Aspects of Electromagnetic Waves Relevant to Cellphones and Human Health

Prepared for the HB522 5G Commission

by

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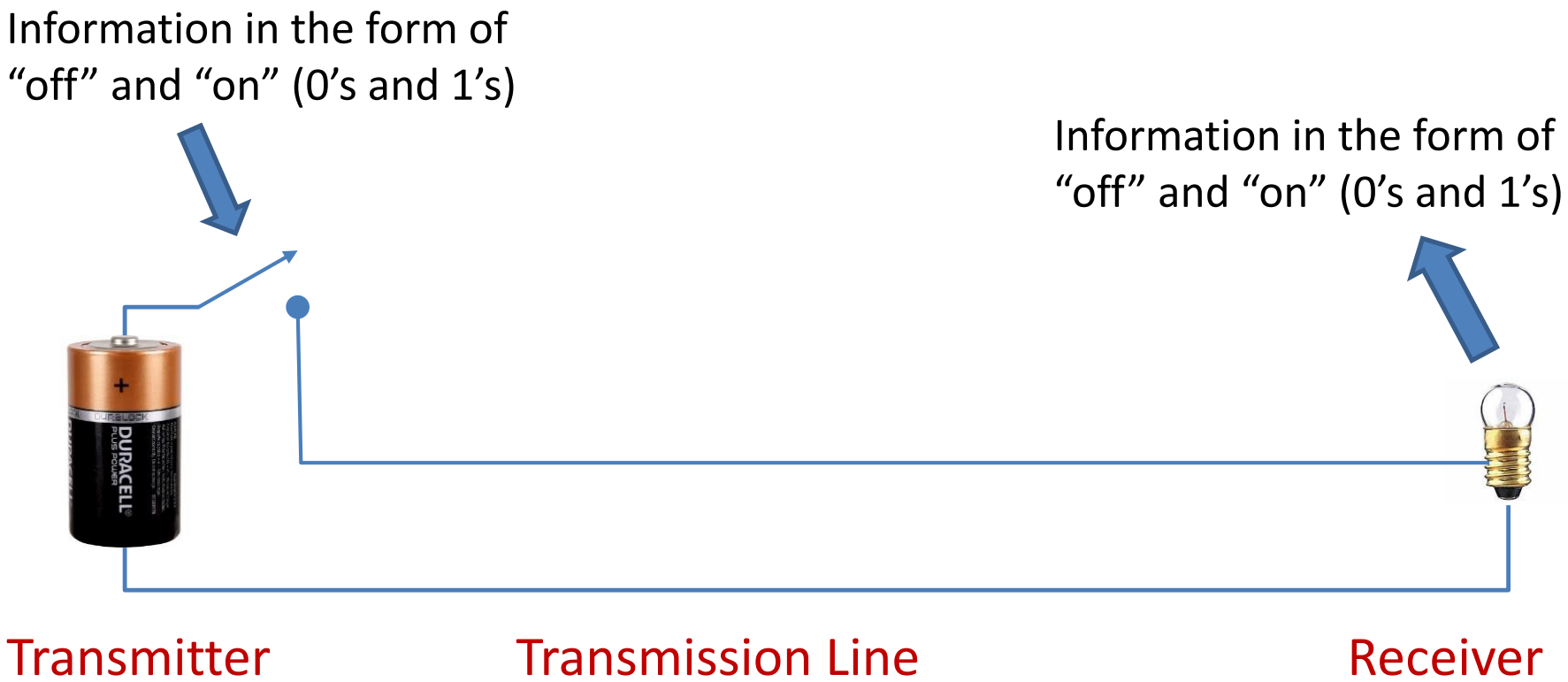
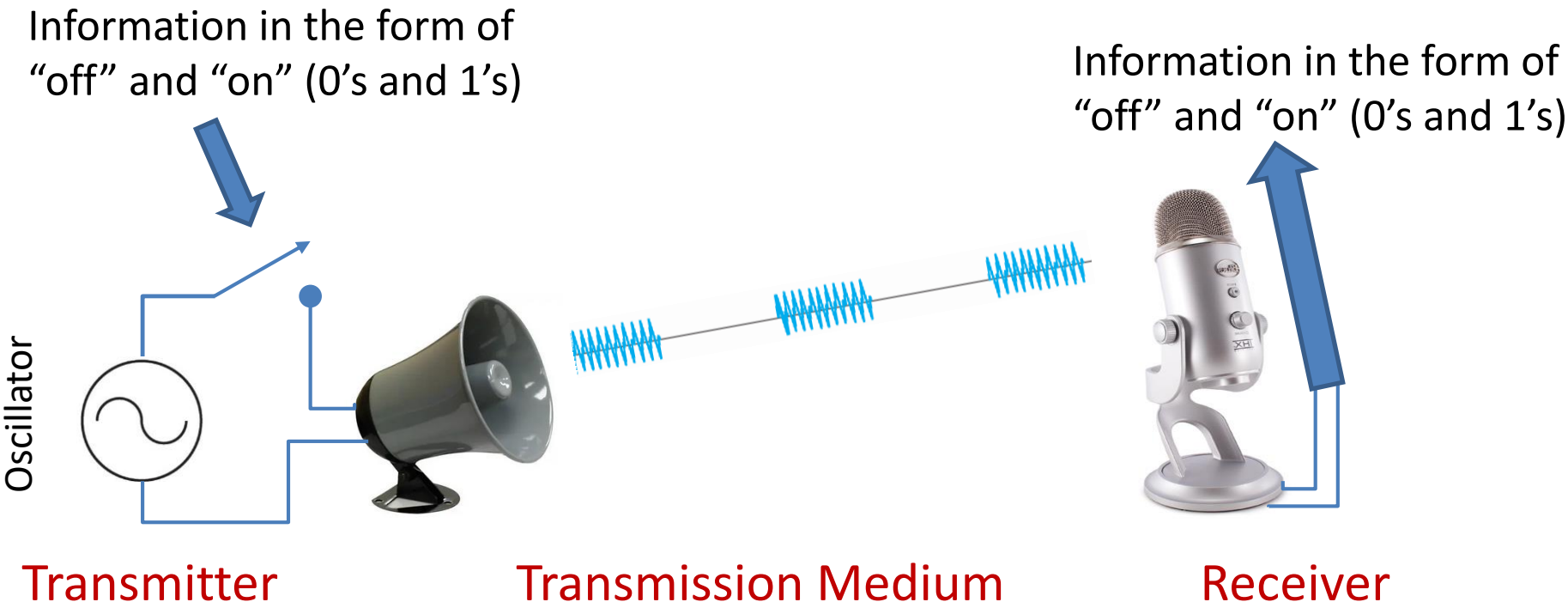
Simple Binary Data Transmission (wired)



- Data rate depends on response time of components
- Data rate is expressed in terms of frequency, bandwidth, bitrate, baud, channel capacity, *et. al.*
- In this example, data is in the form of voltage and current

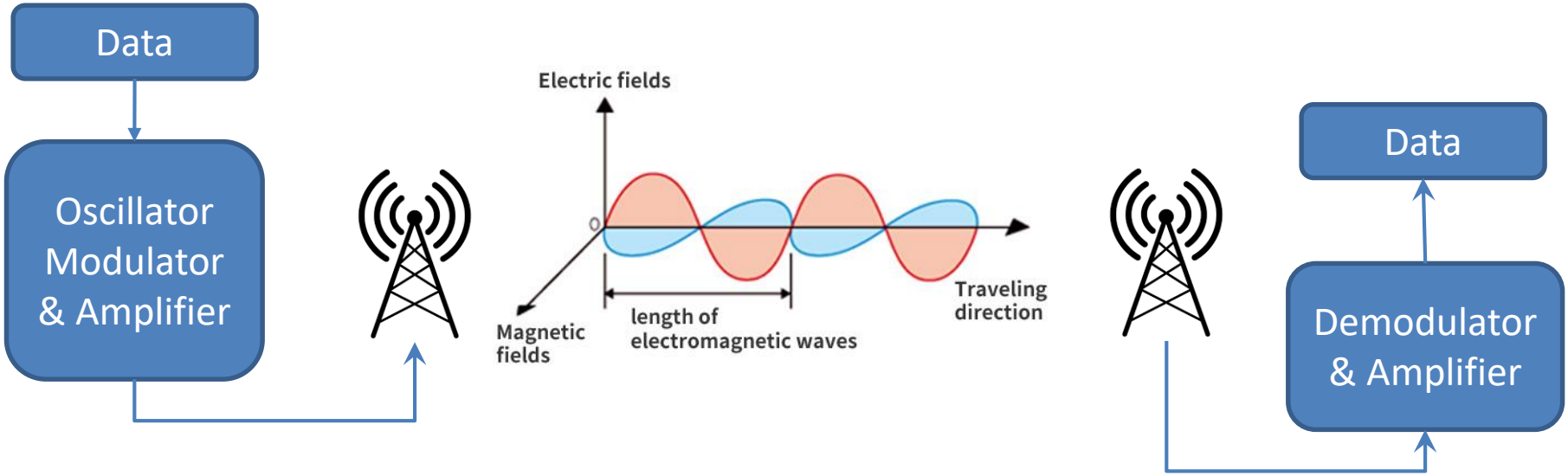
Wireless Binary Data Transmission (acoustic)

Sometimes Used in Underwater Communications

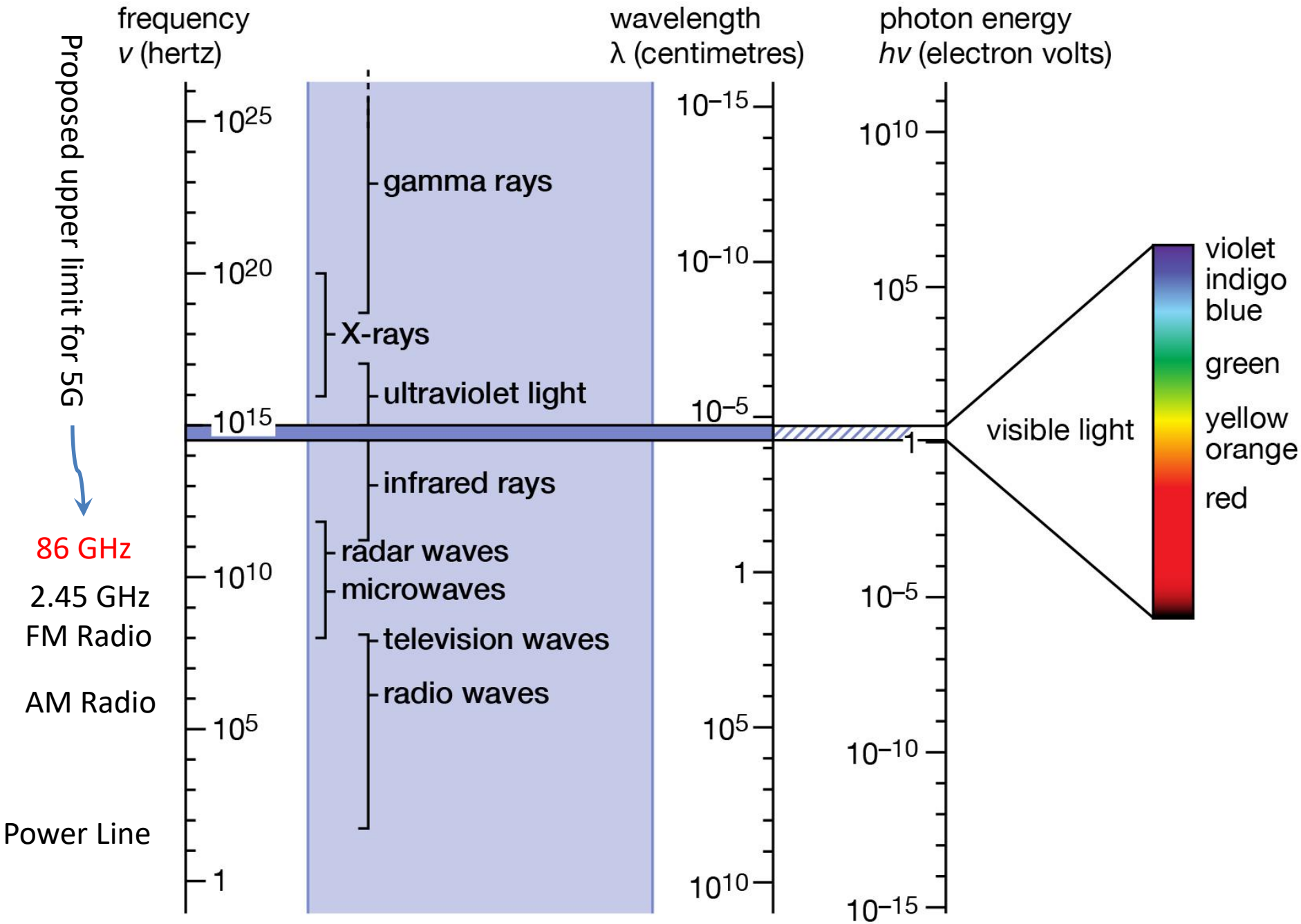


- The speaker converts electrical energy into acoustic energy
- The microphone converts acoustic energy into electrical energy
- The switching of the signal from the oscillator is a form of modulation
- The data rate of the system is limited by the oscillator frequency

Wireless Binary Data Transmission (electromagnetic)



- The transmit antenna converts electrical energy into electromagnetic energy
- The receive antenna converts electromagnetic energy into electrical energy
- The size of the antennas scale with wavelength: to be efficient, they need to be a reasonable fraction of a wavelength

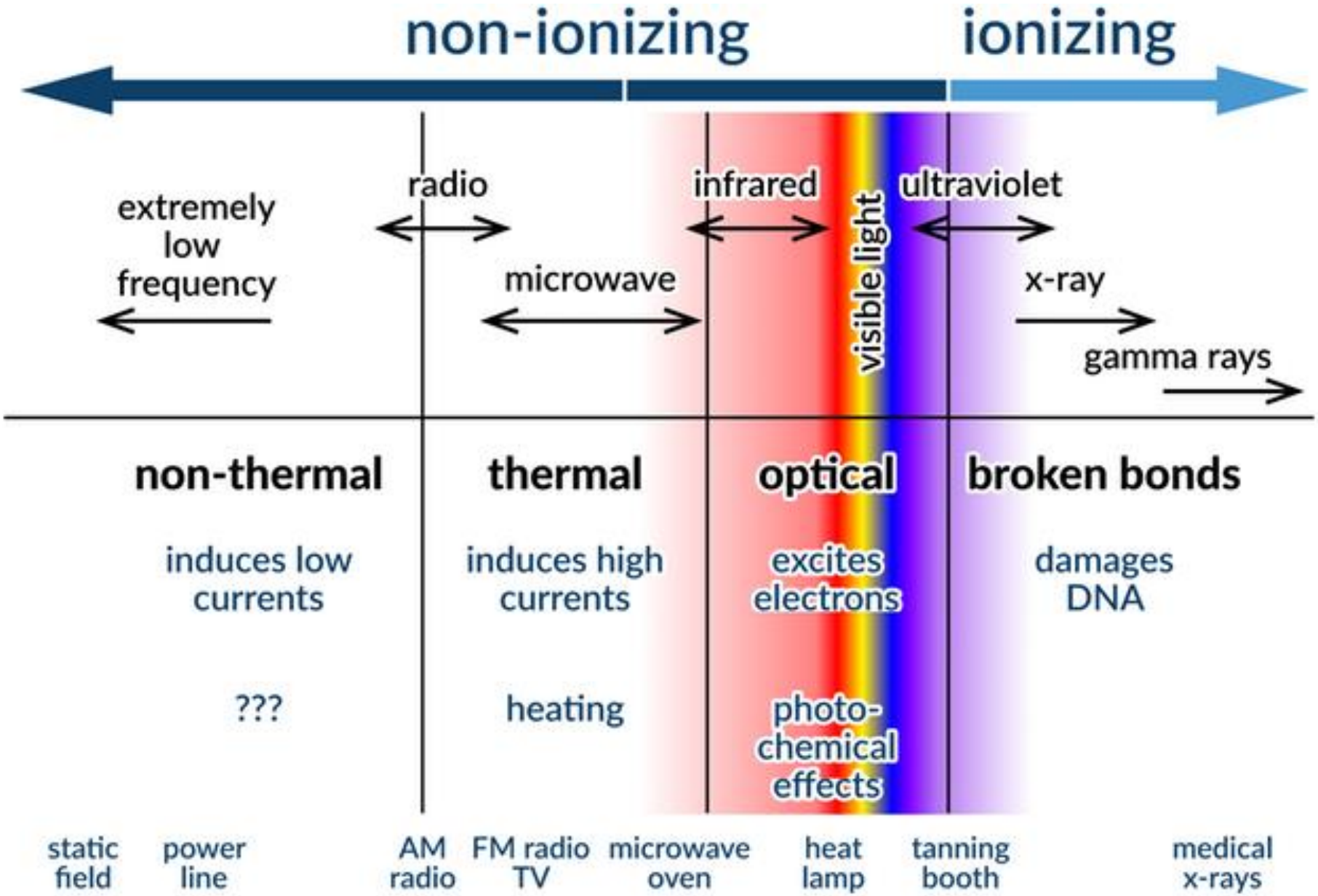


Wave-Particle Duality

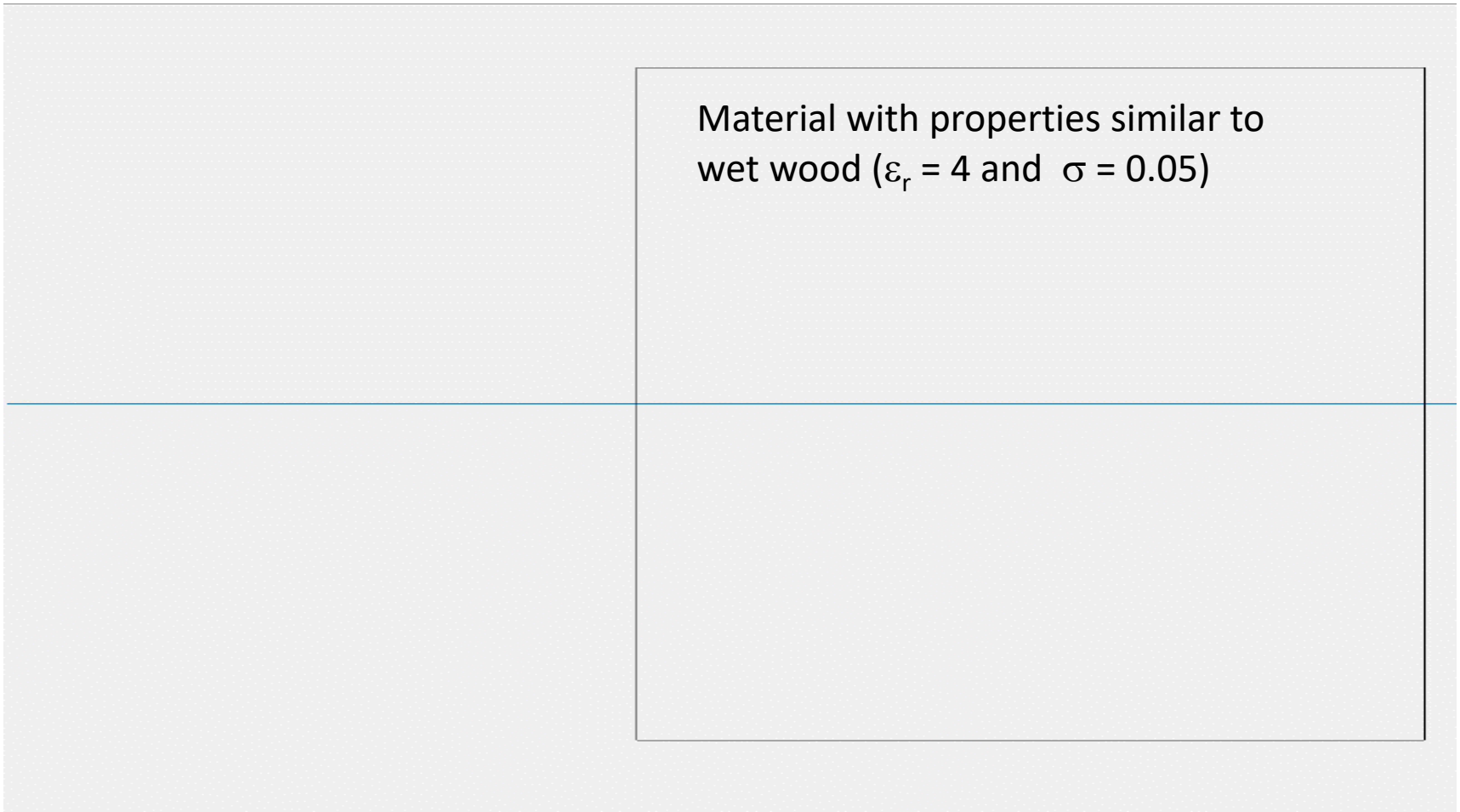
(Quantum Physics)

- Electromagnetic radiation can be represented by discrete packets of energy called photons
- Increasing the transmitter power will increase the number of photons although the energy in each photon will remain the same provided that the frequency remains constant
- The energy in each photon is proportional to the frequency of the transmission
- If the photon energy is great enough to detach electrons from atoms or molecules, it is referred to as ionizing radiation

Energy and Frequency



Electromagnetic Heating (thermal)



The wave gets smaller as it propagates in the material because it gives up energy. This energy will cause the material to heat up.

Some Takeaways about Electromagnetic Fields and Cellphones

- Higher frequencies support higher data rates (greater bandwidth) and allow for conveniently-sized devices due to short wavelength
- Energy in electromagnetic waves increases with frequency
  - Ionizing versus non-ionizing radiation
    - 4G and 5G communication frequencies are below what is commonly considered to be the ionizing-radiation threshold
- Electromagnetic waves lose energy and release heat when propagating in media that have conductivity
  - Heating effects
    - Cellphone radiated power *should not* cause damaging heating
- Signal path loss increases with increasing frequency
  - Which is why 5G requires more-dense placement of cell "towers"
- Power density drops off as $1/R^2$ for all frequencies
- Cellphones adjust their power output as needed to maintain communication with cell towers

Significance of $1/R^2$ Power Relationship

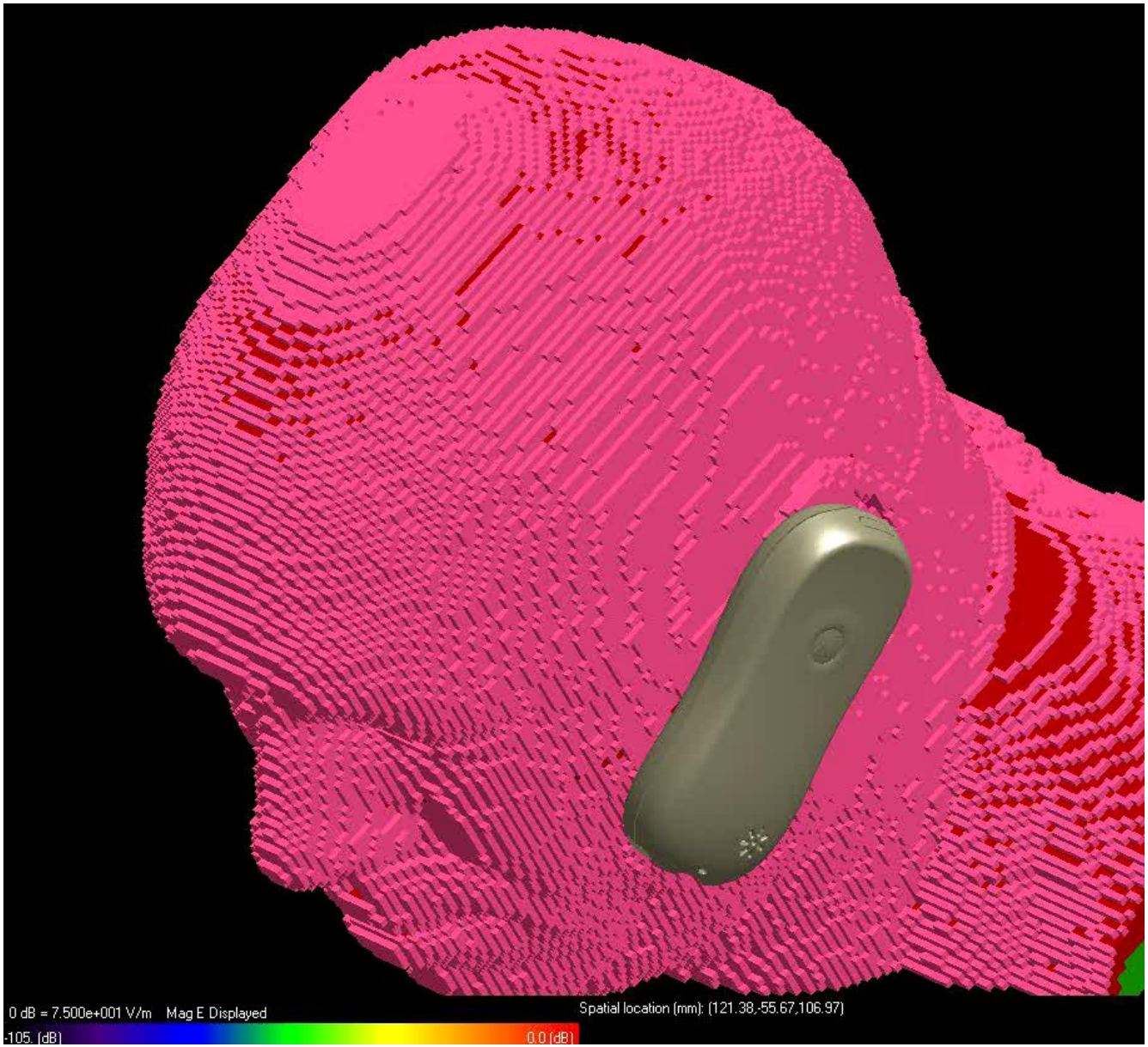
As reference, assume power density at 1 meter is equal to unity. $P = 1\ W/m^2$

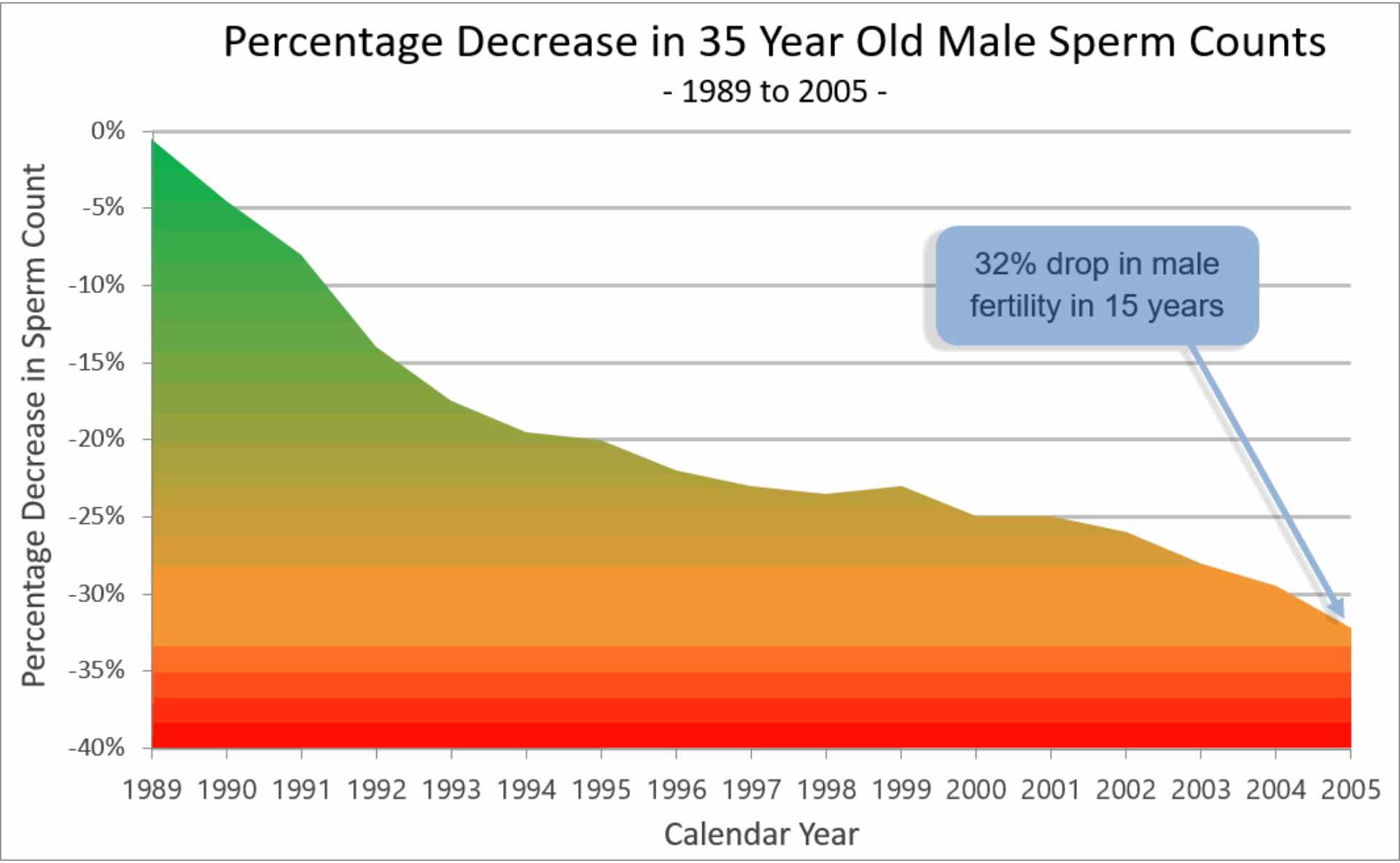
If phone is moved to a distance of 0.5 m, $P = 4\ W/m^2$

In this case, distance is equal to fabric thickness (0.2 mm), so $P = 24\ MW/m^2$

Definitely <u>not</u> a good idea!

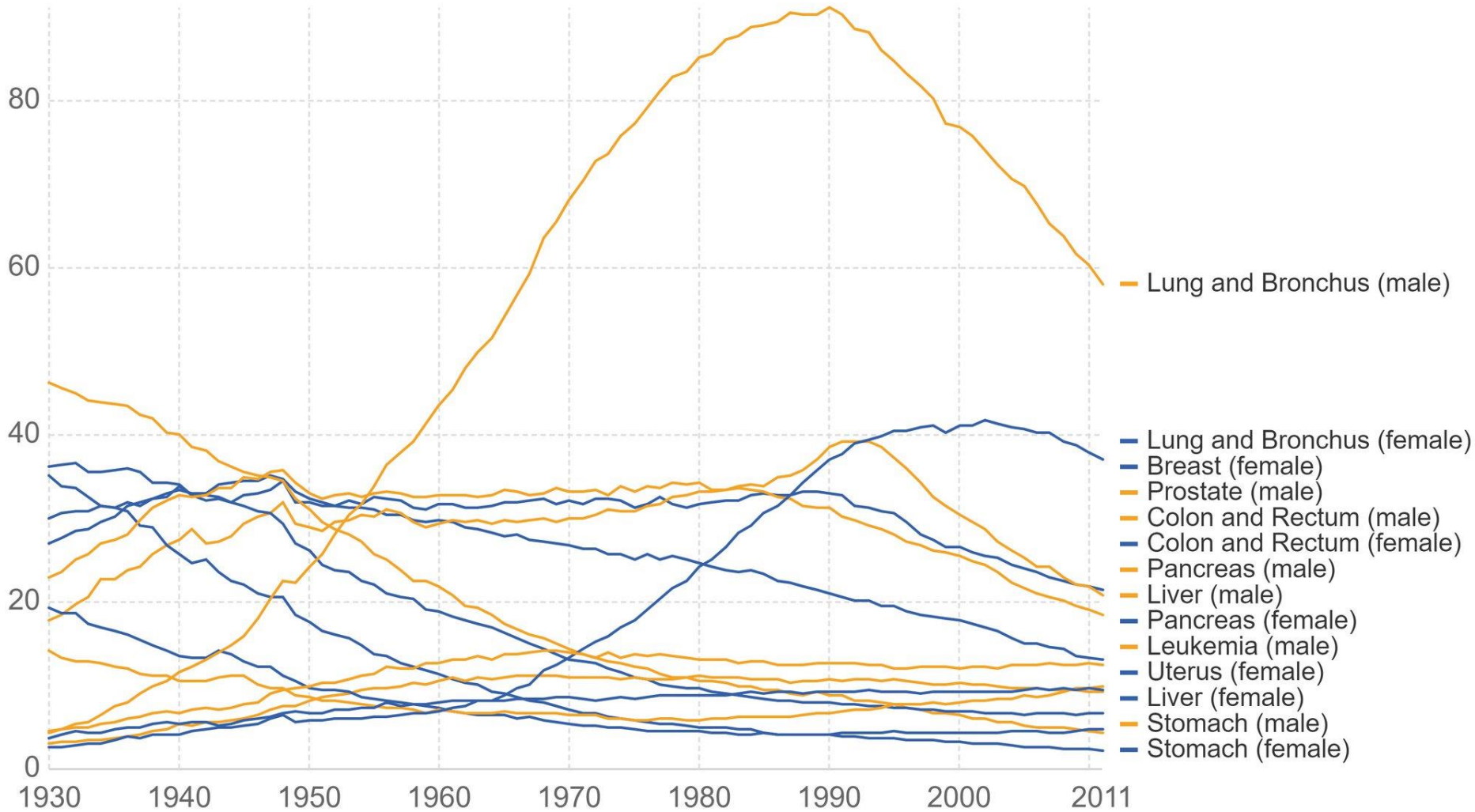
Cellphone-Human Interaction




Percentage Decrease in 35 Year Old Male Sperm Counts
- 1989 to 2005 -
Percentage Decrease in Sperm Count
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%
32% drop in male fertility in 15 years
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Calendar Year

Cancer death rates in the United States over the long-run

Age-standardized death rates from various forms of cancer in males and females, measured as the number of deaths per 100,000 individuals. Age-standardization is based on normalisation to the standard US population structure in the year 2000.



Source: American Cancer Society