Chapter 9

Antennas

Antennas in real channels

- One important aspect is how the channel and antenna interact
  - The antenna pattern determines what the system sees
  - Delay spread and angular spread affected by the antenna pattern

- The user may have a large influence on the behavior of the antenna
  - Change in antenna pattern
  - Change in efficiency: mis-match

Important antenna parameters

- Directivitiy
  - Total power in a certain direction compared to total transmitted power
- Efficiency

$$\eta = \frac{R_{rad}}{R_{rad} + R_{ohmic} + R_{match}}$$

Rrad = real portion of Z = R + jX

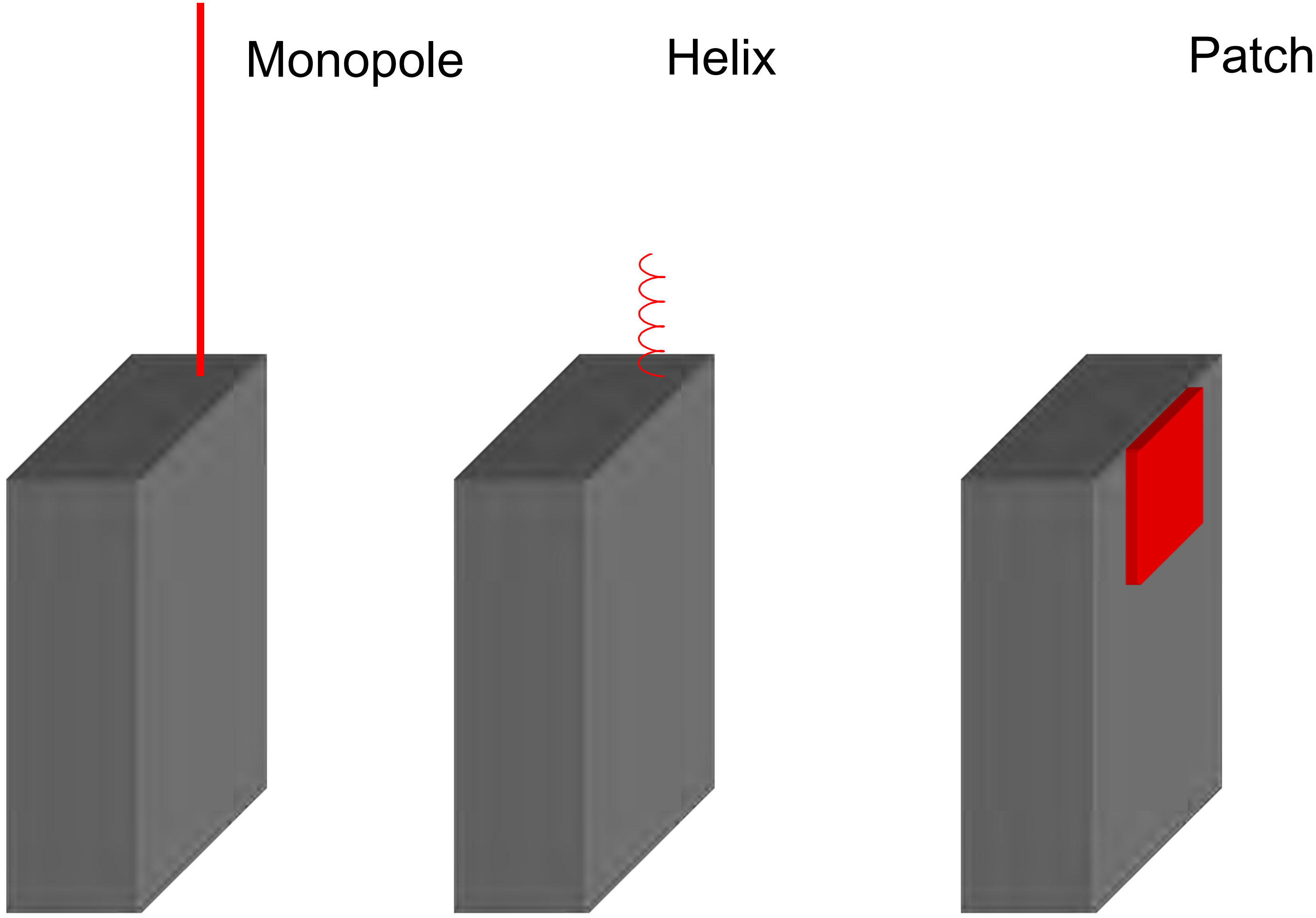
Radiation efficiency of an antenna is the ratio of the total power radiated dividied by net power of a transmitter connected to the antenna.

- Q-factor
  - Stored energy compared to dissipated energy

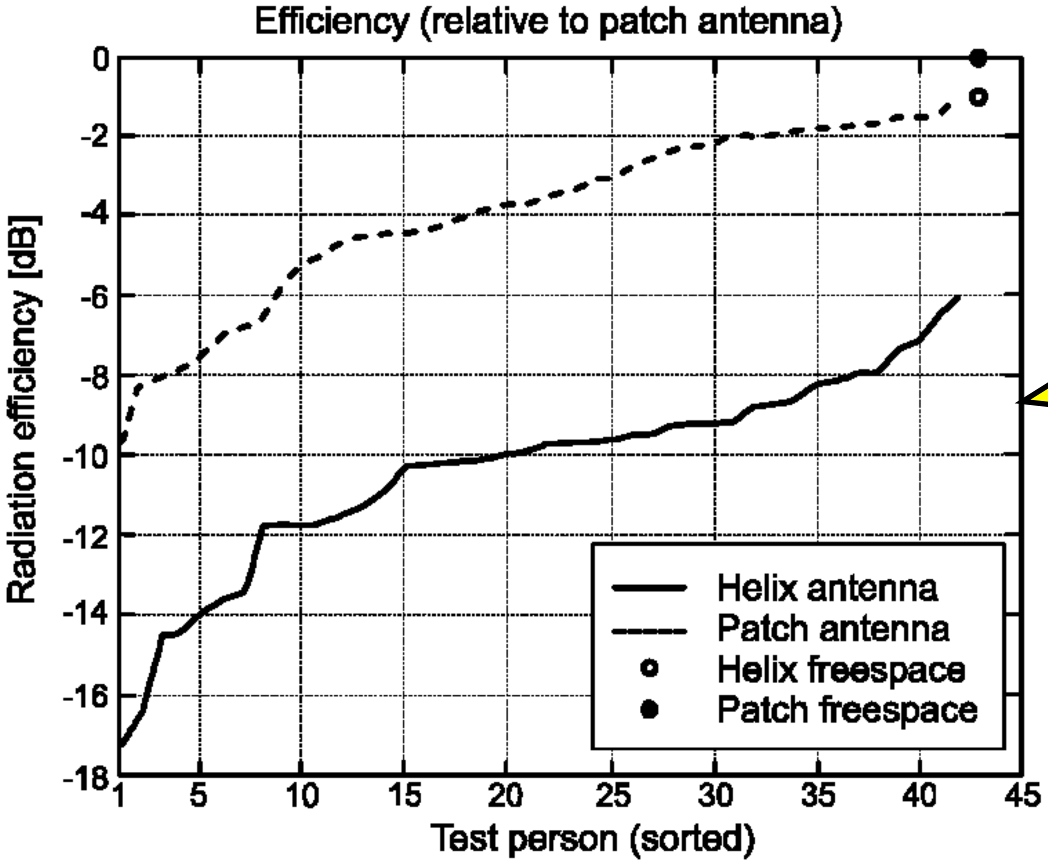
High Q antenna - sharp response, low bandwidth, not desirable

- Mean effective gain
  - Include influence of random channel
  - Average received power compared to average received power by isotropic antenna in real environment (takes ohmic losses into account)
- Polarization vertical, horizontal, circular - both right and left handed
- Bandwidth

Mobile station antennas



Impact of user on MS antenna

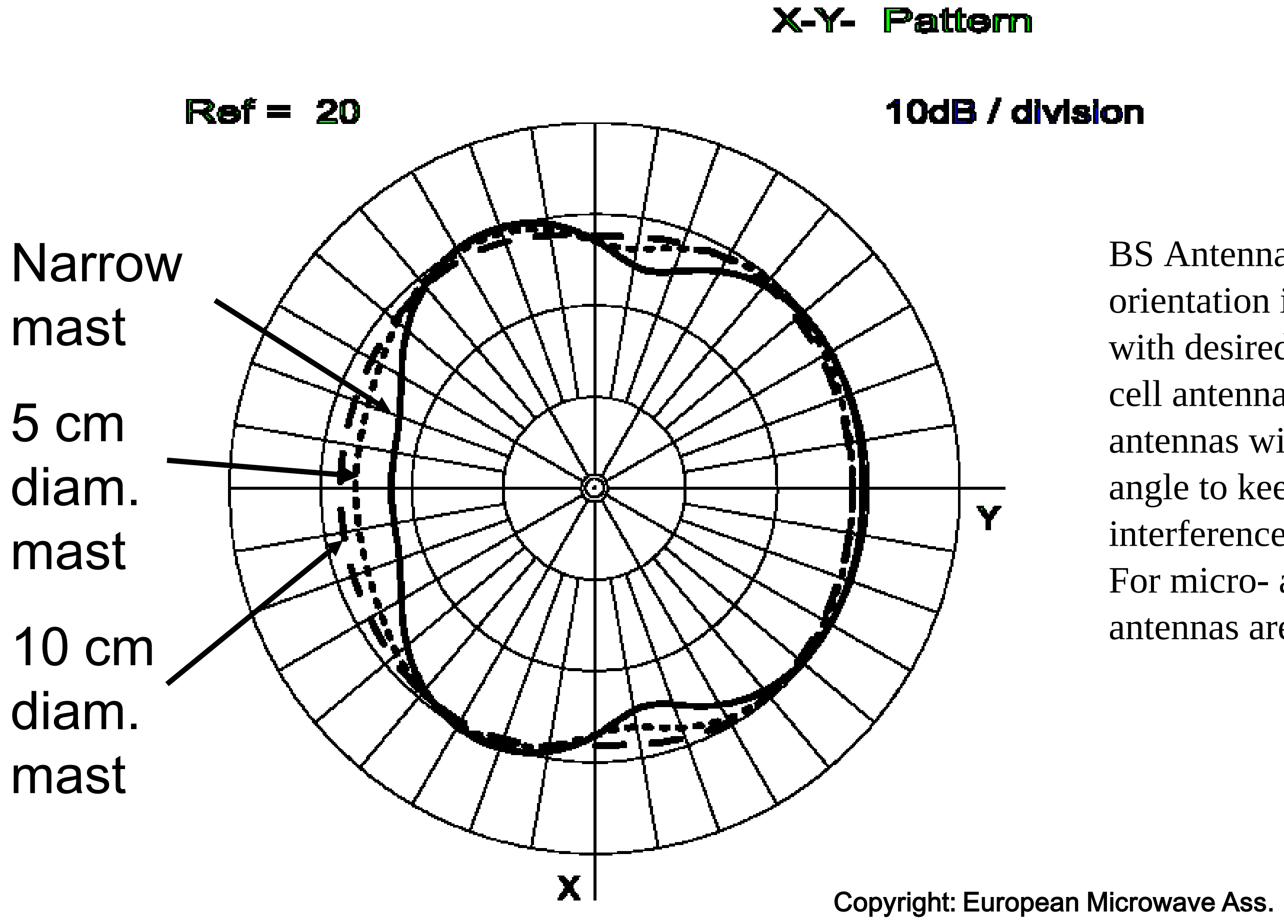


Up to around 10 dB difference, depending on person.

Significant Impact

Base station antennas

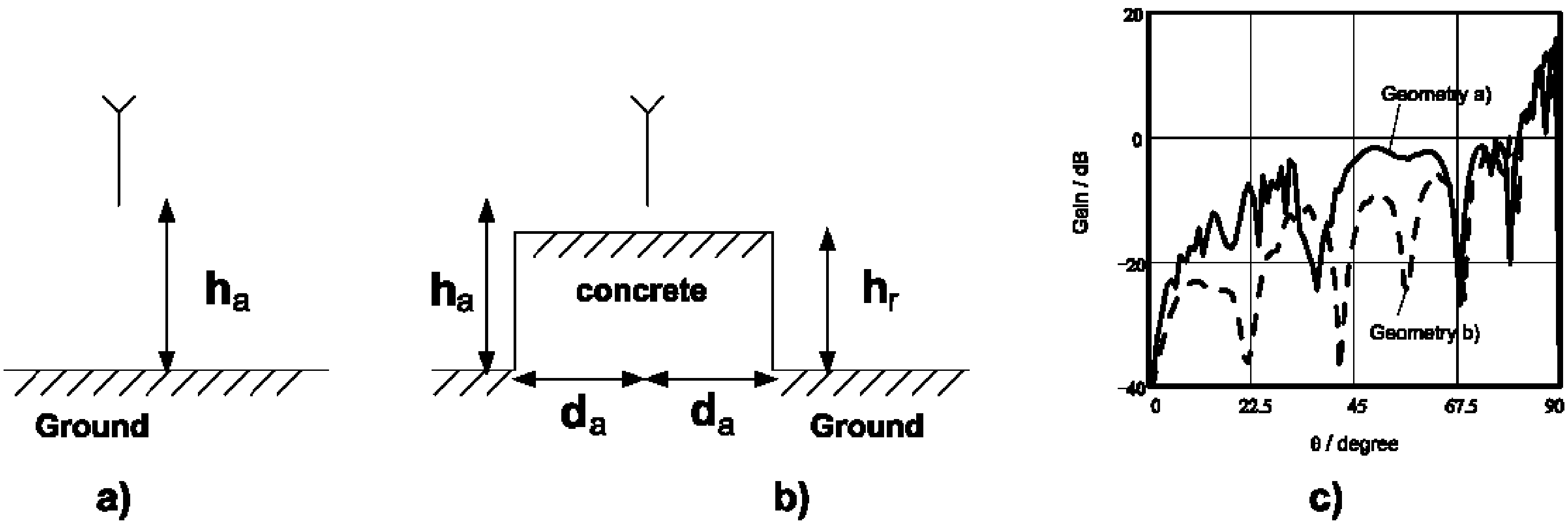
Base station antenna pattern affected by the mast (30 cm from antenna).



BS Antenna - placement and orientation is known, larger with desired pattern. Macro cell antennas are phased array antennas with a low elevation angle to keep adjacent cell interference to a minimum. For micro- and picocells, patch antennas are common

Base station antennas

Base station antenna pattern affected by a concrete foundation.



BS Antenna pattern impacted when antenna is not in free space or above an infinite conducting ground plane. Modern antenna analysis programs can take these effects into consideration if modeled.

Common antenna types

- Linear antennas (dipole, monopole)

normally constructed into antenna arrays

- Helical antennas
- Microstrip antennas
- PIFA and RCDLA antennas

Linear antennas (1)

- Hertzian dipole (short dipole)
  - Antenna pattern:

$$\widetilde{G}(\varphi,\theta) \propto \sin(\theta)$$

  - Gain

$$G_{\max} = 1.5$$

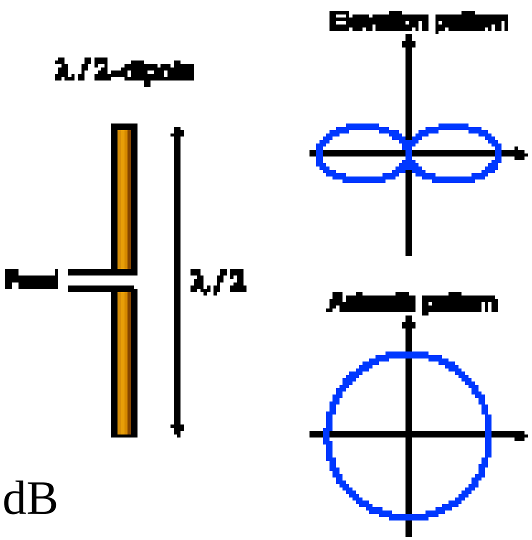
- λ/2 dipole (16 cm long @ 900 Mhz)
  - Pattern

$$\widetilde{G}(\varphi,\theta) \propto \frac{\cos\left(\frac{\pi}{2}\cos(\theta)\right)}{\sin(\theta)}$$

  - Gain (DIRECTIVE)

$$G_{\max} = 1.64 = 2.15 \text{ dB}$$

GdB dipole = GdB isotropic - 2.15 dB



Linear antennas (2)

- Radiation resistance of dipoles
  - Uniform current distribution

Loop antennas have a uniform current distribution but usually antennas that are so short compared to the wavelength will have a uniform current distribution

$$R_{\text{rad}}^{\text{uniform}} = 80\pi^2 (L_a/\lambda)^2$$

L_a is the wavelength of the antenna

  - Tapered current distribution

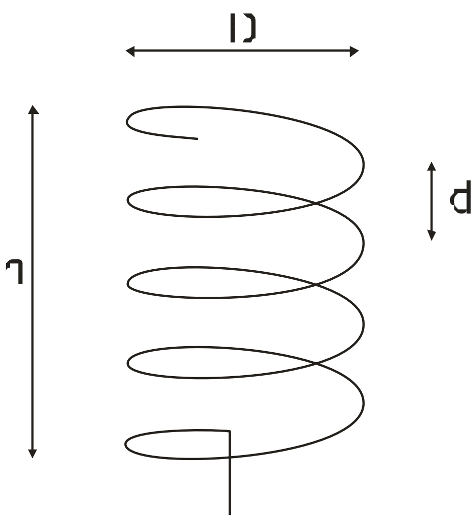
max i at feedpoint & linear decrease towards the end where i = 0 that is antennas that have a current and voltage distribution over their length such as a dipole or antennas that are sizable compared to the wavelength

$$R_{\text{rad}}^{\text{tapered}} = 0.25 R_{\text{rad}}^{\text{uniform}}$$

- Monopole over groundplane
  - Twice the gain of dipole (only radiates into half the space of a dipole antenna with the infinite ground plane visualized as the mirror image of monopole)
  - Half the radiation resistance of dipole 36.8 ohms, dipole 73 ohms
  - -- But all of this applies only for an infinite, perfectly conducting ground plane which is not realistic for the real world.

Helical antenna

- Combination of loop antenna and linear antenna
  - If dimensions much smaller than wavelength, behaves like linear antenna
  - Bandwidth, efficiency, and radiation resistance increase with increasing *h*



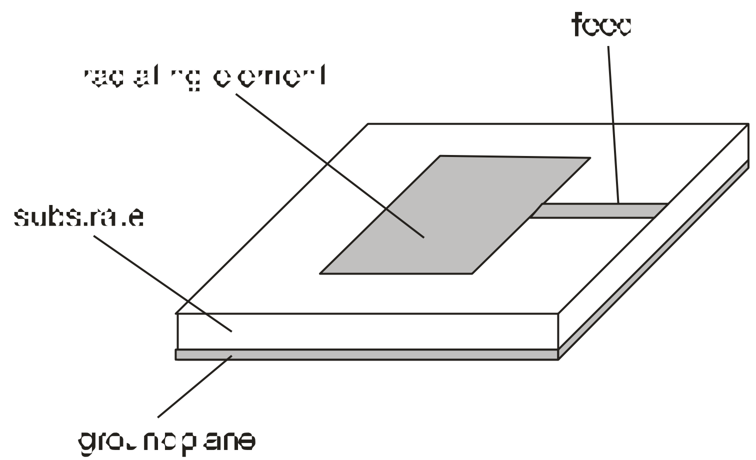
Microstrip antennas

- Dielectric substrate with ground plane on one side, and metallic patch on the other
- Properties determined by
  - Shape of patch: size must be at least

    $$L = 0.5\lambda_{\text{substrate}}$$

  - Dielectric properties of substrate

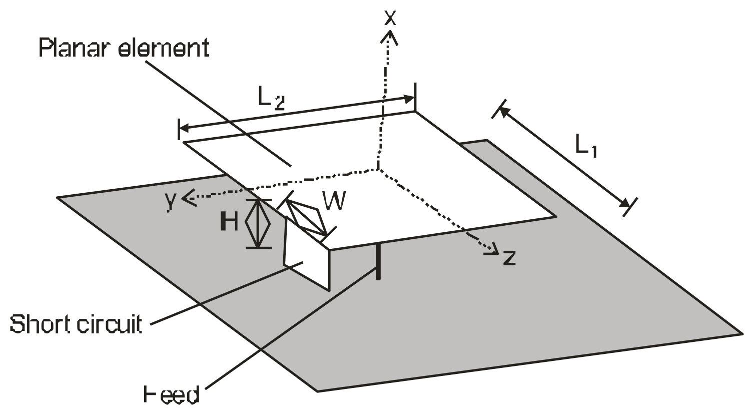
    $$\lambda_{\text{substrate}} = \lambda_0 / \sqrt{\varepsilon_r}$$



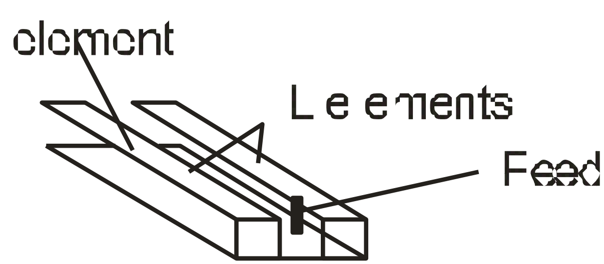
- can be feed with coax, microstrip or even electromagnetic coupling (aperature-coupled)
- low efficiency, low bandwidth but can be easily integrated into the MS case

PIFA and RCDLA

- PIFA (Planar inverted F antenna) Microstrip

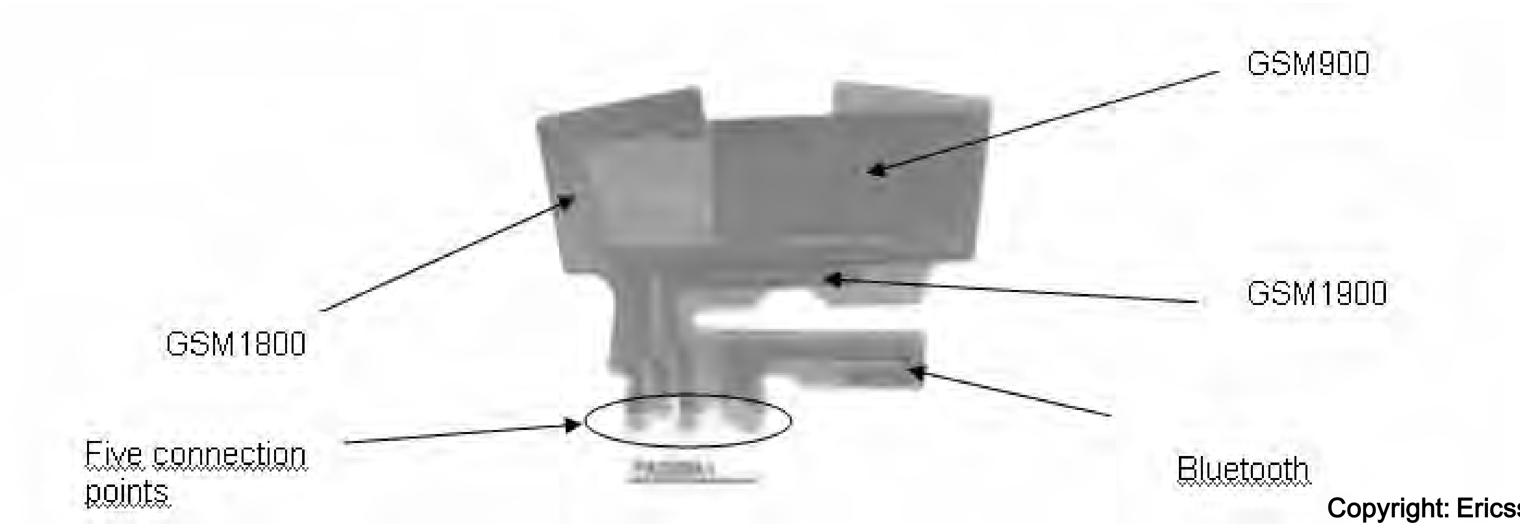


- RCDLA (Radiation-coupled dual-L antenna improved bandwidth



Multiband antennas

- For many applications, different wireless services need to be covered
- Example: cellular handset
  - GSM 900
  - GSM 1800
  - GSM 1900
  - Bluetooth (2.4 GHz)



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