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September 29, 1999

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, S.W. TW-A325
Washington, D.C. 20554

Re: *Ex Parte* Submission, Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, ET Docket No. 98-153

Dear Ms. Roman Salas:

This letter is to advise you that, on September 28, 1999, the undersigned, along with Mr. Roberto Aiello, Ms. Debby Hindus, Mr. William Lynch and Mr. Gerald Rogerson, of Interval Research Corporation ("Interval"), met with the following individuals at the Office of Engineering and Technology ("OET") to discuss the above-referenced proceeding:

- Dale Hatfield, Chief, OET;
- Julius Knapp, Chief, Policy and Rules Division;
- Karen Rackley, Chief, Technical Rules Branch, Policy and Rules Division; and
- John Reed, Technical Rules Branch, Policy and Rules Division.

Pursuant to Section 1.1206 of the Commission's Rules, 47 C.F.R. §1.1206, an original and a copy of this letter, along with copies of the documents provided at this meeting, have been submitted for inclusion in the public record.

Please contact me at (202) 736-1809 if you have any questions concerning this letter

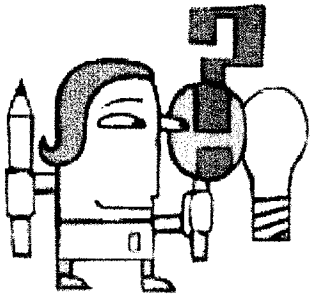
Sincerely,

Tara Kalagher Giunta
Counsel to
Interval Research Corp.

No. of Copies rec'd 0+1
List ABCDE

Encl.

cc: Dale Hatfield (w/o encl.)
Julius Knapp (w/o encl.)
Karen Rackley (w/o encl.)
John Reed (w/o encl.)



# Interval Research Corporation

## *Presentation on Ultra-Wideband Transmission Systems*
## *ET Docket No. 98-153*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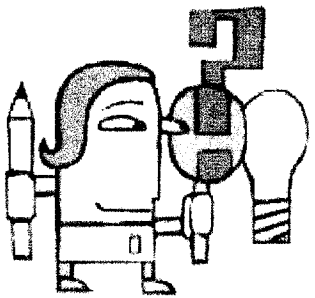

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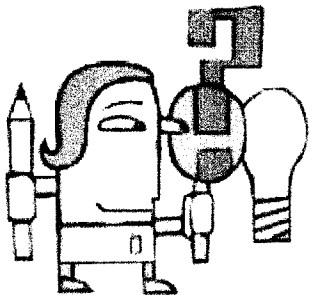


# Summary

**Interval's background**

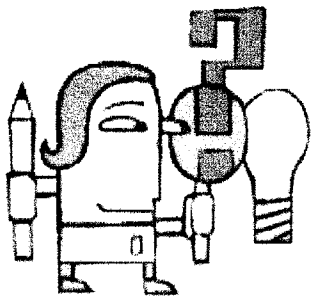
**Ultra-wideband ("UWB") technology**

**Regulatory activities**

**Research results**

- **vision of the future**
- **interference**
- **aggregation**

**Policy recommendations**



# *Interval Research*

**Interval Research Corporation, located in Palo Alto, California, is a research laboratory founded in 1992.**

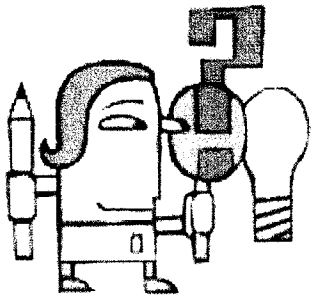
**Founders: Paul G. Allen, a visionary high technology entrepreneur and forth largest cable operator, and Dr. David E. Liddle, a computer industry veteran with deep roots in research and development.**

**Interval's goal is to expand the ways in which people communicate, learn, relax, and live with new technology.**

**Interval employs about 100 researchers, most of them with advanced degrees.**

**Interval has received over two dozen patents, and published over 200 scientific articles.**

**Interval supports research and collaborates with numerous universities, including MIT, Stanford, CMU and NYU.**

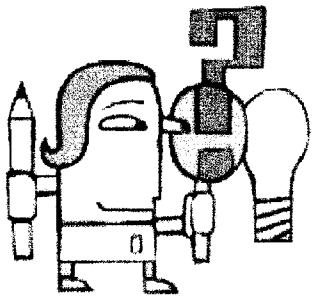


# *Interval Creates New Consumer Experiences*

**Interval is a laboratory and incubator for new businesses in broadband applications and services, consumer devices, interaction design, and advanced technologies.**

**Interval brings an interdisciplinary approach to research. Its staff includes computer scientists, designers, engineers, filmmakers and entrepreneurs.**

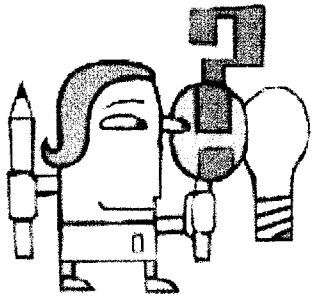
**Interval's business development team works with researchers and capitalizes on its intellectual property by launching spin-off companies and partnerships to take concepts to market.**



# *Interval Creates New Consumer Experiences*

**Interval already has made breakthroughs in developing seedling technologies and building commercial industries around them by spinning-off several start-up companies that are now pursuing commercial endeavors.**

**Interval is currently developing various communications applications and technologies, including those that involve UWB technology.**



# UWB Is A Valuable Technology

**Safety**

- location of people buried by debris after earthquakes
- side auto collisions

**Environment**

- aging pipes location
- highways and runways flaws detection

**Medical**

- wireless implants
- hearing aids

**Education**

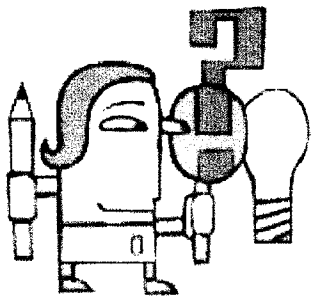
- classroom wiring
- school/library Internet access

**Assistance to the elderly, disabled**

- remote controlled home
- remote monitoring

**Consumers**

- broadband access
- broadband networking
- personal wearable computing



# *A Brave New World of Communication*

**Always in touch**

- **hands free, great sounding next generation phones**
- **simple "presence" devices**

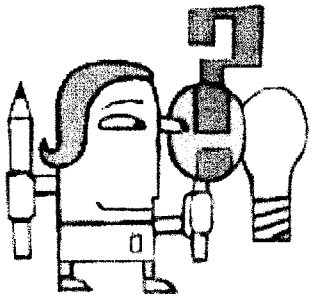
**Toys, games**

**Safe and sound**

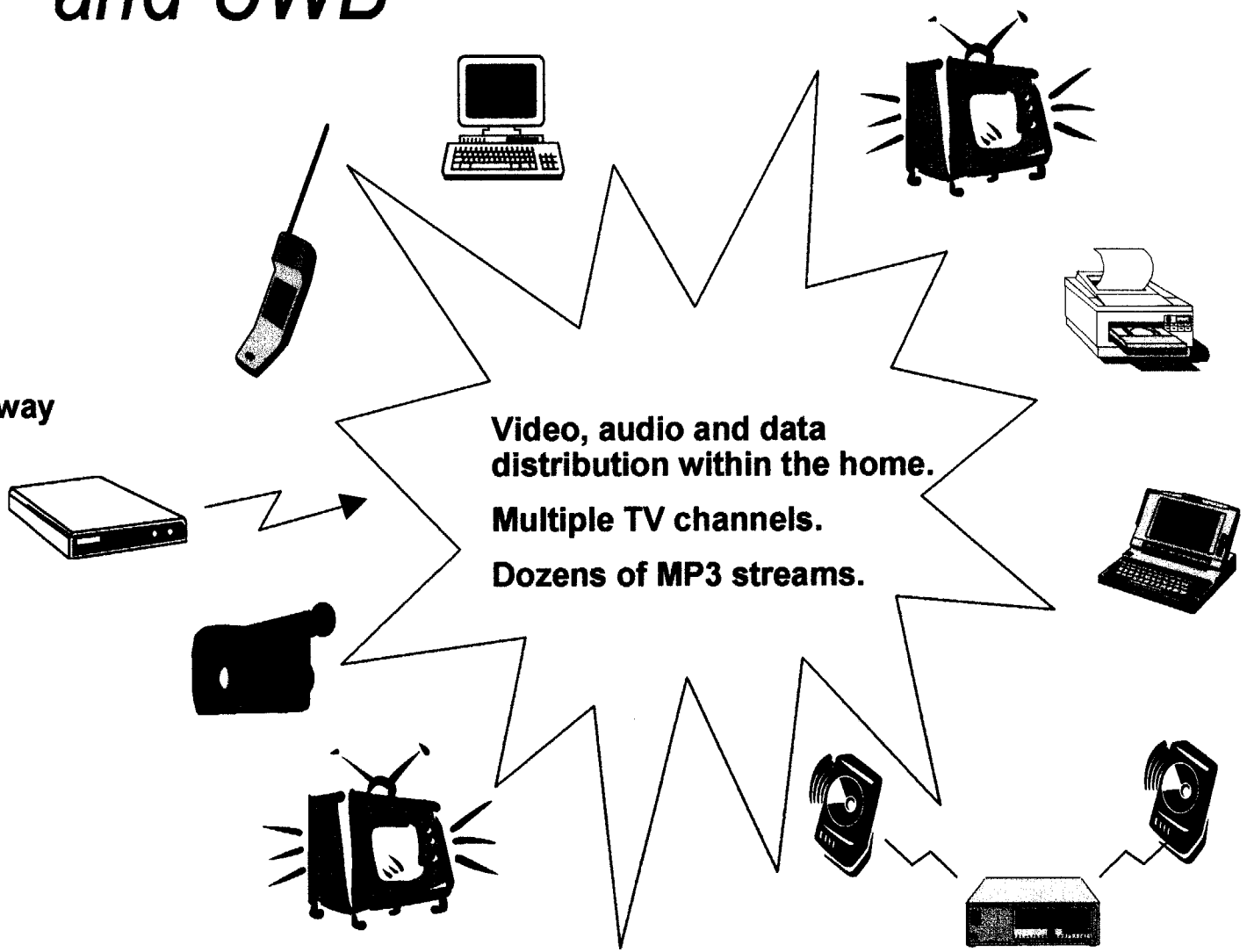
- **medical monitoring**
- **self-driving cars**

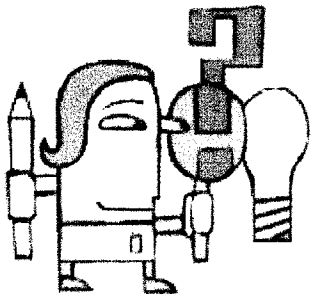
**Nothing but 'net**

- **personal, wearable broadband**
- **ubiquitous networking in schools**
- **Internet access as a right, not a privilege**

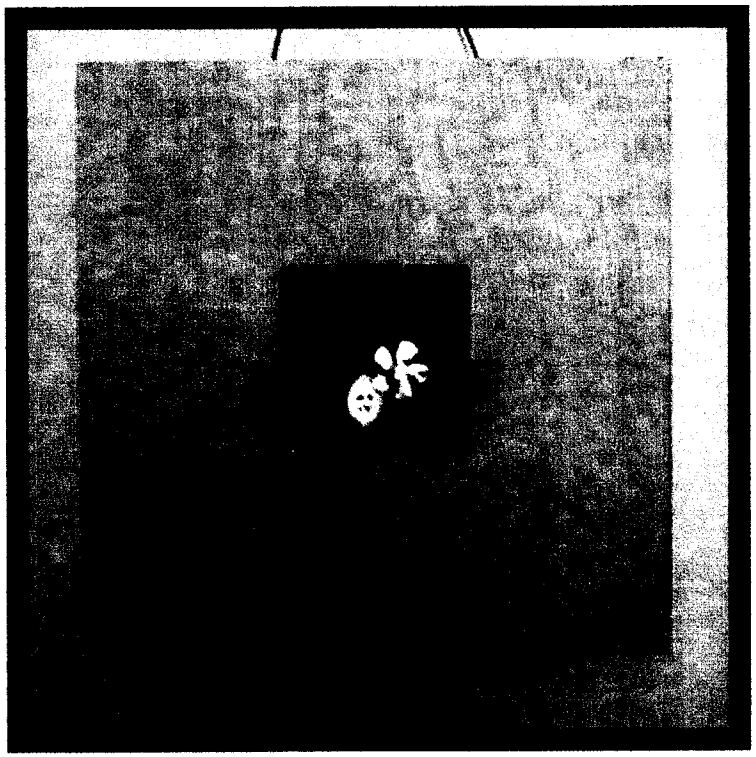


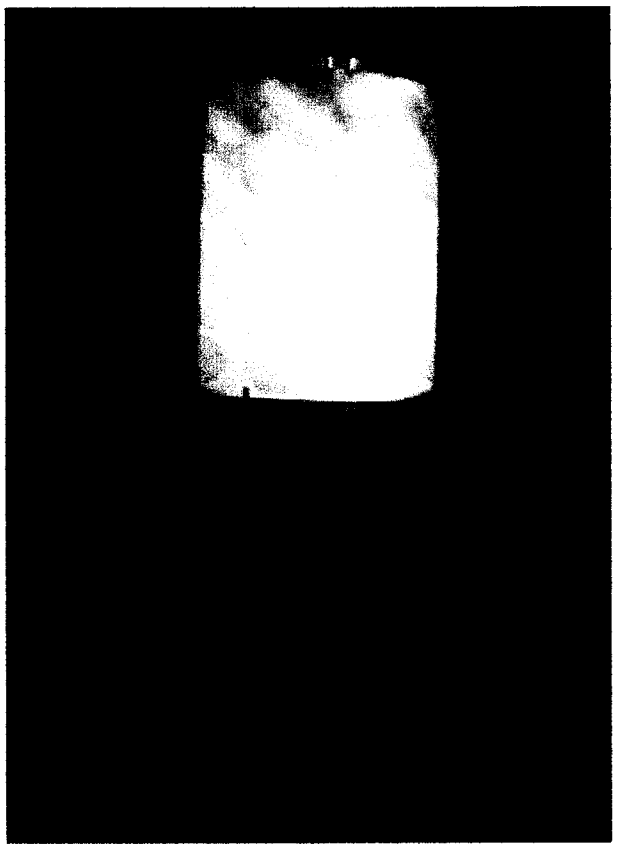
# Broadband Home Networking and UWB

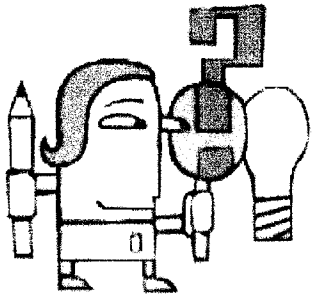




# A Brave New World of Communication







# *The FCC's UWB Docket*

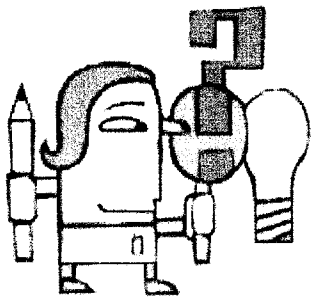
**Interval applauds the FCC for its action on September 1, 1998 issuing a Notice of Inquiry ("NOI") on UWB devices.**

**Interest in promoting UWB devices is high. The NOI prompted over 40 commenters to submit their insights and ideas, and helped frame the important issues relating to the development of UWB applications.**

**There was strong support and general consensus for the development of UWB devices and applications.**

**Interval believes that the few objections to establishing new rules for UWB devices can be addressed, once speculative harms are disregarded.**

**U.S. has a lead on UWB with respect to the rest of the world.**



# *Interval Contributes to UWB*

**Interval filed comments and reply comments in the NOI.**

**Interval co-founded the UWB Working Group (UWB-WG) in November 1998.**

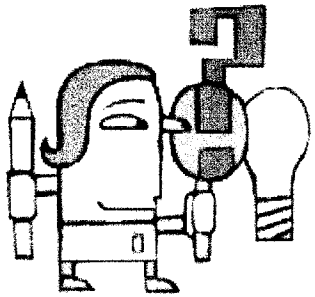
**The purpose of the UWB-WG is to promote public policies that encourage the development and commercialization of UWB technologies.**

**The UWB-WG has approximately two dozen members, including research laboratories and entrepreneurs.**

**Interval provides sound scientific contributions.**

**Interval collaborates with universities to evaluate issues of co-existence with other users of the bands, especially in the restricted bands of operation.**

**Interval researches consumer's needs and technologies that will create new industries.**



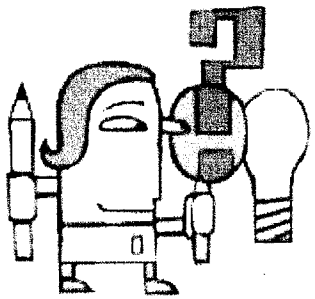
# *UWB Will Not Cause Harmful Interference*

**Concern:**

- **UWB devices will cause harmful interference within the restricted bands of operation, including TV broadcast and GPS.**

**Research results:**

- **UWB systems operate using a very large bandwidth with very low power spectral density.**
- **GPS is the most critical system because of the combination of space-to-earth and safety-of-life application.**
- **An interference study in collaboration with Prof. Enge, GPS Research Group at Stanford University, demonstrates that UWB and GPS can coexist.**



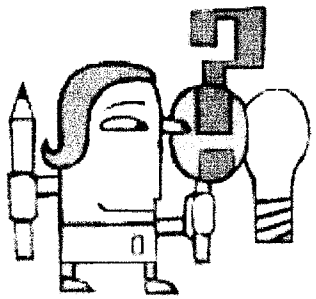
# *Aggregation of UWB Devices Will Not Increase Current Ambient Noise Levels*

**Concern:**

- **Widespread and ubiquitous use of UWB devices will unacceptably increase current ambient noise levels.**

**Research results:**

- **Noise aggregation is caused by any radio transmitter, not just by UWB devices.**
- **Substantial noise aggregation will not occur because of:**
  - **signal attenuation, and**
  - **earth curvature.**
- **Empirical evidence from existing radio systems is consistent with our analysis.**



# *Interval's Recommendations*

**The FCC should continue to move forward and issue a Notice of Proposed Rulemaking ("NPRM") in January 2000.**

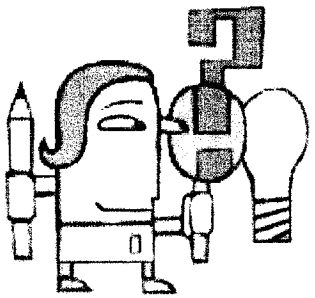
**The FCC should maintain the current levels of Part 15 for unintentional radiators.**

**The FCC should specify different limits for indoors/outdoors.**

**The FCC should reduce the allowed level on the GPS band by 20dB**

**Pulse desensitization should not apply.**

**The FCC should base the limits on measured E field.**



# *Conclusions*

**In recent years, the FCC's initiative and foresight have given birth to many new radio-based technologies that will benefit society (*e.g.*, spread spectrum, unlicensed NII devices, unlicensed PCS devices).**

**Once the FCC proposes specific rules in an NPRM, Interval is confident that any remaining objections can be worked out quickly by the interested parties.**

**Carefully crafted rules that address actual -- and not speculative -- harms should be the FCC's goal.**

**The public stands to greatly benefit from UWB bevices which will not only enhance our daily lives, but also save lives.**

**The FCC should keep the momentum and the lead vis-a-vis the rest of the world.**

**Debby Hindus**

Debby Hindus is a Member of the Research Staff at Interval Research Corporation in Palo Alto, CA. Her current research interests include broadband applications in the home and wireless technologies. Earlier research addressed new kinds of audio-only computer-mediated communication. She has recently published on the intersection of consumers, communications, technology and the home. In 1999, Ms. Hindus taught a new Stanford course on The Design of Domestic and Consumer Technologies. She has also taught at Harvard University Extension. She is a senior member of the computer-human interaction research community.

Ms. Hindus holds an MS degree from the MIT Media Lab and a BSCS degree from the University of Michigan. While in the Media Lab's Speech Research group, her work focused on innovative speech applications for interacting with computers. Before her graduate studies Ms. Hindus worked at Digital Equipment Corporation in Maynard, MA. There she led commercial software development for a top-selling product. She then joined Software Arts in Wellesley, MA, the company that invented computer spreadsheets. Ms. Hindus has extensive industry experience developing software and consulting on user interfaces for such companies as John Hancock and Houghton-Mifflin. She holds one U.S. patent on audio conferencing.

**Dr. William Lynch**

Dr. Lynch received his B.S. in Mathematics from Case Institute of Technology in 1959, and his M.S. (1960) and Ph.D. (1963) in Mathematics from the University of Wisconsin in Madison. From 1963-1976 he was Assistant, Associate, and Full Professor of Computer Engineering and Information Sciences in the Engineering School of Case Western Reserve University. During this period he published extensively on the topics of operating systems, communications, and performance analysis. He has also been on the faculty of or a Visiting Professor at the University of Wisconsin, The University of Newcastle-Upon-Tyne (England), The Federal University of Rio de Janeiro, The State University of Campinas (Brazil), and has taught post-graduate courses at Stanford University.

From 1976 to 1993 Dr. Lynch was employed by the Xerox Corporation in Palo Alto, CA. He was responsible for the design and implementation of the Pilot operating system underlaying the Xerox Star, the first commercial GUI workstation. Later at Xerox he had responsibility for the creation of the specifications for the Ethernet and the adoption of those specifications by IEEE 802.3. After leaving Xerox PARC, Dr. Lynch joined Interval Research Corporation as a Member of the Research Staff. He has conducted research on video processing and on novel radios. Dr. Lynch is member of the American Mathematics Society, the Association for Computing Machinery, the Institute of Electrical and Electronic Engineers, the American Association of University Professors, and the American Association for the Advancement of Science.

**Gerald Rogerson**

Gerald Rogerson is a Member of the Research Staff at Interval Research Corporation in Palo Alto, CA. He received his BSEE from Brigham Young University. He is an RF engineer with experience in numerous radio designs ranging from early research concepts to full production cellular phones. From 1992 to 1995 he worked for RF Engineering, a radio systems consulting firm where he led various efforts. His main projects in this firm included EMI tests, spread spectrum chip development and radio design for medical equipment. From 1995 to 1998 Mr. Rogerson was employed at Siemens Wireless Terminals. At Siemens he worked on GSM, TDMA and CDMA cellular phone designs, including an 18-month stay as a delegate to Germany. He is currently an active member of Interval's UWB team.

# An Analysis of Noise Aggregation From Multiple Distributed RF Emitters

**W. C. Lynch, K. Rahardja, S. Gehring**
**Interval Research Corporation**

**September 29, 1999**

## Noise Aggregation - a Problem?

How much noise will an overflying aircraft hear from an aggregation of UWB devices on the earth's surface?

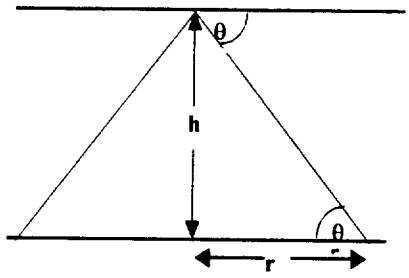
Problem geometry and noise aggregation estimation

Effect of the earth's curvature

Effect of attenuation

Empirical evidence

## Problem Geometry






## Noise Aggregation Estimate (45°)

Assume uniform power density **P** on earth's surface

Use inverse square law for radiated power

Integrate over base of 45° cone

Power density at apex is 2.178 **P**

## Noise Agg. Estimate (100m)

Assume uniform power density **P** on earth's surface

Use inverse square law for radiated power

Assume aircraft is flying at altitude **h** in meters

Integration is cut off at earth's horizon

$$P_{apex}\Big|_{h=100m} = \pi P \ln\left(1+\frac{6,375,000}{h}\right)\Bigg|_{h=100m} = 34.75P$$



## Electromagnetic Damping

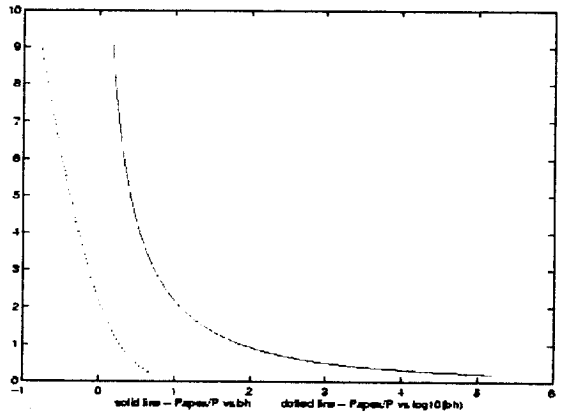
Photons not lost to space must be absorbed

Probability of absorption per unit length is given by an absorption coefficient

Absorption coefficient is a function of height above the earth (density of absorbers)

Any non-zero homogenous absorption makes the apex power finite and a function of bh, the absorption coefficient times the apex height

## Homogeneous Damping





## Inhomogeneous Damping

Measurements of structure interior or ground level propagation give a power law

$P(r) = r^{-(2+\varepsilon)}$ where $2.4<2+\varepsilon<4.0$

This is equivalent to a damping function

$$b\left(h(x),x\right) = \frac{\varepsilon/2}{h^2 + x^2}$$

This describes damping whose average value rapidly goes to zero with altitude or distance

## "Foamy" Propagation Media

- Medium consists of bubbles of various sizes
  - The walls of the bubbles absorb to some degree
  - The interiors of the bubbles are non-absorbent voids
- Inhomogeneous damping corresponds to a "foamy" medium with a certain distribution of void sizes
- Structure interiors and the near-ground form a foam with walls and vegetation for cell walls



## Empirical Evidence - Analysis Does Not Depend on UWB

- FM radio
- Cell phones
- PCs
- AM radio
  - Spherical shell waveguide
  - No effect of finite earth
  - Infinite array of image emitters

## Conclusions

- Substantial noise aggregation will not occur
- Noise aggregation from below (45°) is very limited
- Noise aggregation from the horizon is limited
  - By absorption
  - By the curvature of the earth
- Empirical evidence from existing radio systems is consistent with this analysis

# A Cooperative Program to Assess Interference From Ultra Wide Band Technologies to the Global Positioning System

1999 UWB Conference for Radio and Radar Technology
Washington D.C.
September 29, 1999

Per Enge, Konstantin Gromov and Jaewoo Jung
Stanford University
G. Roberto Aiello and Gerald D. Rogerson
Interval Research Corporation

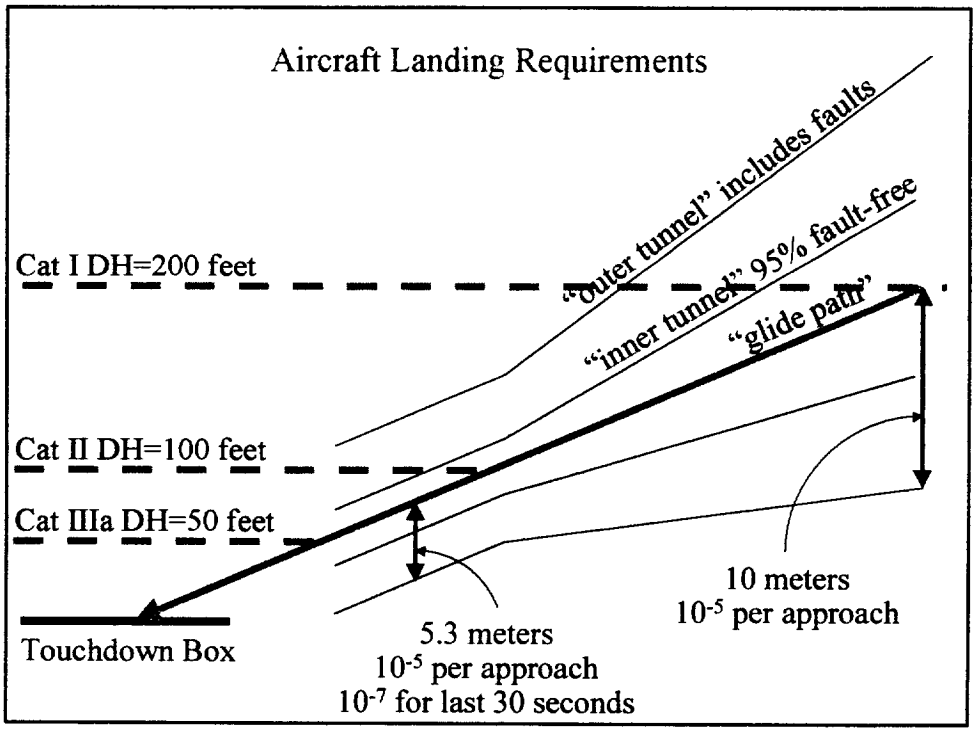
## GPS is the Most Critical Interference Test for UWB

- Space-to-earth signal with a received power of only -164 dBW or $10^{-16}$ Watts
- GPS presently serves around 8 million users including applications at sea, in the air, over land, and in space.
- Many applications protect the safety of the public
  - Harbor approach & narrow waterways
  - Land emergency, such as ambulance guidance
  - Precision approach of aircraft
  - Operational continuity is required
    - one missed approach per 100,000 landings
    - one interruption for 10,000,000 rollouts (Cat IIIb)

Degree of Difficulty:

received power × safety requirement

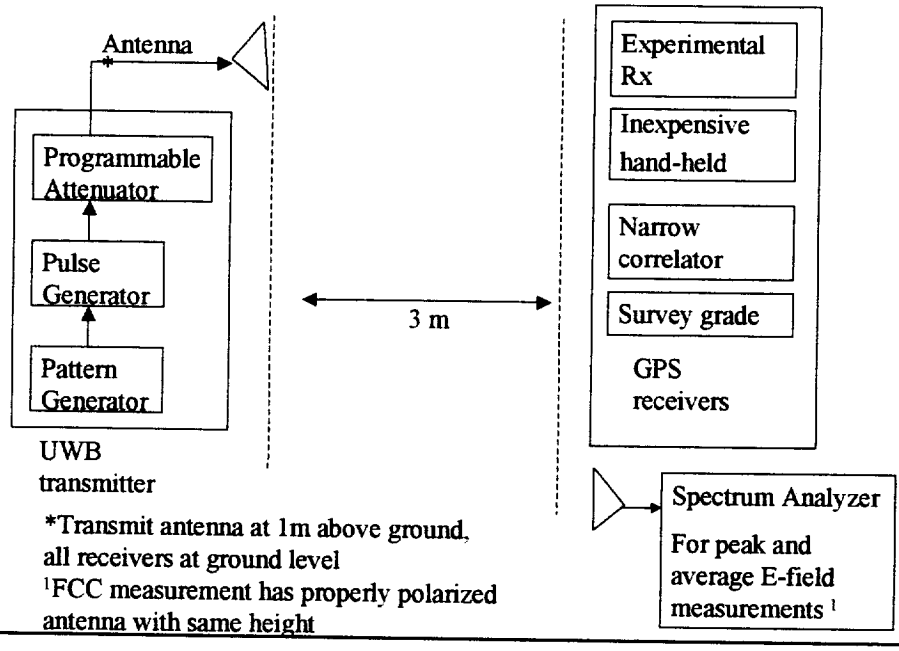
$10^{-16} \times 10^{-7} = 10^{-23} \approx$ Avogrado' s Number!!!




## Purpose

- Interval: "Why worry?"
- Stanford: "The sky is falling!"
- Let's collaborate to establish
  - Develop test methods
  - Identify variables
  - First look at interference effects

## Measurement Setup



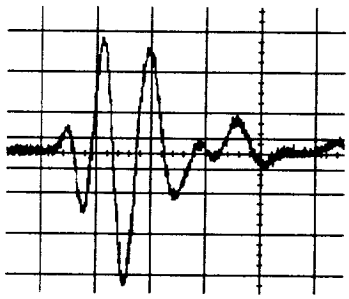

*Transmit antenna at 1m above ground, all receivers at ground level

[1]FCC measurement has properly polarized antenna with same height

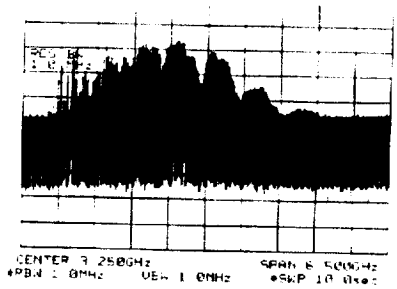
## Assumptions & Protocols

- A specific UWB waveform:
  - pulse trains with PRF=20 MHz
  - UWB transmission line at GPS $L_1$ freq. (1575.42 MHz)
- Single UWB transmitter (no other significant interference)
- Interference criterion: range to loss of first satellite
  - many applications can tolerate the loss of 1 satellite
  - safety applications need redundant satellites & need low lying satellites
- UWB transmit antenna in the main lobe of GPS antenna
- $1/R^2$ propagation
- Average $E$ field of 54 dBuV/m is limiting criterion
  - pulse repetition rate > GPS receiver bandwidth
  - bursts have duty cycles greater than 40%
- Number of satellites in view determined with UWB off
- Four different GPS receivers

## UWB Source



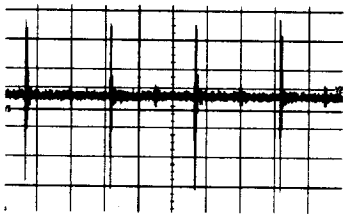
Single Pulse (Time Domain)



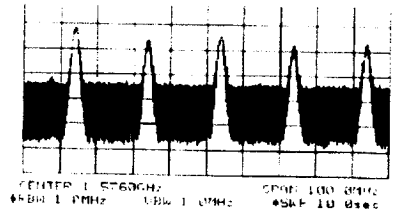
Frequency Spectrum

## Different Patterns

Pulse Train

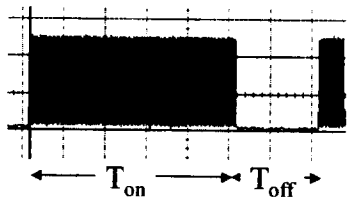


Spectrum With No Modulation



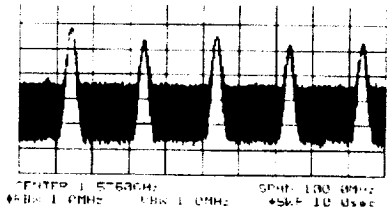
Modulation Types
- Random Pattern: random OOK
- Dithering: Pulses are moved in time
- Pulse repetition interval controls
  - spectral line shift (frequency)
  - distance between pulses changes
- Many other modulations are possible

Pulse Bursts

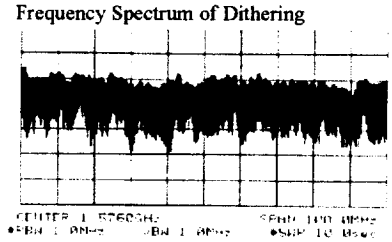


# Frequency Spectrum

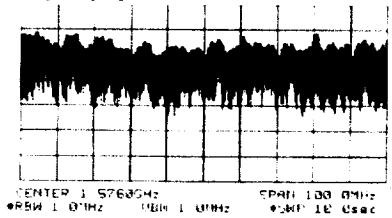
No Modulation



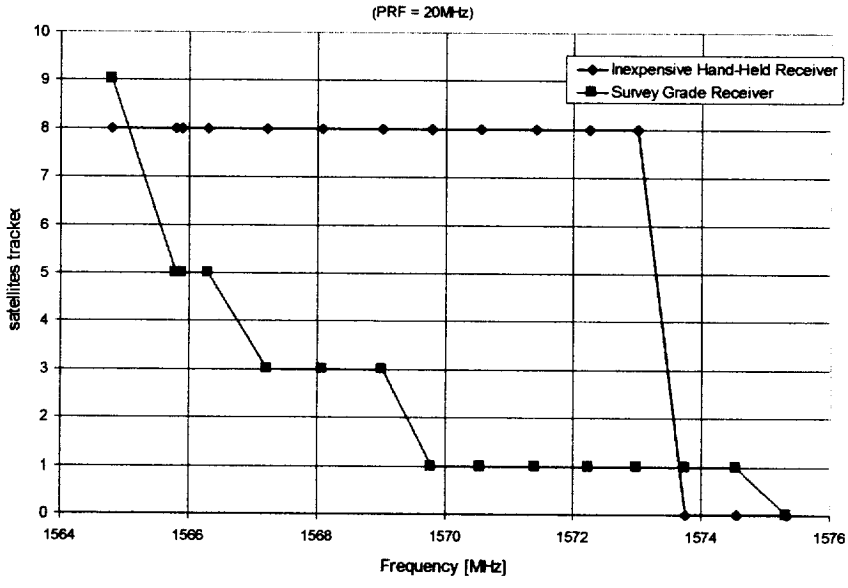
Frequency Spectrum of Dithering

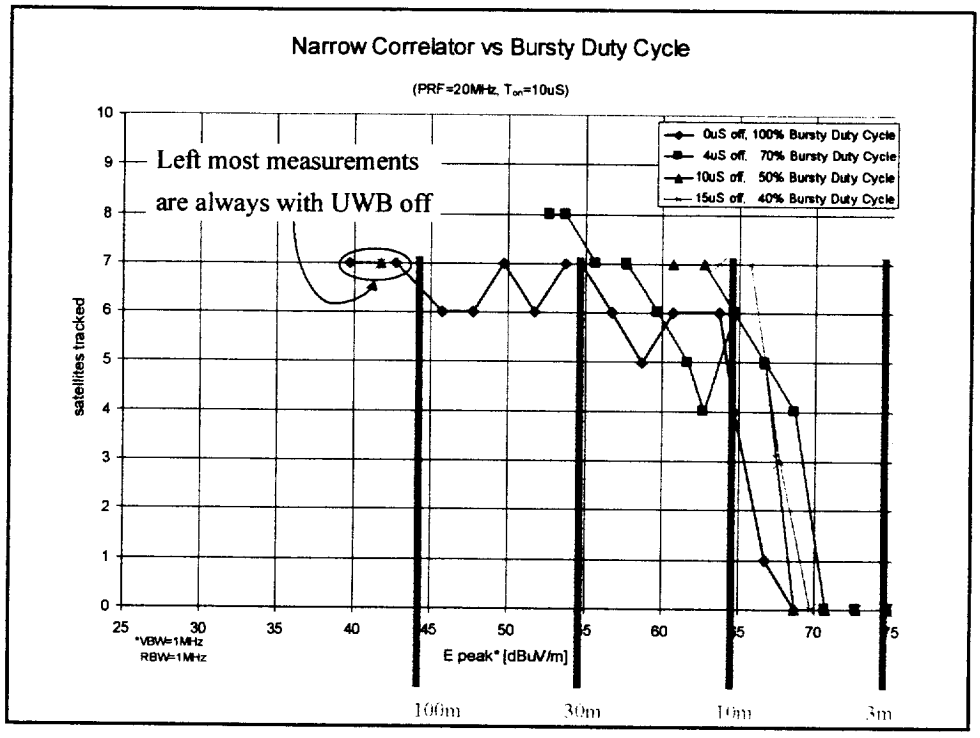


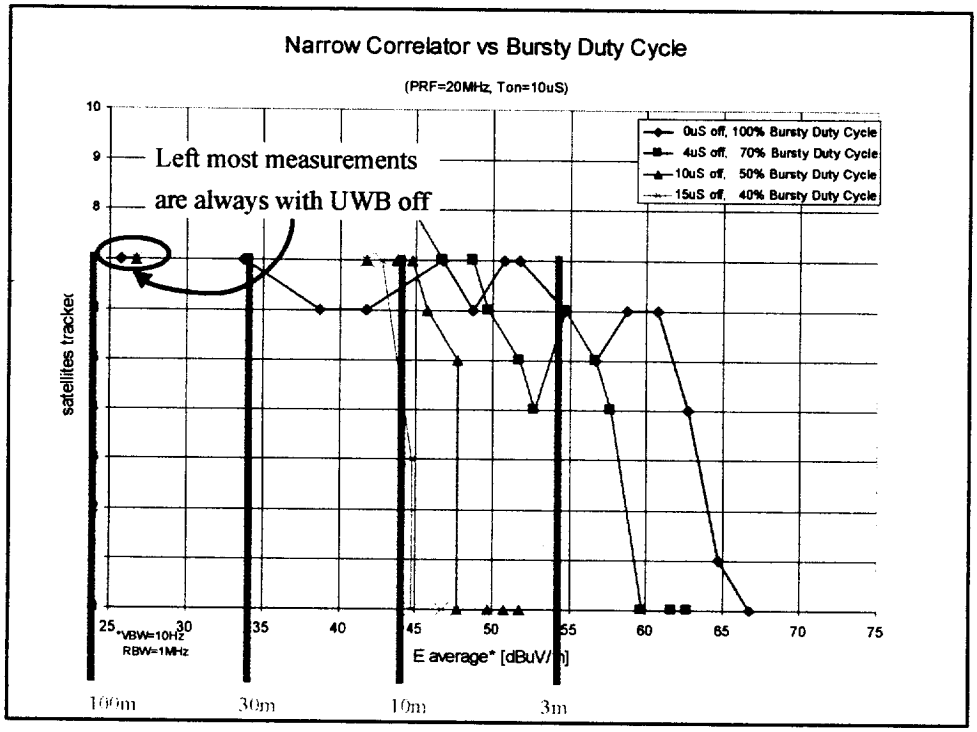
Frequency Spectrum of Random Data

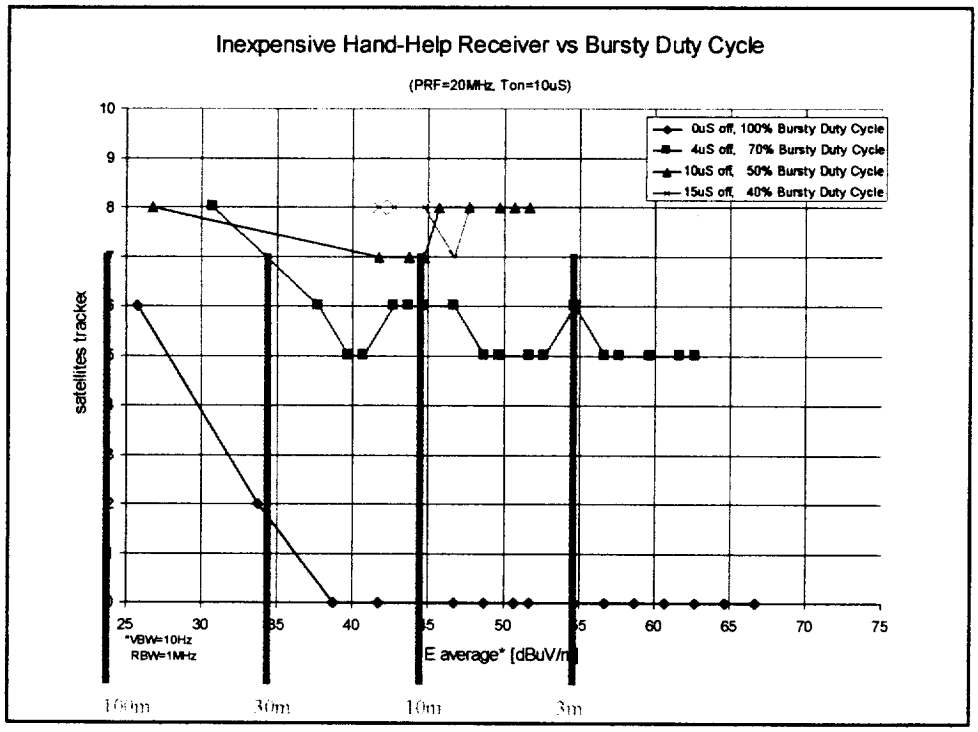


# Frequency sweep




Narrow Correlator vs Bursty Duty Cycle
(PRF=20MHz, Ton=10uS)
Left most measurements
are always with UWB off
0uS off, 100% Bursty Duty Cycle
4uS off, 70% Bursty Duty Cycle
10uS off, 50% Bursty Duty Cycle
15uS off, 40% Bursty Duty Cycle
satellites tracked
*VBW=1MHz
RBW=1MHz
E peak* [dBuV/m]
100m
30m
10m
3m


Narrow Correlator vs Bursty Duty Cycle
(PRF=20MHz, Ton=10uS)
Left most measurements
are always with UWB off
0uS off, 100% Bursty Duty Cycle
4uS off, 70% Bursty Duty Cycle
10uS off, 50% Bursty Duty Cycle
15uS off, 40% Bursty Duty Cycle
satellites tracked
*VBW=10Hz
RBW=1MHz
E average* [dBuV/m]
100m
30m
10m
3m




## Interference Range (meters)

| | Narrow Correlator | Inexpensive Hand-Held | Experimental | Survey Grade |
|---|---|---|---|---|
| Bursty 40% | 3-10 | 3-10 | 30-100 | 30-100 |
| Bursty 50% | 3-10 | 30-100 | 5-15 | 30-100 |
| Bursty 70% | 3-10 | 30-100 | 5-15 | 30-100 |
| Bursty 100% | 3-30 | 30-100 | 3-100 | 30-100 |
| PRF | 1-3 | 5-15 | 30-100 | 1-3 |
| Dither | 3-10 | 30-100 | 30-100 | 30-100 |
| Random | 3-10 | 30-100 | 30-100 | 30-100 |

- Range uncertainty reflects
  - E-field measurement errors
  - Difficult to identify point of degradation
- Based on limited number of UWB signal designs
- Need more exhaustive measurements
- No safety margin

## To Achieve More Protection

- Place UWB center frequency far from GPS
- Tune frequency harmonics out of band
  - subject to clock stability
  - temperature and environment
- Perhaps, reduce burst duty cycle
- Reduce limit of emissions in GPS band

## Conclusions

- UWB to GPS interference measurements are tricky!
  - Interference depends on UWB modulation (PRF etc.)
  - GPS receivers are also very varied
- Our measurements are not exhaustive
- Measurements to continue with more controls

- Even so, interference to 30 meters is commonplace
- GPS requires more protection
- Such protection is possible & would enable UWB to move forward.
- Moreover, GPS is worst case for interference from UWB

An Abstract for the 1999 UWB Conference for Radio and Radar Technology

# A Cooperative Program to Assess Interference From Ultra Wide Band Technologies to the Global Positioning System

Per Enge, Konstantin Gromov and Jaewoo Jung, Stanford University
G. Roberto Aiello and Gerald D. Rogerson, Interval Research Corp.

***Abstract***: In time, ultra wide band (UWB) technologies will serve a wide variety of communication and ranging applications. UWB is based on very short pulses of radio energy and such signals serve particularly well in environments where multipath is likely or where super high resolution ranging is paramount. The signal can also be coded so that multiple UWB users can co-exist in close proximity; and the UWB signal has a very low power spectral density, so interference with existing radio systems is generally low.

However, potential interference from UWB to the Global Positioning System (GPS) is the most critical interference test. GPS commands this distinction for three reasons. First, it is a space-to-earth signal and the received signal only carries -164 dBW. Second, GPS presently serves around 8 million users including applications at sea, in the air, over land, and in space. Third, many of these applications are connected to the safety of the public. For example, GPS is used to guide ships while approaching harbor and navigating within narrow waterways. GPS also provides guidance to land emergency applications, such as ambulances and police cars, while they conduct their critical missions. In addition, GPS serves many aviation applications including the most demanding phase of flight – aircraft approach.

These safety-critical applications require the navigation system to be available continuously after any critical operation has been initiated. Most aircraft approach operations allow no more than one missed approach per 100,000 landings. Many commercial applications, such as the oil industry, also place a high value on the continuous availability of GPS. Today, radio frequency interference is probably the single greatest threat to this continuity of service. At the same time, most GPS applications require connection to a wider information infrastructure, and so the full utilization of GPS requires cost-effective, compatible communication.

For these reasons, Stanford University and Interval Research Corporation have embarked on a set of collaborative interference tests, and this paper will report on the design of those tests and provide preliminary results. In particular, we will report on the strong role of certain UWB signal parameters including pulse shaping, pulse repetition frequency, pulse dithering and pulse bursting.