



DAKOTA STATE
UNIVERSITY®

0x01 Software Defined Radio **(SDR)**

Dr. Mike Ham

**We're going to use a computer
to listen to radio waves.**

**What radio waves surround
you?**

**What radio waves surround
you?**

Get creative!

Radio 101



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Radio 101

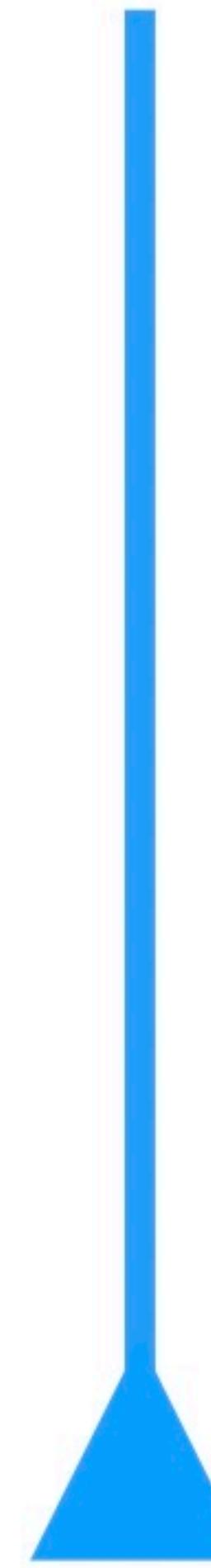


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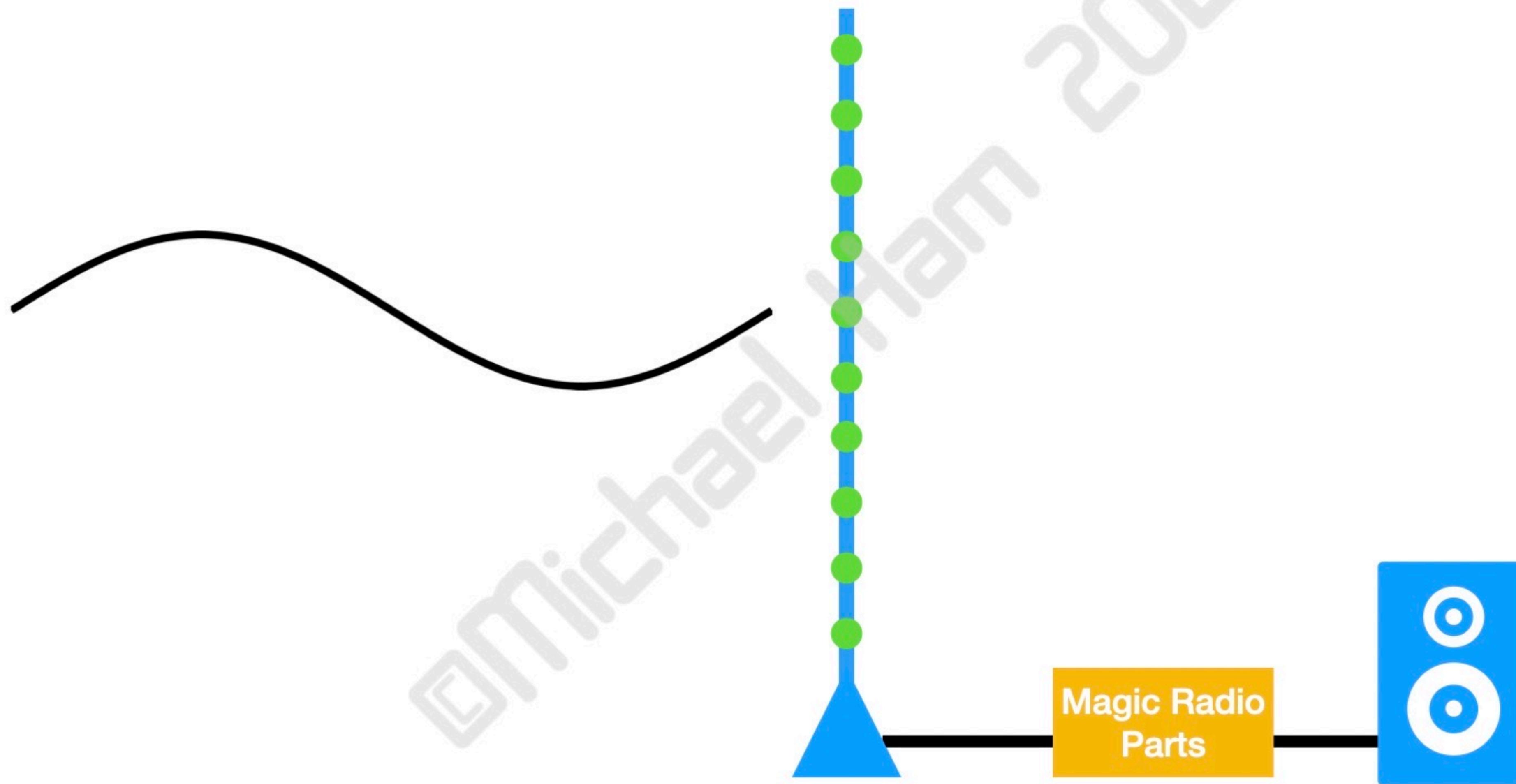
Radio 101



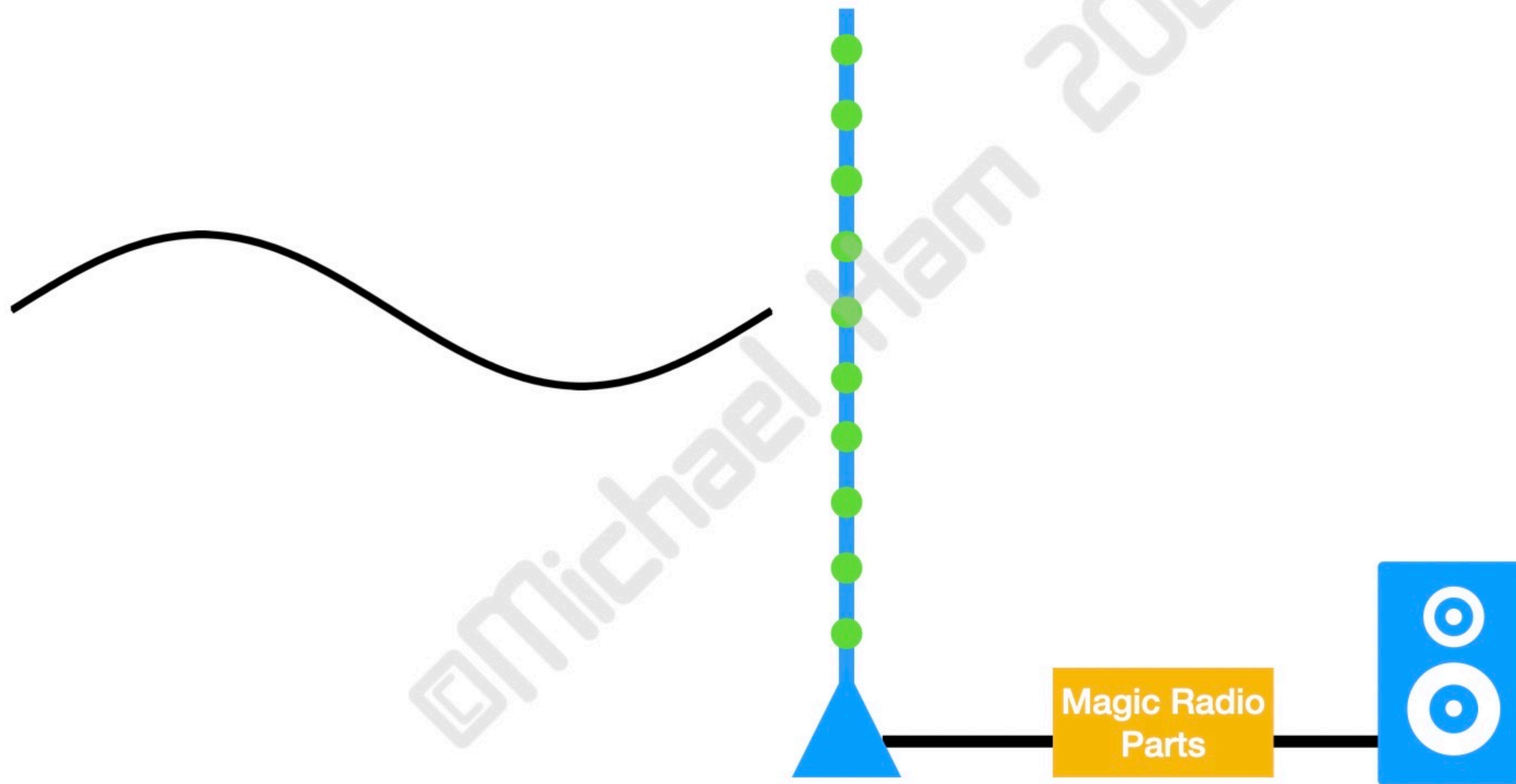
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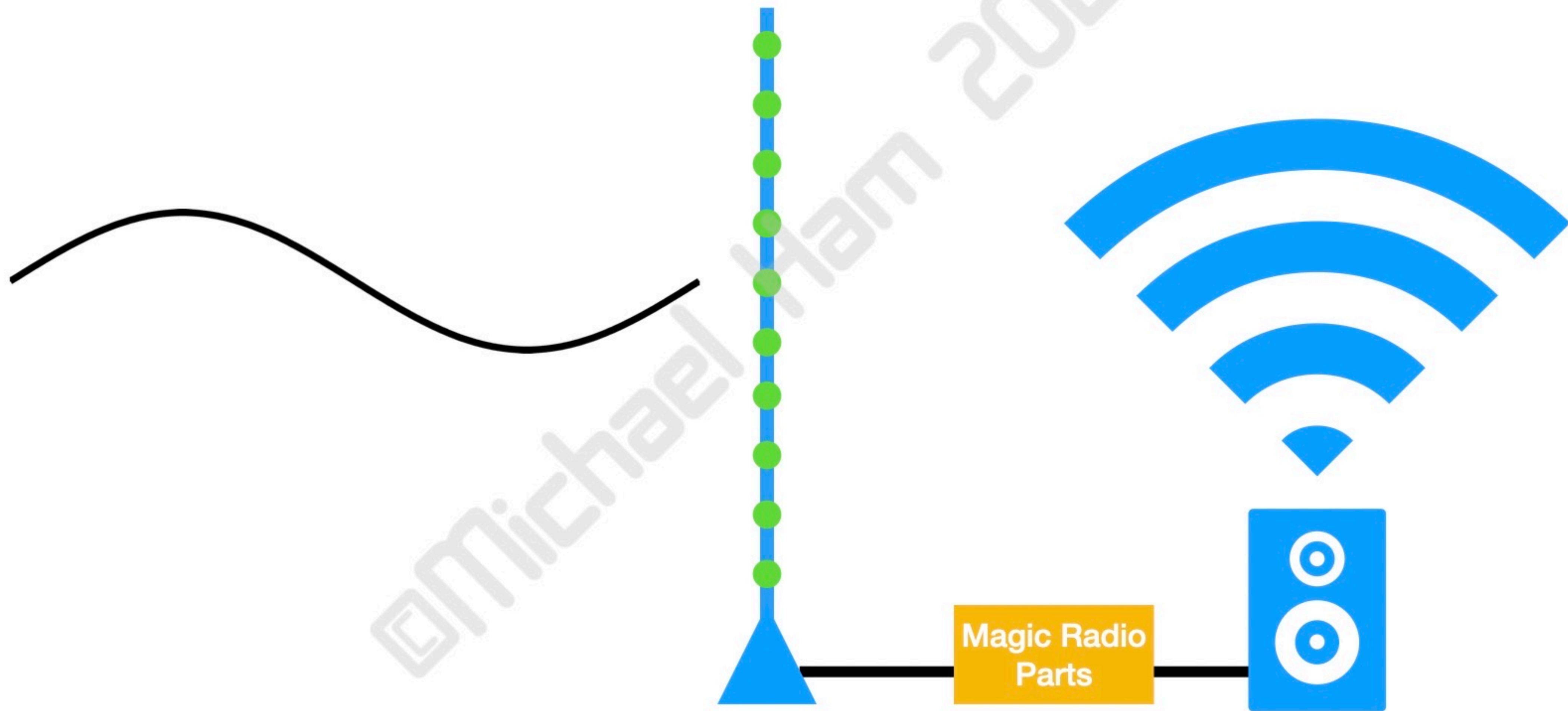
Antenna



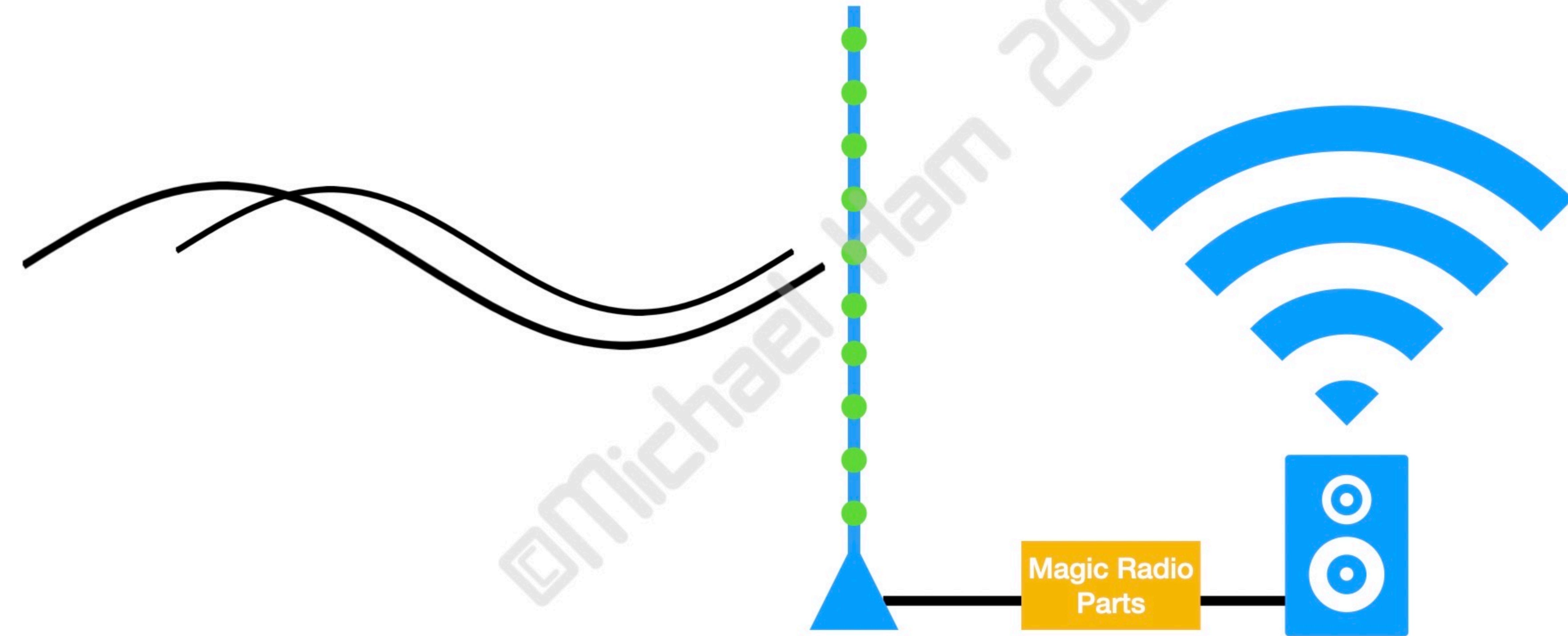
Antenna



Antenna

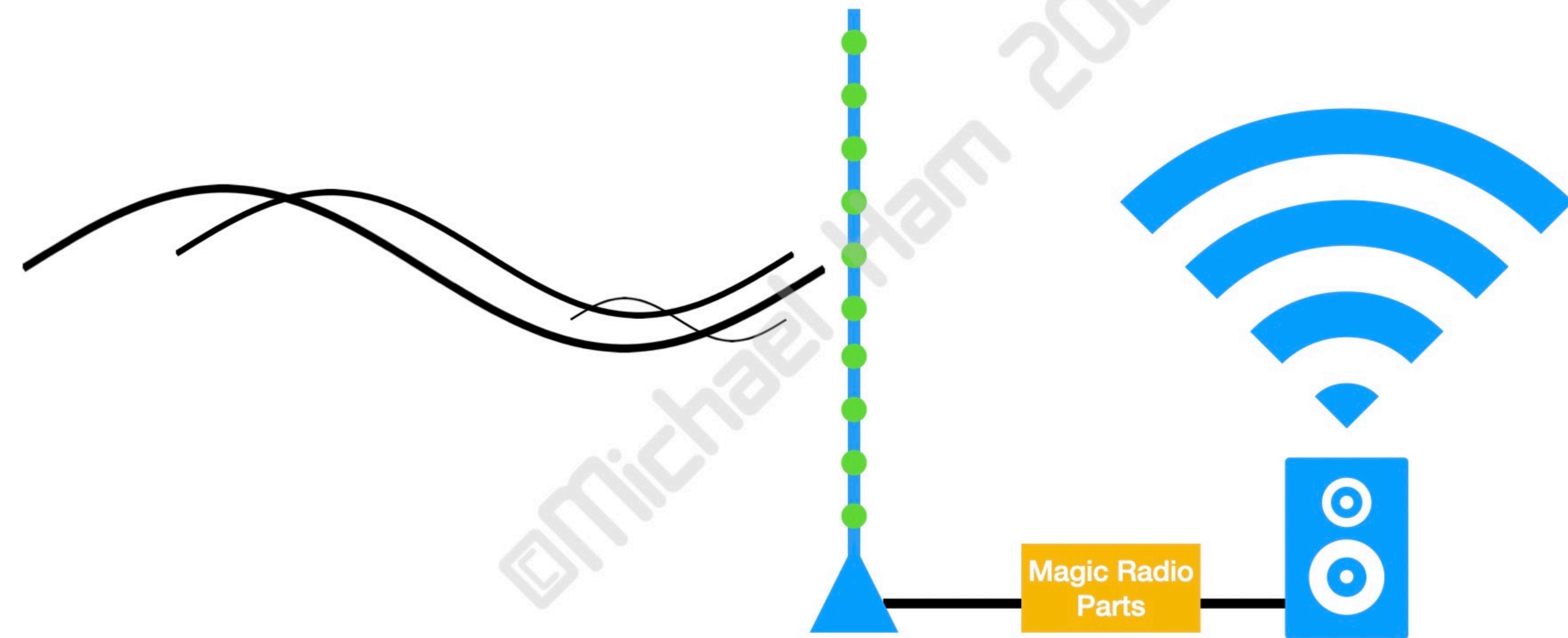


Antenna



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Antenna



One Antenna for All?

- The length and type are hugely important to what it can receive
- There is lots of physics and math involved in antenna design
- What we're looking for is a term called **resonance**
 - Pretty much where the antenna “vibrates” most efficiently
 - Largely determined by length



AM Radio Antenna

- Typical frequency around 1000kHz (kilohertz)
 - FM radio operates around 100MHz (megahertz)
 - $1 \text{ MHz} = 1000\text{kHz}$
- All radio waves traverse the planet at the speed of light
 - Low frequency = big radio wave
 - High frequency = little radio wave
- FM radio waves are roughly 100 times smaller than AM radio waves

How Big

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How Big

- Simple calculation: $m = 300 / \text{frequency MHz}$
 - If I tune into FM103.1, how long of an antenna do I need?
 - Remember, FM operates in megahertz (MHz)
 - $m \underline{\hspace{2cm}} = 300 / \underline{\hspace{2cm}}$

How Big

- Simple calculation: $m = 300 / \text{frequency MHz}$
 - If I tune into FM103.1, how long of an antenna do I need?
 - Remember, FM operates in megahertz (MHz)
 - $m \underline{\hspace{2cm}} = 300 / \underline{\hspace{2cm}}$
- What about AM radio which is kilohertz, let's say 1390kHz
 - $m = 300 / (\text{frequency kHz} / 1000)$
 - $m \underline{\hspace{2cm}} = 300 / \underline{\hspace{2cm}}$

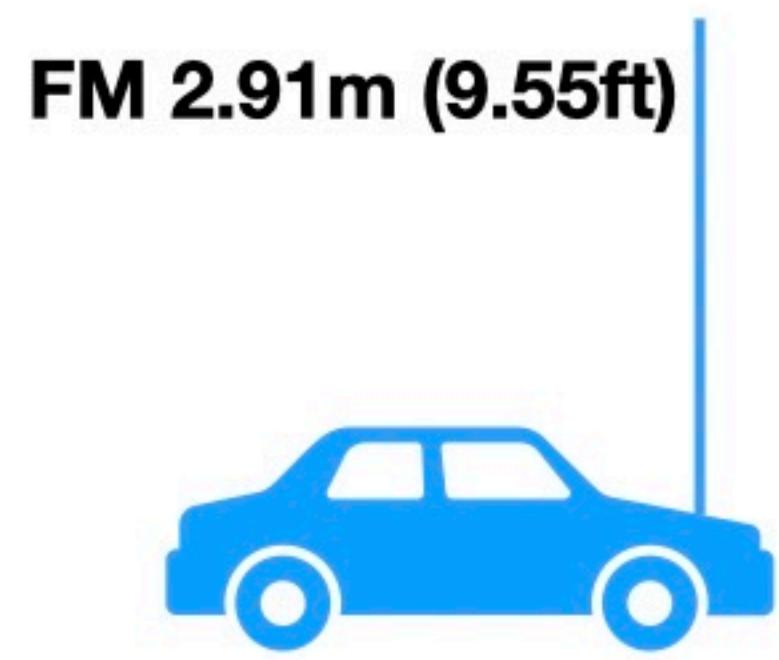
AM - 215.83m (708.1ft)



Oh my...

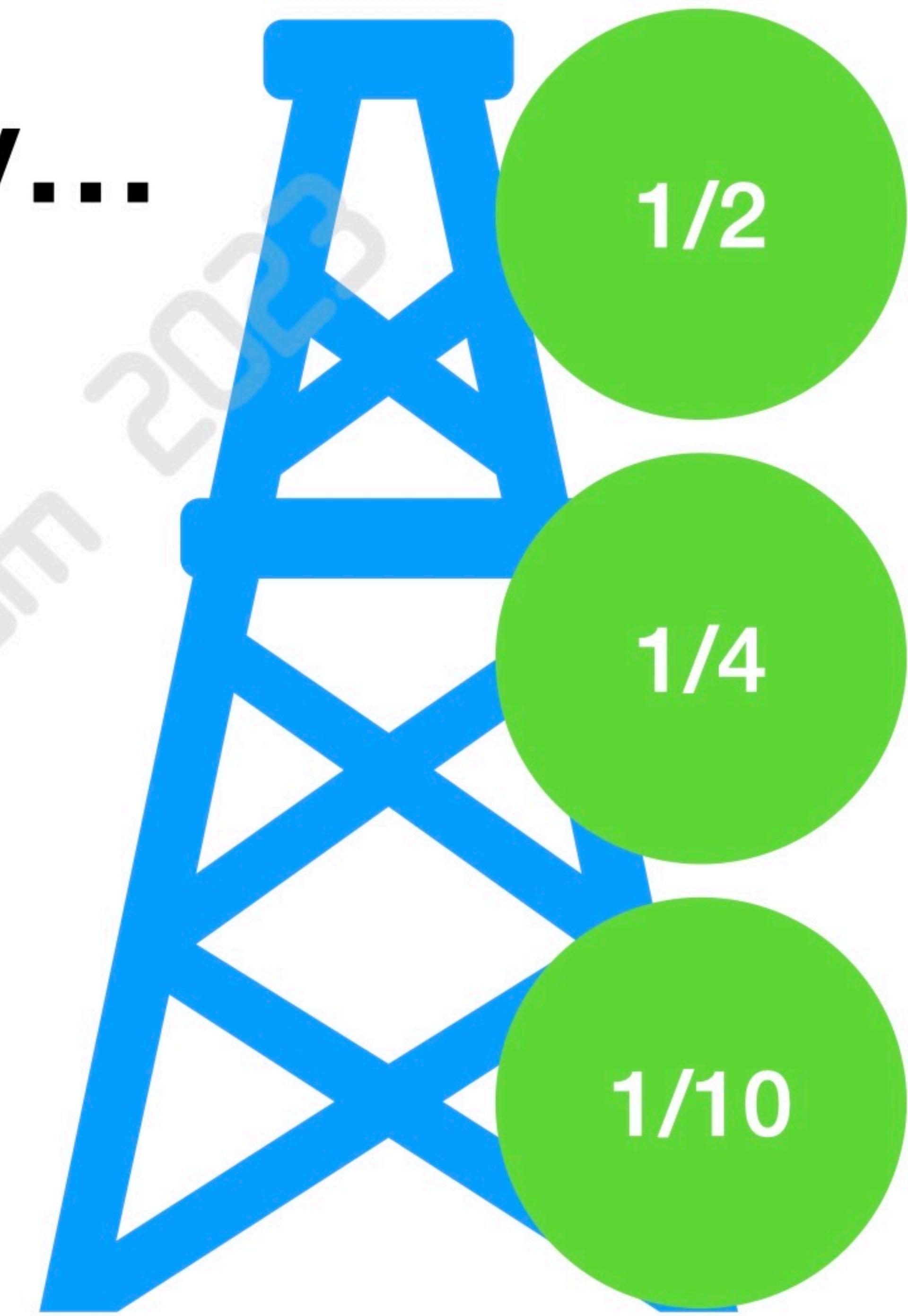
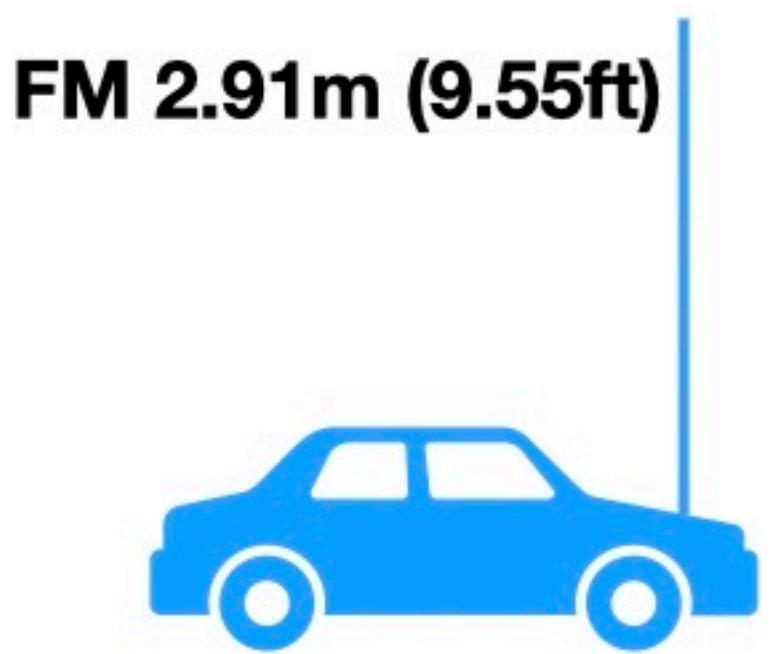
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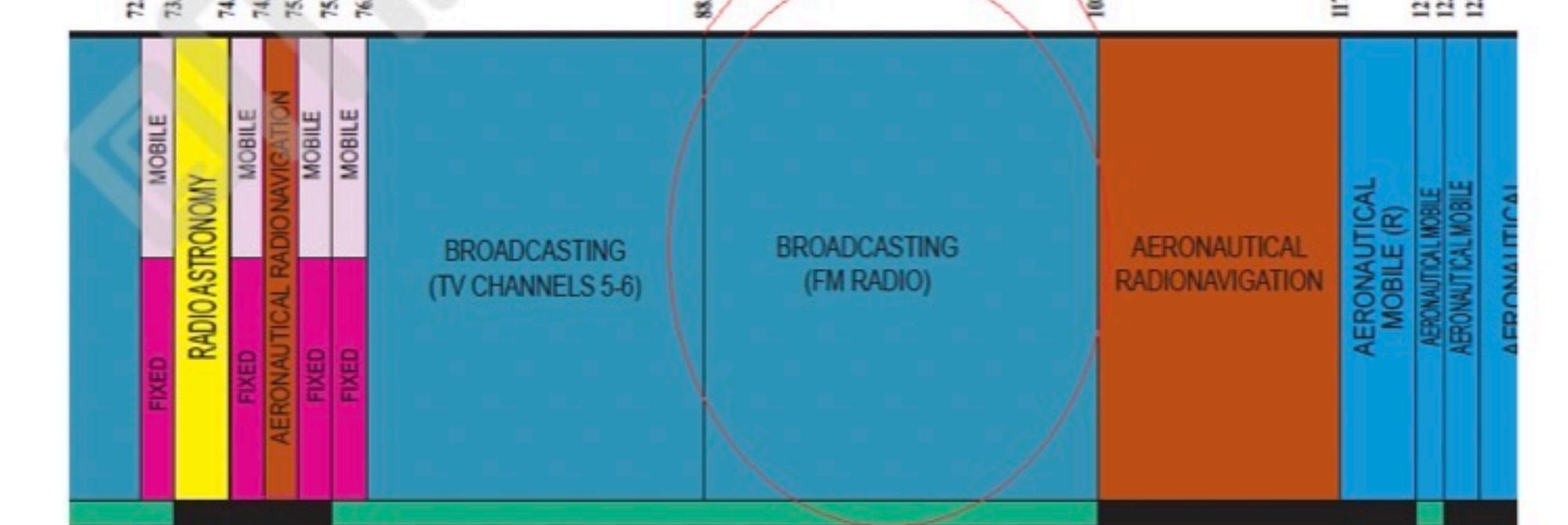
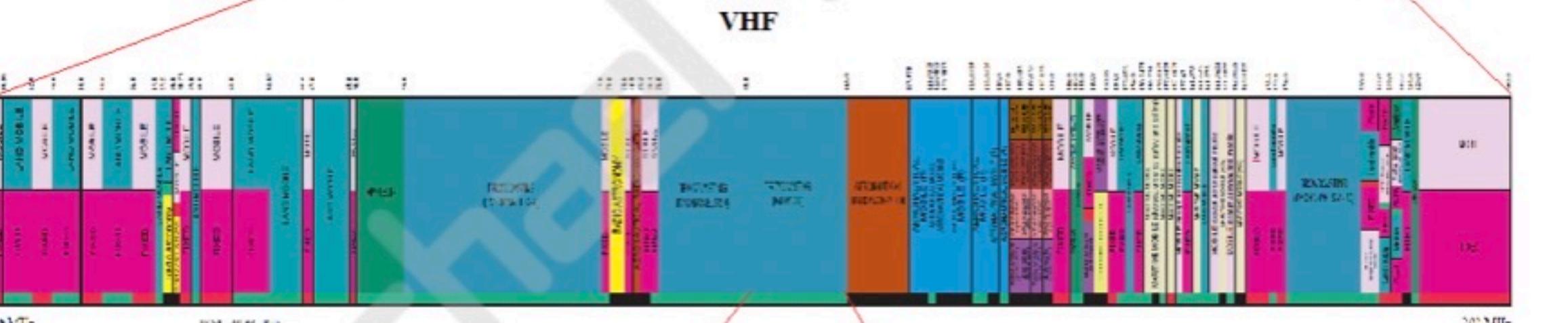
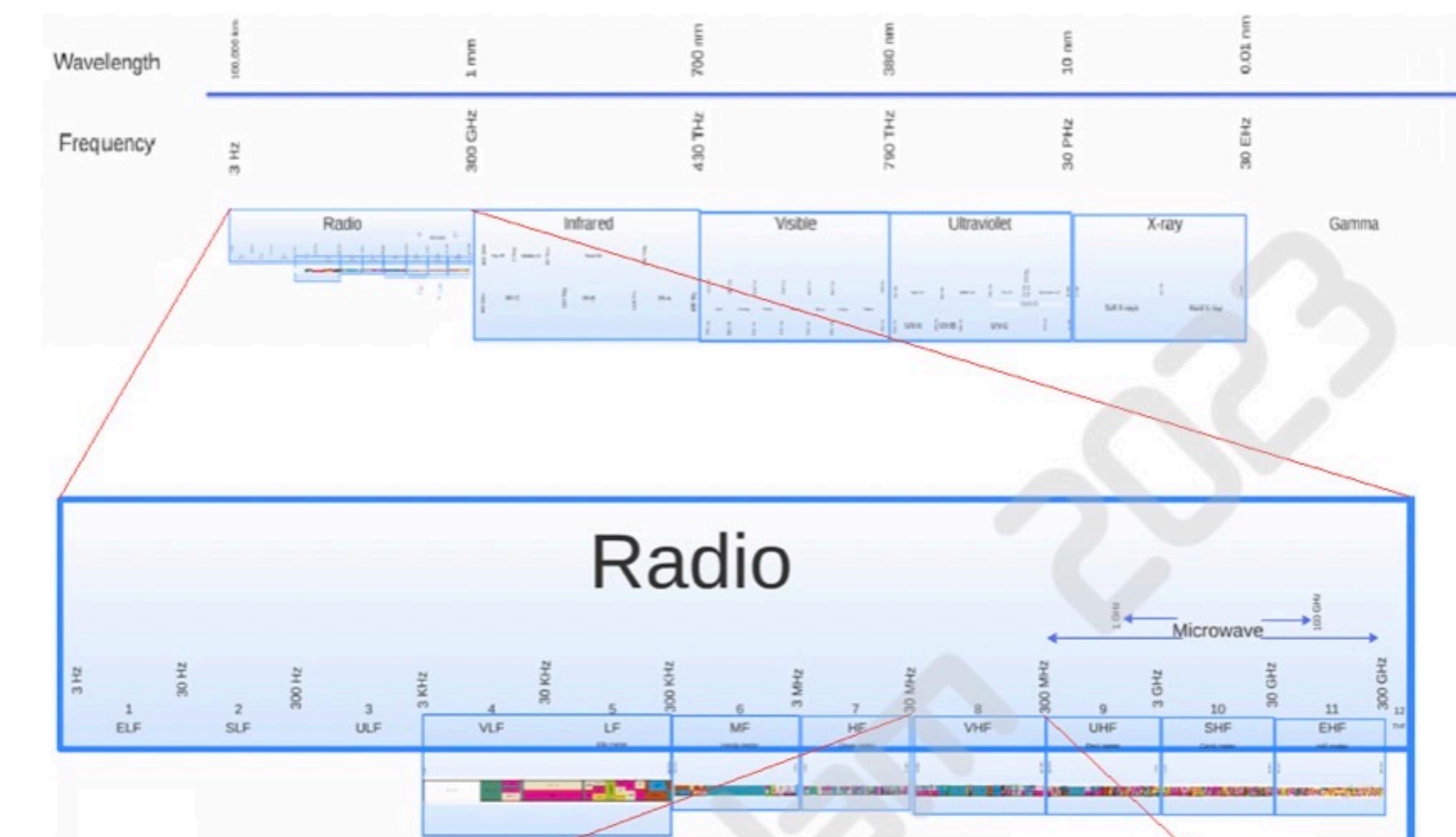
Oh my...



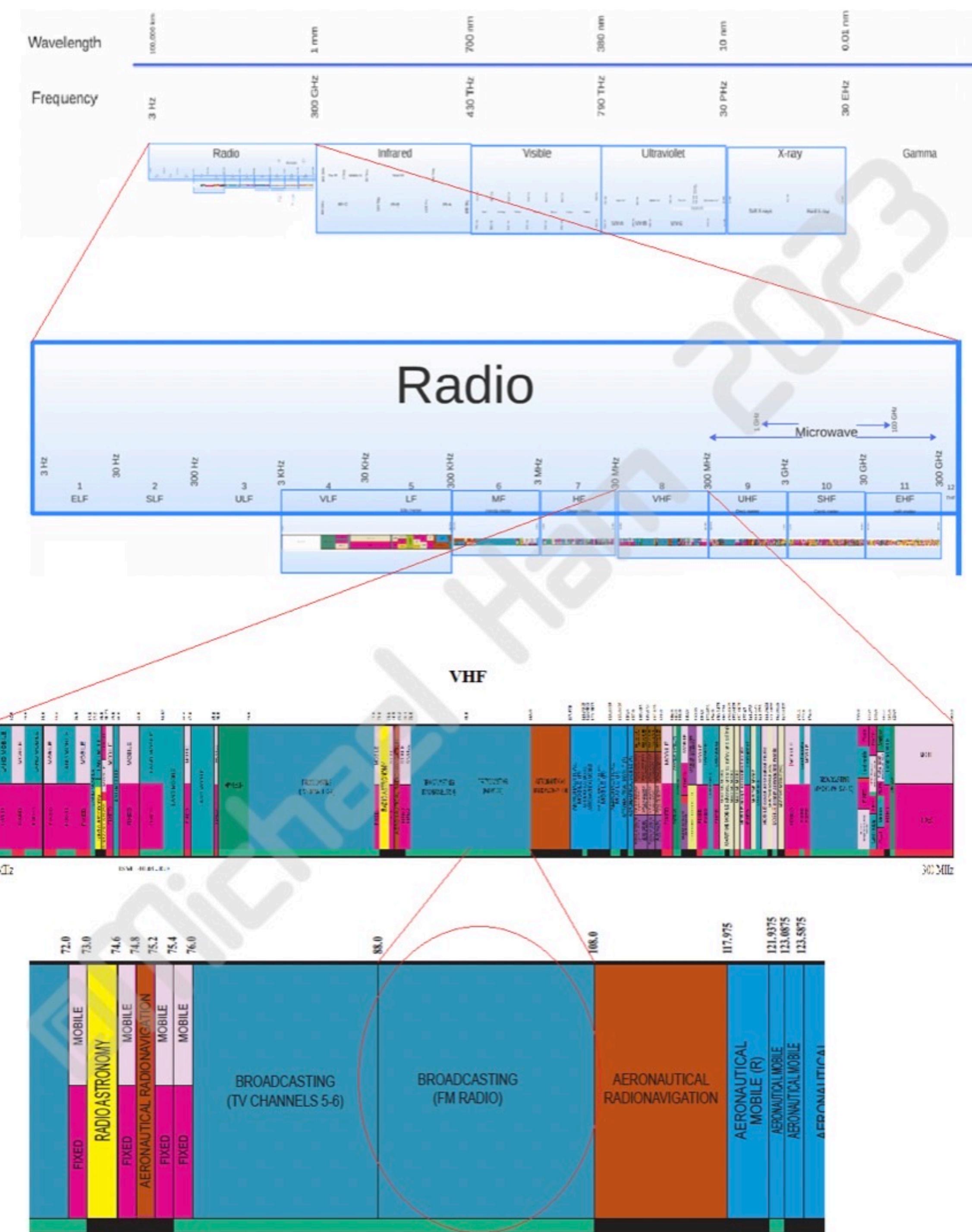
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Oh my...



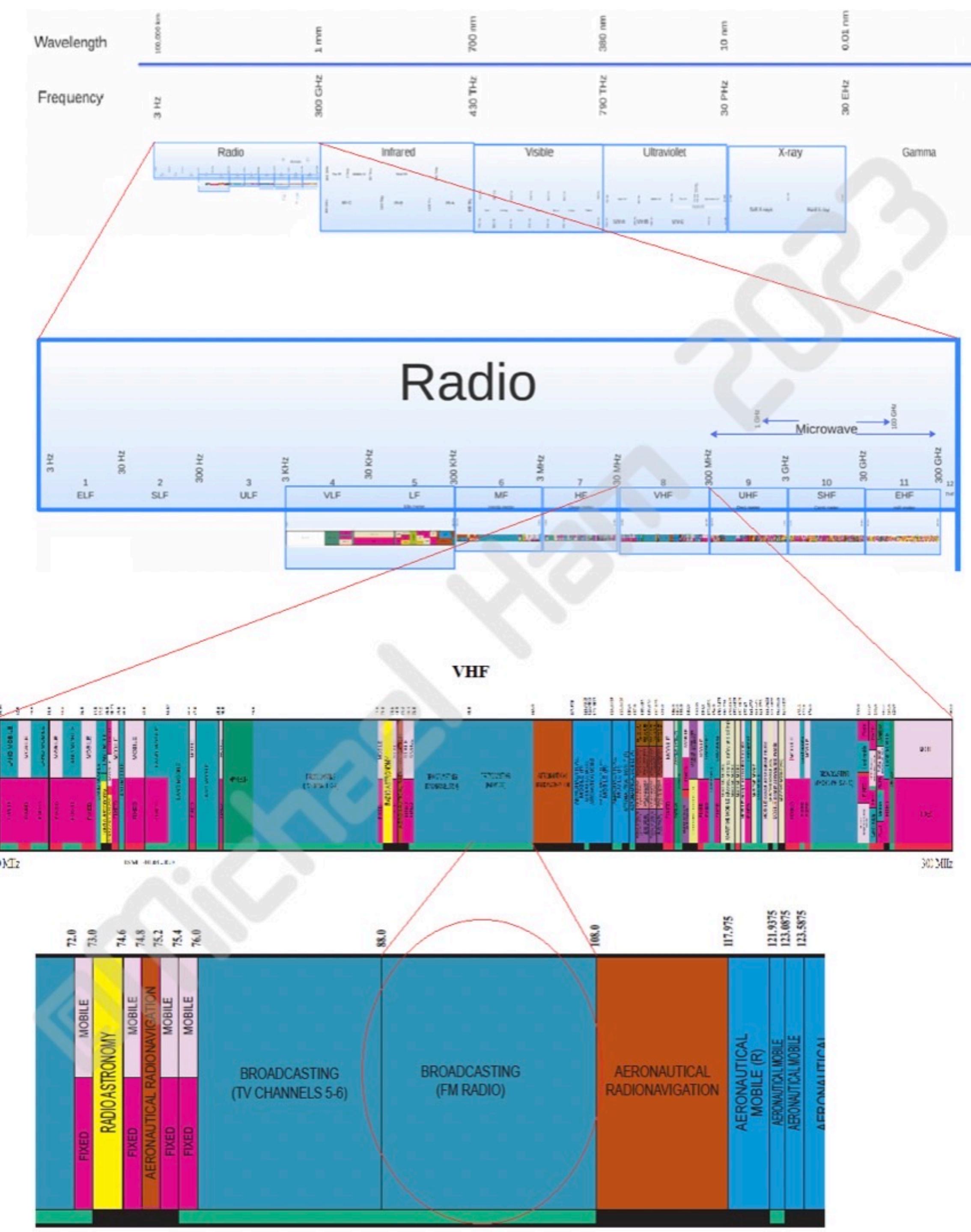


3Hz to 30GHz



3Hz to 30EHz

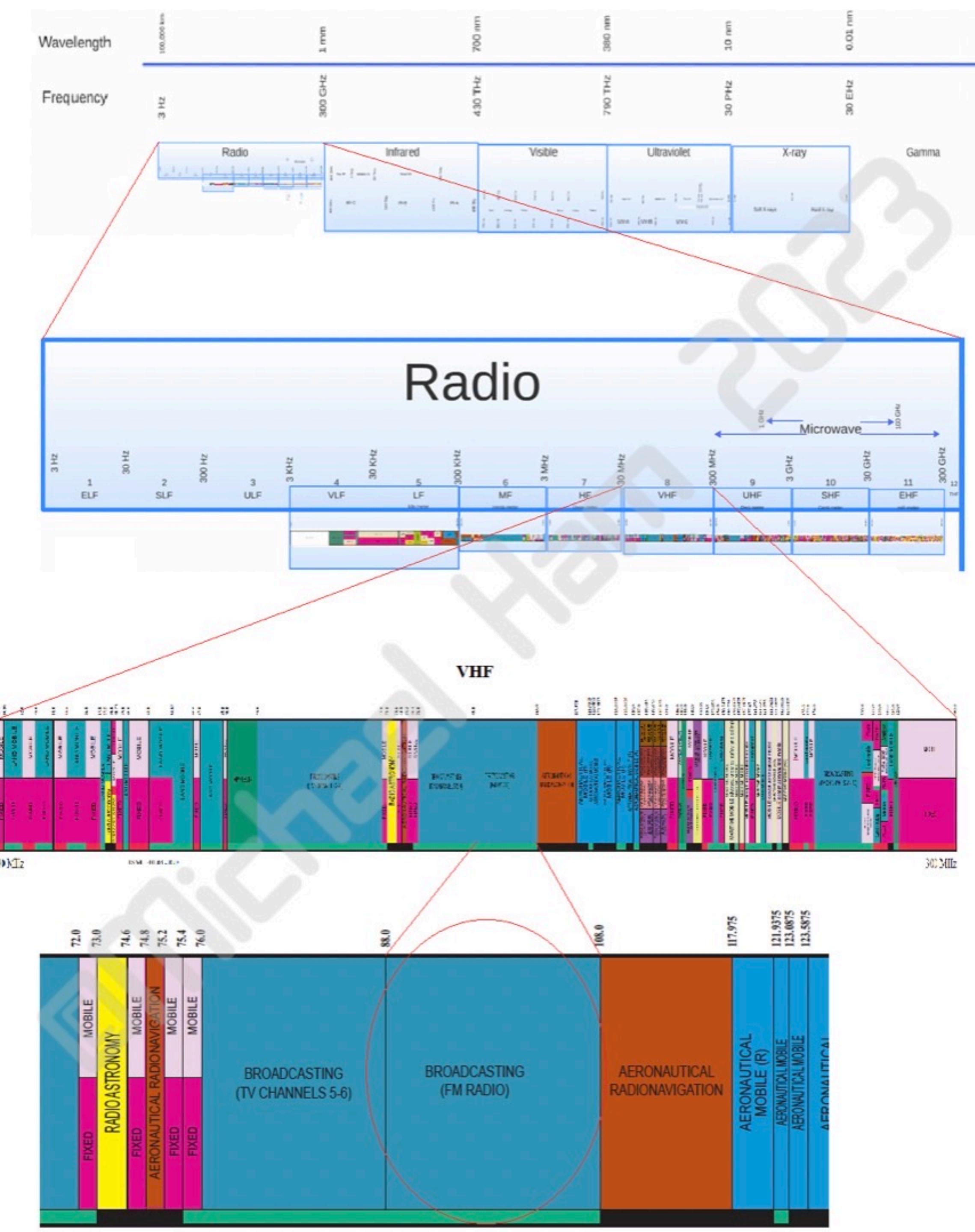
3Hz to 3THz



3Hz to 30EHz

3Hz to 3THz

30MHz to 300MHz

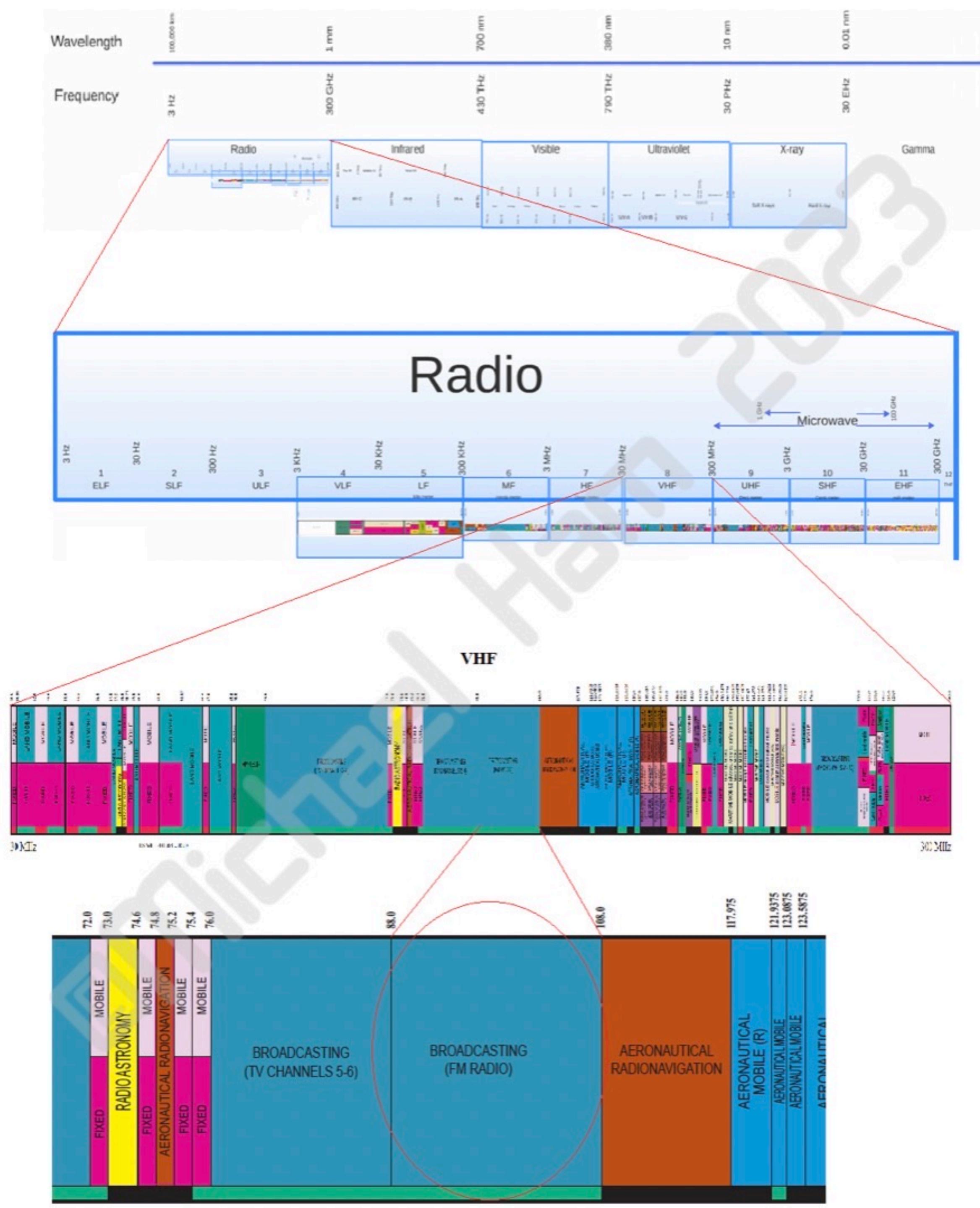


3Hz to 30EHz

3Hz to 3THz

30MHz to 300MHz

88MHz to 108MHz



US Frequency Allocations

- https://www.ntia.doc.gov/files/ntia/publications/january_2016_spectrum_wall_chart.pdf

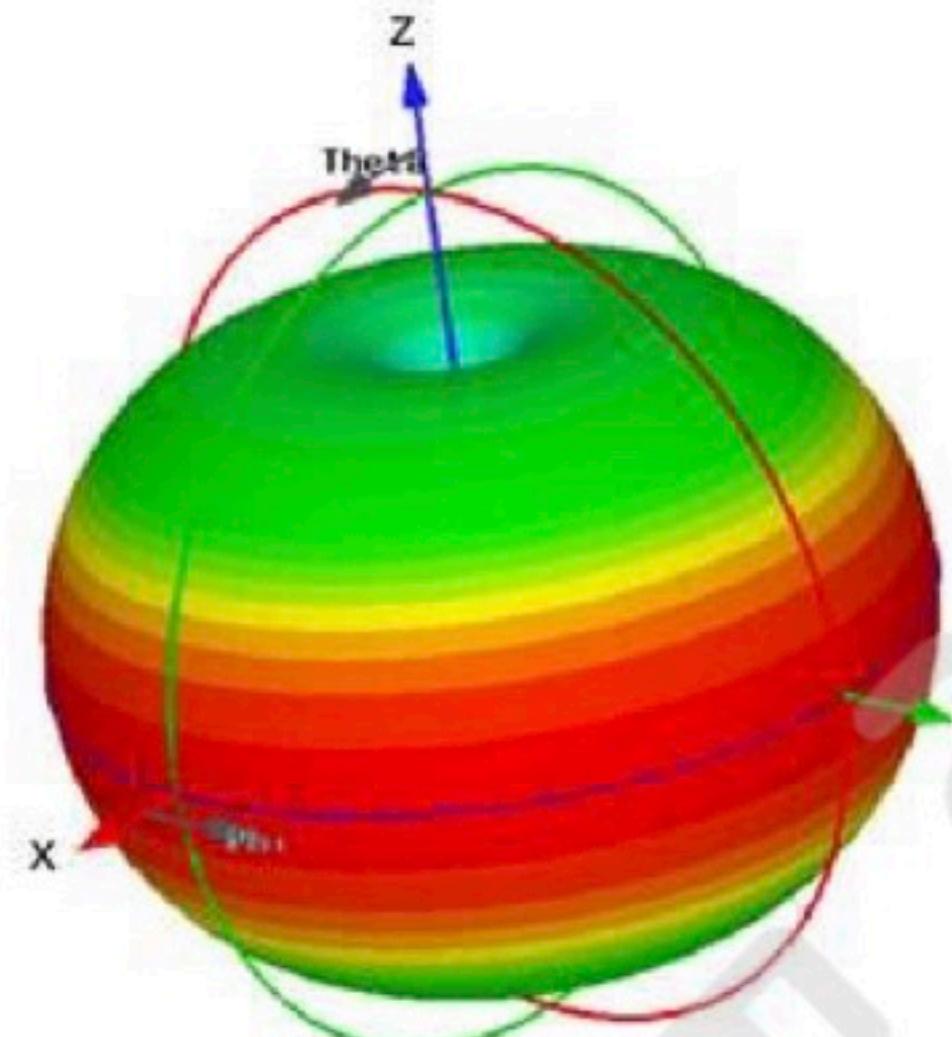


Antenna Types

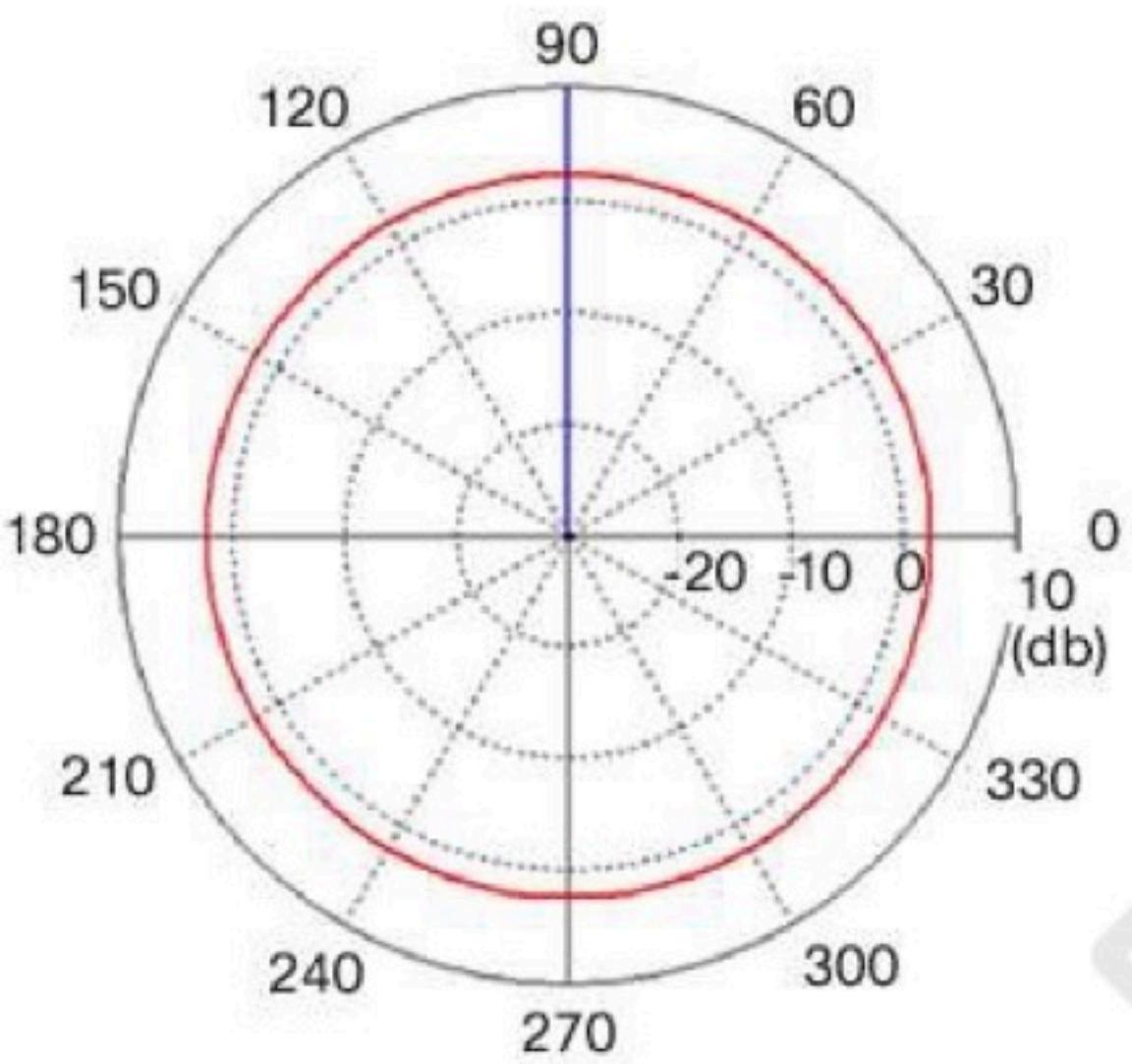
- Omnidirectional
 - Extends your range in all directions
- Directional
 - Let's you focus your signal in a particular direction
- Sensitivity – measured in dBi
 - dBi - gain of an antenna as referenced to an ISOTROPIC (omnidirectional) source
 - Remember, every 3 dBi = double the sensitivity



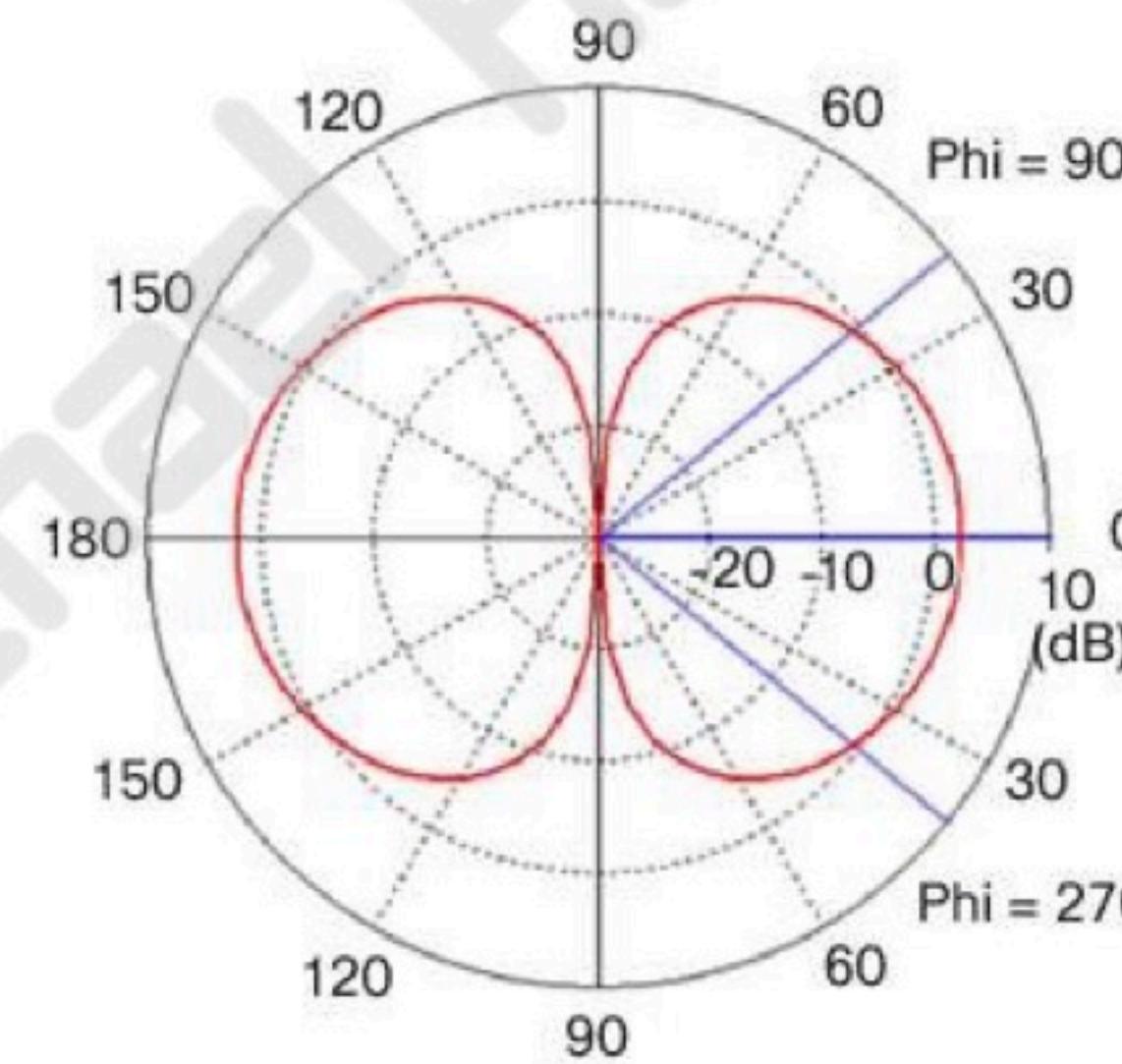
(a) Dipole Antenna Model



(b) Dipole 3D Radiation Pattern

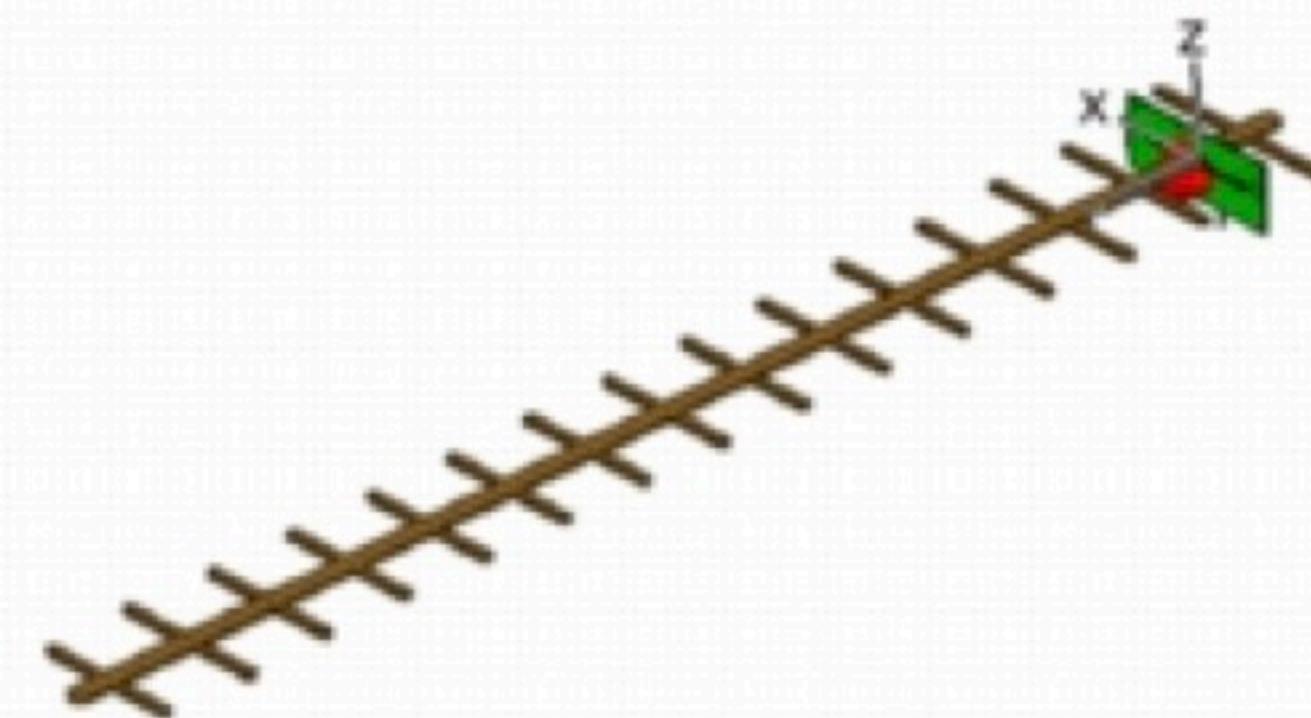


(c) Dipole Azimuth Plane Pattern

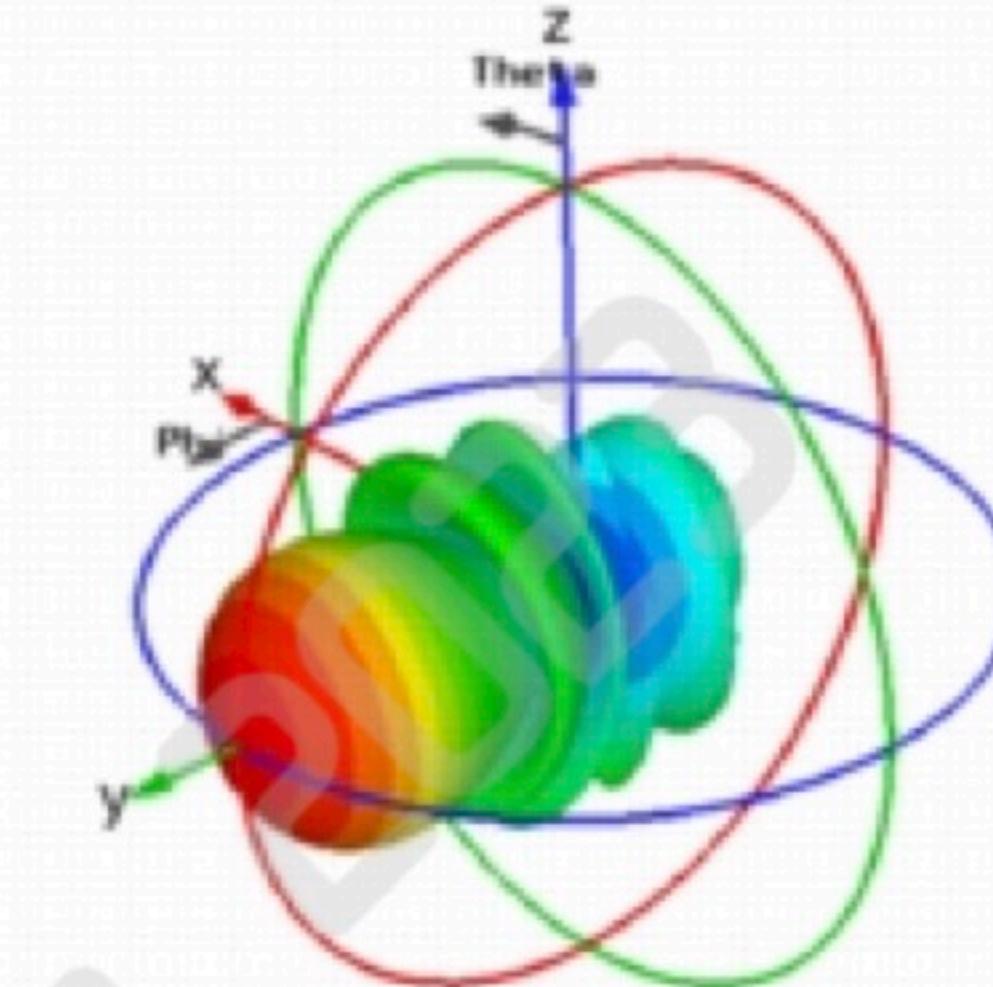


(d) Dipole Elevation Plane Pattern

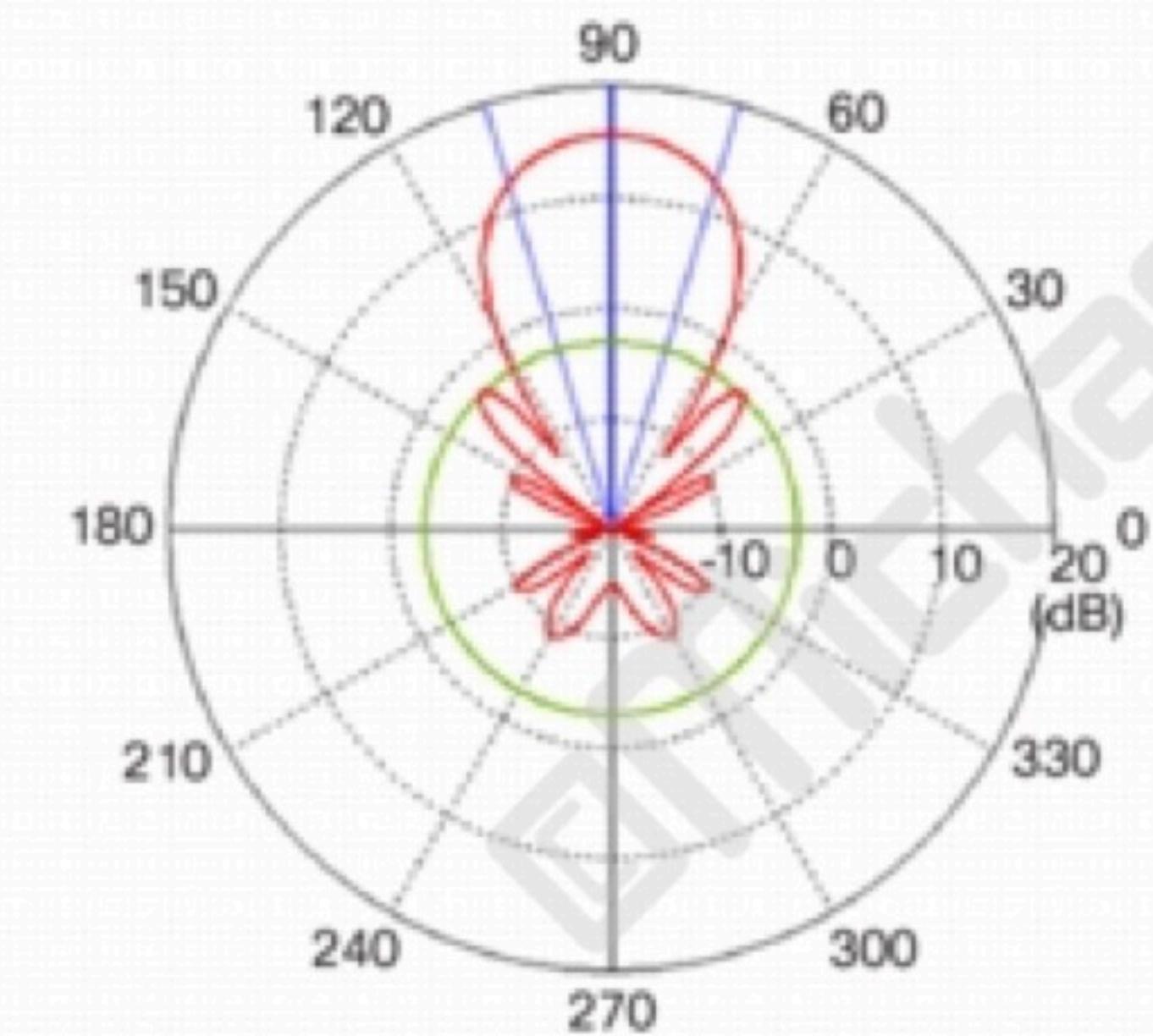




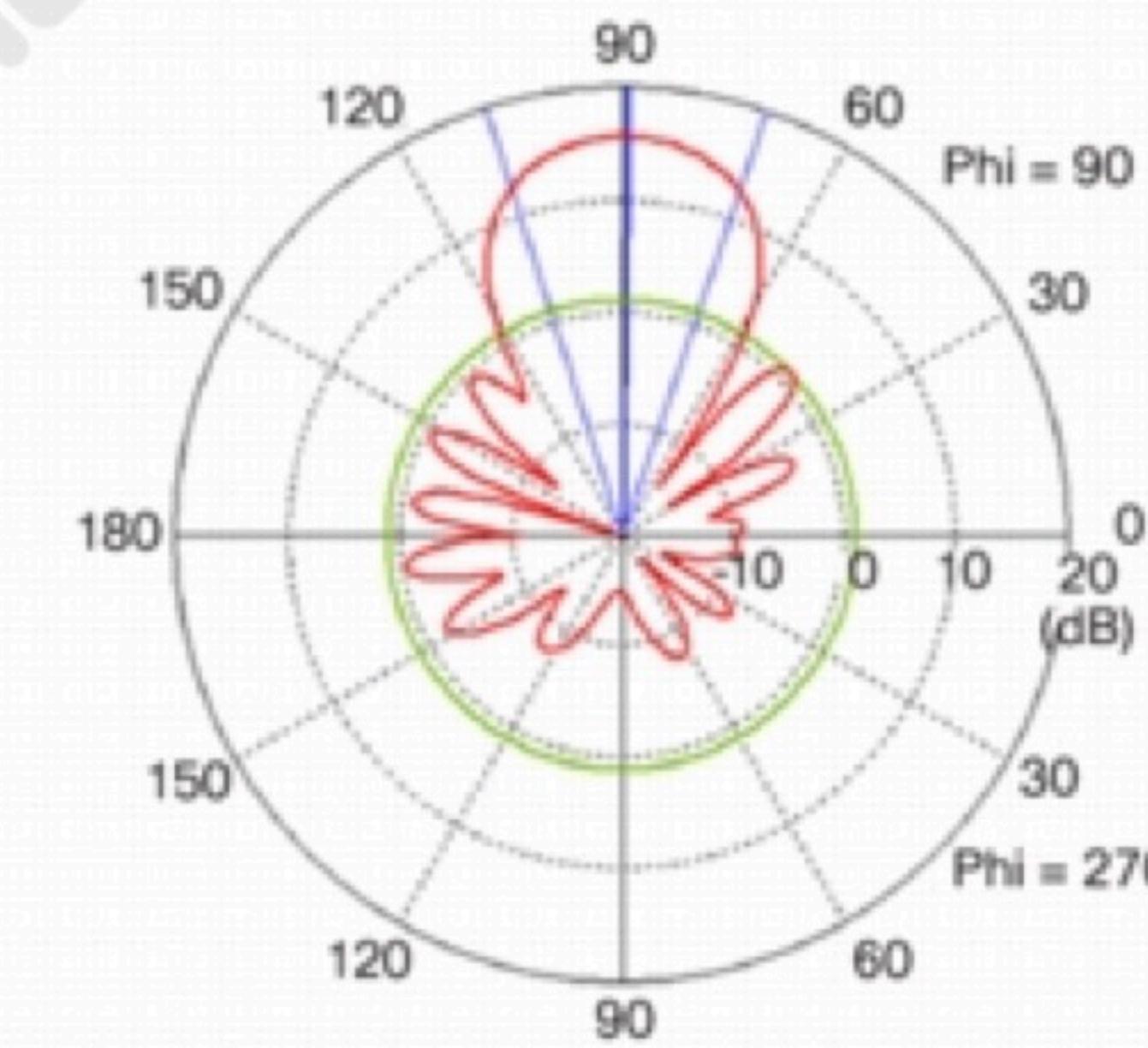
(a) Yagi Antenna Model



(b) Yagi Antenna 3D Radiation Pattern



(c) Yagi Antenna Azimuth Plane Pattern



(d) Yagi Antenna Elevation Plane Pattern

What is SDR?

- Device that allows us to *understand* different signals received by a radio
- Effectively the goal is to remove the analog parts of a radio and do it all in software
 - Think about turning a knob on the radio and replacing that mechanism with software
 - Rather than just being able to tune into one thing (e.g. FM radio), you can capture a wide array of bands

FM Radio



FM Radio



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FM Radio



FM Radio



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FM Radio

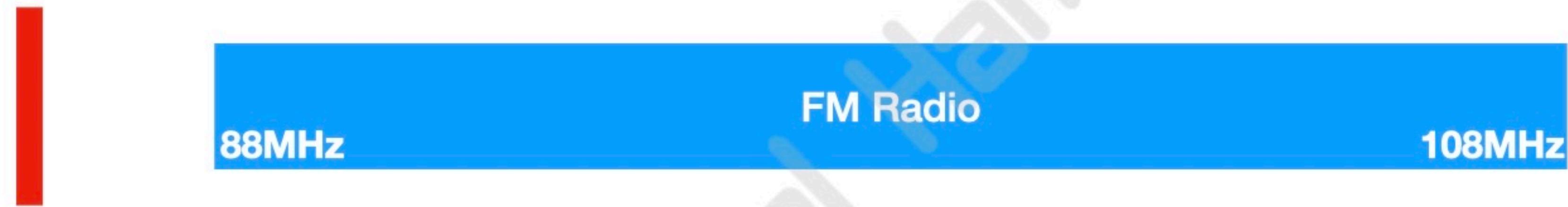


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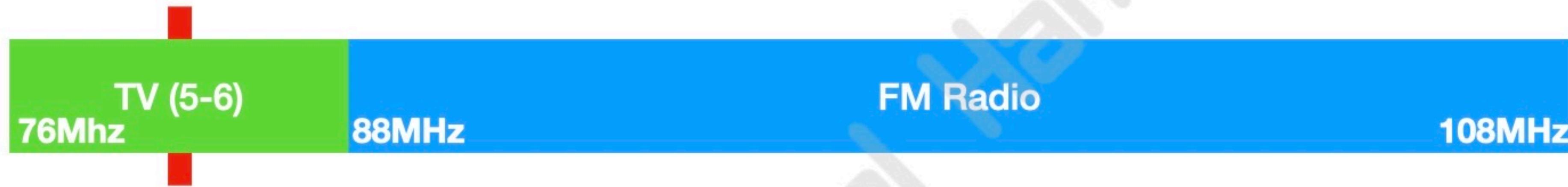
FM Radio



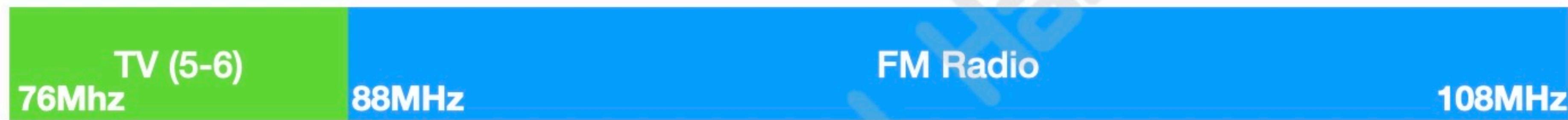
FM Radio



FM Radio



FM Radio



FM Radio



What can SDR do?

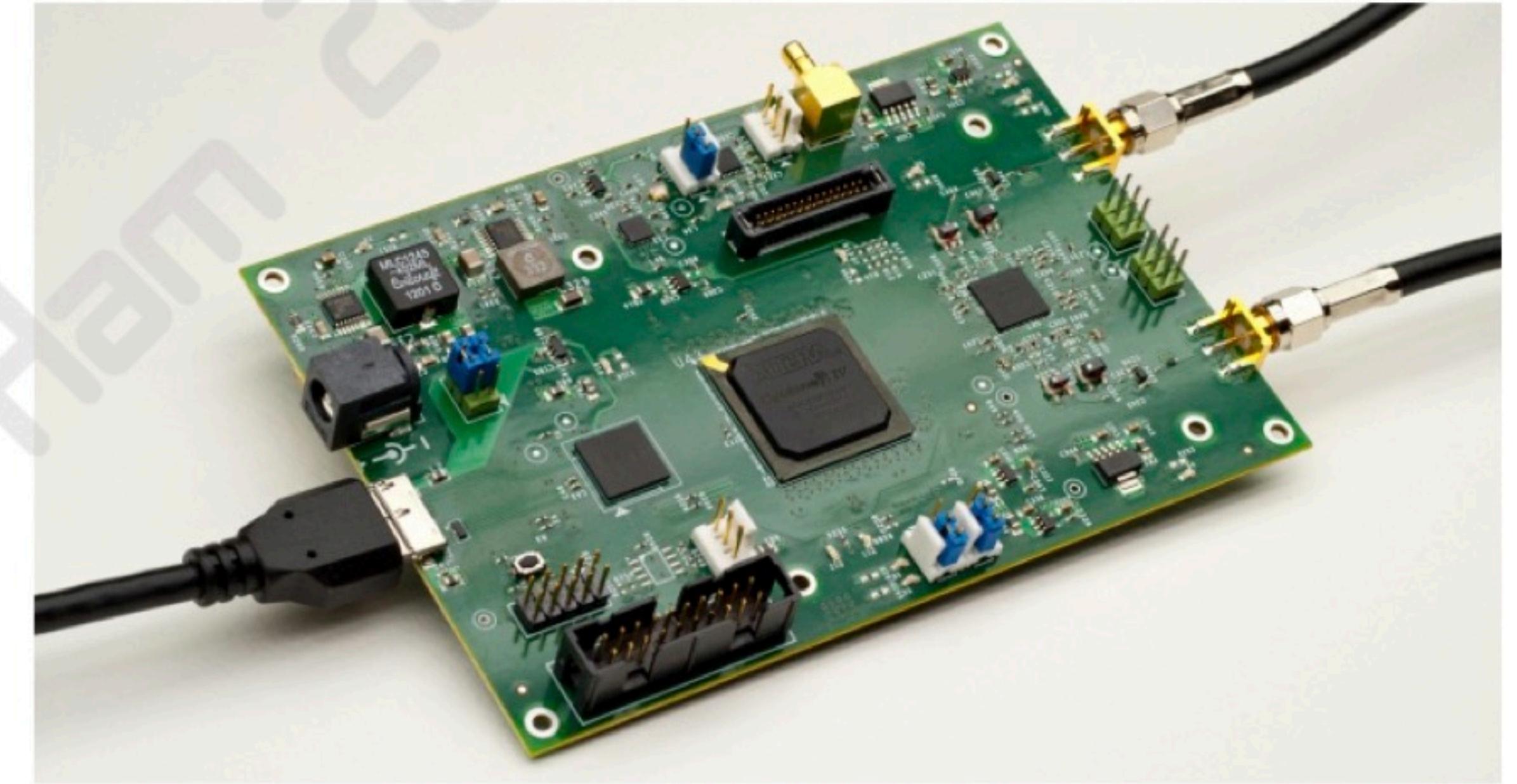
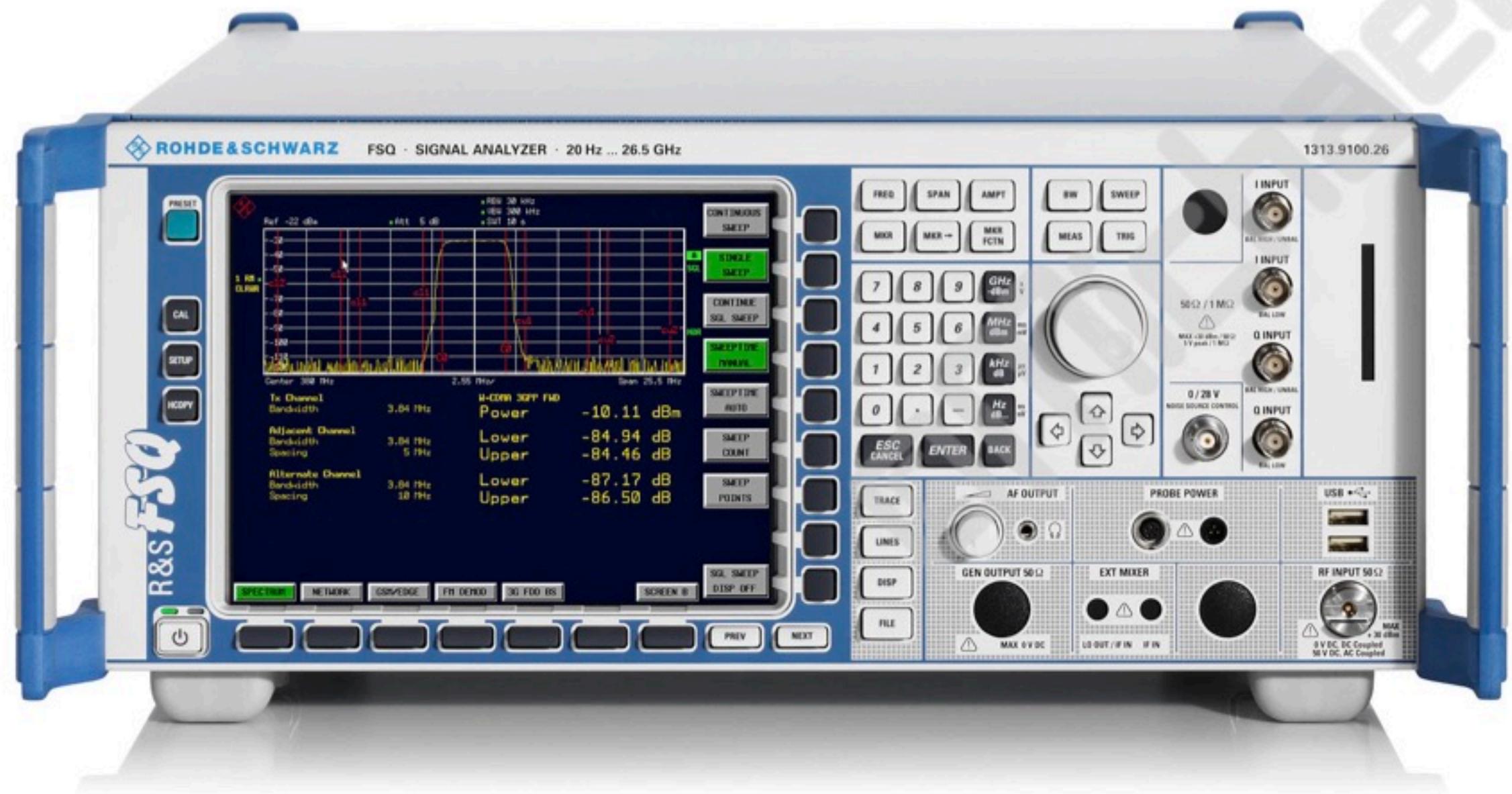
- This can be used as an AM / FM radio, a police scanner, air traffic control listener, etc.
- Receive images from weather satellites
- You're basically packet sniffing with radio
- Isn't that not legit to do?
 - Use common sense when doing stuff like this
 - The antennas you have can only receive not transmit so you're ok here

The Hardware

- Software Defined Radio Receiver USB Stick
 - RTL2832 w/R820T
 - 24MHz to 1850MHz
- ~20 piece of hardware, can definitely get them cheaper if you shop around



Other SDR Hardware



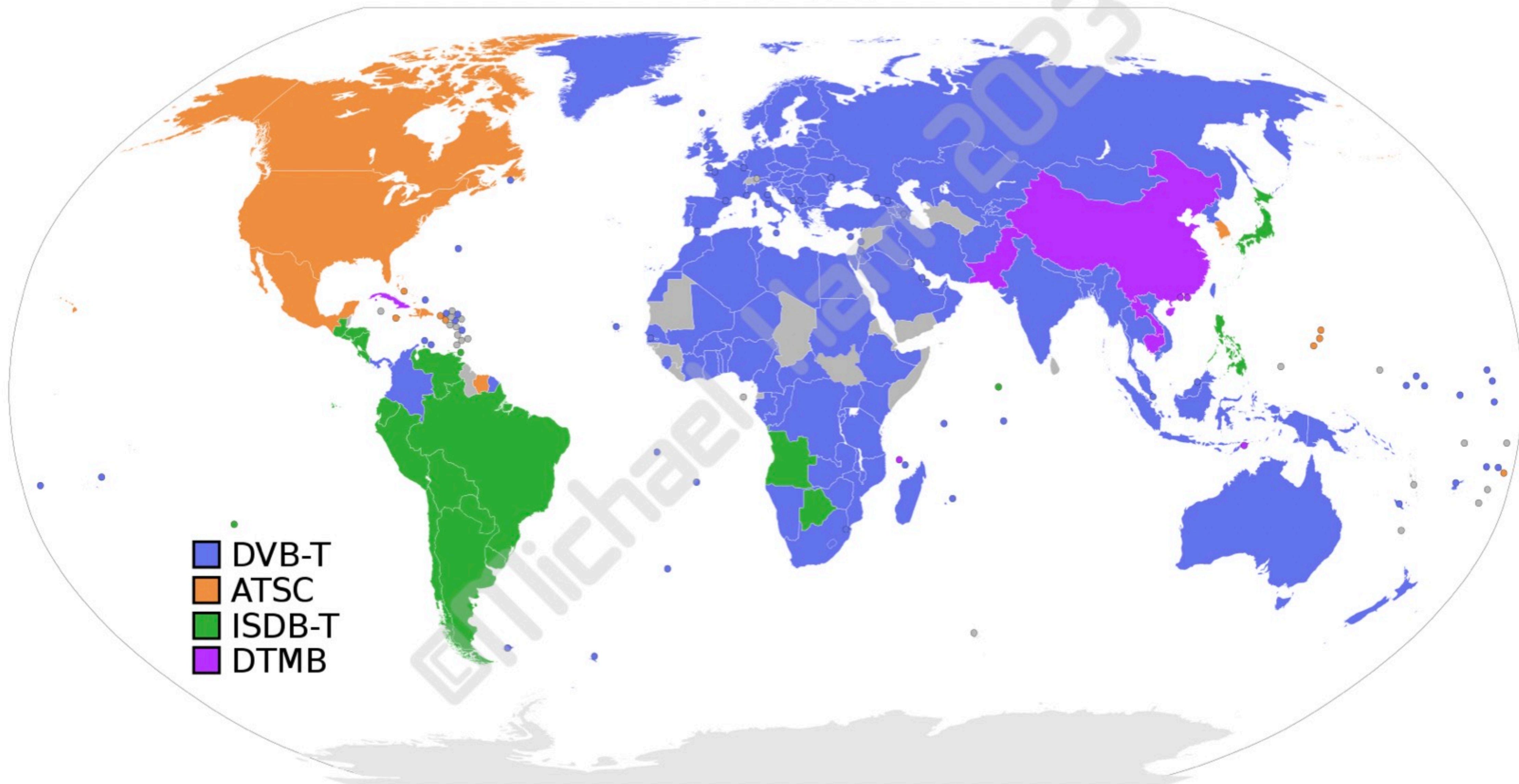
Geeky Specs

- DVBT:48.25 ~863.25 MHZ
- FM radio: 87.5~108 MHZ
- DAB radio: L-Band-1452960~1490624 KHZ
- VHF – 174928~ 239200 KHz
- Will work for both for software defined radio and DVB video capture (where available)
- Compatible with most SDR software. Approx range: 25MHz-1700MHz
- 6-8 MHz Bandwidth

Intended Purpose

- This USB adapter is meant to allow users to record and watch digital TV on a computer
 - Still image snapshots, recording and playback, etc.
 - Play FM radio and DAB digital radio
- Realtek RTL2832U and R820T chipsets
 - With a little trickery, we can actually make these do a lot more

TV?!

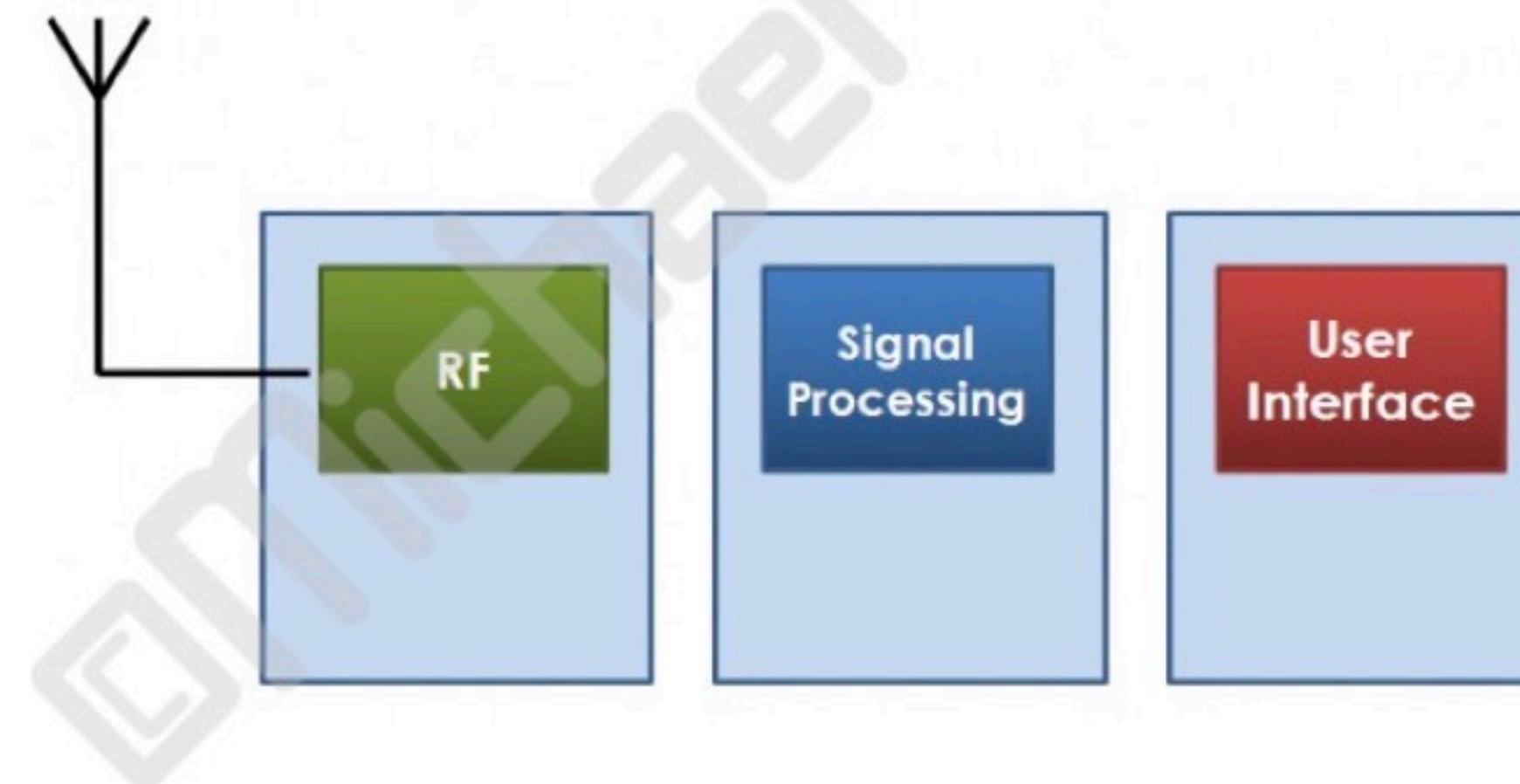


Driver Voodoo

- Some really smart people have crafted a driver for these USB adapters to give us more control
- Driver – software that controls hardware
 - Your mouse, keyboard, printers, etc. all use them
 - Computer has to know how to speak the language of the hardware in order for it to work

How does SDR work?

- At a 10,000' view, SDR converts the analog signals on the antenna into digital signals (1's and 0's)
- Using signal processing techniques, we can make that data more usable



Original → Sampled → Reconstructed

