ULTRA WIDE BANDWIDTH

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TOPICS FOR DISCUSSION

- INTRODUCTION
- ULTRA-WIDEBAND (UWB) DESCRIPTION AND CHARACTERISTICS
- UWB APPLICATIONS AND USES
- UWB WAVEFORMS, DEFINITION, AND EFFECTIVENESS
- UWB TECHNICAL AND OPERATIONAL LIMITS
- UWB DEVELOPMENT
- UWB / BROADBAND MARKET
- FUTURE SPECTRUM OPPORTUNITIES

UWB INTRODUCTION

- UWB TECHNOLOGY HAS BEEN IN LIMITED USE FOR YEARS BY PUBLIC SERVICE, RESEARCH, AND MILITARY AGENCIES, PRIMARILY FOR IMAGING AND RADAR
- CONSUMER UWB DEVICES ARE BEING DEVELOPED FOR WIRELESS COMMUNICATION AND OTHER APPLICATIONS

ULTRA-WIDEBAND (UWB)

- TIMED, CODED PULSES OF EXTREMELY SHORT DURATION
- NOISE-LIKE EMISSION WHICH SPREADS ACROSS THE SPECTRUM
- EXCELLENT IMMUNITY TO MULTIPATH INTERFERENCE
- IDEAL FOR SHORT RANGE APPLICATIONS FOR HIGH BIT RATE COMMUNICATIONS
- IMPLEMENTED BY RELATIVELY LOW COST INTEGRATED CIRCUITS
- CHARACTERIZED BY
  - PULSE REPETITION FREQUENCY,
  - RADIATED POWER DENSITY, AND
  - PEAK POWER IN A WIDE BANDWIDTH
- NECESSARY BANDWIDTH FOR COMMUNICATIONS PURPOSES CAN BE RESTRICTED BY FILTERS

TYPES OF UWB SIGNALS

DIRECT SEQUENCE SPREAD SPECTRUM OR DSSS - - SUGGESTED FOR MULTIPLE ACCESS COMMUNICATIONS

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING OR OFDM - - SUGGESTED FOR MULTI-BAND OPERATION FOR WIRELESS PERSONAL AREA NETWORKS

UWB APPLICATIONS

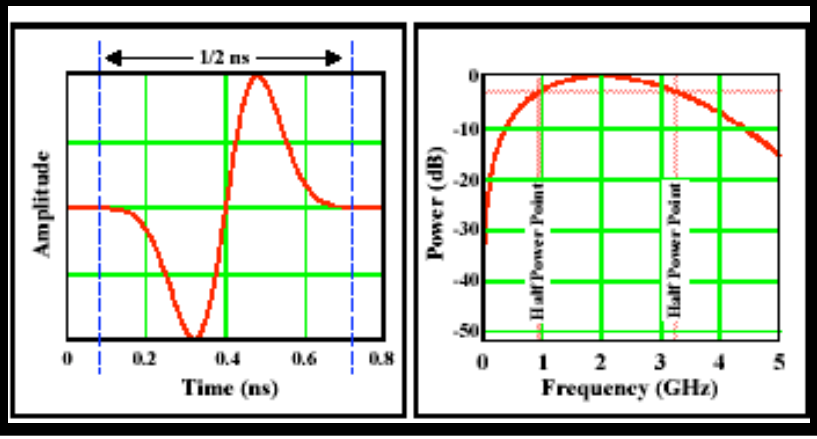
- WIRELESSLY DISTRIBUTE SERVICES SUCH AS PHONE, CABLE, AND COMPUTER NETWORKING
- POTENTIAL IN BOTH HOME AND BUSINESS MARKETS BASED ON ITS LOW COST AND HIGH-SPEED DATA TRANSMISSION CAPABILITY
- IDEAL FOR VARIOUS VIDEO DISTRIBUTION APPLICATIONS

UWB USES

- GROUND PENETRATING RADARS (PUBLIC SAFETY, ARCHEOLOGICAL, CIVIL ENGINEERING, EARTHQUAKE)
- THROUGH-WALL RADAR FOR PUBLIC SAFETY AND CONSTRUCTION
- EMERGENCY MOTION AND IMAGING
- HIGH PERFORMANCE MICROPHONES
- LOCAL AREA VOICE, DATA, AND VIDEO NETWORKS
- SECURITY DEVICES
- COLLISION AVOIDANCE AND AIRBAG SENSORS
- FLUID LEVEL DETECTION
- SHORT RANGE CLANDESTINE COMMUNICATION
- LONG RANGE MILITARY COMMUNICATIONS
- IDENTIFICATION AND LOCATION TAGS

UNLICENSED, UNCONTROLLED, UBIQUITOUS

UWB WAVEFORM CHARACTERISTICS



A MONOCYCLE PULSE IN TIME AND FREQUENCY DOMAIN

- UWB SIGNAL DEFINITION:
  - FRACTIONAL BANDWIDTH IS GREATER THAN 20% OF THE CENTER FREQUENCY, OR
  - THE -10 DB BANDWIDTH OCCUPIES 500 MHZ OR MORE OF SPECTRUM

UWB FRACTIONAL BANDWIDTH

$$\text{FRACTIONAL BW} = 2(F_h - F_l)/(F_h + F_l)$$

WHERE

F_h = HIGHEST FREQUENCY LIMIT WITH SIGNAL 10 dB BELOW PEAK EMISSION

F_l = LOWEST FREQUENCY LIMIT WITH SIGNAL 10 dB BELOW PEAK EMISSION

F_c = CENTER FREQUENCY = $(F_h + F_l)/2$ = 1/(DURATION OF ONE CYCLE)

NOTE THAT NECESSARY BANDWIDTH IS DEFINED AT 10 dB POINTS IN THE FREQUENCY DOMAIN.

UWB EFFECTIVENESS

IMPROVED CHANNEL CAPACITY IS ONE MAJOR ADVANTAGE OF UWB. SHANNON'S CAPACITY LIMIT EQUATION SHOWS THAT INCREASING CHANNEL CAPACITY REQUIRES LINEAR INCREASES IN BANDWIDTH WHILE SIMILAR CHANNEL CAPACITY INCREASES WOULD REQUIRE EXPONENTIAL INCREASES IN POWER.

SHANNON'S CAPACITY LIMIT EQUATION

$$C = BW\,[\log_2(1+SNR)]$$

where:

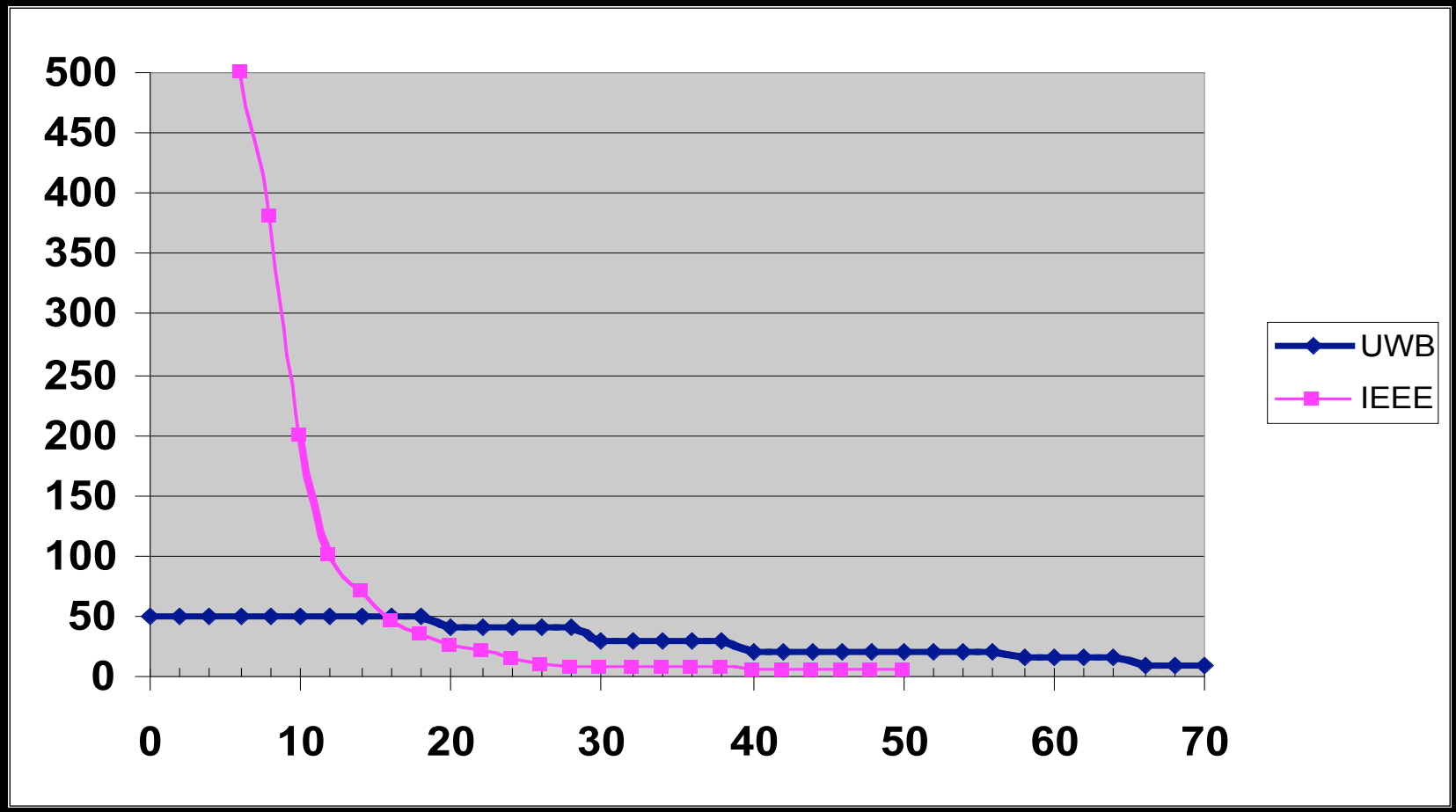
C = Channel Capacity (bits/sec)

BW = Channel Bandwidth (Hz)

SNR = Signal to Noise Ratio

$$= \frac{\text{Received Signal Power}}{(\text{Bandwidth})\,(\text{Noise Power Spectral Density})}$$

UWB AND IEEE DATA RATES AS A FUNCTION OF RANGE*

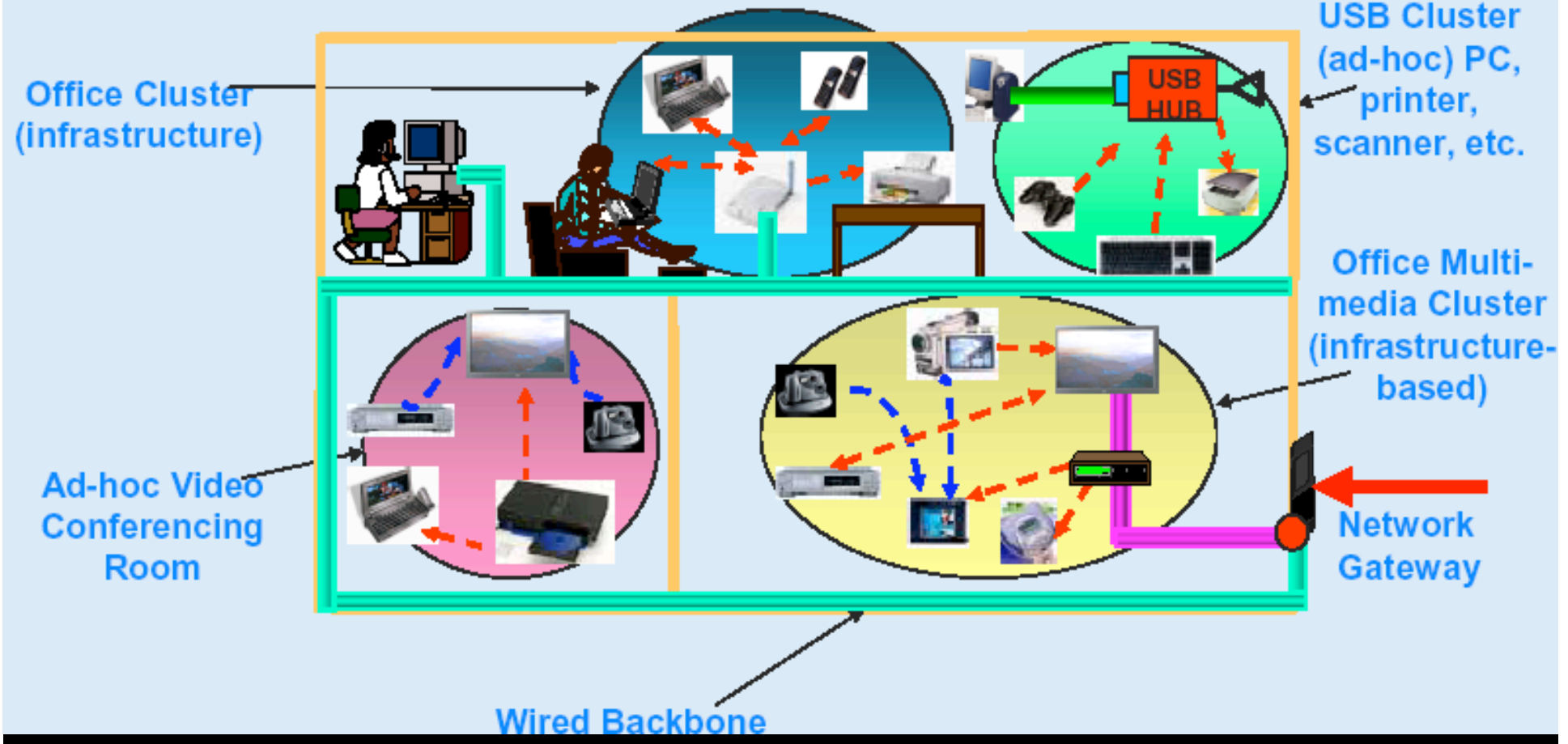


SOURCE: INTEL

*OCTOBER 2004

Ground Penetrating Radars

Wireless Offices & Homes



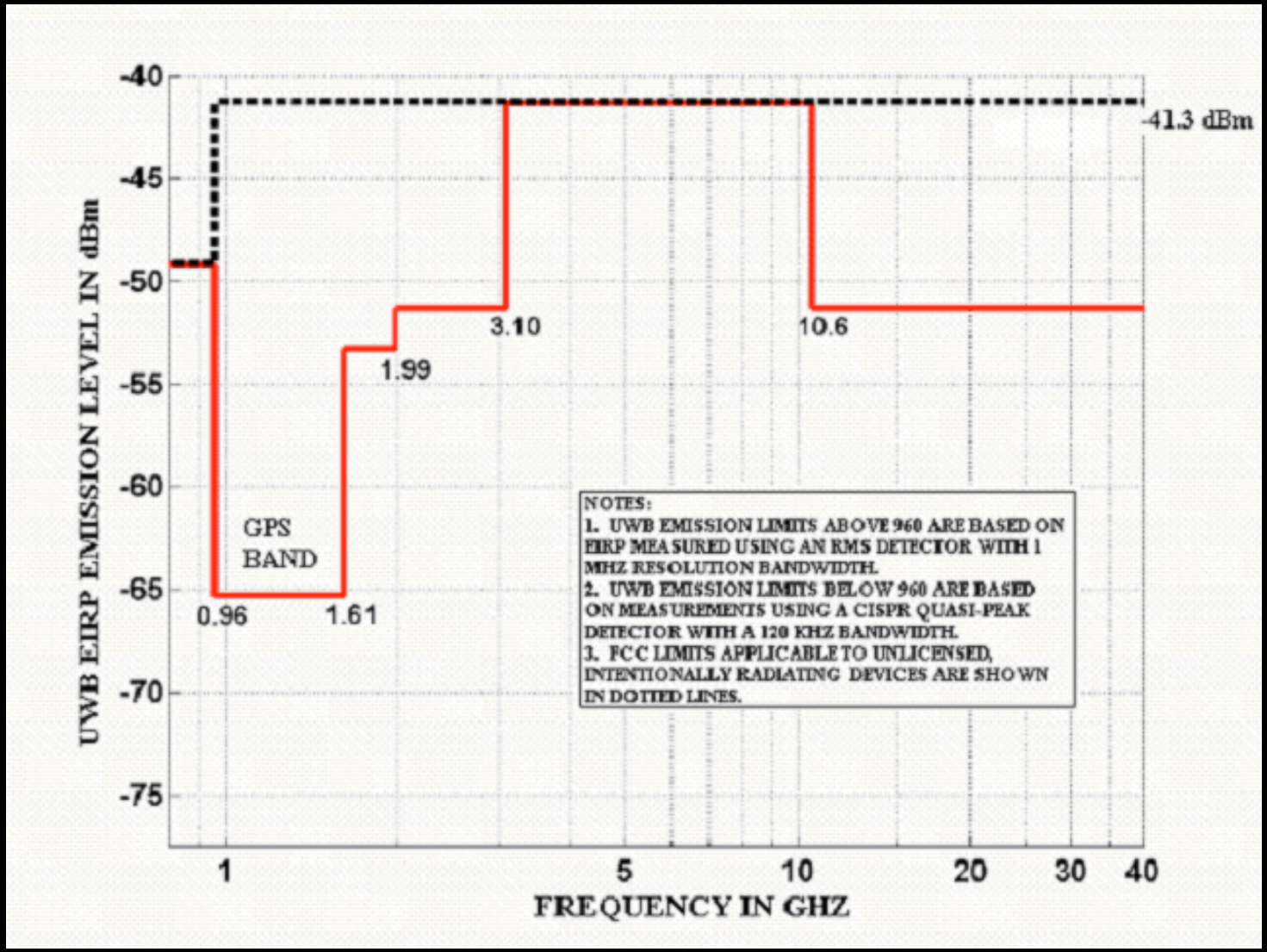
UWB TECHNICAL AND OPERATIONAL SUMMARY TABLE

	GROUND PENETRATING RADARS (GPR) AND WALL IMAGING SYSTEMS	THROUGH-WALL IMAGING SYSTEMS (1)	THROUGH-WALL IMAGING SYSTEMS (2)	SURVEILLANCE SYSTEMS	MEDICAL IMAGING SYSTEMS	VEHICULAR RADAR SYSTEMS	INDOOR COMM SYSTEMS	OUTDOOR, HAND-HELD COMM SYSTMES
OPERATING BANDS	OPERATION MUST BE BELOW 10.6 GHz	OPERATION MUST BE BELOW 960 MHz	OPERATION WITH CENTER FREQUENCY, F_C, AND F_M BETWEEN 1990 AND 10600 MHz	OPERATION MUST BE CONTAINED BETWEEN 1990 MHz AND 10600 MHz	OPERATION MUST BE CONTAINED BETWEEN 3100 MHz AND 10600 MHz	OPERATION MUST BE CONTAINED BETWEEN 22 AND 29 GHz. F_C AND F_M MUST BE GREATER THAN 24.075 GHz	OPERATION MUST BE CONTAINED BETWEEN 3100 MHz AND 10600 MHz.	OPERATION MUST BE CONTAINED BETWEEN 3100 MHz AND 10600 MHz.
LIMITATIONS OF SERVICE	Law Enforcement, Fire Fighting, Emergency Rescue, Scientific Research, Commercial Mining, or Construction	Law Enforcement, Emergency Rescue or Firefighting Organizations that are under the authority of a local or state government	Law Enforcement Applications, Emergency Services, and necessary training operations	Law Enforcement, Fire or Emergency Rescue Organizations, or Manufacturer/ Petroleum/Power Licensees	Used at the direction of, or under supervision of, a licensed health care practitioner	Operation is limited to UWB field disturbance sensors mounted in terrestrial transportation vehicles. These devices shall operate only when vehicle is running.	Operation is limited to UWB transmitters employed solely for indoor operation.	UWB devices are relatively small and primarily hand-held while being operated, and do not employ a fixed infrastructure.
RADIATED EMISSION LIMITS WITH RESOLUTION BANDWIDTH OF 1 MHz	Frequency e.i.r.p. 960-1610 -65.3 1610-1990 -53.3 1990-3100 -51.3 3100-10600 -41.3 Above 10600 -51.3	Frequency e.i.r.p. 960-1610 -65.3 1610-1990 -53.3 Above 1990 -51.3	Frequency e.i.r.p. 960-1610 -46.3 1610-10600 -41.3 Above 10600 -51.3	Frequency e.i.r.p. 960-1610 -53.3 1610-1990 -51.3 1990-10600 -41.3 Above 10600 -51.3	Frequency e.i.r.p. 960-1610 -65.3 1610-1990 -53.3 1990-3100 -51.3 3100-10600 -41.3 Above 10600 -51.3	Frequency e.i.r.p. 960-1610 -75.3 1610-22000 -61.3 22000-29000 -41.3 29000-31000 -51.3 Above 31000 -61.3	Frequency e.i.r.p. 960-1610 -75.3 1610-1990 -53.3 1990-3100 -51.3 3100-10600 -41.3 Above 10600 -51.3	Frequency e.i.r.p. 960-1610 -75.3 1610-1990 -63.3 1990-3100 -61.3 3100-10600 -41.3 Above 10600 -61.3
LIMITS FOR RESOLUTION BANDWIDTH OF NO LESS THAN 1 kHz	Frequency e.i.r.p. 1164-1240 -75.3 1559-1610 -75.3	Frequency e.i.r.p. 1164-1240 -75.3 1559-1610 -75.3	Frequency e.i.r.p. 1164-1240 -56.3 1559-1610 -56.3	Frequency e.i.r.p. 1164-1240 -63.3 1559-1610 -63.3	Frequency e.i.r.p. 1164-1240 -75.3 1559-1610 -75.3	Frequency e.i.r.p. 1164-1240 -85.3 1559-1610 -85.3	Frequency e.i.r.p. 1164-1240 -85.3 1559-1610 -85.3	Frequency e.i.r.p. 1164-1240 -85.3 1559-1610 -85.3

EMISSION LIMITS APPLICABLE TO UWB GROUND-PENETRATING RADAR AND WALL-IMAGING RADAR (BASED ON CISPR QUASI-PEAK-DETECTION) FROM 9 kHz TO 960 MHz

FREQUENCY (MHz)	FIELD STRENGTH (μV/m)	MEASUREMENT DISTANCE (m)
0.009-0.490	2400 / F (kHz)	300
0.490-1.705	24000 / F (kHz)	30
1.705-30.000	30	30
30.000-88.000	100	3
88.000-216.000	150	3
216.000-960.000	200	3

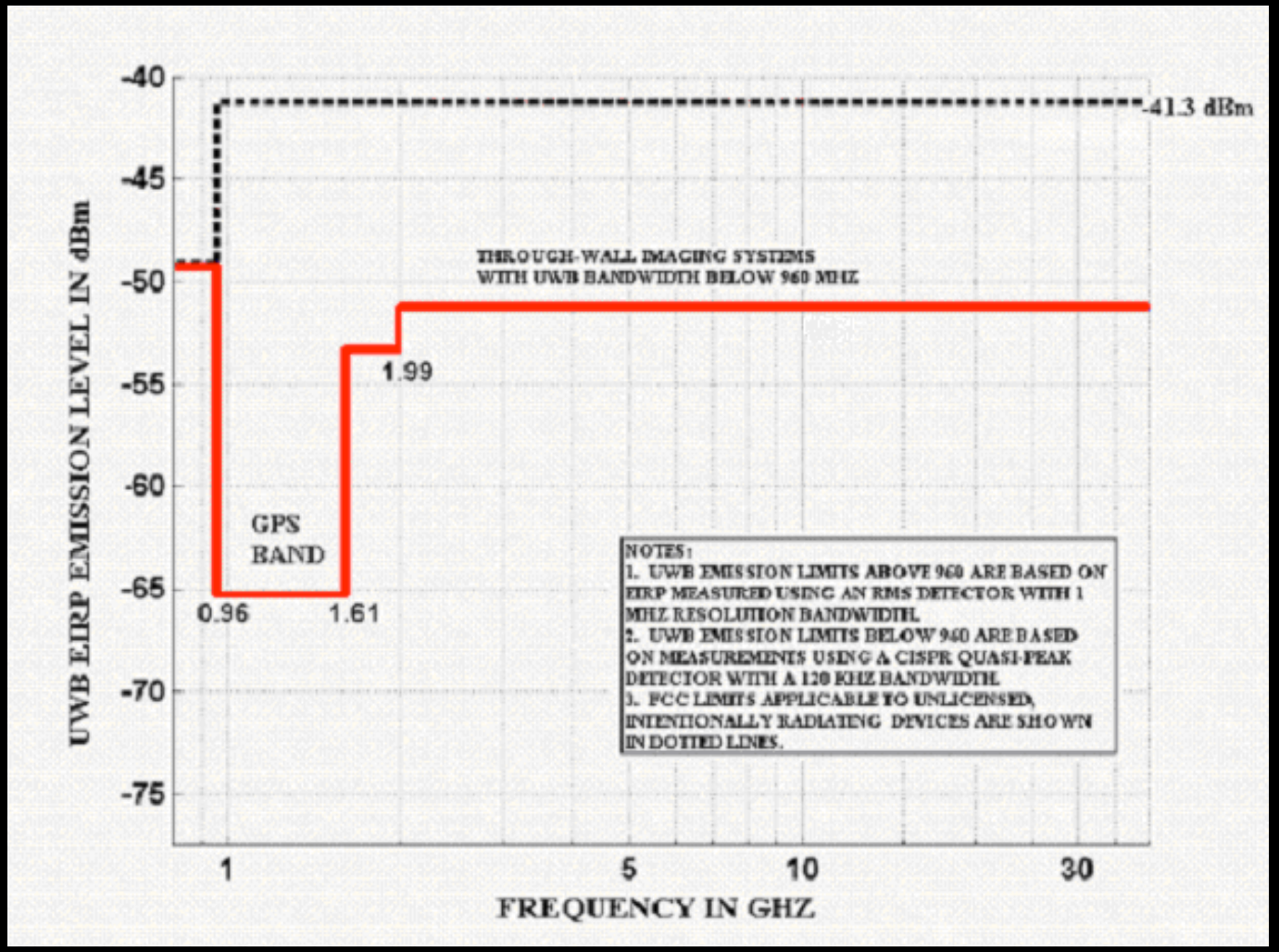
GPR & WALL IMAGING SYSTEMS*



OPERATING BANDS: THE UWB BANDWIDTH OF AN IMAGING SYSTEM MUST BE BELOW 10.6 GHz.

***OPERATION IS LIMITED TO LAW ENFORCEMENT, FIRE AND RESCUE ORGANIZATIONS, SCIENTIFIC RESEARCH INSTITUTIONS, COMMERCIAL MINING COMPANIES, AND CONSTRUCTION COMPANIES.**

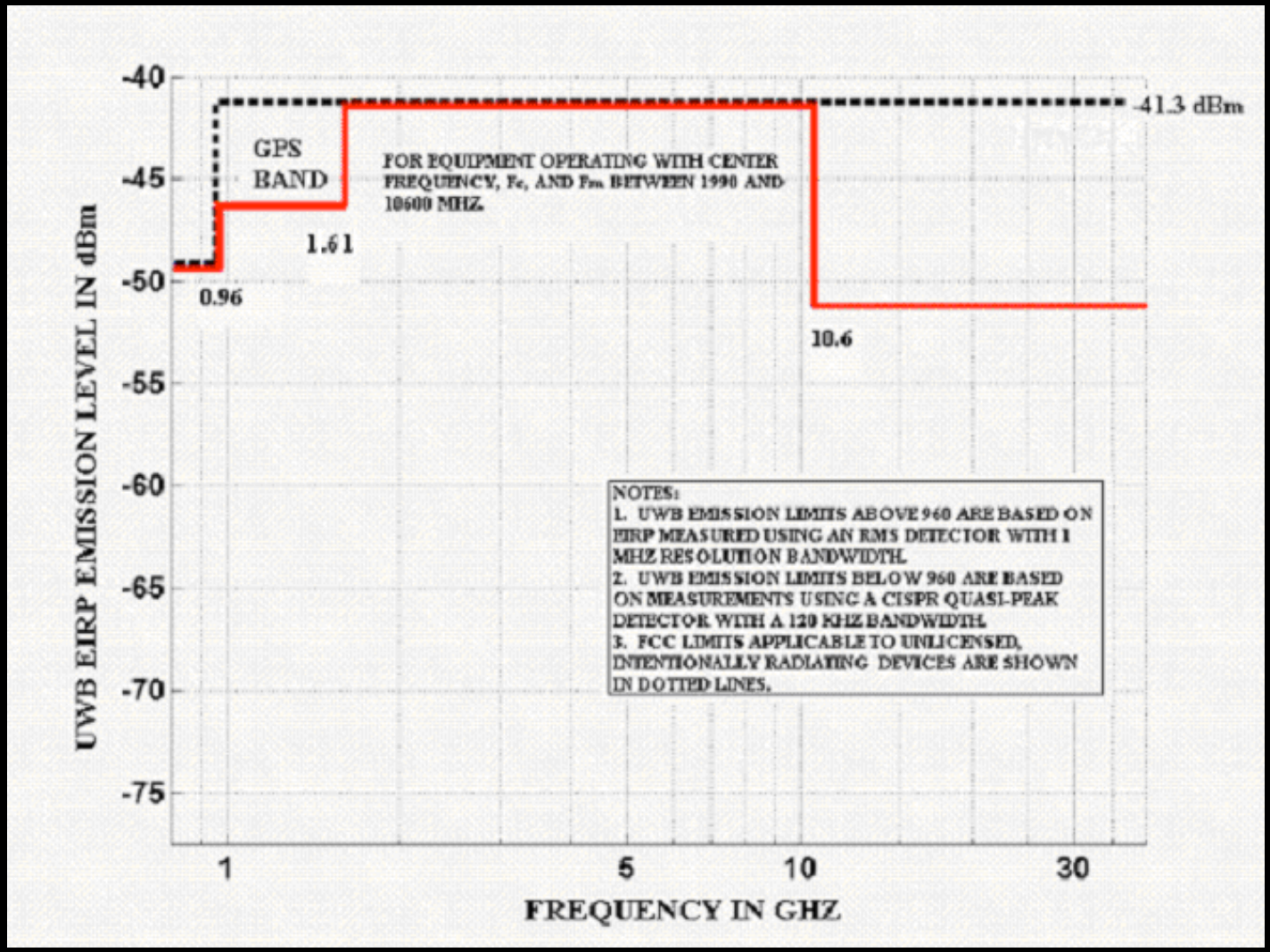
THROUGH-WALL IMAGING SYSTEMS (1)*



OPERATING BANDS: THROUGH-WALL IMAGING SYSTEMS WITH THE UWB BANDWIDTH BELOW 960 MHz.

***OPERATION IS LIMITED TO LAW ENFORCEMENT AND FIRE AND RESCUE ORGANIZATIONS THAT ARE UNDER THE AUTHORITY OF A LOCAL OR STATE GOVERNMENT.**

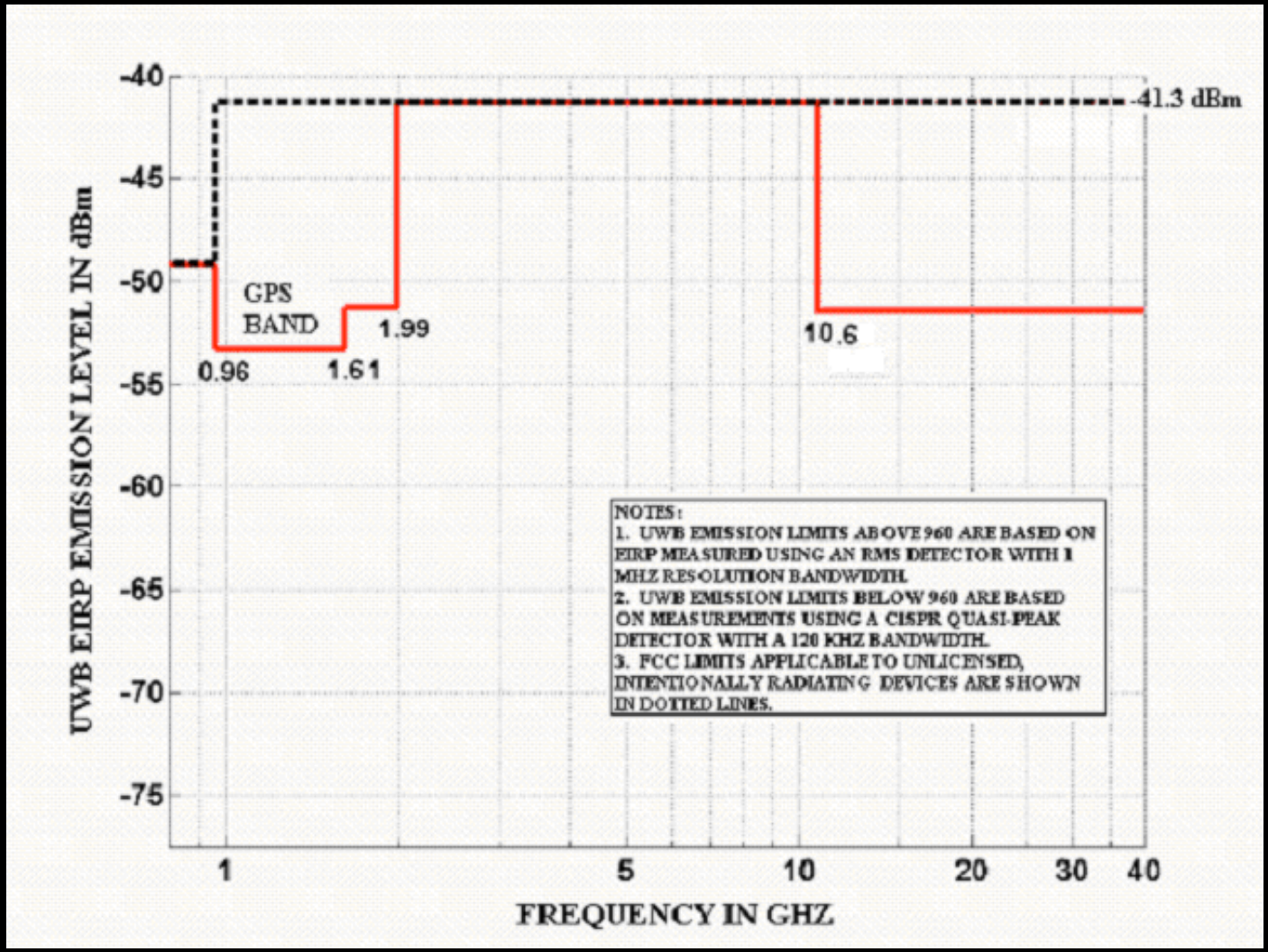
THROUGH-WALL IMAGING SYSTEMS (2)*



EQUIPMENT OPERATING BETWEEN 1990 AND 10600 MHz WITH CENTER FREQUENCY, F_c, AND MAXIMUM EMISSION FREQUENCY, F_M

***OPERATION IS LIMITED TO LAW ENFORCEMENT AND FIRE AND RESCUE ORGANIZATIONS THAT ARE UNDER THE AUTHORITY OF A LOCAL OR STATE GOVERNMENT.**

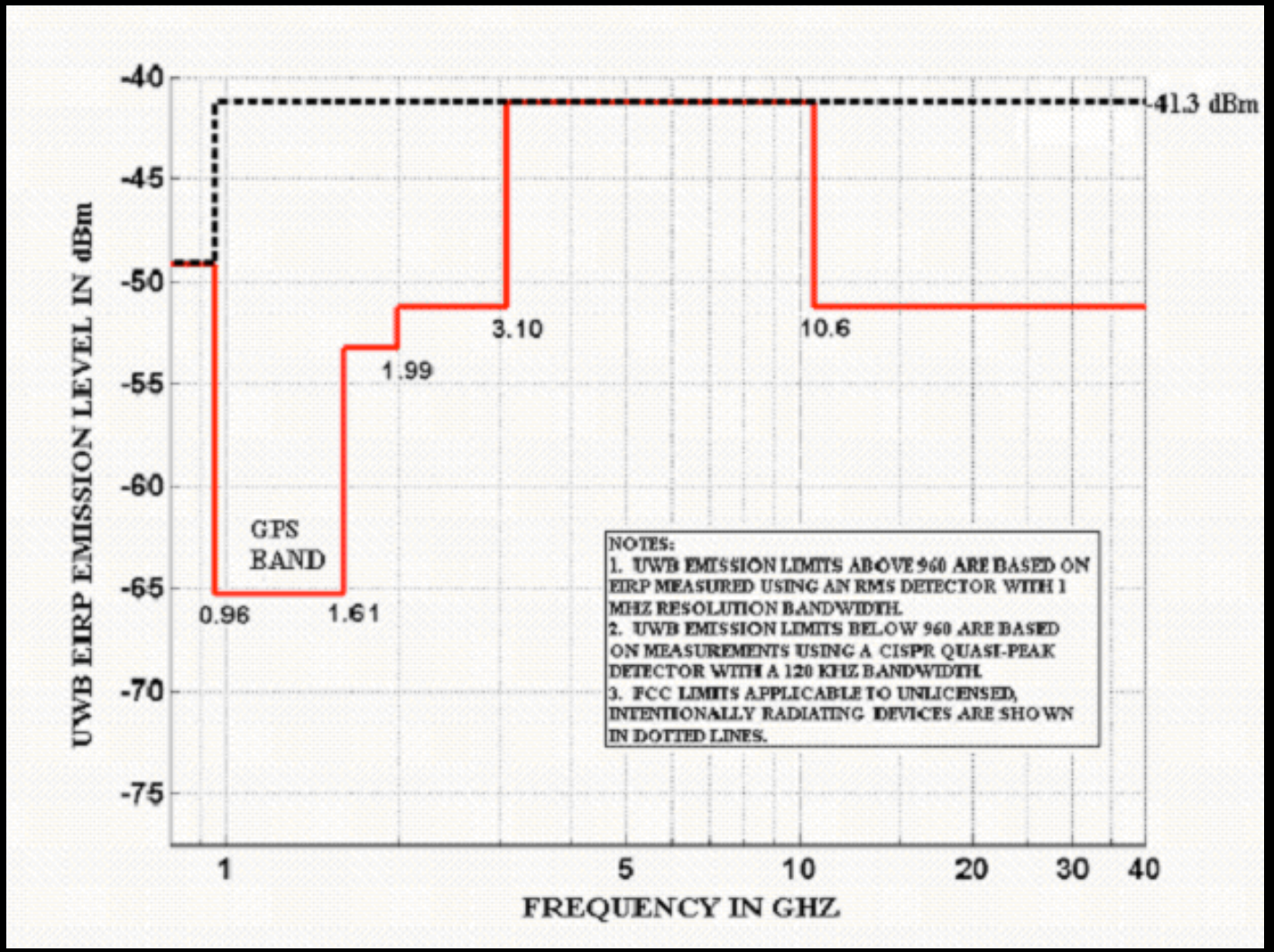
SURVEILLANCE SYSTEMS*



UWB SURVEILLANCE IMAGING SYSTEMS BANDWIDTH MUST BE BETWEEN 1990 MHz AND 10600 MHz.

***SURVEILLANCE SYSTEMS MAY BE OPERATED BY LAW ENFORCEMENT, FIRE OR EMERGENCY RESCUE ORGANIZATIONS OR BY MANUFACTURERS LICENSEES, PERTROLEUM LICENSEES OR POWER LICENSEES.**

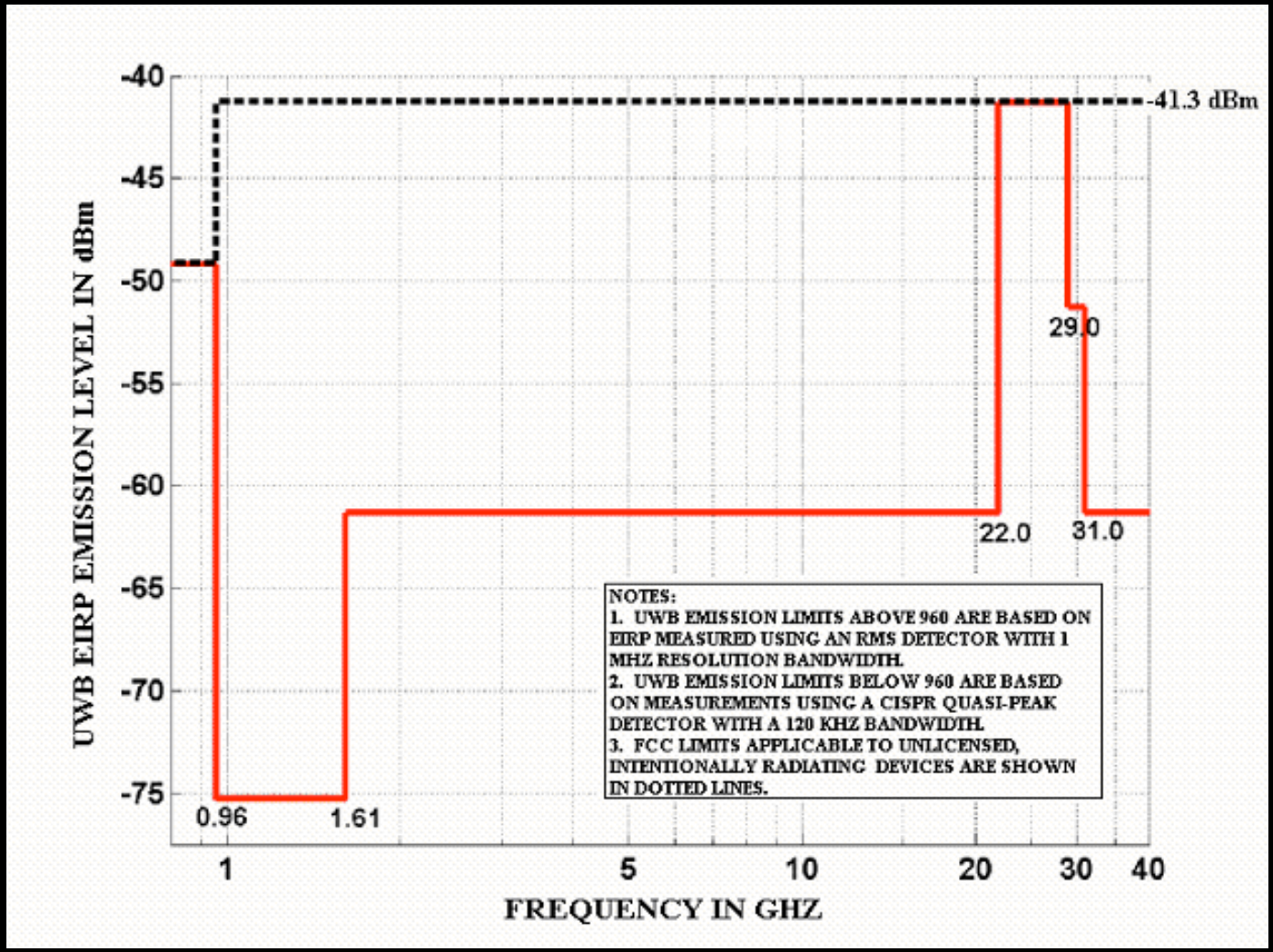
MEDICAL IMAGING SYSTEMS*



MEDICAL IMAGING SYSTEM UWB BANDWIDTH MUST BE BETWEEN 3100 AND 10600 MHz.

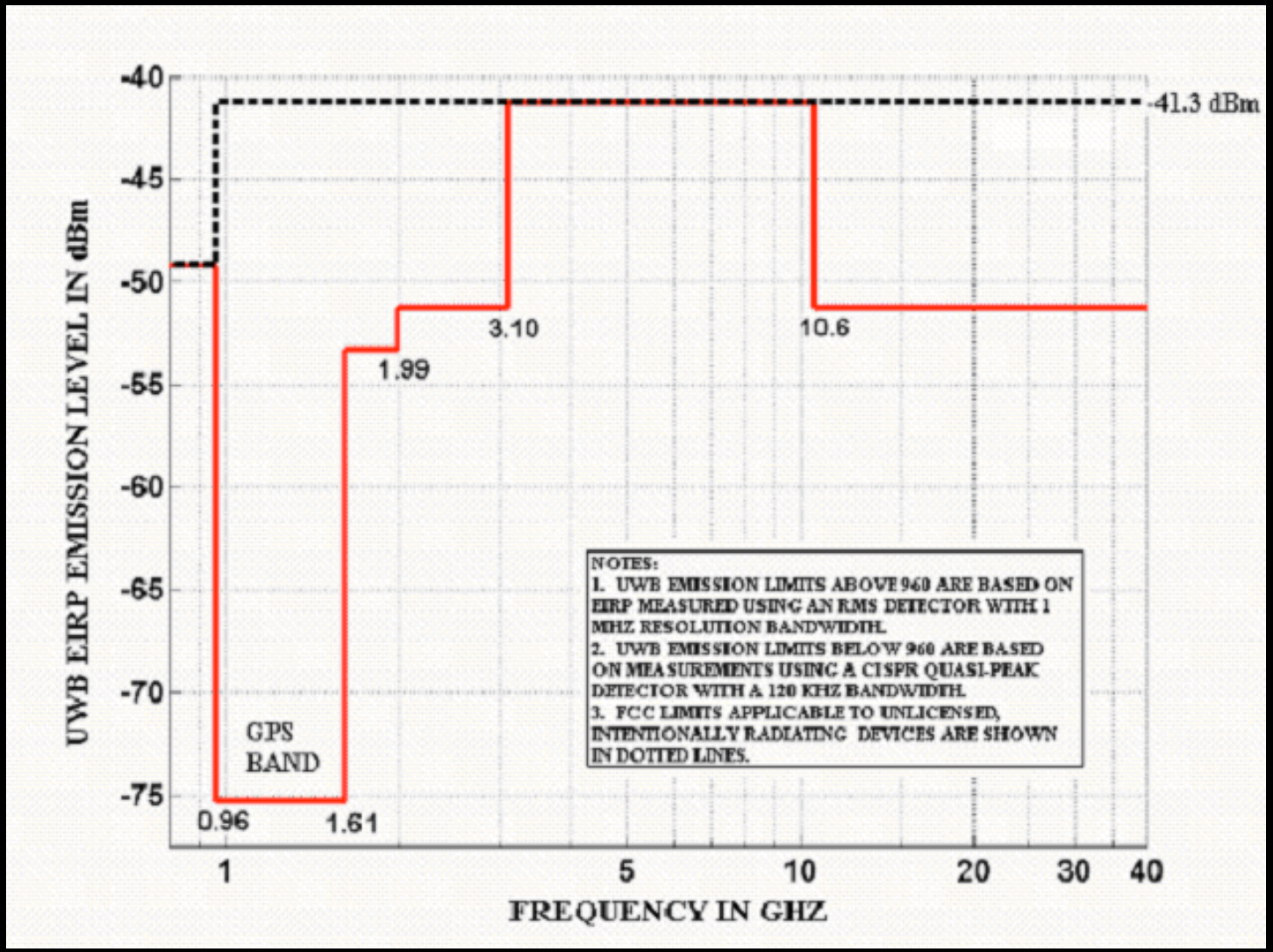
***OPERATION IS LIMITED TO LAW ENFORCEMENT, FIRE AND RESCUE ORGANIZATIONS, SCIENTIFIC RESEARCH INSTITUTIONS, COMMERCIAL MINING COMPANIES, LICENSED HEALTH CARE PRACTITIONERS, AND CONSTRUCTION COMPANIES.**

VEHICULAR RADAR SYSTEMS



OPERATING BANDS: THE UWB BANDWIDTH MUST BE CONTAINED BETWEEN 22 GHz AND 29 GHz. THE CENTER FREQUENCY AND THE FREQUENCY AT WHICH THE HIGHEST LEVEL EMISSION OCCURS MUST BE GREATER THAN 24.075 GHz.

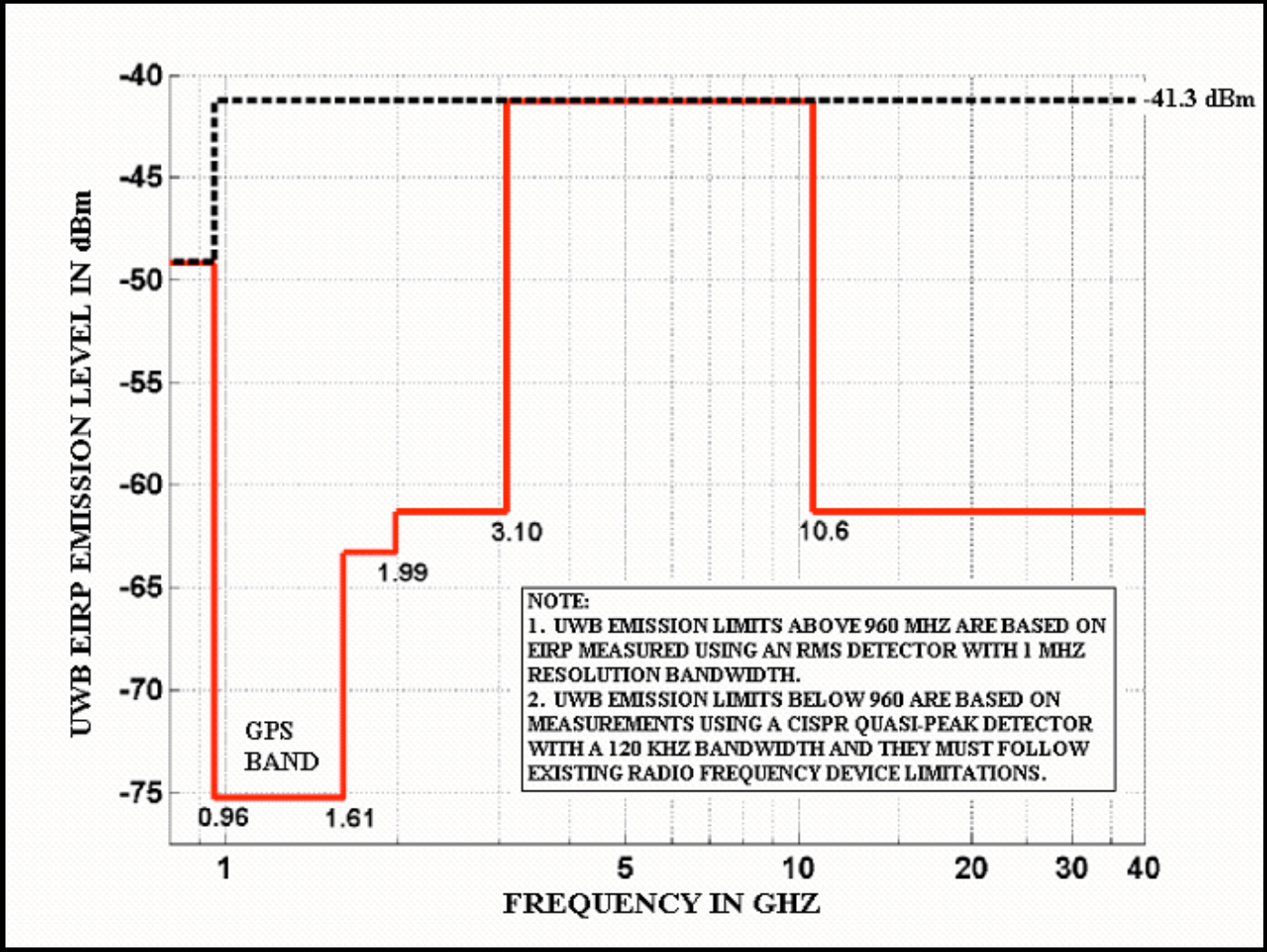
INDOOR COMMUNICATION SYSTEMS*



UWB INDOOR SYSTEM MUST BE BETWEEN 3100 MHz AND 10600 MHz.

***EQUIPMENT MUST BE DESIGNED TO ENSURE THAT OPERATION CAN ONLY OCCUR INDOORS OR IT MUST CONSIST OF HAND-HELD DEVICES THAT MAY BE EMPLOYED FOR SUCH ACTIVITIES AS PEER-TO-PEER OPERATION.**

OUTDOOR, HAND-HELD COMMUNICATION SYSTEMS

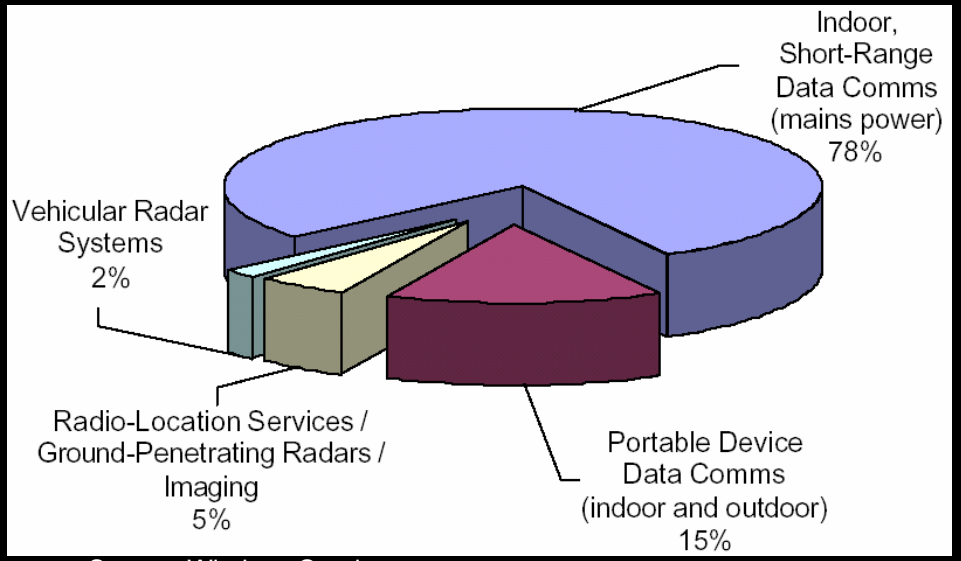


OPERATING BANDS: THE UWB BANDWIDTH OF AN OUTDOOR, HAND-HELD DEVICE MUST BE CONTAINED BETWEEN 3100 MHz AND 10600 MHz.

ULTRA WIDEBAND DEVELOPMENT

- THE UWB SPECIFICATION IS BEING DEVELOPED BY 802.15.3A IN THE NEXT TWO YEARS
- THERE ARE TWO UWB STANDARDS PROPOSALS: MULTI-BAND OFDM (MBOA) BY TEXAS INSTRUMENTS AND DIRECT SEQUENCE SPREAD (DSS) SPECTRUM BY MOTOROLA
  - THE PROPOSALS ARE IN A STALEMATE SITUATION: A YEAR DELAY IN THE STANDARD MAY RESULT
- UP TO 260 MILLION UWB CHIPSETS ARE EXPECTED TO BE SHIPPED BY 2009 (SOURCE: ON WORLD)

UWB APPLICATION TYPES WORLDWIDE (2007 ESTIMATE)



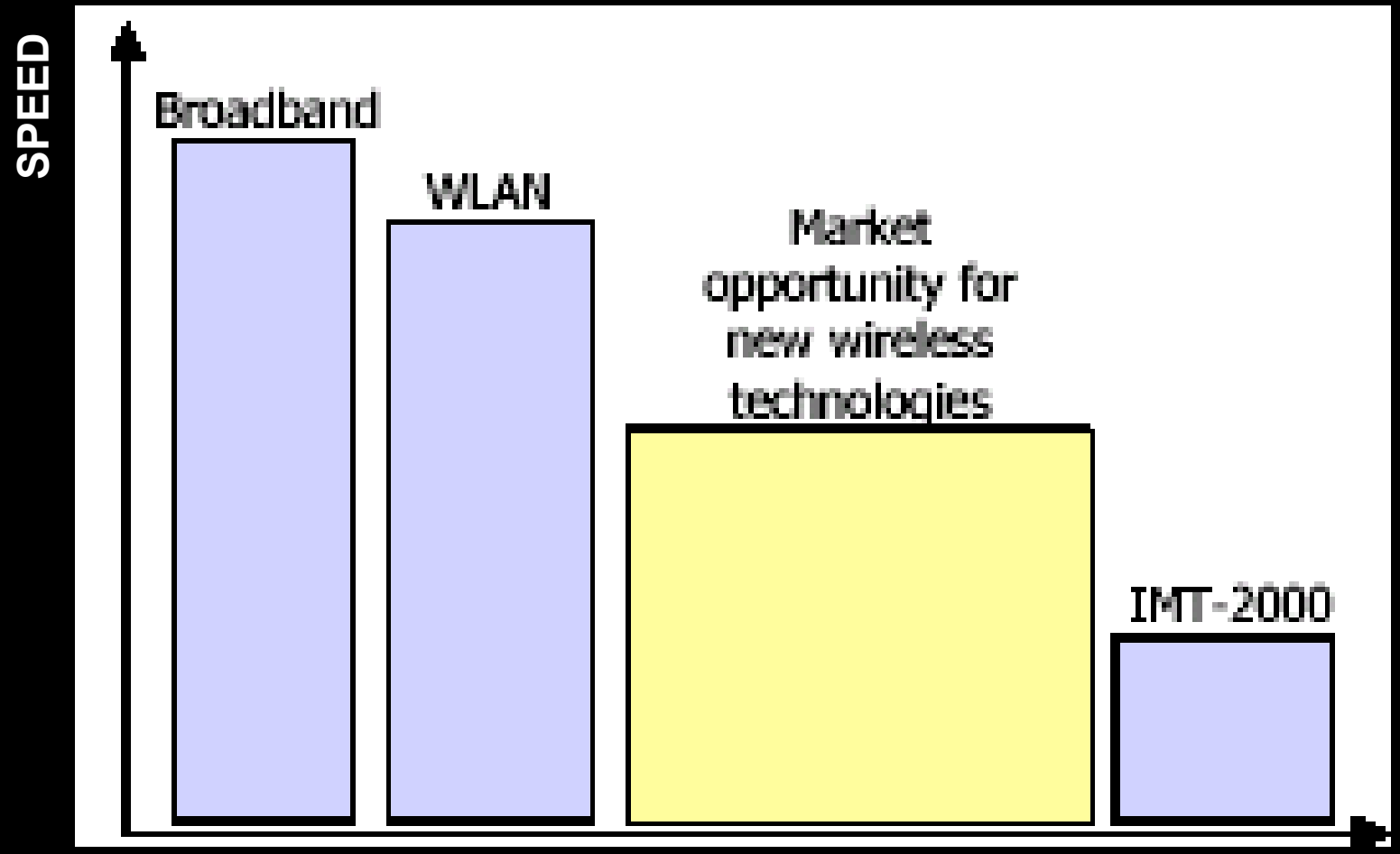
Source: Wireless Oracle

ADDRESSABLE WORLDWIDE BROADBAND (UWB) MARKET

DEVICE UNITS (MILLIONS)	2002	2003	2004	2005	2006
CONSUMER ELECTRONIC DEVICES	124	140	163	192	240
PC AND PERIPHERAL DEVICES	574	616	674	713	754
MOBILE DEVICES	448	483	524	560	606
TOTAL VOLUME	1,146	1,239	1,361	1,465	1,600

THE U.S. IS THE ONLY COUNTRY TO APPROVE ULTRA WIDEBAND SO FAR, BUT SOME COUNTRIES, SUCH AS SINGAPORE AND IRELAND HAVE SET UP "UWB FREE ZONES" OR ALLOTTED A NUMBER OF EXPERIMENTAL OPERATING LICENSES FOR TEST PURPOSES. CANADA, NEW ZEALAND, THE U.K. AND OTHER EUROPEAN COUNTRIES (CEPT) ARE STUDYING IMPLEMENTATION.

THE PORTABLE INTERNET



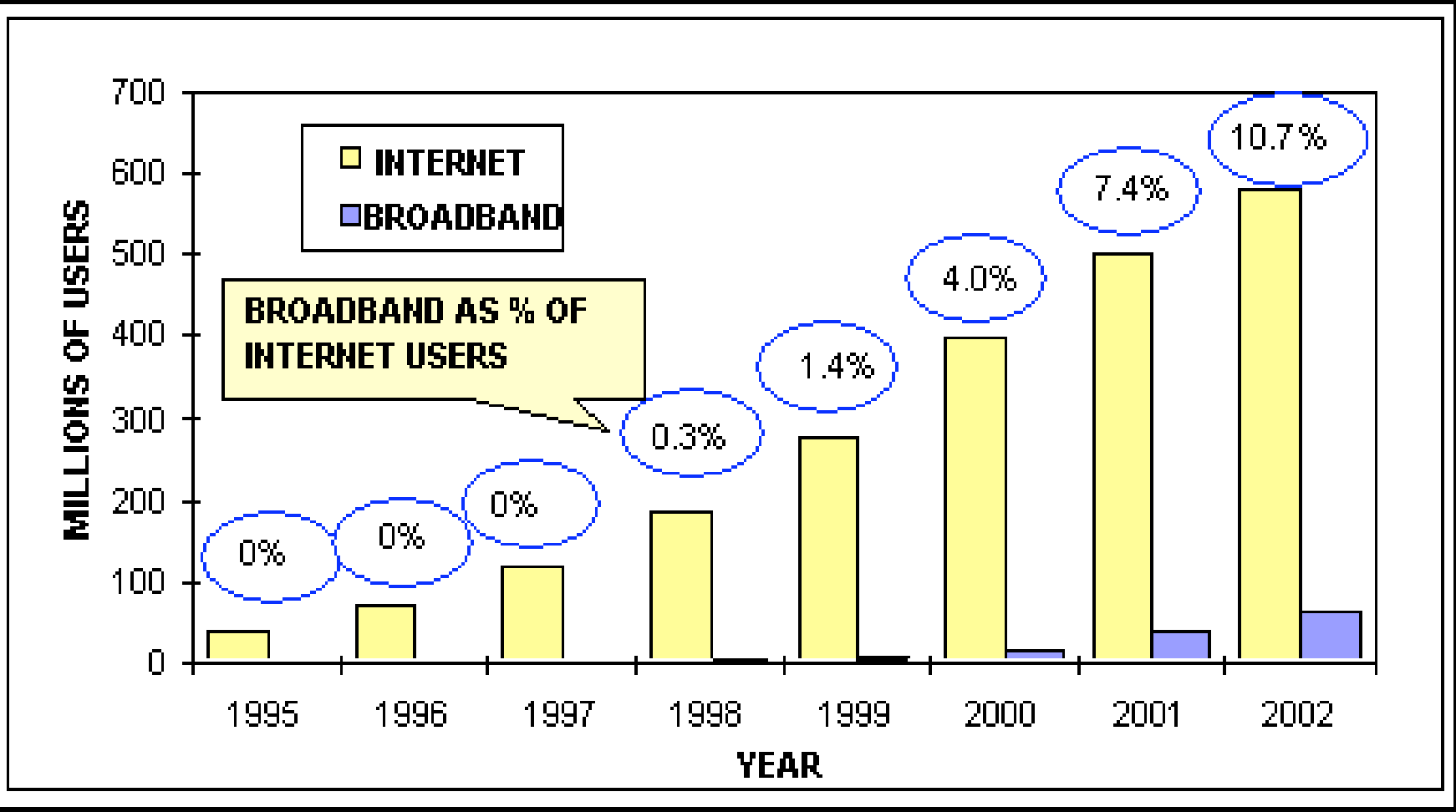
SOURCE: ITU 2004

PORTABLE INTERNET TECHNOLOGIES

Long range	Medium range	Short range
• IMT-2000 (3G)	• WLAN	• Bluetooth
• WiMax – IEEE 802.16	➢ Wi-Fi – IEEE 802.11b	• RFID
• IEEE 802.20	➢ IEEE 802.11a	• ZigBee
• HiperMAN	➢ IEEE 802.11g	
• Satellite	➢ IEEE 802.11i	
• HAPS/LAPS	• Free space optics	
• LMDS	• HiperLAN2	
• MMDS	• Ultra wideband	

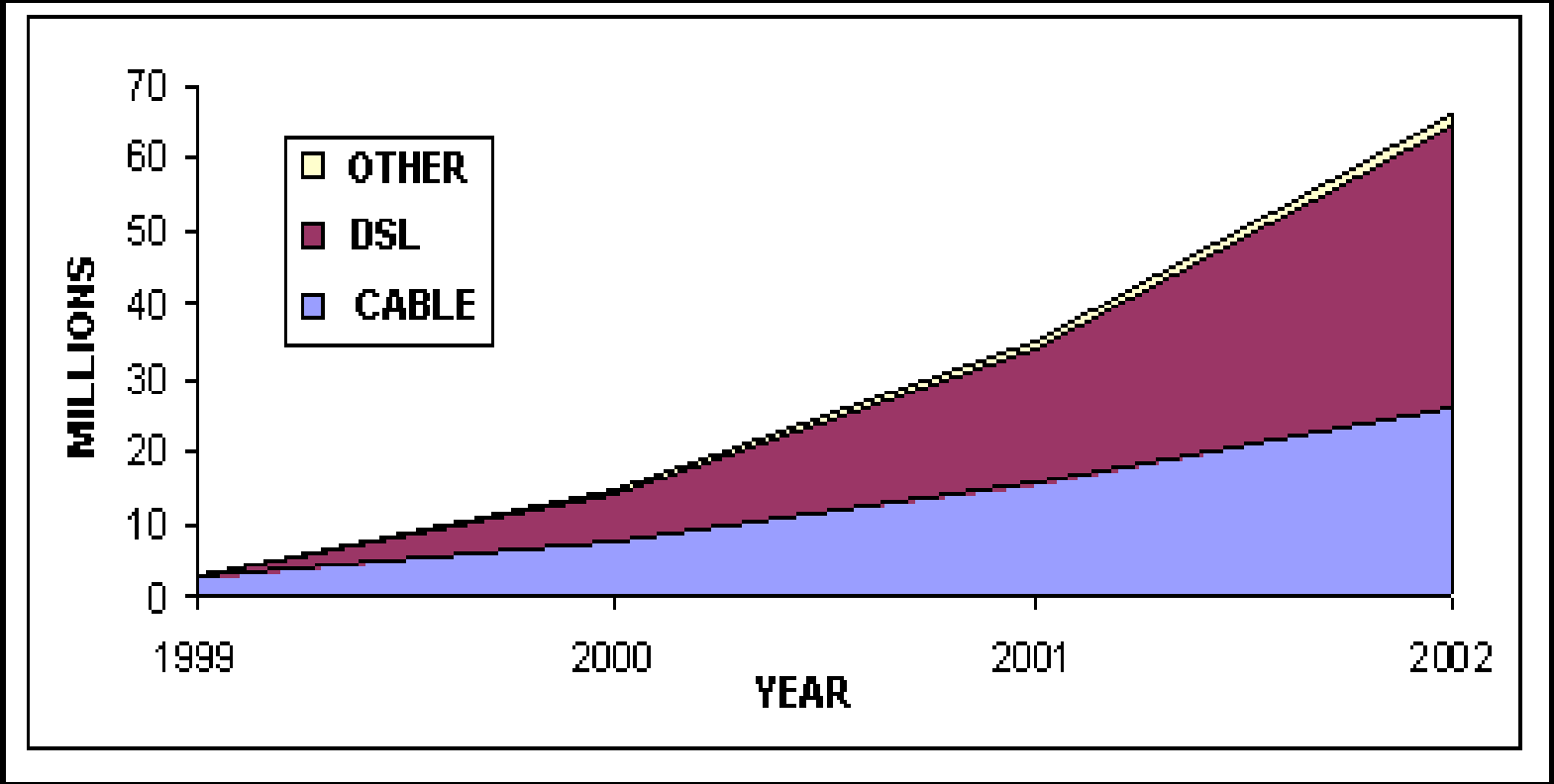
SOURCE: ITU 2004

WORLDWIDE BROADBAND AND INTERNET USE



SOURCE: ITU WORLD TELECOMMUNICATION INDICATORS DATABASE

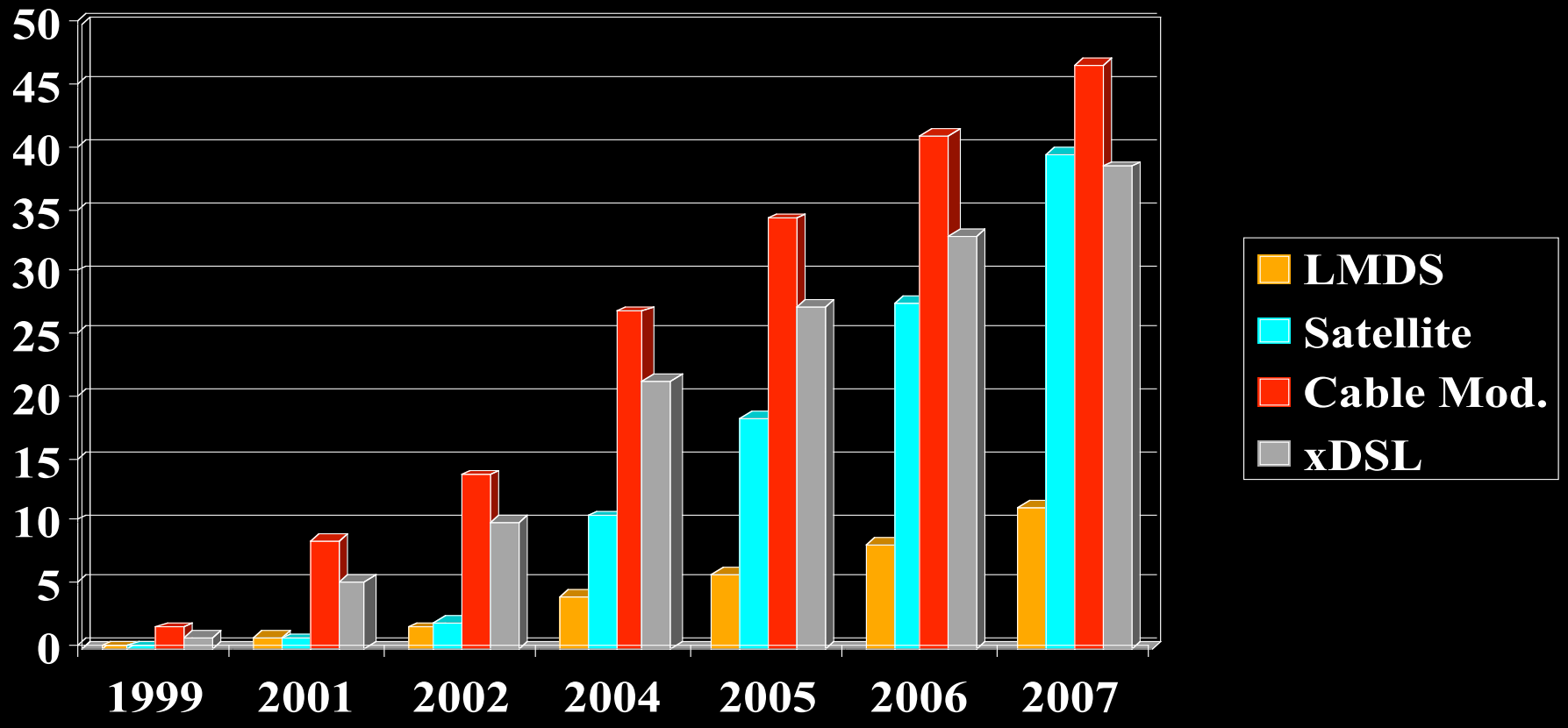
WORLDWIDE BROADBAND PENETRATION



SOURCE: ITU

GLOBAL BROADBAND MARKET

MILLIONS OF SUBSCRIBERS



Source: Publications Resource Group

DEMAND FOR WIRELESS BROADBAND

- TELEMEDICINE
- TELEWORKING
- E-GOVERNMENT
- AGRICULTURE
- DISTANCE LEARNING
- PUBLIC SAFETY
- NATIONAL SECURITY
- E-COMMERCE
- ENTERTAINMENT
- APPLICATIONS FOR PERSONS WITH DISABILITIES
- UTILITY APPLICATIONS
- SMALL BUSINESS ASSISTANCE
- INFORMATION GATHERING
- TOURISM

Source: TIA, “The Economic and Social Benefits of Broadband Deployment”, October 2003

BROADBAND IN VACANT ANALOG AND DIGITAL TELEVISION CHANNELS

IT HAS BEEN PROPOSED THAT UNUSED TELEVISION CHANNELS BE EXPLOITED FOR NEW BROADBAND WIRELESS SERVICES, ACCESSING THE INTERNET, WHILE ENSURING THAT NO INTERFERENCE IS CAUSED TO TELEVISION RECEPTION

THIS INCLUDES WIRELESS COMPUTER NETWORKING, WIRELESS CONNECTIONS TO PRINTERS AND KEYBOARDS, WIRELESS HEADSETS, COMPUTER CONNECTIONS FOR CELLULAR AND PCS PHONES.

http://www.fcc.gov

William.luther@fcc.gov

THE REAL VOYAGE OF DISCOVERY CONSISTS NOT IN SEEKING NEW LANDSCAPES, BUT IN HAVING NEW EYES."

- MARCEL PROUST –

a French novelist