International Committee on
Global Navigation Satellite Systems

The UWB Example
A Place to Start

Disclaimer

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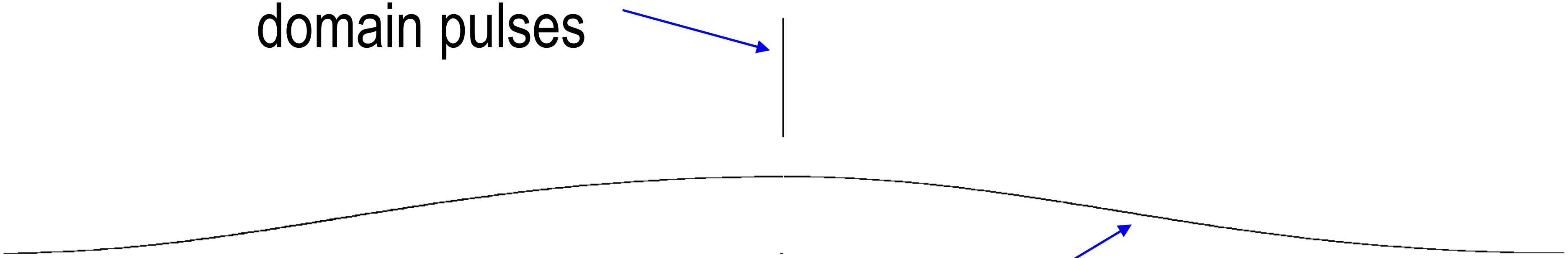
What's Ultra WideBand (UWB)

Very narrow time domain pulses



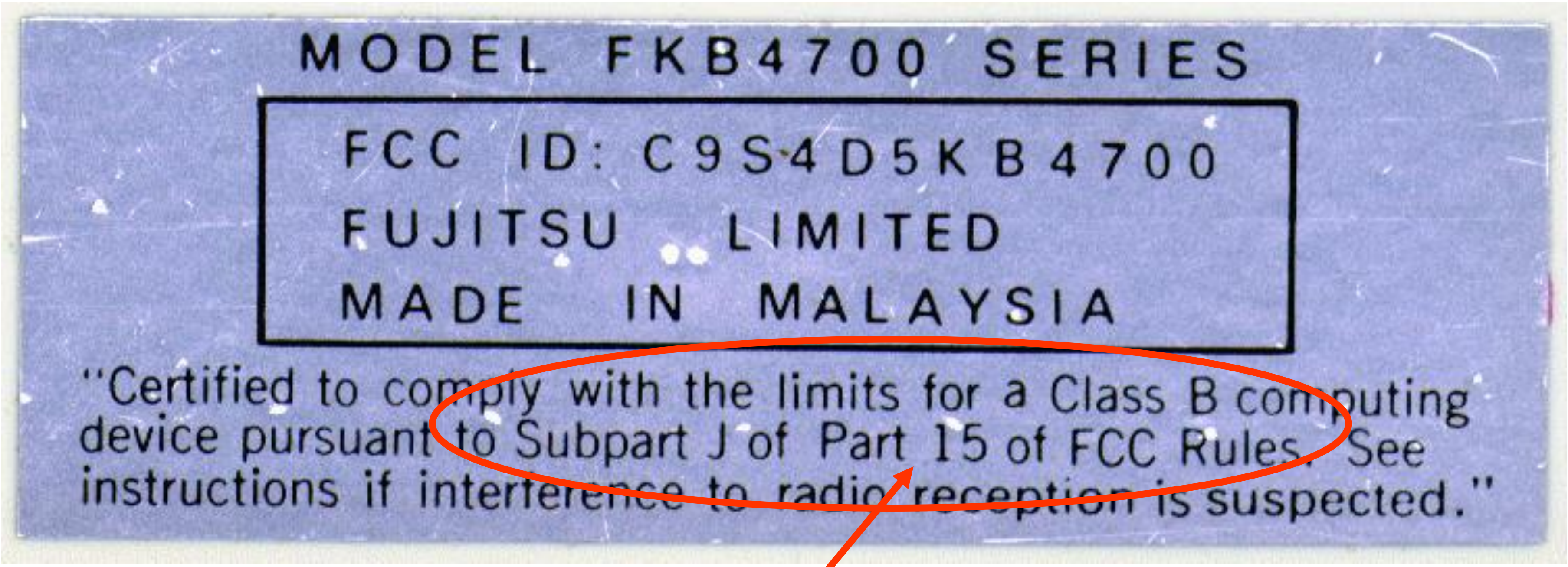
Create a very wide frequency spectrum

Sub-nanoseconds $\Rightarrow$ GigaHertz

UWB vs GPS – Conflict in Priorities

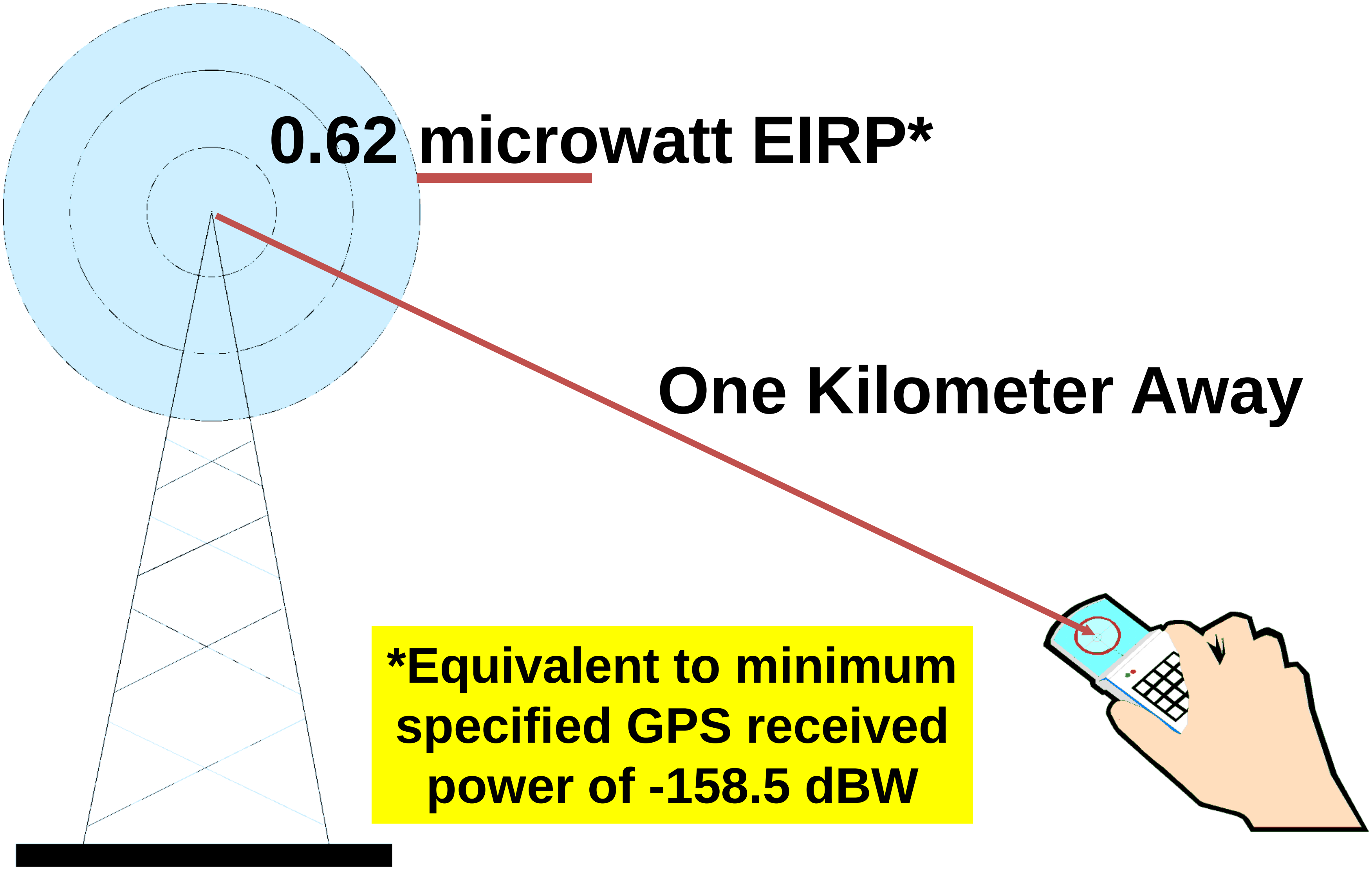
- The FCC and companies like Intel, Microsoft, and Sony saw UWB as an important step forward
  - Wideband, multipath-free communications
  - "Free" spectrum
    - UWB energy is lightly sprinkled across many frequency bands
    - With such low spectral power density, who could care?
- Omnidirectional users of satellite signals care
  - Because satellite signals are extremely weak

Part 15 of FCC Rules

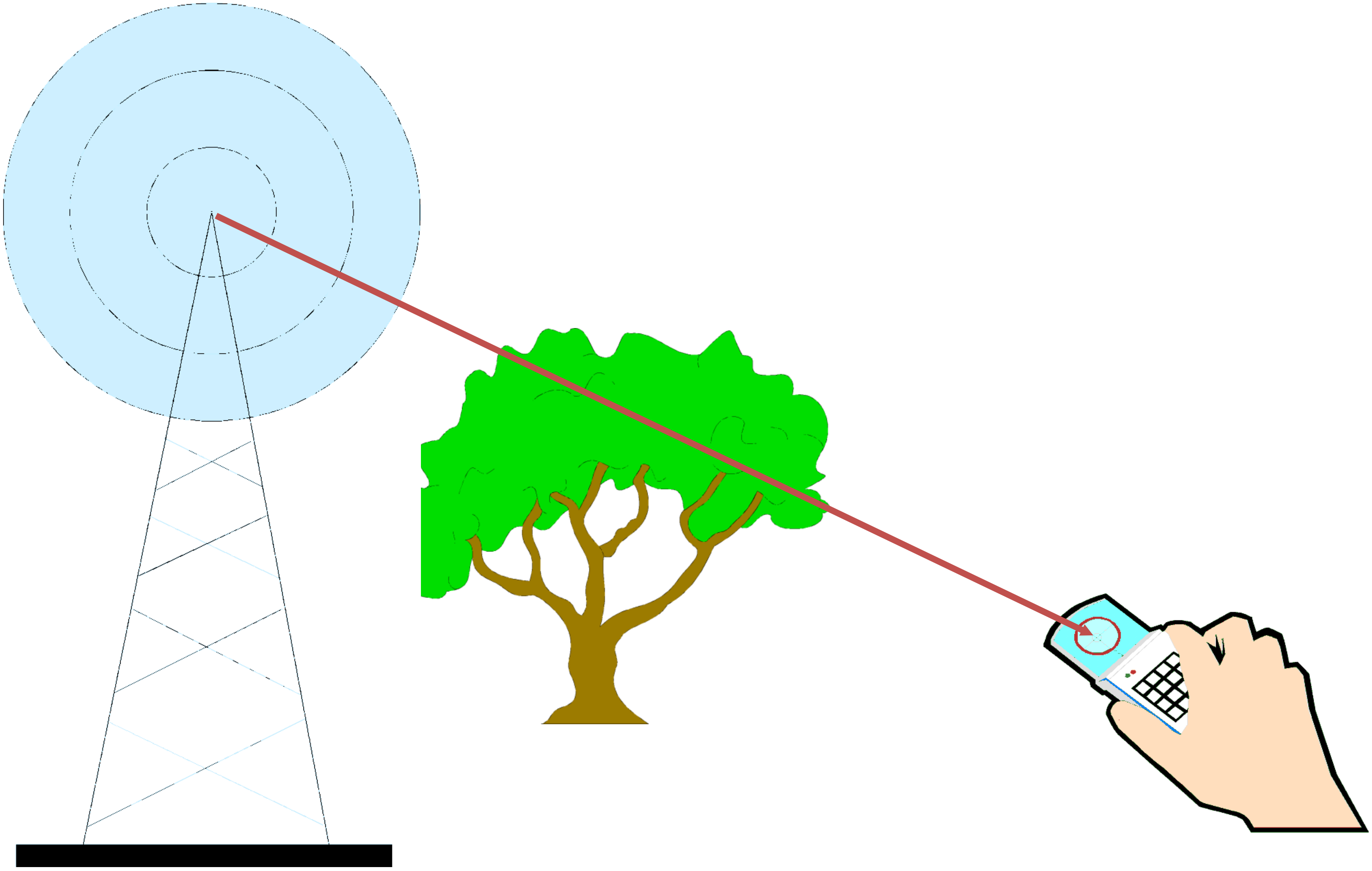


Unintentional radiation is limited by FCC Part 15 rules to –41.3 dBm/MHz EIRP

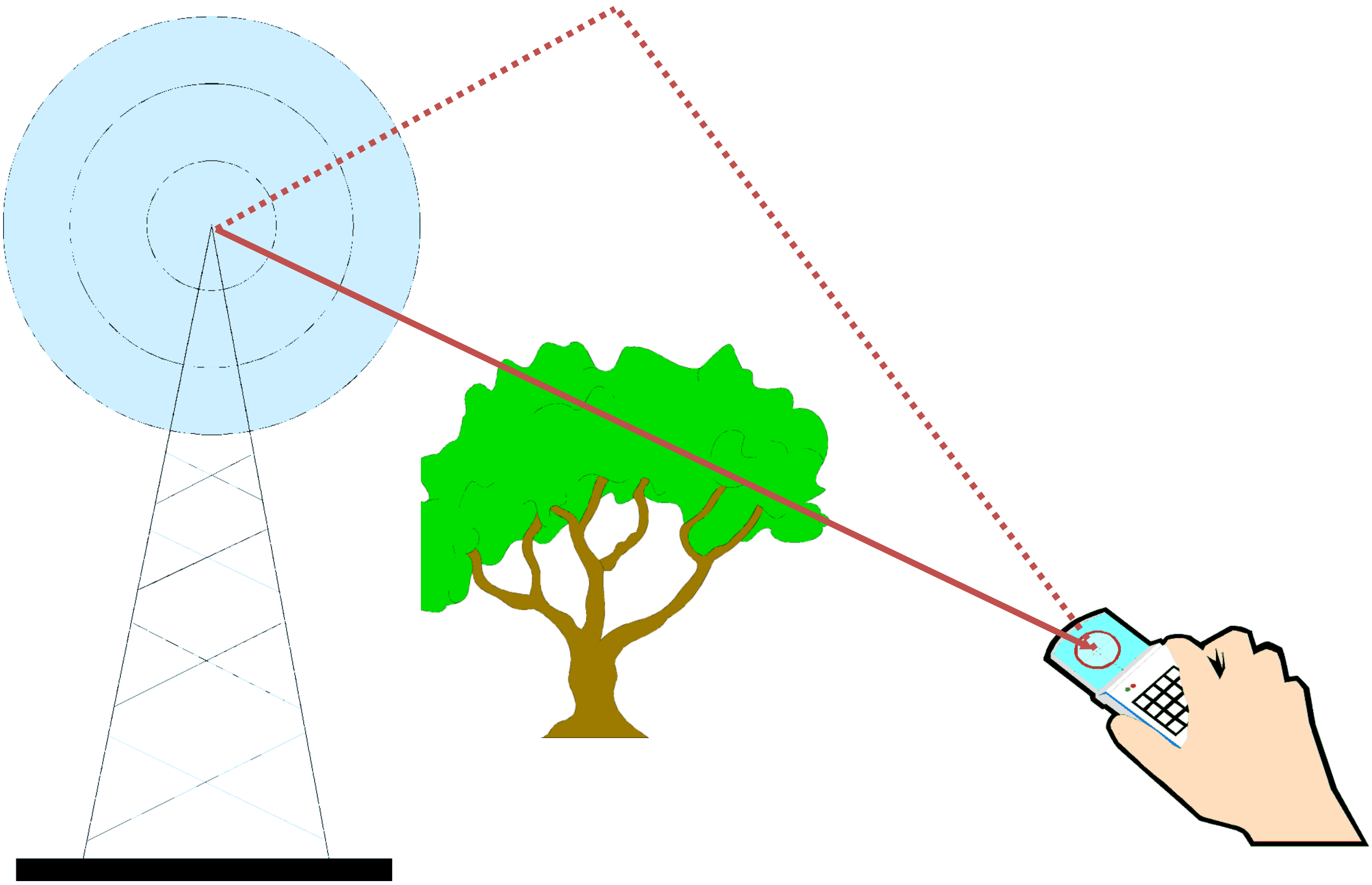
GPS Signals Start Out Very Weak



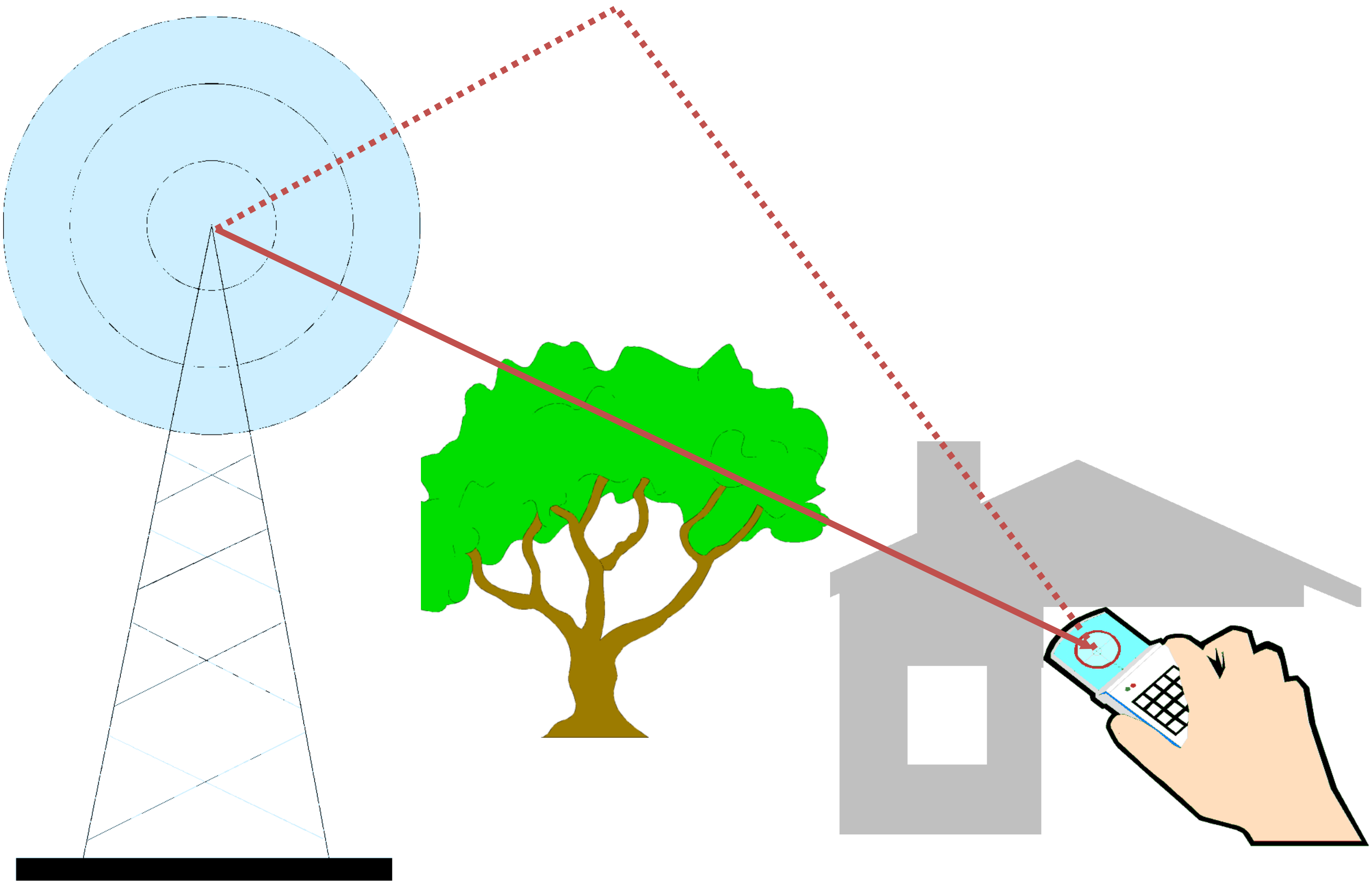
And can be Attenuated by Foliage



Further Attenuated by Multipath



Even More Attenuation Indoors

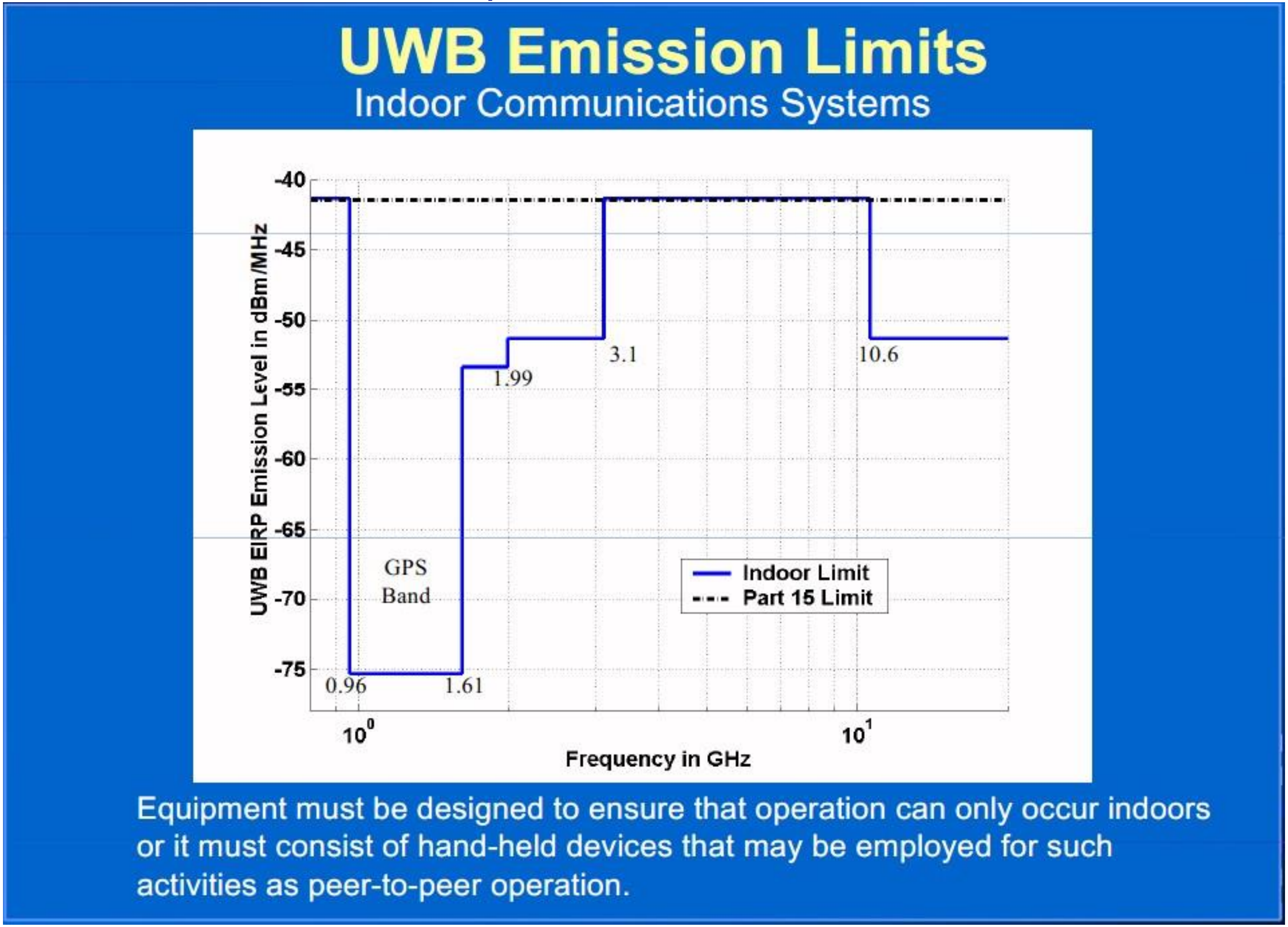


UWB Criteria Selected for GPS Protection

- It is **not** possible to regulate the user density of Unlicensed, Uncontrolled, Ubiquitous UWB emitters
  - One prediction: "1,000's in homes, 1,000,000's in an industry"
- It is only possible to regulate the emissions from **each** individual device
  - Backed by a vigorous testing and product recall program
- Therefore, in the GPS bands the UWB criteria is:
  - Allow <u>each</u> UWB emitter to raise the GPS noise floor
  - By 26% (1 dB) at a distance of 6 feet (1.83 m)
  - Which requires an EIRP at or below –75.3 dBm/MHz (–105.3 dBW/MHz)
- In comparison, the cost and the time required to raise the power of all 28-31 GPS satellites by 26% would be Billions of dollars and at least 15 years

Cover of December 2001 FCC Presentation

-75.3 dBm/MHz, 34 dB Below Part 15 Limit



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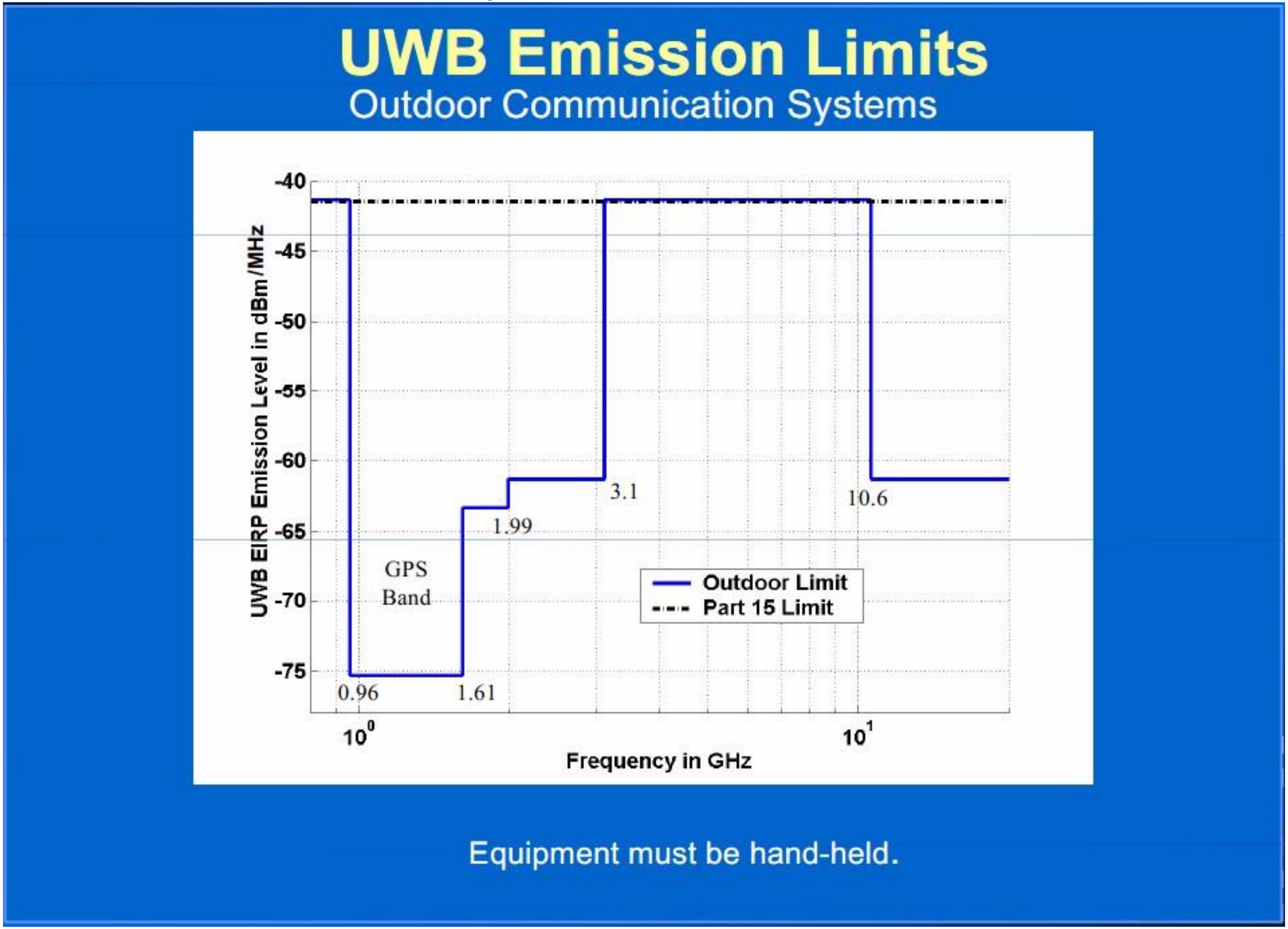
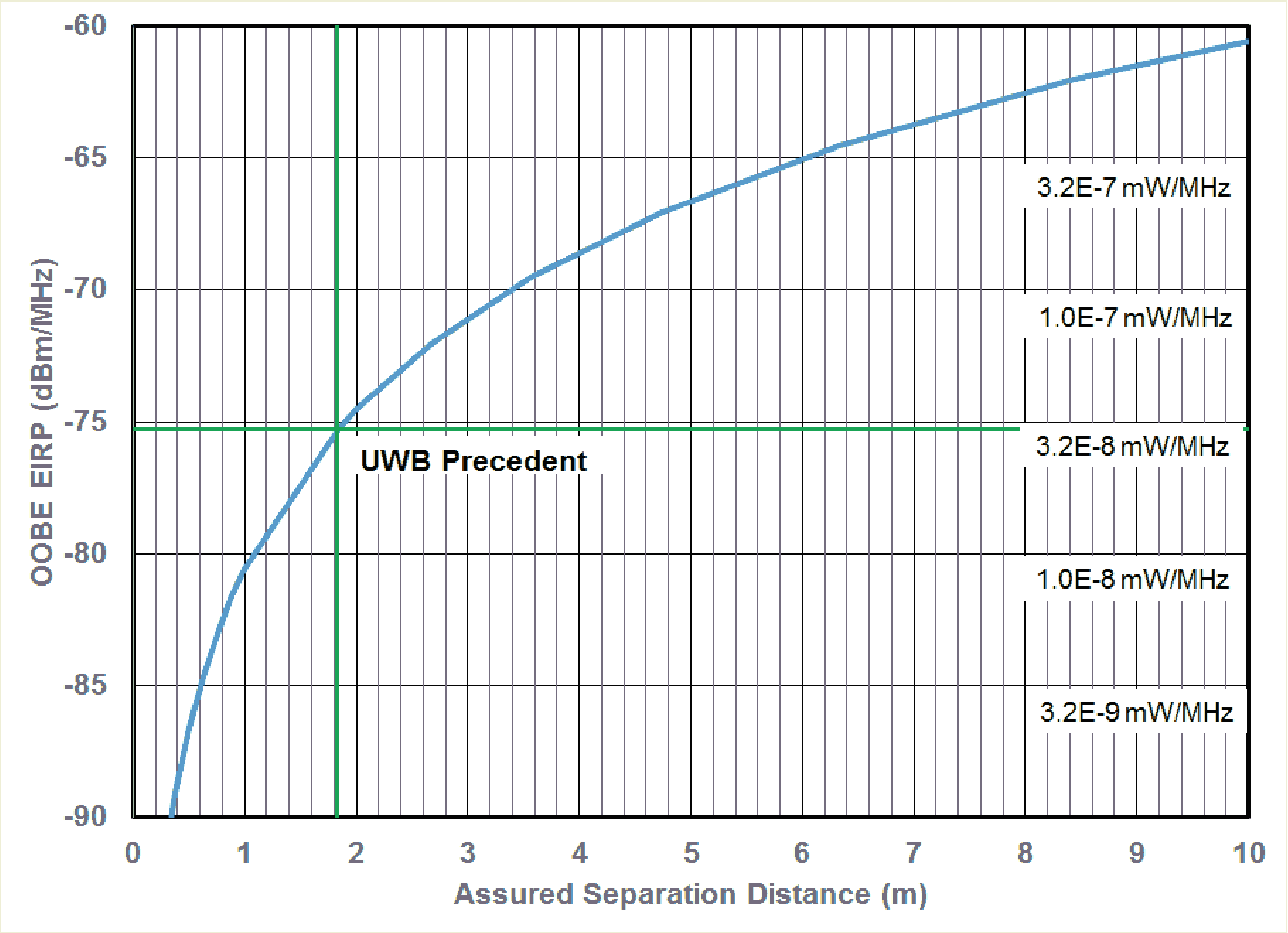


Using the UWB Agreement as a Model

- Based on the UWB Agreement, the following chart shows:
  - The Equivalent Isotropic Radiated Power (EIRP)
  - Of Out-Of-Band-Emissions (OOBE)
  - Received within the GPS L1 band
  - From a transmitter at an assured minimum distance from any GPS receiver
- This must be achieved by
  - Filtering at the transmitter
  - Transmitter power control if needed
- Assured distance means the GPS receiver and the transmitter must never be that close

OOBE EIRP vs. Assured Separation Distance



Unintentional Radiation Limit

- The FCC regulates unintentional radiation with Part 15 rules, requiring EIRP to be less than -41.3 dBm/MHz
- The UWB industry asked the FCC for permission to intentionally transmit that level of noise-like signal, including within the GPS spectrum
- Ultimately,the FCC UWB Report & Order (R&O) limited most UWB emissions to -75.3 dBm/MHz EIRP, 34 dB less than Part 15 power in GPS bands
- What reasonable limit should apply to unintentional radiation?
- What standard does your country use?

GNSS INTERFERENCE FROM TERRESTRIAL BROADBAND NETWORKS IN THE ADJACENT BAND

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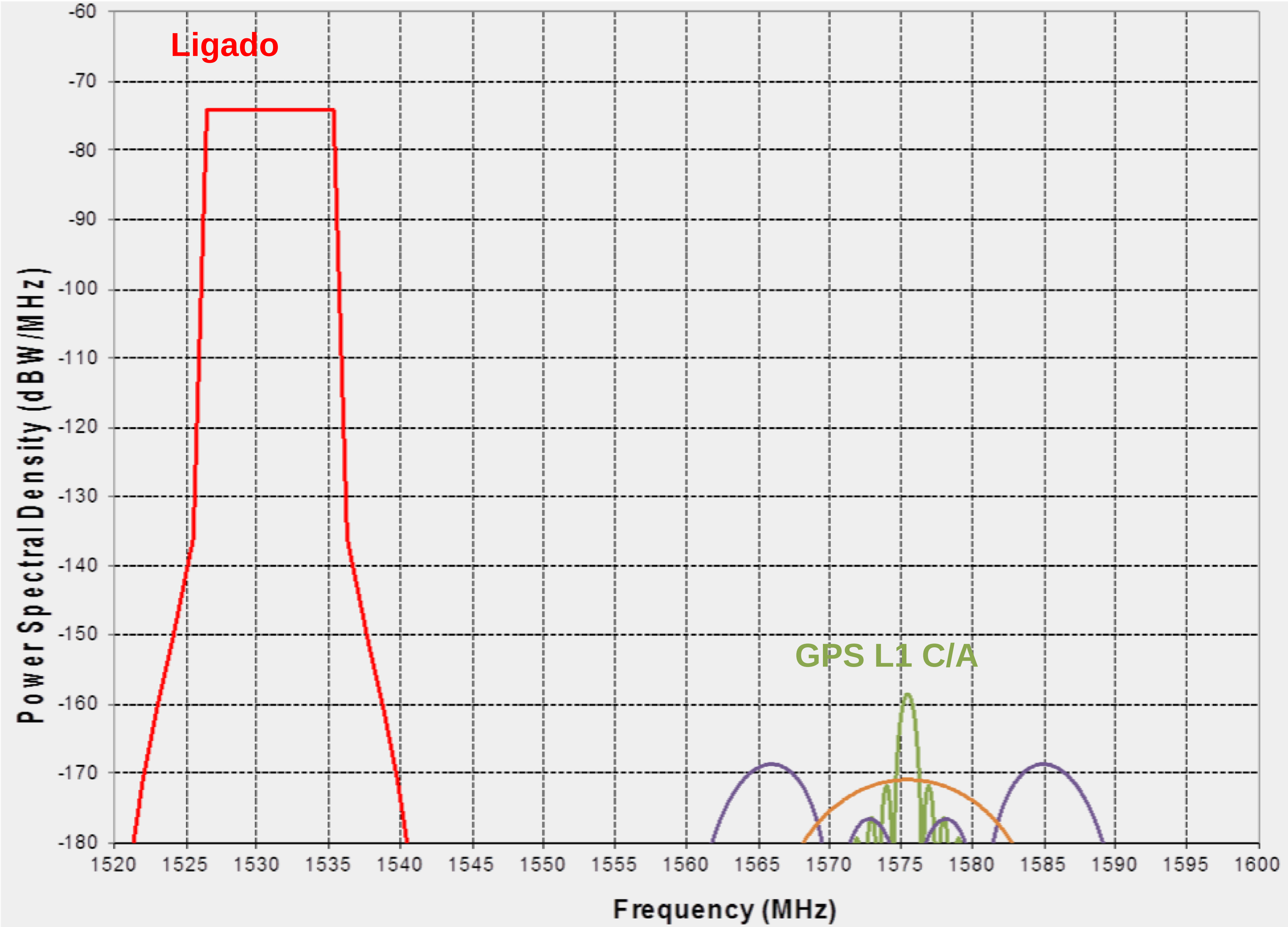
Differences between GPS satellites and terrestrial transmitters

	GPS Satellites	Terrestrial Transmitters
Center frequency	1575 MHz	1531 MHz
Distance from GPS receivers	**≥ 20,000,000 m**	**≥ 76 m**
Transmitter power	107 W	9 W to 1585 W
Received power spectral density at center frequency	≤ -158 dBW/MHz	-75 dBW/MHz
Analogy		

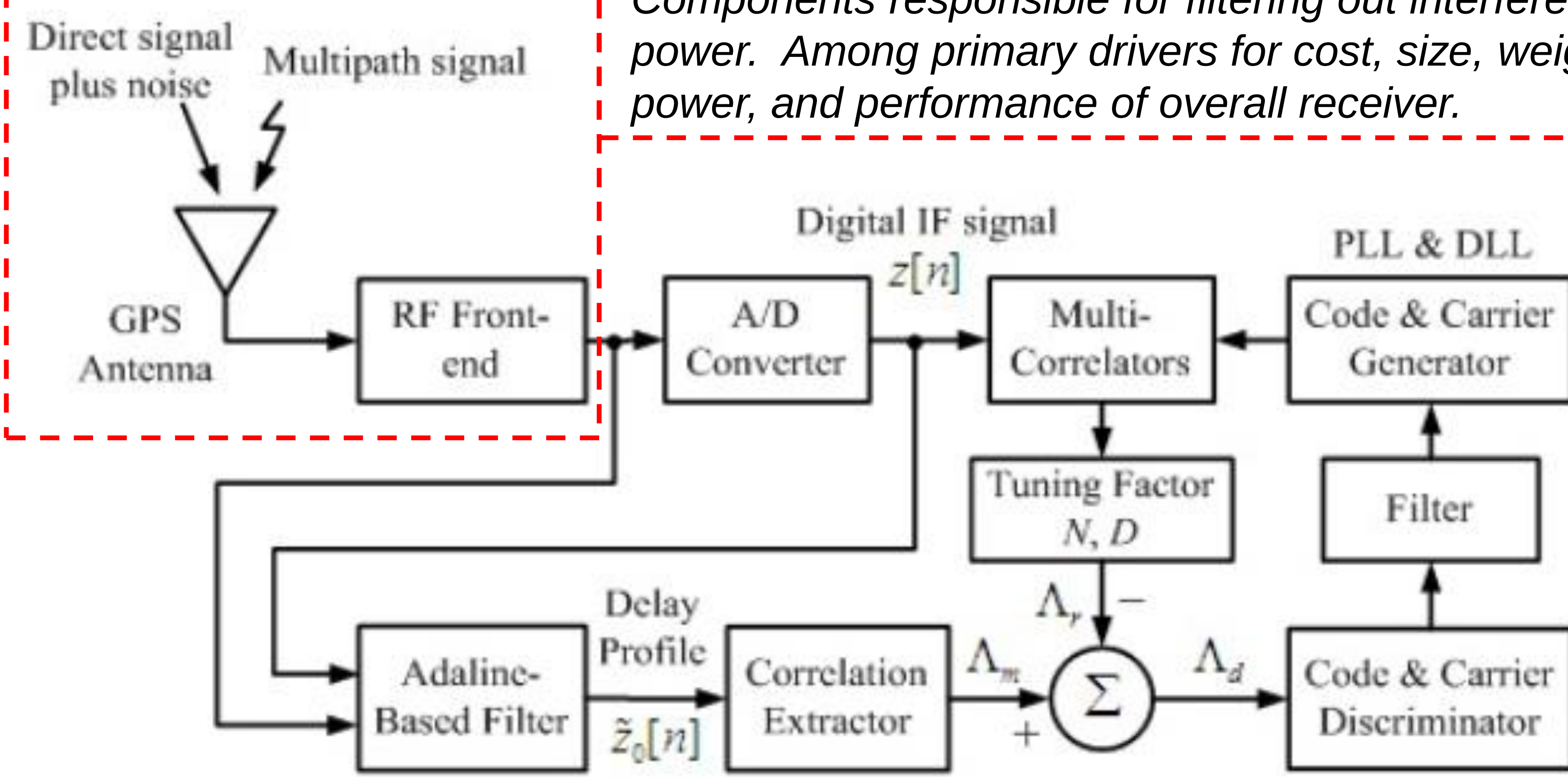
Power differential is analogous to the vibrations from tapping a Q-tip on a Kleenex box vs a jack hammer on concrete



Ligado
GPS L1 C/A
Power Spectral Density (dBW/MHz)
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
1520
1525
1530
1535
1540
1545
1550
1555
1560
1565
1570
1575
1580
1585
1590
1595
1600
Frequency (MHz)

GPS Receiver Diagram

Components responsible for filtering out interference power. Among primary drivers for cost, size, weight, power, and performance of overall receiver.



GPS Receiver Design Tradeoffs

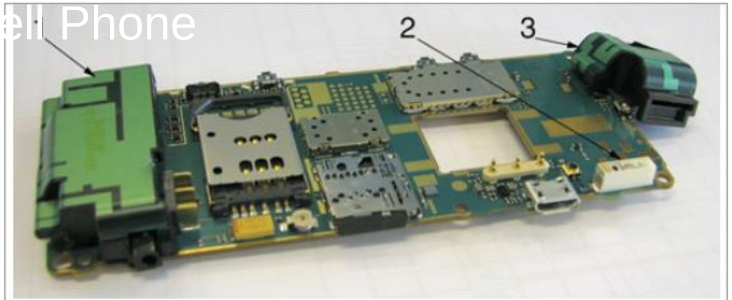


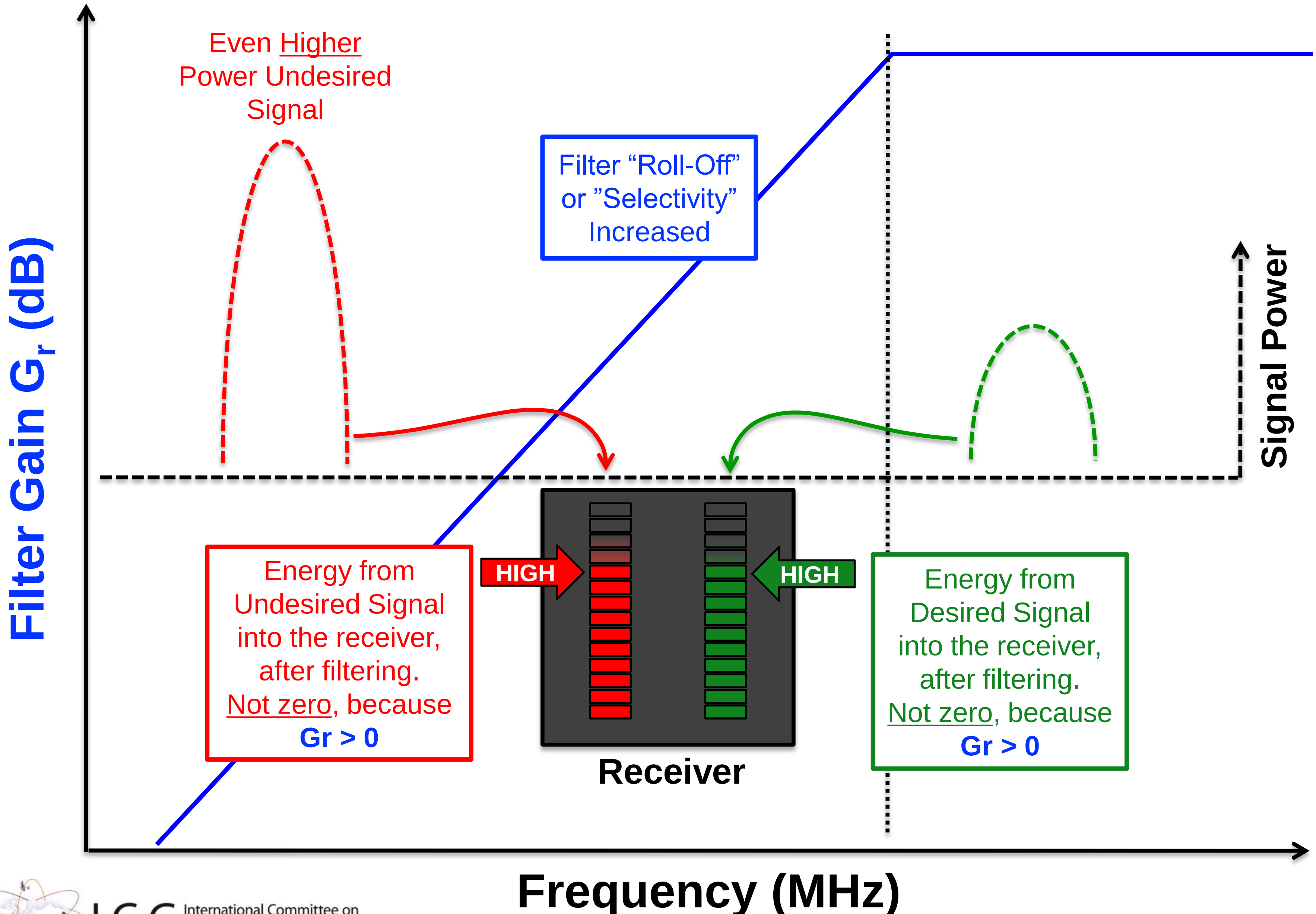
Figure 2. Antennas in a mobile phone: 1. GSM/WCDMA antenna, 2.Wi-Fi/Bluetooth combined ceramic chip antenna, 3. GPS antenna

- Aggressive filtering possible/required
- Relies heavily on Assisted-GPS (A-GPS)
  - Decreases time to first fix
  - Allows navigation to continue when GPS unavailable
  - Requires connection to cell network
- 1-10 m accuracy (w/ A-GPS) is sufficient

- Aggressive filtering degrades precision
- Cannot rely on A-GPS due to lack of coverage in rural environments (nor would traditional A-GPS offer significant improvement due to accuracy requirements)
- Accuracy down to centimeter level can be required

23

Hypothetical Filter Gain versus Frequency



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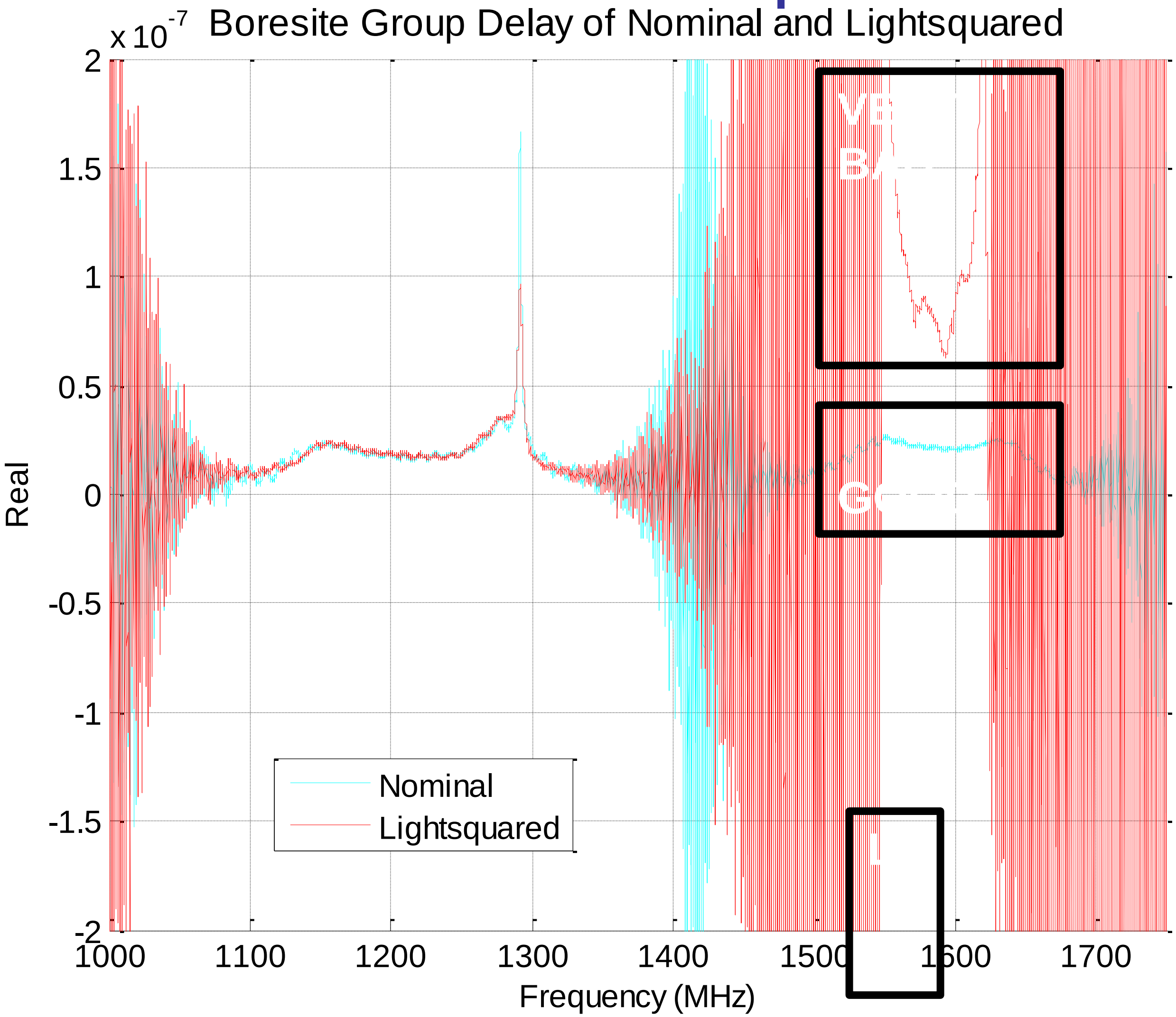
Javad GPS Antenna Group Delay Comparison



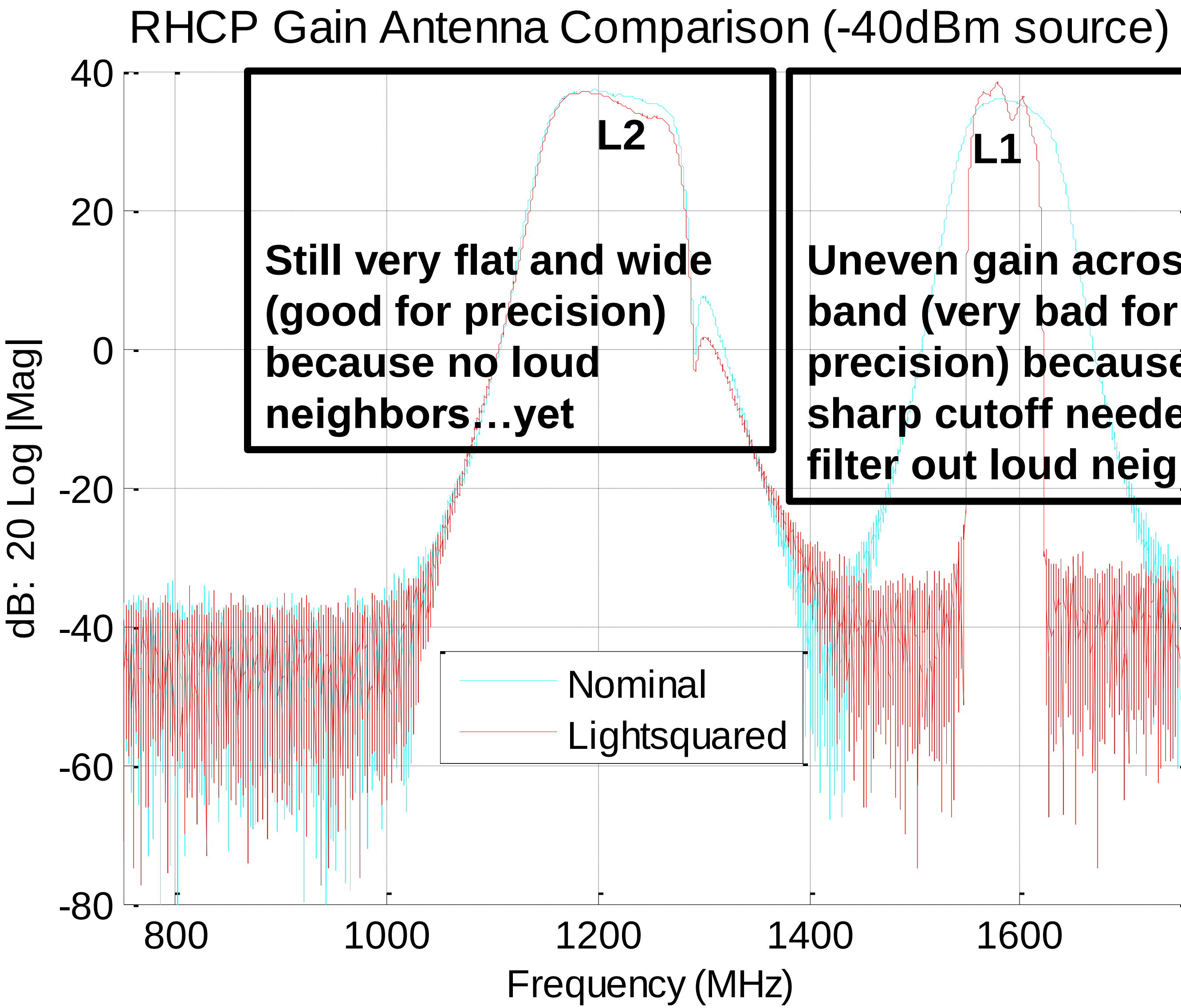
https://www.gps.gov/governance/advisory/meetings/2017-11/scott.pdf

Legend:
Blue – Original antenna filter response

Red – redesigned antenna for LiightSquared era

The Lightsquared antenna demonstrates a larger group delay and much more ripple in the L1 band.

Gain Sweep Comparison Between Antennas



Blue – Original antenna filter response

Red – redesigned antenna for Ligado era

Take Aways

- Spectrum protection is an art, not a science
- GNSS community must continue to educate spectrum regulators on the unique properties of the GNSS receivers vs other RF receivers (e.g., SATCOM)
- Billions of users worldwide and countless applications make GNSS spectrum worth defending