COMP3310/6331 – #5

Media: Wireless

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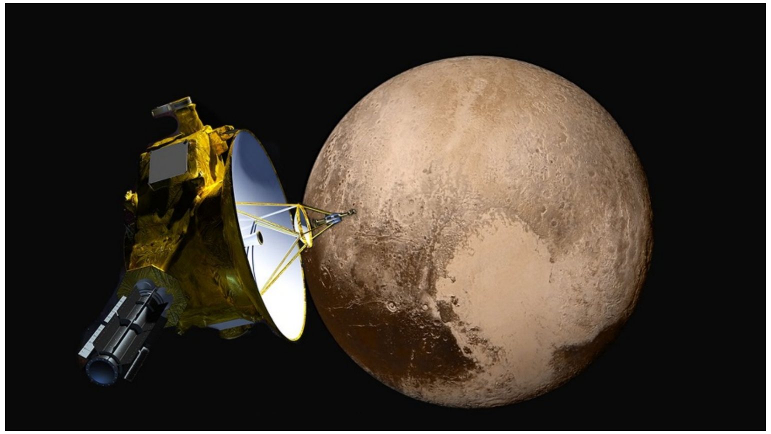
Wireless Characteristics



- When a cable just won't do…
  - Too far, too rough, OR too <u>mobile</u>, …
- Can go a very, **very** long way
  - Just need appropriate kit at both ends.
- Sensitive to "atmospheric" conditions and EM interference, …
- We talk in both frequency and wavelength
  - They both matter

Wireless >> WiFi

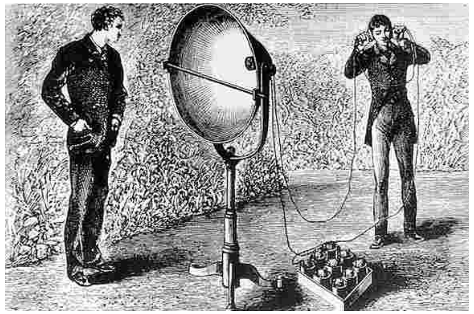
A whole spectrum

Radio Frequencies

Frequency	Wavelength	Designation	Abbreviation[6]	IEEE bands[7]
3–30 Hz	10^5–10^4 km	Extremely low frequency	ELF	-
30–300 Hz	10^4–10^3 km	Super low frequency	SLF	-
300–3000 Hz	10^3–100 km	Ultra low frequency	ULF	-
3–30 kHz	100–10 km	Very low frequency	VLF	-
30–300 kHz	10–1 km	Low frequency	LF	-
300 kHz – 3 MHz	1 km – 100 m	Medium frequency	MF	-
3–30 MHz	100–10 m	High frequency	HF	HF
30–300 MHz	10–1 m	Very high frequency	VHF	VHF
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency	UHF	UHF, L, S
3–30 GHz	10–1 cm	Super high frequency	SHF	S, C, X, Ku, K, Ka
30–300 GHz	1 cm – 1 mm	Extremely high frequency	EHF	Ka, V, W, mm
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF	-

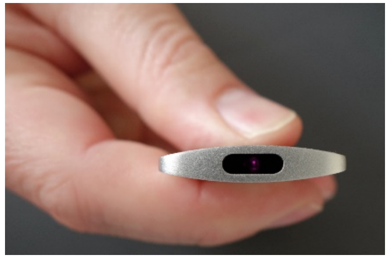
Free Space Optics

Heliograph



Photophone

Gb laser



IR/RF remote

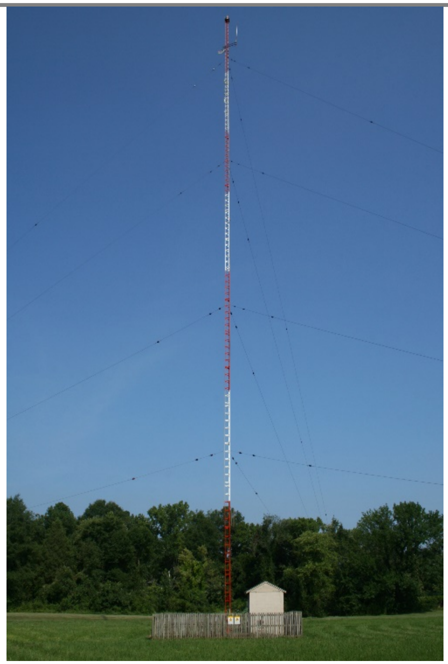
LiFi

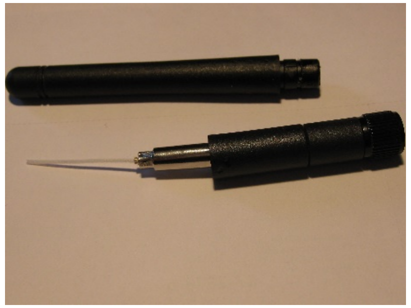
Guidance

- Wireless is an **unguided** transmission
  - At best a directed (focussed) transmission
    - Signal divergence, even for a laser
  - Once you send it out, it keeps going
    - Or bounces around inside a box/room
- Free space is a broadcast medium
  - You have **no** control over other senders
- It is a shared medium
  - Very shared. **Anybody** can listen. And you won't know.

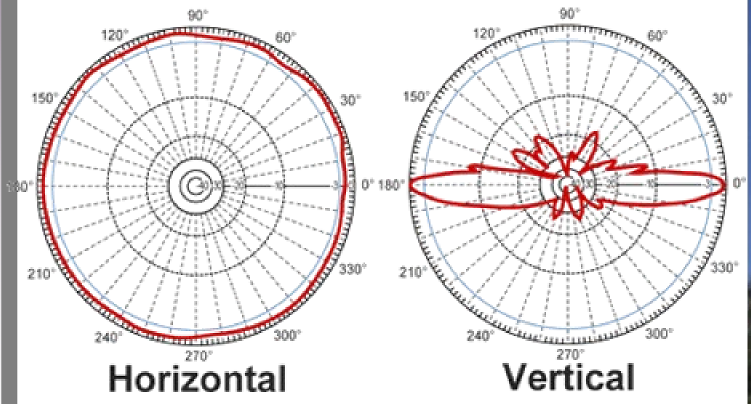
Antennas

- RF Wireless needs antennas, for RX and TX
  - If you want to Transmit and Receive = a <u>Transceiver</u>
  - Antennas are O[wavelength] in size (for TX)
    - Compressed with clever folding, coiling and other tricks
- Your body is a great antenna
  - Wireless can be bad for your health
    - This can also be massively overstated



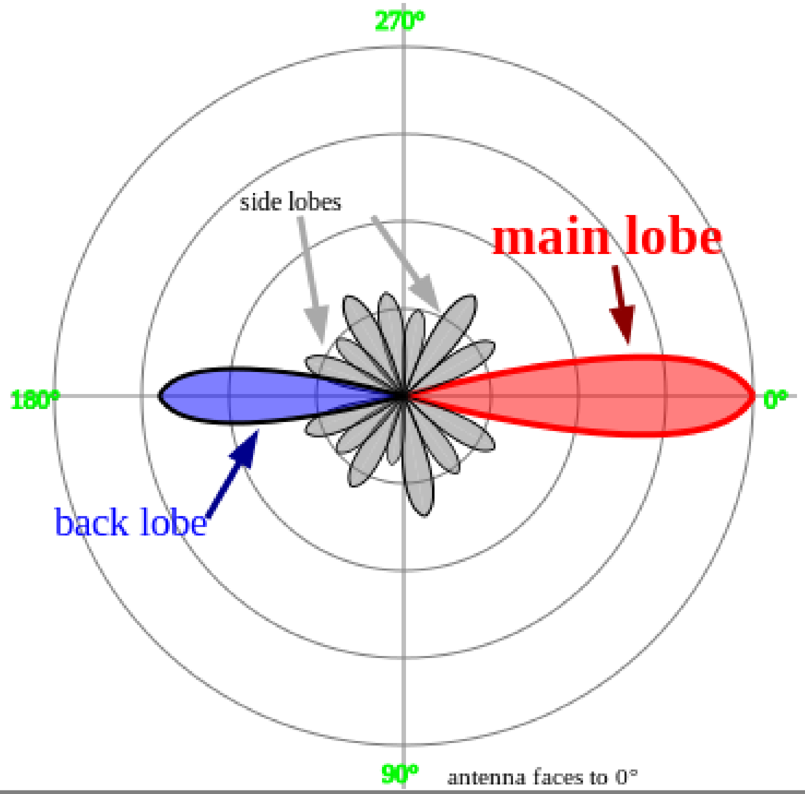


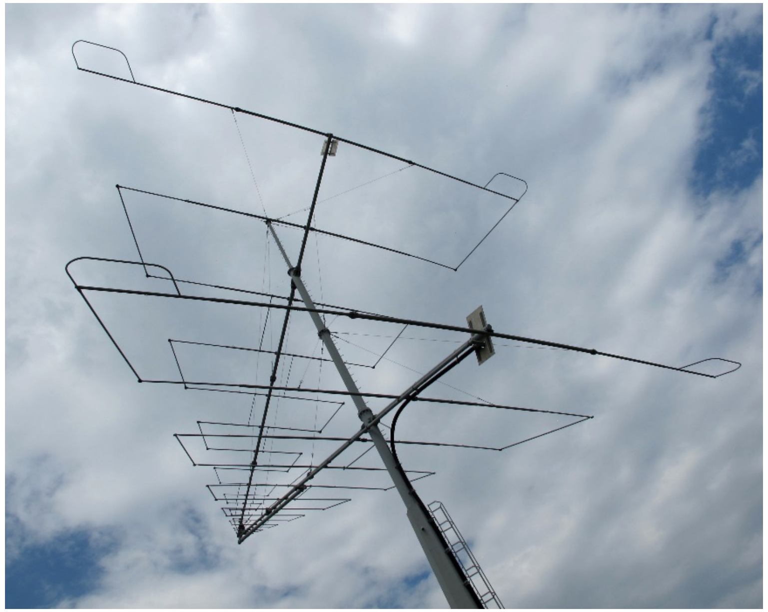
Antennas have directions



Antennas - 3

- Omnidirectional and directional
  - Straight wire: TX/RX in all perpendicular directions
  - A combination of wires – gets complex





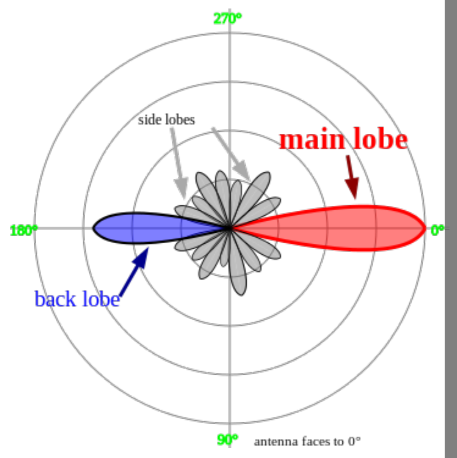
More dB…

- Remember dB? (20dB = 100:1, -30dB = 1:1000)
- Lots of multiplying factors – in log space they become sums

- Power in **dBm**: 0dBm = 1mW.
  - *So 20dBm = 100mW.*
  - *And -70dBm = 0.0000001mW*

- Gains in **dBi**: comparison against an “isotropic transmitter”
  - *Same amount of energy into a narrower beam, in all 3 dimensions*

- *(There are other dB’s)*



Link budgets

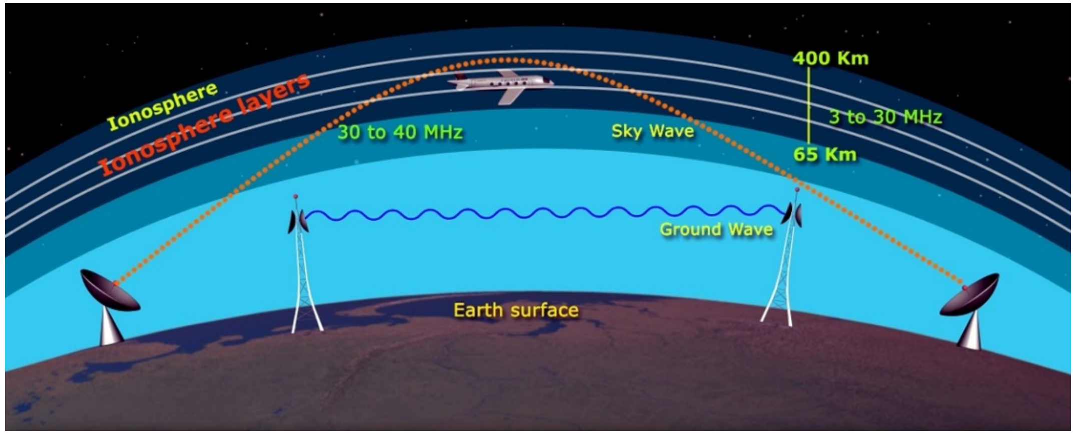
- Start with received power (what do you need for reliable comms?)
  - Add up all your losses/gains
    - TX and RX antenna (gain)
    - Path issues (loss)
    - TX and RX equipment/cabling issues (loss)
  - Calculate your transmit power, based on what you need to receive

$$P(rx)=P(tx)+G(tx)-L(tx)-L(fs)-L(m)+G(rx)-L(rx)$$

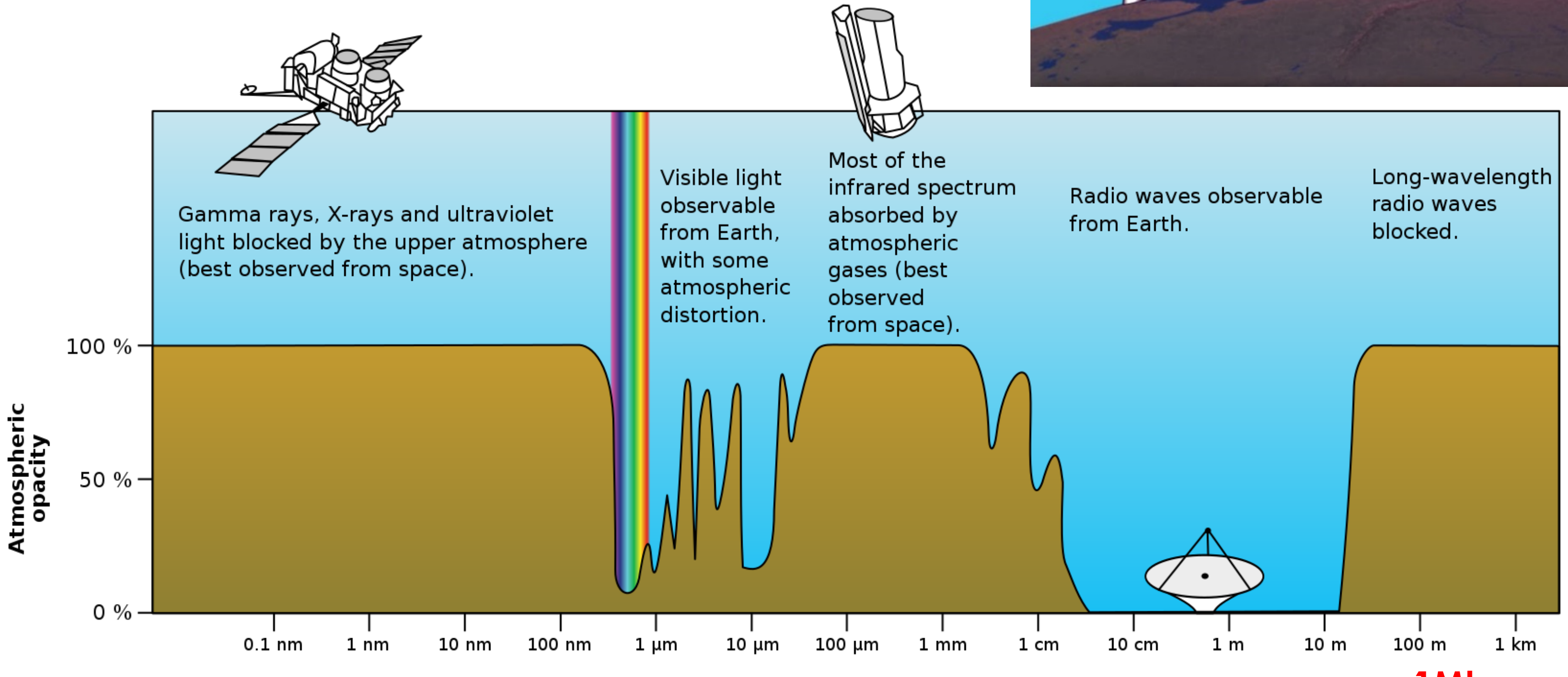
  - P=power we have/need
  - G=gain: antenna
  - L = losses: equipment, free-space path, media,

Atmospheric passbands

Just like fibre



As seen from space!



2.4GHz 100Mhz 1Mhz

Environmental effects

- Think optically, same applies to radio; outdoors and indoors
- **Absorption** (attenuated signals)
  - Gases, vapours, dust, pollution
  - Structures and terrain
- **Noise** (extraneous signals)
- **Reflection, refraction, diffraction** (redirected signals)
  - Temperature differences
  - Turbulence
  - Structures and terrain
    - **Multipath reception**

All of these vary with time

Multipath?

U.S. Patent Jan. 23, 1996 Sheet 1 of 8 5,487,069

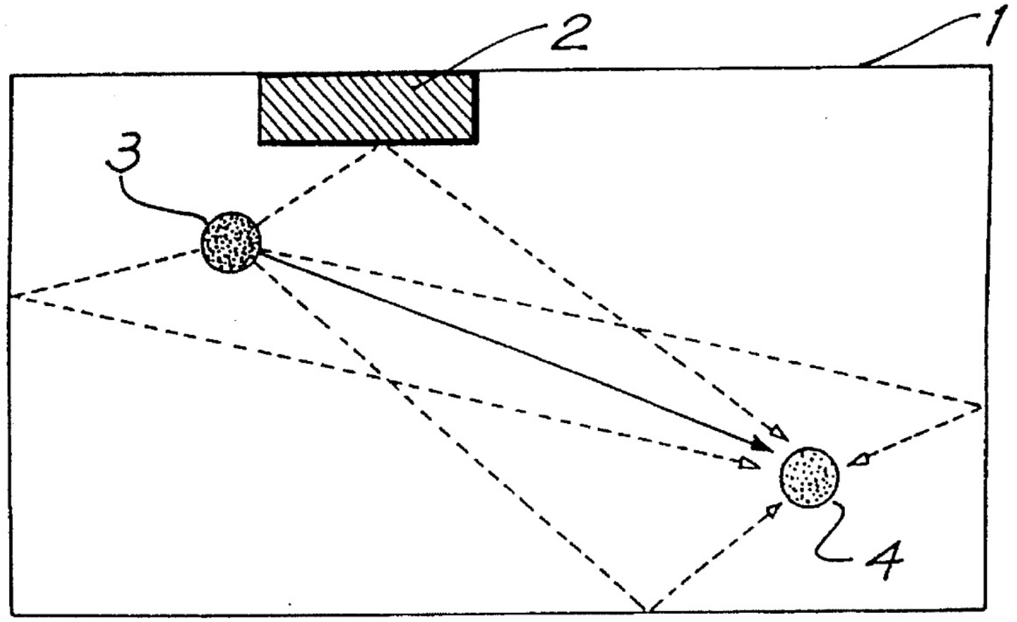


FIG. 1

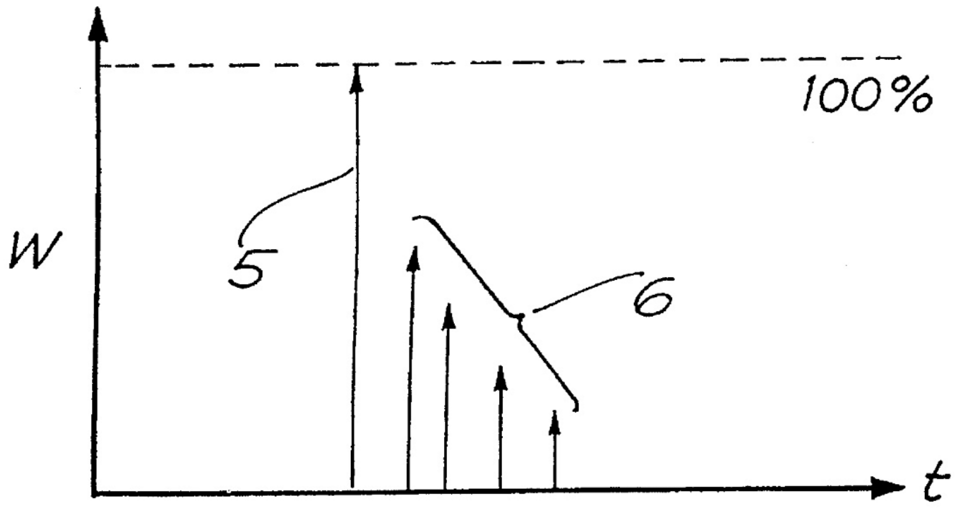


FIG. 2

Doing better, in changing conditions

- Two main approaches:

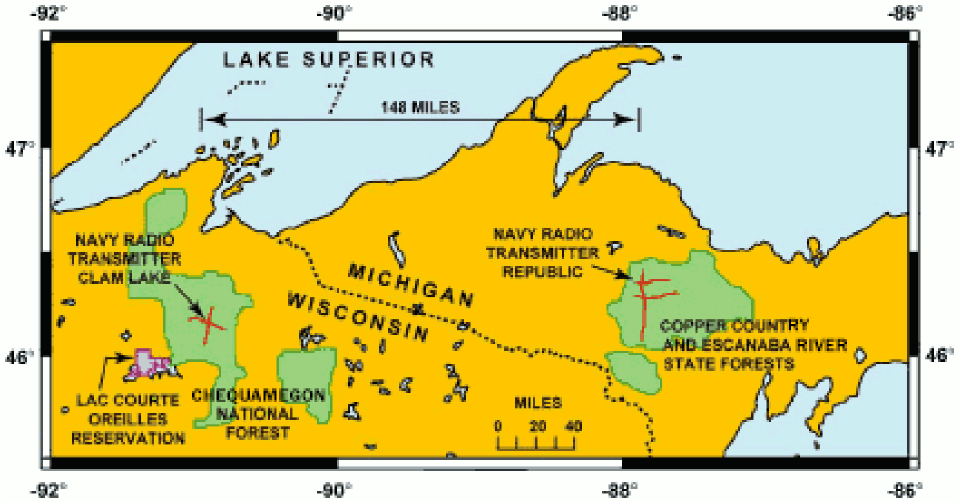
- Be <u>clearer</u>:
  - Shout louder: send more power
  - Slow down: decrease your bitrate

- Be <u>smarter</u>
  - Step around the problem: frequency hopping
  - Focus your efforts: beam-shaping

- You can negotiate these in real-time

Wavelength and functionality

- Long wavelengths can
  - Go round corners (buildings, mountains)
  - Go through walls
  - Go through water (submarines)
    - VLF (3-30kHz) = 20m down
    - ELF (3-300Hz) = ~400m
    - TX antennas can be 20+km wide
      - This is one-way! And slow…
    - Acoustic TX/RX can go km



- Shorter wavelengths need **Line of Sight** (not site)
  - Don't bend or penetrate as well
- Short wavelengths = High frequencies
  - High datarates

Pick your signal…

- Chosen together to suit application need
  - **Frequency** determines data-rate, transmitter/receiver antenna size, penetration, …
  - **Power** determines how far you can go (the range)

- Consider the differing requirements of
  - RFID/NFC (tap-and-go)
  - Room, building, city, country phone coverage
  - Point-to-point vs Area coverage

- So I can just pick something and start broadcasting??
  - Yes!
  - *But you may get into trouble…*

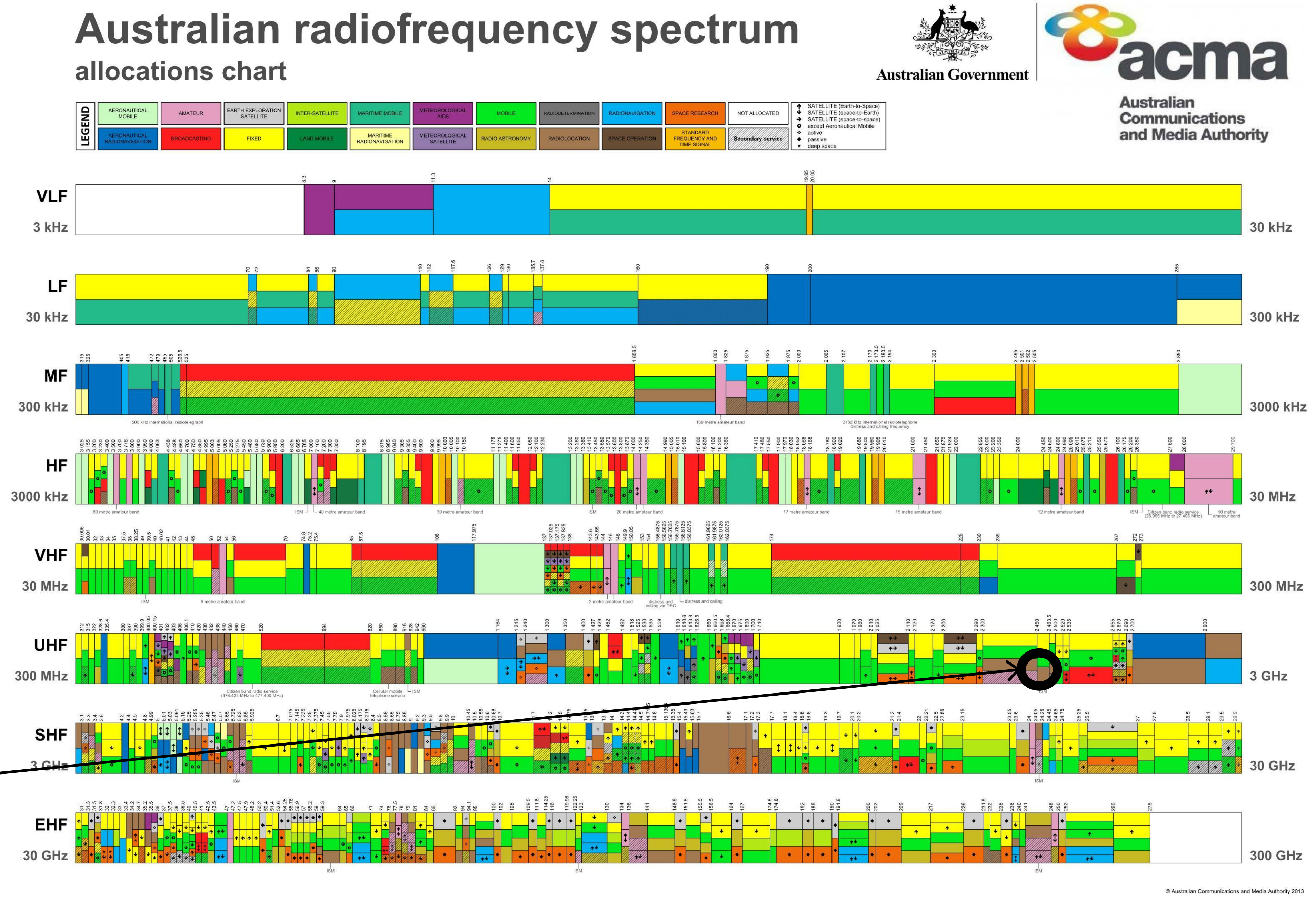
Spectrum allocation

Broadcast, has to be shared

ITU standard+

- Licenses
- Power limits
- Directions
- Locations
- ISM bands

(Industry, Science, Medicine)



Channel allocation

- **Spectrum allocation** sets aside a frequency space for a purpose
- Within each spectrum space, there is **channel allocation** (and gaps)
  - E.g. FM Radio (85-108 MHz) in Canberra has 0.8Mhz channel spacing
  - Digital TV uses 7MHz of bandwidth/channel, spaced accordingly
  - Wifi, (Bluetooth) have various channels, in the ISM bands
- Established by the appropriate standards bodies in each community
- Other communities are just **noise**…

Network design

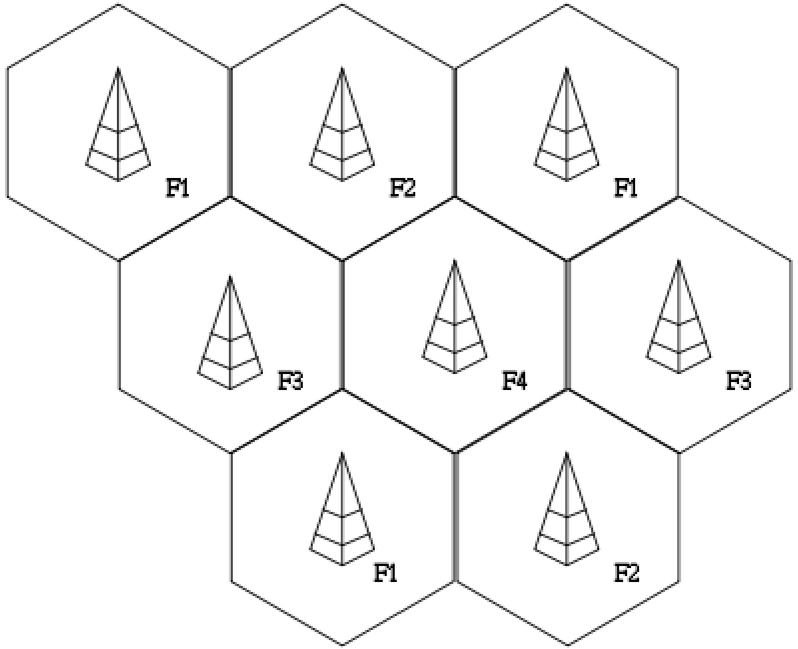
- Transmission A->B only gets you so far
  - Attenuation, noise, …
- Increase range with:
  - Repeaters
  - Taller towers
    - See further
  - Mix and match
    - Link wireless to wired
  - Need their own underlying network paths, power, …
    - Where does a tower forward a signal it receives?

Terrestrial wireless

- Fixed vs mobile clients
  - Directional - Tower-to-tower
  - Broadcast – Tower-to-mobile

- Mobile+cellular = “cell handover”
  - Inter-tower comms

- Smart phones:
  - 4G (800-2200MHz),
  - Wifi, Bluetooth (2.4GHz, 5GHz),
  - GPS (1200-1600MHz),
  - FM radio (100MHz)



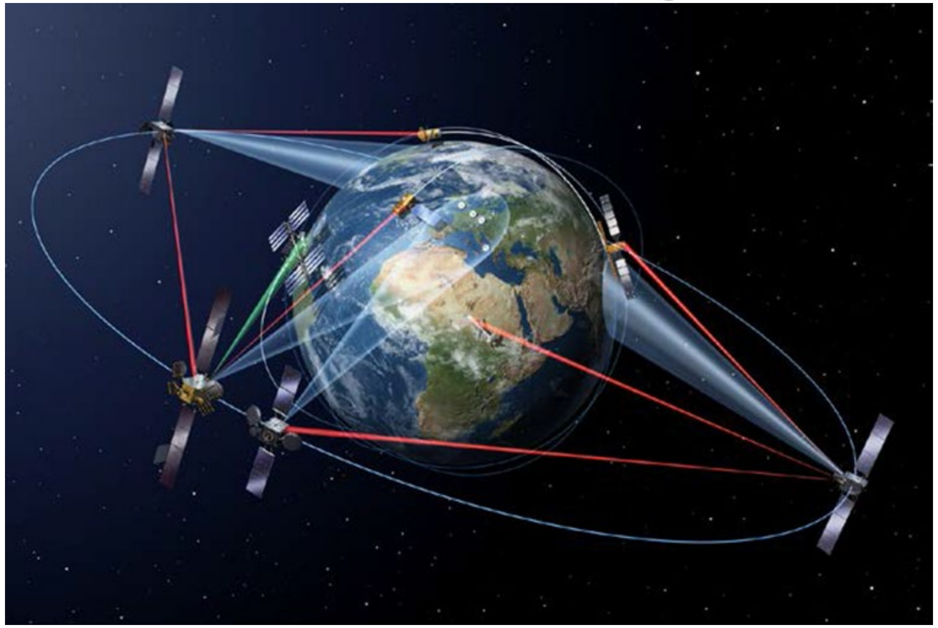
Space wireless

- Satellite-to/from-ground
- Satellite-to-satellite

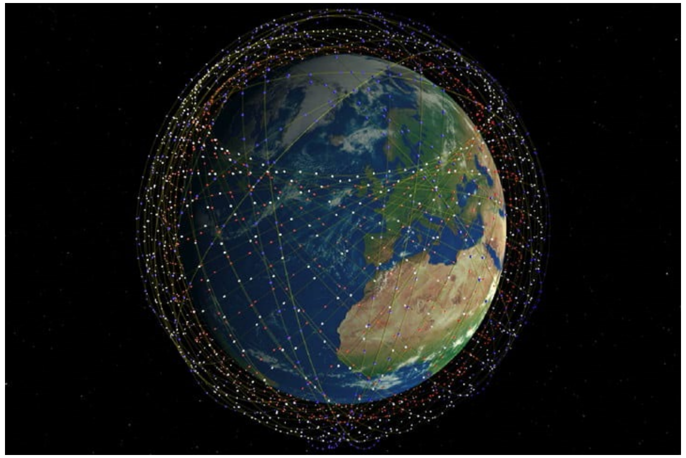
- Ground/space switching

- Orbits yield a moving transceiver
  - Geostationary Orbit = 36,000 km, 1 day/orbit
  - LEO = 400 km, = 90 min/orbit = 2 min per pass
    - Introduces tracking issues, or broad-gain antenna

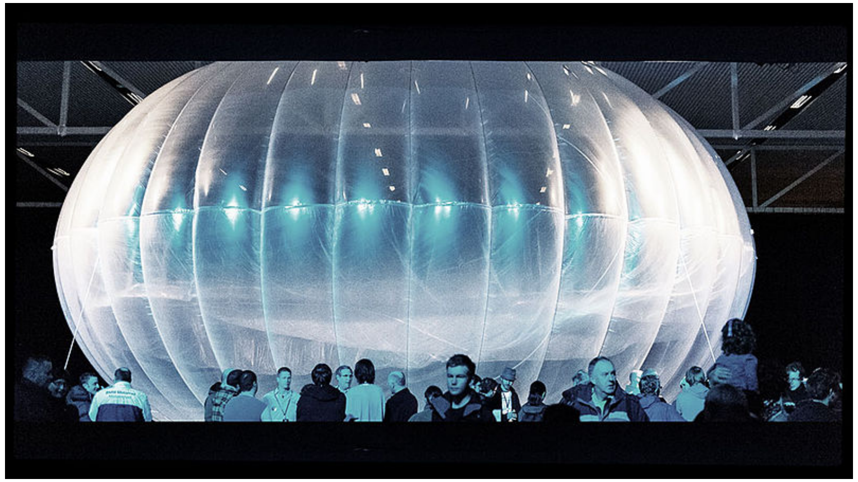
- High delay, potentially
  - 250ms to Geostationary and back



Between Earth and Space



- Very LEO – e.g. SpaceX Starlink
- In-between
  – Atmospheric transceivers – balloons, drones, blimps, …
    - Stable-ish locations, great coverage area
    - Power and station-keeping are a challenge



Deep space

- Moon, Mars, Jupiter, Saturn
- Pluto, MU69 and further
  - Very loud TX
  - Very faint RX
  - Receiver moving at 190 km/sec…
  - Delays measured in days…