Multiband Radio
(Update from Spring 2006)
April 24, 2007

Steve Ellingson

NIJ

CommTech
“Low-Cost All-Band All-Mode Radio”

Focus of this research

New User – Not pre-coordinated, But able to use a single radio

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency (MHz)</th>
<th>Mode(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHF</td>
<td>138-174</td>
<td>TIA-603, P25</td>
</tr>
<tr>
<td></td>
<td>220-222</td>
<td>Voice/Data (not TIA-603)</td>
</tr>
<tr>
<td>UHF</td>
<td>406-512</td>
<td>TIA-603, P25</td>
</tr>
<tr>
<td>700 MHz</td>
<td>764-776</td>
<td>TIA-603, TIA-902, P25, 802.16(e)</td>
</tr>
<tr>
<td></td>
<td>794-806</td>
<td>TIA-603, TIA-902, P25, 802.16(e)</td>
</tr>
<tr>
<td>800 MHz</td>
<td>806-817</td>
<td>TIA-603, P25</td>
</tr>
<tr>
<td></td>
<td>824-849</td>
<td>Cellular (many modes)</td>
</tr>
<tr>
<td></td>
<td>851-862</td>
<td>TIA-603, P25</td>
</tr>
<tr>
<td></td>
<td>869-894</td>
<td>Cellular (many modes)</td>
</tr>
<tr>
<td>PCS</td>
<td>1850-1990</td>
<td>PCS (many modes)</td>
</tr>
<tr>
<td>ISM</td>
<td>2400-2483</td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td>4.9 GHz</td>
<td>4940-4990</td>
<td>IEEE 802.11, VoIP, UMTS/ TDD</td>
</tr>
</tbody>
</table>
Objectives

• Develop a prototype radio capable of supporting all frequency bands and all protocols commonly used in U.S. public safety operations.

• Document capability / performance / cost tradeoff for various technical approaches

• Not specifically an SDR problem. Also not cognitive radio. But, could be enabling technology for both.

Project Schedule

• Year 1 (Started 10/05)
  – Preliminary RF, digital, and software designs
  – Not necessarily integrated or optimized for cost

• Year 2 (Started 10/06)
  – Refined RF, digital, and software designs
  – Performance/cost tradeoff
  – Fully-integrated prototype

• Year 3 (Starting 10/07)
  – Laboratory results on final/recommended design
  – Capstone demonstration

We are here
Achievements Through Dec 06

• Considered technical requirements and possible existing solutions for such a radio (Technical Reports 4 and 8)

• Developed an approach based on porting SCA to “OMAP”, an embedded platform commonly used in cell phones, using the “USRP” as a digital front end (Technical Reports 1, 3, 5, 6, 9, and 14). *Does not appear to viable at this time, due to extensive work required to port SCA to an embedded platform, plus limitations in interfaces available on target hardware.*

• Developed an approach based on multithreaded C-language executables on an embedded “Blackfin” processor running the µClinux OS, using a Stratix-class FPGA + custom HDL as a digital front end (Technical Reports 2, 7, 11, and 12).

• Explored antenna problem – how to avoid the “porcupine effect” (Technical Reports 13 and 15). *No good solutions in sight – this problem needs work!*

• Developed prototype superheterodyne RF up/down converters (RFDC: Tech. Rep. 16, RFUC: In prep.)
Superhet-Based Strawman Design

Favored prior to Jan 2007

Analog Devices AD6636

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FPGA-Based Predetection Processor
µP-Based Baseband Processor

Audio I/O, User Datacom, Control Interface

Documentation (Tech. Reps.)
SCA: 1, 3, 5, 6, 9, 15
Non-SCA: 2, 7, 11, 12, 18
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Direct Connect (1 per RFIC*) – Dramatically simplifies front end!

Dramatically simplifies RF chain!

Collaboration w/ UCI

Rationale addressed in TR 17 and Jan07 PI meeting Presentation.

Validated in VT lab measurements (TR 19).

Direct Conversion-Based Strawman Design
Favored since Jan 2007
Achievements Since Jan 07

• In collaboration with an industry partner, developed an alternative approach based on a direct conversion RFIC (Motivation described in Tech. Rep. 17). This approach appears to have dramatic consequences for cost and possibly also size, weight, and power.

• Preliminary version of RFIC has been bench-tested; looks promising for public safety applications (Tech. Rep. 19).

• Developed “optimum noise figure specification”; this addresses a problem that emerges in the design of receivers with very large contiguous tuning range.

• AD6636 (digital downconverter) prototyping: Processes 4-6 channels at ~$30/k per IC; dramatic cost reduction compared to comparable functionality in FPGA (Prototype design and report to be published as tech. rep.). Still potentially useful as a baseband channelizer.

• Further Blackfin-based baseband processor software development (Tech. Rep. 18).
Challenges Remaining

- **Front End** (Duplexing/Switching). Now: Hard, not risky. MEMS may eventually make this easy.

- **Power amplifiers.** Not scary; broadband (100-2500 MHz) ~1W SiGe solutions out there; order of magnitude increase desirable.

- **Power supply noise in integrated configuration.** Potentially limiting sensitivity.

- **Antennas.** *Vehicles:* Not a show-stopper, but existing solutions are ugly. *Handhelds:* Needs attention, have ideas.
Upcoming Milestones

06/01/2007: Phase II ("Design for Cost") Report
07/31/2007: Semi-Annual Progress Report
10/01/2007: Phase III ("Integration") Complete – Test article!
Outreach

• **Technical Reports**
  – 19 since project start
  – Available via web site

• **Trade Press:**
  – March 2007 *MissionCritical Communications* Article
  – “Uncut” version available on web site as TR 17.

• **Presentations**
  – SDR Forum (Orlando FL, Nov 2006)
  – NIJ CommTech PI Meeting (Irvine CA, Jan 2007)
  – IWCE 2006 & 2007

• **Wireless@VT “Summer School”** (Blacksburg VA, Jun 6-8 2007)
  – Short course on Public Safety Comms by Rick Taylor (Tyco (M/A-COM))
  – Short course on Active Antennas by Ellingson
Thanks!

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Web Site:
http://www.ece.vt.edu/swe/chamrad/

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