

# Ultrawideband Technology: Spectrum Sharing and Regulation

Paul C. Roosa, Jr.

Wednesday, March 6, 2002

INTERNATIONAL SYMPOSIUM ON ADVANCED  
RADIO TECHNOLOGIES  
Boulder, Colorado

Photo by D.J. Atkinson

Program Manager for Spectrum Policies,  
Office of Spectrum Management  
National Telecommunications & Information Administration

Phone: 202-482-1559  
Fax: 202-482-4396  
proosa@ntia.doc.gov

# **HISTORY**

- **February - May 98 – U.S. Radar, Time Domain & Zircon, applied for waivers to market UWB Devices.**
- **September 98 – FCC issued a *Notice of Inquiry* to investigate whether to authorize UWB devices on an unlicensed basis (prohibiting interference to licensed services & operation in certain “restricted” bands).**
- **June 99 – FCC granted the waivers to U.S. Radar, Time Domain, & Zircon with NTIA concurrence.**
- **May 00 – FCC issued *Notice of Proposed Rulemaking (NPRM)* For Comment**
  - **Regulatory**
  - **UWB Definition**
  - **Frequency Bands of Operation**
  - **Further Testing & Evaluation**
  - **Emission Limits**
  - **Measurement Procedures**
  - **Prohibition Against Class B Damped Wave Emissions**
  - **Other Matters**

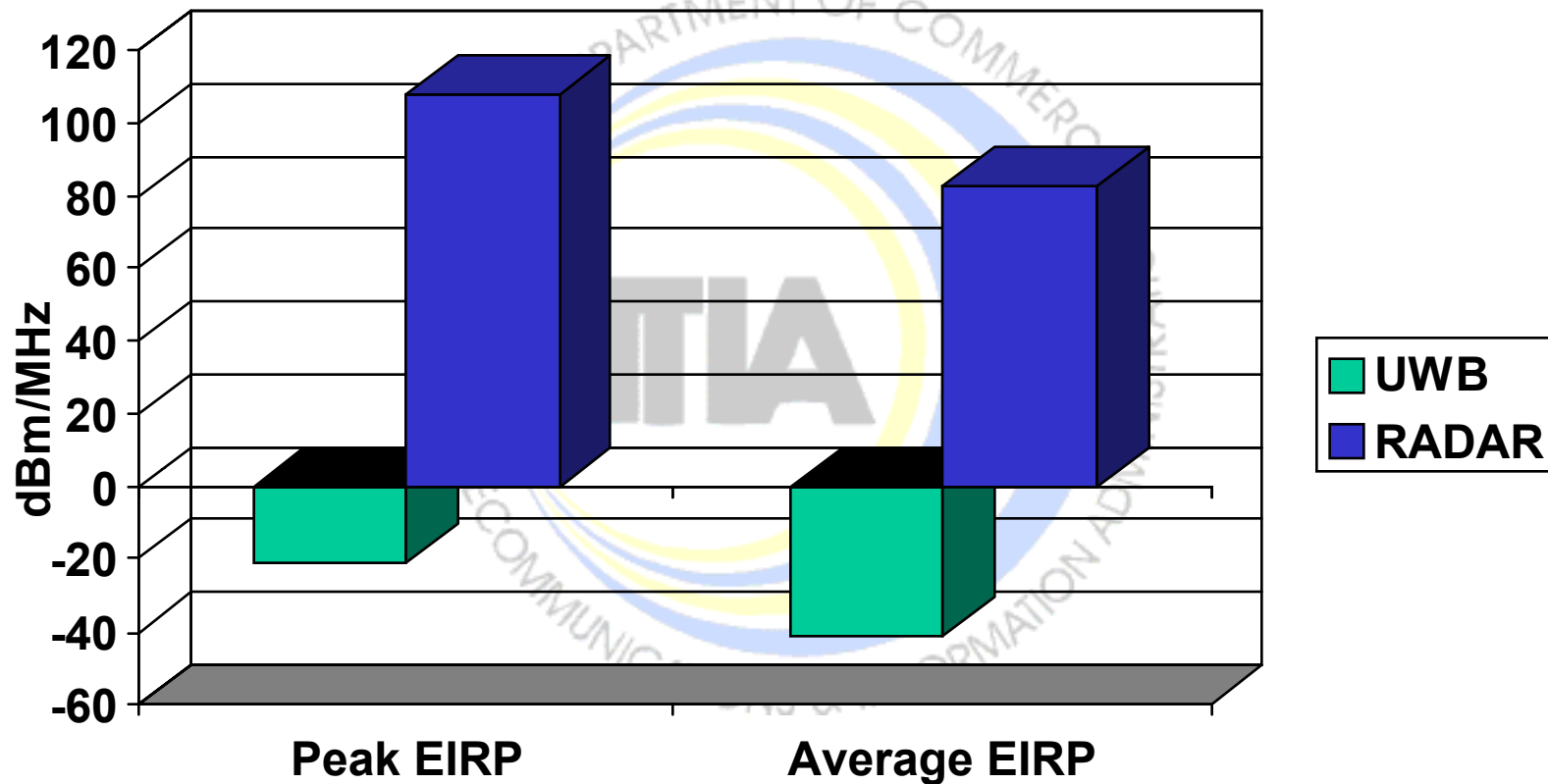


## 2) The “RESTRICTED BANDS”

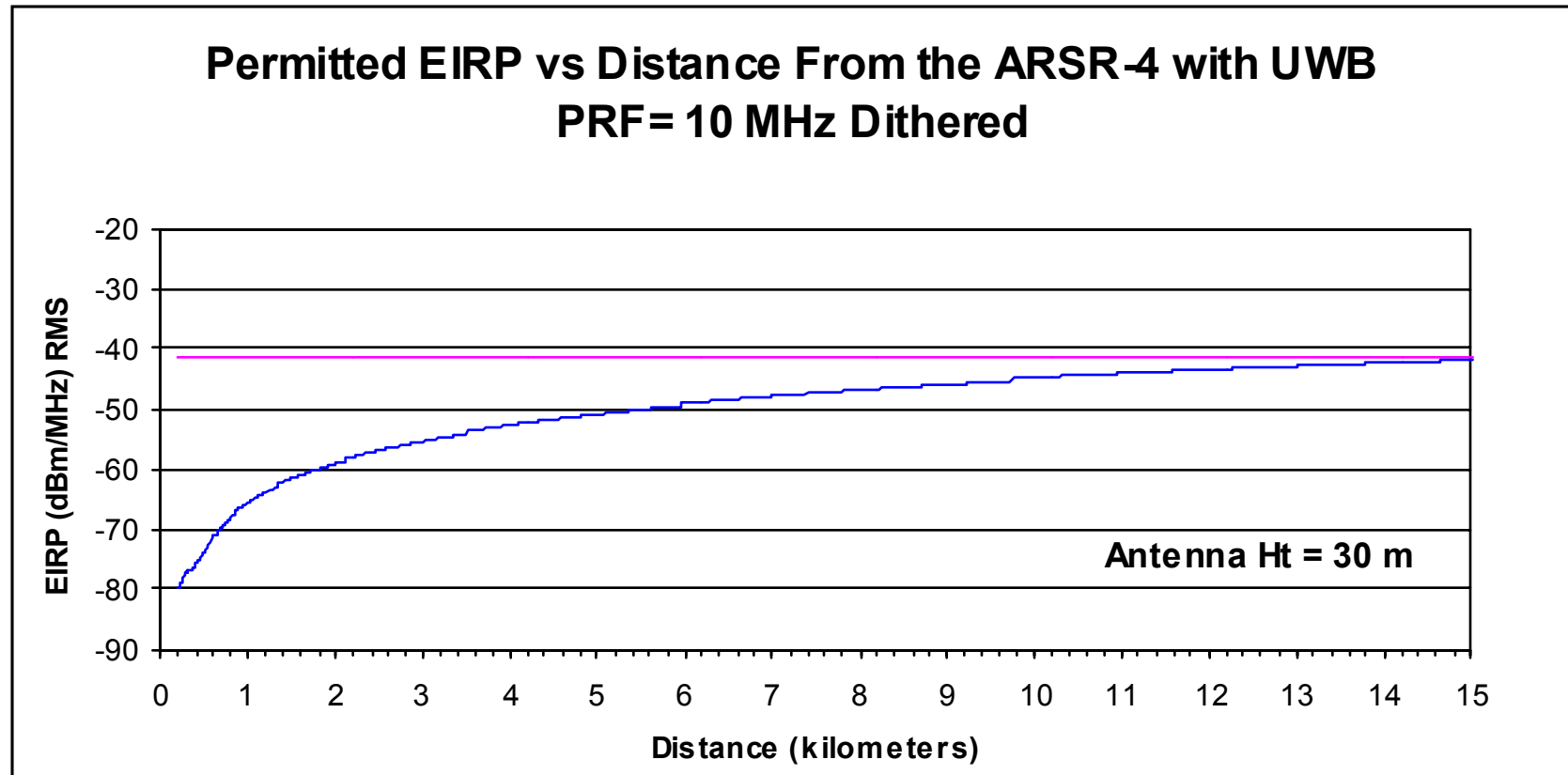
47 CFR Part 15 Section 15.205 titled “Restricted Bands of Operation” permits only spurious emissions in any of the below listed frequency bands:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2655-2900	22.01-23.12
8.41425-8.4147	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			

# Is It The Hugely Different Relative Transmitter Powers?



### 3) Not Transmitter Power But Received Power!



# Major Players

- **Federal Government Executive Branch Agencies**
  - DOD
  - DOT (Includes FAA & Coast Guard)
  - NASA
  - NOAA
- **Federal Communications Commission (FCC)**
- **UWB Industry (XtremeSpectrum, Time Domain Corp, MSSl ...) Investors (Intel, Texas Instruments, Sony, Motorola, Siebel Systems ...)**
- **Global Positioning System (GPS) Community**
- **Public Safety Community**
- **Vehicle Safety Community**

# **WHO REGULATES UWB?**

- **NTIA and the FCC**
  - **Co-regulate the affected spectrum.**
  - **Have constituencies that may be affected by and benefit from UWB technology.**
  - **Must not act alone and intend to reach an agreeable solution to protect our existing constituents while allowing UWB.**



# **Roles In Developing UWB Rules**

- **The FCC Gathered Information Filed in Response to its *NPRM*.**
  - All Responses Accessible to Public.
  - Lively Exchanges of Opinion were Common.
  - The FCC Staff Must Winnow the Wheat From the Chaff and Develop a Sound Rule.
- **NTIA Measured and Analyzed UWB Devices and Their Impact on Federal Radio Communication Systems.**
  - Non-GPS (Concentrating on Critical Radio Navigation Systems operating in Restricted Bands).
  - GPS.
  - Filed Reports for Public Comment.
  - Developed and Coordinated with Federal agencies Technically Based Rules, to the extent possible.

# **HISTORY (continued)**

- **June 00 – NTIA Began Non-GPS Measurements and Analysis Task At Washington & Boulder.**
- **August 00 – NTIA Began GPS Measurements and Analysis Tasks At Washington & Boulder.**
- **January 01 – NTIA Non-GPS Measurements & Analysis Report Sent to the FCC as part of rulemaking record for public comment.**
- **March 01 – Measurements & Analyses Sent to the FCC as part of rulemaking record for public comment by:**
  - **NTIA – GPS (Funded partially by DoT and DoD).**
  - **Stanford Research Institute – GPS (Funded by DoT).**
  - **Applied Physics Lab/Univ. of Texas – GPS (Funded by Time Domain Co).**
  - **QualComm – Digital PCS Systems**
- **September 01: NTIA Published its GPS Addendum Measurement & Analysis & filed with FCC**

# **Goals of NTIA Non-GPS**

## **Tasks**

- **Develop practical, accurate and repeatable methods for portraying the temporal and spectral characteristics of very narrow pulses (and pulse trains) of UWB systems.**
  - Institute for Telecommunication Sciences in Boulder, Colorado.
- **Estimate or measure the potential for UWB systems to interfere with existing (narrowband, channelized, band-limited, and wideband) radio communication or sensing systems.**
  - Office of Spectrum Management, in Washington, D.C.

# **UWB Devices Vs. Non-GPS Systems: Measurements**

- **Measured Temporal & Spectral Characteristics of 5 UWB devices.**
- **Assessed COTS approaches for measurement of UWB devices.**
- **Measured effects of UWB signals on 3 Federal Government systems in the field.**
- **Limited Measurements of UWB aggregate effects.**

# UWB Devices Vs. Non-GPS Systems: Analytical Models

- Both one-on-one & aggregate models are supported by measurement results.
- Major functions of the models are to calculate:
  - UWB power that would not exceed receiver protection criterion (one-on-one).
  - Required distance between the UWB device & effected receiver if UWB device is operated at the current Part 15 maximum level (one-on-one).
  - Required UWB density to exceed protection criterion (aggregate).

# UWB Devices Vs. Non-GPS Systems: Analysis

- **Used Environmental Receiver Protection Criteria from:**
  - International Telecommunications Union (ITU)
  - International Civil Aviation Organization (ICAO)
  - Radio Technical Commission on Aeronautics (RTCA)
  - Using Agency
- **Evaluated UWB vs. 12+ Federal Government Systems**
- **Calculated distance and maximum UWB power for:**
  - 7 UWB pulse repetition rates (10 kHz - 500 MHz)
  - 2 UWB heights (2 and 30 meters)

# Federal Systems Analyzed

- Search and Rescue Satellite (SARSAT) Uplink (406-406.1 MHz) (Aggregate Only)
- Distance Measuring Equipment (DME) Interrogator Airborne & Ground Transponder Receivers (960-1215 MHz)
- \*Air Traffic Control Radio Beacon System (ATCRBS)  
Ground (1090 MHz) and Airborne Receivers (1030 MHz)
- \*Air Route Surveillance Radar (ARSR-4) (1240-1370 MHz)
- Search & Rescue Satellite (SARSAT) Ground Station Local User Terminal (LUT) (1544-1545 MHz)
- \*Airport Surveillance Radar (ASR-9) (2700-2900 MHz)

\* Measured at the FAA's Oklahoma City, OK facility.

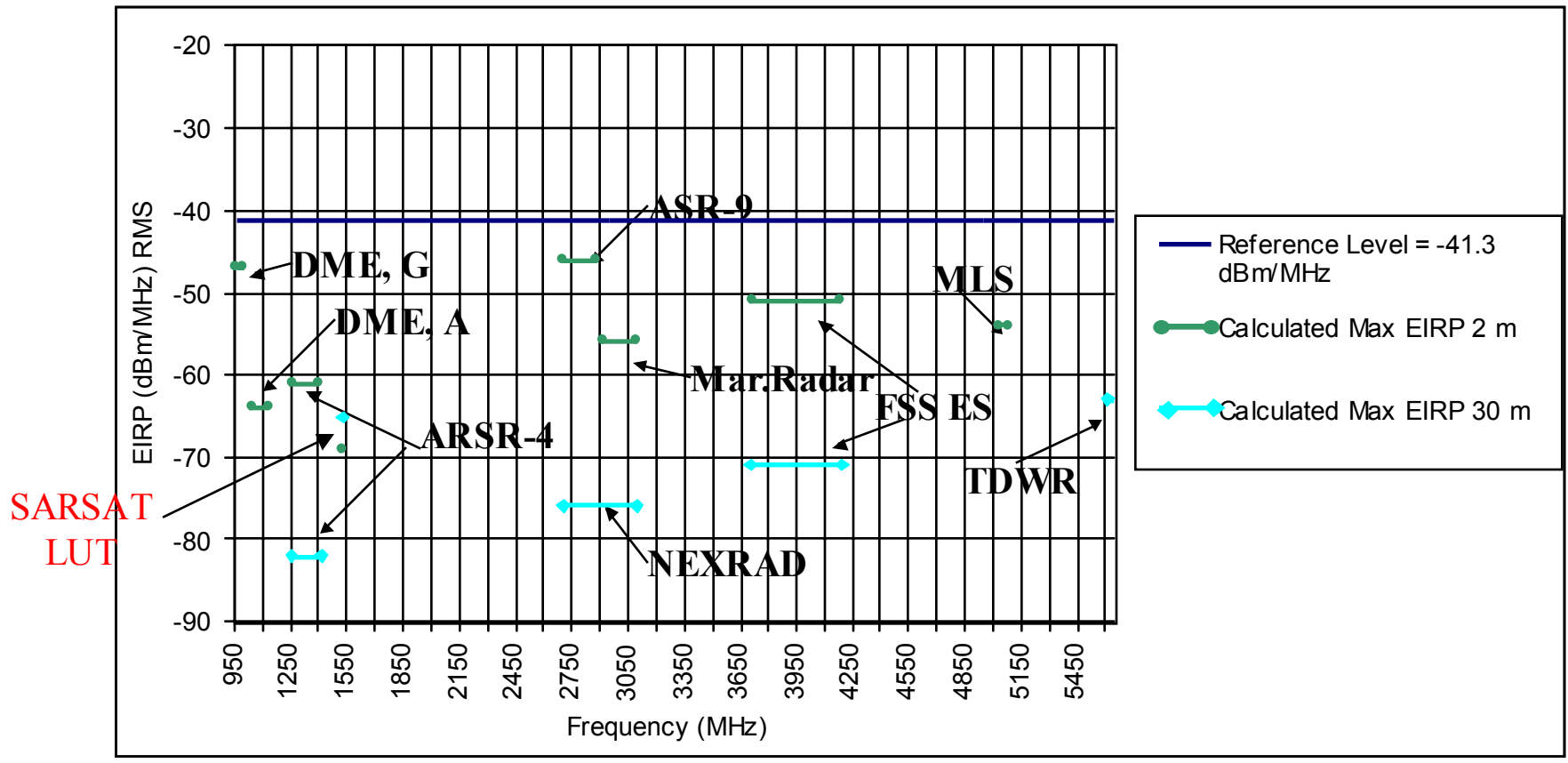
# **Federal Systems Analyzed**

(Continued)

- **Next Generation Weather Radar (NEXRAD)**  
**(2700-3000 MHz)**
- **Maritime Radionavigation Radar**  
**(2900-3100 MHz)**
- **Fixed Satellite Service (FSS) Earth Station**  
**(3700-4200 MHz)**
- **Radar Altimeters (4200-4400 MHz)**
- **Microwave Landing System (5030-5091 MHz)**
- **Terminal Doppler Weather Radar (TDWR)**  
**(5600-5650 MHz)**



# Analysis & Meas. Results Showing UWB Device EIRP Constraints for Government Systems Protection: Non-GPS



# GPS Study Objectives

- **Overall** – Define maximum allowable UWB EIRP in the Radionavigation Satellite Service (RNSS) bands that can be tolerated by GPS receivers without causing degradation to operations.
- **Measurements** – Determine UWB interference susceptibility levels at GPS receiver input for various GPS receiver architectures.
- **Analysis** – Determine maximum EIRP for various GPS scenarios.

# UWB-GPS Measurements

- **Developed measurement plan** to obtain GPS receiver susceptibility data.
  - Published in *Federal Register* and obtain public comments, including Federal agencies and FCC
- **Establish Interference Criteria**
  - **Reacquisition** ... undesired signal level at which an abrupt increase from nominal reacquisition time is observed.
  - **Break-lock** ... the loss of lock between GPS receiver & a GPS satellite that occurs when interfering signal reduces the carrier-to-noise level so that the GPS Rx can no longer adequately determine pseudo-range from the satellite signal.

# **GPS Receiver Architectures** **Studied**

- **Coarse Acquisition (C/A) Tracking**
- **Semi-codeless**
- **C/A code tracking employing multiple narrowly-spaced correlators**

# **UWB Parameters & Values Measured**

**(32 Permutations)**

<b>PARAMETER</b>	<b>VALUE</b>
<b>Pulse Repetition Frequency (MHz)</b>	<b>0.1, 1.0, 5.0, 20.0</b>
<b>Modulation</b>	<b>None, On-Off Keying, 2% Relative Dithering, 50% Absolute Dithering</b>
<b>Gating</b>	<b>100% On, 20% On (4 millisecc on, 16 millisecc off</b>

# GPS Simulator & Background Noise

- **Simulated signals from 4-5 satellite constellation ... actual GPS ephemeris data on 16 Dec 99 ... one satellite near zenith set at minimum specified limit & 3 satellites near horizon set 5 dB higher.**
- **Broadband noise added (cross-correlation from other satellite's) except for codeless receiver.**

# Measurement Cases

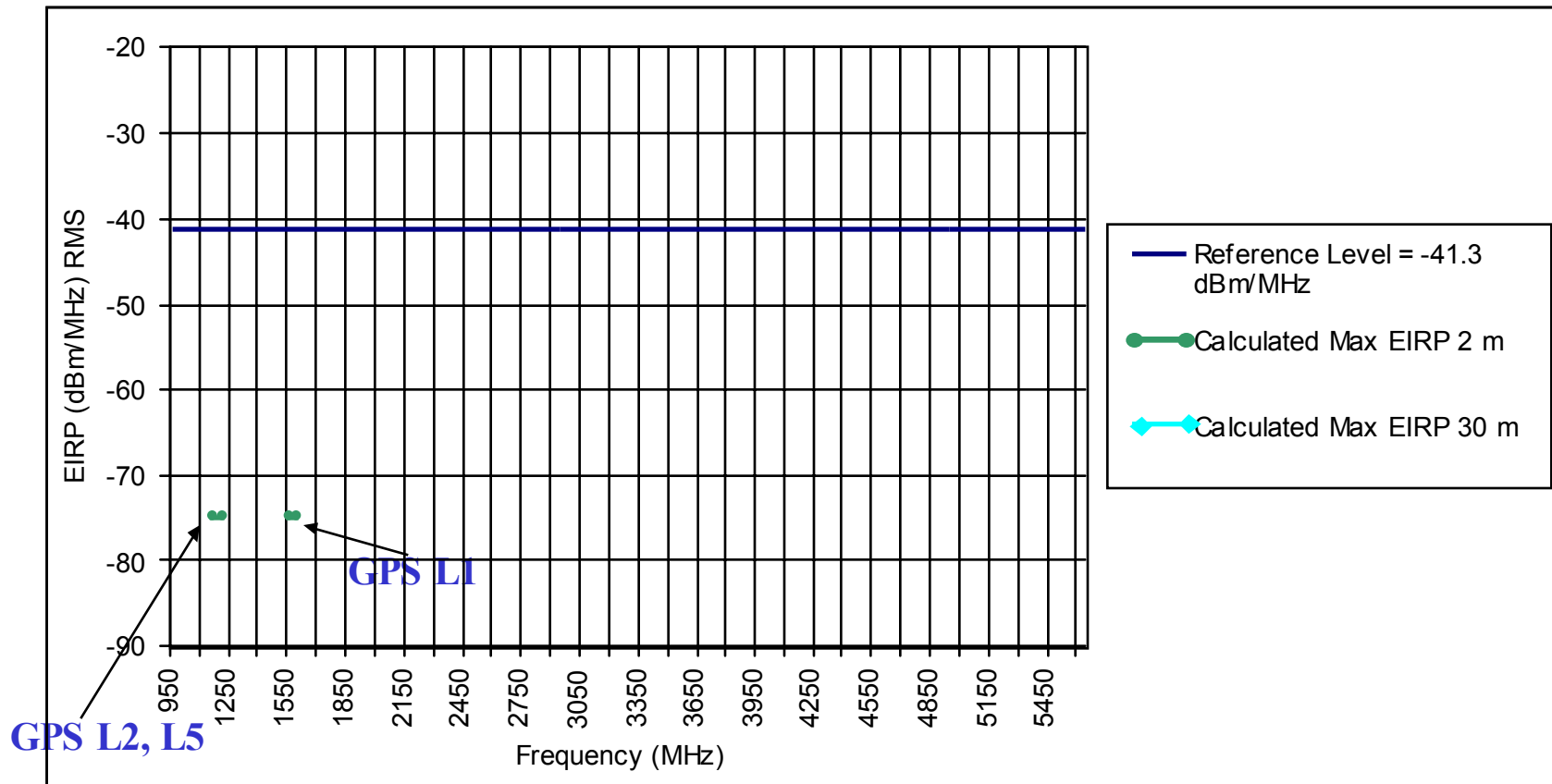
- **Single Entry**
  - **GPS Satellite Signal + Noise + UWB**
- **Multiple Entry (Aggregate)**
  - **How UWB signals add & combine in GPS Receiver**
  - **5 combinations of UWB parameters (PRF, gating, & dithering) using up to 6 UWB generators**
- **Radiated Antenna – Determine impact of GPS antenna on UWB signal**

# **Operational Scenarios Analyzed**

- **Developed and coordinated in public meetings included FCC, Federal agencies, & GPS and UWB industries**
- **GPS applications considered:**
  - **Railway**
  - **Aviation**
  - **Maritime**
  - **Surveying**
  - **Terrestrial (land-based)**
- **Total of 13 operational scenarios studied**



# Analysis & Meas. Results Showing UWB Device EIRP Constraints for Government Systems Protection: GPS



# RECEIVERS ANALYZED

## GPS Receivers

1. \*Coarse Acquisition (C/A) Code Tracking
2. \*Semi-codeless
3. \*C/A code tracking employing multiple narrowly-spaced correlators
4. \*Technical Standard Order (TSO) – C129 compliant aviation Rcvr used in en-route & non-precision approach (C/A Code Tracking type)

## GPS Applications

1. Terrestrial
  - E-911
2. Maritime
3. Railway
4. Surveying
5. Aviation
  - Cat I Precision Approach
  - Cat II/III Precision Approach
  - Enroute Navigation
  - Non-Precision Approach

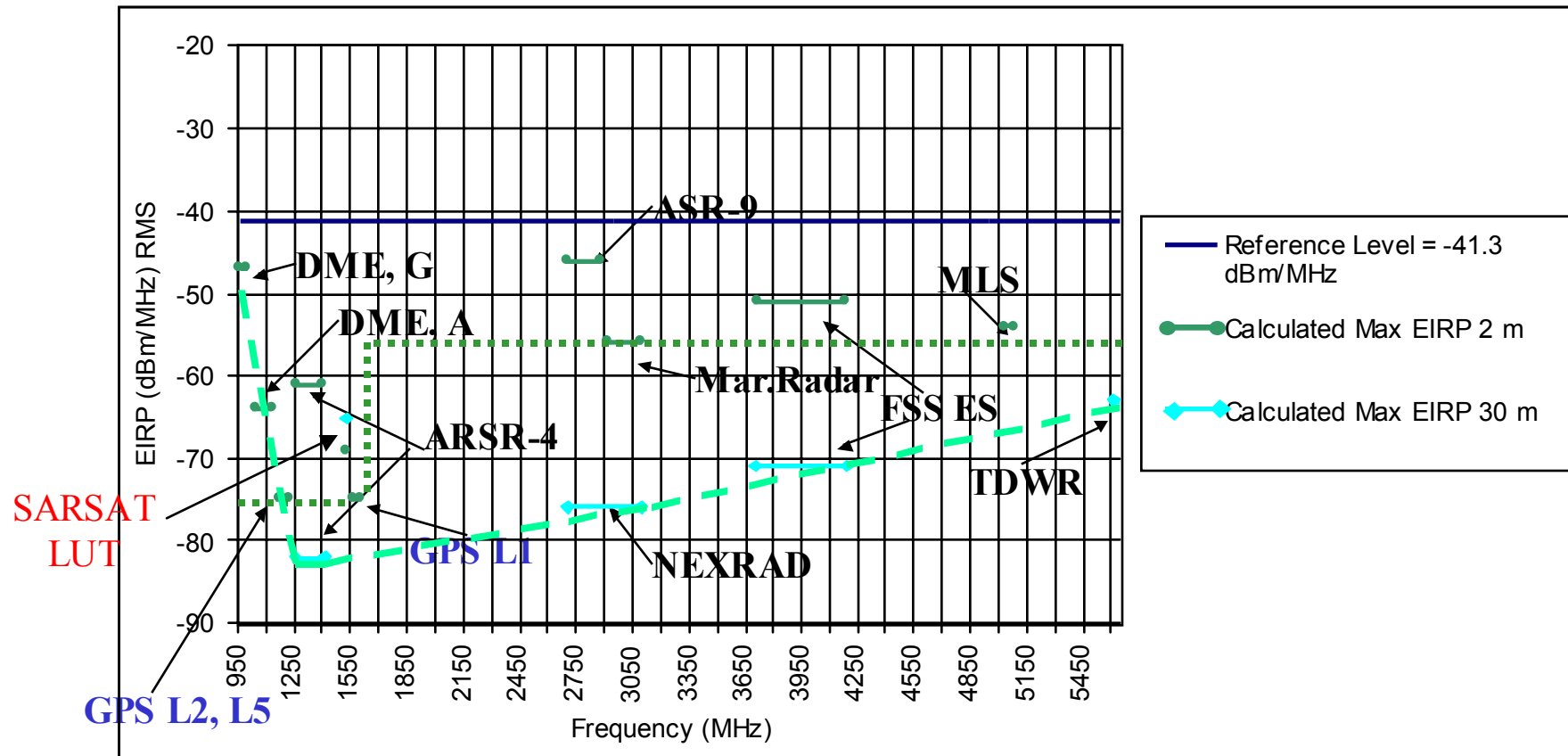
## GPS Scenarios - 13

## Non-GPS

1. Distance Measuring Equipment (DME) Interrogator Airborne Rcvr
2. DME Ground Transponder Rcvr
3. \*Air Traffic Control Radio Beacon System (ATCRBS) Air Transponder Rcvr
4. ATCRBS Ground Interrogator Rcvr
5. \*Air Route Surveillance Radar (ARSR-4)
6. Search & Rescue Satellite (SARSAT) Ground Station Land User Terminal (LUT)
7. \*Airport Surveillance Radar (ASR-9)
8. Next Generation Weather Radar (NEXRAD)
9. Maritime Radars
10. Fixed Satellite Service (FSS) Earth Stations (20 deg Elevation)
11. FSS Earth Stations (5 deg Elevation)
12. CW Radar Altimeters at Minimum Altitude
13. Pulsed Radar Altimeters at Minimum Altitude
14. Microwave Landing System
15. Terminal Doppler Weather Radar (TDWR)
16. SARSAT Uplink

\* Or Blue: Measurements Made

# Analysis & Meas. Results Showing UWB Device EIRP Constraints for Government Systems Protection



# **HISTORY (continued)**

- **December 01: Secretary Evans letter to FCC stating Government could have position on *R&O* in ~ 60 days ... Chairman Powell response delays FCC action to Feb 02**
- **January 02: Government position on *R&O* sent to FCC**
- **January – February 02: Seven major meetings on *R&O* with DOT, NASA, DOD & FCC ... NTIA & FCC agree on major principles & NTIA provides changes to Final Draft *R&O***
- **February 02: Commissioners Approve Draft *R&O* & FCC/NTIA begin editorials.**
- **The FCC has published Press Releases with the *R&O* Spectral Power Density Levels.**
- **To Present: ~925 Comments Filed in the Docket**

# Summary of UWB EIRP Limits (dBm/MHz at Antenna Output) & Use Constraints

(February 13, 2002)

Bands (MHz)/Bandwidth/Use	Imaging <sup>1</sup>	Indoors <sup>2</sup>	Outdoors (Includes Peer to Peer) <sup>2</sup>	Vehicular	Public Safety Through-wall & Surveillance Sys
0.009-960	Part 15.209				
960-1,610	-65.3	-75.3	-75.3	-75.3	-53.3
1,610-1,990	-53.3		-63.3	-61.3	-51.3
1,990-3,100	-51.3		-61.3	-61.3	-41.3
3,100-10,600	-41.3		-41.3	-61.3	-41.3
10,600-22,000	-51.3		-61.3	-61.3	-51.3
22,000-24,000	-51.3		-61.3	-51.3	-51.3
24,000-29,000	-51.3		-61.3	-41.3	-51.3
29,000-31,000	-51.3		-61.3	-51.3	-51.3
Above 31,000	-51.3		-61.3	-61.3	-51.3
NTIA/FCC Coordination Required <sup>3</sup>	Yes	No			Yes
Lower -10 dB point	Above 3.1 GHz			Above 24 GHz	Above 1.99 GHz
Upper -10 dB point	Below 10.6 GHz (Or Below 960 MHz for Imaging Only) <sup>1</sup>			Below 29 GHz	Below 10.6 GHz
Directional Antennas with min suppression of [25] dB below max gain at angles 35° from main beam centerline.	No			Yes <sup>4</sup>	No
Measurement shall not exceed EIRP (dBm) in resolution bandwidth of 1 kHz or > @ 3 m for 1164-1240 & 1559-1610 MHz.	-75.3	-85.3		-85.3	-63.3
Law Enforcement, Fire Fighting and Emergency Rescue Users Eligible for Part 90	May Use GPRs & Through-wall & Wall Imaging	<u>No User Restrictions</u>			May Use Through-Wall & Surveillance Systems
Scientific Research Institutes, Commercial Mining, or Construction Companies & Utilities/Industrial Entities (Surveillance Systems only) eligible for Part 90.	May Use GPRs & Wall Imaging				Utility & Indust Entities (Pub Util & Indust, elig for Part 90) May Use Surv. Syst
Medical users under supervision of licensed health care practitioner.	May Use Medical Imaging				

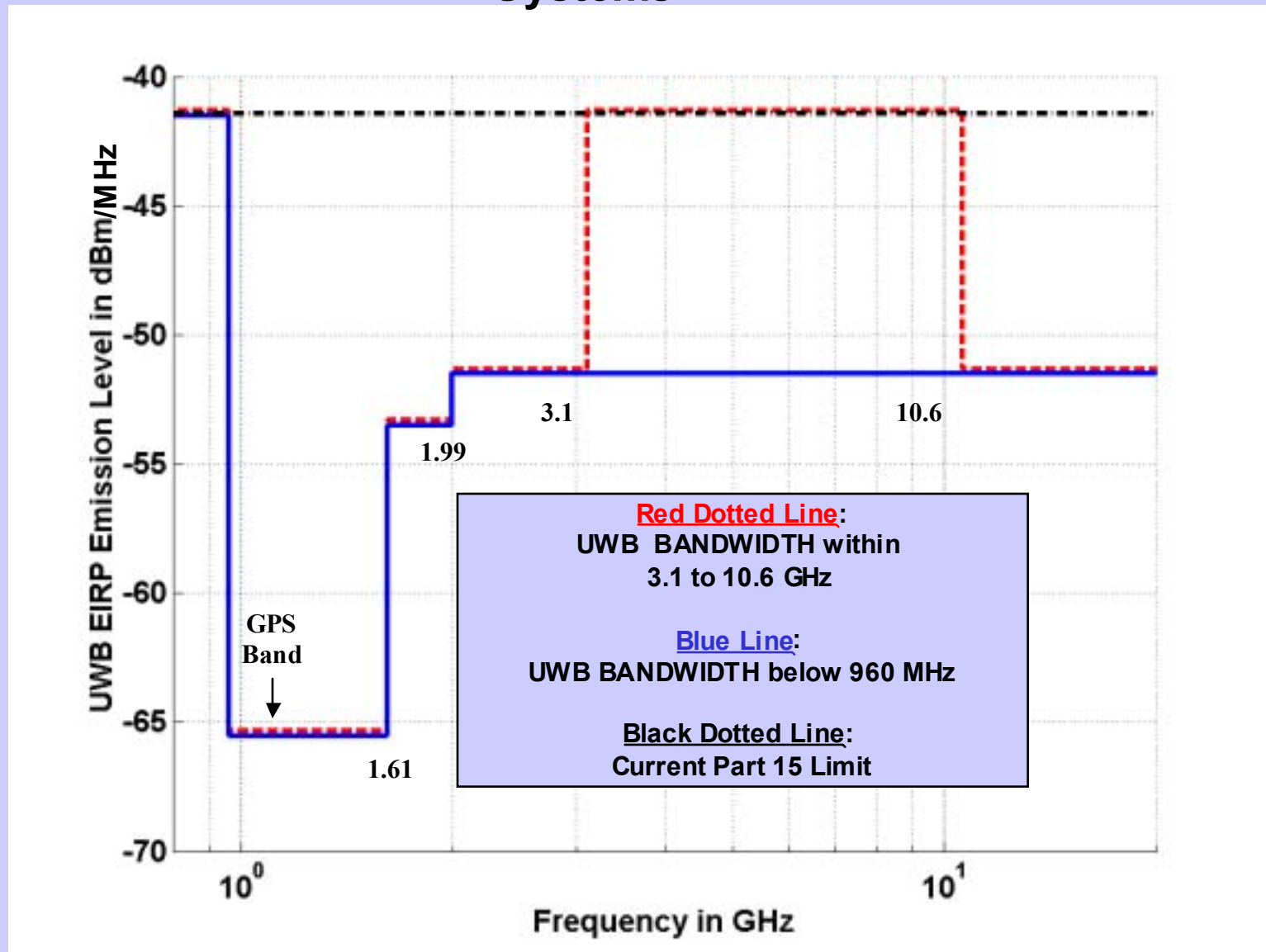
1 Imaging systems may operate below 960 MHz as long as the upper -10 dB points on their emission spectra are less than 960 MHz.

2 Tags, data transfer, and voice are included in the "Indoors" and "Outdoors Peer to Peer" categories above but are not part of Imaging, Vehicular, Public Safety, Through-wall, or Surveillance system categories.

3 Coordination is to be addressed within 15 working days of the date of the UWB use request or it will be automatically approved.

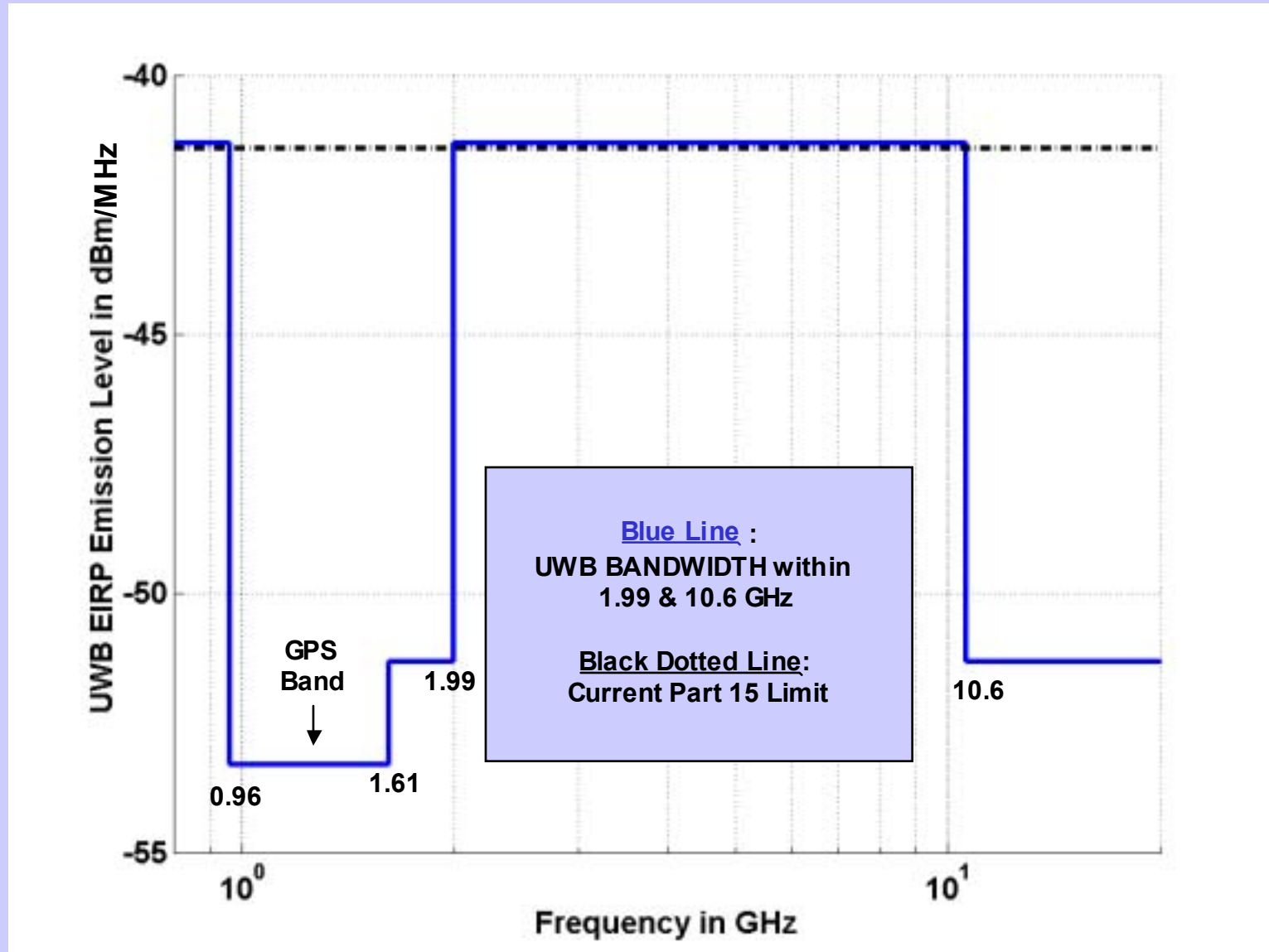
4 NTIA's analysis indicates there is interference to the earth exploration satellite service (EESS) passive satellite receivers from automotive radars if they operate at 24.125 GHz. The analysis was based on 22 to 23 dB antenna discrimination at elevation angles above 30 degrees above the horizon. The analysis concluded that the vehicular radar emissions must be least 35 dB below (at elevation angles greater than 30, above the horizon) the current Part 15 level at 24 GHz to resolve the potential interference problem. Currently, the radar system can attain attenuation of 25 dB from the main beam gain at elevation angles of 30, or greater above the horizon. The radars will be placed on automobiles over a period of time and a phased in approach to attain the necessary attenuation is warranted. Therefore, to attain this additional 10 dB and based on a 5/4 year development cycle the attenuation of 25 db is satisfactory beginning in 2005; if it is increased to 30 db by [2010], and further increased to 35 dB by [2014]. Methods to obtain this 10 dB of attenuation at 24 GHz could include but are not limited to: spectral shaping, lower duty cycle, reduced power, and increase antenna discrimination.

# UWB Emission Limits for GPRs, Wall Imaging, & Medical Imaging Systems



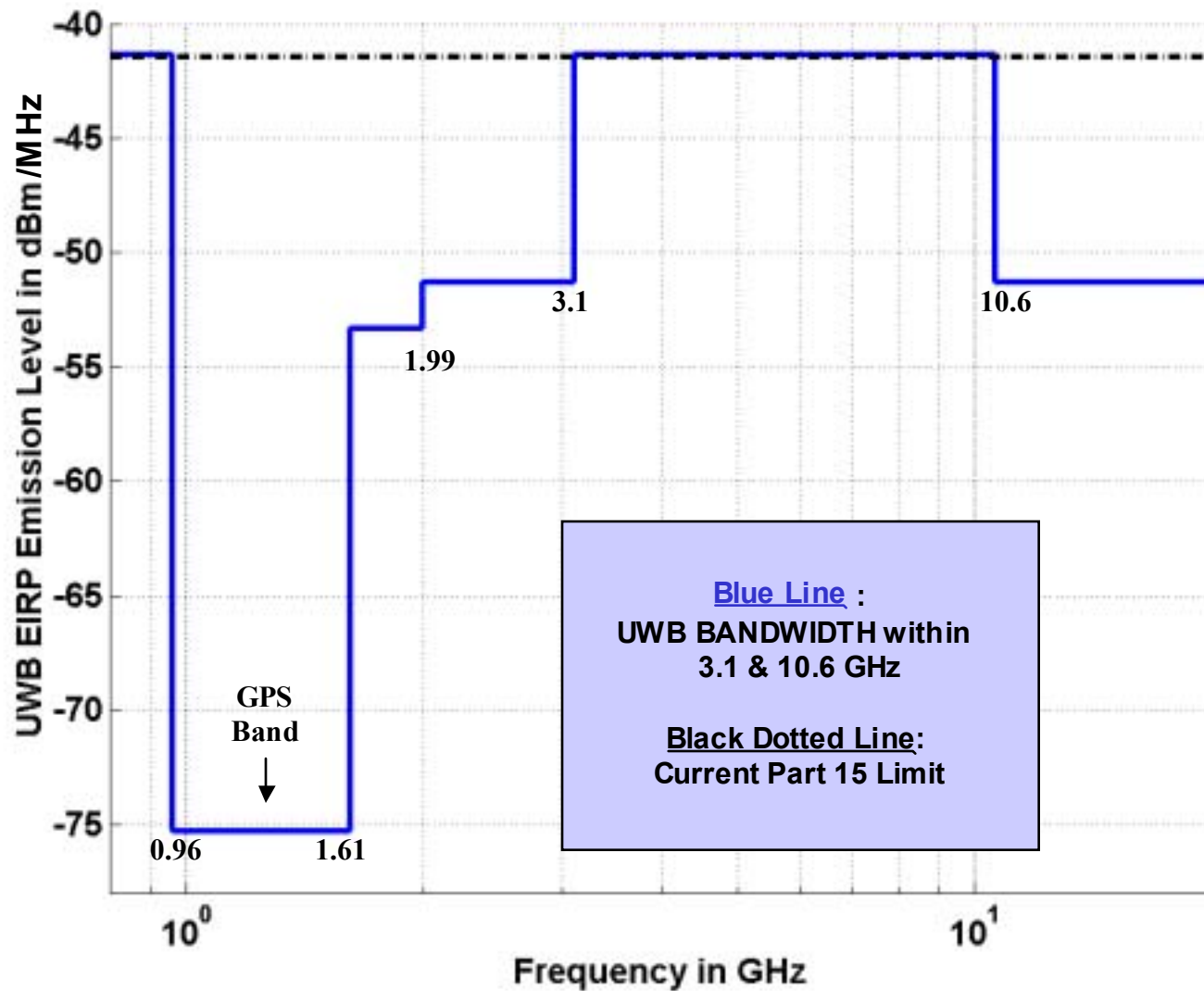
Operation is limited to law enforcement, fire and rescue organizations, scientific research institutions, commercial mining companies, and construction companies.<sup>30</sup>

# UWB Emission Limits for Thru-wall Imaging & Surveillance Systems



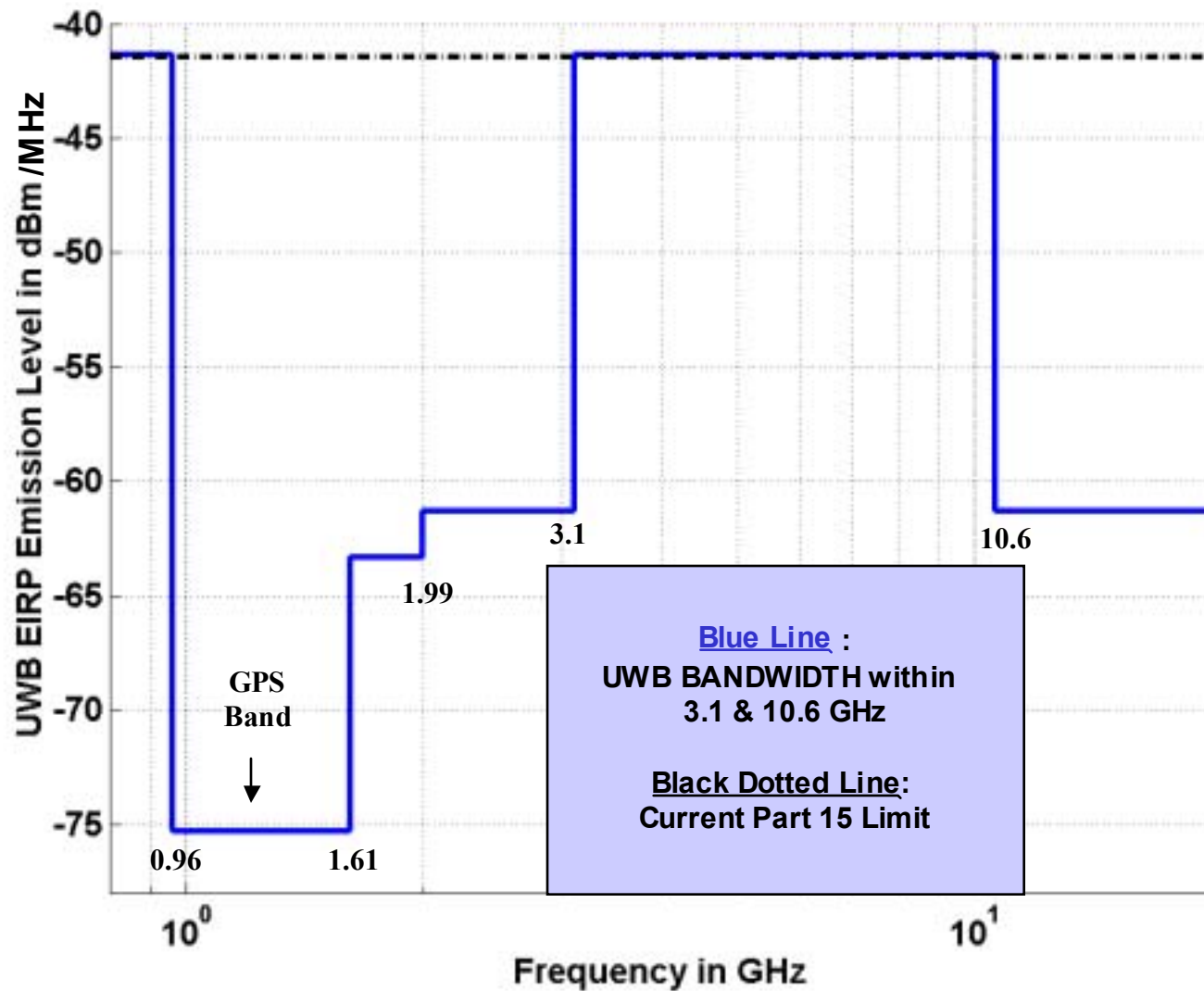
Operation is limited to law enforcement, fire and rescue organizations. Surveillance systems may also be operated by public utilities and industrial entities.

## UWB Emission Limit for Indoor Systems





## UWB Emission Limit for Outdoor Hand-held Systems



# **FUTURE**

- **The Full *R&O* would normally be expected by no later than March 14, 2002.**
- **The FCC has Promised to Revisit UWB Within 6-12 Months.**
- **An Interested Party may Petition for Reconsideration within 30 days of Publication.**
- **A New Petition May be Introduced at any Time.**

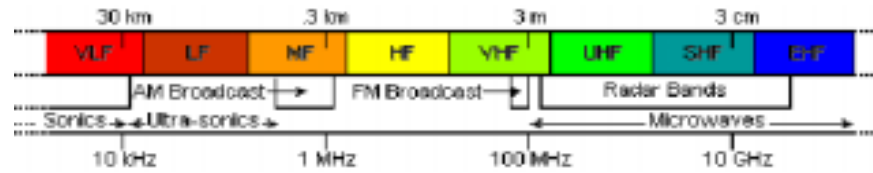
# Web Sites For NTIA UWB Publications

- <http://www.ntia.doc.gov/osmhome/osmhome.html>
- [http://www.its.bldrdoc.gov/pub/all\\_pubs/all\\_pubs\\_index.html](http://www.its.bldrdoc.gov/pub/all_pubs/all_pubs_index.html)
- [http://gulfoss2.fcc.gov/prod/ecfs/comsrch\\_v2.cgi](http://gulfoss2.fcc.gov/prod/ecfs/comsrch_v2.cgi)



# OSM

## Office of Spectrum Management



Washington, DC



# ITS

## Institute for Telecommunication Sciences

Boulder, Colorado