately 30cm which is within user distance to the head
- The far field zone is approximately 5cm (could be less than this)
- The electric field strength at 5cm is approximately 155 V/m…at 2.2 cm is 400V/m!!!!!

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Propagation through Human Head

- The question is the efficiency of the human head as shield
- Ideally we want it to be a good reflector but that has implications
- We would assume the human head is fat

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Electrical properties of human head

- Given in terms of complex permittivity
- Can obtain this from Maxwell's Equations

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

$$\nabla \times \vec{H}_s = \underbrace{\vec{J}_s}_{\text{conduction current}} + \underbrace{j\omega \vec{D}_s}_{\text{displacement current}} = \sigma \vec{E}_s + j\omega\varepsilon \vec{E}_s$$

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Electrical properties of human head

- For a good insulator, the conduction current should be small compared to the displacement current

$$\sigma E \ll \omega \varepsilon E \text{ or } \frac{\sigma}{\omega \varepsilon} \ll 1$$

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Electrical properties of human head

- For a good conductor, the conduction current should be large compared to the displacement current

$$\sigma E \gg \omega \varepsilon E \text{ or } \frac{\sigma}{\omega \varepsilon} \gg 1$$

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Electrical properties of human head

- The human flesh is a good conductor at low frequency (e.g. 50 Hz) but a poor conductor at high frequency

$$\nabla \times H = j\omega\left(\varepsilon + \frac{\sigma}{j\omega}\right)E = j\omega\varepsilon_0\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)E$$

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Electrical properties of human head

$$\varepsilon^{*} = \varepsilon_0 \left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0} \right) = \varepsilon_0 \left(\varepsilon' - j\varepsilon'' \right)$$

$$\Rightarrow \varepsilon' = \varepsilon_r = \underbrace{k}_{\text{dielectric constant}}, \quad \varepsilon'' = \frac{\sigma}{\omega\varepsilon_0}$$

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Electrical properties of human head

- Assuming the following:

$$\varepsilon^{'} = \varepsilon_r = 5.5$$

$$\sigma = \omega\varepsilon_0\varepsilon^{''} \approx 0.036 - 0.078$$

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Electrical properties of human head

$$\frac{\sigma}{\omega\varepsilon} \approx 0.13 - 0.28$$

Not a good insulator or a good conductor

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How thick should the human fat be?

- Skin depth (or penetration depth) is given by

$$\delta = \frac{1}{\omega\sqrt{\frac{\mu\varepsilon}{2}\left(\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}-1\right)}}$$

$$= 0.06 - 0.13m$$

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Attenuation inside body

- Impedance is given by

$$Z_1 = \sqrt{\frac{j\omega\mu_0}{0.036 + j\omega 5.5\varepsilon_0}}$$

$$Z_2 = \sqrt{\frac{j\omega\mu_0}{0.078 + j\omega 5.5\varepsilon_0}}$$

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- Reflection coefficient is given by

$$\left|\frac{Z_1 - Z_0}{Z_1 + Z_0}\right|; \qquad \left|\frac{Z_2 - Z_0}{Z_2 + Z_0}\right|$$

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- Transmission coefficient is given by

$$\left|\frac{2Z_1}{Z_1 + Z_0}\right|; \qquad \left|\frac{2Z_2}{Z_2 + Z_0}\right|$$

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- Roughly, reflection loss is about 40%, while transmission is about 60%
- The reflection coefficient implies that majority of the 155V/m will propagate through the head
- This will be absorbed in the body resulting in localised heating…but

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