

Radio Frequency, Band and Spectrum

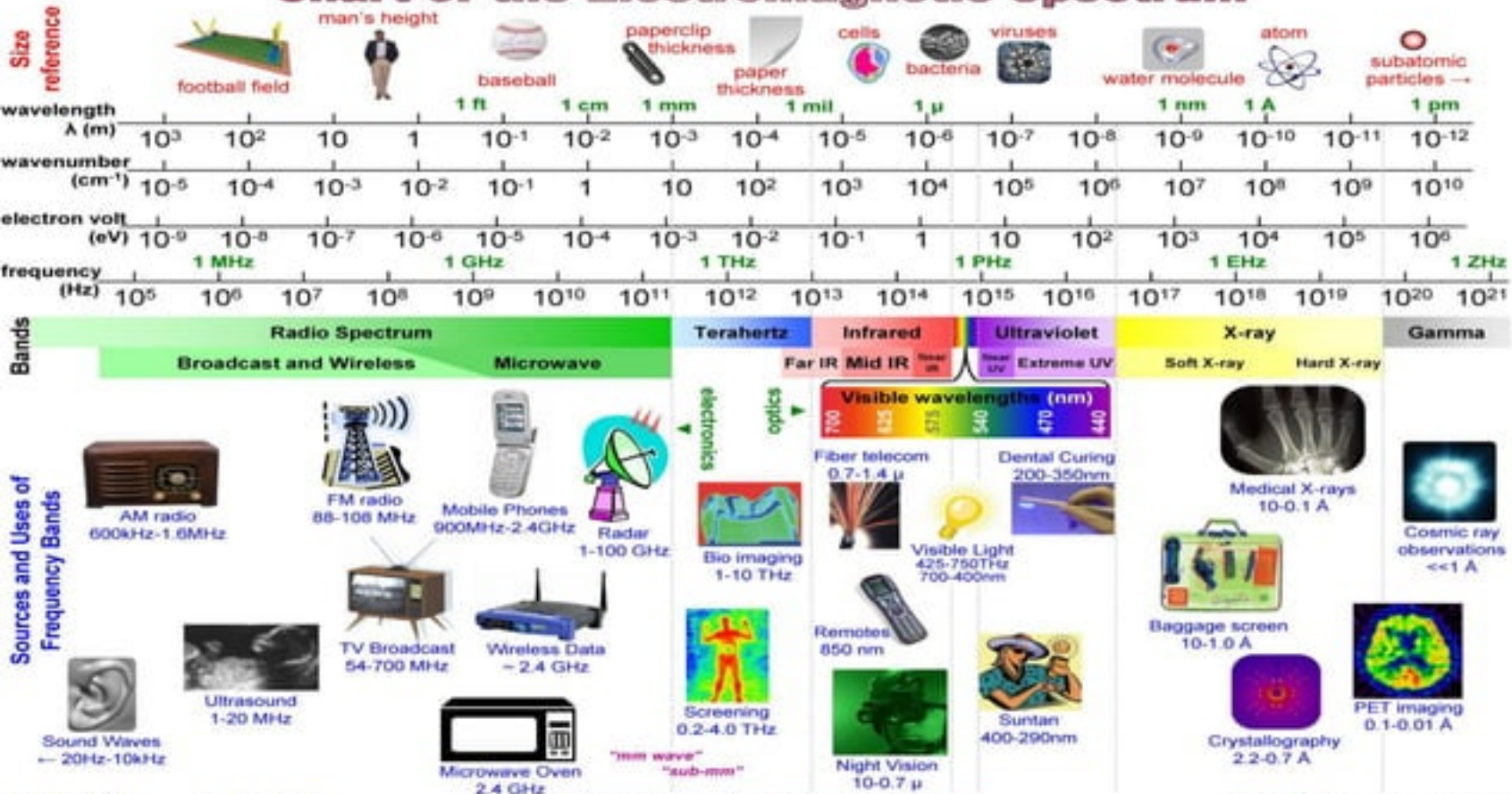
Before we begin

This video provides a very simplistic explanation for a very complex topic.

Spectrum

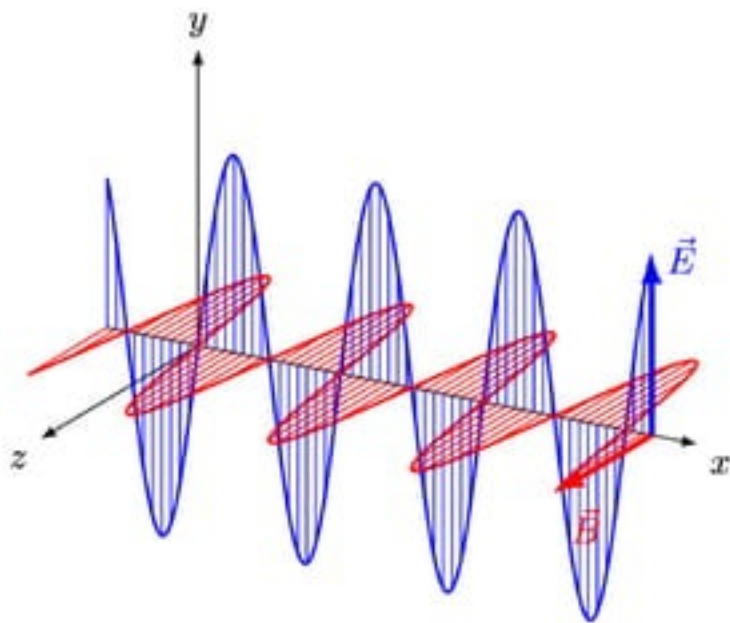
- A Spectrum (plural 'spectra' or 'spectrums') is used to classify something on a scale between two extreme points. For example:
 - The 'political' spectrum consisting of extreme left and extreme right and different ranges in between
 - The 'socio-economic' spectrum comprising of working class, middle class and upper class.
- In this video we will look at 'Radio' spectrum which is part of 'Electromagnetic' spectrum.

Chart of the Electromagnetic Spectrum



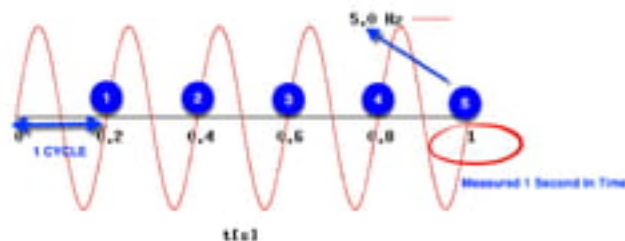
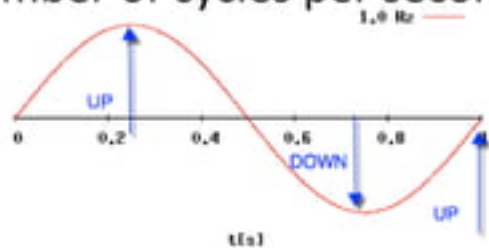
$$\lambda = 3 \times 10^8 / \text{freq} = 1 / (\text{wn} \times 100) = 1.24 \times 10^{-4} / \text{eV}$$

Electromagnetic Waves



What is 'Frequency'?

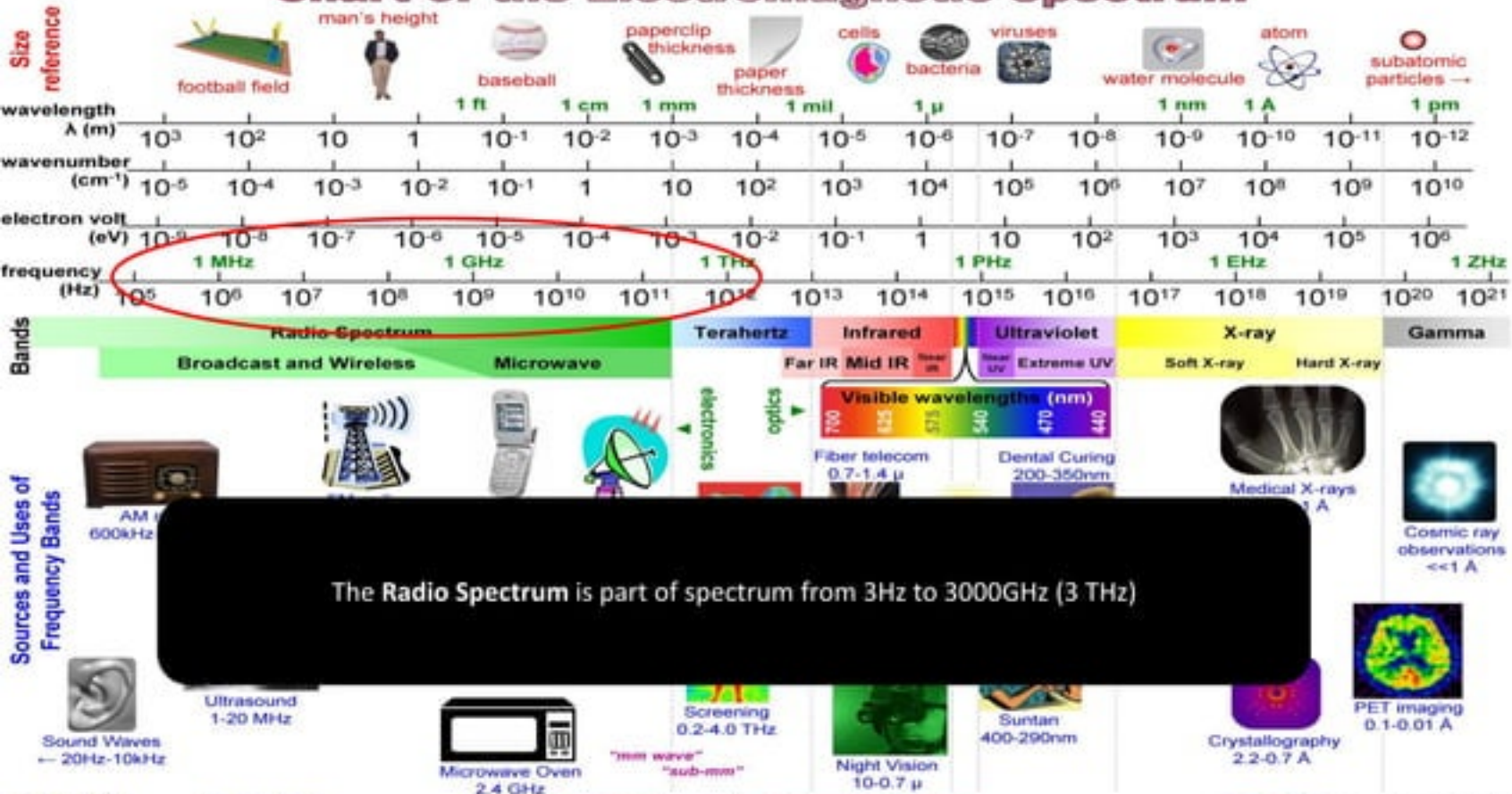
- Radio Frequency is a electromagnetic wave using AC (Alternating Current).
- "frequency" is something that happens over and over and over again.
 - It is very frequent, consistent, and repetitive
- Frequency is the number of times a specified event occurs within a specified time interval. A standard measure of frequency is hertz (Hz) – number of cycles per second



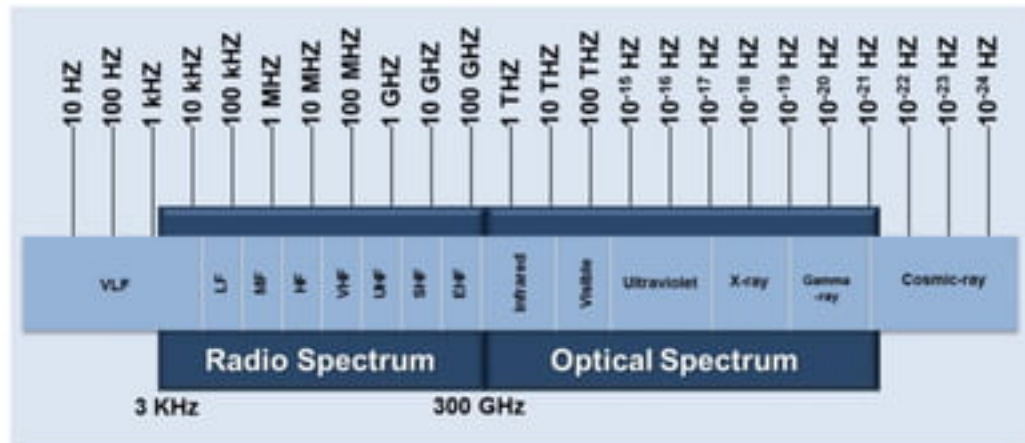
The Electromagnetic Spectrum

- The electromagnetic spectrum is a collective term to refer to the entire range and scope of frequencies of electromagnetic radiation, from 3 Hertz (written as Hz) to 300 Exahertz (300,000,000,000,000,000,000 Hz)
- 1000 Hz = 1 kilo Hz (kHz)
- 1000 kHz = 1 Mega Hz (MHz)
- 1000 MHz = 1 Giga Hz (GHz)
- 1000 GHz = 1 Tera Hz (THz)
- 1000 THz = 1 Peta Hz (PHz)
- 1000 PHz = 1 Exa Hz (EHz)

Chart of the Electromagnetic Spectrum

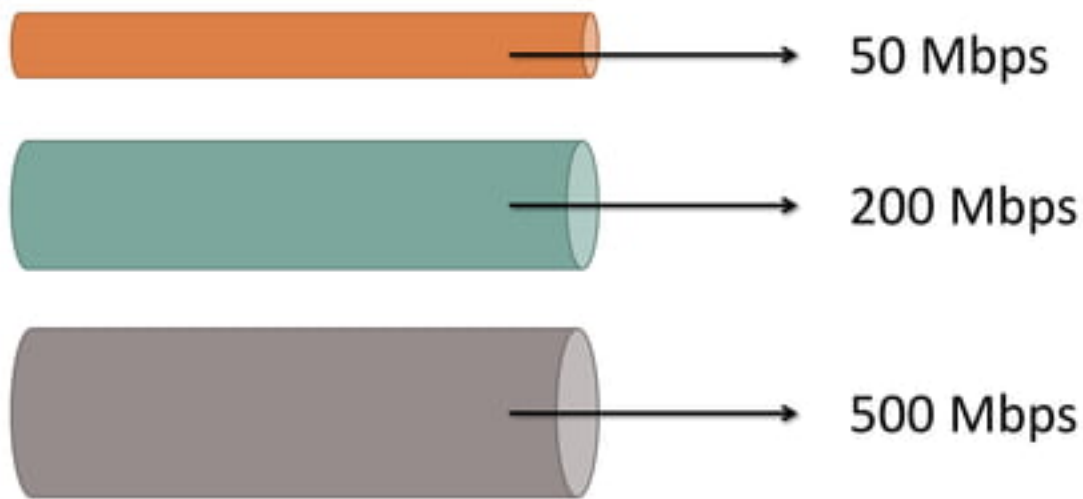


What is Frequency or Spectrum 'Band'



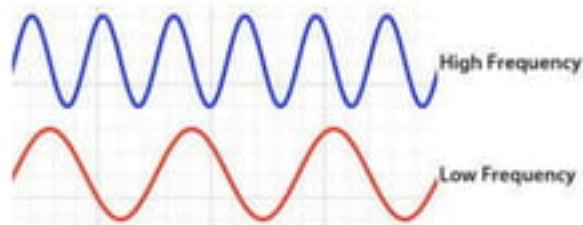
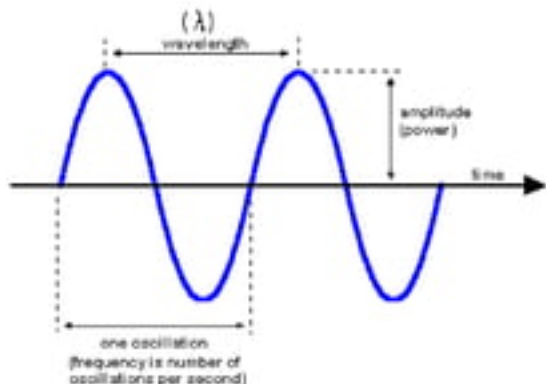
- Bands are group of frequencies, defined to make it easier to remember
- Bandwidth (BW) is the difference between max and min of any defined or undefined band.
 - For example you have a band from 700MHz to 800MHz, BW = 100MHz

Larger Bandwidth means more data flow



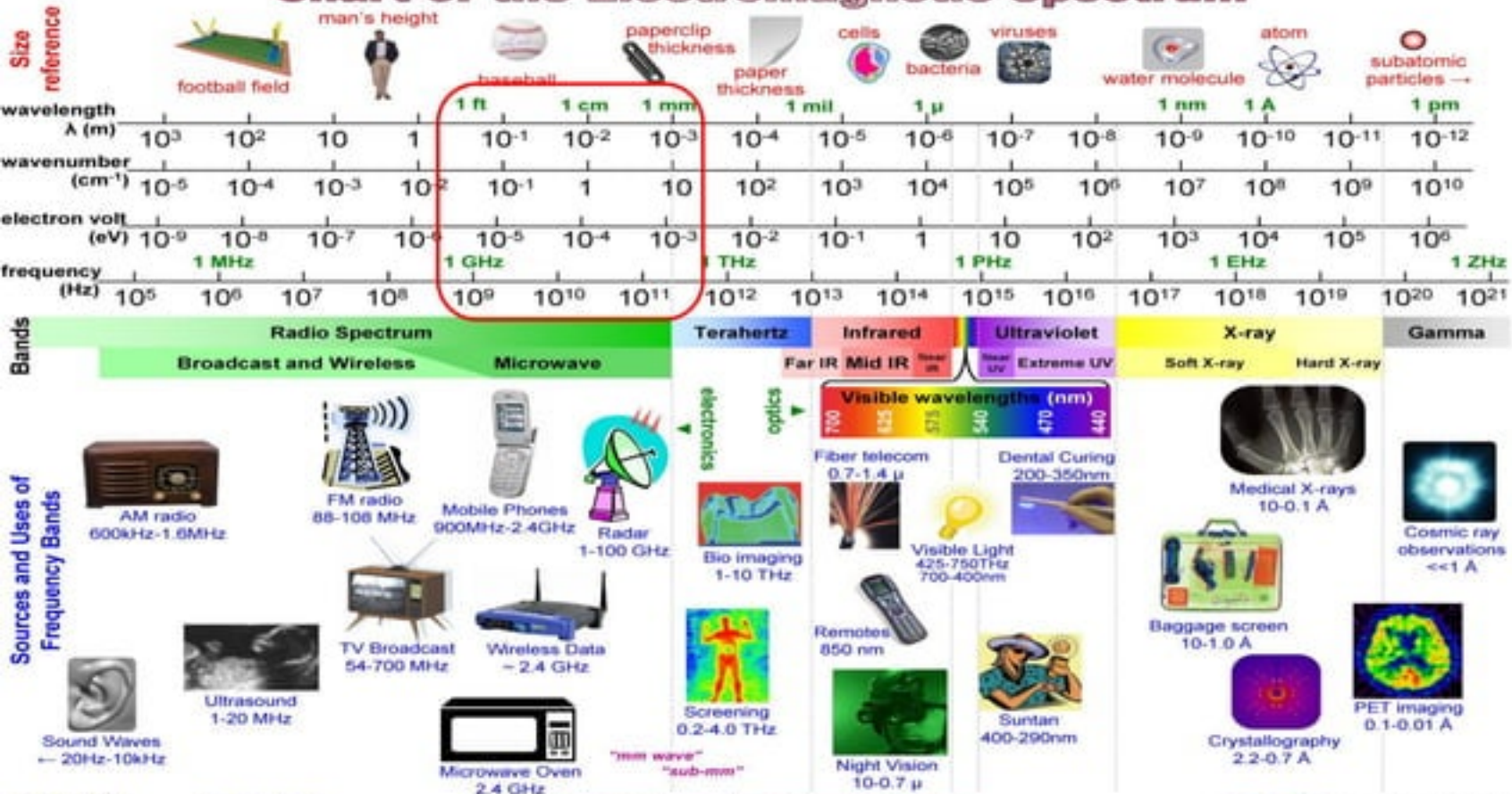
- Visualise bandwidth as pipes carrying water. The fatter the pipe, the more water can flow through it

Wavelength



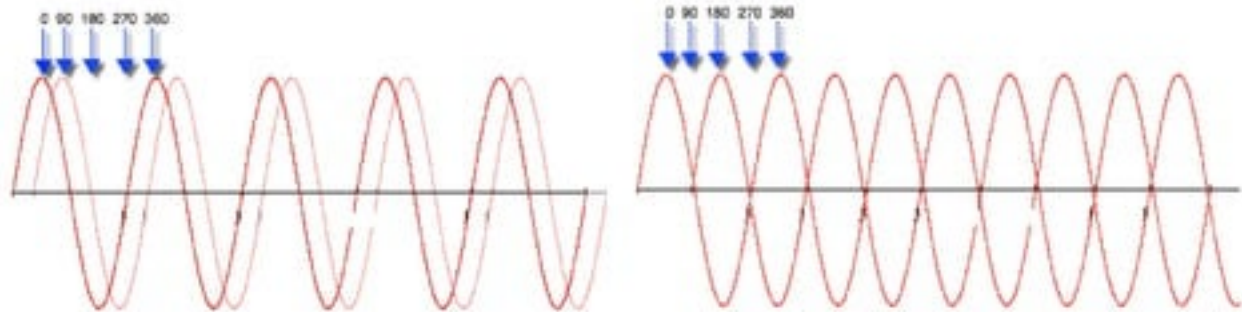
- Wavelength (generally written as Greek letter Lambda ' λ ') is the distance between similar points on two back-to-back waves.
- Its calculated $\lambda = c / f$, where c is the speed of light, 299,792,458 m/s
 - For 1MHz, $\lambda = 299.792458$ metres or roughly 300 m
 - For 1GHz, λ is roughly 30cm

Chart of the Electromagnetic Spectrum

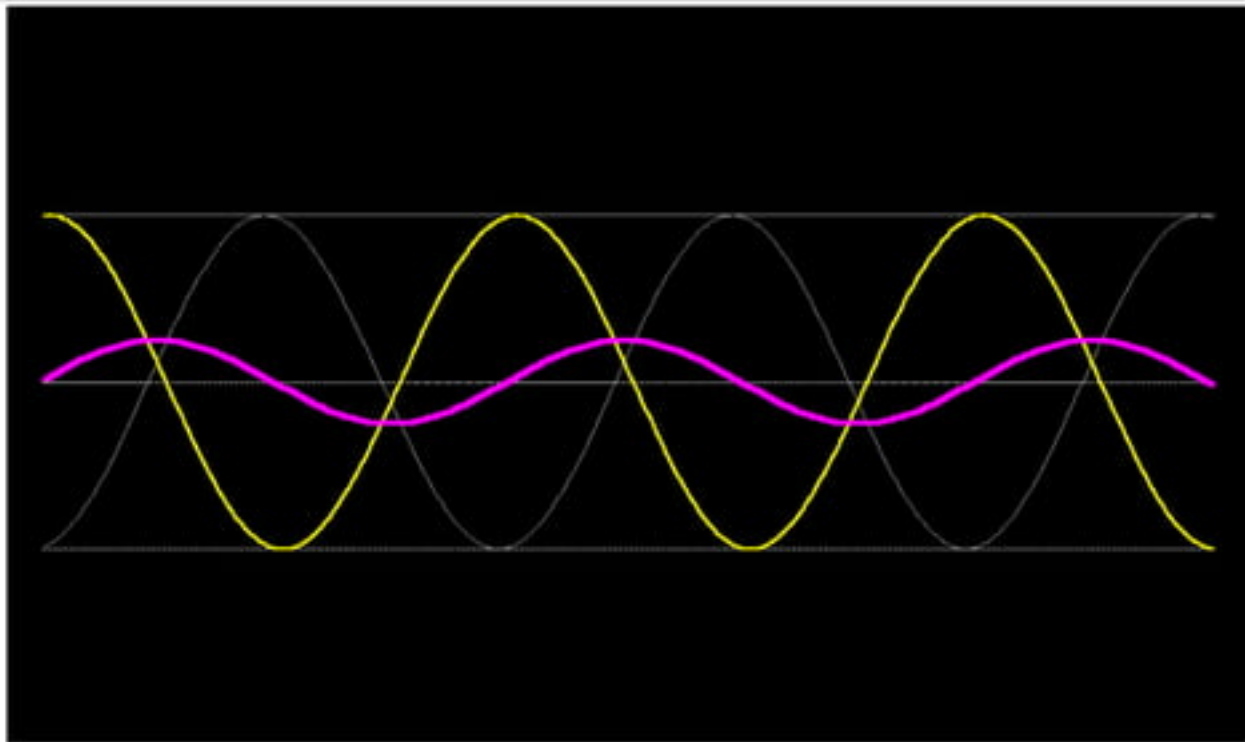


Phase

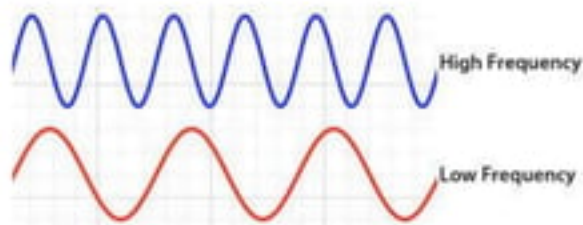
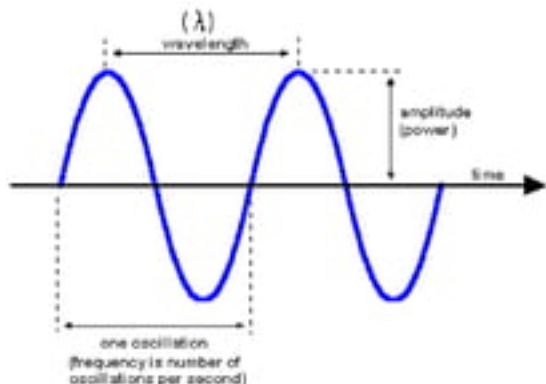
- Phase is the same frequency, same cycle, same wavelength, but are 2 or more wave forms not exactly aligned together
- Phase can be measured in distance, time, or degrees.



Effect of Phase shifts



Amplitude



- Amplitude is the height, force or power of the wave
 - The power of signal is proportional to its amplitude
- Amplitude has no relationship with frequency, wavelength or phase of a signal

Antennas and wavelength

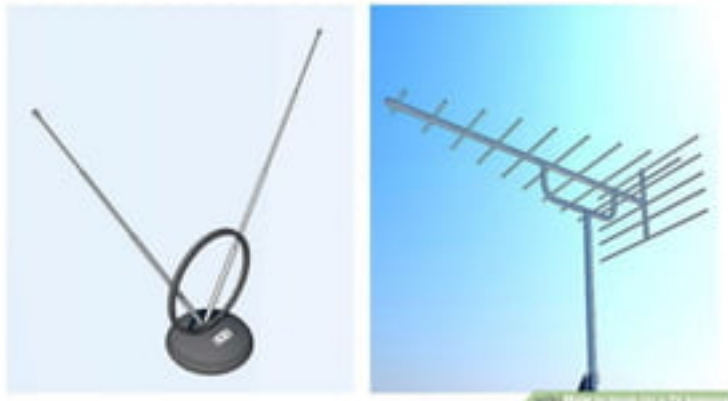
- Antennas should be half wavelength ($\lambda/2$) for perfect reception but can be as low as $\lambda/10$



- Car on left: FM Radio (88 – 108 MHz) antenna
- Car on right: Digital DAB Radio (175 – 230 MHz) antenna

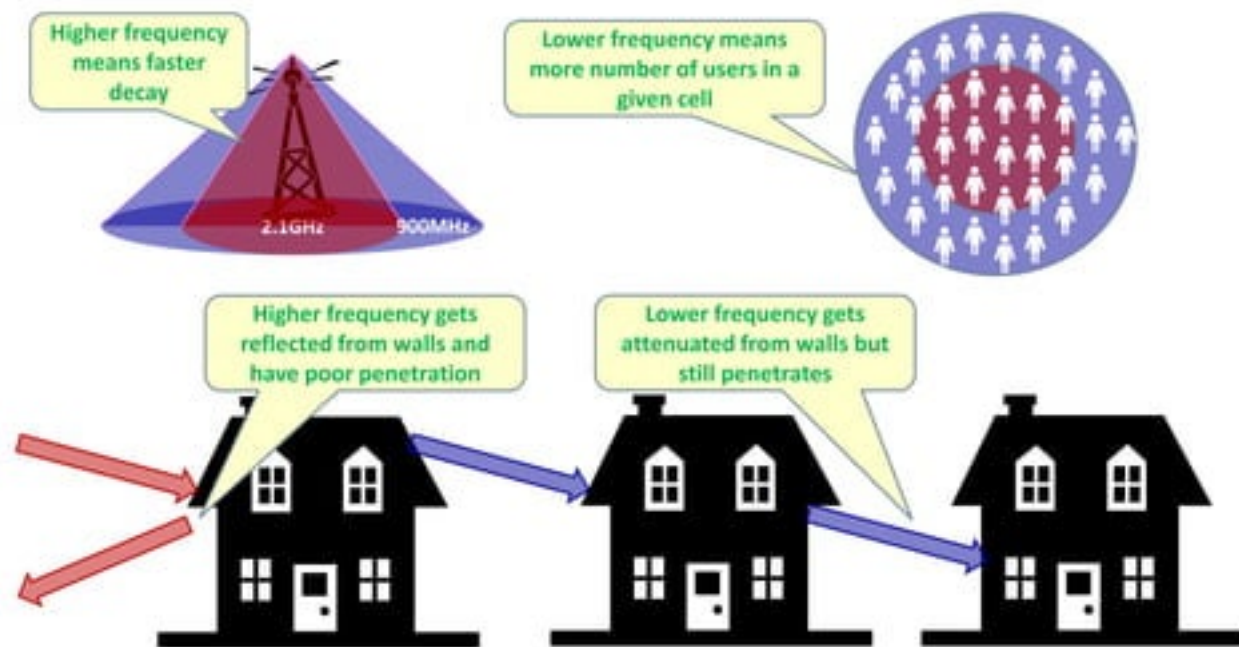
Antennas and wavelength

- Antennas should be half wavelength ($\lambda/2$) for perfect reception but can be as low as $\lambda/10$

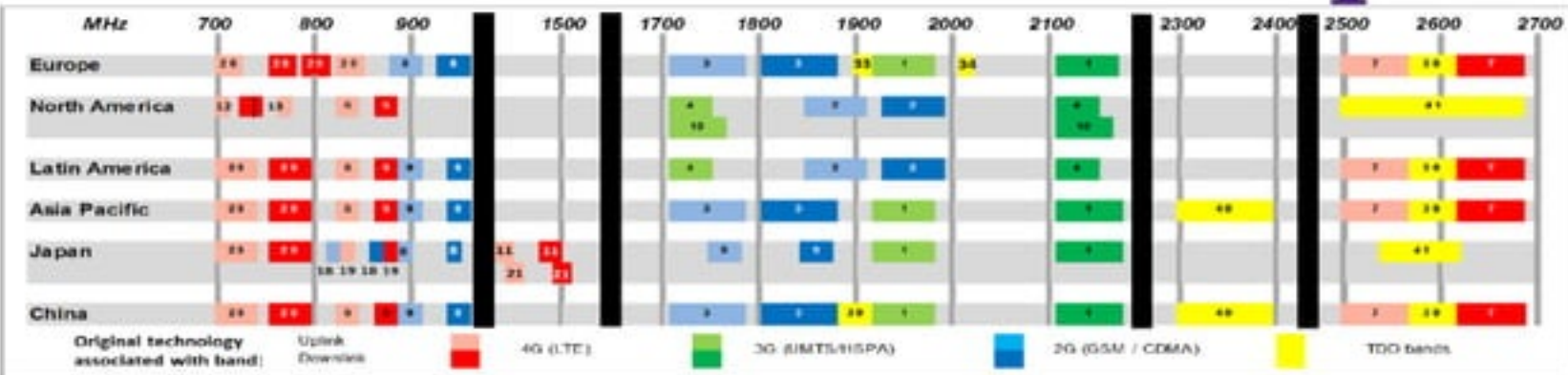


- Left: Rabbit ears antenna optimised for receiving VHF signals (30 – 300 MHz) with good quality (high amplitude) signal
- Right: Multi-element beam antenna to catch more frequencies than just VHF and also works with poor quality (low amplitude) signal

Importance of Frequency selection



Cellular Spectrum around the World



FDD (PAIRED) FREQUENCY BANDS

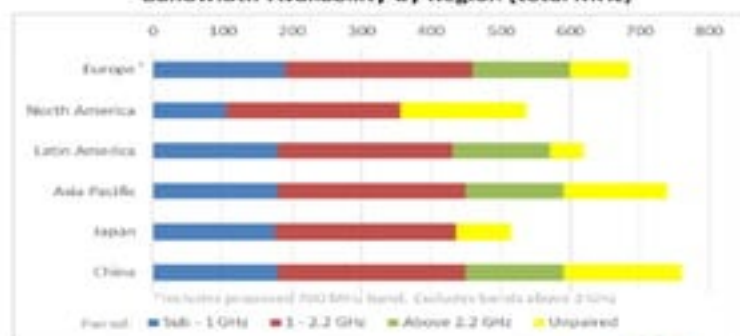
3GPP Band	Regions	Frequencies (MHz)
1 (2 GHz)	Global exc. Amer.	1920-1980/2110-2170
2 (1900 MHz)	Americas	1850-1915/1850-1900
3 (1800 MHz)	Global exc. Amer.	1710-1785/1800-1850
4 (800 MHz)	Americas	1710-1755/2110-2155
5 (850 MHz)	Americas, APAC	824-849/869-894
6 (850 MHz)	Nor. used	825-845/875-895
7 (2.6 GHz)	Global exc. N. Amer.	2600-2670/2620-2690
8 (900 MHz)	Global exc. N. Amer.	880-915/925-960
9 (1800 MHz)	Japan	1755-1785/1845-1880
10 (AWS-3)	N. America	1710-1770/2110-2170
11 (1.5 GHz)	Japan	1426-1448/1470
12 (700 MHz) Low	N. America	698-710/726
13 (700 MHz) Up	N. America	777-787/758-768
14 (700 MHz) PS	N. America	733-748/758-768
15	Reserv. for future use	
16	Reserv. for future use	
17 (700 MHz) LTT	N. America	758-773/726-740
18 (900 MHz)	Japan	815-825/890-895
19 (900 MHz)	Japan	895-915/875-890
20 (800 MHz)	Europe	825-862/791-827
21 (1.5 GHz)	Japan	1445-1465/1465-1511
22 (3.5 GHz)	Not yet in use	3410-3490/2650-3600

3GPP Band	Regions	Frequencies (MHz)
23	Not yet in use	2000-2020/2180-2200
24 (S-band)	Satellite band	1620-5-1625-1558
25 (1900 MHz)	N. America	1850-1915/1930-1995
26	Not yet in use	814-849/858-894
27	Not yet in use	907-924/932-969
28 (700 MHz)	Global exc. Amer.	703-748/758-803 ¹
29 (700 MHz)	N. America	717-728

TDD (UNPAIRED) FREQUENCY BANDS

3GPP Band	Regions	Frequencies (MHz)
33 (1900 MHz)	Not yet in use	1850-1920
34 (2 GHz)	Not yet in use	2010-2025
35 (1900 MHz)	Not used	1850-1910
36 (1900 MHz)	Not used	1930-1990
37 (1900 MHz)	Not used	1910-1930
38 (2.6 GHz)	Europe	2615-2620
39 (1900 MHz)	China	1880-1920
40 (2.3 GHz)	Asia Pacific	2300-2400
41 (2.5 GHz)	N. America	2490-2590
42 (3.5 GHz)	Europe, APAC	3400-3600
43 (3.7 GHz)	Europe	3600-3800
44 (700 MHz)	Not used	703-803

Bandwidth Availability by Region (total MHz)



¹ FDD AWS-3 band extends to 1755/2160 MHz.

² 1.4 GHz band (700 MHz) band 703-748/758-803 MHz. Regions which have current and planned allocations.



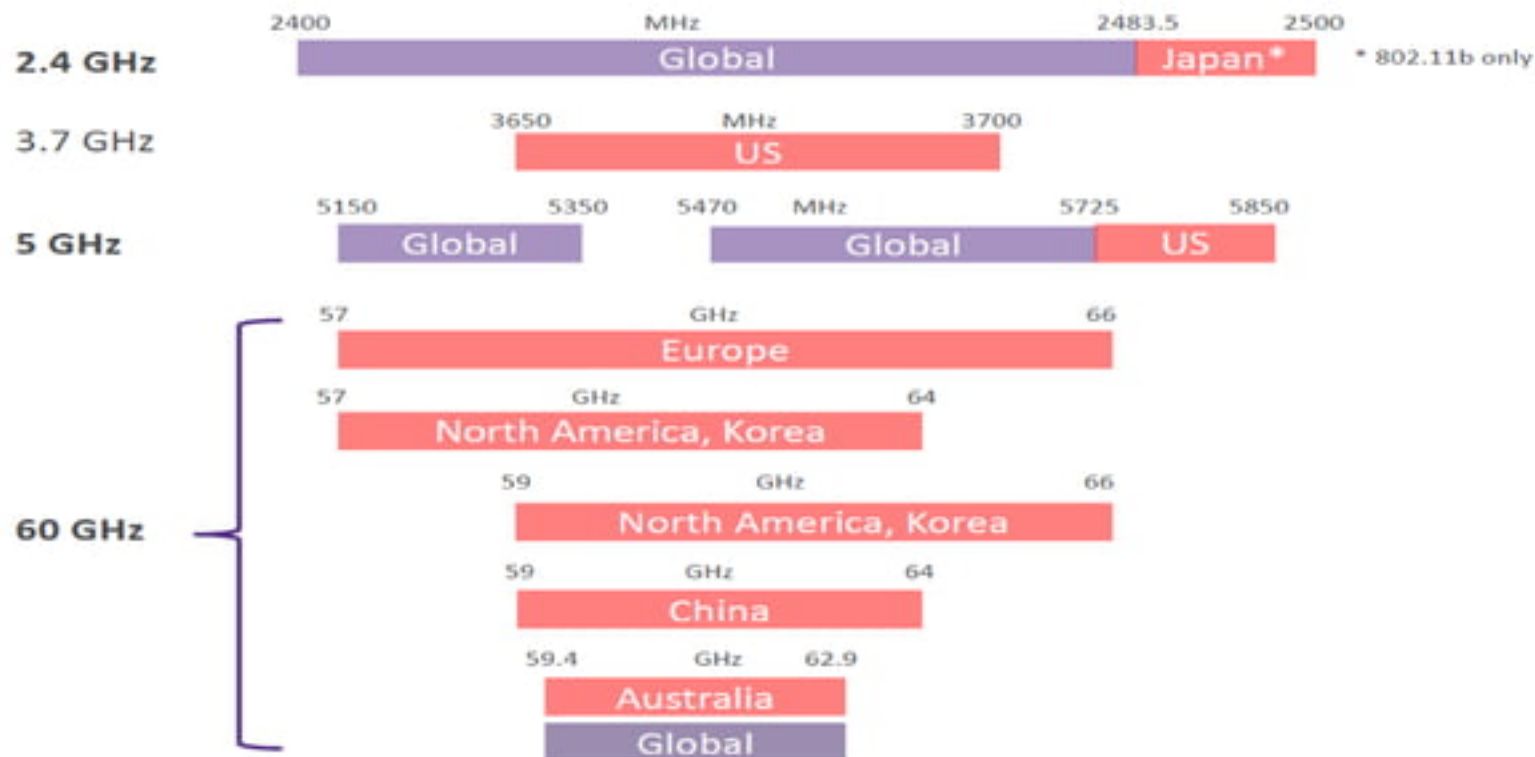
Antennas and wavelength

- Antennas should be half wavelength ($\lambda/2$) for perfect reception but can be as low as $\lambda/10$



- Old GSM 900MHz feature phone

Wi-Fi Spectrum around the world



Antennas and wavelength

- Antennas should be half wavelength ($\lambda/2$) for perfect reception but can be as low as $\lambda/10$



- iPhone 4 Antennas

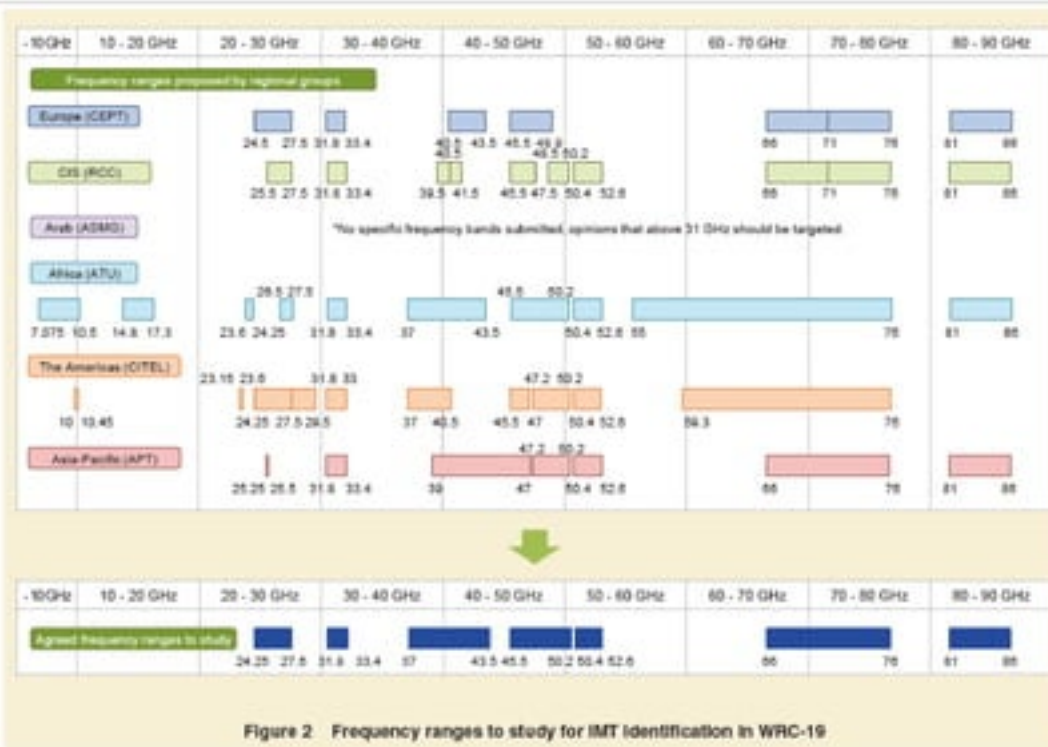
Antennas and wavelength

- Antennas should be half wavelength ($\lambda/2$) for perfect reception but can be as low as $\lambda/10$



- Samsung Galaxy S8 Antennas

5G Spectrum



5G: Multiple Layers for multiple needs

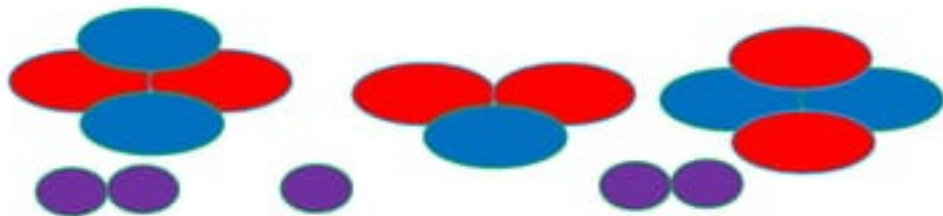
Coverage Layer
Sub-1GHz



Capacity Layer
1GHz – 6GHz



High Throughput Layers
6GHz – 100GHz

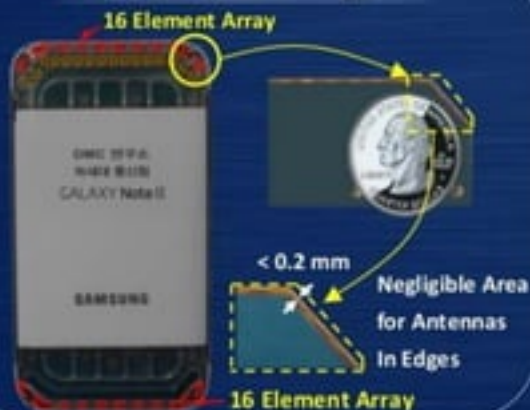


Device Antennas at 28GHz

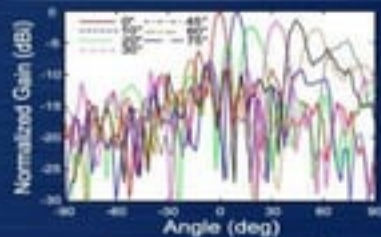
Device Feasibility - Antenna Implementation for Devices

32 Elements Implemented on Mobile Device with "Zero Area" and 360° Coverage

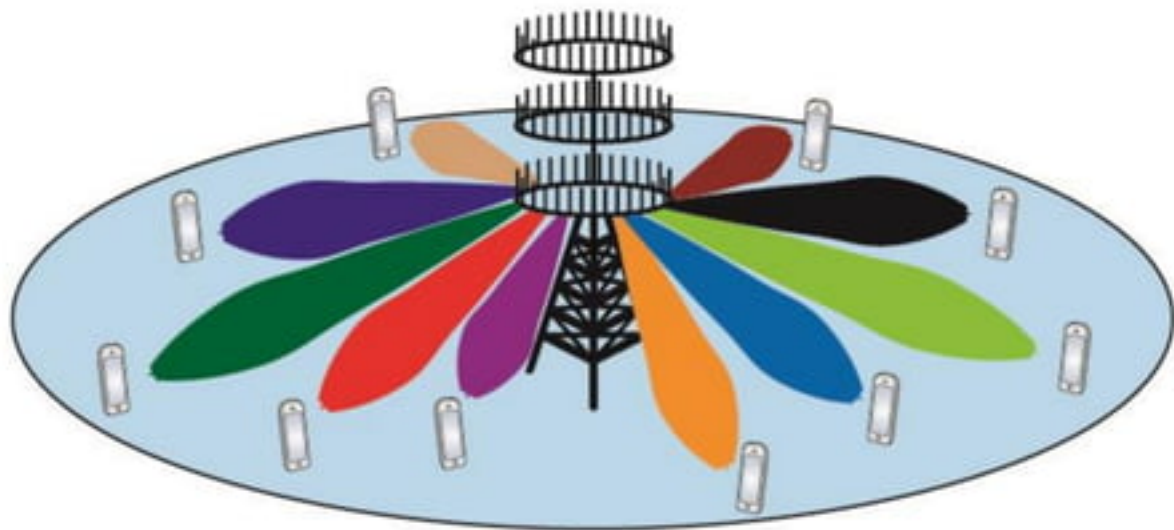
"Zero Area" Design



Measurement Results



Massive MIMO Base Station



- Massive number of antennas possible due to high frequencies
- Beamforming to device thereby increasing receive strength and reliability

Thank You

To learn more, visit:

3G4G Website – <http://www.3g4g.co.uk/>

3G4G Blog – <http://blog.3g4g.co.uk/>

3G4G Small Cells Blog – <http://smallcells.3g4g.co.uk/>

Follow us on Twitter: <https://twitter.com/3g4gUK>

Follow us on LinkedIn: <https://www.linkedin.com/company/3g4g>