Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of Revision of Part 15 of the FCC's Rules Regarding Ultra-wideband Transmission Systems	ET Docket 98-153

Reply Comments of Time Domain Corporation

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Executive Summary

The comments in this proceeding overwhelmingly demonstrate the need for the Commission to authorize ultra-wideband (UWB) on a Part 15 unlicensed basis. The record reflects great interest in the use of UWB for a variety of applications that can save lives and benefit the public in numerous areas of endeavor including:

- critical communications, location and tracking capabilities in fire and rescue situations;
- improved security and criminal detection and location for use by police officers;
- military applications for electronic fences, covert communications, and location applications;
- technological assistance for the disabled and the elderly to live more independently;
- improved health care monitoring;
- safer workplaces by detection of unseen hazards;
- collision avoidance systems in automobiles;
- additional aviation security, safety, and efficiency;
- continued technological and economic leadership for the United States; and

- mitigation of the "spectrum drought" by affording efficient short-range communications for wireless LAN applications and the completion of voice calls within buildings as handed off by other networks.

Time Domain Corporation (TDC) underscores in these Reply Comments why Part 15 regulation stands out as the most appropriate mechanism for the introduction of UWB to the American public. The Commission has a long and useful history under Part 15 of fostering innovation while protecting licensed users of the spectrum from harmful interference. For some fifty years, unlicensed operations have evolved so that today virtually every consumer utilizes a host of Part 15 devices every day at home, at work, in school, and in other pursuits. TDC estimates that there are over five billion devices in the United States that operate under Part 15. Over twenty years ago the Commission developed emissions limits for narrowband and broadband noise emanating from computers and other digital devices. In 1989, the Commission found that those standards could form the basis for new general limits. As it considers UWB, the Commission should work against this background of general limits and alter the application of the limits only if testing and analysis in this proceeding clearly support such changes.

As the Commission considers the emissions limits for UWB, it should keep in mind its recent decisions in which emissions mask requirements for new land mobile and mobile satellite services were adopted that implemented standards for the protection of GPS that are slightly less rigorous than the general Part 15 limits. Having found that these limits are appropriate, the Commission should now assess how these limits can be applied in the UWB context. On the basis of its testing and analysis thus far, TDC

believes that the Commission should continue to require that GPS be protected in a manner consistent with the levels most recently applied by the Commission (*e.g.*, a limit of –70 dBW/MHz). In the UWB proceeding, the Commission seeks to fulfill its statutory mandate to foster new and beneficial services and technologies. To hold these new entrants to a higher standard than that now applied to others calls into question whether such technologies can ever be authorized.

With regard to calls for additional testing *ad infinitum,* TDC urges the Commission to recognize that many of these pleas come from those who do not dispute the potential benefits of UWB, but who wish to delay the provision of those benefits to the public.

Finally in these Reply Comments, TDC points out numerous flaws in the technical analysis submitted by UWB critics in this proceeding. TDC also offers its observations in response to certain emissions limit and measurement issues.

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This proceeding represents a momentous start to a new century of technological innovation. By building on the knowledge it has gained over the last fifty years in the regulation of numerous types and innumerable numbers of low power devices emitting all types of radio noise, the Commission is well-poised to move toward the next step in this proceeding and the eventual adoption of a first report and order. TDC appreciates the opportunity to offer its views and looks forward to continued participation in this proceeding.

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Comments of Time Domain Corporation

I. Introduction

Time Domain Corporation ("TDC") submits this reply to the broad collection of opening comments filed in response to the Commission's Notice of Proposed Rule Making ("NPRM").[1] The comments reflect widespread interest in Ultra-Wideband ("UWB") technology, and the record contains numerous views underscoring the benefits of the technology. Even those who would like to delay introduction of UWB do not dispute its potential. The Commission has received compelling confirmation of the many benefits that UWB systems offer, and TDC urges the FCC to fulfill its responsibilities to serve the public by allowing this beneficial new technology to develop.

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[1] *See* Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, *Notice of Proposed Rulemaking*, ET Docket 98-153 (rel. May 11, 2000) ("NPRM").

The central question for this rulemaking is whether UWB technology will be afforded the opportunity to explore its potential in the marketplace or whether it will fall victim – either through unnecessary delay or overly restrictive regulation – to ungrounded fears. TDC strongly believes that rapid deployment of UWB devices is in the public interest and can be achieved by regulations that allow for compatible spectrum sharing with existing services. Indeed, because many UWB applications can be deployed successfully at the existing Part 15 limits, this technology will lessen the pressure on current spectrum usage.

The Commission has properly structured this rulemaking. As part of its own rulemaking process, it is monitoring concurrently the extensive testing and analysis underway at other government agencies and university research centers. At this stage, it is requesting feedback on the comments made in response to the numerous regulatory issues raised in the NPRM. The latter part of TDC's reply comments responds to specific technical issues raised in the opening NPRM comments. TDC also has included a number of detailed technical appendices to respond to the various theoretical analyses presented in the opening comments. The initial sections that follow below summarize the overwhelmingly positive response to UWB in the opening comments and responds to the broad themes that were presented.

TDC is confident that once the Commission weighs the technical and policy issues and assesses carefully the interference testing, it will promulgate sound rules that

permit the technology to proceed to meet public needs and ensure that existing licensees, including safety-of-life services, are protected from harmful interference.[2]

II. The Comments Affirm the Benefits of UWB Technology.

The comments support the Commission's finding that "UWB technology holds promise for a vast array of new and improved devices that could have enormous benefits for public safety, consumers and businesses….and create new business opportunities…that will enhance competition and the economy."[3]

UWB benefits cited in the comments include applications that will save lives of victims of crimes, accidents and disasters; enhance the safety and effectiveness of police, fire and rescue personnel, the military and construction workers, aviators and drivers; protect the environment; and improve the quality of life for the ill, the disabled and the elderly. Wireless broadband connections will increase Internet access opportunities for homes, schools and libraries, and thereby address the increasing concerns about avoiding a "digital" or "broadband" divide. Other applications will improve aviation and highway safety, provide alternative approaches to local area networking, and enhance the performance of low power devices, including those used for the location and handling of hazardous materials. Many comments describe the global leadership potential of this breakthrough technology, with the accompanying possibility of improved economic and

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[2] *See* 47 C.F.R. § 15.5 (1999).

[3] NPRM at ¶ 8.

productivity opportunities, new job creation, increased competition and innovation and declining prices.

The Comments Echo the Public Benefits of UWB Technology

Many congressmen and senators encourage the deployment of UWB for the many public benefits it offers.[4] Even among parties seeking to defer authorization of UWB through additional testing or new regulatory burdens, there is acknowledgement that UWB is an extremely promising and important new technology.[5] Other "legacy" industries are motivated perhaps by fear of competition, "rather than by an authentic concern for public safety."[6]

Saving and Protecting Life. Lives can and will be saved with UWB technology, so it follows that the sooner FCC rules are modified to allow UWB operation, the sooner UWB can provide this most compelling of public benefits. As On Scene, Inc., stated,

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[4] *See* Comments of The Honorable Billy Tauzin (LA), The Honorable John Kerry (MA),The Honorable Bud Cramer (AL), The Honorable Curt Weldon (PA), The Honorable Jeff Sessions (AL), The Honorable Trent Lott (MI), The Honorable Robert Alderholt (AL), The Honorable Sonny Callahan (AL), The Honorable Spencer Bachus (AL), The Honorable Bob Riley (AL), The Honorable Terry Everett (AL), The Honorable Chip Pickering (MS), The Honorable Ed Markey (MA), The Honorable Steve Largent (OK), The Honorable Ron Kind (WI), The Honorable Nathan Deal (GA), The Honorable James Rogan (CA), The Honorable Albert Wynn (MD), and The Honorable Curt Weldon (PA).

[5] *See, e.g.*, Comments of AT&T Wireless Services, Inc. at 1 ("a range of promising new applications"); Aircraft Owners and Pilots Association at 1 ("shows great promise"); *see also* The Boeing Company; Cisco Systems, Inc.; National Business Aviation Association; Nortel Networks, Inc.; Lockheed Martin Corp. (". . . substantially increased utility for some types of simulation and training technology systems, allowing operation at substantially reduced power, and producing significant operational cost savings").

[6] *See* Comments of Consumer Federation of America at 1.

"our country…has one of the highest fire death rates in the industrialized world," with over one hundred fire-fighter deaths each year. Mere seconds count in fire, disaster, and toxic exposure rescues, and UWB technologies can accelerate rescues.[7] Citing the tragedy in Worcester, MA, that claimed the lives of six firefighters, On Scene reported that their deaths were not due to a failure of procedures but to the inadequacy of today's firefighting technology. The President of the Clovis Firefighters' Association writes about the deaths of a crew of firefighters who died in a building collapse, but whose lives could have been saved by the use of UWB devices in search and rescue operations.[8] UWB is one important contribution to this void, as at least eighteen fire departments and their representatives have confirmed. These comments repeatedly affirm that UWB can provide critical communications, location and tracking capabilities in fire and rescue situations. Whether victims or fire personnel are in smoke-filled or collapsed buildings, mine shafts or rural areas, the comments from fire department throughout the nation repeatedly attest to the fact that uninterrupted communication and location capability will facilitate quicker and more effective rescue operations and protect fire and rescue personnel.[9]

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[7] *See* Comments of Donn W. Hill, Fire Chief, South Dakota; James J. Schaffer, Fire Lieutenant/Paramedic, Spokane, Washington.

[8] *See* Comments of Clovis Firefighers' Association.

[9] *See*, *e.g.*, Comments of Berwyn Fire Department; City of Burbank; City of Farmington, Michigan; City of Fairlawn; Globe Fire Department; City of Helena; Irmo Fire Department; Donald Lirette, Louisiana Volunteer Firefighter; Leesburg Fire Department; Maricopa County Emergency Management Department; Claypool Fire District; Redwood City Fire Department; Sioux City, SD; Virginia Task Force One; State of West Virginia Department of Health and Human Resources; International Association of Fire Chiefs; National Volunteer Fire Council; Apple Valley Fire Protection District; Clovis

Police departments' comments from across the country echo those of the fire departments and add improved security and criminal detection and location to UWB's significant, life-saving application potential. Recalling the myriad of barricade and hostage situations they routinely confront, police teams would be empowered and safer if they could detect the location of victims and criminals behind walls and within buildings. The police departments affirm that UWB is an important life saving "tool,"[10] which provides improved communications capability and concealed weapons detection in addition to tracking and location.[11] The Department of Justice, Office of Security Technology, describes UWB as a "new direction for law enforcement surveillance."

Military applications are another area of clear public benefit. UWB is "the next generation of technological breakthrough that can provide military and public safety organizations a host of new and improved capabilities…."[12] Several of the comments note the importance of consistent and undetectable communications to covert operations, such as between in-flight aircraft, and rescue operations such as locating pilots downed in

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Firefighters' Association; Fire and Emergency Rescue, City of Fairlwn, Ohio; Plymouth (MI) Township Police Dept.

[10] *See* Comments of Town of Astatula.

[11] *See, e.g.*, Comments of Town of Astatula; Decatur Police Department; Federal Law Enforcement Wireless Users Group (FLEWUG); Groveland Police Department; Houma Police Department; City of Houston, Texas; Los Angeles County Sheriff's Office; Office of the Sheriff, County of San Mateo, California; Wakefield Police Department and Office of Law Enforcement Technology Commercialization; Plymouth Township Police Department, Plymouth, Michigan; Grand Lodge Fraternal Office of Law Enforcement Technology Commercialization; U.S. Dept. of Justice, Federal Bureau of Prisons; County of San Mateo, Office of the Sheriff; Office of Sheriff, Houma, Louisiana.

[12] *See* Comments of Ball & Associates.

enemy territory or sailors thrown overboard, as well as for improved landing capability.[13] Civilian police also noted the benefits of improved communications, including "covert radio, enabling police and special units to operate radios while maintaining 'radio silence' to avoid eavesdroppimg by unauthorized persons."[14]

Other military and civilian security applications include improved concealed weapons detection and "electronic fences," an improved intrusion detection capability which can be established quickly and which is portable as the force or ship moves from one location to another. New weapons also may be forthcoming, such as unmanned aircraft using UWB to avoid collision and to detect and intercept the enemy, such as movement in dense foliage.[15] The comments of the Office of the Assistant Secretary of the Navy affirm many of the military applications and note the ability monitor and track individuals on ships during damage control operations.

While the Commission does not regulate the use of spectrum by the Department of Defense, the Commission's regulatory decisions can have a very real effect on the development and ready availability of technology in support of our nation's defense. To the extent that non-military uses of UWB are enabled by reasonable regulations – both

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[13] *See, e.g.*, Comments of Ball & Associates; the Safety and Survivability Office, Office of the Assistant Secretary of the Navy; The Honorable Curt Weldon (PA), Chairman, Research and Development Subcommittee, Committee on Armed Services, US House of Representatives; General Roger Smith (Ret.).

[14] Comments of Fraternal Order of Police at 1.

[15] Comments of Science Applications International Corporation; Lt. Gordon E. Fornell (USAF Ret.).

commercial-off-the-shelf and government-use only equipment can evolve more efficiently and provide innovations that benefit both. By allowing non-government uses of UWB, the Commission will facilitate joint military-commercial use and product development, which in turn will spur the introduction of new devices and lower overall equipment costs.

Independent Living/Lower Health Care Costs. UWB can preserve and restore dignity to the ill and the aging. The elderly and the disabled repeatedly express their preference for independent living and their aversion to posing a burden on their families or to being placed in institutionalized care facilities. Yet, in many cases they must be institutionalized at considerable emotional suffering and expense because they cannot be monitored adequately in their own homes. The health care professionals who filed comments in this proceeding unanimously cited the liberating potential of UWB, as a remote monitoring "safety net" to track patients and provide quick responses when emergencies arise.[16]

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[16] *See, e.g.*, Comments of The Arc of Tennessee; Florida Adult Day Care Association; Iberia Parish Council on Aging; Iberia Medical Center; NAMI of Illinois; NAMI of Tennessee; Ohio Statewide Independent Living Council; Roanoke County Committee on Aging; Support and Techniques for Empowering People; Spokane WA Search and Rescue; Senior Citizens Inc.; South Dakota Coalition of Citizens with Disabilities; Singing River Hospital; Tennessee Disability Coalition; Upper East Tennessee Human Development Agency; Van Buren Community Development and Services Board; West Virginia State College; Disability Rights Education and Defense Fund, Inc. (DREDF); William E. English M.D., FAAFP; SBK Capital, LLC.

The examples of improvements in the quality of health care cited in the comments included "ICU quality monitoring for outpatients"[17] and the complete visualization of internal organs -- a far superior diagnostic tool compared to ultrasound.[18] Cost reduction possibilities go hand-in-hand with these improvements beginning with better and earlier detection and with patients living safely at home without needing 24-hour supervision or being confined to hospitals and nursing homes, and they proceed to include a wide range of improved therapeutic tools and operational efficiencies in the health care industry. Medications can be monitored remotely and accurately to prevent incorrect dosages and to determine patient reactions. Likewise, pacemakers can be monitored and adjusted without requiring a hospital visit.[19] A small inexpensive UWB device can alert nurses immediately when a patient falls or loses consciousness, and it can locate wandering Alzheimer's patients.[20] "Smart Homes" can allow the disabled to operate voice-activated lights, televisions, computers, security systems, appliances and other networked devices.[21]

Workplace Safety. Utility and construction workers will have a safer work environment when UWB applications are permitted. "Every year lives are lost due to direct contact [by utility workers] with buried utilities," observed the International

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[17] *See* Comments of The Heart Center, P.C.

[18] *See* Comments of Comprehensive Cancer Institute.

[19] *See, e.g.*, Comments of The Arc of Tennessee; Comprehensive Cancer Institute; Envoy; Florida Adult Day Care Association; The Heart Center; Thomas Cooper at 3.

[20] *See* Comments of SBK Capital, LLC; American Association of People with Disabilities (AAPD).

[21] *See* Comments of Disability Rights Education and Defense Fund, Inc. (DREDF).

Brotherhood of Electrical Workers (IBEW). The IBEW comments further noted that UWB can assist utility crews in quickly and accurately locating wires and pipes underground as well as those in building walls, and it can indicate the condition of the conduits and the level of liquids or other materials therein.[22] IPEG Corporation states that UWB can even detect buried *plastic* pipes, which had been impossible with traditional methods.[23] UWB facilitates the tasks of decommissioning nuclear facilities and removing unexploded ordnance, the combination of rapid emergency response and increased ground and container penetration.[24] The same UWB penetrating properties will protect construction workers by locating electrical wires and other in-wall hazards and by assessing the condition and location of joists and other structural elements.[25]

Automotive and Aviation Safety. UWB devices, provided on an unlicensed basis in cars and trucks, will mean a host of low cost devices for the mass market, including those that enhance automotive safety and accident prevention.[26] Safety features would include enhanced visibility in fog, darkness and other unfavorable weather conditions, as well as advanced notice of a potential obstacle or collision, automatic response systems in the case of an incident and improved impact protection. These

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[22] *See also* Comments of Endress & Hauser GmbH & Co. and Krohne America, Inc.

[23] *See* Comments of IPEG Corp.

[24] *See* Comments of Laborers International Union.

[25] *See, e.g.*, Comments of Zircon Corp.

[26] *See* Comments of Robert Bosch GmbH at 1.

applications "can and will save lives" and prevent serious personal injuries and property damage.[27]

Even where UWB seems to have sparked the greatest concerns, namely among GPS users, several comments suggest that UWB can complement GPS technology and that their combined use will increase overall performance and thus the safety of the flying public and aviation personnel. As one party observed, GPS and UWB are not "either-or" choices.[28] In the case of aviation applications, Level 3 Communications observed that UWB could augment GPS, leading to safer aircraft landings. National Safe Skies Alliance cited runway incursions which UWB could detect, as a "major threat to passengers." UWB also can provide new runway inspection devices and more effective flight support communication to supplement existing communications links.[29] Aether Wire agreed and added significantly improved on-ground aircraft and personnel tracking applications.[30] In the area of enhanced emergency location ("E-911"), Aether Wire referred to the Commission's required performance level of 100 meter accuracy in 67% of the cases and contended that this performance level does not solve the problem of

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[27] *See, e.g.*, Comments of Delphi Automotive Systems Corp. at 2; Saab Marine Electronics AB Valeo Schalter and Sensoren GmbH; Daimler Chrysler.

[28] *See* Comments of National Safe Skies Alliance.

[29] *See also* Comments of Aircraft Owners and Pilots Association at 2; Rockwell Collins, Inc.

[30] *See* Comments of Aether Wire & Location, Inc. at 15.

locating individuals in emergencies. On the other hand, "using UWB, along with the primary E-911 device, will make it possible to locate the individual to the last meter."[31]

Aviation Management Associates ("AMA") states, "Seldom, if ever, has AMA been exposed to a technology as promising as Time Modulated Ultra Wide Band (TM-UWB) to address so many critical aviation safety and efficiency concerns."[32] AMA states that TM-UWB could help prevent airline crashes by "replac[ing] hundreds of miles and thousands of pounds of aging deteriorating wiring" in use in aircraft today. TM-UWB would improve, at a lesser expense, aircraft maintenance and operations, runway safety, aircraft navigation, and travel communication and even provide entertainment services for passengers.[33]

Environmental Protection. The low-power characteristic of UWB technologies will benefit the environment. STMicroelectronics writes from Amsterdam to state that "decreasing the overall level of transmitted power of wireless systems throughout industry will contribute to the protection of the environment."[34]

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[31] *Id.* at 10. Incorporation of UWB with other technologies such as GPS equipped cell phones or teaching devices so that both can function in the same piece of equipment is within the state of the art.

[32] *See* Comments of Aviation Management Associates, Inc. at 1.

[33] *Id* at 2.

[34] Comments of STMicroelectronics.

Economic Security Through Technological Leadership

UWB is a "key enabling technology"[35] that may portend a "major paradigm shift in US industry."[36] Whether UWB technology is used to save lives, improve health care services, increase broadband access, or open new businesses and commercial opportunities, the benefits of this "innovative technological breakthrough"[37] will enhance the economy. The comments support the Commission's conclusion that this technology will create new businesses and jobs, increase efficiency, productivity and innovation, and lower costs. [38] Its spectrum efficiency attriibutes promise to mitigate the "spectrum drought" about which the Commission has expressed concern, another point which drew support as well from those otherwise opposed to proceeding with UWB authorization. [39]

In underserved areas such as schools and libraries, low income neighborhoods, and older and historic buildings, UWB will "open the power of the Internet" by creating wireless broadband "pipes" to deliver high speed Internet and other data services as well as voice communications at affordable prices.[40] It poses a "once in a generation chance

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[35] Comments of Sony Corporation.

[36] Comments of General Electric Company at 1.

[37] Comments of The Honorable Trent Lott, United States Senate.

[38] *See* Comments of Daniel Group LLC (increased business efficiency); Deutsche Bank Securities, Inc. ("major impetus to economic growth"); Frontier Capital I, LLP (broad variety of new entrepreneurial opportunities); General Electric Company (higher productivity, jobs); Staenberg Private Capital LLC (cost effective new services); Tacoma Pierce County Chamber of Commerce (help to grow the local economy).

[39] *See, e.g.*, Comments of FLEWUG; Nortel Networks; *see also* Fantasma Networks, Inc. (efficient use of scarce spectrum); Stroud Engineering Services, Inc. at 1.

[40] Comments of General Electric at 2.

to narrow the gap between bandwidth 'haves' and 'have-nots.'"[41] In many cases, school systems are forced to provide broadband capability in older buildings, and to do so through wired applications will be very expensive, and in many cases unaffordable. As the National Catholic Educational Association states, "UWB has tremendous potential for schools, allowing the fast and flexible networking of buildings at relatively low cost,"[42] a point echoed by many other commenters, including the Council of Chief State School Officers.

Because technology is developed in a global environment, some comments remind the Commission that if the U.S. fails to move rapidly and purposefully to adopt appropriate rules, it risks losing businesses to offshore locations or having offshore companies "steal the march."[43] As IAI observed, "if the U.S. does not approve UWB, other countries will, and very likely at higher levels than are currently being considered by the FCC."[44] When UWB operations are approved and developed offshore, IAI reasoned, their operation will show no harmful interference. At that point, the technology will be brought into the U.S. by foreign manufacturers, and the only effect of U.S.

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[41] *See* Comments of Fantasma Networks at 2; *see also* Comments of Virtual Education Inc.; Hewlett-Packard Co.; The Honorable Jeff Sessions, United States Senate; The Honorable Bud Cramer and The Honorable Robert Aderholt, United States House of Representatives.

[42] *See* Comments of National Catholic Educational Association (filed Oct. 7, 2000) at 1.

[43] *See, e.g.*, Comments of Thomas Cooper (failure to act in a timely manner may result in companies moving offshore); Stroud Engineering Services, Inc.; Dain Rauscher Wessels Equity Capital Markets.

[44] Comments of Intelligent Automation, Inc. (IAI) at 3.

regulatory inaction will be the lost commercial opportunities and lives which could have been saved if U.S. regulations had been modified sooner.

III. The Question for the Commission is How to Foster the Innovative and Breakthrough Nature of this Technology.

The case for this technology, for the lives it can save, and for the benefits it can bestow on the public, is compelling. The case for unlicensed service, balanced judgments, and reasonable regulation is equally compelling. The pending issue, therefore, is how quickly the Commission can act, and in doing so, apply the positive attributes of its Part 15 policy and approach to ensure that regulation does not stifle or otherwise obstruct the public benefits and innovative potential of UWB.

Real Time Applications. UWB represents the "next generation of unlicensed short range wireless technology,"[45] and much of its technological potential can be tapped right away. UWB is not a speculative technology, and the Commission should pay particular attention to the fact that many applications can begin to deliver new, better, and less expensive services for safety and commercial users as soon as the Commission's rules are modified. Many comments point to services that are being provided or are currently in development, including through government contracts or offshore licenses. Given the immediacy of many applications, clearing the regulatory obstacles to their commercial introduction in the U.S. should not be delayed.

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[45] *See* Comments of Fantasma Networks at 1.

Delphi Automotive Systems cited its automotive "Back up Aid," and comparing the U.S. version with the superior European version, noted that the latter could be provided in the U.S. when the Commission modifies its rules.[46] Advanced radar detection devices would be permitted and rapidly available from Endress + Hauser GmbH when the Commission's rules are modified.[47] Sony predicted that UWB could be incorporated into cameras, video recorders and editors "in the near future"[48] while in September 2001, OnScene plans market introduction of a firefighter tracking and communication system.[49] Kohler cites its ventilating toilet kit, which has been developed but cannot be provided without rule changes.[50] Siemens states that it is "actively working to develop products using these [UWB] technologies…."[51]

Many comments cited indoor local area networking as one of UWB's most exciting areas of innovation. For example, Fantasma Networks "has developed and intends to bring to market innovative UWB communications products for wireless networking in homes, libraries, schools and similar short-range, information-intensive network environments."[52] This is the sort of system competition that the Commission has

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[46] *See* Comments of Delphi Automotive Systems Corp. at 4.

[47] *See* Comments of Endress & Hauser GmbH & Co. at 2.

[48] *See* Comments of Sony Corp. at 1.

[49] *See* On Scene, Inc., (letter dated Aug. 3, 2000).

[50] *See* Comments of Kohler Co. at 2.

[51] *See* Comments of Siemens Corp. at 1.

[52] *See* Comments of Fantasma Networks at 1.

previously sought to generate through appropriate changes in its Part 15 rules.[53] To delay its availability would be completely inconsistent with the Commission's policies and with other comments.

The Commission repeatedly has supported multiple entry and regulatory flexibility[54] as the best means for competition to spur innovation and lower costs, and it has declined to use its regulations to pick "winners" and "losers" in the market. That policy is reiterated in this NPRM. Noro-Moseley agrees that "success in the market should be determined by the strength of ideas and technology, not regulatory hurdles."[55] while General Electric states that it is "best that the market determine the usefulness of the [UWB] technology."[56]

In fact, General Electric underscores the breakthrough potential of indoor UWB applications, while rebutting any presumption that current technology is adequate. GE observed that "reliable indoor communication is one of the largest unsolved problems in the wireless industry,"[57] citing performance shortfalls and fragmented approaches. It

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[53] *See, e.g.*, Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices, *First Report and Order*, ET Docket 99-231, August 31, 2000 ("Spread Spectrum R&O") at ¶ 10.

[54] *See, e.g.*, Revision of Part 15 of the Rules Regarding the Operation of Radio Frequency Devices Without an Individual License, *Notice of Proposed Rule Making*, GEN Docket 87-389, 2 FCC Rcd 6135 (1987). In proposing a major overhaul of FCC Part 15 rules the Commission stated that "regulatory flexibility fosters an effective competitive marketplace in … low power telecommunications."

[55] Comments, Noro-Moseley Partners.

[56] Comments of General Electric at 2.

[57] *Id*.

concludes that "ultra-wideband technology offers a unique solution"[58] and commits that "GE is poised to integrate the technology in its medical and industrial systems."[59] Lucent agrees that short-range communications is one of the primary applications of UWB,[60] while Siemens Communications Division is currently working on short-range communication systems including wireless LANS and wireless IP telephones and on dual mode mobile terminals for cordless coverage in-building.[61] Siemens underscored the need for timely Commission action, it stated that while it is actively working on these product applications, "we cannot move forward toward developing the products until we can be assured that they will meet Part 15 requirements and can be legally distributed and sold."[62] In the same vein, SAIC stated that "commercial application for this technology will be inhibited if the FCC does not act promptly" on the NPRM, concluding that "without an FCC ruling, the technology development [of UWB] will be delayed."[63]

The comments cited numerous ongoing government contracts designed to develop UWB potential applications. SAIC cited its DARPA-sponsored Self-Healing Anti-Tank Minefield program to eliminate the need for anti-personnel landmines in mixed systems as well as other military applications, including robotics. Aether Wire and Location has a DARPA contract to develop "Integrated Low Power, Ultra-Wideband Transceivers for

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[58] *Id.* at 1.

[59] *Id.* at 2.

[60] *See* Comments of Lucent Technologies, Inc. at 2.

[61] *See* Comments of Siemens Corp.

[62] *Id.* at 2.

[63] *See* Comments of SAIC.

Pervasive Internet Connectivity," while AIA is developing distance learning applications for DARPA. The Department of the Navy's 2-year investigation of ways to identify personnel overboard has shown UWB to have significant capability.

IV. UWB Technology Belongs In Part 15.

This proceeding is about how (or as some comments posit, whether) UWB will be permitted to operate in a timely and reasonable manner. If it cannot be accommodated under the Part 15 structure, it will fall short of its innovative and competitive potential, and it may fail to survive at all, aside from a few niche applications such as ground penetrating radar (GPR). TDC and many other parties contend in their comments that the case for UWB as a Part 15 technology is clear and compelling. Others disagree, and in so doing, they challenge Part 15's basic approaches to new market entry and interference measurement and protection.

Consequently, the outcome of this proceeding will affect more than whether UWB technology will fulfill its potential. This proceeding also will set precedents affecting whether future innovative technologies will be encouraged and developed. Findings herein of how to determine "harmful interference" criteria will affect future Part 15 technologies, and they can affect other spectrum management efforts as well, such as increased sharing among licensed commercial and government users. Moreover, the issue of what constitutes reasonable levels of emissions outside of defined bands confronts the Commission every time a new licensed or unlicensed service is proposed. Such "emission mask" concerns will inevitably be affected -- through not necessarily controlled -- by the Commission's considerations of UWB signal levels. In a world of

3G capacity demands, "spectrum drought" and incumbent relocation challenges, it would be particularly unfortunate to add new and unnecessary complexities to the Commission's spectrum management responsibilities.

The Commission has "gotten it right" in past Part 15 proceedings, and it should not lose sight of these decisions and the benefits that flowed therefrom. Nor should the Commission lose sight of the parallels between the "doomsday" arguments made in those proceedings and the ones made herein. Those earlier arguments were determined by the Commission to be excessive, and experience has shown that the Commission's rejection of those arguments was correct. The same skepticism and adherence to sound engineering analysis of real-world conditions should be applied in this proceeding.

TDC responds in two ways to the comments seeking licensing or other extraordinary regulatory burdens for UWB as well as lengthy and costly[64] further tests. First, because these proposals challenge the core of the Part 15 pragmatic approach, TDC will highlight Part 15's successful history and the similarities of earlier decisions to the present situation. Second, TDC will address specific proposals for regulating or forestalling UWB services.

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[64] *See* Ex Parte Comments, U.S. GPS Industry Council, Sept. 29, 2000 ("Each UWB waveform must be independently tested", and the amount of time and cost required are "large" and "unknown").

Part 15 Strikes a Pragmatic Balance Between Fostering New Technology and Protecting Against Harmful Interference.

Part 15 is a success story. It is a regulatory success because it has protected licensed operations from harmful interference by unlicensed Part 15 devices. It is a deregulatory success because it has fostered new and innovative technologies that could not have survived under the traditional, individual licensing regime. The Commission has shown that these two goals are not mutually exclusive, but can coexist, making the public the ultimate winner.

Over its 50-year evolution, Part 15 has spawned the development and market entry of countless new and innovative products. It has spurred competition, and it has lowered consumer costs while opening for them new security convenience, leisure, learning and business options.

From cordless phones and baby monitors, home security systems, personal computers, wireless modems, garage door openers to even hair dryers, Part 15 devices and other products that emit radio "noise" are part of our every day lives. There are over 100 devices capable of emitting RF energy in the average home. As the Commission has reported, "at any time of day most people are within a few meters of consumer products that use low-power, non-licensed transmitters"[65] and digital devices,[66] all of which emit radio "noise" into the environment.[67]

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[65] *See* Understanding the FCC Regulations for Low-Power, Non-Licensed Transmitters at 1, OET Bulletin No. 63, edited and reprinted Feb. 1996.

Today, billions of devices emit radio noise, either intentionally or unintentionally, into the environment with minimal interference impact, which demonstrates that the interference assessments and protections in Part 15 work. Part 15 takes a pragmatic approach to frequency coordination and interference protection. In prior decisions, the Commission set out its obligation to "balance competing goals," namely eliminating unnecessary regulatory barriers to new equipment while maintaining adequate interference protections.[68] The continued successful, interference-free environment for licensed services despite the overlapping operation of countless Part 15 devices shows that the Commission has succeeded in protecting against harmful interference.

Prior Commission decisions also affirm the important role Part 15 has played in fostering new and innovative technologies.[69] Many of the billions of devices now in operation would not have been economically viable if Part 15 did not exist and, instead, each device needed an individual license. How viable and cost effective would it be, for example, if each new car owner had to obtain an FCC license before operating the car's

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[66] *See* Understanding the FCC Regulations for Computers and Other Digital Devices at 2, OET Bulletin No. 62, edited and reprinted Feb. 1996.

[67] In addition, multiple millions of non-communications devices such as microwave ovens emit energy as RF noise on an unlicensed basis pursuant to Part 18 of the Commission's Rules.

[68] *See* Revision of Part 15 of the Rules Regarding the Operation of Radio Frequency Devices Without an Individual License, *First Report and Order* ("Part 15 Revision R&O"), 4 FCC Rcd 3493, at ¶¶ 13, 150 (1989).

[69] *See Id.* at ¶ 8; Spread Spectrum R&O at ¶ 21 (changing Part 15 rules to permit spread spectrum devices would increase product diversification and yield greater design flexibility and networking approaches).

keyless entry device? The success story of Part 15 for regulating unlicensed consumer equipment stands in stark contrast to "the majority of tightly structured Rule Parts which govern the individually licensed radio services…."[70] UWB devices largely fall into this category of mass-market devices, the individual licensing of which would be impractical and would chill its commercial success.[71]

Part 15 rules have evolved and have been modified periodically to recognize new technologies and improvements in technology that have permitted further openness and while maintaining protection against harmful interference. The Commission has viewed these rules as operating in a dynamic technological environment, and accordingly it has adapted its rules as innovations and new spectrum uses arise. The economy and the public have been the beneficiaries of this flexibility, in the form of technological advances, better and more efficient devices, increased competition and lower prices. In 1989, for example, the Commission made a fundamental and liberating change by adding to the existing incremental, device-specific authorization process, a set of technical regulations available to all technologies of that period without regard to product application. It rightly found that its original approach had resulted in an "overly complex and . . . unnecessarily restrictive" body of rules.[72] Having adapted to new technologies and devices by modifying its rules on numerous occasions, the Commission recently

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[70] Petition of TRICO 11-Meter Radio Club to Amend Part 15 to prohibit the Use of Low Power Communications Devices for Diversion, Entertainment or the Airing of Obscenities, *Memorandum Opinion and Order*, 32 FCC 2d 495 (1971).

[71] *See, e.g.*, Comments of Delphi Automotive.

[72] Part 15 Revision R&O, *supra*, at ¶ 4.

reiterated the need, as technology evolves, to "amend our rules … so that innovation is not discouraged."[73]

The instant proceeding presents the next opportunity for the Commission to recognize the innovation potential of a new technology and to adapt its rules, once again, to embrace the opportunities inherent therein. The alternative, proposed by some comments, would be a return to the pre-1989 "complex and restrictive" device-specific authorizations. As the Commission found in 1989 and has endorsed thereafter, such an archaic approach is tantamount to stifling the innovation and competitive potential of the technology. The practical effect of such rules would be to stifle UWB technology and impose regulatory costs that would affect product marketability.[74] For this reason alone, such approaches should be rejected.

Similarly, the Commission has been presented with extreme hypothetical interference scenarios in prior Part 15 proceedings. The Commission has always approached these types of concerns pragmatically, as has characterized its overall Part 15 inquiry. For example, in addressing its spread spectrum rules earlier this year, the Commission rejected challenges based on the possibility of large numbers of devices co-located and contemporaneously operating. The Commission found that while such a situation could occur, it was not likely "in practice,"[75] based upon an assessment of how

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[73] Spread Spectrum R&O, *supra*, at ¶ 16.

[74] *See* Comments of Endress + Hauser (individual licensing is unnecessary and would impose regulatory costs on products); Siemens Corp. (unlicensed operation would facilitate and accelerate marketability).

[75] Spread Spectrum R&O, *supra*, at ¶ 13.

the devices would be used and by whom, as well as factors which would mitigate interference. The same arguments are being made in the instant proceeding, and they should be addressed in the same "real-world" manner as the Commission has used previously.

The Commission also has addressed concerns raised in earlier proceedings that Part 15 does not provide sufficient regulatory authority over unlicensed devices. Again, in the spread spectrum decision the Commission summarized the authority it has and the rules to which Part 15 devices must adhere. First, as the rules and all the literature make clear, Part 15 devices do not have any protections from interference and must accept any and all interference from others.[76] In addition, they cannot cause interference to others, even if they are in compliance with Part 15 rules, and in many cases must carry a label stating this situation as well as the operator's obligation to stop operations if interference is caused to licensed operations. Commission rules require strict adherence to the authorization and certification procedures, and the Commission has extensive enforcement authority including assessment of substantial civil and criminal penalties. These rules and the Commission's Part 15 track record provide ample rebuttal to opponents' concerns. When the Commission authorizes UWB deployment and establishes its rules therefor, it will continue to have sufficient authority to enforce those

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[76] *See, e.g.*, Spread Spectrum R&O, *supra*, at ¶ 14.

rules to maintain compliance of UWB equipment and prevent UWB operations that cause harmful interference.[77]

The Part 15 Limits Should Be Applied to UWB Equipment.

In this rulemaking proceeding it is of utmost importance to keep in mind that UWB equipment uses extraordinarily low power levels to provide new and useful communications and radar applications. When the Commission was first developing the Part 15 regulations in the 1950's, the agency was faced with an interference problem caused by a category of unintentional radiators known as receivers. The local oscillator energy being radiated from the antenna of receivers was causing unacceptable interference to other radio services and to the service it was designed to receive. The Commission established Part 15 as the proper place to regulate the unwanted radiations from "radio receivers and a wide array of electronic equipment that has become an integral part of our daily life."[78] Levels and limits for receivers were adopted subsequently to prevent those devices from generating what was termed "harmful interference."[79] During the 1970s, the Commission adopted regulatory provisions for low

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[77] *See* Ex Parte filing, U.S. GPS Industry Council, Sept. 29, 2000; *see also* Comments of Wireless Communications Association International, Inc.

[78] *See* Amendment of Part 15of the FCC Rules Governing Restricted Radiation Devices, *First Report and Order*, 13 RR 1543 (1955).

[79] *See id* at 1545.

power transmitters (intentional radiators) that placed maximum limits on these devices preventing them from causing harmful interference to existing radio services.[80]

Then, in late 1979 and the early 1980s, the FCC implemented rules for a new emerging technology known as digital devices.[81] These digital devices exhibited broadband emission characteristics. In particular, they radiated discrete spectral lines from their clock frequencies and wider band emissions from the high-speed switching of their microprocessors. Emissions from these devices range from a narrow band of frequencies to bandwidths of several hundred megahertz. The limits adopted in that proceeding and subsequent "digital device" proceedings were developed with the expectation and knowledge that digital technology would proliferate into the millions and now billions of devices that are commonplace today. Although the environment contains all of these devices, their existence, is hardly noticed from an interference standpoint.

The limits adopted for digital devices were divided into Class A (commercial device) limits and Class B (consumer device) limits. The Class A limits are about 10 dB higher than Class B limits. This relaxation was deemed appropriate, because the harmful interference potential from Class A equipment was perceived to be smaller because such

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[80] *See* Amendment of Rules Part 15 Subpart E--Low Power Communication Devices--to Delete the Frequency Band 26.97-27.27 MHz, to Add the Frequency Band 49.8-49.9 MHz and to Promulgate Technical Specifications, *Report and Order*, 57 FCC 2d 1134 (1976).

[81] *See* Amendment of Part 15 to Redefine and Clarify the Rules Governing Restricted Radiation Devices and Low Power Communication Devices, *First Report and Order*, 79 FCC 2d 28 (1979) *and revised by* Amendment of Part 15 to Redefine and Clarify the Rules Governing Restricted Radiation Devices and Low Power Communication Devices, *Order Granting in Part Reconsideration of First Report*, 79 FCC 2d 67 (1980).

equipment would be located in industrial and commercial environments where existing ambient noise levels were already relatively high and they would be farther away from victim receivers.

In 1989, the Commission adopted a major revision of Part 15.[82] In that proceeding, among other things, the Commission adopted new provisions for intentional radiators, now set forth in Section 15.209. This new rule section was based on the existing Class B limits for unintentional radiators and included the requirement that the fundamental and out-of-band emissions may not fall within the restricted bands.[83]

Further, and most importantly, in almost every other category of intentional radiator regulated under Part 15 in the 1989 rulemaking and subsequent rulemakings, the Commission adopted a provision stipulating that spurious emissions, and in some cases out-of-band emissions, do not require attenuation below the general 15.209 limits. Thus, essentially all devices regulated by Part 15 (*e.g.*, receivers, computers, peripherals, telephones, TV interface devices, cable converters, carrier current systems, security transmitters, garage door opener transmitters, cordless phones, unlicensed personal communications devices, U-NII devices, etc.) can radiate all or some portion of their emissions throughout the regulated spectrum, including the restricted bands, at levels equivalent to the Section 15.209 levels. These levels effectively establish a floor below which Part 15 devices are not required to suppress their emissions. Conservatively

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[82] *See* Revision of Part 15 of the Rules Regarding the Operation of Radio Frequency Devices Without an Individual License, GEN Docket No. 87-389, *First Report and Order*, 4 FCC Rcd 3493 (1989).

speaking roughly 3 billion Part 15 devices are in operation in residential environments at any given time[84] with scant interference impacts.

Added to this number are many digital devices that have been exempted from technical compliance with the emissions limits and are allowed to emit radio energy in excess of the Part 15 limits.[85] This exemption applies, for example, to digital devices used exclusively in: (1) a transportation vehicle including aircraft and motor vehicles; (2) an electronic control or power system used by a public utility or in an industrial plant; (3) a digital device used exclusively as industrial, commercial, or medical test equipment; (4) a digital device that is part of an appliance; and (5) specialized medical digital devices generally used under the supervision of a licensed health care practitioner whether in a home or health care facility.

Combining these exempted devices with the higher level Class A industrial devices and the 3 billion Class B residential devices, there are well over 5 billion electronic devices in operation within the continental U.S. and they are having no appreciable impact on licensed operations.[86] Further, many of these devices are

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[83] *See* 47 C.F.R. § 15.205.

[84] A typical home has over 100 digital devices, approximately 25 to 30 percent of which are in operation at any one time. With approximately 100 million U.S. households, this means that about 3 billion devices nationwide are operating at any given time.

[85] *See* 47 C.F.R. § 15.103.

[86] This is not to ignore the fact that interference occurs. When licensees fail to follow FCC Rules, the result can be interference. When licensees at complex multi-user sites fail to cooperate and employ good engineering practices, interference can result. Similarly, users can experience interference if they fail to follow manufacturers'

permitted to radiate at levels well beyond the levels TDC and others are asking the Commission to authorize for UWB technology.

The Commission handled many of the same issues in the digital device proceeding that it currently faces with the emerging UWB technology. In the digital device rulemaking, proponents urged that any adopted limits should reflect limits that were necessary to prevent harmful interference while permitting maximum flexibility to the technology. Opponents expressed concern over the potential for interference to existing services and suggested limits equivalent to the old ("pre-1989") Section 15.7 requirement.[87] The Commission recognized the validity of the test program instituted by a proponent of digital technology, CBEMA, an organization of manufacturers of computing devices,[88] and adopted the provisions developed by that test program. The intervening years have proven that the Commission acted appropriately because the industry has flourished with few, if any, instances of harmful interference caused by digital devices compliant with the provisions of Part 15.

In addition to billions of operational Part 15 unlicensed intentional and unintentional radiators, there are countless numbers of unregulated incidental radiators. Incidental radiators do not intentionally generate radio energy, but do so by virtue of their

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instructions. These situations contrast greatly with the everyday operational experience of compliant Part 15 devices. *See also*, NPRM ¶32.

[87] The old general limit was 15 μV/m at a distance equal to the wavelength divided by 2π.

[88] In December 1994, CBEMA, the Computer and Business Equipment Manufacturers Association, changed its name to the Information Technology Industries Council (ITI).

operation. Incidental radiators include electric razors, drills, saws, fluorescent lights, neon lights, gasoline engine ignition systems including automobile and truck ignition systems, hair dryers and any motor using carbon brush contact rotating commutator technology. Each of these devices can radiate at levels greatly in excess of Part 15 limits. Emissions from this additional category of devices are characterized by extremely high, short duration random energy pulses producing emissions across a bandwidth equivalent to that produced by many UWB devices, but with pulse repetition rates that are typically lower than most UWB devices. The number of intentional, unintentional and incidental radiators is certainly not shrinking.[89] Nevertheless, the Part 15 general limits have proven to be quite effective overall at limiting radio noise without stifling innovations.

Opponents of UWB technology have made claims that UWB will create interference to existing radio services. They try to distinguish between UWB devices and other Part 15 devices by citing the nature of the UWB impulse technology that generates spectral components across a very wide bandwidth. They also cite differences with existing technologies that generate narrowband and broadband noise (as distinguished from ultra-wideband noise) such as computing devices and other Part 15 devices. Moreover, they treat UWB devices as one ubiquitous source, that is, that each and every UWB device will generate noise across the entire regulated spectrum at the maximum permitted level.

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[89] It is curious then, why some commenters are now designing systems that are not less, but more susceptible to radio noise. *See* Comments of Motorola, Inc. at 2-3; Sprint PCS Supplemental Comments at 14-16.

Nothing could be further from the truth. TDC has previously shown that each particular product application dictates the radiation characteristics of the UWB device.[90] For example, ground penetrating radar systems typically generate spectral content below 1 GHz, through wall radar systems radiate in the 1 to 3 GHz band, and the stud finder sensor granted a waiver by the Commission operates at levels approximately 20 dB below the limit. In short, just as narrowband technologies adapt their operating parameters to fulfill the requirements for a specific product application, so will UWB technology.

These same opponents' arguments fail to acknowledge the existing ambient noise signals that are in their specific frequency band of interest. For example, one analysis concluded that UWB would preclude operation in the 2.4 to 2.485 GHz band.[91] Yet that analysis failed to recognize the existence of higher power Part 15 transmitters[92] and microwave ovens that are already authorized to operate in that band. Another analysis, that presented a model based on a generic receiver concept using a specific licensed service system, failed to address interference in their model as a signal to noise ratio, which is the determining factor for deployment and design of that system.[93] Neither did it recognize the existence of existing ambient levels of noise from the previously identified sources.

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[90] *See* Comments of TDC at 10-20.

[91] *See* Comments of National Association for Amateur Radio (ARRL).

[92] *See* 47 C.F.R. § 15.247.

[93] *See* Comments of Motorola, Inc.

Given the Commission's prior decisions and its statements in the instant NPRM, TDC is encouraged that the Commission will not forego the current capabilities and future promise of UWB technology based on unverified claims of harmful interference. Harmful interference is the result of interfering signals in the passband of a victim receiver causing unacceptable operation of the victim receiver. It makes no difference in the overall sense whether that emission is emanating from a UWB device, another Part 15 regulated device, or from an unregulated source. The Commission's experience shows that the general Part 15 limits, which were based on the digital device limits, have worked extremely well in preventing harmful interference.

V. TDC Reply to NPRM Technical Comments

Applications and General Characteristics

Some of the comments submitted demonstrate that there are still many misconceptions about UWB technology. One comment[94] discussed the spectral characteristics of UWB signals in a manner that implied that all UWB approaches using high pulse repetition frequencies would produce high power spectral lines – and therefore significant interference – with an analysis that assumed that the radiated UWB waveform contained a DC component. A more accurate analysis (provided in Appendix B to this Reply) shows that transmitters with perfect clocks and without random non-periodic modulation of some sort have power spectral densities that are composed of components at discrete frequencies (*i.e.*, spectrum lines). Even radios controlled by pseudo-random

finite-state machines (*e.g.*, direct sequence spread spectrum devices) have this characteristic. Moreover, as shown in Appendix B, it is possible to noise code the UWB signal such that radiated signals have a random spectral characteristic. Thus, there is no basis for arguing on the basis of theoretical spectral characteristics that UWB systems using high pulse repetition frequencies and noise coding will cause harmful interference.

Another misconception presented in this submission was that UWB antennas were susceptible to significant changes in both frequency and bandwidth with accidental changes[95]. The argument asserted that this "susceptibility" means that UWB systems with very large bandwidths could not be trusted to remain in compliance with the FCC's rules. As explained in Appendix D, well-designed and properly implemented UWB systems will have stable characteristics, just like narrowband systems do. Thus, absent malicious tampering,[96] damage to, or a failure in a UWB transmitter, the output characteristics will not somehow change to be out of compliance with its initial certification. The same is true with narrowband transmitters.

Regulatory Treatment

Authorization of UWB on a Part 15 basis would be consistent with low power applications and the Commission's statutory obligation to foster the development of

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[94] *See* Comments of Multispectral Solutions, Inc. ("MSSI") at 19.

[95] MSSI at 3-9.

[96] Representatives of the U.S. GPS Industry Council have even suggested (US GPS IC Ex Parte presentation of Sept. 29, 2000) that UWB devices might be deliberately converted into GPS jammers. TDC finds it ludicrous to think that someone would try to

beneficial new technologies. In considering the regulatory structure for UWB within the confines of Part 15, the Commission should recognize that a regulatory framework based on the Part 15 general limits would mandate emissions limits lower than the out-of-band limits imposed on most licensed services, including services with large user bases.[97]

Calls in the opening comments to handle UWB on a licensed basis appear to be designed to engender regulatory delay.[98] While there will remain a legitimate role for experimental licenses to foster UWB development, Part 15 remains the realistic way to introduce some UWB operations for the benefit of the public overall . UWB presents challenges, but not insurmountable obstacles. The FCC should move forward with adoption of a first report and order.

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modify devices with microwatts of RF output power given the simplicity of creating multiwatt narrowband noisemakers within the GPS band.

[97] As discussed, *supra*, TDC submits that the Commission should utilize for UWB emissions levels that are consistent with the general Part 15 limits. TDC notes that the Commission has rejected calls for the suppression of emissions in the GPS bands by more than –70 dBW/MHz, a limit that is slightly less severe than the Part 15 general limits. *See* The Development of Operational, Technical and Spectrum Requirements For Meeting Federal, State and Local Public Safety Agency Communication Requirements Through the Year 2010, Establishment of Rules and Requirements for Priority Access Service, WT Docket No. 99-86, *Third Memorandum Opinion and Order and Third Report and Order*, FCC 00-348 (rel. October 10, 2000) at ¶ 70; Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168, *Memorandum Opinion and Order and Further Notice of Proposed Rulemaking*, FCC 00-224 (rel. June 30, 2000) at ¶ 30; Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions to Part 27 of the Commission's Rules, WT Docket No. 99-168, *First Report and Order*, 15 FCC Rcd 476, 524 (2000); AirTouch Satellite Services US, Inc.; Application for Blanket Authorization to Construct and Operate up to 500,000 Mobile Satellite Earth Terminals Through the GLOBALSTAR Mobile Satellite System, 14 FCC Rcd 17328 (1999).

[98] *See, e.g.*, Comments of Aeronautical Radio, Inc., Air Transport Association of America.

The critical issue in this rulemaking proceeding is whether the Commission should forego the current capabilities and future promise of UWB technology based on unverified claims that it will create harmful interference. As previously stated, harmful interference is the result of interfering signals in the passband of a victim receiver causing unacceptable operation of the victim receiver. It makes no difference in the overall sense whether that emission is emanating from a UWB device, another Part 15 regulated device, or from an unregulated source. The Commission's experience shows that devices complying with the limits in Section 15.209 for intentional radiators and its counterpart Section 15.109 for unintentional radiators have worked extremely well in preventing harmful interference. The Commission should follow the same general approach in authorizing UWB.

Definition

In its opening comments, TDC advocated a definition based on the *fractional bandwidth* of pulsed systems because this is the one factor that most closely correlates with the beneficial features of UWB.[99] The comments offered the Commission a variety of other proposed considerations designed to encompass a wide variety of modulations. Clearly, the Commission must make a choice. While a more wide-ranging definition would appear to authorize a greater variety of technologies, the Commission should evaluate non-pulsed systems from the standpoint of whether the likely benefits to flow from flexibility in the definition of UWB brings with it operating characteristics

sufficiently akin to those of the UWB systems the Commission has studied to warrant inclusion at this time in the rules. More limited bandwidth systems could, in many cases, be authorized under the existing rules. Thus, the issue revolves around the extent to which the Commission can conclude that it understands the characteristics of non-pulsed UWB technologies or those with less than 20% fractional bandwidth sufficiently that the authorization of such devices at this point in time would serve the public interest.

Frequency Bands of Operation

As was learned during the FCC UWB NOI, there is almost an unending list of applications for UWB technologies above 1 GHz. Now, Aether Wire and Location has added to the list by identifying potential non-ground penetrating radar UWB applications below 1 GHz. Thus, the possible bands of operation of UWB devices span from nearly VHF up to millimeter wave frequencies. This broad applicability of UWB makes it difficult to identify a single band within which to allow the initial operation of UWB devices. The difficulty is compounded by the fact that existing spectrum users, while hailing the potential of UWB technology, are saying "not in my backyard." What these incumbent users fail to recognize is that even if the Commission does not define regulations allowing UWB devices to be designed and marketed in the U.S., the level of radio energy that the FCC already allows within the bands of these current radio services will still be present. There are billions of Part 15 devices in operation that can emit signals at the same or greater levels proposed by the Commission for UWB. Indeed,

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[99] *See* Comments of TDC at 21-24.

cellular, PCS, MMDS and DARS equipment, for example, can place and does place spurious emissions[100] into the restricted bands at the same levels as Part 15 unintentional radiators.

Unfortunately, today's regulations do not define what constitutes "not having emissions within a band" for UWB emissions. Thus, comments stating the UWB emissions should be above some given frequency[101], do not fully understand the issue. If UWB emissions are not to "be within a band," the question should be: To what level must UWB emissions be attenuated?

GPS

As part of its internal process of evaluating susceptibility of various systems to UWB signals, TDC has conducted tests of GPS and UWB as well as 1.9 GHz CDMA PCS and UWB. Throughout our experimentation, TDC has seen no evidence to suggest that UWB devices should not be approved at Part 15 levels. TDC will study the results from the various GPS testing and analyses currently underway.

PCS

TDC has conducted sufficient testing and analysis of the interaction between PCS and UWB to conclude that the existing Part 15 levels are adequate to ensure no significant risk of harmful interference will result from the fielding of UWB systems

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[100] Spurious emissions include signal harmonies, *i.e.*, signals that are multiples of the fundamental frequency.

[101] *See e.g.* Comments of ARRL at 16.

operating at Part 15 power levels -- a level that is already authorized under existing FCC regulations since the PCS band is not a restricted band.

TDC has been working with Sprint PCS to develop an understanding of nature of the interaction between TM-UWB and a 1.9 GHz CDMA PCS ("CDMA") system and to account for the interactions under a wide variety of situations.[102] The Telcordia model submitted jointly by TDC and Sprint PCS on September 12th is an excellent theoretical analysis of the interaction between a 1.9 GHz CDMA PCS system and TM-UWB emissions. However, results from real-world tests differed dramatically from the model's predictions. The reason for this difference appears to be that many real world noise sources are always present to a varying extent and combine to limit the impact of TM-UWB on CDMA communications.

Crucial findings of this work on which both Sprint and TDC agree were that:

1. For a Time Modulated UWB emitter with a PRF greater than the bandwidth of the CDMA channel, the UWB signal could be accurately modeled as Additive White Gaussian Noise (AWGN). Because of the wide knowledge base with regard to AWGN, the impact of TM-UWB emissions in this regard are already well characterized;
2. The model predicts blocking when the CDMA received signal strength is -95 dBm and the handset is within 1.5 meters of a continuously transmitting UWB device.
3. When operating in an anechoic chamber, the test results conform to the model's predictions; and

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[102] *See* Joint Comments of Sprint PCS and TDC (submitting the model developed with the assistance of Telcordia).

4. UWB emissions are unlikely to have an impact on the reverse link when the base station has an outdoor elevated antenna, *i.e.*, that the CDMA base station receiver will not be affected by UWB emissions.

TDC differs from Sprint on the following points:

1. The claim that CDMA signal levels below –95 dBm are sufficiently reliable to constitute a useful coverage area;
2. The claim that UWB causes loss of cell capacity;
3. The assumption in the model that all UWB transmitters emit UWB signals continuously; and
4. The claim that an aggregation of TM-UWB units will significantly increase the probability of harmful interference.

As discussed in Appendix A, testing and analysis show that there would be a low probability of UWB signals interfering with 1.9 GHz CDMA PCS systems. At the outset of TDC's joint testing with Sprint PCS, there was a concern that UWB signals might either cause call blocking or cause the system to direct additional power to handsets in near proximity to a UWB emitter at the expense of other handsets (*i.e.*, "power pumping"). Additionally, Sprint has expressed concern about the aggregate effects of UWB emitters.

The model predicts that when an operating UWB transmitter is within 1.5 meters of a CDMA handset it may cause call blocking but only if the received PCS signal strength is less than –95 dBm. In practice, UWB *will not be the primary* cause of blocking. Other real-world factors (*e.g.*, Rayleigh fading, path blockages, and other nearby PCS users) are usually the dominant sources of noise. For example, the anechoic

chamber tests demonstrated that the frame error rate should not exceed 2% until the received signal strength is nearly at the minimum sensitivity levels of the handset (-105 dBm) with no UWB signal present. However, RF design experience suggests that any model that does not consider Rayleigh fading will dramatically overstate real-world performance; one need only watch a cellphone's signal strength readings fluctuate even when one is not moving to get a rough sense of the impact of the real-world.

In nearly any environment where UWB signals will be encountered, most especially indoors where there is a lot of clutter, Rayleigh fading will be the dominant factor in the link budget. If the received signal is at the minimum sensitivity of the handset of –105 dBm, then there is no margin for a Rayleigh fade. The model used by Sprint unrealistically assumes that a –105 dBm level represents an adequate received power level for service. In fact, using a standard Rayleigh fading model, this –105 dBm link will be less than -105 dBm about 63% of the time, *i.e*, the standard Rayleigh fading model suggests the link is probably down 63% of the time. Such a link cannot be expected to provide quality service, given the 2% frame error rate criterion. Rayleigh fades and other sources of noise are sufficiently common that the threshold for evaluation should be at a minimum –95 dBm. At this level, a Part 15 TM-UWB device should not have a significant impact unless it is less than 1.5 meters away from the CDMA handset, and probably closer than 1 meter.

A further refinement of a model of the interaction between 1.9 GHz CDMA PCS and UWB incorporates a model of UWB emissions activity. The most likely high volume in-building communications application of UWB technology is as a wireless

local area network (WLAN) or wireless personal area network (WPAN). WLANs and WPANs are packet radios, *i.e.*, they transmit short bursts of data and are then silent. A UWB transmitter can only cause interference when transmitting. Based on an analysis of traffic on an Ethernet network, it would appear that the duty cycle of a WLAN is relatively low -- perhap less than 0.1% of the time.[103] This, of course, significantly reduces the probability of there being any detectable impact on PCS from UWB devices.

In addition, the UWB propagation channel could also be considered as "blockage," and Rayleigh fading of the emitted UWB signal would also tend to significantly reduce the impact of UWB emissions. While some might argue that at the short ranges at which UWB becomes a factor, the propagation path could be modeled as free space, in reality, in many indoors environments significant clutter will block or reflect signals – and therefore lessen the UWB signal strength – even when separation distances are on the order of a meter.

Other Systems, Including MMDS and SDARS

Appendix E clarifies and corrects a model submitted by Motorola during the NPRM comments period.[104] This model did not take into account the impacts of the propagation channel, and demonstrates once again, that a simple link budget equation will grossly overestimate the impact of UWB and the performance of a system even without the presence of UWB emissions.

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[103] *See* Appendix A.

[104] *See* Comments of Motorola.

Sirius, a satellite digital audio broadcaster, also commented that UWB might interfere with their service by stating that propagation losses are only 1.2 dB higher at 2.3 GHz than at 2 GHz.[105] No doubt a simple link budget equation would show this potential, but given that both XM and Sirius are authorized to augment their satellite transmitters with terrestrial transmitters,[106] it appears that shadowing and fading are their real problem.

TDC believes that the interference concerns regarding MMDS systems are overtstated. Fading and other noise sources must be considered when developing an interference model as should the expected usage characteristics of UWB devices.

UWB Antenna and Design Issues

In narrowband systems, it has been long recognized that changing the loading on an antenna can pull the system off frequency if the system is not designed properly. One comment[107] implies there is something mysterious about UWB system engineering and construction; that the structure of UWB antenna design does not allow for repeatable, stable performance, that these differences can result in UWB systems spontaneously

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[105] *See* Comments of Sirius Satellite Radio Inc. at 14.

[106] *See CD Radio Promises Data and Audio Listening Relief*, MICROWAVE JOURNAL, Oct. 2000, at 22-42. The article states that XM is planning to field 1500 2 kW (or greater) terrestrial repeaters.

[107] *See* comments of MSSI at 3-8.

changing their frequency bands of operation and emitted field strength. This comment suggests that only a particular UWB implementation should be allowed.[108]

As discussed in Appendix D, standard engineering practices ensure that this does not happen in properly designed and manufactured UWB systems any more than it occurs in properly designed narrowband systems. Time Domain's antennas have predictable and stable performance. Moreover, UWB systems can be designed to make modifying or improper replacement of the antenna as difficult as it can be for narrowband systems.

Part 15 already contains a requirement that only antennas furnished with the transmitting device shall be used.[109] This is accomplished by requiring a permanently attached antenna or one that connects via a unique coupling. UWB equipment can simply be required to comply with this regulation, as would be the case under existing Part 15 regulations.

Further Testing and Analyses

If the Commission were to entertain all of the calls for further testing made in the comments, UWB would do well to emerge as a technology of the Twenty-second Century instead of the Twenty-first. Studying a matter *ad infinitum* stands out as a tactic long recognized in Washington as a means to an end -- a dead end. The Commission

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[108] Additionally, the impact of nearby objects on the radiated field should be recognized for what it is: using nearby objects create directionality. By putting a reflecting plate a quarter wavelength away from the antenna of a cordless telephone, the field strength in one direction can be increase by approximately 6 dB; but in another direction the field strength decreases.

[109] *See* 47 C.F.R. Section 15.203

correctly asked for testing on the degree of interaction between UWB signals and those of GPS. While TDC expects that parties will draw somewhat conflicting conclusions from the three known GPS testing programs, the Commission will at least have the benefit of these efforts as it considers the key issue of the degree to which UWB emissions should be suppressed below the general Part 15 limits within the GPS bands. Time Domain looks forward to submitting comments and replies in response to the test data filed in this proceeding, but urges the Commission not to become enamored with calls to test every conceivable implementation of UWB with all existing – and even future – wireless communications systems. Such an approach has not been used before in the implementation of new technologies and services.[110] To do so would effectively halt development of new technology. While some testing is prudent, testing should not be used as a tool for delay.

The Interdepartmental Radio Advisory Committee (IRAC) representatives from the Army, Navy, and Air Force have raised questions concerning the protection of important federal systems.[111] While acknowledging that UWB has many beneficial defense applications, the IRAC representatives urged that any FCC decision concerning UWB emissions limits and operating spectrum be based on "credible analysis and measurements" and that the Commission not simply base its decisions on "historical antidotes and comparisons with unintentional radiators."[112] Unlike some of the

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[110] The same approach as applied to the development of digital technology would have set back the information revolution for years.

[111] Hereinafter, "DoD IRAC Rep Comments."

[112] *Id.* at 5.

comments, the DoD IRAC representatives do not appear to be calling for testing *ad infinitum*.

Obviously, the Commission has encouraged testing efforts.[113] Several are underway. A large amount of data has already been made available.[114] Additional data and analysis will be forthcoming. NTIA has undertaken testing of both GPS and other critical federal systems. Even though TDC has expressed some concerns with the procedures and analytical scenarios associated with these tests, NTIA is to be commended for undertaking this work and for facilitating an open process in seeking input.[115] The results and the comments on the data and analysis should assist both NTIA and the Commission as these agencies work through the issues associated with UWB. The Commission will not only have the assistance of UWB testing efforts, it also has the benefit of its own experience with nearly five decades of evolving operations under Part 15, including more than twenty years of experience with comparatively low level broadband digital emissions. Congress created expert agencies such as the FCC to bring their institutional knowledge and problem solving skills to seemingly complex technical issues. As such, the FCC cannot ignore the overall history of Part 15 as a success story in

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[113] NPRM at ¶¶ 31 - 33.

[114] Ex Parte Presentation of Miguel Cardoza on behalf of Applied Research Laboratories: The University of Texas at Austin, October9, 2000.

[115] TDC has provided comments to NTIA and the Department of Transportation urging that the test plans reflect real world applications of GPS.

making publicly beneficial use of spectrum while reducing the potential for harmful interference.[116]

With regard to the specific analysis set forth in the DoD IRAC Rep Comments, TDC submits that the analysis need not preclude authorization of UWB emissions that fall within the band 2200–2290 MHz at the general radiated emissions limits equal to those now set forth in Section 15.109 and applicable to literally billions of devices. In its airborne radar example of a system operating at 10,000 feet from a tethered balloon, the commenters note that the analysis does not include several mitigation factors including terrain, foliage, antenna discrimination and building attenuation. The example also posits UWB devices radiating outside of automobiles at signal levels equal to the general Part 15 limits in the 2200–2290 MHz band. The analysis assumes, incorrectly, that UWB devices used for automobile collision avoidance would likely place emissions at the general limit in this band. To the contrary, automotive sensors are likely to be centered well above this band, so emissions will not be at the limit in this band. In order to obtain the requisite discrimination and resolution of the radar's target, such systems are likely to operate with nominal center frequencies of 8 GHz or greater.[117] Accordingly, emissions in the 2200–2290 MHz from such systems would be attenuated at least 8 dB below the general limits even without filtering.[118]

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[116] *See* Section IV, *supra*, at 19-33.

[117] *See* TDC Comments at 11-18.

[118] *Id.* at 18.

Even with respect to the small S-band terminal, the preliminary analysis assumes what is essentially free space propagation over many tens of meters in a cluttered urban environment, which is far from a realistic assumption.[119] Nevertheless, the DoD IRAC representatives cannot be faulted for raising the question of compatibility for to do so is their duty. In the same vein, however, the Commission must assess realistic operating scenarios for both UWB and licensed services entitled to protection from harmful interference. Thus, not every interaction, nor every perceptible effect, will cause *harmful* interference.[120]

The critical issue in this rulemaking proceeding is whether the Commission should forego the current capabilities and future promise of UWB technology based on unverified claims that it will create harmful interference. The emissions from UWB equipment are not significantly different, and are in many instances weaker, than the signals the parties opposing this rulemaking are already required to deal with and design around.[121] Since the Part 15 general limits were revised more than a decade ago, wireless

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[119] In fact, if the small earth station terminal were about 500 meters away from the UWB device, it would be likely to be just within the first Fresnel zone even if both devices were at about four feet above ground level. Attenuation at this distance would be $1/r^4$, assuming no intervening obstructions. Obstructions would further attenuate the UWB signal.

[120] Section 15.3 of the Commission's Rules defines "harmful interference" as "[a]ny emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with this chapter."

[121] TDC is asking the Commission to allow UWB equipment to generate signals that do not exceed the Class B limits. The Class A limits, which are considerably higher, govern emissions from equipment used exclusively in business, industrial and commercial settings.

service providers have been on notice that out-of-band emissions from other radio services and radio energy from electronic devices up to the Part 15 Class B limits (and Class A limits, which are greater) would be part of the wireless environment in which they currently operate.

Several commenters noted that GPR systems operating at levels somewhat higher than the levels the Commission is considering authorizing for UWB devices have been in use for decades, in large cities and in and around airports.[122] TDC agrees with these commenters who rely on this evidence to suggest that the experience with GPR radar systems shows that UWB GPR equipment does not interfere with existing wireless services, including GPS and other safety-of-life systems.

Other commenters would like to hold UWB equipment to a more stringent requirement by requiring a reduction in power levels that go well beyond the Part 15 limits.[123] Not only would such a requirement severely impact UWB viability, but it makes little sense in the face of tens of millions of Commission authorized intentional radiators with out-of-band emissions and billions of already authorized unintentional radiators and incidental emitters that exceed these limits.[124]

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[122] *See generally* Comments of A. Peter Annan; comments of Professor G.R. Olhoeft, Colorado School of Mines.

[123] *See generally* Comments of Motorola; Rockwell Collins, Inc; XM Radio, Inc.

[124] These calls also raise the specter of "be careful for what you wish" since, as noted previously, the same sorts of arguments could be raised with respect to the development of emissions masks for many new licenses services.

Emissions Limits

The Commission has proposed both average and peak emissions limits to protect against harmful interference. TDC agrees that both sets of limits are necessary. It is also important to recognize that the emissions limits and measurement techniques are directly coupled to one another – the limits have no real meaning without specifying the technique. Moreover, these limits should be consistent with one another and have relevance to the perceived impact of UWB emissions by a victim receiver. In general UWB systems will be bound by one set of limits or the other. For low PRF systems, the transmit power will be limited by the peak limits; and for high PRF systems, the transmit power will be limited by the average limit. The following sections discuss the emissions levels for both the average and peak limits, and the issues associated with them.

Average and Quasi-peak Emission Levels

From the testing that has been completed to date, TDC believes that the current average and quasi-peak emission limits, if applied to UWB emitters, are adequate to protect against harmful interference and still provide a reasonable amount of power such that useful short range systems can be built. TDC recognizes that there are still interference testing efforts underway and that the final decision on what the average limit should be relative to frequency may not occur until completion of those tests and analyses. Moreover, many of the analyses in Appendix A and Appendix E provide calculations and measurements that reflect that the average limit of 54 dBµV/m (at 3 meters in a 1 MHz bandwidth) or 63.5 dBµV/m at 1 meter in a 1 MHz bandwidth is adequate to protect against harmful interference.

The arguments put forth by Bosch, Valeo, and Siemens Automotive for increasing the field strength limits at increasingly higher frequencies are intriguing.[125] They, in essence, note that as frequency of operation increases the effective area of an isotropic antenna decreases and so captures less energy. TDC believes this concept warrants further consideration. However, this consideration should occur as progress is made in developing systems with operating center frequencies above 20 GHz and should not delay a rulemaking for systems operating below 20 GHz.

Peak Emission Limits

Band Limited Peak. The FCC proposes two radiated electric field peak emission limits. The first one is based on a 50 MHz bandwidth. According to the Commission, "[t]he IF output of a microwave receiver that uses a wide bandwidth, *e.g.*, 50 MHz, can be analyzed using a conventional oscilloscope in order to measure the peak level of the waveform in the time domain."[126] TDC has performed testing using the IF output of a spectrum analyzer and a wideband receiver as well as alternate techniques using a bandpass filter. The important aspect of any measurement technique is the robustness of the technique as well as predictability and repeatability of the results during a calibration. The 50 MHz bandwidth peak limit must be based on receiver performance degradation that is directly related to receiver impulse response to peak amplitude, not a legacy limit of low PRF systems. Moreover, it is not clear that the bandlimited peak measurement

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[125] *See* Robert Bosch GMBH at 4; Valeo Schalter und Sensoren GmbH at 5; Siemens Automotive at 2.

bandwidth need be 50 MHz. A better bandwidth may be 30 MHz, which is supported in the WINFORUM comments in response to the NOI in this proceeding.

As the bandlimited peak technique currently stands, only UWB systems with PRFs exceeding about 16 MHz will be able to meet the 20 dB limit.[127] TDC does not believe that this is reasonable. Not only would it require UWB systems with PRFs less than approximately 16 MHz to cut their power, but the 20 dB limit is not relevant to true receiver performance degradation. As highlighted in TDC's Comments, the receiver characteristics that relates to allowable peak emissions is dynamic range. For typical receivers, this value is well above the 20 dB limit set, and typically on the order of 50 to 70 dB. A reasonable limit may need to be set to protect against systems with extremely high peaks and very low PRFs. However, this limit needs to be based on both reasonable assumptions about UWB equipment as well as performance degradation characteristics of a typical victim receiver.

TDC appreciates the need to have peak limits. A bandlimited peak limit is reasonable since it represents the peak impulse response to which a wideband receiver would be subjected.

Absolute (Total Peak). There is not a compelling reason for an absolute (*i.e.* total) peak, the second peak limit discussed in the NPRM and the comments. Clearly, people may have an intellectual curiosity about the absolute peak, but no victim

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[126] NPRM at ¶ 52.

[127] *See* Comments of Lucent Technologies at 25-26.

receiver can see or respond to the absolute peak (unless it has a bandwidth on the order of one gigahertz and if it does, it is a UWB receiver). TDC does not see the need to have an absolute peak limit for UWB systems. TDC has cooperated in various GPS and PCS interference testing using TDC UWB devices that exceed the proposed NPRM peak limits but meet the average limits. All test results to date have indicated that all interference predictions and measurements coincide with equating the TM-UWB signal to a noise like distribution. Pulse overload and front-end compression have not been a factor in any receiver performance degradation.

However, if the absolute peak is still desired, then the Commission should realize the strong connection between the limit and the measurement technique. It should then consider the difficulty involved in an absolute peak measurement. Depending on the calculation or technique used to determine the absolute peak (or for that matter, how one defines the absolute peak emissions), one can get drastically different answers. For example, one could calculate the peak to average ratio by using 10*log(PRF*Pulsewidth), which for a 5 MHz PRF and a pulsewidth of 0.5 nanoseconds is 26 dB. Some people choose to perform the same calculation as the one above, but believe the relationship should be 20*log rather than 10*log (voltage versus power relationship). Using 20*log yields an answer of 52 dB. These two views lead to a misunderstanding of the limit and calculation of the peak. An alternate technique may be to measure the area under the waveform (Volt-seconds) and have an entirely different limit altogether (see discussion below).

An alternative peak limit and measurement is based around Volt-second relationship, not just a peak voltage as the NPRM is proposing. TDC believes that if there is to be an absolute peak limit a more accurate absolute peak limit should be based on the received impulse electric field volt-second area. From the studies supplied in Appendix C, it is shown that the peak impulse response of a filter is directly proportional to the area under the waveform (Volt-seconds), not simply the peak amplitude of the waveform. According to Engelson," The peak circuit output does not depend on the pulse shape but on its spectrum amplitude which is twice the pulse area (in units volt-seconds), and the circuit impulse bandwidth (B_i in Hz)." The reason why the volt-second area is more important than the peak amplitude of the impulse is because the impulse volt-second rating is the characteristic that determines the peak impulse response of a bandpass filter. An impulse with lower peak amplitude, but having a greater volt-second value, can cause a larger voltage to appear at the filter output than one with a higher peak voltage due to a larger pulse width of the lower amplitude impulse. For example a square pulse with a 1 ns pulse width and peak amplitude of 100 mv, 1ns x 100 mv = 1×10^{-10} V-s, has a larger volt-second rating than one with a 150 mv amplitude and 600 ps pulse width, 600 ps x 150 mv = 9×10^{-11} V-s. The proposed absolute peak limit should be compatible with the Class B average limit, but as currently proposed, it is not. The present NPRM limit will not allow a UWB device to transmit at the average limit with a PRF of 1 MHz and pulse width of less than 4.75 ns, assuming a triangular shaped impulse. TDC uses pulse widths that are equal to or less than 1 ns due to critical timing and multipath considerations. The NPRM absolute peak limit proposes to cap the maximum average electric field emission, using a 1 MHz PRF, at 105 μV/m @ 3m,

which is one fifth (or 14 dB less than that) of the allowable 500 μV/m. Absolute and band limited peak limits need to change to be consistent with the average limit and directly relatable to receiver degradation. Accordingly TDC suggests that if a total peak output (*i.e.* absolute peak) limit is deemed to be in the public interest, the Commission should employ the technique described herein with the limit being specified as $5x10^{-10}$V-s.

In closing, the Commission needs to finalize the measurement techniques for UWB systems before resolving the final peak limits. TDC believes that through the current interference test efforts underway the Commission will gain valuable insight into (1) appropriate measurement techniques, (2) the mechanisms by which interference may be perceived by common receivers, and (3) the receiver characteristics by which limits relating to receiver performance degradation can be established. The limits need to be instituted in such a way as to protect existing users of the spectrum, but not to be so overly conservative (without a real justification) such that they hinder the ability of UWB manufacturers to make viable products.

Filtering UWB Signals

Some commenters would require UWB to filter signals to minimize the impact on incumbent services and to avoid the restricted bands.[128] As TDC has stated, it is impossible to realize fully the potential of UWB technologies without placing emissions into the restricted bands. Filtering not only adds unnecessary cost and complexity to a

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[128] *See* Comments of AT&T Wireless at 8; National Business Aviation Assoc. at 7-8.

system that is already operating at the Part 15 limits, it affects severely the range resolution prized by radar systems and the critical timing characteristics of UWB communications applications (*i.e.*, by degrading multipath immunity).[129]

There is also a fundamental difference between filtering in a typical wireless communications system and filtering a UWB signal. An ultra wide-band signal, by definition, is a signal that operates via a low level signal pulse that makes effective use of the broad frequency spectrum it spans. A typical wireless communications system uses filtering to reduce the levels of extraneous signal components, *i.e.*, out-of-band and spurious emissions. These signal components provide no useful communications purpose. Although all communications systems generate these extraneous signals, they are not processed by the receiving equipment and only add noise to the system. UWB equipment, on the other hand, makes use of nearly the entire low-level wide-band signal that is generated. Because of this, filtering bands in the midst of a contiguous wide band signal removes critical UWB signal components.

Cumulative Impact

As TDC has explained in this proceeding, there are a number of real-world factors that limit the cumulative impact of many UWB devices operating at Part 15 limits.[130] With these factors taken into consideration, the closest UWB emitter will be shown to

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[129] *See* Comments of TDC at 19-20; NOI Comments of TDC at 39-40, Appendix D; NOI Reply Comments of TDC at 8-9.

have the greatest impact on the noise level because signals from more distant devices at the Part 15 limits in the range of 1 to 3 GHz will quickly be subsumed by the noise floor. Propagation losses are significant and even a modest distance between emitters can lessen the cumulative impact of a large number of users. Even in Motorola's view (whose overall assessment is disputed by TDC because it makes some erroneous assumptions regarding UWB signal effects), the cumulative field strength from multiple UWB emitters provides only a slight increase over the contribution of a single emitter.

Some commenters who have expressed concern about the aggregate effect of UWB devices[131] are ignoring the radiated effects of UWB signals. Like noise, UWB signals add non-coherently and will not have a directly additive impact.[132] UWB signals are not coherent because UWB devices are generally designed with different PRFs (pulse repetition frequencies), have different start times due to asynchronous clocks, and different signal coding schemes. Even within wireless local area networks one would not expect to find simulcast synchronized transmissions for to do so would impair the functioning of the network.

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[130] *See* NPRM comments of TDC at 35-36; NOI comments of TDC at 33-36. These factors include propagation effects, UWB antenna polarization, victim receiver antenna effect, user density, operational duty cycle, time duty cycle, and ambient noise.

[131] *See* comments of Aircraft Owners and Pilots Association; comments of the National Association of Broadcasters; comments of Nortel Networks, Inc; comments of Satellite Industry Association; comments of Wireless Communications Association Int'l, Inc..

[132] *See* Appendix C, Study 5.

Measurement Procedures

The measurement technique and the associated limits that regulate the power or electric field strength are critical components of any set of regulations that govern RF emitting equipment. This is a challenge for UWB due to the diversity of signal structures, and the time domain nature of the waveform. The goal is a measurement technique that is repeatable, not overly complicated, cost effective, and relates the results to accurately quantify the levels of power that would be perceived by a common victim receiver. To that end, the FCC has recommended an average, bandlimited peak, and absolute peak measurement.

After reviewing the FCC's NPRM and several of the comments supplied, TDC studied the different possible techniques for making the above measurements to determine their feasibility and limitations. Appendix C covers in detail the experiments performed and information gathered on UWB signal measurement techniques. This effort focused on developing the peak measurements and investigating in more detail the average technique. As noted previously, TDC understands that there could be many different approaches to measuring UWB signals. The studies in Appendix C are not exhaustive, but do represent some very interesting observations and recommendations on how to move forward with practical measurement techniques for UWB systems. Through this process TDC has developed several recommendations on the different measurement techniques. These are discussed below.

UWB Signal Measurements

One of the general radiated measurement issues that was uncovered through experimentation is that both the peak and average measurements should be performed at 1 meter rather than 3 meters (with an appropriate adjustment made to the limit to reflect the electric field strength at 1 meter) in order to get the necessary sensitivity.[133]

Average and Quasi-peak Measurements

TDC is in support of performing the average measurement based on the way the FCC is currently using for all other Part 15 emitters. The average measurement should be performed using a 1MHz RBW, and VBW equal to or less than 10 kHz using a peak detector. However, one of the studies shown in Appendix C highlights that if the PRF is less than the specified 1 MHz RBW, then either a correction factor needs to be used for the narrow VBW averaging technique or the use of a true average detector with a wide VBW should be employed.

Peak Measurements

The following points outline the major recommendations regarding the bandlimited peak and absolute peak measurements for UWB systems. Each point is discussed in more detail in Appendix C.

- Antenna heights, for both the transmit and receive antennas, should be at least 2 meters above the floor. This is in order to separate the direct path pulse from the reflected path pulse for time domain peak measurements, since the overlap of

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[133] This was discussed in detail in TDC's comments to the NPRM, and is not covered in more detail in these studies.

those pulses may be either deconstructive or constructive, which would change the peak measurement.

- Peak measurements are best performed using a horn antenna and digital sampling oscilloscope (DSO) with input from a tunable bandpass filter rather than the IF output of a wideband receiver.

- Using the above technique, it is fairly straightforward to determine the peak electric field in a 50 MHz bandwidth. However, the same is not true for the absolute (*i.e.* total) peak measurement. Rather than calculating the absolute peak electric field, it is easier to determine the ratio or relative peak compared to the average, or to measure the area under the waveform (Volt-second), which is really the determinant of an impulse response.

- Since the peak measurements need to be made with fast DSOs, UWB manufacturers should make the peak measurements and supply them to the certification lab for approval and submittal to the FCC. This would be much less expensive than requiring all certification labs to purchase DSOs.

VI. Conclusion

The risks associated with the implementation of regulations that will permit UWB technology to be employed in this manner, pale in comparison to the risks of not moving forward. Failure to move forward with a First Report and Order in this proceeding risks not only U.S.-international technological leadership and depriving the public of valuable products and services, but, more importantly, would needlessly risk lives that could be saved using applications of UWB technology. TDC urges the Commission to move expeditiously in this proceeding and looks forward to continued participation.

Respectfully,

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