UWB Poll Results

initiated and compiled by

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On March 25, 2004, we sent out questions to a group of people in the UWB community in an attempt to determine current perceptions and opinions of the state-of-the-art in UWB technology. The questions were generated by R. A. Scholtz with the assistance of Keith Chugg and Won Namgoong of USC and David Pozar of the University of Massachusetts. On April 8, 2004, the poll also was made available to the community at large by posting it on the UltRa Lab web site http://click.usc.edu/New_Site/, where it remained until June 1, 2004. Preliminary results were mentioned on May 19, 2004, at the IWUWBS&UWBST Conference in Kyoto, Japan.

The original mailing was as follows:

I'm writing to you to solicit your opinion of a few (15) questions about UWB technology. Please take a few minutes to respond to those questions that you feel comfortable in answering, and send your answers back to me at (e-mail: scholtz@usc.edu or FAX (213) 740-8729). Please rest assured that your answers will be confidential, and contribute only to a statistical summary of all replies received. You are welcome to forward this questionaire to other interested experts, grad students working on UWB radio, etc.

The results of this poll will be presented at my talk at UWBST&IWUWBS 2004
in Kyoto in May (see http://www1.ilcc.com/uwbst_iwuwbs2004/ for conference details). I will send results to all who participate in the survey after that meeting.

There is considerable leeway in interpreting questions, and we may just find out if the UWB community is composed of optimists or pessimists. You can use any means of arriving at the answers that makes sense to you, e.g., consideration of economic or political factors, technological problems, market factors, etc.

Here are the questions with 1-10 scoring scales:
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UWB Performance Issues
Scenario: Commercial/consumer indoor applications in the 3.1-10.6 GHz band.
Scoring: 10 = easy, 6 = possible with effort, 3 = needs major breakthroughs, 1 = impossible.
_____ 1Gbps data rate, in-room single-link operation
_____ 1 Gbps aggregate data rate to a single receiver in a multiple access environment
_____ Sub-centimeter ranging accuracy
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UWB Hardware Challenges
Scenario: CMOS or SiGe full-band implementation across the 3.1-10.6 GHz band.
Scoring: 10 = easy, 6 = possible now with effort, 3 = may be available in 5 years, 1 = impossible
_____ High-quality antenna (full-band)
_____ LNA (full-band)
_____ Transmitter (full-band)
_____ All-digital receiver (including correlators/matched filters, full-band)

_____ Hybrid receiver (full-band, analog correlators/matched filters)
_____ 500 MHz bandwidth all-digital receiver
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UWB Applications
Scenario: Viable business applications in the next 3 years.
Scoring: 10 = a sure money maker, 6 = competitive in the market place, 1 = a good way to lose money
_____ position location
_____ imaging through materials
_____ intrusion alarms
_____ personal area networks
_____ radio-frequency tags
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For communication purposes, which is the better UWB modulation format:
_____ direct-sequence impulse _____ OFDM
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Do you have a personal financial stake in the success of a UWB enterprise?
_____ YES _____ NO
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Thanks for your response!
Bob Scholtz

Responses

A total of 89 people responded to the poll. Their position and location are shown in the following table:

Respondents	*Pacific Rim*	*Europe*	*North America*	*Other*	*Total*
Faculty	9	6	14	0	29
Government Labs	9	0	3	0	12
Industry	4	2	11	1	18
Students	4	2	19	2	27
Anonymous	1	0	0	2	3
Total	27	10	47	5	89

The location *Pacific Rim* includes Australia, China, Japan, Korea, Singapore and Taiwan. The location *Europe* includes Austria, Great Britain, Germany, and Switzerland. The location *North America* includes Canada, Mexico, and the USA. The location *Other* includes anonymous responses as well as other countries.

Note that some respondents did not answer all of the questions, and some tended to use the scoring benchmarks given for the questions, resulting in many 3 and 6 ratings.

The tables below give the number of respondents that gave a particular technology attribute a given rating. The last column gives the average response, and the last row gives the results for all respondents. The standard deviation is stated for all responses.

UWB Performance Issues

Scenario: Commercial/consumer indoor applications in the 3.1-10.6 GHz band.
Scoring: 10 = easy, 6 = possible with effort, 3 = needs major breakthroughs, 1 = impossible.

Rating Counts for: 1Gbps data rate, in-room single-link operation

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	1	1	3	1	4	15	3	1	0	0	5.35
Government Labs	0	0	4	1	1	1	2	1	1	1	5.67
Industry	0	0	4	2	1	6	2	3	0	0	5.50
Students	0	0	4	2	2	10	2	3	2	2	6.15
Anonymous	0	0	0	0	0	2	0	0	0	0	6.00
Overall	**1**	**1**	**15**	**6**	**8**	**34**	**9**	**8**	**3**	**3**	**5.68**

Standard deviation 1.90

Rating Counts for: 1 Gbps aggregate data rate to a single receiver in a multiple access environment

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	0	1	13	5	3	6	0	0	0	0	4.00
Government Labs	0	0	5	0	1	5	0	0	0	0	4.55
Industry	0	1	6	3	3	5	0	0	0	0	4.28
Students	2	1	5	3	5	7	3	1	0	0	4.70
Anonymous	0	0	2	0	0	0	0	0	0	0	3.00
Overall	**2**	**3**	**31**	**11**	**12**	**23**	**3**	**1**	**0**	**0**	**4.33**

Standard deviation 1.53

Rating Counts for: Sub-centimeter ranging accuracy

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	1	0	7	0	2	8	2	5	1	1	5.67
Government Labs	1	1	2	1	1	2	1	1	0	1	5.00
Industry	1	2	5	2	2	4	1	0	0	0	4.06
Students	1	0	4	4	1	6	4	4	0	3	5.93
Anonymous	0	0	0	0	1	0	0	0	0	0	5.00
Overall	**4**	**3**	**18**	**7**	**7**	**20**	**8**	**10**	**1**	**5**	**5.33**

Standard deviation 2.33

UWB Hardware Challenges

Scenario: CMOS or SiGe full-band implementation across the 3.1-10.6 GHz band.
Scoring: 10 = easy, 6 = possible now with effort, 3 = may be available in 5 years, 1 = impossible

Rating Counts for: High-quality antenna (full-band)

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	2	0	5	1	1	10	5	2	0	0	5.27
Government Labs	1	1	2	0	1	4	2	0	0	1	5.17
Industry	0	0	2	2	3	3	1	2	1	3	6.41
Students	0	1	1	6	2	9	2	4	0	0	5.56
Anonymous	0	0	0	0	0	3	0	0	0	0	6.00
Overall	**3**	**2**	**10**	**9**	**7**	**29**	**10**	**8**	**1**	**4**	**5.60**

Standard deviation 2.04

Rating Counts for: LNA (full-band)

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	0	0	8	1	2	8	3	1	0	1	5.21
Government Labs	1	1	2	0	3	0	2	0	0	3	5.67
Industry	0	1	1	2	6	4	1	0	0	2	5.53
Students	0	0	4	4	3	10	2	0	0	0	5.09
Anonymous	0	0	0	0	1	2	0	0	0	0	5.67
Overall	**1**	**2**	**15**	**7**	**15**	**24**	**8**	**1**	**0**	**6**	**5.33**

Standard deviation 1.99

Rating Counts for: Transmitter (full-band)

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	0	0	5	2	0	14	1	3	0	1	5.69
Government Labs	1	1	0	3	0	4	1	0	0	2	5.50
Industry	0	1	3	1	4	4	1	0	1	2	5.59
Students	0	0	4	1	3	12	3	0	1	0	5.54
Anonymous	0	0	0	2	0	0	0	0	0	1	6.00
Overall	**1**	**2**	**12**	**9**	**7**	**34**	**6**	**3**	**2**	**6**	**5.61**

Standard deviation 2.01

Rating Counts for: All-digital receiver (including correlators/matched filters, full-band)

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	1	4	15	2	2	2	1	0	0	0	3.37
Government Labs	1	1	4	1	2	2	0	0	0	1	4.25
Industry	1	4	7	1	1	2	0	1	0	0	3.47
Students	1	2	9	1	5	4	1	1	2	0	4.54
Anonymous	0	0	1	1	1	0	0	0	0	0	4.00
Overall	**4**	**11**	**36**	**6**	**11**	**10**	**2**	**2**	**2**	**1**	**3.89**

Standard deviation 1.90

Rating Counts for: Hybrid receiver (full-band, analog correlators/matched filters)

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	0	0	3	3	3	12	2	2	1	1	5.81
Government Labs	0	1	1	0	4	5	1	0	0	0	5.17
Industry	0	0	4	1	4	5	2	1	0	0	5.18
Students	1	1	3	1	3	7	4	4	1	0	5.68
Anonymous	0	0	0	0	1	2	0	0	0	0	5.67
Overall	**1**	**2**	**11**	**5**	**15**	**31**	**9**	**7**	**2**	**1**	**5.55**

Standard deviation 1.72

Rating Counts for: 500 MHz bandwidth all-digital receiver

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	0	0	3	3	6	9	0	3	1	1	5.69
Government Labs	0	0	2	0	2	3	2	1	0	2	6.33
Industry	0	0	2	1	0	5	6	2	0	1	6.35
Students	0	1	3	1	1	11	1	2	4	2	6.35
Anonymous	0	0	0	1	1	0	1	0	0	0	5.33
Overall	**0**	**1**	**10**	**6**	**10**	**28**	**10**	**8**	**5**	**6**	**6.11**

Standard deviation 1.97

UWB Applications
Scenario: Viable business applications in the next 3 years.
Scoring: 10 = a sure money maker, 6 = competitive in the market place, 1 = a good way to lose money

Rating Counts for: position location

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	1	0	1	1	3	8	4	8	1	2	6.62
Government Labs	1	0	1	1	1	2	2	1	2	1	6.25
Industry	1	0	2	1	2	6	1	4	0	1	5.89
Students	0	0	0	1	1	4	3	8	3	6	7.88
Anonymous	0	0	0	1	0	1	0	0	0	0	5.00
Overall	**3**	**0**	**4**	**5**	**7**	**21**	**10**	**21**	**6**	**10**	**6.76**

Standard deviation 2.15

Rating Counts for: imaging through materials

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	0	0	4	3	2	13	2	4	0	1	5.79
Government Labs	0	1	0	0	1	4	2	2	0	2	6.75
Industry	2	1	0	2	4	3	1	2	0	3	5.72
Students	1	0	0	0	4	5	3	6	4	2	7.04
Anonymous	0	0	0	0	0	1	0	0	0	0	6.00
Overall	**3**	**2**	**4**	**5**	**11**	**26**	**8**	**14**	**4**	**8**	**6.28**

Standard deviation 2.17

Rating Counts for: intrusion alarms

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	5	3	1	0	3	7	2	5	0	2	5.18
Government Labs	0	0	0	0	2	5	1	1	0	2	6.82
Industry	3	1	1	2	3	5	1	2	0	0	4.67
Students	1	1	2	2	4	7	2	2	4	2	6.11
Anonymous	0	0	0	0	1	1	0	0	0	0	5.5
Overall	**9**	**5**	**4**	**4**	**13**	**25**	**6**	**10**	**4**	**6**	**5.58**

Standard deviation 2.50

Rating Counts for: personal area networks

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	2	2	1	1	0	10	5	4	2	2	6.14
Government Labs	0	1	0	1	0	2	2	2	1	3	7.25
Industry	0	0	0	2	0	6	2	2	2	4	7.33
Students	0	0	1	1	5	7	1	2	4	6	7.15
Anonymous	0	0	0	0	0	2	0	0	0	0	6.00
Overall	**2**	**3**	**2**	**5**	**5**	**27**	**10**	**10**	**9**	**15**	**6.84**

Standard deviation 2.27

Rating Counts for: radio-frequency tags

Respondents\Rating	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Mean*
Faculty	2	1	2	1	1	10	5	4	0	2	5.93
Government Labs	1	1	0	0	1	6	1	1	0	1	5.75
Industry	2	1	2	3	1	5	2	1	0	1	4.94
Students	0	0	1	0	2	5	2	11	2	2	7.32
Anonymous	1	0	0	0	0	0	0	0	0	0	1.00
Overall	**6**	**3**	**5**	**4**	**5**	**26**	**10**	**17**	**2**	**6**	**6.05**

Standard deviation 2.34

Answer Counts for the question: For communication purposes, which is the better UWB modulation format: direct sequence impulse or OFDM?

Respondents\Choice	*DS impulse*	*OFDM*
Faculty	12	15
Government Labs	3	8
Industry	6	8
Students	15	9
Anonymous	1	1
Overall Count	**37**	**41**
Overall Percentage	**47.4%**	**52.6%**

Of the 83 respondents that answered the question, "Do you have a personal financial stake in the success of a UWB enterprise?" 24% answered affirmatively.

Comments

Many of the questions in the poll were chosen because it was believed that there was no consensus on their correct answer. For example, that was obvious in the sub-centimeter ranging question where 4 respondents indicated that it was "impossible" and 5 indicated that it was "easy". On the average, the respondents were more optimistic (in the given numerical scales) about the selected business opportunities in the next few years than they were about technological questions, but not by much. However, for the most part, the standard deviations on technological questions were smaller than on business opportunity questions.

Notable difficult technological issues in the views of the respondents are:

- Achieving 1 Gbps aggregate data rate to a single receiver in a multiple access environment (mean = 4.33) This evaluation also had the lowest standard deviation (1.53), indicating relatively good agreement among the respondents.
- Building an all-digital receiver including correlators/matched filters, that employs the full FCC allocated band from 3.1 to 10.6 gigahertz (mean = 3.89)

Most other technical objectives have an average rating of well over 5, indicating that most feel that these objectives have been achieved or are nearly achievable, and hence their occurrence is primarily a matter of time and effort.

The most fruitful business opportunities in the eyes of the respondents are in applications to position location and personal area networks, though 4 of the 5 questioned areas are rated on the average as at least "competitive in the market place". The lone application rated below 6 is intrusion alarms, where there probably is stiff competition with established technologies.

The question of the better modulation format for UWB communication, namely DS-impulse or OFDM, is not resolved by this poll, just as it has not been resolved in the IEEE 802.15.3 standards committee.

Data was collected with regard to the geographic distribution of respondents. We have not analyzed the results to determine if there is a geographic bias, but collected the information to give the readers of the poll a feeling for the breadth of participation.

Thanks to all who have responded to this poll. Your efforts are very much appreciated!