Future Wireless Based on SDR and UWB
Latest Wireless Technologies:
Software Defined Radio (SDR) and Ultra Wideband (UWB) Wireless Communications

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National Institute of Information and Communications Technology (NiCT)
Chairman
IEICE SDR Technical Committee, Japan
Future Wireless Based on UWB and SDR

Agenda

1. Trends of Wireless Communications
2. State of Arts for SDR (Software Defined Radio) and Anticipation of SDR Evolution
3. State of Arts for UWB (Ultra Wideband) Radio and Anticipation of UWB Evolution
Current Wireless Communication Networks

Office Networks (Wireless LAN etc).

Home Networks.

Mobile Networks.

Machine Networks.

Home Link

ITS (Intelligent Transport Systems).

Vehicle-to-Roadside.

Inter-Vehicle Communication

Current Wireless Communication Networks

Office Networks

(Without LAN etc).

Home Networks.

Mobile Networks.

Machine Networks.

ITS (Intelligent Transport Systems).

Vehicle-to-Roadside.

Inter-Vehicle Communication
Wireless Infrastructure and Ad-Hoc Communication Networks

2. **Multimedia Mobile Access Control Systems**: 4G (B3G) (MMAC, BRAN, U-NII, E2R)
3. **Digital Terrestrial TV Broadcasting System** (DAB, DVB, DMB)
4. **Intelligent Transport System** (ITS: ETC, DSRC, Car LAN)
5. **Wireless Local Loop**: (WLL)
6. **Wireless LAN**: (WiFi, WiMax, Bluetooth, IEEE802.11a,b,g,n,p)
7. **Home Network**: (ADSL, FTTH, Wireless 1394, Wireless USB)
8. **Wireless PAN**: (WPAN over UWB: IEEE802.15.3a, 3c)
9. **Sensor Network**: (RFID Tag, Zigbee, IEEE802.15.4a)
Core Physical Layer Techniques for Wireless Communication Systems

1. Spread Spectrum (CDMA, Radar)
2. Adaptive Array Antenna (Smart Antenna, MIMO)
3. Multi-Carrier Modulation (OFDM)
4. Channel Coding (Turbo Coding and Decoding, Space-Time Coding, Network Coding)
7. Ultra Wide Band (UWB) by Impulse Radio and others
### Core PHY Technologies Satisfying Multiple Demands in Wireless Communications

1. **Countermeasure against Fading**
   - Equalization, Diversity, EC Code, Antenna, etc.

2. **Ranging and Positioning**
   - Radar, Navigation, Roaming

3. **Recognition and Control of an Object**
   - Environment and Circumstance Observation, Sensor, Adaptive Control

4. **Information Security & Authentication**
   - Information of Charge, Protection of Privacy, Countermeasure against Terrorism

5. **Human Interface**
   - Driving Assist (handicapped) and Better QoS

6. **Interference Suppress & Diversity Gain**
   - Improving S/I+N and User Capacity

7. **Adaptability and Reconfigurability**
   - Adapting Environment and Multimode Service

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**Spread Spectrum & UWB technique**

**Array Antenna & MIMO technique**

**Software Defined Radio (SDR) technique**
Future Wireless Based on UWB and SDR

Agenda

1. Trends of Wireless Communications
2. State of Arts for SDR (Software Defined Radio) and Anticipation of SDR Evolution
3. State of Arts for UWB (Ultra Wideband) Radio and Anticipation of UWB Evolution
Balance between Integration and Personalization of Networks

**IP-base Network**

**Satellite/HAPS**
- F-PACH
- S-UMTS

**Broadcasting**
- DAB
- DVB-S
- DVB-T
- Satellite Broadband
- EGPRS
- UMTS
- UMTS++
- EDGE
- GPRS
- ISDN

**Cellular**
- GSM
- CDMA2000
- HDR
- MBS 60
- MBS 40
- IS-95
- CDMA 95
- MBS 40
- MBS 60

**Wireless Local Loop**
- Body LANs
- Personal Networks
- WLL
- FWA
- WFA
- MWS
- xMDS
- Quasi-Cellular
- Cellular
- Broadband WFA
- MBS 60
- MBS 40
- Local Area Networks
- Wireless Local Loop

**Balance between Integration and**
**Personalization of Networks**

**Satellite Broadband**
- SS-UMTS
- SS-DVBDVBDSS-UMTS

**Broadband**
- xDSL
- ISDN
- IPV4
- IPV6
- F-Wowość
- Power Line Communication
- MobileIP
- VIP
- BRAN
- MMAC
- IEEE 802.11a/b
- IR
- Bluetooth
- IS-95
- IPv6
- IPv4
- GPRS
- GPRS
- UMTS
- JSR
- CDMA2000
- IPv4
- IPv6
- PDSN
- IPv6
- IPv4
- MBS 60
- MBS 40
- MWS
- xMDS
- Quasi-Cellular
- Wireless Local Loop

Ryuji Kohno's Properties, Confidential

Colloquium, Institute EUROCOM, France, June 23, 2005
<Integration of Networks>

• **IP-base**
  (Voice over IP, Internet TV, Mobile IP, ….)

<Personalization of Network>

Software Reconfigurable Radio
Software Defined Radio (SDR)

SDR is a broad concept that all functions of wireless communications like bands, modulation and coding scheme, protocol can be reconfigured with software including all-digital transceivers and software-based adaptability for multi-purposes and multi-applications in multi-environments.

【Necessary Properties】
1. Broadband & Multi-band for Multi-mode Service
2. Re-configurability of System Hardware
3. Downloadability of System Configuration Software
4. Adaptability for Environment

- Huge Demands for Broadband Wireless Communications
- Co-exit of Various Wireless Systems
- Space Division (SDMA) Based on Beamforming
- Omit of IF Circuits (Direct Conversion)
- Software Reconfigurability (Re-Configuration)
- Inter-System Interference
- Low Power Consumption
- Demand for Multi-Mode
- Software Antenna
- Software Defined Radio (SDR)
Multi-mode Reconfigurable Radio System

Download of system software to change system configuration

Device is reconfigured as
a wireless LAN terminal
Multi-mode Reconfigurable Radio System

Device is reconfigured as a **TV receiver**

Device is reconfigured as a **car navigation system**

Device is reconfigured as a **cellular phone**

Device is reconfigured as a **wireless LAN terminal**
Software Reconfigurable TV Broadcasting Terminal (Using MPEG-2 standard)

- BS/CS compatible antenna
- UHF antenna
- BS tuner (channel selection part)
- CS tuner (channel selection part)
- Terrestrial tuner (channel selection part)
- CATV
- Digital demodulation 1 (BPSK, QPSK, 8PSK)
- About 2000KG
- Digital demodulation 2 (OFDM)
- About 5000KG
- Digital demodulation 3 (64QAM)
- About 1000KG
- MPEG decoder
- Image speech data decode & OSD
- DE MUX
- About 10MB
- Firmware
- About 100KG
- System CPU (64bitRISC)
- About 100KG
- Inner Code correcting
- FEC (trellis) (viterbi)
- Outer Code correcting
- ECC (RS)
- CA descrambler
- About 100KG
- About 200KG
- About 500KG
- Compatible element
- Memory
- About 1MB
- Speech data
- About 100KG
Software Reconfigurable ITS Terminal

- TV receiver
- VICS receiver
- TV broadcast station
- VICS beacon antenna
- TV car-mounted antenna
- FM radio car-mounted antenna
- Cellular phone car-mounted antenna
- FM radio receiver
- Celluar phone terminal

Bandwidths:
- 800MHz band
- 1.5GHz band
- 90-700MHz band
- 2.5GHz band
- 76-90MHz band
### Table 2: Examples of Multimode Terminals

<table>
<thead>
<tr>
<th>Systems</th>
<th>Demand</th>
<th>Commonality</th>
<th>Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDC+PHS</td>
<td>Already Exists</td>
<td>FDD/TDD</td>
<td>800M/1.5G/1.9G</td>
</tr>
<tr>
<td>PDC+GPS</td>
<td>Already Exists</td>
<td>TDMA/SS</td>
<td>800M/1.5G</td>
</tr>
<tr>
<td>PDC+3G</td>
<td>Both cover nationwide</td>
<td>TDMA/CDMA</td>
<td>800M/1.5G/2G</td>
</tr>
<tr>
<td>3G+4G</td>
<td>Complementary</td>
<td>? CDMA/?</td>
<td>? 2G/3-10G</td>
</tr>
<tr>
<td>3G+WLAN11b</td>
<td>Seamless coverage</td>
<td>CDMA/SS</td>
<td>2G/2.4G</td>
</tr>
<tr>
<td>4G+WLAN11a</td>
<td>Seamless coverage</td>
<td>OFDMA/OFDM</td>
<td>4G/5.2G</td>
</tr>
<tr>
<td>DSRC+WLAN11a</td>
<td>Seamless coverage</td>
<td>QPSK/OFDM</td>
<td>5.8G/5.2G</td>
</tr>
<tr>
<td>3G+4G+WLAN+WPAN</td>
<td>Seamless coverage</td>
<td>? CDMA/OFDM/?</td>
<td>? 2G/5.2G/3-10G</td>
</tr>
</tbody>
</table>
Demands for SDR in Beyond 3G

- Software radio is one of key technology to realize next generation (beyond 3G) mobile communication systems from the viewpoint of:
  - Remote Maintenance without recall (Bug fix)
  - Reduction of industrial waste
  - Frequency re-allocation (viewpoint of regulation)
  - Coexistence between old and new systems
    - Communication systems on demand
Applications of Software Defined Radio

- Broadcasting (BS, CS, Terrestrial, CATV)
- Wireless LAN (Bluetooth, IEEE802.11a, b)
- Satellite and Space Communications
- Mobile Communications
  - Intelligent Transport Systems
    - ITS
      - Positioning, Ranging, ETC, VICS, IVC
      - Detecting Illegal radio
      - Medical Services (ICU,)
      - Tele-metering, Tele-control
      - Wireless LAN (Bluetooth, IEEE802.11a, b)
- FWN (Fixed Wireless Network)
- Broadcasting
SDR Forum

http://www.sdrforum.org/

- Non-profit organization in the USA to promote SDR
- Proposing a CORBA-based SDR system architecture
- Starting members were involved in the Speakeasy project in USA

<Major Purposes>
1. **Standard of API** (Application Program Interface) for common interfacing among various modules of SDR terminal.
2. **Standard of download procedure** for SDR services
IEICE Software Radio Technical Committee
(http://www.ieice.or.jp/cs/sr/jpn/index-e.html)

- **Society:** IEICE Communication Society
- **Established:** December, 1998
- **Discussion Topics:**
  - Theory on SDR
  - Software and hardware technology for SDR
  - Applications of SDR
  - Research on APIs (Application Programmable Interface)
  - Standardization for SDR
  - Collaboration and cooperation with active organizations in other countries such as SDR-Forum
Members of the IEICE Software Radio Technical Committee

<table>
<thead>
<tr>
<th>Chair:</th>
<th>Ryuji Kohno</th>
<th>Yokohama Nat. Univ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vice-Chairs:</td>
<td>Kazuhiro Uehara</td>
<td>NTT</td>
</tr>
<tr>
<td></td>
<td>Masaaki Katayama</td>
<td>Nagoya Univ.</td>
</tr>
<tr>
<td>Secretaries:</td>
<td>Hiroshi Harada</td>
<td>NICT</td>
</tr>
<tr>
<td></td>
<td>Yokitoshi Sanada</td>
<td>Keio Univ.</td>
</tr>
<tr>
<td></td>
<td>Hiroshi Tsurumi</td>
<td>Toshiba</td>
</tr>
<tr>
<td></td>
<td>Junichi Takada</td>
<td>Tokyo Inst. Tech.</td>
</tr>
<tr>
<td></td>
<td>Atsuya Yokoi</td>
<td>Sunsong</td>
</tr>
<tr>
<td>Members:</td>
<td>Yoshi Akaiwa</td>
<td>Kyushu Univ.</td>
</tr>
<tr>
<td></td>
<td>Osamu Atsumi</td>
<td>Sangikyo</td>
</tr>
<tr>
<td></td>
<td>Nobukazu Doi</td>
<td>Hitachi</td>
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<tr>
<td></td>
<td>Kiyomichi Araki</td>
<td>Tokyo Inst. Tech.</td>
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<tr>
<td></td>
<td>Tetsushi Ikegami</td>
<td>Meiji Univ.</td>
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<td></td>
<td>Hiroyuki Ishii</td>
<td>NEC</td>
</tr>
<tr>
<td></td>
<td>Teruo Ohnishi</td>
<td>Ericson Japan</td>
</tr>
<tr>
<td></td>
<td>Yoshitaka Ogawa</td>
<td>Hokkaido Univ.</td>
</tr>
<tr>
<td></td>
<td>Yoshio Karasawa</td>
<td>Univ. Electro-Comm.</td>
</tr>
<tr>
<td></td>
<td>Takashi Ohira</td>
<td>ATR Lab</td>
</tr>
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</table>

Kei Sakaguchi Tokyo Inst. Tech.
- keiki Fujii Tokyo Nougou Univ.
- Tatu Koljonen Nokia Japan
- Mamoru Sawahashi NTT DoCoMo
- Shintaro Taira National Defense Agency
- Masao Nakagawa Keio Univ.
- Yoshio Nakamura Tohoku Univ.
- Tatsuaki Sakai KDDI
- Masachika Harada T.I Japan
- Takuzo Fujii Hitachi Kokusai
- Toshiiharu Kojima Mitsubishi
- Kouichi Honma Panasonic
- Masakazu Sampei Osaka Univ.
- Hitoshi Murata Kyoto Univ.
- Hiroyuki Morikawa Univ. Tokyo
- Daisaku Yamane JRC
- Osaka Univ.
- Kyoto Univ.
- Univ. Tokyo
- JRC
- MITRE
- enVia, Inc.
Activities of IEICE Software Radio Technical Committee in 1999

- **January 27**: The first technical committee meeting (Tokyo)
- **March 11**: The first technical conference: Joint Workshop (Yokusuka Research Park: YRP) together with the SDR Forum (March 9-11).
- **June 30**: 2nd technical conference (Osaka)
- **September**: Panel session was held in the PIMRC‘99 conference (10th International Symposium on Personal, Indoor and Mobile Radio Communications)(Osaka)
- **November 17**: 3rd technical conference (Nagoya)
Activities of IEICE Software Radio Technical Committee in 2000

- April 11-13: SDR Workshop (Seoul, Korea)
- April 17: 4th technical conference: Joint Workshop (Yokosuka Research Park: YRP) together with the SDR Forum.
- May 16: Panel session at VTC spring (Vehicular Technology Conference) 2000 (Meridian Pacific Hotel Shinagawa, Tokyo)
- June: Publication of the special Issue on SDR in IEICE Trans. on Communications (English Volume)
- July 21: 5th technical conference (Keio Univ., Yokohama)
- September 13-15: Tyrrhenian Workshop on SDR (Italy)
- September 30: Panel session in IEICE Annual Conference (Nagoya Inst. Tech., Nagoya)
- October 20: 6th technical conference and Technical Exhibition (NTT Musashino, Tokyo)
Research Trend in 1\textsuperscript{st} Stage

\textbf{Before 2001 (from Activities of IEICE SR-TC)}

- Introduce software radio, Search research items, and applications
- Developed key technologies
  - Broadband and multipurpose receivers
    - Direct conversion, Low IF
  - \textit{Software processing (adaptive) antenna}
  - \textit{Broadband and multipurpose analog-to-digital converter}
    - Effect of resolution of AD converter to Digital signal procession hardware
    - Adaptive multi-sampling method
  - Configuration of software
    - Software architecture
    - Flexible synchronization method, adaptive coding and decoding technique
  - Software download method
    - \textit{Download protocol}
    - Software architecture to reduce the volume of software
  - \textit{Auto-recognition of modulation scheme}
- Development of prototype systems
## Prototypes 1

<table>
<thead>
<tr>
<th>Affiliation</th>
<th>Name</th>
<th>Configuration</th>
<th>Application</th>
<th>Coverage</th>
<th>Processing frequency</th>
<th>IF frequency</th>
<th>Channel bandwidth</th>
<th>Transmission speed</th>
<th>Modulation scheme</th>
<th>DAC/ADC</th>
<th>DSP power</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RF part (PHS,GPS,ETC), IF/ADC/DAC part, FPGA/DSP part, Control part</td>
<td>Software Radio Base Station and Terminal for Cellular &amp; Ad-hoc networks</td>
<td>27,900,500,2000 MHz</td>
<td>32 kHz</td>
<td>10MHz(PHS),40MHz(ETC)</td>
<td>384kbps(PHS),1023Mcps(GPS),1024kbps(ETC),384,270,833kbps(User)</td>
<td>BPSK, QPSK, pi/4QPSK, GMSK, FM, AM</td>
<td>None / 5 M sample (12bit)</td>
<td>1600*4 MIPS</td>
<td>MUSIC, DCMP algorithm included</td>
<td></td>
</tr>
<tr>
<td>NICT(1999) *CRL</td>
<td></td>
<td>RF/IF part, ADC/DAC part, pre/post processor part, DSP part, IF part, CPU part</td>
<td>Software Radio ITS Multimode Terminal</td>
<td>1900,1500,5200MHz 帯</td>
<td>2048kHz</td>
<td>25,39MHz</td>
<td>2048kHz (MAX)</td>
<td>384kbps(PHS),96kbps (quasi cellular communication)</td>
<td>Pi/4QPSK(PHS), BPSK, GMSK, pi/4QPSK,</td>
<td>50 Mbps (14bit) / 60 Mbps (10bit)</td>
<td>1600*4 MIPS</td>
<td>Baseband over-sampling</td>
</tr>
<tr>
<td>NTT(1999)</td>
<td></td>
<td>RF part, Direct conversion receiver part, transmission part, ADC/DAC part, DDC part, DSP part</td>
<td>Surveillance to Detect Illegal Radio</td>
<td>2.45GHz</td>
<td>13MHz</td>
<td>300KHz(PHS),75kHz</td>
<td>384kbps(PHS),270.833kbps(GSM),42kbps (PDC)</td>
<td>Pi/4QPSK(PHS), BPSK, GPS, ASK(ETC), QPSK, GMSK, pi/4QPSK</td>
<td>27,900,500,2000 MHz带</td>
<td>1MHz (TX), 10MHz (RX)</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Toshiba(1999)</td>
<td></td>
<td>Antenna part, Direct conversion receiver part, transmission part, ADC/DAC part, DDC part, DSP part</td>
<td>PHS, quasi cellular communication</td>
<td>1.5～2GHz</td>
<td>25MHz</td>
<td>25～192kHz</td>
<td>8.6,32 kbps</td>
<td>384kbps(PHS),1023Mcps(GPS),1024kbps(ETC),384,270,833kbps(User)</td>
<td>BPSK, QPSK, pi/4QPSK, GMSK, FM, AM</td>
<td>50 Mbps (14bit) / 60 Mbps (10bit)</td>
<td>1600*4 MIPS</td>
<td>Software Radio Prototype by Direct Conversion</td>
</tr>
</tbody>
</table>
Examples of the Prototype Software Radio Hardware Developed in Japan

Fig. 1 Block Diagram of prototype SDR receiver for ARIB.
# Prototypes 2

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyo communication Equipment and Tohoku electronics power company (1999)</td>
<td>Intelligent Base Station</td>
<td>Software Radio prototype</td>
<td>Software Receiver</td>
</tr>
<tr>
<td>Configuration</td>
<td>RF part, ADC/DAC part, DSP part, ADC/DAC part, DSP part, I/F part, CPU part, monitor</td>
<td>ADC/DAC/FPGA part, DSP part, I/F part, control part</td>
<td>RF part, signal processing part (ADC+DSP+CPU), control part</td>
</tr>
<tr>
<td>Sampling</td>
<td>IF under sampling</td>
<td>IF under sampling</td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td>IF under sampling</td>
<td>PHS (Layer 1)</td>
<td></td>
</tr>
<tr>
<td>Coverage</td>
<td>370-380 MHz</td>
<td>25MHz-3GHz</td>
<td></td>
</tr>
<tr>
<td>Processing frequency</td>
<td></td>
<td>10MHz</td>
<td></td>
</tr>
<tr>
<td>IF frequency</td>
<td>TX:10-20MHz, RX:65-75MHz</td>
<td>455kHz-100MHz</td>
<td>21.4MHz</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>TX:1.25MHz, RX:650kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission speed</td>
<td>50bps-64kbps</td>
<td></td>
<td>384kbps (PHS)</td>
</tr>
<tr>
<td>Modulation scheme</td>
<td>pi/4QPSK,FM</td>
<td>FSK, BPSK, QPSK, 6QAM, AM, FM, SSB</td>
<td>BPSK, QPSK, pi/4QPSK, 8PSK, 6QAM, FSK, MSK, GMSK, AM, FM</td>
</tr>
<tr>
<td>DAC/ADC</td>
<td>40 MspS(12bit)/ 40 MspS(12bit)</td>
<td>125 MspS(14bit)/65 MspS(12bit) MAX</td>
<td>None/40 MspS(12bit)</td>
</tr>
<tr>
<td>DSP power</td>
<td>320 MFLOPS/board</td>
<td>3200 MIPS/module</td>
<td>1200 MFLOPS</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Identification algorithm of modulation schemes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activities of IEICE Software Radio Technical Committee in 2001

- **Feb.6:** Publication of *Two Years Activities Report of SR-TG IEICE in Communication Society Steering Committee Meeting*
- **March 26-29:**
  1. Panel session on Applications of SDR
  2. Symposium on Latest Technologies of SDR in *IEICE Annual Conference* (Ritsumeikan University, Kusatsu)
- **April 26:** 7th technical conference: Joint Workshop (IEICE Headquater, Kikaishiko-Kanikan, Tokyo) together with the SDR Forum (April 24-26)
- **July:** Publication of *the special Issue on SDR in IEICE Trans. on Communications (Japanese Volume)*
- **September 18-21:**
  1. Panel session on SDR
  2. Technical Session on Latest Technologies of SDR in *IEICE Joint Societies Conference* (Univ. Electro-Communications, Tokyo)
- **October 17:** *FCC-MPHPT SDR Workshop* (MPHPT headquater, Tokyo)
- **October 18:** 8th technical conference (CRL, Tokyo)
- **December 14:** 9th technical conference (Kyushu Univ., Fukuoka)
## Prototypes 3

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Software Radio Prototype for ITS</td>
<td>Software Radio Base Station and Terminal</td>
<td>Software Radio Universal Platform (SOPRANO)</td>
</tr>
<tr>
<td>Configuration</td>
<td>RF part (PHS,GPS,ETC), IF/ADC/DAC part, FPGA part, Control part</td>
<td>RF/IF part, ADC/DAC part, pre/post processor part, DSP part, IF part, CPU part</td>
<td>RF part, signal processing part, control part</td>
</tr>
<tr>
<td>Sampling</td>
<td>IF under-sampling</td>
<td>IF under-sampling</td>
<td>BB Over Sampling</td>
</tr>
<tr>
<td>Application</td>
<td>ETC,VICS,AM/FM radio,FM Multiple Service GPS( Fully installed), PHS,GSM (Layer 1), User</td>
<td>PHS,IEEE802.b Wireless LAN (Fully installed)</td>
<td>Triple Mode WLAN</td>
</tr>
<tr>
<td>Coverage</td>
<td>5.8GHz,1.5GHz, 76-00MHz, 0.5-.6MHz</td>
<td>1.519,2.45GHz</td>
<td>2.45GHz,5.25GHz</td>
</tr>
<tr>
<td>IF frequency</td>
<td>70kHz-5MHz</td>
<td>66 MHz</td>
<td>None</td>
</tr>
<tr>
<td>Transmission speed</td>
<td>1023Mcps(GPS),1024kbps(ETC),384kbps(PHS), 270.833kbps(GSM)</td>
<td>384kbps(PHS),96kbps (IEEE802.11b )</td>
<td>Signals with its bandwidth of 15 MHz</td>
</tr>
<tr>
<td>Modulation scheme</td>
<td>ASK(ETC),BPSK+SS(GPS),QPSK,GMSK, Pi/4QPSK, BPSK</td>
<td>Pi/4QPSK(PHS),CCK-SS(IEEE802.11b )</td>
<td>BPSK,QPSK,8PSK,16QAM,64QAM</td>
</tr>
<tr>
<td>DAC/ADC</td>
<td>20 Mps(14bit)/20 Mps(10bit)</td>
<td>88Mps(14bit)/88Mps(12bit)</td>
<td></td>
</tr>
<tr>
<td>DSP power</td>
<td>Only FPGAs</td>
<td>1600*4 MIPS</td>
<td></td>
</tr>
<tr>
<td>Characteristics</td>
<td>Simultaneous processing (MAX 5 systems), Parameter controlled circuit, Small size, 12V-2A</td>
<td>Flexible Rate Pre/Post Processor</td>
<td>Broadband Direct Conversion Based on Multi-Port Junction MMIC ( Zero IF) (500MHz-9GHz)</td>
</tr>
</tbody>
</table>
First Prototype of Software Radio Receiver in SONY CSL/ATL

**SOPRANO 1.1**

1. **Hardware Platform**: SDR Platform which demodulates received signal of dual band in 2.45GHz and 5.25GHz and was operated by 5-port Junction Direct Converter with broadband (500MHz--9GHz) and low power consumption.

2. **Software Platform**: Software design framework of baseband circuit through system high-level language (C++, System C) to circuit implementation.
NICT’s Development of SDR prototype for new generation mobile communication systems

- Consists of general-purpose FPGA, CPU, and RF boards
- Software modules for W-CDMA and IEEE802.11a is prepared
- Layer 1, 2, and 3 for both systems are completely implemented
- SDR can communicate with W-CDMA BTS and access point for wireless LAN
- Communication systems can be changed manually or automatically

Developed by Dr. Hiroshi Harada, Leader of Wireless Access Group, Yokosuka Radio Communications Research Center, National Institute of Information and Communications Technology (NICT)
FPGA board, CPU board, and RF board
<table>
<thead>
<tr>
<th>Item</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FPGA board</strong></td>
<td></td>
</tr>
<tr>
<td>ADC</td>
<td>2ch/170 Msps/12bit/0dBm input</td>
</tr>
<tr>
<td>DAC</td>
<td>2ch/500 Msps/12bit/0dBm output</td>
</tr>
<tr>
<td>FPGA</td>
<td>Xilinx XC2V4000, 6000, 8000 (selectable)</td>
</tr>
<tr>
<td>IF to RF board</td>
<td>Analog in (2ch)/Analog out(3ch)/Cont(5bit)</td>
</tr>
<tr>
<td>External clk I/F</td>
<td>Input 5M-66MHz, 0dBm</td>
</tr>
<tr>
<td></td>
<td>2, 4, 8, 16 times clk generate automatically</td>
</tr>
<tr>
<td>External output</td>
<td>CPU-IF (Max 80Mbyte/s)</td>
</tr>
<tr>
<td></td>
<td>External output(Max 600Mbyte/s)</td>
</tr>
<tr>
<td><strong>CPU board</strong></td>
<td></td>
</tr>
<tr>
<td>CPU</td>
<td>430 MIPS (240MHz) ÷ 2</td>
</tr>
<tr>
<td>OS</td>
<td>-ITRON (PrKERNEL v 4)</td>
</tr>
<tr>
<td>I/O</td>
<td>Compact Flash, RS232C, USB, Ethernet/J TAG</td>
</tr>
<tr>
<td>RF boards</td>
<td>5 GHz band board + 2 GHz band board</td>
</tr>
</tbody>
</table>
Activities of IEICE Software Radio Technical Committee in 2002

- **March 27-30**: IEICE Annual Conference (Waseda University, Tokyo)
  1. Panel session on Applications of SDR
  2. Symposium on Latest Technologies of SDR
- **March 29**: Publication of the special Issue on SDR in IEICE Trans. on Communications (English Volume) in December
- **April 16-18**: SDR Forum in National Science Academy, Tokyo
- **April 19**: 10th technical conference (Will-Aichi, Nagoya)
- **July**: 11th technical conference (Sumson Lab, Yokohama)
- **September 18-21**: IEICE Joint Societies Conference (Univ. Electro-Communications, Tokyo)  
  1. Panel session on SDR
  2. Technical Session on Latest Technologies of SDR
- **October 27-30**: WPMC’02 (Hawaii, USA) Keynote & Panel on SDR
- **November 6-8**: ITST2002 (Seoul, Korea) Talk on SDR for ITS
- **November 11-12**: 2002 Software Defined Radio Technical Conference and Product Exposition (SDR’02) in San Diego, USA
- **December 13**: 12th technical conference (ATR Lab, Kyoto)
Activities of IEICE Software Radio Technical Committee in 2003

- March 19-22: IEICE Annual Conference (Tohoku University, Sendai)
  (1) Panel session on Applications of SDR
  (2) Symposium on Latest Technologies of SDR
- March 28: Publication of the special Issue on SDR in IEICE Trans. on Communications (English Volume) in December
- April 14: SDR Forum in Mita Hall, Keio University, Tokyo
- June 27: 13th technical conference (Ritsumeikan University, Shiga)
- September 22-26: IEICE Joint Societies Conference (Niigata University, Niigata)
  (1) Panel session on SDR
  (2) Technical Session on Latest Technologies of SDR
- September: SDR Forum in Paris
- October 19-22: WPMC’03 (Yokosuka, Japan) Panel & Technical sessions on SDR
- October 12-18: ITU TelecomWorld’03 (Geneve, Switzerland) Invited speech on Future Wireless with SDR and UWB
- October 30: SDR Seminar (Shinchu, Taiwan) Intro. Japanese Activities
- November 17-20: 2003 Software Defined Radio Technical Conference and Product Exposition (SDR’03) in Orlando, USA
- December 9: 14th technical conference (Tokyo NoKo University, Tokyo)
Activities of IEICE Software Radio Technical Committee in 2004

- March 22-25: IEICE Annual Conference (Tokyo Institute of Technology, Tokyo)
  (1) Panel session on Applications of SDR
  (2) Technical Sessions on Latest Technologies of SDR
- May 7: 2004 Workshop on Smart antenna and SDR in cooperation with SDR Forum, Hanyang University, Seoul in Korea
- May 31: 15th technical conference (Toshiba Training Center, Shiyokohama)
- September 21-24: IEICE Joint Societies Conference (Tokushima University, Tokushima)
  (1) Tutorial Session on SDR
  (2) Technical Sessions on Latest Technologies of SDR
- September 12-15: WPMC’04 (Abano Terme, Italy) Panel & Technical sessions on SDR
- October 10-13: ISITA2004 (Parma, Italy) Technical Sessions on SDR
- October 29: 16th technical conference (Nagoya University, Nagoya)
- November 15-17: 2004 Software Defined Radio Technical Conference and Product Exposition (SDR’04) in Phoenix, USA
Developed Key Technologies for SDR Systems

(Part 1)

(1) Antenna

- **Phased array antenna** in which phase of received signals in each element antenna can be controlled to design beamform.
- **Adaptive array antenna** is which both phase and amplitude can be adaptively controlled for adaptive beamforming.
- Antenna spacing of adjacent elements is used to be half a wavelength, so these are implemented with micro-strips for millimeter waves.
- **Digital Beam Forming (DBF)** for Multi-band or Broadband Software Reconfigurable Antenna

Space-Time Signal Processing

- **Digital Beam Forming (DBF)** Adaptive array antenna can digitize signals received at each element and control beamform or antenna pattern with software algorithm.
- **MIMO, Space-Time Coding** & Space Division Multiple Access (SDMA) Software antenna can distinguish multiuser signals in space domain and enable to Multiple Access in space domain.
Smart Antenna: Adaptive Array Antenna

Adaptive array antenna can suppress undesired signal waves by beamforming or directivity in spatial domain.

Spatial Filter, Array Sensor

Adaptive Array Antenna: Software Antenna

Software Radio
Creation of Future Social Infrastructure Based on Information Telecommunication Technology

Yokohama National University Colloquium, Institute EUROCOM, France, June 23, 2005

Mobile Station
HUB Station

Both Station located in Academia - Industry Collaboration Center

VSAT antenna + Transceiver
DBF array antenna + Receiver

Uplink: 30GHz
Downlink: 20GHz

1.8m Parabolic Antenna

Geostationary Satellite (Ka-band)

Project on Mobile Satellite Communication Systems Using Ka-band with Ministry of Posts and Telecommunications in Kohno Lab of Yokohama National University
Mobile Station of Mobile Satellite Communication System
Using Ka-band in Yokohama National University

Refrection Antenna
Developed Key Technologies for SDR Systems (Part 2)

(2) AD Conversion Technique

- **Quadrature Sampling** … demodulating IF signal as 2 channel with two low-speed ADC
- **Bandpass Sampling** … Under sampling band limited IF signal and changing into base-band
- **Super-fast sampling ADC by the superconductive device**

(3) Digital Signal Processing Technologies: DSP, FPGA, ASIC etc

(a) **DSP** can perform adaptive signal processing but processing speed should be improved higher.
(b) **FPGA** can perform fast signal processing but reconfigurability should be improved.
(c) **Software Reconfigurable LOGIC**

Example: **Quicksilver Technology**, **MorphICs**
(4) RF Circuit Technique
(a) Linearity of PS (Phase Shifter), ATT (Attenuator) and LNA (Low Noise Amplifier) should be calibrated when array weights are controlled in analogue.
(b) The dynamic range of the MMIC should be wide enough to avoid the design which requires an experience in RF.
(c) Power consumption increase in Wideband RF Circuit
   RF performance declines, because the third inter-modulation distortion and dynamic range becomes worse.
(d) Direct Conversion
   RF signals are directly converted into baseband signals instead of complex IF transform (Circuit simplify, Possible to generalize)

(5) RF Analog Processing
(a) Analog Adaptive or Tunable Antennas and Filters is developed for multi-band service.
(b) Analog processing and LOGICS in RF can reduce digital processing in baseband and improve real-time reconfigurability.
Remained Research Issues for Software Reconfigurable Radio and Networks

1. Mass Production of **Software Reconfigurable antenna**, RF module and baseband LOGIC
2. Description Language and module definition for **Standardization of API**
3. Inter-operable OS for **Multiple Processors**
4. **System Handover** for Transparency of Various Networks
5. **Secure Protocol for System Software Download**
6. **End-to-end Reconfigurabilty** (E2R) via Various Networks
Research on SDR in Yokohama National University

- Kenta UMEBAYASHI
  - Concept of Universal radio in SDR
  - Multimode PLL for carrier recovery and modulation identification

- Kentaro IKEMOTO
  - Adaptive Modulation & Channel Coding Technique
  - Modulation & Channel Coding Identification Technique
  - Channel and System Sensing for SDR+UWB communication system

- Kazuyuki OKUIKE
  - On-Board Automatic Certification System (ACS) for Type-approval of SDR Terminals

- Motoko TANIGUCHI
  - Remote Maintenance based on FPGA Fault Detection Using Error Correcting Codes for SDR Systems
  - Adaptive Radio Resource Management Using SDR Basestations and Terminals
2005 Software Defined Radio Technical Conference and Product Exposition
November 14-18, 2005 - Hyatt Regency - Orange County, California (near the Anaheim resorts)

Call for Papers

The Software Defined Radio Forum will sponsor a Technical Conference and Product Exposition that will focus on technology, standards and business activity related to software radios and will provide an international perspective of the current state of the art. Papers will be reviewed by both technical peers and business leaders and only those with the best combination of technical innovation, technical quality, and potential for broad impact in practical applications will be accepted.

The SDR community is invited to participate in this program and to share research results and status of other activities. Some suggested topics are presented below, but consideration will be given to papers on other relevant subjects. Proceedings of the conference will be provided to participants.

The deadline for abstracts is 1 May 2005. See details below for submission of abstracts and accepted papers.
Anticipation of SDR Evolution

- There are two directions of SDR Evolution.
  1. From Physical Layer to Network Layer
     **Terminal Reconfigurability** → **Baseline Station Reconfigurability** → **Network Reconfigurability**
  2. From Radio to Consumer Electronics
     **Reconfigurable Radio** → **Reconfigurable Network** → **Reconfigurable Equipments**
     Audio/Video, Consumer Electronics
     Reconfigurable Toy,
     Reconfigurable Automobiles?
Anticipation of SDR Evolution (continue)

- What is the most important issue for these directions?
  1. To Network level: (1) Sophisticated Measurement or Sensing Radio Environment → Cognitive radio
     (2) Multi-layer Reconfigurability between physical and network layers → E2R (End-to-end Recofigurability)
  2. To Consumer Electronics: Reconfigurable Architecture Software-Hardware Compatibility, → Software-Hardware Co-Design

- What shall we do next?
  1. Business: Make valuable business models!
  2. Education: Educate experts for SDR who can cover cross-over field between Computer Science and Radio Communication Engineering!
Elementary and Cross-over Technologies for SDR

Transmission Tech.
(Signal Design and Detection Theory)

Modulation & Demodulation
Multiplexing
Multiple Access

Netowrk Routing Protocol (Transfrom)

Cryptography
Inf. Security

Coding & Decoding

Equalization

User Interface

Software Defined Radio

Air Interface

Channel Estimation

Adaptive Array Antenna

Download
Reconfiguration Simulation

Device Process
(SemiCon, Super Conductive)
Memory

Wireless Tech.
(Elec-Mag Field Analysis, Propagation Modeling)

Signal Processing Tech.
(Digital Filter, FFT)

Network Routing Protocol

Equipment

Antenna
RF Circuit
Battery

Processor

Transceiver

Sampling
Processor

Device Driver

Adaptive Algorithm
Filtering

Software Eng.
(Algorithm, Program Language)

Application Program

Real-time OS

Remote Software

Cryptography
Inf. Security

User Interface

Netowrk Routing Protocol

Channel Estimation

Device Driver

Adaptive Array Antenna

Sampling
Processor

Download
Reconfiguration Simulation

Signal Processing Tech.
(Digital Filter, FFT)

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(Digital Filter, FFT)
Future Wireless Based on SDR and UWB

Agenda

1. Trends of Wireless Communications
2. State of Arts for SDR (Software Defined Radio) and Anticipation of SDR Evolution
3. State of Arts for UWB (Ultra Wideband) Radio and Anticipation of UWB Evolution
Background of UWB R&D

Current Demands on Radio → Higher Capacity and Better QoS Systems

Wideband Radio Systems, e.g. 3G(UMTS, IMT2000), WLAN(IEEE802.11.a,b,g) by Wideband CDMA, SS, OFDM etc.

The wider bandwidth radio system, the better performance will be obtained.

**UWB (Ultra Wideband)** is attractive because
- Low Interference to Coexisting Systems
- Very Small Power Consumption
- Ultra High Speed Data Transmission.
- High Multipath Resolution
- One-chip Implementation: SoC
Comparison of Spectral Distribution

- **Conventional Narrowband system:**
  - Transmitted power is extremely low ($10nW/MHz$)

- **Spread Spectrum System:**

- **Limit of Radiated Noise Power By FCC Part15**
  - $(-41.3dBm/MHz)$

- **Ultra Wideband (UWB) System:**
  - Ultra Wideband at GHz is occupied by a pulse with ultra short time duration (1nsec - 100 psec)
Definition of UWB

- **UWB Bandwidth**
  - Fractional bandwidth (BW) = (Bandwidth)/(Central Frequency) > 25% (DARPA)
  - Fractional bandwidth (BW) > 20% or Bandwidth > 500MHz (FCC)

Fractional bandwidth formula:

\[
\text{Fractional BW} = 2 \frac{f_H - f_L}{f_H + f_L} = \frac{f_H - f_L}{f_c}
\]

- **Comparing Examples**
  - AM 6.8kHz/530kHz = 1.3%
  - cdmaOne 1.25MHz/800MHz = 0.15%
  - W-CDMA 5MHz/2200MHz = 0.23%
  - WLAN(IEEE802.11) 22MHz/2450MHz = 0.9%
Modulation and Multiple Access Schemes for UWB Transmission

1. Modulation
1.1 Modulation without Carrier (Impulse Radio, Carrier-free)
   - Using a train of impulsive signals
     (1) PPM (Pulse Position Modulation)
     (2) Bi-phase Modulation
     (3) PSM (Pulse Shape Modulation) using orthogonal pulses

1.2 Modulation with Carrier
   (1) FH, TFH
   (2) DS
   (3) OFDM

2. Multiple Access Scheme for Multi-users
   (1) Time Hopping (TH)/CDMA
   (2) DS/CDMA
   (3) CSMA/CD, CA
What is Impulse Radio UWB (UWB-IR) ?

- **UWB-IR (Ultra Wide Band based on Impulse Radio)** is defined as a radio communication scheme using **a train of pulses with duration of less than 1nsec.**
- Its spectrum is ultra-widely spread **over several GHz in width.**

BPSK Signal with Sinusoidal Carrier

UWB Signal with Pulse Train
Time Waveforms and Frequency Spectra at Tx and Rx Antennas

At TX antenna:

In time:

In frequency:

RX antenna load:

In time:

In frequency:
Typical Transmission of UWB-IR Signal with PPM and TH

Case of Datum=0

• Data Modulation: Pulse Positioning Modulation (PPM)
• Multiple Access: CDMA based on Time Hopping (TH)

Remark: Both are Time-Domain Processing!
Typical Transmission of UWB-IR Signal with PPM and TH

• Data Modulation: Pulse Positioning Modulation (PPM)
• Multiple Access: CDMA based on Time Hopping (TH)

Remark: Both are Time-Domain Processing!

Case of Datum=1

Output
Modulation and Multiple Access in Time Domain (TH/PPM)

\[ S_{tr}^{(e)}(t^{(e)}) = \sum_{j=-\infty}^{\infty} w_{tr} (t^{(e)} - jT_f - c_j^{(e)}T_c - \delta D_j^{(e)}) \]

- Pulse waveform
- Pulse Repitition time
- TH Chip length
- TH pattern for User ID
- Shift value for binary modulation
- Tx Datum

\[ D_j = (1,1,0,1,0,1,L) \]

Channel Capacity (Max Transmission Rate)

- **Shannon Capacity in AWGN Channel (bit/sec)**

\[
C = B \log_2 \left( 1 + \frac{P}{N} \right)
\]

\[
C = \text{Max channel capacity in bits/s} \\
B = \text{Channel bandwidth in Hertz} \\
P = \text{Signal power in Watts} \\
N = \text{Noise power in Watts}
\]

- Since UWB systems use **ultra wideband width** B over **several GHz**, transmission rate can theoretically achieve **ultra high speed more than 1Gb/s.**
Properties and Benefits of UWB

1. Power Spectrum Density is extremely low (lower than noise)
   - Possible to coexist with other systems due to low interference (High immunity to interference due to large effective processing gain)

- UWB can keep all features of Spread Spectrum and emphasize its advantages.

- Information Theoretical interest for capacity limit

- Low cost implementation based on Signal Processing only in time domain (e.g. One-Chip SoC)

- New business creation in wireless industry as well as novel research paradigm in Academia

- Possible to achieve ultra-high capacity (many users) or high speed transmission (over 100 Mbps)
Potential Applications of UWB

- **Wireless communications**
  - High speed/low speed and high user capacity
  - Short distance communication (e.g., a few ten meters)
  - Indoor wireless CE (e.g., WPAN, wireless tags, Sensor Network)
  - Outdoor communications (e.g., WLL)

- **ITS: Intelligent Transport Systems**
  - Collision avoidance radar
  - Realization of both communication and ranging with a single hardware

- **Imaging and sensors**
  - Medical imaging
  - Ground penetration

- **Security systems**
  - Intrusion detection and sensing
Targeting of UWB Wireless Communications

- Achievable Transmission Rate (b/s)
- Power Consumption during Transmission

- Low Power
- Higher Capacity

- IEEE 802.11a
- IEEE 802.11b
- Bluetooth
Problems of UWB

1. Design and Mass-Production of **Pulse Generators**, **RF devises, Antennas etc for UWB**

2. **Detection of Accurate Pulse waveform in Receiver Inter-Pulse Symbol Interference in the Presence of Multipath**

3. **Multi-user Interference or Intra-system Interference**

4. **Inter-system Interference with Co-existing Overlaid Systems**

5. **Spectral Management for UWB Systems to Avoid Collision or Interference with Conventional Systems**
UWB Emission Limit for **Indoor Communication Systems** defined by the **FCC** Feb 14, 02 [between 3.1-10.6 GHz. ]
UWB Emission Limit for Outdoor Communication Systems defined by the FCC Feb 14, 02 [between 3.1-10.6 GHz.]
Subjects of Current Research (1/2)

- **Transmitters, pulse generation, waveforms and basis functions**
  - High-speed pulse generation
  - Spectrum shaping and wavelet basis functions
  - More efficient and adaptive modulation techniques

- **Receivers and baseband**
  - High-speed sampling \( T_m = 1 \text{ ns}, 2s/pulse \Rightarrow f_s = 2 \text{ Gsps} \)
  - Interference rejection techniques
  - UWB RAKE receiver designs (e.g., SW radio architecture)

- **Access control and network integration**
  - UWB MAC protocol
  - Coding techniques
  - Novel access techniques (e.g., hybrids)

- **Regulation**
  - Noise aggregation, limits and thresholds
Subjects of Current Research (2/2)

- **Synchronization and time base stability**
  - Picosecond accuracy
  - Jitter reduction

- **Propagation**
  - Measurement of UWB signal Propagation for indoor communication (e.g., very short range)
  - Channel models for higher frequency (e.g., above 2.4 GHz)

- **Antennas**
  - Low cost, efficient, electrically small antennas for portable applications

- **Technology**
  - High-speed CMOS implementation
Research Issues on UWB in Kohno Laboratory

1. Interference Analysis between UWB and conventional Systems
2. Multi-level or M-ary schemes for Improvement of UWB Transmission Efficiency
3. Pulse Shaping and Multi-pulse Shaping schemes for Improvement of UWB Transmission Efficiency
4. Multi-user Detection and Interference Cancellation Technologies for Improvement of UWB-CDMA User Capacity
5. Design of Sequences with Appropriate Correlation Properties for UWB-CDMA and Synchronization
6. Space-Time Equalization Technologies in the Presence of Multipath Distortion
7. Space-Time Interference Cancellation Technologies in the Presence of Overlaid or Co-existing Conventional Systems
8. Ultra Wideband Antenna for UWB
9. Joint Communicating and Ranging Systems Based on UWB
10. Joint Optical and Radio Implementation for UWB Transmission
2004 Doctor, Master, and Bachelor Theses on UWB in Kohno Laboratory

1. **Doctor Thesis (a part):** *Orthogonal Pulse-Shape Design in Jitter Channel and in Differentiating Channels* (Giuseppe Abreu)

2. **Master Thesis:** *Array Antenna Using Element Antenna with Different Frequency Characteristics for UWB Wireless Transmission* (Tadatomo Satoh)

3. **Master Thesis:** *Multiuser Detection for Ultra Wideband Code Division Multiple Access* (Senei Segawa)

4. **Master Thesis:** *ITS Inter-Vehicle Communication and Ranging Using Ultra Wideband Impulse Radio* (Takeshi Matsumura)

5. **Master Thesis:** *Ultra Wideband Radio Transmission Using Fiber Bragg Grating* (Takehiro Yamamoto)

6. **Bachelor Thesis:** *Non-linear Swept Chirp Waveform for UWB Multiple Access Communications* (Shunpei Ida)

7. **Bachelor Thesis:** *Error-Detection for Synchronization Using Orthogonal Sequences in UWB Impulse Radio Communications* (Kyoichi Obana)

8. **Bachelor Thesis:** *Adaptive Modulation in Multiband OFDM in the Presence of Narrow Band Interference* (Sumikazu Yahata)

9. **Bachelor Thesis:** *Estimation of Direction of Arrival Using Array Antenna with Modified Hermitian Waveform in UWB Communication Systems* (Takashi Uefuji)
Regulatory Activities on Commercial UWB

> In the USA, the FCC released the UWB regulations on February 14, 2002 with strict guidelines on transmitting power.

> In Europe, ETSI is making the UWB regulations while EC established IST projects, e.g. Ultra Waves, UCAN, PULSERS.

> In Japan, NICT(CRL) established UWB technology Institute and organizes UWB Consortium to promote R&D and make radio regulation for commercial use of UWB.
NICT UWB Project in NICT

Wireless Communications department

NICT UWB Project

UWB technology group

Millimeter-wave promotion project

Millimeter-wave device group

Communication system EMC group
UWB standardization activities

NIC T contributes standardization in Telecommunication Council in Japanese government, IEEE, ITU-R in cooperation with academia and industry on the basis of result of research activity.

For instance;

A) IEEE 802.15 TG3a : Proposal of Soft Spectrum Adaptation

B) IEEE 802.15 TG4a : Proposal being prepared

C) ITU-R TG1/8 : Contributions in 3 meetings from October 2003
Japanese UWB Consortium among Industry, Academia, and Government

> Organization:
NICT(CRL) UWB Technology Institute and associating Manufacturers (over 30 companies) and Academia (6 universities)
(1) Microwave Group: Short-term R&D of WPAN etc
(2) Millimeter wave Group: Mid-term R&D of millimeter applications

> Aim:
(1) R&D and Regulation of UWB Wireless Systems
(2) Channel Measurement and Modeling with Experiment
    Design and Implementation of UWB System Test-bed in band (960MHz, 3.1-10.6GHz, 22-29GHz, over 60GHz)
(3) R&D of Low Cost Module with higher data rate over 100Mbps
(4) Contribution in Standardization and regulation with ARIB, MMAC, IEEE802.15, MPHPT, and ITU-R etc
NICT UWB Project and Japanese UWB Collaboration

NICT UWB Project
- R&D, Standardization, Regulation, Collaboration -
  - UWB Technology Group
  - Millimeter-wave promotion project
  - Millimeter-wave device group
  - Communication system EMC group

Japanese UWB Consortium
- Joint research group
- Joint proposal for standard

Domestic Activities
- Yokosuka Research Park (YRP)
- International Conferences
  - IWUWBS & IWBST 2004 in Kyoto
  - IWUWBT 2005 in Yokosuka
- Private Companies
- MIC’s Regulation for UWB
- MMAC’s Domestic Standardization for UWB

Cooperation of R&D

International Activities
- PULSERS Project
- SARA Project
- Proposal & Contribution
- International Standard: IEEE 802.15
- International Regulation: ITU-R TG1/8
- Standardization and Regulation activity

Colloquium, Institute EUROCOM, France, June 23, 2005
Major Research Issues in UWB Consortium

> Ultra Hi-speed Transmission Technologies (over 100Mbps)
  (pulse shaping, modulation, multiple access schemes, protocol)
> Ultra Hi-accuracy Ranging and Positioning Technologies (less than 1cm accuracy)
> UWB Devices Technologies in Micro and Millimeter Wave Bands
> UWB Antennas Technologies in Micro and Millimeter Wave Bands
> Propagation Measurement and Channel Modeling for UWB
> Interference Suppression Technologies in intra- and inter-systems: coexistence with conventional systems
> Measuring Methods for Type-Approval of UWB Commercial Products
Potential UWB Application of Micro Wave Band

- IEEE 802.15 [Wireless PAN (Personal Area Network)]
  - TG3a (Alternative PHY)
    - Transmission Data Speed: Over several 100Mb/s
    - Communication Range: less than 10 meters
    - “The 3rd generation” Bluetooth?
      - Wireless PAN (Personal area network)
    - Wireless USB (Universal serial bus) 2.0
      - Data rate: 480Mbps (USB 2.0)
  - DS-UWB (Motorola, NICT etc: UWB Forum) and
    MB-OFDM UWB (Intel, TI etc: MBOA) are competing in standardization.

(Ref.) IEEE 802.15.1 Bluetooth 1 Mb/s
       IEEE 802.15.3 WiMedea 20 Mb/s
Expected UWB Applications in Millimeter Wave Band

- **ITS: Intelligent Transport Systems**
  - Collision avoidance radar (in 22-29GHz and 76GHz)
  - Realization of both communication and ranging with a single hardware

- **Wireless Communications**
  - Ultra high speed and user capacity: over 10 Gb/s
  - Short and long distance communication

- **Satellite and Inter-Satellite Communications, Ranging & Positioning**
  - Realization of both communication and ranging without interference
Standardization of Wireless PAN (Personal Area Network) in IEEE 802.15 TG3a (Alternative PHY)

- **March 13-17, 2003: Dallas**
  - First round of proposal

- **May 12-16, 2003: Dallas**
  - Second round (13 Proposals)

- **July 20-25, 2003: San Francisco**
  - Down-selection started (to 6 Proposals)

- **Sept., 2003, Singapore**
  - Draft improvements

- **Nov., 2003, Albaque**
  - Try to Harmonize two proposals to a single one

- **Jan., 2004, Vancouver**
  - Compromising two proposals with enhanced MAC

- **March, 2004, Orlando**
  - Common Signaling Mode (CSM) was proposed

- **May, 2004, Anaheim**
  - Revised to remained Two Major Proposals

- **July, 2004, Portland**
  - NICT&Motorola Group won to be 1th majority proposal.

- **Sept., 2004, San Francisco**
  - Down-selection started (to 6 Proposals)

- **Nov., 2004, Albaque**
  - Confirmation to be a single standard failed.

- **Jan., 2005, Monterey**
  - NICT&FreeScale won to be 1th majority

- **March 2005, Atlanta**
  - Panel Discussion on FCC Waiver for MB-OFDM

- **May 2005, Carins**
  - MBOA won with 4 more votes

**Major Specification of Requirement**

- **Data Rate & Range:** 110Mbps (over 10m), 200Mbps (over 4m), 480 Mbps (closer)
- **QoS:**
  - Without ARQ, PER (Packet Error Rate) < 8%
  - After FEC (Forward Error Correction), BER < 10^-9
- **Power Consumption:**
  - Less than 100 mW (in 110 Mbps)
  - Less than 250 mW (in 200 Mbps)
- **Max No. of Terminals:** 256 (in a single network)
- **Max No. of Simultaneous Networks:** 4
- **Size of Implemented RF Circuits:** PC Card Size
- **Expected Coexisting Systems:** IEEE802.11a/b, IEEE802.15.1/3/4, PHS, Cellular Phones, GPS etc.
- **Expected Cost of RF Circuits:** Equal or lower than Bluetooth
- **MAC:** IEEE802.15.3
Variation of UWB Modulation for Wireless PAN including DS-UWB and MB-OFDM

- DS schemes
  - Spread Spectrum
  - Orthogonal DS
  - DS/FH schemes
  - Orthogonal Multi Carrier FH

- FH schemes
  - Frequency Hopping
  - Orthogonal DS/FH schemes
  - Orthogonal DS-CDMA-FDMA

- Orthogonal Multi Carrier FH-CDMA schemes
  - Frequency Hopping
  - Other User

Ryuji Kohno's Properties, Confidential

Colloquium, Institute EUROCOM, France, June 23, 2005
Creation of Future Social InfrastructureBased on Information Telecommunication Technology

Yokohama National University

Colloquium, Institute EUROCOM, France, June 23, 2005

http://www.uwbforum.org/

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**UWB Forum Membership**

UWB Forum serves as a resource for industry to build awareness of the unique benefits and advantages of the UWB; which is the only UWB solution positioned to reach the commercial market. Due to the ongoing IEEE consensus process this candidate proposal has been updated to support DSSM. The Forum is also committed to achieving a UWB global standard and we encourage you to join us — just complete the Membership Agreement.

**MEMBER LIST**

- AbiCom Systems, Inc.
- Adaptive Labs, Inc.
- AppleVision Technologies, Inc.
- Arthmi Ltd
- CoWare, Inc.
- Recanati Ltd.
- DSP enabled Communications
- Eaton Corporation
- Electronic Technology Systems
- Emerging Technologies Limited (ETL)
- Freescale Semiconductor, Inc.
- Furako, Inc.
- Genie Institute of Technology
- Global Sun Technology
- Graduate Student Union
- Haier Group

- InnoVrs™, LLC
- Ibexworks
- Micro-Star International Co., Ltd.
- Motorola, Inc.
- Multibase Systems
- Nara Technology Co., Ltd.
- NiCT
- Profile Tele®
- Pulse-LLiK, Inc.
- RoyalDigital Inc.
- TimeDrempse, Inc.
- University of Wollongong
- Urgex Communications, Inc.
- Veho, Inc.
- Wireless Dynamics, Inc.
- Wong's Electronics Co., Ltd.
OUR MISSION

To develop the best overall solution for ultrawideband-based products in compliance with worldwide regulatory requirements, to ensure peaceful coexistence with current and future spectrum users, and to provide the most benefits to the broadest number of end consumers.

MEMBER COMPANIES
NiCT-UWB Consortium’s Soft-Spectrum UWB PHY Proposal for IEEE 802.15.3a

Basic Concept → Soft-Spectrum Adaptation (SSA)

- Design proper pulse waveform to avoid interference to coexisting radio systems in the same band.
- Match its spectra with required spectral mask, even if regional spectral mask is different and changed.
Basic Formulation

\[ f(t) = \sum_{k=1}^{N} f_k(t) \]

**Synthesize pulse waveform**

*In case of multiband: Kernel function is Sinusoidal*

\[ f_k(t) = \cos \left[ 2\pi \left( f_L + \frac{(1 + 2k)B}{2N} \right)t \right] \times \frac{\sin(B\pi t)}{N\pi t} \]

---

Example of Pulse Generator

Feasible Solution: Pulse design satisfying Spectrum Mask

- Divide (spread-and-shrink) the whole bandwidth into several sub-bands → *Soft Spectrum* (spectrum matching)
- Pulse synthesized by several pulses which have different spectra → *Soft Spectrum, M*-ary signaling
2.2 Soft-Spectrum Adaptation (SSA) Classification

(1) Free-Verse Type of SSA
   → A kernel function is non-sinusoidal, e.g. Gaussian, Hermitian pulse etc.
   → Single band, Impulse radio (Carrier free)

(2) Geometrical Type of SSA
   → A kernel function is sinusoidal with different frequency.
   → Multiband with carriers (Multi-carrier)
Gaussian Mono-cycle Pulse and its Spectrum

Gaussian Dual-cycle Pulse and its Spectrum

\textit{K-2} Free-verse \textit{Soft-Spectrum} pulse (Dual-cycle)

(Note: several band notches can be designed so as to avoid interference with W-LANs in 2.4 and 5.2GHz)
(1) **Free-verse Type Soft-Spectrum Adaptation**

- Freely design pulse waveforms by synthesizing pulses, e.g. overlapping and shifting.

Design proper pulse waveform in order to avoid interference to co-existing systems such as WLAN’s at 2.4 and 5.2 GHz bands.

Match its spectra with required spectral mask in flexible and adaptive, even if regional spectral mask is changed.
(2) **Geometrical Type Soft-Spectrum Adaptation**

→ Freely design pulse waveforms using various geometrical type envelopes

**Triangular-type envelope**

**Exponential-type envelope**

**Cosine-type envelope**

**Gaussian-type envelope**
Time-frequency-hopping (TFH) for *Soft-Spectrum* multi-band UWB with geometrical-type envelopes
Adaptive, controllable *spread-and-shrink* of frequency bandwidths is feasible, according to the actual interference environment and the spectrum requirements → *Soft-Spectrum* adaptation philosophy as mentioned before.
(3) Optimized Pulse Shaping for SSA

**Optimized pulse shapes**

- **Mutually orthogonal**
  - Available to
    - Pulse shape multiple access
    - Pulse shape modulation
- **Available notches**
  - In order to reduce narrowband interferences
- **Non-spiky in both time and frequency domain**

**Free-verse Type + Geometrical Type**

*Ex.: Modified Hermitian Pulsed Sinusoidal Wavelets*

Pulse width and center frequency is adaptively changeable.
Japanese Spectral Allocation of Coexisting Systems in 3.1～10.6GHz (no blank frequency slot)
Modified SSA-UWB pulse wavelet with adaptive spectral notches achieving coexistence, flexibility and efficient power transmission.
Summary of Soft-Spectrum Adaptation

- **Globally Regulatory Satisfaction**: Soft-Spectrum adaptation (SSA) can satisfy the FCC Spectrum Mask and any Mask adaptively.

- **Interference Avoidance**: SSA can be applied to avoid possible interferences with other existing narrowband wireless systems.

- **Global Harmonization**: SSA is good for harmonization among different UWB systems because SSA includes various proposed UWB systems as its special cases.

- **Future Version-up**: SSA is so scalable as to accept future UWB systems with better performance like Software Defined Radio (SDR).
NICT’s Implementation of UWB Transceiver CMOS-MMIC for WPAN in Microwave Band (Feb.2004)

Geometrical-type SSA-UWB (MB-OFDM) transceiver module

- 0.18-micron CMOS-MMIC
- Disize: 3mm²
- Max TX rate: 320Mb/s

Free-verse-type SSA-UWB (Impulse Radio) transceiver module
NiCT developed SLOT BOW-TIE UWB Antenna

IEEE802.15.3a meeting, Nov. 2003, Albaquaque

(1) Small and thin FR-4 substrate
(2) Frequency coverage: 3.8 - 10.6 GHz
(3) VSWR = 2.8
(4) Return loss ≈ -6.5 dB
(5) Gain ≈ 2.2 - 4.7 dBi

IEEE802.12.3a meeting, Jan. 2004 Banquver

(1) Size: 44 × 20.5 × 0.5 mm
(2) Substrate: Teflone (\(\varepsilon_r = 2.2\), \(\tan\theta = 0.0009\))
(3) Patch: Copper (18 um)
(4) Feed: Microstrip Line 50Ω
Characteristics of NiCT developed SLOT BOW-TIE UWB Antenna

- **VSWR**
  - Frequency GHz: 3 to 10.6 GHz
  - Magnitude of VSWR: < 3

- **S11**
  - Frequency GHz: 3.8 to 10.6 GHz
  - Magnitude of Scattering Matrix: S11 < -6 dB

- **Gain**
  - Frequency (GHz): 3 to 10.6 GHz
  - Magnitude of Gain: > 2 dBi
Trend on UWB-based Sensor Network (IEEE802.15.4a)

- Low Rate Sensor Network
- Study Group 4a was established July 2003
- Technical Requirements for 15.4a
  - Low cost
  - Low data rate (>250kbps)
  - Low complexity
  - Low power consumption
    - Additional requirements (different from 15.4)
      - Mobility (over 11mph)
      - Accurate Positioning (<30cm)
      - Robustness against interference
      - Long distance
- Call for Applications
  - 19 responses
  - Proposals based on UWB transmission

What is the optimal modulation scheme for IEEE802.15.4a?

- Hi Accuracy Positioning: Wideband
- Low Cost: Simple Modulation
- Low Power Consumption: less processing complexity

Pulsed DS UWB has been chosen as a single standard of IEEE802.15.4a.
Baseline Agreement of IEEE802.15.4a in March 2005

- Points of Agreement for UWB signalling
  - **Modulation scheme** should admit multiple classes of receivers
    - Transmitter based on deterministic pulse structures
    - Should allow reception by coherent, differentially-coherent (can be TR) and non-coherent receivers
    - Provision for homogeneous operation when membership supports it
  - **Ternary modulation**
    - Specific modulation format TBD
  - **Sub-banding:** (3.1-10.6GHz)
    - Center of three bands is mandatory (500MHz bandwidth)
    - Other two optional
    - Wider bandwidth (1.5 GHz+) concentric with center band is optional
    - CDMA within frequency bands
  - **Harmonic chip rate** – integer relationship between center frequency and chip rate
    - Consider ways to avoid Japanese UNII band (shift band lower)
      - Integer-plus-half is also proposed, some concerns with DC balance
      - Maintain 3.1 corner
    - Constant PRF is desired as possible
  - **Specific band plan** - TBD
  - **Cost effective reference frequency** with appropriate PPM
    - Specific frequency and tolerance is TBD
  - **Potential for optional chirp mode** (at best, if and where allowed)
Specified Issues and Optional Issues in Baseline Agreement of IEEE802.15.4a, March 2005

- As noted on previous slide

- **Mandatory**
  - \( \sim 500 \text{ center band} \)
    - AM of 3.1-4.9 is 3.975
    - GM of 3.1-4.9 is 3.877
    - Center band frequency is TBD, but must be in [3.85 to 4.05]

- **Optional**
  - 2 additional 500 MHz bands for FDM – center frequencies TBD
  - Wideband concentric with center specified above
  - Sub-GHz band
  - **Chirp** of some form (could be 2.4 GHz band – Merger E)
  - Chaotic waveform and SOP mechanisms for homogeneous (chaos-only) networks
  - Add TH as additional SOP mechanism
  - Add chirp specifically for UWB as SOP mechanism
  - Add specific optional band > 6 GHz with guaranteed >1.5GHz BW
  - Support mode for higher data rates (few to 10 Mbps)

- **Other issues**
  - Desire to have common packet for communications and ranging if possible
  - Multiple (2-few) PRF in band
Additional Issues in Chirp Signaling in 2.4GHz band in the Baseline Agreement

- UWB signalling is one of the two valid modes for communication
- 2.4 GHz chirp is a valid mode for communication only
- Ranging shall not be supported for 2.4 GHz chirping, and shall be supported for UWB signalling
- UWB is valid for both communications and ranging
Channel Propagation Models in IEEE802.15.4a

UWB Channel Model in 2-10GHz band (Average power decay profile)

Industrial, Indoor residential, Indoor office, and Outdoor

Agricultural areas / Farms

- Industrial environments (LOS/NLOS)
- Indoor residential (LOS/NLOS)
- Indoor office (LOS/NLOS)
- Outdoor (LOS/NLOS)
- Agricultural areas/Farms
- Body-worn devices

- The following models for UWB schemes in 2-10GHz band
  - Industrial environments (LOS/NLOS)
  - Indoor residential (LOS/NLOS)
  - Indoor office (LOS/NLOS)
  - Outdoor (LOS/NLOS)
  - Agricultural areas/Farms
  - Body-worn devices

- The model for UWB scheme in VHF and UHF bands
  - LOS/NLOS

- No restriction for Narrow band schemes

3 Signaling Schemes are assumed
- UWB Scheme in 2-10GHz band
- UWB Scheme in VHF and UHF bands
- Narrow band schemes (ISM bands such as 2.4GHz band)
### Merged Proposal D: NICT/Fujitsu/OKI/Hitachi/YRP_UNL/WidebandAccess/Freescale/decawave/TTU

<table>
<thead>
<tr>
<th>Proposer's Name</th>
<th>Stated Company</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryuj Kohno</td>
<td>NICT, Fujitsu, OKI</td>
<td></td>
</tr>
<tr>
<td>Akira Maek</td>
<td>Hitachi, YRP_UNL</td>
<td></td>
</tr>
<tr>
<td>Matt Weibom</td>
<td>Freescale Semiconductor, decawave</td>
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</tr>
<tr>
<td>Ismail Lakkis</td>
<td>Wideband Access, Inc.</td>
<td></td>
</tr>
<tr>
<td>Robert Caoming Qiu</td>
<td>Tennessee Technological University</td>
<td></td>
</tr>
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### Merged Proposal A: CWC/AetherWire/CEA-LETI/STM/EREL

<table>
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<tr>
<th>Proposer's Name</th>
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<tbody>
<tr>
<td>Philippe Rouzet</td>
<td>STMicroelectronics, Aether Wire &amp; Location, CEA-LETI, CWC</td>
<td></td>
</tr>
<tr>
<td>Andy Molisch</td>
<td>Mitsubishi Electric Research Laboratories</td>
<td></td>
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<tr>
<td>Rick Roberts</td>
<td>Harris Corporation</td>
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<tr>
<td>Paul Popescu</td>
<td>France Telecom R&amp;D, LLC</td>
<td></td>
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<tr>
<td>Vern Brothour</td>
<td>Time Domain</td>
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### Merged Proposal B: IIR/GA/Thales/KERI/SSU/KWU/CreateNet/ChinaUWBForum/Staccato/Wisair

<table>
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<tr>
<th>Proposer's Name</th>
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<tbody>
<tr>
<td>Francois Chin</td>
<td>Institute for Infocomm Research</td>
<td></td>
</tr>
<tr>
<td>Naiele Askar</td>
<td>General Atomics</td>
<td></td>
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<tr>
<td>Fabrice Legrand</td>
<td>Thales Communications, CELCONICS</td>
<td></td>
</tr>
<tr>
<td>Youngjin Park</td>
<td>Korea Electrotech. Research Inst (KERI) &amp; Korean UWB Industry Application</td>
<td></td>
</tr>
<tr>
<td>Honggang Zhang</td>
<td>CreateNet, China UWB Forum</td>
<td></td>
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<tr>
<td>Roberto Atillo</td>
<td>Staccato Communications</td>
<td></td>
</tr>
<tr>
<td>Gadi Shor</td>
<td>Wisair</td>
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</table>

### Merged Proposal C: SAW/IRE/SEDM/ETRI/KAIST/HEU/AFU/Inha

<table>
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<tr>
<th>Proposer's Name</th>
<th>Stated Company</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Namhyong Kim</td>
<td>Samsung Electronics (DM)</td>
<td></td>
</tr>
<tr>
<td>Chia Chin Chong</td>
<td>Samsung Electronics (SAIET), IRE, Samsung Electro-Mechanics(SEM)</td>
<td></td>
</tr>
<tr>
<td>Choohyo Lee</td>
<td>ETRI, KAIST, HGU</td>
<td></td>
</tr>
<tr>
<td>Kyung Sup Kwak</td>
<td>Inha University/ Simon Fraser University</td>
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### Merged Proposal E: Nanotron/Orthotron

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<tbody>
<tr>
<td>John Lampe</td>
<td>Nanotron Technologies GmbH</td>
<td></td>
</tr>
<tr>
<td>Kyung-Kuk Lee</td>
<td>Orthotron, Hanyang Univ.</td>
<td></td>
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### メール来信

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<th>Proposer's Name</th>
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<tr>
<td>Dani Rapaheli</td>
<td>SandLinks</td>
<td></td>
</tr>
<tr>
<td>Soo-Young Chang</td>
<td>California State University, Sacramento</td>
<td></td>
</tr>
</tbody>
</table>
NiCT Proposal:
DS-UWB with an Optional CS-UWB for Low-Rate Wireless Personal Area Networks

Advantages of using direct sequence UWB (DS-UWB) and chirp signaling UWB (CS-UWB)

- High frequency efficiency
  - Uniform use of frequency within the band
- High robustness against noise and multipath
  - Correlated processing
- High compatibility with other existing systems
  - Low interference level
- High feasibility for SOP
  - Use DS codes, chirp slopes/patterns
DS-UWB with an Optional CS-UWB for IEEE802.15.4a

Transmitter

(24,12)-Golay encoder → BPSK → Spreading → Pulse shaping → CHIRP → GA

Local oscillator

Receiver

Pre-Select Filter → LNA → De-CHIRP

LPF → GA → 1 or 2-bit ADC → Decision / FEC decoder

Local oscillator

Additional circuits to DS-UWB as an option

Sync.
Waveforms With/Without Chirp
of DS-UWB with an Optional CS-UWB

- Gaussian pulse
- Gaussian pulse
- Gaussian pulse
- Gaussian pulse
- Gaussian pulse

(24,12)-Golay encoder
BPSK
Spreading
Pulse shaping
CHIRP
GA

Local oscillator

linear-chirp
linear-chirp
linear-chirp
linear-chirp
linear-chirp

Ryuji Kohno's Properties, Confidential
Colloquium, Institute EUROCOM, France, June 23, 2005
# DS-UWB Link Budget (500MHz)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data rate (Rb)</td>
<td>1</td>
<td>1024</td>
<td>(kbps)</td>
</tr>
<tr>
<td>Modulation</td>
<td>BPSK</td>
<td></td>
<td>Coherent detection</td>
</tr>
<tr>
<td>Coding rate (R)</td>
<td>1/2</td>
<td></td>
<td>(24,12)-Extended Golay Hard-decision decoding</td>
</tr>
<tr>
<td>Raw Symbol rate (Rs)</td>
<td>2</td>
<td>2048</td>
<td>Rs=Rb/R (ksymbol/s)</td>
</tr>
<tr>
<td>Pulse duration (Tp)</td>
<td>2.649</td>
<td>2.649</td>
<td>(ns)</td>
</tr>
<tr>
<td>Spreading code length (Ns)</td>
<td>1024</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Chip rate (Rc)</td>
<td>2.048</td>
<td>131.072</td>
<td>=Rs*Ns (MHz)</td>
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<tr>
<td>Chip duration</td>
<td>488.3</td>
<td>7.63</td>
<td>=1/Rc (nsec)</td>
</tr>
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</table>

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<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Distance (d)</td>
<td>30</td>
<td>10</td>
<td>m</td>
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<tr>
<td>Peak payload bit rate (Rb)</td>
<td>1</td>
<td>1024</td>
<td>kbps</td>
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<tr>
<td>Average Tx power (Pt)</td>
<td>-16.9</td>
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<td>dBm</td>
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<tr>
<td>Tx antenna gain (Gt)</td>
<td>0</td>
<td></td>
<td>dBi</td>
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<tr>
<td>Frequency band</td>
<td>3.85 - 4.35</td>
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<td>GHz</td>
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<td>Geometric center frequency (fc)</td>
<td>4.09</td>
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<td>GHz</td>
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<td>Path loss @ 1m (L1)</td>
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<td>dB</td>
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<tr>
<td>Path loss @ d m (Ld)</td>
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<td>dB</td>
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<tr>
<td>Rx antenna gain (Gr)</td>
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<td>dBi</td>
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<tr>
<td>Rx power (Pr)</td>
<td>-81.12</td>
<td>-81.58</td>
<td>dBm</td>
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<tr>
<td>Average noise power per bit (N)</td>
<td>-144.00</td>
<td>-114.00</td>
<td>dBm</td>
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<tr>
<td>Rx Noise figure (Nf)</td>
<td>7.00</td>
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<td>dB</td>
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<tr>
<td>Average noise power per bit (Pn)</td>
<td>-137.00</td>
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<tr>
<td>Minimum required Eb/N0 (S)</td>
<td>6.25</td>
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<td>dB</td>
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<tr>
<td>Implementation loss (l)</td>
<td>3.00</td>
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<td>dB</td>
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<tr>
<td>Link Margin</td>
<td>36.63</td>
<td>16.07</td>
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<tr>
<td>Min. Rx Sensitivity Level</td>
<td>-127.75</td>
<td>-97.65</td>
<td>dBm</td>
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### CS-UWB Link Budget (500MHz)

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<td>=Rs*Rb/R</td>
</tr>
<tr>
<td>Chirp signal duration (Tc)</td>
<td>25</td>
<td></td>
<td>(ns)</td>
</tr>
<tr>
<td>Spreading code length (Ns)</td>
<td>1024</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Chip rate (Rc)</td>
<td>2.048</td>
<td>8.192</td>
<td>=Rs*Ns (MHz)</td>
</tr>
<tr>
<td>Chip duration</td>
<td>488.3</td>
<td>122.1</td>
<td>=1/Rc (nsec)</td>
</tr>
<tr>
<td>Peak payload bit rate (Rb)</td>
<td>1</td>
<td>1024</td>
<td>(kbps)</td>
</tr>
<tr>
<td>Average Tx power (Pt)</td>
<td>-15.38</td>
<td>dBm</td>
<td></td>
</tr>
<tr>
<td>Tx antenna gain (Gt)</td>
<td>0</td>
<td>dBi</td>
<td></td>
</tr>
<tr>
<td>Frequency band</td>
<td>3.85 – 4.35</td>
<td>GHZ</td>
<td></td>
</tr>
<tr>
<td>Geometric center frequency (fc)</td>
<td>4.09</td>
<td>GHZ</td>
<td></td>
</tr>
<tr>
<td>Path loss @ 1m (L1)</td>
<td>44.68</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Path loss @ d m (Ld)</td>
<td>29.54</td>
<td>20.00</td>
<td>dB</td>
</tr>
<tr>
<td>Rx antenna gain (Gr)</td>
<td>0</td>
<td>dBi</td>
<td></td>
</tr>
<tr>
<td>Tx power (Pr)</td>
<td>-89.60</td>
<td>-80.06</td>
<td>dBm</td>
</tr>
<tr>
<td>Average noise power per bit (N)</td>
<td>-144.00</td>
<td>-114.0</td>
<td>dBm</td>
</tr>
<tr>
<td>Rx Noise figure (NF)</td>
<td>7.00</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Average noise power per bit (Pn)</td>
<td>-137.00</td>
<td>-106.90</td>
<td>dBm</td>
</tr>
<tr>
<td>Minimum required Eb/N0 (S)</td>
<td>6.25</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Implementation loss (l)</td>
<td>3.50</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Link Margin</td>
<td>37.65</td>
<td>17.09</td>
<td>dB</td>
</tr>
<tr>
<td>Min. Rx Sensitivity Level</td>
<td>-127.25</td>
<td>-97.15</td>
<td>dBm</td>
</tr>
</tbody>
</table>

The items given in red characters have different values from those of DS.
SOP with DS Codes or Chirp patterns

16 chips

Code 1
Code 2
Code 3
Code 4

DS Codes
Time

SOP with DS codes.

Subband 1
Subband 2
Subband 3

Frequency
SOP with chirp patterns.

Time
SOP Performance Examples

(a) Simulation setting.

interference #1

interference #2

interference #3

(b) Simulation results.

Eb/N0=  6dB
Eb/N0=10dB
Eb/N0=15dB

Pc/Pi (dB)

BER

Coordinated

Eb/N0

DS CS

100

10-1

10-2

10-3

10-4

10-5

-10  -9  -8  -7  -6  -5  -4  -3  -2  -1

Pc/Pi (dB)
Single Link Performance (AWGN)

One Packet includes 32 bytes.
Performance With 15.4a Channels

DS-UWB
- Data rate: 1kbps (nominal)
- Modulation: BPSK
- Pulse shape: Gaussian monocycle
- Spreading code: 1024 chips
- ADC: 1Gs and 1bit
- Channel models
  - CM1: Indoor residential LOS
  - CM5: Outdoor LOS
  - CM8: Industrial environments
  - NLOS

[Graph showing performance with 15.4a channels]
Interference Models for Coexistence

- **IEEE802.11a**
  - Center frequency: 5.18 GHz
  - Emission power: 15 dBm
  - Antenna gain: 0 dBi

- **MB-OFDM**
  - Frequency band: Group 1, lower three bands
  - Emission power: -41.3dBm*528MHz*Duty cycle
  - Antenna gain: 0 dBi
Interference Evaluation

The minimum criteria requires a 1m separation.

<table>
<thead>
<tr>
<th>Interference models</th>
<th>Tolerable distance to achieve PER&lt;1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE802.11a</td>
<td></td>
</tr>
<tr>
<td>BW = 2GHz</td>
<td></td>
</tr>
<tr>
<td>Eb/N0 = inf.</td>
<td>0.52 m</td>
</tr>
<tr>
<td>Eb/N0 = 10 dB</td>
<td>0.80 m</td>
</tr>
<tr>
<td>MB-OFDM</td>
<td></td>
</tr>
<tr>
<td>BW = 2GHz</td>
<td></td>
</tr>
<tr>
<td>Eb/N0 = inf.</td>
<td>0.012</td>
</tr>
<tr>
<td>Eb/N0 = 10 dB</td>
<td>0.022</td>
</tr>
<tr>
<td>BW = 500MHz</td>
<td></td>
</tr>
<tr>
<td>Eb/N0 = inf.</td>
<td>0.104</td>
</tr>
<tr>
<td>Eb/N0 = 10 dB</td>
<td>0.115</td>
</tr>
</tbody>
</table>

UWB: Propagation distance = 1m. Data rate = 2 Mbps, FEC off.

BW = 2 GHz, fc = 4.1 GHz. BW = 500 MHz, fc = 3.35 GHz.
Successful Unification for IEEE802.15.4a based on NICT Proposal
Comparison between NICT’s and Unified Proposals

<table>
<thead>
<tr>
<th>NICT Proposal</th>
<th>UWB Scheme</th>
<th>Band Plan and Bandwidth(BW)</th>
<th>Data Rate</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mandatory: <strong>DS-UWB</strong></td>
<td>UWB band: BW=500MHz &amp; 2GHz, variable center frequency</td>
<td>Support Higher than 10Mbps</td>
<td><strong>Chirp in ISM 2.4GHz band</strong> is option</td>
</tr>
<tr>
<td></td>
<td>Option: <strong>CS-UWB</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Chirp Signaling)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unified Proposal</th>
<th>UWB Scheme</th>
<th>Band Plan and Bandwidth(BW)</th>
<th>Data Rate</th>
<th>others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mandatory: <strong>DS-UWB</strong></td>
<td>UWB band: BW=500MHz &amp; more in 3.85 ~ 4.05GHz</td>
<td>Mandatory lower than 10Mbps</td>
<td><strong>Chirp in ISM 2.4GHz band</strong> is standard</td>
</tr>
<tr>
<td></td>
<td>(Coherent, Defferential Non-Coherent)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Option: <strong>CS-UWB</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and others</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Expected UWB Applications in Millimeter Wave Band

- **ITS: Intelligent Transport Systems**
  - Collision avoidance radar (in 22-29GHz and 76GHz)
  - Realization of both communication and ranging with a single hardware

- **Wireless Communications**
  - Ultra high speed and user capacity: over 10 Gb/s
  - Short and long distance communication

- **Satellite and Inter-Satellite Communications, Ranging & Positioning**
  - Realization of both communication and ranging without interference
24 GHz Short Range Radar Safety Features

- Pedestrian Protection
- Pre-crash/Emergency Brake
- Side Obstacle Warning
- Stop & Go

Type A

Type B
UWB Radar

Conventional Radar

Advanced Radar

SS (Spread Spectrum) Radar

UWB Radar

Ryuji Kohno's Properties, Confidential

Colloquium, Institute EUROCOM, France, June 23, 2005
Applicable Bands for Vehicular Radar

5.8GHz:
- Integration of large antenna sizes into vehicle bumpers is not feasible
- Fractional BW for high resolution not achievable with AM (e.g. 50%)

24GHz:
- Integration of moderate antenna sizes into vehicle bumpers is feasible
- Acceptable attenuation of µWave propagation trough bumper material
- Fractional BW for high resolution achievable with AM (e.g. 12.5%)
- Availability of off-the-shelf components, mature production processes
- Economical hybrid design on softboard possible without MMIC‘s

61GHz / 77GHz:
- Unacceptable attenuation of µWave propagation trough bumper material
- no discrete packaged components available
- no priceworthy hybrid design, but MMIC‘s

===> RTTT concepts uses different bands for various applications

5.8GHz: Communication near range
24GHz: Near Range Radar with moderate antenna focussing
61GHz: Communication/Telematics mid range
77GHz: Mid Range Radar with high antenna focussing like ACC
NICT’s Implementation of 26 GHz UWB Impulse Radar System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Frequency</td>
<td>26.3 GHz</td>
</tr>
<tr>
<td>Transmission power</td>
<td>1.26 mW (Peak)</td>
</tr>
<tr>
<td>Modulation scheme</td>
<td>Pulse(ASK)</td>
</tr>
<tr>
<td></td>
<td>Pulse-width 1 nsec</td>
</tr>
<tr>
<td></td>
<td>Pulse-repetition period 300 nsec</td>
</tr>
<tr>
<td>Occupied band-width</td>
<td>&gt; 2 GHz</td>
</tr>
<tr>
<td>Preciseness of measurement</td>
<td>&lt; 30 cm</td>
</tr>
<tr>
<td>Max. detection distance</td>
<td>10 m @ bore-sight</td>
</tr>
<tr>
<td>Update period of output data</td>
<td>40 msec</td>
</tr>
<tr>
<td>Total NF</td>
<td>10 dB</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>15 dBi</td>
</tr>
<tr>
<td></td>
<td>Beam-width &gt; 40 deg. (Horizontal)</td>
</tr>
<tr>
<td></td>
<td>&gt; 10 deg. (Vertical)</td>
</tr>
</tbody>
</table>

GaAs MMIC

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Colloquium, Institute EUROCOM, France, June 23, 2005
Ubiquitous UWB Sensor Network Test Room

Geolocation Equipment

Measurement Equipment

3D Positionor

Measurement Antenna

UWB Sensor Node

Variable Wall
3.1 UWB Radio Systems Regulatory Committee in MPHPT Telecommunications Council

> Four working groups were set up to investigate compatibility between UWB and other radio communication systems in Nov. 2002:
  
  Group 1: the Compatibility Model Working Group,
  Group 2: the Fixed-Broadcasting systems Working Group,
  Group 3: the Radar-Aviation and Maritime systems Working Group,
  Group 4: the Satellite-Low Power systems Working Group

> Comments were invited on the Draft Interim Report
  22 submissions received in the period 2 – 27 February 2004
Proposed Compatibility Models and Spectral Mask

- Different types of UWB radio systems under consideration

**Impulse Radio type**

**MB-OFDM type**

**DS-UWB type**

- Proposals for emission power spectral mask

**Proposal 1**
- Based on FCC Outdoor specifications

**Proposal 2**
- Standards for Extreme Low Power Stations in Japan applied to portion of spectrum outside the range 3.1 – 10.6 GHz
ITU-R TG1/8 for UWB Global Regulation

1. Starting: ITU-R established Task Group 1/8 in the meeting of SG1 in July 2002. Assigned Questions are
   > Q.226 (Spectrum management framework related to the introduction of ultra-wideband (UWB) devices)
   > Q.227 (Compatibility between ultra-wideband (UWB) devices and radiocommunication services)

2. Working Plan: Meetings are planned 4 times from 2003 to 04. General Chairman: Mr. Salim Hanna (Canada).

WP 1: UWB characteristics Chair: William Gamble (USA)
WP 2: UWB compatibility Chair: Yves Ollivier (France)
WP 3: UWB spectrum management framework Chair: Christoph Wöste (Germany)
WP 4: UWB measurement techniques Chair: Tetsuya Yasui (NiICT, Japan)
ITU-R TG1/8: Summery of 1st meeting

Date and place: Geneva from 21-24 January 2003
Attendees: 85 delegates
representing 17 Administrations,
18 Sector Members including NICT,
Input documents: 44 input documents
Output (Temporary) documents: 23 temporary documents

ITU-R TG1/8: Summery of 2nd meeting

Date and place: Geneva from 27-31 October 2003
Attendees: 118 delegates
representing: 26 Administrations
18 Sector Members including NICT
Input documents: 57 input documents
Output (Temporary) documents: 37 temporary documents
## Japanese Contributions on Measurements of UWB Signals for ITU TG1/8

<table>
<thead>
<tr>
<th>ITU Document 1-8/44-E</th>
<th>CONCERNING RADIATED MEASUREMENTS IN REVERBERATION CHAMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITU Document 1-8/45-E</td>
<td>CONCERNING LIMITATION AND EXTENSION OF FREQUENCY DOMAIN MEASUREMENTS USING CONVENTIONAL SPECTRUM ANALYZER</td>
</tr>
<tr>
<td>ITU Document 1-8/46-E</td>
<td>CONCERNING METHOD OF PEAK POWER MEASUREMENTS</td>
</tr>
<tr>
<td>ITU Document 1-8/47-E</td>
<td>CONCERNING PEAK POWER MEASUREMENT BY USING A SPECTRUM ANALYZER</td>
</tr>
<tr>
<td>ITU Document 1-8/48-E</td>
<td>CONCERNING EMISSION MASK MEASUREMENTS USING A SPECTRUM ANALYZER FOR UWB EQUIPMENT WITH AN INTERNAL ANTENNA CONNECTOR</td>
</tr>
<tr>
<td>ITU Document 1-8/49-E</td>
<td>CONCERNING TIME DOMAIN MEASUREMENTS BY USING OSCILLOSCOPES</td>
</tr>
<tr>
<td>ITU Document 1-8/50-E</td>
<td>CONSIDERATION OF MEASUREMENT OF UWB FH SYSTEM</td>
</tr>
</tbody>
</table>
ITU-R TG1/8: NiCT work for 3rd meeting

Date and place: Boston, USA, June 2004
Draft contributions from NiCT in Japan:
1 doc for Characteristics (WG1)
7 docs for Measurement (WG4)
7 participants from NiCT and UWB consortium

ITU-R TG1/8: NiCT Work for 4th meeting

Date and place: Geneve, Switzerland, Nov. 1-7 2004
Draft contributions from NiCT in Japan:
1 doc for Characteristics (WG1)
7 docs for Measurement (WG4)
8 participants from NiCT and UWB consortium
ITU-R TG1/8: NiCT work for 5th meeting

Date and place: San Diego, USA, May 18-27 2005
Draft contributions from NiCT in Japan:
- 2 doc for Characteristics (WG1)
- 2 doc for Coexistence (WG2)
- 1 doc for Measurement (WG4)
12 participants from NiCT and UWB consortium

ITU-R TG1/8: future meeting schedule

Final meeting will be held October 13-19 in Geneve
And SG1 will be held Oct. 24-25.
>NiCT contribute the activities of ITU-R TG1/8 positively.
>NiCT aims that UWB can be introduced to the users soon under the harmonization in the world.
>NiCT seeks best way from the point of users’ view.
Anticipation of UWB Evolution

- UWB is widely applicable practical physical layer technology.
  1. Within a few years, wireless PAN and sensor network based on UWB must be started servicing for the time to market.
  2. More successive UWB products will bring us more business opportunities in wireless CE, PC, Handset, ITS etc.

- UWB brings various new research subjects in academic works.
  1. From Information Theoretical aspect, capacity analysis, channel coding in space, time, and frequency domains
  2. RF circuit and antenna for UWB need new design rule.

- Regulatory key issues for commercial UWB systems;
  1. Compatibility: Avoidance of Interference to co-existing systems should be ensured for radio regulation first.
  2. Harmonization among different standards and regulations
Creation of Future Social Infrastructure Based on Information Telecommunication Technology

Yokohama National University

Colloquium, Institute EUROCOM, France, June 23, 2005

The ICU 2005 (former Joint UWBST / IWUWBS) will be held from September 5 - 8, 2005 in Zurich, Switzerland. The conference is co-organized by the Swiss Federal Institute of Technology (ETH Zurich) and IBM Research GmbH, Zurich Research Laboratory. The conference will cover all aspects of UWB technology including information theoretic limits, antennas and propagation, signal processing, circuits and systems, multi-access and coding as well as innovative applications and coexistence. We cordially invite all experts in the UWB field to submit papers for the ICU 2005 conference.

Important Dates:

- **Attention**
  - Extended paper submission deadline
  - March 31, 2005

- Conference:
  - September 5-8, 2005

- Camera ready paper:
  - July 4, 2005

- Technical Exhibition:
  - September 5-7, 2005
  - Registration deadline: July 1, 2005
New Book Release on this May by John Wiley&Sons:

Ultra Wideband Signals and Systems in Communication Engineering by Ghavami, Michael, and Kohno
Concluding Remark

- **SDR** and **UWB** are the most promised technologies for future wireless communication networks and create new applications, e.g. ITS, medical care etc.

- **Software reconfigurability** (SDR, E2R) in multiple layers can improve ad-hoc wireless networks (WLAN, WPAN etc) as well as infrastructure wireless networks (UMTS, 4G) in terms of ubiquitous connectivity, network transparency, and adaptive resource managements.

- **UWB technology** makes speed and capacity of ad-hoc wireless networks ultra higher, and ranging and positioning resolution of sensor networks ultra higher.

- However, many unsolved problems have still remained in SDR and UWB, so we hope to start collaborating with you for comprehensive solution!
NiCT-UWB Consortium’s Soft-Spectrum UWB PHY Proposal for IEEE 802.15.3a

Basic Philosophy → Soft-Spectrum Adaptation (SSA)

- Design proper pulse waveform corresponding to required band restriction
- Match its spectra with required spectral mask in flexible and adaptive, even if regional spectral mask is changed

**Soft-Spectrum Adaptation (SSA)**

Ryuji Kohno's Properties, Confidential
(1) Free-verse Type Soft-Spectrum Adaptation
→ Freely design pulse waveforms by synthesizing pulses, e.g. overlapping and shifting

K-3 Free-verse Soft-Spectrum Adaptation pulse
(Note: band notches clearly happen at 2.4 and 5.2 GHz as well)

K-4 Free-verse Soft-Spectrum Adaptation pulse
(Note: pulse waveform has more freedom)
Motorola exhibits its UWB demo kit that can convey up to 3 HD streams in the air. PHY, MAC and IEEE1394 functions are packed in a 15.6cmx12cmx3cm box. IEEE1394 is simply chosen for its popularity among AV products and for demonstration purpose.

Contact:
Kojino Nagatake
Tel: +81 3 3260 6626
E-mail: rty913@motorola.com

1. **Quasi millimeter-wave UWB radar technology**
   Nowadays UWB short-range radar systems are attracting the attention in the world. NICT has recently developed a quasi millimeter-wave UWB impulse radar technology. In our exhibition site we show the developed radar system and its principle by posters.

2. **UWB test bed**
   NICT constructed a UWB test bed. It can emulate various type of UWB system and be utilized for system verification and performance evaluation with radiating UWB signal. We plan to prove the efficiency of some novel UWB techniques such as the Soft Spectrum Adaptation (SSA).

3. **CMOS MMICs and Tx/Rx modules for UWB implementation**
   We exhibit the UWB Tx/Rx modules that use CMOS MMICs for either of the multiband OFDM system or the...
Anticipation of UWB Evolution

- UWB is much more practical technology than SDR, so within a few years, wireless PAN based on UWB etc should be started servicing.

- Technical key issues for commercial UWB systems:
  (1) Specification of signaling, modulation, chip design and architecture
  (2) Protocol matched with UWB nature
Anticipation of UWB Evolution (continue)

- Regulatory key issues for commercial UWB systems;
  
  (1) Interference to and from co-existing systems
  
  (2) International fair competition rather than monopoly
  
  (3) Collaboration and cooperation among industry, academia, and government.
Elementary and Cross-over Technologies for SDR & UWB

Software Defined Radio
Ultra WideBand Radio

Transmission Tech.
- Modulation & Demodulation
- Multiplexing
- Multiple Access

Air Interface
- Channel Estimation
- Equalization
- Adaptive Array Antenna

Signal Processing Tech.
- Coding & Decoding
- Description Language
- Interface

Device Process
- SemiCon, Super Conductive
- Memory

Wireless Tech.
- (Elec-Mag Field Analysis, Propagation Modeling)

Device Driver
- Adaptive Algorithm
- Filtering

User Interface
- Reconfiguration
- Simulation

Software Eng.
- Application Program
- (Algorithm, Program Language)

DSSR
- Simulation
- Measurement
- Equipments
- Antenna
- RF Circuit
- Battery

Processor
- (FPGA, DSP, ASIC)

Converter
- Sampling
- Processor

Download
- Reconfiguration
- Simulation

Real-time OS
- Application
- Program

Ryuji Kohno's Properties, Confidential

Colloquium, Institute EUROCOM, France, June 23, 2005
This technical conference and product exposition is focused on technology, standards, and business activity related to software defined radios.

The conference will be held immediately prior to the November general meeting of the Software Defined Radio Forum, it provides an international perspective of the current state of the art for software defined radios.

The Conference and General Meeting will be held at Disney's Contemporary Resort in Orlando.

Room reservations at the SDR Forum's preferred rate can be made by calling +1 407-824-3869, or by sending an email to the SDR Forum office (info@sdforum.org) and asking for the reservation form.
Receiver Architectures

**Conventional Superheterodyne receiver:**
Even though this is widely used now, it is difficult to change system parameters such as bandwidth, because RF and IF signals are processed by fixed analog components.

**IF sampling:**
Down-conversion from IF to baseband is done digitally undersampling is necessary to sample bandpass IF signals

**Near-zero IF down conversion:**
RF is down-converted to near-zero IF, which is sampled digitally need not deal with DC offset problem

**Direct (zero IF) down conversion:**
RF (Radio Frequency) is directly down-converted to baseband in analog domain have to deal with DC offset problem
Security problem for SDR

1. What is a secure way to download and reconfigure a software to a software radio terminal?

2. Is there a way to prevent hacking operation of a software radio terminal?

3. How can we change radio regulation based on type-approval so as to match with SDR commercial products?
Part I

Research on Software Reconfigurable Technology in Kohno Laboratory
Research on SDR in Yokohama National University

- Kenta UMEBAYASHI
  - Concept of Universal radio in SDR
  - Multimode PLL for carrier recovery and modulation identification

- Kentaro IKEMOTO
  - Pulse Shape and Coded Modulation Technique Under Multi Path Fading Channel
  - Adaptive Modulation & Channel Coding Technique
  - Modulation & Channel Coding Identification Technique
  - System Sensing for SDR+UWB communication system

- Kazuyuki OKUIKE
  - On-Board Automatic Certification System (ACS) for Software Defined Radio

- Motoko TANIGUCHI
  - FPGA Fault Detection Using Error Correcting Codes for Software Defined Radio Systems
Concept of Universal radio in SDR

Main advantages of an Universal Radio

- Ultimate flexibility and adaptability
- Dramatic improvement of Frequency utilization efficiency
- Universal radio can adapt to the multiple communication systems
- Universal radio can estimate the environment and adapt it.
- Universal radio can be realized by using SDR techniques.

Fig.1 Basic Concept of Universal radio

Subjects of the universal radio in SDR

- Channel estimation algorithm without any supplemental information is necessary to realize high adaptability
- Universal algorithm which can adapt multiple types of the module is necessary to reduce number of the mode changing
- Mode change recognition or identification is necessary to realize ultimate flexibility

Our research focuses on this subject with Modulation Identification technique without any supplemental information. In conventional technique, supplemental information is employed to control the mode change.
Multimode PLL for carrier recovery and modulation identification

Multimode PLL

Multimode PLL can recover the carrier and identify the modulation type without supplemental information.

“Modulation identification” is key technology which can identify the mode change.

Contributions of this research:

Carrier and initial phase offset problem is considered with digital PLL.
Carrier lock and modulation identification are processed at same time, therefore, acquisition time is reduced.
Multimode PLL is evaluated in the Adaptive Modulation System in ISDB-S.

In modulation identification, other detection techniques, e.g. carrier recovery, countermeasures for fading have to be considered.

Modulation identification technique has to be evaluated on the concrete application.
This research show the solutions for above problems.
Pulse Shape and Coded Modulation Technique Under Multi Path Fading Channel

Hermite polynomials function
Hermite Pulse are orthogonality respectively
Transmits symbols simultaneously

Received Signal $r(t)$

$C_n = \int_{-\infty}^{\infty} r(t) \cdot h_n(t) dt$

$D_n = 2^{C_n} - 1$

Theoretical and Simulated BER Characteristics of Hermite Pulse

System Model

Transmitter Side

Receiver Side

Iterative Decoding

Decoding Process

Several Iterative Processing

E.M. Algorithm

HMM for Fading Environment

Pseudo LLR

Sum-Product

Decoding Output

P/S

Output

P/S
Adaptive Modulation & Channel Coding Technique

System Model for Adaptive Modulation & Channel Coding Technique

Transmitter Side
Select Optimum Encoder and Gradual Transition for Channel Condition

Receiver Side
Viterbi Estimation in the Trellis Estimation of the used Encoder

Constellation for Soft Decision Decoding

Adaptive Coding System

Source Encoder
Convolutional Code Encoder 1
Convolutional Code Encoder N

Switch

Finite State Machine

Codes from Channel Estimation Result

Encoder Information

Demodulator

Viterbi Estimation

Viterbi Decoder 1
Viterbi Decoder N

Source Decoder

Modulator

BPSK BPSK QPSK 8PSK 8PSK 8PSK 16QAM 16QAM 16QAM 8PSK QPSK 8PSK

Frame Structure for Adaptive Modulation & Channel Coding Technique

<table>
<thead>
<tr>
<th>Frame</th>
<th>1200 Bit</th>
<th>2400 Bit</th>
<th>3600 Bit</th>
<th>4800 Bit</th>
<th>1200 Bit</th>
<th>2400 Bit</th>
<th>3600 Bit</th>
<th>3600 Bit</th>
<th>4800 Bit</th>
<th>4800 Bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0010</td>
<td>01100</td>
<td>0101</td>
<td>0001</td>
<td>01100</td>
<td>0101</td>
<td>0001</td>
<td>01100</td>
<td>0101</td>
<td>0001</td>
</tr>
<tr>
<td>SNR</td>
<td>11111</td>
<td>0111</td>
<td>0011</td>
<td>11111</td>
<td>0111</td>
<td>0011</td>
<td>11111</td>
<td>0111</td>
<td>0011</td>
<td></td>
</tr>
<tr>
<td>SNR</td>
<td>0000</td>
<td>0101</td>
<td>0101</td>
<td>0001</td>
<td>0101</td>
<td>0101</td>
<td>0001</td>
<td>0101</td>
<td>0101</td>
<td>0001</td>
</tr>
<tr>
<td>SNR</td>
<td>1111</td>
<td>0111</td>
<td>0011</td>
<td>1111</td>
<td>0111</td>
<td>0011</td>
<td>1111</td>
<td>0111</td>
<td>0011</td>
<td>1111</td>
</tr>
<tr>
<td>SNR</td>
<td>1111</td>
<td>0111</td>
<td>0011</td>
<td>1111</td>
<td>0111</td>
<td>0011</td>
<td>1111</td>
<td>0111</td>
<td>0011</td>
<td>1111</td>
</tr>
</tbody>
</table>

BPSK
QPSK
8PSK
16QAM
8PSK
16QAM
8PSK
QPSK
8PSK
Creation of Future Social Infrastructure Based on Information Telecommunication Modulation & Channel Coding Identification Technique

Yokohama National University

Modulation Identification Technique

Channel Coding Identification Technique

Flowchart

Step 1. Initialization
Step 2. Sum-Product Decoding
Step 3. Calculation of Soft Decision Bit
Step 4. Phase Error Estimation Using MMSE
Step 5. Phase Error Offset Using Soft Decision Bit
Step 6. Update of LLR
Step 7. Stop Regulation of Soft Decision
Step 8. Frame Synchronization
Step 9. General Sum-Product Decoding
Step D. Estimate Modulation Scheme

Modified LLR

$$\text{Modified LLR} = \frac{1}{\text{Num}_\text{Bit}} \sum_{i=1}^{\text{Num}_\text{Bit}} |L(u_i)| \times \text{Modified}$$

BMPSK QPSK 8PSK 15QAM
2/3 3/4 4/5 1

System Model

LDPC Encoder
Carrier Sense
Sampling & Buffering
Modulation Scheme Estimator
Phase Estimator
Frame Synchronization

Combination Iterative Algorithm of Sum-Product Decoding + Frame Synchronization and Phase and Carrier Offset

Decode: Convolutional code

1st in viterbi decoding

2nd in viterbi estimation of encoder transition

3rd in viterbi estimation of FSM transition

Trellis diagram

(Combined with several trellis diagram)

Estimate the encoder automatically

Converted to encoder information

Observation corresponds to encoder information

Estimate the ML trellis encoder transition

Converted to FSM information

Frame Synchronization

Observation corresponds to FSM information

Estimate the ML trellis FSM transition

FSM 1
FSM 1
FSM 1
FSM 3
FSM 3
FSM 3
FSM 2
FSM 2
FSM 4
FSM 4
FSM 4

Ryuji Kohno's Properties, Confidential

Colloquium, Institute EUROCOSM, France, June 23, 2005
Ryuji Kohno's Properties, Confidential

Creation of Future Social Infrastructure Based on Information Telecommunication Technology

Yokohama National University Colloquium, Institute EUROCOM, France, June 23, 2005

System Sensing for SDR+UWB communication system

Hermite Polynomial

\[ h_n(t) = (-1)^n e^{t^2} \frac{d^n}{dt^n} (e^{-t^2}) \]

Modified Hermite Polynomial

\[ h_n(t) = (-1)^n e^{t^2} \frac{d^n}{dt^n} (e^{-t^2}) \]

Frequency Response Order (Between \( n=1-7 \) and \( n=8-14 \))

Bandwidth extends wider as the number of order increases

Modified Hermite Polynomial

Transmitter Side

\[ d(t) \]

Info

Pulse Generator

System Model

s(t)

n(t)

Narrow Band Signal

Noise

Receiver Side

Correlation

Detection

\[ h(t) \]

\[ D_n = 2C_n - 1 \]

\[ C_n = \int_{-\infty}^{\infty} r(t) \cdot h_n(t) dt \]

Correlation Characteristics in Frequency Domain between Narrowband signal and Template for Modified Hermite Pulse

Spectrum Analyses of Narrowband Signal (BPSK)

Using Template for Modified Hermite Pulse (Left)

Using Conventional Scheme (Right)
Huge Demands for Broadband Wireless Communications
- Co-exit of Various Wireless Systems

- Low Power Consumption
- System Stabilization
- Inter System Interference
- Demand for Multimode

Hardware

- Software
- Software Reconfigurability (Re-Configuration)
- Omit of IF Circuits (Direct Conversion)
- System Sensing
- Auto Certification
- One-Chip Implementation
- Remote Maintenance

Software

- Environments
- Broadband Wireless Communications Techniques
- Privacy of Communication & Certification
- Inter System Interference Countermeasure
- Inter User Interference Countermeasure
- Interference Countermeasures

Environments

- Applications
- Fading Countermeasures
- Home Networks
- Office Networks

Applications

Concept of Software Defined Radio & Ultra WideBand Communications

MIMO
- Multi User Detection
- Fading Countermeasure
- System Handover

SDR
- Adaptive Modulation
- Coded Modulation
- Coding

For Environment

UWB
- System Sensing
- Pulse Shape Coded Modulation

For Application

Concept of Research

Adaptive Resource
- Adaptive Equalizer
- Adaptive Array Antenna
- Adaptive Sampling
- Channel Estimation

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**BACKGROUND**

Current Radio Regulation
Radios can’t reconfigure the system.

**HOWEVER**
SDR Terminal can reconfigure the system.

**THEREFORE**
We have to change the radio regulation based on type approval to match SDR commercial products.

**ACS ARCHITECTURE**

**RELATIONSHIP AMONG THE PARTIES INVOLVED**

**IN THE ACS**

**COMPARISON OF ACS- AND C3PC- BASED FRAMEWORK**

<table>
<thead>
<tr>
<th>Role (ACS)</th>
<th>Role (C3PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governmental Authority</td>
<td>Authorize SDR Hardware and Software</td>
</tr>
<tr>
<td>Certification Authority</td>
<td>Provide the Public Key Infrastructure (PKI)</td>
</tr>
<tr>
<td>Operator</td>
<td>Provide the Wireless Communication Infrastructure</td>
</tr>
<tr>
<td>Hardware Manufacturer</td>
<td>Make SDR Hardware and Acquire the Type Approval</td>
</tr>
<tr>
<td>Software Manufacturer</td>
<td>Make SDR Software and Acquire the Type Approval with Hardware Manufacturer</td>
</tr>
<tr>
<td>User</td>
<td>Use the SDR terminal without complicated operation</td>
</tr>
</tbody>
</table>
Remote maintenance of the SDR System
- It is possible to maintain remotely because the terminal system is remotely self-reconfigurable
- Significant advantage for users and manufactures

Fault Detection of FPGA in the SDR terminal after shipment
- Possible to repair itself by using fault free parts
- The purpose is only detecting and pinpointing the fault part
- Reduction of the computational cost is required

A remote fault detection system with **low computational cost** at the terminal

FPGA hierarchical fault detection using error correcting code

- Based on the regularity of error correcting code which is beforehand given to the test output
- The test areas are hierarchically distributed

Protocol of the proposed system

- In the SDR terminal:
  - Compute syndrome
  - Transmit FPGA data about fault rate and fault part to the base station

- In the base station:
  - Find \( \Delta(x) \)
  - Find positions
  - Find error values

\[ S = 0 ? \]

- Yes: Re-implement
- No: Transmit \( S \) and the output code word \( w \)

- Implement \( TD \) on the FPGA and compute syndrome \( S \) as the test.

- Generate a configuration data \( CD \) for the FPGA test and transmit \( CD \) to SDR terminal

- If \( S = 0 \), implement \( TD \) on the FPGA and compute syndrome \( S \) as the test.

- Transmit \( S \) and the output code word \( w \) to SDR terminal.

- Test complete notice to Base station.

- Data of the FPGA is renewed.

Selection of error correcting code for test

- Probability of aliasing
- Check circuit area
- The average of the transmit information quantity

Trade-off

- Degradation
- Reduction

- Probability of not detecting fault correctly

Computational cost of the terminal

- The probability of aliasing
- Check circuit area
- The average of the transmit information quantity

Selection of error correcting code for test
UWB History

- Ross 1963: \( \delta(t) \) response for microwave N-ports
- Ross 1970s: US patents
- Harmuth 1980s: UWB antennas
- 1990s UWB development programs
- 06 1999: UWB devices
- CRL 05 2002: UWB project start

Ross 1965: UWB technology research at Sperry
Bennet and Ross 1978: Time Domain Electromagnetics
Barrett 1989: UWB term
1998: FCC UWB NOI
FCC 14/02 2002: UWB regulatory approval
2004 and beyond: Commercialization of UWB applications

(1) impulse radio
(2) time domain
(3) carrier-free
Research Issues on Impulse Radio/UWB in Kohno Laboratory

1. Comparison between UWB and SS Systems

2. Multi-level or M-ary schemes for Improvement of UWB Transmission Efficiency

3. Pulse Shaping and Multi-pulse Shaping schemes for Improvement of UWB Transmission Efficiency

4. Multi-user Detection and Interference Cancellation Technologies for Improvement of UWB User Capacity

5. Space-Time Equalization Technologies in the Presence of Multipath Distortion

6. Space-Time Interference Cancellation Technologies in the Presence of Overlaid or Co-existing Conventional Systems

7. Joint Communicating and Ranging Systems Based on UWB

8. Ultra Wideband Antenna for UWB
**Important Aspects for UWB systems implementation**

- UWB commercial systems can be available only if low cost implementation of UWB circuits and antennas are ready for mass production as well as a theoretical performance analysis and a regulation rearrengement.

- New methods of measuring UWB signals and measurement equipments should be developed.

- New Design rules of RF circuits for UWB impulse response should be invented and established different from conventional sinusoidal response.
UWB Technology Institute in CRL

Aim:
1. Promote R&D of UWB Commercial Systems and Its Related Technologies
2. Cooperation with Industry and Academia
3. Modify Radio Regulation and Establish Guidelines and Standard

Date: Officially July 1, 2002 (Effectively May 2002)
Place: CRL (Communication Research Laboratory) in YRP
Director: Ryuji Kohno

UWB Consortium between Industry and Academia

Aim:
1. R&D and Regulation of UWB Wireless Systems
2. Experimental Analysis of UWB System Test-bed in band 960MHz, 960MHz, 3.1-10.6GHz, 22-29GHz)
3. R&D of Low Cost Module with higher data rate over 100Mbps
4. Contribution in Standardization and Regulation in ARIB, MPHPT, ITU etc
Companies participating in UWB Consortium (1)

Advantest Corporation
Anritsu Corporation
CASIO Computer Co., Ltd.
Fuji Electric Co., Ltd.
Fujitsu Limited
Furukawa Electric Co., Ltd.
Hitachi Cable, Ltd.
Hitachi Communications Technologies, Ltd.
Hitachi Kokusai Electric Inc.
Matsushita Electric Industrial Co., Ltd.
Matsushita Electric Works, Ltd.
Companies participating in UWB Consortium (2)

NEC Corporation
NEC Engineering, Ltd.
NTT Advanced Technology Corporation
Oki Electric Industry Co., Ltd.
Omron Corporation
Samsung Yokohama Research Institute
Samsung Electronics
SANYO Electric Co., Ltd.
Taiyo Yuden Co., Ltd.
Telecom Engineering Center
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Creation of Future Social Infrastructure Based on Information Telecommunication Technology
Yokohama National University

Colloquium, Institute EUROCOM, France, June 23, 2005

COMMUNICATION SYSTEMS AND APPLICATIONS (CSA2004), Banff, July 8, 2004
Japanese UWB Consortium

UWB Microwave Group:

> **Leader**
  Dr. Ryuji Kohno (CRL, Yokohama National Univ.)

> **Sub Leader**
  Dr. Hiroyo Ogawa (CRL)

> **Leaders of 5 Working Groups**
  Dr. Takehiko Kobayashi; **WG on Channel Propagation**
  Dr. Jun-ichi Takada; **WG on System Measurement**
  Dr. Ryuji Kohno; **WG on UWB System Design**
  Dr. Toshiaki Matsui; **WG on UWB System Implementation**
  Mr. Tetsuya Yasui; **WG on International Collaboration**

> **Registered Researchers (incl. part-time researcher)**
  83 Researchers from 22 organizations
### Comparison of System Specification

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Bluetooth</th>
<th>Bluetooth Ver.2</th>
<th>5.2GHz Mobile Access</th>
<th>License Free System in 60GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upto 721kbps</td>
<td>2Mbps</td>
<td>Upto 54Mbps</td>
<td>Home-link 1.6Gbps</td>
<td></td>
</tr>
<tr>
<td>Communication Range</td>
<td>10~100m</td>
<td>10~100m</td>
<td>100m</td>
<td>10m</td>
</tr>
<tr>
<td>Drawback</td>
<td>Low rate</td>
<td>High power consumption</td>
<td>High Cost</td>
<td></td>
</tr>
<tr>
<td>Advantages</td>
<td>Ad-Hoc Low Cost</td>
<td>Ad-Hoc Low Cost</td>
<td>Indoor Only</td>
<td></td>
</tr>
<tr>
<td>Low Cost &amp; Low Power Consumption</td>
<td>High Transmission Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CRL-UWB Consortium’s
Soft-Spectrum UWB
PHY Proposal for IEEE 802.15.3a
March 2003

Ryuji KOHNO
Director, UWB Technology Institute, CRL
Professor, Yokohama National University
Chair, CRL-UWB Consortium
Honggang ZHANG, Hiroyo OGAWA

Communications Research Laboratory (CRL)
& CRL-UWB Consortium
Advantages of Soft-Spectrum Adaptation (SSA)

- **Soft-Spectrum Adaptation (SSA)** can adapt signal spectra to any spectral requirement by flexible pulse waveform shaping similar to **Software Defined Radio (SDR)**.

1. **Global regulation satisfaction**: SSA can flexibly adjust UWB signal spectrum so as to match with spectral restriction in transmission power, i.e. spectrum masks.

2. **Interference avoidance for co-existence**: SSA can adaptively avoid interference from and to co-existing systems in the same band and maximize spectral efficiency.

3. **Harmonization for various proposed systems**: SSA is good for harmonization among different UWB systems because SSA includes various proposed UWB systems as its special case, e.g.
   - XSI’s DS-CDMA as a case of **Free-verse type SSA**
   - MBOA’s MB-OFDM as a case of **Geometrical type SSA**

4. **Future system version-up**: SSA is so scalable as to accept future UWB systems with better performance like SDR.
2.5 Improved Common Signaling Mode (ICSM) using PSWF-type SSA pulse wavelets

DS-UWB operating bands

MB-OFDM operating bands
Basic principles of compatibility model in Japan

(1) Radio spectrum is a finite resource. As such, radio spectrum usage should adhere to international systems of rules and should be carefully designed to avoid future problems.

(2) As yet, UWB stations do not belong to any designated service and the UWB format is not based on the Radio Regulations (RR) allocations. As such, it is not considered in compliance with stipulations.

(3) The study of compatibility conditions is predicated on radio regulations (RR) Section 4.4 concerning interference.

[Radio Regulations. Section 4.4]
Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.
Japanese Contributions on Measurements of UWB Signals for ITU TG1/8

Regulatory Committee for UWB Radio Systems in Ministry: MPHPT

- Japanese Regulator (MPHPT) has been investigating mutual interference between UWB and victim systems.

- Some results on measurements of UWB signals have been presented at ITU TG1/8.

- This is important for a regulator to approve type of UWB systems. Regulators in ITU Region 3 (Korea, China, Singapore etc in Asia) may be mostly same situation.
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Creation of Future Social Infrastructure Based on Information Telecommunication Technology
Yokohama National University

Colloquium, Institute EUROCOM, France, June 23, 2005

Joint UWBST&IWUWBS 2004
Hotel Granvia Kyoto, Kyoto, Japan, May 19-21, 2004

General Chair: Ryuji Kohno Yokohama National Univ.
Technical Program Chair: Tetsushi Ikegami, Meiji Univ.
Technical Program Committee Co-Chairs:
Yukitoshi Sanada, Keio University
Shigenobu Sasaki, Niigata University
Organizing Committee Chair: Shinsuke Hara, Osaka Univ.
Organizing Committee Co-Chair: Akifumi Kasamatsu, CRL

Sponsor
National Institute of Information and Communications Technology (NICT)
Yokosuka Research Park R&D Promotion Committee (YRP)
Yokohama National University 21st Century COE

Technical Sponsors(Tentative)
IEEE Communication Society (COMSOC)
IEEE Microwave Theory and Technology Society (MTT)
IEICE Technical Group on Wide Band Systems (WBS)
IEICE Technical Group on Radio Communication Systems (RCS)
IEICE Technical Group on Microwave (MW)
PULSERS, Europe
Korean UWB Forum, ETRI
Japanese UWB Consortium

In Cooperation with
Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT), Japan
Multimedia Mobile Access Communications Committee (MMAC)

Antennas and Propagation:
- Antennas
- Channel measurement and modeling
- Field trials and measurements
Modulation Schemes and Systems:
- Modulation and detection
- Interference and capacity
- Receiver architectures
Implementation:
- RF modules
- Integrated circuit design and implementation
- Low power consumption technique
Regulatory issues:
- Signal modeling
- Co-existence scheme with the other systems
UWB Applications:
- Radar
- Positioning
- Ad-hoc networks
- Tools for system analysis

Important Due Dates
Submission of 5 page full paper: 31 Dec, 2003
Notification of acceptance: 10 Feb, 2004
Camera ready submission due: 10 March, 2004
Further Studies

(1) **Harmonization with international studies** is required, particularly with **ITU-R and IEEE studies**. Similarly, the outcomes of technical studies in Japan should be contributed in recommendations from organizations such as the ITU-R.

(2) Theoretical calculations based on the ITU-R recommendations and the proposed compatibility model incorporating FCC emission power proposals found that long separate distance or limitations on the number of devices would be required for **compatibility between UWB and other radio systems**, necessitating further studies as follows:

> Study of actual effect of UWB based on experimental data and simulations
> Detailed investigation to consider actual deployment of radio systems
> Other strategies for mitigating interference
> Review of emission power proposals
Potential Applications of UWB

- **Wireless communications**
  - High speed/low speed and high user capacity
  - Short distance communication (e.g., a few km)
  - Indoor wireless (e.g., WLANs, wireless tags, WPAN)
  - Outdoor communications (e.g., WLL)

- **ITS: Intelligent Transport Systems**
  - Collision avoidance radar
  - Realization of both communication and ranging with a single hardware

- **Imaging and sensors**
  - Medical imaging
  - Ground penetration

- **Security systems**
  - Intrusion detection and sensing
M-ary Pulse Shape Modulation (PSM) or Pulse Shape Multiple Access (PSMA) based on geometric Soft-Spectrum waveforms
The COE Covering Research Fields

Major Fields of Government Committee of Science and Technology: Environmental Energy, Life Science, Information Telecommunications, Nano-Technology

The COE Leading Fields in a World

Appropriate Size: Various Staffs within one Course

Evolution

Middle Range Objective: Creation of Social Infrastructure Based on Information Telecommunications Technologies

Close Collaboration between System Design and Device Development

Wireless Communications + Integrated Photonics: Integrated Optical and Radio Communications

Partners: Communication Research Laboratory (CRL), Yokosuka Research Park (YRP)

Long Range Objective: Grand Design of Infrastructure for Future Society

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Creation of Future Social Infrastructure Based on Information Telecommunication Technology

Yokohama National University Colloquium, Institute EUROCOM, France, June 23, 2005

Prof. Ryuji Kohno: System Architecture, Space-Time Signal Processing

Prof. Yasuo Kokubun: Optical Integrated Circuits for Wave-length Multiplexing


Asso. Prof. Yasushi Takemura: High-Density Memory/Storage Devices

Prof. Tsutomu Matsumoto: Information Security, Tamper Resistancy

Prof. Atsuo Kawamura: Mechatronics, Robotics

Prof. Rokuya Ishii: MultiMedia Signal Processing, Processors

Asso. Prof. Toshihiko Baba: Photonics Crystal, Opto-Electronics

Research on System Architecture

Research on RF System Implementation

Research on Intelligent Storage Devices

Research on Optical-Radio Transform

The COE's Covering Research Fields

System Design Group

Device Research Group
Receiver Architectures

Conventional Superheterodyne receiver:

Even though this is widely used now, it is difficult to change system parameters such as bandwidth, because RF and IF signals are processed by fixed analog components.

IF sampling:

Down-conversion from IF to baseband is done digitally undersampling is necessary to sample bandpass IF signals

Near-zero IF down conversion:

RF is down-converted to near-zero IF, which is sampled digitally need not deal with DC offset problem

Direct (zero IF) down conversion:

RF(Radio Frequency) is directly down-converted to baseband in analog domain have to deal with DC offset problem
### Table 1 Mobile Communication Systems in Japan

<table>
<thead>
<tr>
<th>System</th>
<th>Frequency bands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cellular</strong></td>
<td></td>
</tr>
<tr>
<td>PDC</td>
<td>4.5 GHz</td>
</tr>
<tr>
<td>IMT-2000(CDMA1X)</td>
<td>2.0 GHz</td>
</tr>
<tr>
<td>PHS(micro cell)</td>
<td>800MHz, 1.5 GHz</td>
</tr>
<tr>
<td></td>
<td>1.9 GHz</td>
</tr>
<tr>
<td><strong>Wireless LAN</strong></td>
<td></td>
</tr>
<tr>
<td>IEEE802.11a,b,g,n</td>
<td>2.4 GHz, 5.2GHz(ISM band)</td>
</tr>
<tr>
<td>MMAC</td>
<td>5.15-5.25 GHz</td>
</tr>
<tr>
<td>Altair(Motorola)</td>
<td>19 GHz</td>
</tr>
<tr>
<td><strong>Wireless PAN</strong></td>
<td></td>
</tr>
<tr>
<td>IEEE802.15.3a</td>
<td>3.1GHz – 10.6GHz (Ultra Wideband Tech.)</td>
</tr>
<tr>
<td>UWB-WPAN</td>
<td></td>
</tr>
<tr>
<td><strong>Pager</strong></td>
<td>Pocket Bell</td>
</tr>
<tr>
<td></td>
<td>250 MHz</td>
</tr>
<tr>
<td><strong>Cordless Phone</strong></td>
<td></td>
</tr>
<tr>
<td>Analog</td>
<td>250/400 MHz</td>
</tr>
</tbody>
</table>
Fig.1  PDC/PHS Dual Mode Terminal  “Doccimo”
Fig.2 PDC Mobile Location Terminal by GPS (Naviewn)
2. IEICE Workshop on Software Radio in June 30, 1999

Life Science Center, Senri, Osaka, Japan

Regular Sessions
(1) Opening Address by Ryuji Kohno (Yokohama National University)
(2) “Research of Developing Software Radio Receiver in the ARIB Project” by Tokihiko Yokoi (Toshiba) et al.
(3) “Implementation and Evaluation of Software Radio Receiver” by Yoko (Toyocom)
(4) “Programable Real-time Simulator” by Ohta (MPT, CRL)
(5) “Algorithm to Estimate Modulation Scheme and Symbol Synchronization” by Kenta Umebayashi, Ryuji Kohno (Yokohama National University)

Invited Talks
(6) “Application of Super-conductor Device to Software Radio Systems” by Katayama and Fujimaki (Nagoya University)
(7) “Integration of Circuits for Software Radio Portable System” by Kenji Yaniguchi, Ryuji Yoshimura, Tan Boon Keat, Tohru Ogawa (Osaka University)
(8) “Software Antenna Based on Eigenvector Analysis” Toshio Karasawa (University of Electro-Communications)
(9) “Identify System for Unknown Modulated Signals” Shintarou Taira (National Defense)
(10) “Shannon vs. Moore: Digital Signal Processing for Broadband Wireless Communications” by Ravi Subramaniam (Morphics Technology)
4. IEICE Workshop on Software Radio in April 17, 2000

Yokosuka Research Park (YRP), Kanagawa

Invited Talks
(1) “The Software Defined Radio Forum; An Overview” by Allan Margulies (MITRE Co.)
(2) “Software Defined Radio Forum Technical Committee Operations” by Peter Cook (SDR Forum)

Regular Sessions
(3) “Proposal of a super-conducting tunable filter for software-defined radio” by Shigeki Mototsu (Kinki Univ.) et al.
(4) “A study on an adaptive symbol timing synchronization method for multi-mode & multi-service software radio communication system” by Ryo Sawai (Chuo Univ.) et al.
(5) “Space Hopping Scheme Under Short Range Rician Multipath Fading Environment” by Satoshi Ishii (Yokohama National Univ.) et al.
(6) “Adaptive Block Coding and Decoding For Channel Condition Based on a Concept of Software Defined Radio” by Kentaro Ikemoto (Yokohama National Univ.) et al.
(7) “A Study on an Over-the-Air Download Scheme for Software Radios” by Hiroyuki Shiba (NTT) et al.
(9) “A Software Defined Radio using Direct Conversion Principle” by Hiroshi Yoshida (Toshiba Co.) et al.


[10] “A Study on Blind Adaptive Modulation Scheme for Rain Attenuation by using Multimode PLL,” by K. Umebayashi (Yokohama National University), R. M. Zaragoza (San Jose State University) and R. Kohno (Yokohama National University)

[1] “Experiment of Analog-Digital Signal Processing For Multi-Channel Reception,” by A. M. BOSTAMAN, Y. SANADA (Keio Univ.)


Fig. 3 Configuration of NTT’s prototype SDR station.

CPU: 300MHz, 64MB Memory
HDD: 2GB

RF: 2.45GHz

39MHz
6.5MHz
A/D: 10 bit, 104MHz
A/D: 12 bit, 52MHz

1600Mbps, 200MHz

Fig. 3 Configuration of NTT's prototype SDR station.
11. MPHPT/FCC/IEICE/SDR-Forum Joint SDR Workshop for Regulation

1. Date: **October 17, 2001**
2. Place: **Conference Hall, Ministry of Public management, Home affairs, Posts and Telecommunications (MPHPT), Tokyo**
4. Program
   - 13:00-13:10 Opening remarks: Ryuji Kohno (Chairman of IEICE SR-TG)
   - 13:10-13:40 Invited speech 1
     "New FCC Software Defined Radio Policy" Speaker: **Mike Marcus** (FCC, USA)
   - 13:40-14:10 Invited speech 2
     "System Aspects of SDR Regulation" Speaker: **Stephen Blust** (SDR Forum, USA)
   - 13:40-14:10 Invited speech 2
     "System Aspects of SDR Regulation" Speaker: **Stephen Blust** (SDR Forum, USA)
   - 14:10-14:45 Invited speech 3
     "Activity on the technical regulation conformity certification of software radio - Japan -" Speaker: **Kiyoshi Sekiguchi** (MPHPT) and **Koichi Sazanami** (TELEC)
   - 14:45-15:00 Coffee Break
   - 15:00-16:30 Panel Session (Simultaneous interpretation available)
     "Subjects and its solutions for the technical regulation conformity certification of software radio"
     Moderator: Ryuji Kohno (Chairman of IEICE SR-TG)
     Panelists: Mike Marcus (FCC), Stephen Blust (SDR Forum), Koichi Sazanami (TELEC), Mark Cummings (enVia), Mike Chartier (Intel), Hiroshi Harada (CRL), Kazuhiro Uehara (NTT), Masaaki Katayama (Nagoya Univ.), Junichi Takada (Tokyo Inst. of Tech.), Shinnichiro Haruyama (SONY CCL), Hiroshi Tsurumi (Toshiba)
Commission C – Signals and Systems
Session C.1: Software Reconfigurable Radio Systems(I)
Chair: Ryuji Kohno (Yokohama National University, Japan)

- 8:30-8:50 C.1.1 Security Issues of Downloading for Software Re-Configurable Radio Systems Versus Usual Internet Downloading (invited paper)
  Miodrag Mihaljevic (SONY CSL) and Ryuji Kohno (Yokohama National University)
- 8:50-9:10 C.1.2 Software Defined Radio: Current State/Future Directions of The Technology and the Need for International Coordination on Regulation (invited paper), Mark Cummings (EnVia, USA)
  Stephen Pearce and David Murotake (Mercury Computer Systems, USA)
- 9:30-10:00 Break
- 10:00-10:20 C.1.4 A Solution for Regulatory Issues with SDR (invited paper)
  Nigel Jefferies, Walter Tuttlebee, and Klaus Moessner (Vodafone, VCE, UK)
- 10:20-10:40 C.1.5 Channel Diversity in Mobile Software Radio Receivers:
  Harald Schnepp, Johann-Friedrich Luy, Peter Russer (DaimerChrysler, TU Muenchen, Germany)

URSI-GA 2002, Maastricht, August 19, 2002
Colloquium, Institute EUROCOM, France, June 23, 2005
Research Trend in 2nd Stage

- After 2001 (from Activities of IEICE SR-TG)

  - Developed key technologies
    - Software Processing (adaptive) Antenna and Space-Time Processing
    - Broadband and multipurpose analog-to-digital converter
    - Software Reconfigurable LOGIC
    - Direct Converters for low power consumption and high reconfigurability
    - RF Analog Processing and LOGIC

  - Solutions for problems when we introduce software radio
    - Security for hardware and software
      - Security for software download
    - Problems when certification bodies give license for software radio equipments:
      New Type Approval Scheme
      - Electrical labeling

  - New applications

  - Development of prototype
Technical certification framework -Present-

- The hardware and software for the radio are integral and inseparable --- Hardware Defined Radio (HDR)

Certification Agency: Performs the test for technical conformity issues and controls the certificate.

Terminal Manufacturer: Radio Equipment

Users: User Terminal

Application and certification for technical regulation conformity

Sales and purchase

The hardware and software for the radio are integral and inseparable --- Hardware Defined Radio (HDR)
Technical certification framework
-Near Future-

- The hardware and software for the radio are not integral and separable.
- Software manufacturer and hardware manufacturer belong to a common company or a common alliance.

Certification Agency
Performs the test for technical conformity issues and controls the certificate

Terminal Manufacturer
Radio Equipment
Software
Hardware

Users
User Terminal

Application and certification for technical regulation conformity
Sales and purchase
Technical certification framework
-Future-

**Hardware Flow**

- **Certification Agency**
  - Performs the test for technical conformity issues and controls the certificate

- **Software Manufacturer**
  - Radio Equipment
    - Software

- **Hardware Manufacturer**
  - Radio Equipment
    - Hardware

**Software Flow**

**Sales and purchase**

- **Users**
  - User Terminal
    - Software
    - Hardware

Certified hardware and software are integrated at the user.
Configuration of the SDR Terminal

Diagram showing the configuration of the SDR terminal with various components such as CPU boards, FPGA boards, RF boards, and other interconnected elements.
Security problems for SDR

1. **Secure Download**: What is a secure way to download and reconfigure a software to a SDR terminal?

2. **Secure Operation**: Is there a way to prevent hacking operation in a SDR terminal?

3. **Secure Certification**: How can we approve a type of SDR terminals (*type-approval*) by radio regulation?
Overview

- Demands for Software Defined Radio (SDR) or Reconfigurable Radio and Network
- Researching Bodies for SDR in Japan
- Trend of R&D for SDR in Japan
- Anticipation for Future SDR
NICT’s New Generation Mobile (NeGeMo) Network Project

- **Seamless access** to the public and private networks (ex. Internet) through heterogeneous radio access networks (RANs)
- **Secure service (application) handover** between public and private networks

![Diagram of network connections]

- Wireless LAN network
- Multimode terminal
- Broadcasting network
- Intelligent Transport Systems (ITS) network
- Cellular phone network
- Home network
When software radio is applied to new generation mobile communication systems

- Internet
- L2Sw / L3Sw / Mobile IP
- 2G
- 3G
- SDR Terminal
- BS
- AP
- WLAN .11a .11b/g
- System handover mode
- Multiple service mode
To realize NeGeMo (Beyond 3G)

- System “selection” (System handover) mode
  - Soft handover mode between different systems
  - Hard handover mode between different systems

- System “multiplexing” mode
  - Multiplexing between different systems
  - Multiplexing between same systems

- System “avoidance” mode

Software Reconfigurable Radio and Network

1. Broadband & Multi-band for Multi-mode Service
2. Re-configurability of Hardware with Software
3. Secure Downloadability
4. Adaptive Sensing Radio Environment
Beyond 3G & Hotspot System Based on Software Reconfigurable Radio and Network

- Internet
- Core Network
- Edge router
- Switch
- To other network
- Segment Network (Bus type)
- SDR-based Access point (AP)
- Segment Network (Star type)
- Sub-Segment Network (ROF type)
- Control AP
- Local AP
- SDR-based terminal
- High mobility

High mobility

Beyond 3G & Hotspot System Based on Software Reconfigurable Radio and Network

Beyond 3G

Hotspot System Based on Software Reconfigurable Radio and Network

Colloquium, Institute EUROCOM, France, June 23, 2005
Targeting UWB Systems (Data rate vs Mobility speed)

- **Indoor**
  - 2M Data Speed
  - Bluetooth

- **Nomadic**
  - 10M Data Speed
  - IMT-2000 (3G-cellular)

- **Pedestrian**
  - 50Mbps Data Speed
  - 5.2GHz-Wireless Access
  - UWB Systems

- **GSM**, **PDC**, **PHS**

- **4G-Cellular**

- **UWB Systems**

- **200 Mbps**

Colloquium, Institute EUROCOM, France, June 23, 2005
Used Cases and Interference to Existing Systems

> **Proposed used cases**

The main specifications of proposed used cases in the compatibility model are as follows:
- Indoor usage (wall attenuation: 12 dB)
- Users density: 3,000 devices per km²
- Active ratio: averaging 1% – 5% on per time basis
- Operation on board an aircraft, a ship or a satellite is prohibited

> **Interference with coexisting radio systems**

The proposed compatibility model was subject to interference calculation under the following conditions to assess interference by a single UWB device with other radio communication systems (test details shown separately).
- FCC transmission power mask: -41.3 dBm/MHz at 3.1 – 10.6 GHz
- Free space propagation
- Wall attenuation: 12 dB (assuming indoor use; outdoor use: four times greater separate)
- Average power and peak power evaluation
Working Group 1 (WG 1) – UWB characteristics
Chairman: William Gamble (USA)
Mandate: To collect and document key technical and operational characteristics of UWB;

Working Group 2 (WG 2) - UWB compatibility
Chairman: Yves Ollivier (France).
Mandate: To address compatibility issues
Deliverables:
1  One or more ITU-R Recommendation(s) on compatibility between UWB devices and Radiocommunication services.
2  ITU-R Report summarizing the results of technical studies on compatibility between UWB devices and Radiocommunication services.
Working Group 3 (WG 3) - UWB spectrum management framework
Chairman: Christoph Wöste (Germany).
Mandate: to prepare a spectrum management framework intended as guidance to administrations considering the introduction of UWB devices.

Working Group 4 (WG4) - UWB measurement techniques
Chairman: Tetsuya Yasui (NiCT, Japan)
Mandate: To develop appropriate measurement techniques for UWB emissions
Deliverables:
Develop one or more ITU-R Recommendation providing guidance to administrations how to measure emissions from devices using UWB technology.
ITU-R TG1/8: Summary of 1st Meeting

Date and place: Geneva from 21-24 January 2003
Attendees: 85 delegates
representing 17 Administrations,
18 Sector Members including NiCT,
Input documents: 44 input documents
Output (Temporary) documents: 23 temporary documents

ITU-R TG1/8: Summary of 2nd Meeting

Date and place: Geneva from 27-31 October 2003
Attendees: 118 delegates
representing: 26 Administrations
18 Sector Members including NiCT
Input documents: 57 input documents
Output (Temporary) documents: 37 temporary documents
Traditional UWB (Impulse Radio, Carrier-free)

1. Modulation
   - Carrier Free
   - Using a train of impulsive signals
     (1) PPM (Pulse Position Modulation)
     (2) Bi-phase Modulation
       - DS (Direct Sequence), TH (Time Hopping)
     (3) PAM (Pulse Amplitude Modulation)
     (4) PSM (Pulse Shape Modulation) using orthogonal pulses

2. Multiple Access
   (1) TH/CDMA
Japanese Regulatory Schedule on Commercial UWB Systems

- **May, 2002**  NICT(CRL) established **UWB technology Institute**
- **August 2002**  MMAC established UWB committee  
  for commercial UWB WPAN and home-link.
- **Sept. 2002**  NICT(CRL) established **UWB Consortium**
- **Nov. 2002**  MPHPT organized **UWB regulatory committee**
- **March, May, July, Sept., Nov. 2003, Jan., March, May and July 2004**  
  NICT(CRL) and UWB consortium proposed a **Soft - Spectrum Adaptation(SSA)** scheme for IEEE 802.15 TG3a
- **Feb., 2004**  MPHPT released an interim report of UWB Radio regulation.
- **3rd Q, 2004**  MPHPT will partially approve a commercial UWB regulation.
2.4 Implementation realization of SSA-UWB transceiver CMOS-MMIC

Press Release by NiICT (CRL):

“Tokyo, Japan, March 15, 2004 – NICT (former CRL) today announced an achievement for having developed a world’s first Ultra Wideband (UWB) transceiver modules using 0.18-micron CMOS-MMIC (3mm²) technology, realizing maximum data rate of 320 Mbps jointly with a number of industry members in UWB Consortium. These UWB transceiver modules can be applied to Soft-Spectrum Adaptation (SSA), not only for impulse radio transfer but also for multi-band OFDM transfer etc. It will be used for high data rate transmission evaluation, interference avoidance and UWB regulation establishment. Detailed information are expected to be published at the Joint UWBST&IWUWBS 2004, Kyoto, in May 2004.”
Remained Research Issues for Software Reconfigurable Radio

1. Reconfigurable Hardware Architecture: **Mass Production of Reconfigurable LOGICs**

2. API among Several Modules:
   - **Description Language, Range of Standardization**

3. Inter-operable OS: **Multiple Processors & CORBA**

4. Various Network Architectures: **System Handover**

5. **Secure Protocol of Download Services**

6. **End-to-end Reconfigurability via Various Networks**
1. Secure Download: What is a secure way to download and reconfigure a software to a SDR terminal?

2. Secure Operation: Is there a way to prevent hacking operation in a SDR terminal?

3. Secure Certification: How can we change radio regulation based on type-approval so as to match with SDR commercial products?
### SDR versus Internet Download

#### 1. Security needs

<table>
<thead>
<tr>
<th></th>
<th>SDR</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>integrity</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>authenticity</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>secrecy</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>non-repudiation</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

#### 2. Parties involved

<table>
<thead>
<tr>
<th></th>
<th>SDR</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Provider</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Approval authority</strong></td>
<td><strong>mandatory</strong></td>
<td><strong>not mandatory</strong></td>
</tr>
</tbody>
</table>
### SDR versus Internet Download

#### 3. Requested cryptographic primitives

<table>
<thead>
<tr>
<th></th>
<th>SDR</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secret-key ciphers</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Public-key ciphers</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Hash functions</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Digital signature</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

#### 4. Dedicated requirements

<table>
<thead>
<tr>
<th></th>
<th>SDR</th>
<th>Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>User inaccessibility to the security System</td>
<td>mandatory</td>
<td>usually not required</td>
</tr>
<tr>
<td>Approval label</td>
<td>mandatory</td>
<td>usually not required</td>
</tr>
</tbody>
</table>
UWBセンサーネットワーク
(IEEE802.15.4a)の要求条件

- Location-awareness（Mandatory）
  - 数10cm程度の精度を持つ測位技術
- ビットレート
  - * Individual link bit rate: peer to peerで最低1kbps @ PHY_SAP
  - * Aggregated bit rate: data collectorは最低1Mbps @ PHY_SAPのデータ捕捉が可能であること（緊急事態や、同時に各ノード情報を更新する場合に備えて）
- 距離
  - * 0-30m（数100mといった長距離の要求もあるが、距離を伸ばすとリンク内のノード数が増加するため、data collectorが捕捉すべきデータレートを高くする必要が生じる）
- 共存と干渉耐性
  - * 既存システムからの影響、既存システムへの影響を考慮したPHY設計
  - * 工場のような高マルチパス環境、高ノイズ環境でも動作可能であること
- QoS
  - * 信頼性を維持するために強力な誤り訂正技術が必要
  - * その他に次の項目を要求する:
    - 実時間通信接続
    - ノード間同期(主に局所化)
    - 緊急時の高速対応の容量確保
- 消費電力
  - * MACとPHYを含めて、充電なしで数ヶ月から数年間の利用可能
- 形状
  - * センサーネットワークやRFタグへの応用も可能であること
- モビリティ（Mandatory）
  - * 歩行、作業用機械搬車程度ならトラッキング可能であること、オプションとしてより遠い速度
- アンテナ
  - * 無指向性アンテナで頑強であること
- Regulation
  - * alt-PHYは各国・地域の規制を満たす

Ryuji Kohno's Properties, Confidential
ユビキタスUWB共同研究の成果イメージ

全体システムを使った実証実験の実施

大規模な病院、大学、イベント会場、レジャー施設などにおけるアドホックUWBネットワークのアプリケーションを実現

UWB無線端末I/F装置（YRC）を組み

T-Engine搭載UC（YRP ユビキタスネットワーク研究所 坂村教授）にUWB無線UNITを実装したシステム

ユビキタスネットワーク研究所と横須賀無線センターを中心とした共同研究開発
Creation of Future Social Infrastructure Based on Information Telecommunication Technology
Yokohama National University

Colloquium, Institute EUROCOM, France, June 23, 2005

ITU-R TG1/8: 第5回におけるNICTの役割
日時と場所: 2005年5月18-27日、米国サンディエゴ
日本: 情報通信研究機構NICT から寄書 (全体: 86件)
WG1の特性解析関連: 2件
WG 2の周波数共用: 2件
WG 4の測定関連: 1件
NICT とUWBコンソシアムから12名参加 (全体 146名)

(1) WG1 (特性): Emissionに関する定義、変調法に関してNICT貢献、スペクトルマスク(欧州CEPT, 米国FCCマスクなど併記)
(2) WG2 (共用): 共用勧告案がままでよりつつあり、日本寄書の干渉軽減技術がほぼ認められた。
(3) WG3 (フレームワーク) 勧告案が固まった。
(4) WG4 (測定法): 日本寄書が概ね採用された。

ITU-R TG1/8 今後の予定
第6回 (最終回): 2005年10月13-19日スイス、ジュネーブ
その後 親委員会SG1: 10月24-25日
UWBに関する電波法の国際協調を目指す。
DS-UWB Modulation/Demodulation

Modulation:

- Gaussian Filter
- LO $f_c \sim 4\text{GHz}$

Demodulation:

- LO $f_c \sim 4\text{GHz}$
- LPF
- ADC
Chirp/De-chirp Processing

Chirp can be done by passing a pulse signal through a DDL.

De-chirp is realized by doing correlated processing.

- B: 3-dB bandwidth of chirp
- T: time interval of chirp

Correlated processing

Time shift[s]

Correlator output
Why CS-UWB is needed?

-0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4

Cross-correlation coefficient

Normalized time difference

DS-UWB

CS-UWB

Ryuji Kohno's Properties, Confidential

Colloquium, Institute EUROCOM, France, June 23, 2005
On-Board Automatic Certificating System (ACS) for SDR

**Concept of on-board ACS**

- Type-Approval function in Licence-Certificate-Body can be carried out with **On-Board, On-Chip, On-Line, and Real-time**.
- **Each reconfigurable module** in SDR architecture can be approved on board or on chip.
- ACS consists of **tamper resistant hybrid hardware and software**.
Radio Resource Management in Network Using SDR Basestation and Terminals

- one SDR Basestation (BS)
- Several Terminals
  - SDR and conventional terminals are mixed
- Downlink

\[
G = (S, M) \\
S = \{s_1, s_2, \ldots, s_x \mid x \leq N\} \\
M = \{m_1, m_2, \ldots, m_y \mid y \leq N!\}
\]

\[m_i = (\text{Scheme of terminal}_1, \text{Scheme of terminal}_2, \ldots, \text{Scheme of terminal}_N)\]
UWB Technology Institute in NICT(CRL)

Aim
1. Promote R&D of UWB Commercial Systems and Its Related Technologies
2. Transfer the Technologies to Industry by Cooperation with Industry and Academia
3. Modify Radio Regulation and Establish Guidelines and Standard

Date: May 1, 2002
Place: NICT(former CRL: Communication Research Laboratory) in YRP (Yokosuka Research Park)
Director: Ryuji Kohno
Motivation for UWB research in NICT

Focus has turned to wireless communications capable of providing broadband communication environment any time anywhere. Above all, UWB is attracting attention for ubiquitous wireless system. Therefore, NICT established UWB Technology Institute (Director: Prof. Ryuji KOHNO) in Yokosuka Radio Communications Research Center in May, 2002.

NICT:
National institute of Information and Communications Technology

Duty: Fundamental or public R&D regarding information technology, communication technology and radio technology
Budget: Funded mainly by Japanese government
NICT has a lot of study items for UWB.
For instance as follows;
A) Optimization of communication method and protocol
   with regard to communication and ranging
B) Implementation of circuit and device to generate
   shaped pulse with SSA (soft spectrum adaptation),
   and UWB antenna
C) Propagation characteristics and measurement for
   UWB signal in wide frequency bandwidth and lower
   power
D) Interference with wireless systems sharing the same
   frequency band
NICT UWB Project

NICT-UWB project

A) This project is advanced by the collaboration with related study groups in NICT in the leadership of UWB Technology Group.

B) Several researchers in NICT as well as excellent researchers in the field of UWB study participate in this project.

C) Collaboration with academia, industry and international forum is promoted positively.