Millimetre Waves for 5G (And Beyond) Mobile Networks

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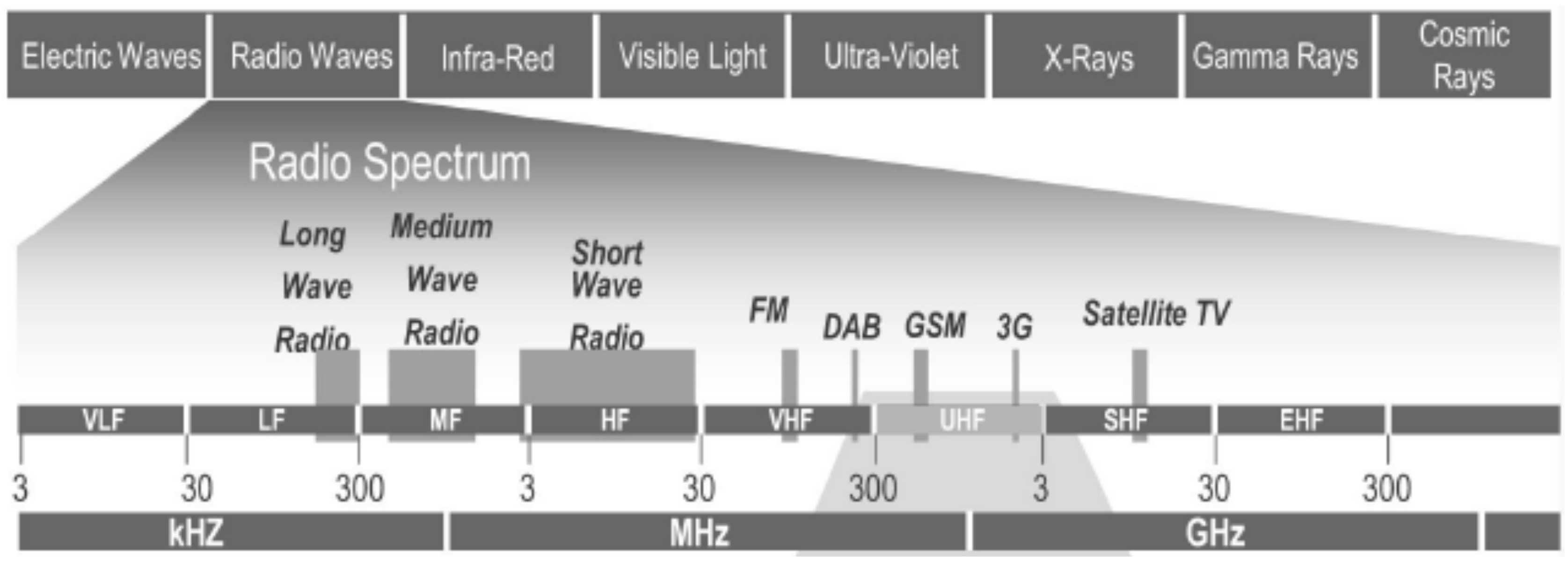
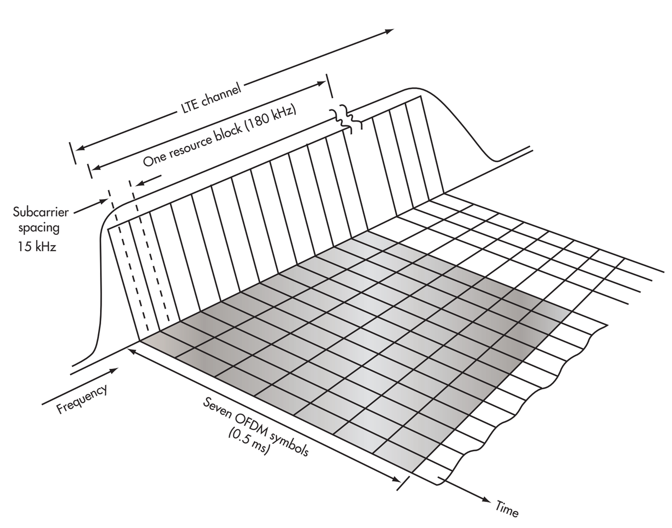
Basics

- Fraction of electromagnetic spectrum used for radio communication: 3 kHz to 300 GHz
- Ultra-high frequencies (UHF): 300 MHz to 3 GHz (wavelengths of 1 m to 10 cm)
- Mobile network bands: 800 MHz, 1900 MHz, 2600 MHz
- WiFi: 2.45 GHz and 5.8 GHz (ISM bands)
- Microwave oven: 2.45 GHz (ISM band)
- *Millimetre waves:* 30 GHz to 300 GHz (wavelengths of 1 cm to 1 mm)



Motivation



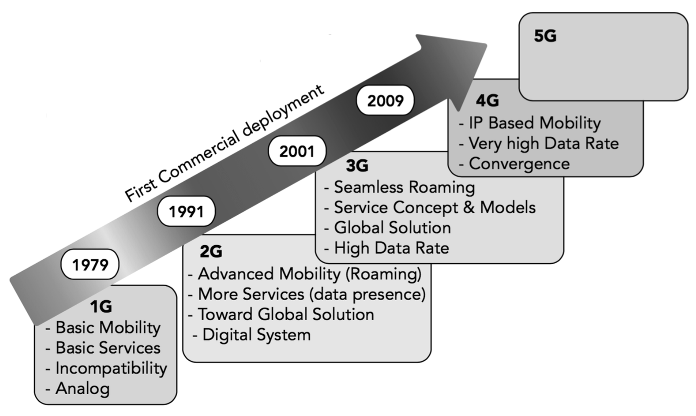
High data rates in today's 4G LTE mobile networks (e.g. 300 Mbit/s) are achieved by *broadband* communication (OFDM): multiple *subcarriers* with slightly different frequencies (15 kHz spaced) carry information to the user in parallel. Bandwidths range from 1.4 MHz to 20 MHz (72 to 1320 subcarriers).

In order to achieve higher data rates (e.g. 30 Gbit/s) in 5G, larger bandwidths are necessary. However, the bands used for 4G (800 MHz, 1900 MHz, 2600 MHz) are already fully utilized.

$\longrightarrow$ **New frequency bands are needed in order to support higher data rates.**

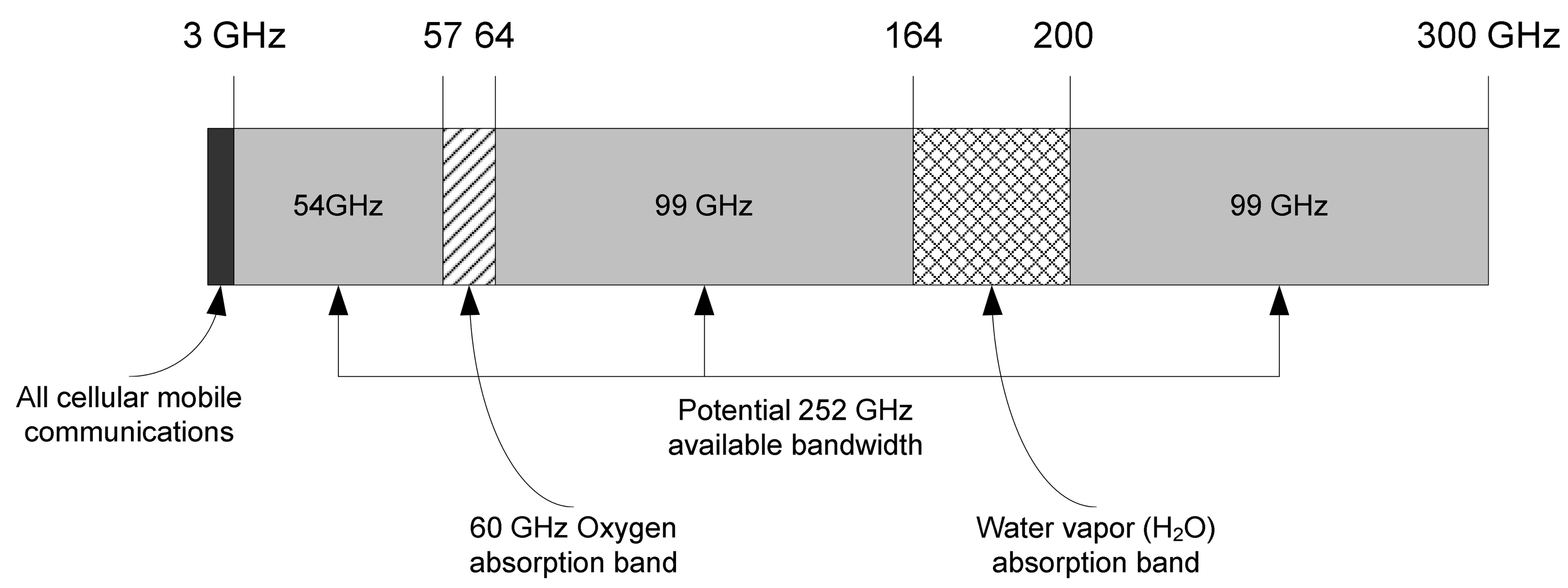
From 1G to 5G

- 1G (AMPS), 2G (GSM, GPRS, EDGE), 3G (UMTS, HSPA, HSPA+), 4G (LTE, LTE-A)
- A new "generation" roughly every decade
- Since 1999 standardised by 3GPP
- 5G standardisation work will start in 2016 (3GPP Release 15)
- First deployments of 5G expected in 2020



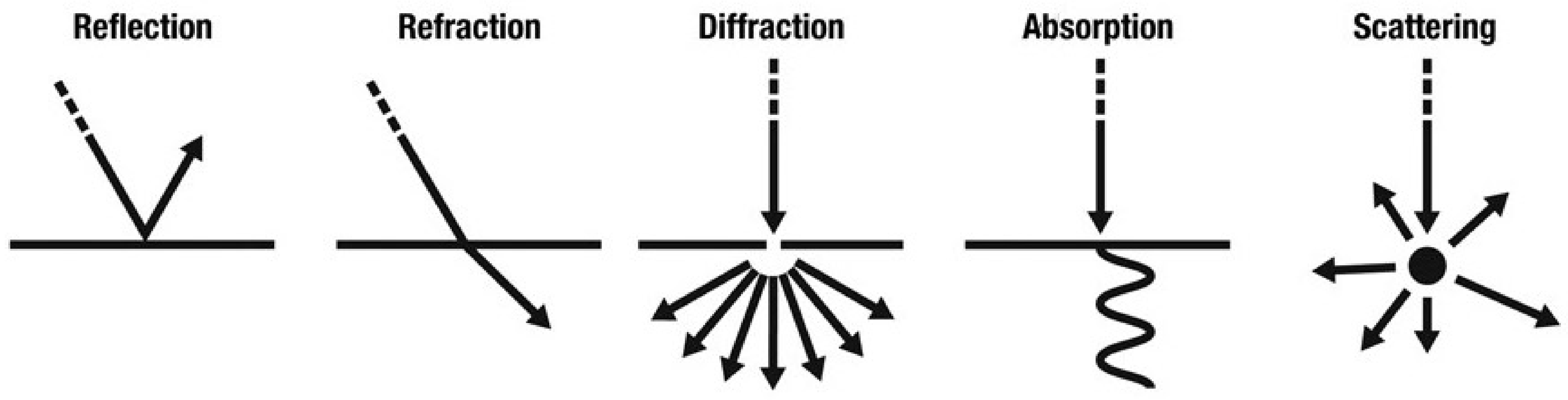
Millimetre Waves

- Extremely-high frequencies (EHF): 30 GHz to 300 GHz
- Wavelengths from 1 cm to 1 mm (hence the name *millimetre* waves)
- Largest part of this spectrum is *unlicensed* and *unused*
- Potential of *huge bandwidths* for the mobile network (>100 GHz)
- To compare, total bandwidth available to LTE today: several 100 MHz
- Millimetre waves have to date been considered impractical for radio communication



Characteristics of Millimetre Waves

Main difficulty to the application of millimetre waves are their propagation characteristics that are very different than the ones of UHF waves:



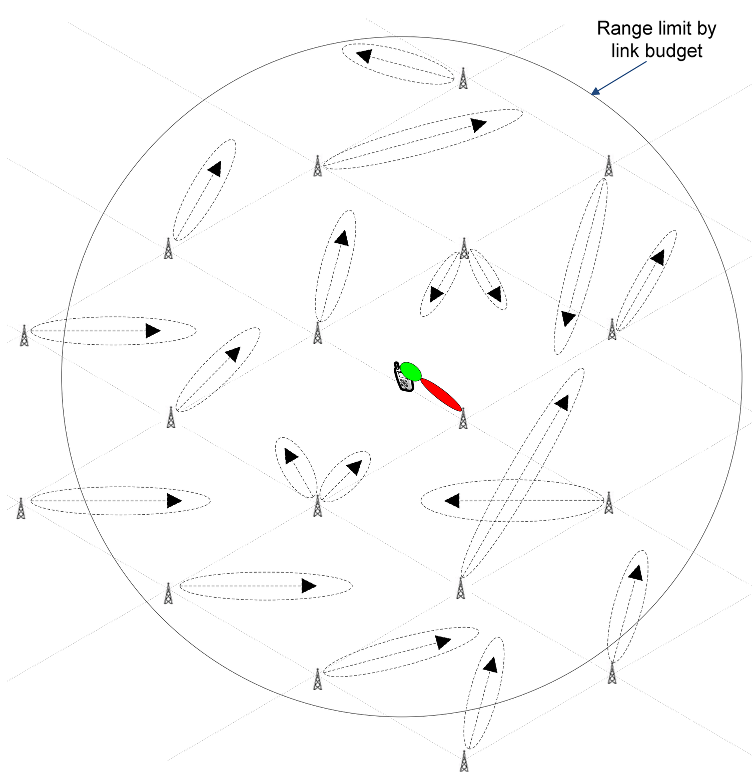
In general, the higher the frequency of an electromagnetic wave, the larger the portion of the energy that is absorbed by obstacles.

That is, for millimetre waves, there is:

- Higher path loss (signal fades out very quickly)
- Stronger shadowing (dense obstacles, e.g. walls, may block a signal completely)
- Higher penetration losses (signal is attenuated strongly by obstacles, e.g. human body)

Implications of Millimetre Wave Propagation Characteristics

Cell size and form: no omnidirectional antennas can be used, because the path loss is too high for achieving an acceptable range with a low transmit power. Instead, *beams* are formed and pointed directly at the individual users. In this way, ranges of 200 m can be achieved.

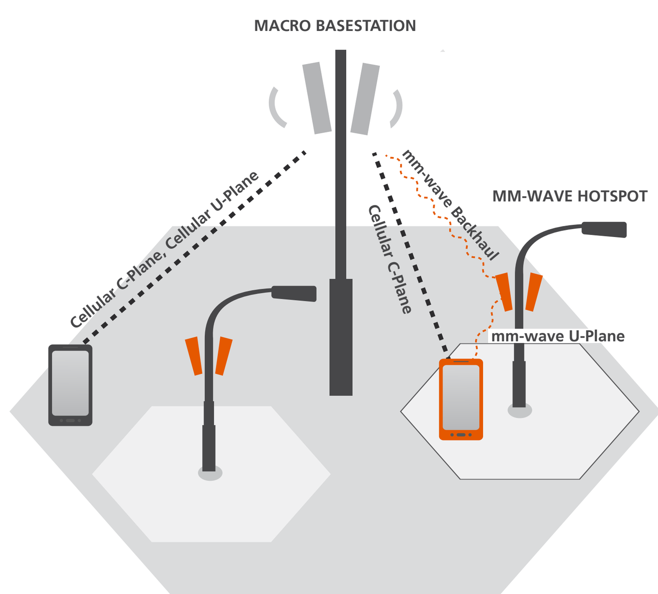


Multiple input multiple output (MIMO): for supporting user-specific beams, the number of antennas of the base station must be larger than the number of users connected to the base station. In *massive MIMO*, this ratio is typically >100.

Line-of-sight (LOS): because of the high penetration loss and shadowing, in most cases a LOS between terminal and base station is required.

Reflection: non-LOS communication might possible by leveraging reflected paths instead of the direct LOS path (e.g reflection of the signal at a wall around the corner of a building).

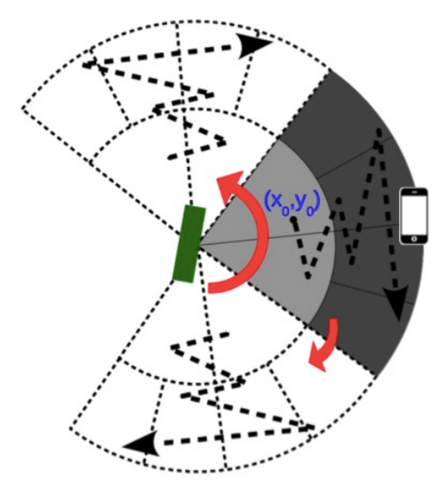
Integration With Macro Cells



- Decoupling of user plane (U-plane) for data transmission, and control plane (C-plane) for signalling
- Two-layered architecture: multiple millimetre wave (mmWave) cells inside the coverage of a macro cell
- U-plane via mmWave cell, and C-plane via macro cell (e.g. 800 MHz)
- Backhaul from mmWave cell to macro cell can be achieved by millimetre wave beam as well
- Macro cell has overview over "spotty" mmWave cell environment, and can assist *connection establishment* between terminals and mmWave cells, *load balancing*, and *mobility* (handovers, cell reselections)

Cell Discovery

- In order for a terminal to connect to a mmWave cell, the terminal and base station must first *discover* each other, i.e. pointing their beams towards each other
- Base station can locate terminals by sweeping with its beam over different sectors of its coverage area
- Causes a significant delay to the association process
- Possibility to speed up by conveying approximate terminal location to mmWave cell (possibly through macro cell)



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