Analysis of Very Narrowband Requirements for Hydrologic Frequencies

Final Report
September 30, 2011

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This material is based on work supported by the Department of Commerce under order number: DG133W10SE3038. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the Department of Commerce.

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1. Project Summary

This report summarizes the activities and results of the "Analysis of Very Narrowband Requirements for Hydrologic Frequencies" project, work performed by Salo IT Solutions, Inc. under a contract awarded by the National Oceanic and Atmospheric Administration (NOAA).

1.1 Current Narrowband Mandate

The FCC has mandated that most Land Mobile Radio (LMR) licensees migrate to narrowband operation (12.5 kHz channels) by January 1, 2013. This requirement includes licensees of VHF and UHF hydrologic frequencies. The Federal Communications Commission (FCC) has stated that waivers for continued wideband operation will be difficult to obtain.

Hydrologic warning system (HWS) operators are required to migrate their systems to narrowband, 12.5 kHz channel, operation prior to January 1, 2013; they must also vacate by that date several frequencies that are no longer authorized for hydrologic use. Licensees should also ensure that their information in the FCC licensing database is updated to include a narrowband emission mode and contains correct contact information.

1.2 Future Very Narrowband Mandate

The FCC remains committed to migrating LMR licensees to very narrowband operation (6.25 kHz channels). The Commission says that the very narrowband migration will use the same processes as are being used for the narrowband operation. Presumably, this requirement will include hydrologic frequencies.

The HWS community must plan to migrate to very narrowband operation (6.25 kHz channels) at some point in the future. However, to the extent that the future very narrowband migration is similar to the current migration to narrowband operation, the community likely has at least a decade, and perhaps even two, before the deadline for very narrowband operation.

1.3 Standards and Interoperability for VHF/UHF Data Radios

Interoperability between VHF and UHF data radios manufactured by different vendors is virtually nonexistent. This has raised serious concerns within the HWS community. For example, an HWS vendor, an HWS operator, or the HWS community might standardize on a particular data radio, only to find that compatible radios are no longer available when the manufacturer stops offering the radio.

Several standards for data transmission over very narrowband (or equivalent) channels are available, are under development, or have been proposed. Widespread adoption of one or more of these emerging standards by data radio vendors would be highly beneficial to the HWS community: it would enhance competition between vendors, would permit HWS operators to easily deploy radios from multiple vendors within a single network, and would enable HWS operators to gracefully migrate from one data radio vendor to another, if the incumbent vendor becomes untenable.

NOAA and the HWS community should consider using their influence to convince two or more data radio vendors to offer very narrowband products that implement one of the standard on-the-air protocols and that provide interoperability between radios manufactured by different vendors.

1.4 ALERT2 Protocol Suite Review

The principal investigator submitted extensive review comments on the initial versions of the National Hydrologic Warning Council (NHWC) ALERT2 protocol specifications. Many of these review comments were integrated into the April 2011 version of these specifications.

Based on his examination, the principal investigator believes that the proposed ALERT2 protocols will operate with very narrowband channels, with the likely exception of the ALERT2 AirLink modem. The principal investigator believes that there is a significant risk that the AirLink modem will not, and cannot easily be made to, operate with very narrowband radios.

The principal investigator is also concerned that there may be a mismatch between the needs and expectations of the HWS community and the capabilities of the ALERT2 protocols. Most significantly, while the traditional HWS vendors advertise or have deployed two-way functionality, this capability is not supported by the initial version of the ALERT2 protocols. Moreover, the technical and economic feasibility of developing an AirLink modem that supports two-way communications is very unclear.

Finally, the principal investigator recommends that the ALERT2 protocols be enhanced to cleanly separate from the higher-layer protocols the basic functionality that is likely to be implemented in future, standards-compliant data radios. This will offer the HWS community the option of using cost-effective, commercial, off-the-shelf (COTS) very narrowband data radios with the ALERT2 protocols, when these devices become available.

1.5 Data Radio Testbed Results

A wide-area, point-to-point, wireless testbed was constructed and used to evaluate two pairs of data radios: a 900 MHz, license-free, spread-spectrum data radio and a VHF, licensed, narrowband data radio. The testbed results were not as conclusive as had been hoped.

License-free, 900 MHz, spread-spectrum data radios *may* offer a useful *adjunct* to other communications facilities that are available to HWS operators. However, these radios appear to be more likely to be adversely affected by terrain and by interference from other unlicensed users. As a result, these radios *cannot*, in general, *eliminate* the need for VHF and UHF data radios that operate on licensed hydrologic frequencies.

At least one relatively inexpensive narrowband data radio is available that *might* be of benefit to the HWS community. While, this radio does not appear to interoperate with those of any other vendor, the on-the-air protocol *is* documented. But, use of this radio still presents a potential risk that the vendor will discontinue the product at some point, forcing HWS operators to migrate to an incompatible alternative.

2. Project Activities

This project was composed of several activities that relate to a future FCC mandate that licensees of hydrologic frequencies migrate to very narrowband operation (6.25 kHz channels). These activities included:

1. A brief review of the status of the FCC's current narrowband (12.5 kHz channel) requirement

2. An examination of the FCC's plans for a future very narrowband (6.25 kHz channel) requirement

3. An assessment of the state of standards for and interoperability among currently available VHF/UHF data radios and the prospects for standardization and interoperability for future very narrowband VHF/UHF data radios

4. A detailed review of the NHWC's ALERT2 protocol specifications, with an emphasis on how they will be affected by a future very narrowband requirement

5. Evaluation of two data radios, including a commercial, off-the-shelf (COTS) data radio that supports narrowband, but not very narrowband, operation

6. Outreach activities that publicized the results of this project

2.1 Current Narrowband Mandate

The FCC requires that virtually all users that operate under Part 90 of the FCC regulations, "Private Land Mobile Radio Services" [47 C.F.R. § 90], migrate to narrowband (12.5 kHz channel) operation (or technology that achieves equivalent spectral efficiency) by January 1, 2013. This includes users of the hydrologic frequencies in the 169 – 172 MHz and 406 – 416 MHz bands that are licensed under Section 265 of Part 90, "Assignment and use of frequencies allocated for Federal use" [47 C.F.R. § 90.265].

Section 265 of Part 90 stipulates that users of hydrologic frequencies must, after January 1, 2013, operate with an authorized bandwidth that does not exceed 11.25 kHz (i.e., 12.5 kHz channels). This Section also requires that new systems licensed after May 27, 2005 in the 169-172 MHz band and after January 1, 2008 in the 406-416 MHz band operate with an authorized bandwidth that does not exceed 11.25 kHz. However, existing systems that are authorized to use bandwidths greater than 11.25 kHz are permitted to continue to operate and to expand until January 1, 2013, with some limitations. Additionally, existing stations may continue to use until January 1, 2013 certain frequencies that are no longer authorized for hydrologic use (169.575 MHz, 409.675 MHz, 409.725 MHz, and 412.625 MHz).

The FCC will prohibit after January 1, 2013 the manufacture or importation of equipment that includes a 25 kHz mode of operation; this may affect some radios that are currently used by the

HWS community. After January 1, 2011 the FCC will not certify new equipment that includes a 25 kHz mode of operation.

The FCC recommends that licensees migrating to narrowband operation:

- Modify their licenses to include a narrowband emission designator before they begin operating in narrowband mode; that is, licensees may include both wideband and narrowband emission designators on their licenses while they migrate their systems

- Migrate their systems to narrowband operation

- Modify their licenses to remove the wideband emission designators, after they have migrated their systems to narrowband operation [FCC 2011c]

The FCC warns that stations that operate in wideband mode after the deadline will not be compliant with the Commission's rules, unless the licensee has received a waiver. "Operation in violation of the Commission's rules may subject licensees to appropriate enforcement action, including admonishments, license revocation, and/or monetary forfeitures of up to $16,000 for each such violation or each day of a continuing violation and up to $112,500 for any single act or failure to act" [FCC 2011e]. Furthermore, noncompliant systems will not be protected against harmful interference caused by compliant systems. Additionally, noncompliant systems may cause interference with compliant systems, or may experience interoperability problems with compliant systems [FCC 2011c]. The FCC has made it clear that wavers of the January 1, 2013 narrowbanding deadline will *not* be routinely granted. Rather, requests for waiver "will be subject to a high level of scrutiny" [FCC 2011e].

The risks to hydrologic licensees of noncompliance with the narrowband requirement may be even greater, because the hydrologic frequencies are allocated for Federal use. As a result, non-Federal users must avoid interfering with, and must accept interference from, Federal users. Furthermore, the National Telecommunications and Information Administration (NTIA) required Federals users to migrate to narrowband operation on a much earlier schedule [NTIA 2011a]. Additionally, licensees seeking waivers face the risk that their waivers will need to be coordinated with the Federal Interagency Hydrologic Radio Frequency Coordination Group and perhaps other groups, further delaying and confusing the waiver process.

2.1.1 Narrowbanding Resources

The FCC appears to be concerned about the seemingly slow rate at which licensees are migrating to narrowband operation. In an effort to ease and spur migration, the Commission and other agencies have made a number of resources available. Some of the most informative or useful include:

- **VHF/UHF Narrowbanding Information**. The FCC has created a Web page devoted to narrowbanding, <http://www.fcc.gov/narrowbanding/> [FCC 2011a]. This Web page, headlined by a clock that is counting down to January 1, 2013, contains a summary of the

narrowband requirement, as well as links to extensive, detailed information about the mandate.

- **Workshop on VHF/UHF Narrowbanding**. On January 26, 2011, the FCC hosted a very informative workshop on narrowbanding. The FCC website contains links to the presentations made during the workshop and to a video of the proceedings [FCC 2011b]. Several of the presentations are of particular interest to the HWS community, including:

  - "VHF/UHF Narrowbanding Information for Public Safety Licensees" This opening presentation by Roberto Mussenden of the FCC Public Safety and Homeland Security Bureau (PSHSB) give a nice overview of the FCC's narrowbanding requirement [FCC 2011c]. Note that the requirements for licensees of hydrologic frequencies are subtly different than they are for most LMR licensees. Furthermore, licensees of the UHF 406-416 MHz hydrologic frequencies must upgrade to narrowband operation, even though the presentation (and most other FCC material) refers only to the 421-512 MHz band.

  - "Licensing and the Narrowband requirement" The presentation by Tracy Simmons, also of the FCC PSHSB, provides detailed instructions on using the FCC's Universal Licensing System (ULS) to file a modification application to, for example, add a narrowband emission designator to an FCC license [FCC 2011d].

  - "Frequency Mapping Tool (FMT) Overview" Richard Reed of the Department of Homeland Security (DHS) Office of Emergency Communications (OEC) described the use of the Narrowbanding License Status tool and the Frequency Mapping Tool, tools developed the DHS/OEC that extract and display information from the FCC license database [DHS 2011]. Perhaps, the most useful information from these slides is the URL of the tools: <http://www.publicsafetytools.info>.

  - Video of January 26, 2011 "Workshop on VHF/UHF Narrowbanding". A video of the workshop is available online, see [FCC 2011b]. The more interesting portions of the video include the opening presentations by Roberto Mussenden and Tracy Simmons of the FCC PSHSB. Some viewers may find Mr. Mussenden's highly nuanced answer to "What happens if we don't migrate to narrowband operation by the deadline?" informative and perhaps even entertaining. Also, video of Richard Reed's presentation on the Frequency Mapping Tool, which includes a demonstration of the tools, may be more useful than the slides of his presentation.

- **Public Safety Technical Assistance Tools: Narrowband License Status**. The Department of Homeland Security (DHS) Office of Emergency Communications / Interoperable Communications Technical Assistance Program (OEC/ICTAP) has created a web-based tool that provides information about the narrowband status of licenses in the FCC database. The Narrowband License Status (NLS) tool can display the results on a map of the geographic area being examined, or can write the data to a file that can be manipulated with Excel. The NLS tool is somewhat unwieldy, and has some difficulty processing UHF hydrologic frequencies. Nonetheless, with a bit of patience, a user can obtain a lot of information about the licensees of hydrologic frequencies within a geographic area, and can determine whether

the licensees have included narrowband emission designators in their licenses.

The "Map Data" feature of the Narrowband License Status tool displays the locations of licensed stations on a geographic map, and graphically indicates the wideband/narrowband status of the license. When the user selects a specific station, this tool displays a popup with detailed information about the license for that station. Unfortunately, this tool does not have an option that displays only the hydrologic frequencies. Figure 1 shows a display of Part 90 public safety licensees in Sacramento County, California.

The "Report" feature of this tool writes data from the FCC license database to a file that can be manipulated by Excel. A user can create a spreadsheet containing information about hydrologic frequency licenses in a region by deleting the information about non-hydrologic frequencies. Figure 2 displays a small portion of an Excel file that contains information about licenses for the VHF hydrologic frequencies in the Capital - Bay Area region of California.

- **Public Safety Technical Assistance Tools: Frequency Mapping Tool**. The Frequency Mapping Tool displays geographically stations licensed under Part 90. Conveniently, it permits the user to specify a frequency range, such as the VHF hydrologic frequencies. Unfortunately, the "Map Data" feature doesn't display the narrowbanding status of a license. Nonetheless, this tool is useful is quickly displaying all of the public safety stations licensed to use the hydrologic frequencies within a region. Figure 3 contains a display of the stations licensed for public safety use of the VHF hydrologic frequencies in California. The "Report" feature of this tool is of limited use in supporting narrowband migration, because detailed wideband/narrowband information is not as easily accessible as it is in the reports generated by the Narrowband License Status tool.

Several private-sector information sources are available that are useful to those who are responsible for (or even just interested in) migrating hydrologic warning systems to narrowband operation.

- **WirelessRadio.net** This website contains and references a wealth of information about the FCC's narrowband requirement.

- **Yahoo! LMR_Narrowbanding Group** This group includes a number of people with substantial experience with all aspects of narrowbanding, including making changes to the FCC's Universal Licensing System (ULS); avoiding FCC fees while updating narrowband emission designators in the ULS; and acquiring, deploying and upgrading equipment for narrowband operation. While the members of this group are largely focused on voice operations, rather than data operations, and contain few hydrologic users, inquiries related to narrowband operation usually receive highly informed responses.

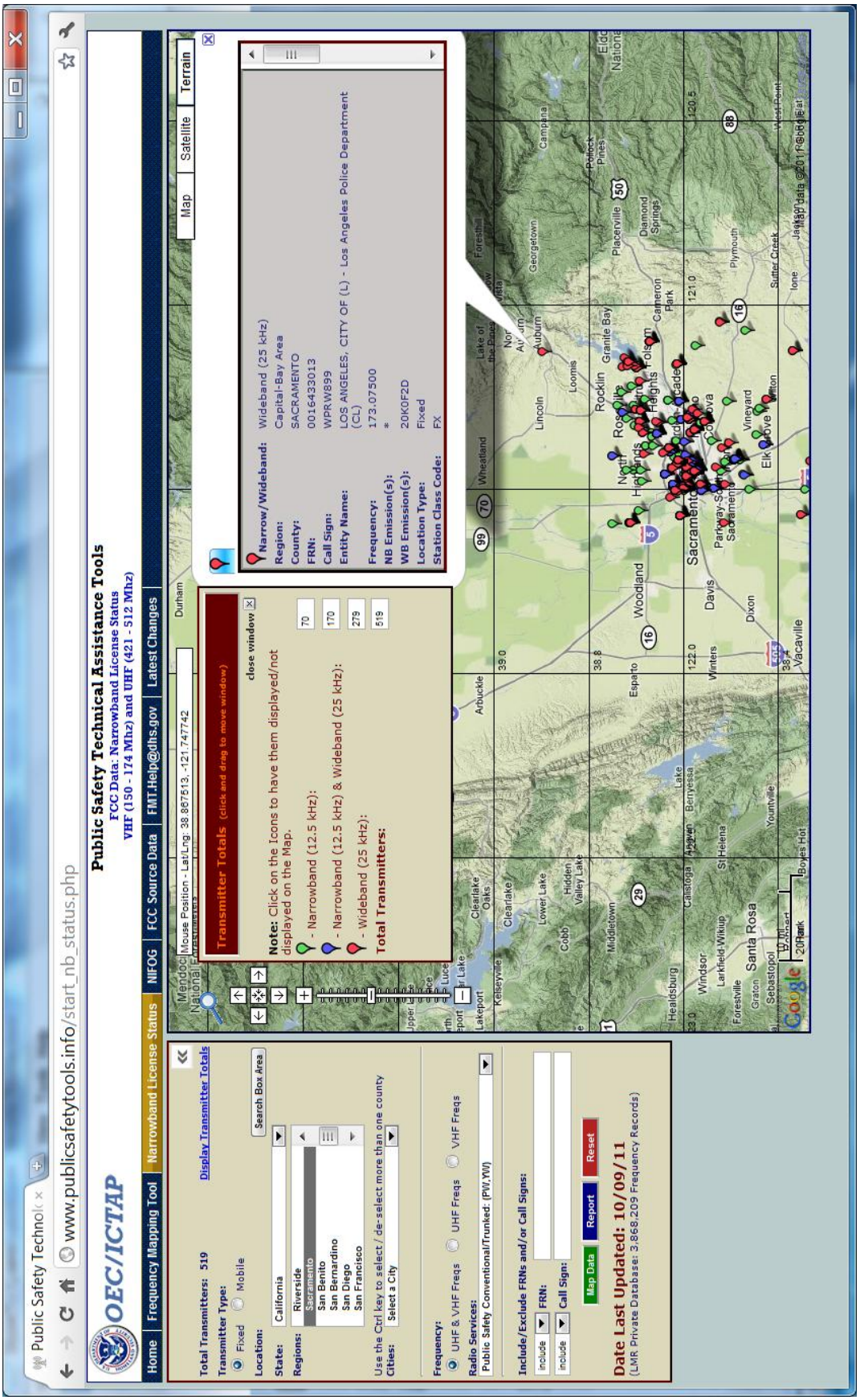
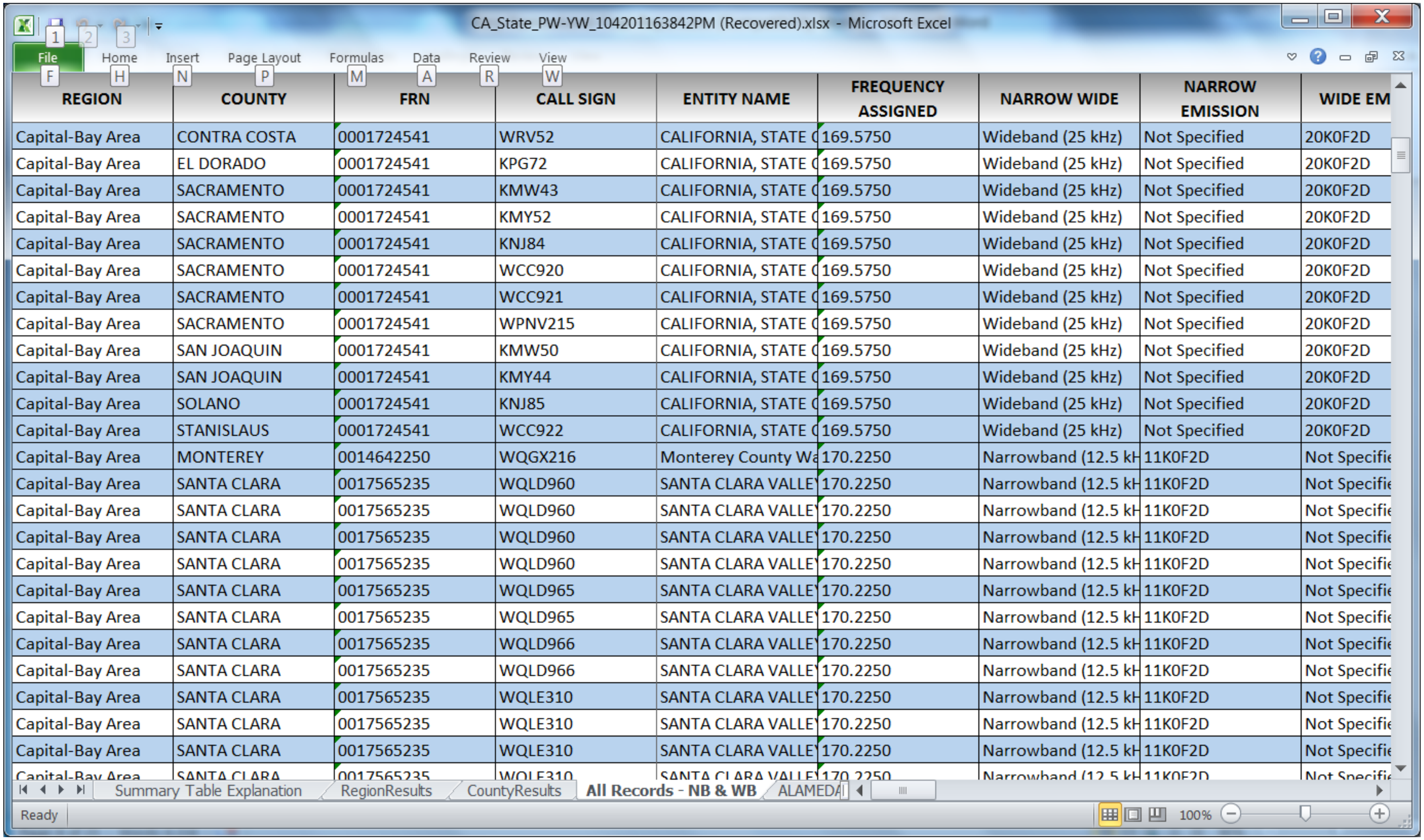


Figure 1. "Map Data" Feature of "Narrowband License Status" Tool.



REGION	COUNTY	FRN	CALL SIGN	ENTITY NAME	FREQUENCY ASSIGNED	NARROW WIDE	NARROW EMISSION	WIDE EM
Capital-Bay Area	CONTRA COSTA	0001724541	WRV52	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	EL DORADO	0001724541	KPG72	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SACRAMENTO	0001724541	KMW43	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SACRAMENTO	0001724541	KMY52	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SACRAMENTO	0001724541	KNJ84	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SACRAMENTO	0001724541	WCC920	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SACRAMENTO	0001724541	WCC921	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SACRAMENTO	0001724541	WPNV215	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SAN JOAQUIN	0001724541	KMW50	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SAN JOAQUIN	0001724541	KMY44	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	SOLANO	0001724541	KNJ85	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	STANISLAUS	0001724541	WCC922	CALIFORNIA, STATE (	169.5750	Wideband (25 kHz)	Not Specified	20K0F2D
Capital-Bay Area	MONTEREY	0014642250	WQGX216	Monterey County Wa	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD960	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD960	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD960	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD960	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD965	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD965	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD966	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLD966	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLE310	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLE310	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLE310	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifie
Capital-Bay Area	SANTA CLARA	0017565235	WQLE310	SANTA CLARA VALLE	170.2250	Narrowband (12.5 kH	11K0F2D	Not Specifi

Figure2. "Report" Feature of "Narrowband License Status" Tool.

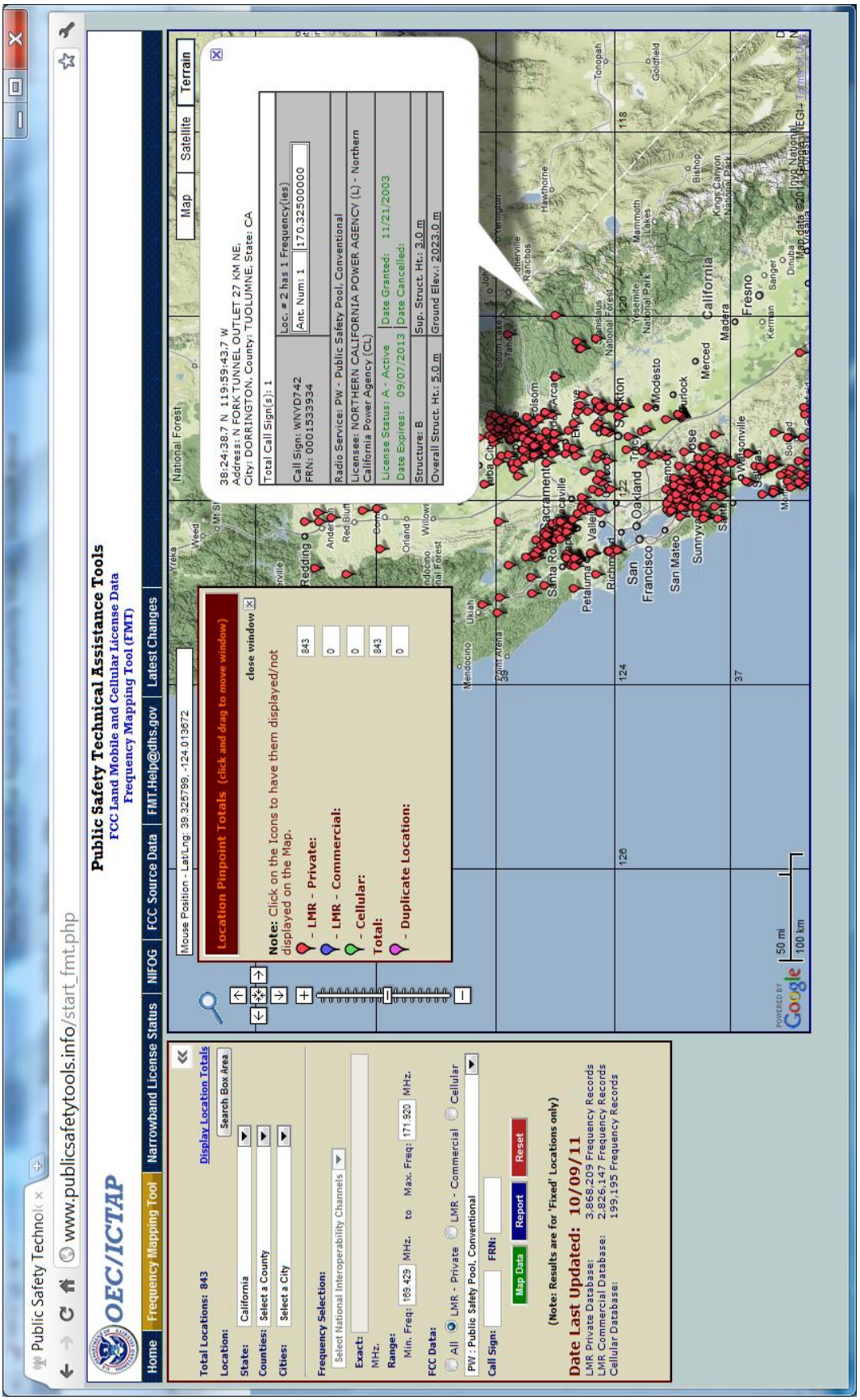


Figure 3. "Map Data" Feature of "Frequency Mapping Tool".

2.2 Future Very Narrowband Mandate

The FCC has repeatedly stated that it remains committed to migrating Land Mobile Radio licensees to very narrowband operation (6.25 kHz channels). But, the FCC emphasizes that it has *not* set a deadline for this migration. Furthermore, the FCC assures licensees that the migration to very narrowband operation will involve the full processes, including notices and comments, that were part of the 12.5 kHz narrowbanding migration [FCC 2011c]. In support of a future very narrowbanding requirement, the FCC requires that equipment certified after January 1, 2013 must support 6.25 kHz operation; some very narrowband-capable equipment, including data radios, is already available from vendors.

At its January 26th narrowbanding workshop, the FCC gave the impression that licensees were not migrating to narrowband operation as quickly as it had hoped. An FCC attorney observed that the FCC will use the lessons learned in the 25 kHz-to-12.25 kHz transition when it plans for the 12.5 kHz-to-6.25 kHz transition. This appears to suggest that the FCC expects the migration to 6.25 kHz to be a very slow process, and that the FCC understands that licensees face numerous hurdles (particularly funding) in making this transition.

The narrowband migration has been a 20-year process. Rulemaking started in 1992 and 12.5 kHz-capable products were available in 1997. Deadlines for the narrowband migration were set in 2003 and modified in 2010. Based on this history, it seems reasonable to speculate that the deadline for very narrowband operation is at least a decade in the future, and perhaps even two decades. Of course, licensees of hydrologic frequencies may migrate to very narrowband operation voluntary in advance of the deadline.

Several vendors advertise data radios that can operate within 6.25 kHz channels, although it is not yet clear how widely these radios are deployed in 6.25 kHz operation. These data radios all use proprietary on-the-air protocols.

2.3 Standards for UHF/VHF Data Radios

As HWS operators are acutely aware, most currently available data radio use proprietary on-the-air protocols. This is particularly true for data radios that operate at speeds greater than 1,200 bits-per-second (bps). Because these data radios use proprietary protocols, radios acquired from different vendors do *not* interoperate over the air. That is, attempts to communicate over-the-air between radios from different manufactures generally fail. This state of affairs puts HWS operators at a disadvantage to data radio vendors. In particular, it is expensive and labor intensive for an HWS operator to migrate from a data radio provided by one vendor to a radio manufactured by a different vendor. This can cause serious heartburn if a vendors stops marketing a radio used by an HWS operator, or if the price of the radio increases significantly.

For users of the legacy ALERT protocol, this lack of inter-vendor interoperability is not a problem, because HWS vendors have integrated 300-bps modems into their electronics. These integrated 300-bps ALERT modems operate with voice-grade radios, and so ALERT users have avoided the problems caused by data radios that use proprietary on-the-air protocols.

As the HWS community looks to upgrade to faster over-the-air transmission speeds with the ALERT2 protocols, it has several choices, including: standardizing on a vendor-proprietary on-the-air protocol or developing its own modem. The ALERT2 AirLink modem is the result of a decision by the HWS community to develop its own modem. The AirLink modem uses an on-the-air protocol that is unique to hydrologic warning systems.

Fortunately for the HWS community, there are several standards for narrowband and very narrowband data operation that are being developed. Conceivably, one or more of these standards could mature to the point that the HWS community could adopt one of them as its standard for very narrowband operation. This would offer the considerable advantage of permitting HWS operators to purchase commercial, off-the-shelf equipment, rather than relying on a modem that is unique to the HWS community.

Several protocols are being developed that *might* be supported by COTS data radios at some point in the future, and might be useful in hydrologic warning systems. The first four of these protocols or proposed protocols are standards, while the final one is vendor-proprietary.

- **dPMR (digital Private Mobile Radio)**. dPMR is a European 6.25 kHz digital standard that includes both a voice mode and a data mode. Voice products are just starting to become available in Europe, although no data radios employing this standard have been found. Icom has a family of dPMR products that it has released in Europe, but these products don't appear to have yet been released in the U.S. The principal investigator believes that, if the dPMR standard was to be adopted by U.S. vendors, it would likely result in cost-effective, interoperable data radios being available from multiple manufacturers. The dPMR Memorandum of Understanding (MOU) Group hosts a website that offers considerable information about the dPMR protocols [dPMR]. The website contains links to the dPMR specifications, which are hosted on the European Telecommunications Standards Institute (ETSI) website and can be downloaded without charge.

- **DMR (Digital Mobile Radio)**. DMR is another European standard. It is digital and uses a 12.5 kHz channel. The availability of DMR products at this time is unclear; the DMR standard appears to be approximately as recent as the dPMR standard. The DMR Association website contains information about the standards, as well as links to the DMR standards on the ETSI website, (which can also be downloaded without charge).

- **TETRA**. This is yet another European standard. TETRA is the most mature of these three European standards. Numerous TETRA products are available, although it isn't clear how many of them are available in this country. The TERA association hosts an informative website [TETRA], and the ETSI maintains a website devoted to the TETRA standards [ETSI].

- **P25 (Project 25)**. P25 is the American solution for interoperable public safety radios. There are reports that there was an effort to specify a P25 data-only mode, but that this work is on hold. There doesn't seem to be any data-only P25 products available. Presumably, if this effort was restarted, it would offer the possibility of data radios that would be able to leverage the extensive P25 networks that are being deployed.

- **NXDN**. Kenwood and Icom have developed a proprietary 6.25 kHz protocol, NXDN. While this protocol is proprietary, it may be similar enough to dPMR that radios that support NXDN could easily be enhanced to support dPMR. Information about the NXDN technology and protocol is available on the NXDM Forum website [NXDN]. At this point, no vendor offers a data radio that supports the NXDN protocol.

These standards activities offer the prospect that standards for very narrowband data radios will be developed and implemented by vendors, at some point in the future. These products may offer HWS operators cost-effective, commercial, off-the-shelf solutions for higher-speed data transmission.

2.3.1.1 Informal Requirements for Next-Generation HWS Data Radios

The principal investigator drafted an informal requirements document that summarizes his views of the requirements for a next-generation data radio for hydrologic warning systems (HWS). The motivation for this document was to formalize his thoughts in a document that could provide a basis for discussions with data radio vendors. The document was circulated among several hydrologic warning system and data radio vendors. The few members of the HWS community that reviewed the documents had few objections to its contents, while the reactions of the data radio vendors ranged from a mild interest to a reiteration by one vendor that it felt no need for interoperability between data radios offered by different vendors.

2.3.2 Data Transmission Standards for Hydrologic Warning Systems

NOAA and the HWS community should consider using their influence to convince two or more data radio vendors to offer products that implement a standard on-the-air protocol and that provide interoperability between equipment manufactured by different vendors. This would address the community's long-standing concerns about being "locked in" to a data radio vendor that uses a proprietary on-the-air protocol. This use of proprietary protocols usually prevents a HWS operator from deploying data radios from more than one vendor within a single network. As a result, migrating a network from a proprietary data radio to another product is typically an expensive, time-consuming task. The HWS community also ought to consider teaming with other communities that rely upon data radios in order to increase their collective influence, and should jointly select an on-the-air standard for data transmission to advocate. NOAA would likely benefit from this effort: there are numerous groups within NOAA that use VHF and UHF data radios, and NOAA works with several external communities that also rely on these devices. If fact, NOAA may wish to consider taking a leadership position in this effort.

2.4 ALERT2 Protocol Suite Review

The principal investigator compiled extensive review comments on the National Hydrologic Warning Council (NHWC) ALERT2 specification documents. Four sets of review comments were written against the three ALERT2 documents that were available at the time:

- *ALERT2 AirLink Protocol Specification*, (the ALERT2 modem)

- *ALERT2 MANT Protocol Specification*, (the ALERT2 multiplexing protocol)

- *ALERT2 Application Layer Protocol Specification*

These review comments were submitted to the NHWC ALERT2 Technical Working Group (ALERT2 TWG) and were made available to the NOAA manager that sponsored this work. The review comments are attached to this report.

The ALERT2 TWG subsequently revised substantially these three specifications and drafted a fourth document, *ALERT2 Intelligent Network Device Application Program Interface Specification*. It is clear that substantial effort went into revising the documents. Many of the principal investigator's comments were included in the revised specifications. A brief inspection of the revised ALERT2 specifications shows that they have improved significantly over the original documents. As such, a detailed discussion here of the review comments against an earlier version of these documents is not warranted.

Based on his examination, the principal investigator believes that the proposed ALERT2 protocols will operate with very narrowband channels, with the likely exception of the ALERT2 AirLink modem. The principal investigator believes that there is a significant risk that the AirLink modem will not, and cannot easily be made to, operate with very narrowband radios.

The principal investigator is also concerned that there may be a mismatch between the needs and expectations of the HWS community and the capabilities of the ALERT2 protocols. Most significantly, while the traditional HWS vendors advertise or have deployed two-way functionality, this capability is not supported by the initial version of the ALERT2 protocols. Moreover, the technical and economic feasibility of developing an AirLink modem that supports two-way communications is very unclear.

It is not clear to the principal investigator whether a built-from-scratch modem that is unique to the HWS community is economically viable. The HWS market may not be large enough to enable a manufacturer of a HWS-specific modem to achieve reasonable economies of scale.

The principal investigator recommends that the ALERT2 protocols be enhanced to cleanly separate from the higher-layer protocols the basic functionality that is likely to be implemented in future, standards-compliant data radios. This will offer the HWS community the option of using cost-effective, commercial, off-the-shelf (COTS) narrowband and very narrowband data radios with the ALERT2 protocols, when standards-based devices become available.

2.5 Data Radio Testbed Results

Two types of data radios were deployed and evaluated in a wide-area testbed.

2.5.1 License-Free 900 MHz Spread-Spectrum Data Radio

A pair of one-watt, 900 MHz, license-free, ISM band, spread spectrum radios were deployed over a five-mile, non-line-of-sight path. A series of increasingly powerful antennas were installed. However, efforts to establish communications over this five-mile radio path were unsuccessful. Testing was terminated when the radios caused serious radio frequency interference (RFI) problems with a nearby consumer electronics device (a baby monitor). This interference most likely highlights how heavily the license-free 900 MHz spectrum is used. While 900 MHz data radios may be useful in rural areas, they are probably not usable over any reasonable distance in urban areas. Additional details of this activity are contained in [Salo 2011b].

2.5.2 Licensed VHF Narrowband Data Radio

A pair of Maxon SD-171E radios with optional ACC 513 modems was acquired for use in the testbed. The Gaussian minimum shift keying (GMSK) modem operates at 4,800 bits per second (bps) when the radio operates in narrowband mode (12.5 kHz channels). The modem use a frame structure based, perhaps loosely, on a small portion of the MPT 1327 standard, a standard developed in the United Kingdom for trunked radio networks. This radio does *not* operate in very narrow band mode (6.25 kHz channels).

Software, called Data Radio Exerciser (DRE) was written to facilitate testing of the radio. The DRE software is written in Java, and is designed to be easily extended to work with other data radios. Figure 4 is a screen snapshot of the DRE software being used to transfer test traffic between a pair of SD-171E data radios. The source code for the DRE software is attached to this report.

The Maxon SD-171E is a contemporary implementation of the Midland SD-171. The Maxon SD-171E and the Midland SD-171 are reported to operate, when they are equipped GMSK modems. However, the SD-171E appears to be a much better radio, and so this interoperability is of little use to the HWS community.

The Maxon SD-171E radio and ACC 513 modem appear to work as advertised. While the host-to-radio interface is a bit complicated, and the available documentation is outdated, sketchy, and inconsistent, the radios can be made to work with a bit of persistence. These data radios have significant advantages and disadvantages: they are readily available, cost-effective and field-proven, but they use a unique, if not proprietary, on-the-air protocol.

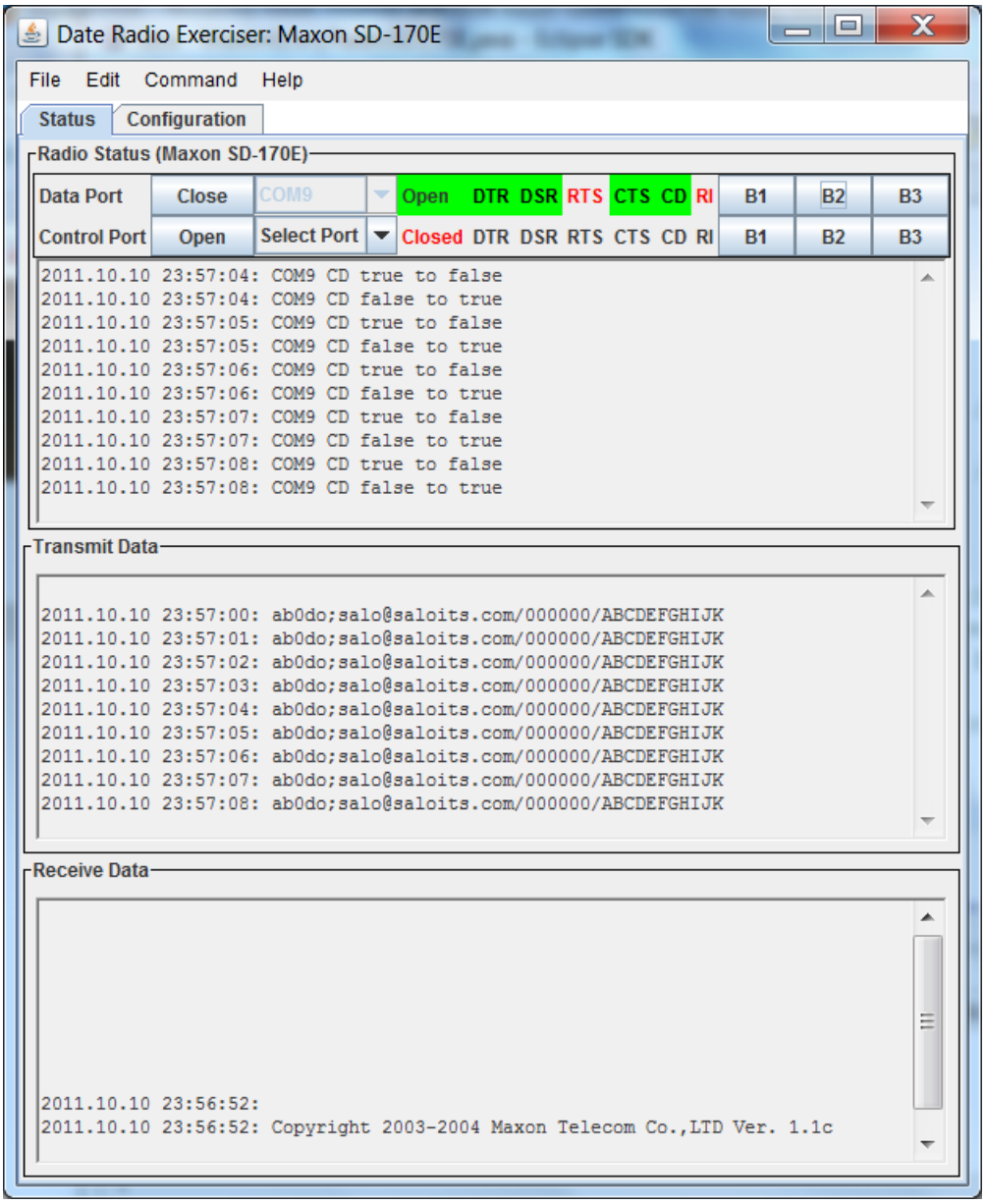


Figure 4. Sample Data Radio Exerciser (DRE) Output.

2.6 Outreach Activities

The principal investigator undertook several outreach activities that publicized some of the results of this project; he anticipates undertaking additional outreach activities in the near future. These outreach activities include:

- A presentation, “Future Very Narrowband Radio Requirements”, was made at the National Hydrologic Warning Council 2011 Conference, May 9-11, 2011, San Diego, CA. A copy of the presentation is attached.

- A Web page was created that provides a brief summary of this project. The Web page is available online at: <http://www.saloits.com/news-10-1-10.html>.

- A brief announcement about the start of this project was included in the NHWC *News Alert*, which simply referred readers to the Web page noted above.

- A brief article about this project, based on material provided by the principal investigator, appeared in *The NHWC Transmission*.

- Discussions were held with hydrologic warning system vendors and data radio vendors, including Timewave Technology, Inc., High Sierra Electronics, Inc., Maxon, Midland Radio, and the Data Radio division of CalAmp.

In the near future, the principal may also:

- Make this report, including the attachments, available on a web page;

- Give a brief presentation on narrowbanding at the ALERT Users Group (AUG) meeting October 27th, 2011 in Sacramento; and

- Write an article, based on the material in this report, about the FCC's narrowband and very narrowband requirements, which may be submitted for inclusion in an NHWC publication.

3. Findings and Recommendations

The significant observations and recommendations that resulted from this work are summarized below.

3.1 Current Narrowband Mandate

HWS operators should ensure that their systems are migrated completely to narrowband operation by January 1, 2013. They should *not* assume that a waiver of this requirement will be granted.

3.2 Future Very Narrowband Mandate

While the requirement that hydrologic warning systems operate in very narrowband mode is probably at least a decade away, the HWS community and HWS operators should avoid plans or technologies that may impede the migration to very narrowband operation.

3.3 Standards and Interoperability for VHF/UHF Data Radios

NOAA and the HWS community should consider using their influence to convince two or more data radio vendors to offer very narrowband products that implement one of the emerging standard on-the-air protocols and that provide interoperability between radios manufactured by different vendors.

3.4 ALERT2 Protocol Suite Review

The principal investigator recommends that the ALERT2 protocols be enhanced to permit the use of commercial, off-the-shelf data radios. That is, the ALERT2 protocols should be modified to cleanly separate from the higher-layer protocols the basic functionality that is typically implemented in data radios. This will offer the HWS community the option of using cost-effective, commercial, off-the-shelf (COTS) narrowband and very narrowband data radios with the ALERT2 protocols. This capability will be particularly valuable to HWS operators when standards-compliant narrowband and very narrowband data radios become readily available.

The principal investigator is also concerned that there may be a mismatch between the needs and expectations of the HWS community and the capabilities of the ALERT2 protocols, such as support for two-way communications. This may be an opportune time for the HWS community to reexamine its needs and expectations for a suite of next-generation HWS protocols, and to evaluate how well the current ALERT2 protocols meet those expectations.

4. References Cited

- [DHS 2011] DHS, "Frequency Mapping Tool (FMT) Overview". Presented by Richard Reed at FCC "Workshop on VHF/UHF Narrowbanding". <http://transition.fcc.gov/pshs/docs/summits/narrowbanding-2011/Reed-Richard-Narrowbanding-FCC-Panel-01262011.pdf>.

- [DMR] DMR Association, Website, <http://dmrassociation.org/>.

- [dPMR] dPMR MOU Group, Website, <http://www.dpmr-mou.org/>.

- [ETSI] European Telecommunications Standards Institute (ETSI), TETRA Website, <http://www.etsi.org/website/Technologies/TETRA.aspx>.

- [FCC 2011a] FCC, Web site: "VHF/UHF Narrowbanding Information". <http://www.fcc.gov/narrowbanding/>. Viewed October 6, 2011.

- [FCC 2011b] FCC, "Workshop on VHF/UHF Narrowbanding", <http:// http://transition.fcc.gov/pshs/summits/#narrowbanding_workshop>, viewed October 6, 2011.

- [FCC 2011c] FCC, "VHF/UHF Narrowbanding Information for Public Safety Licensees". Presented by Roberto Mussenden at FCC "Workshop on VHF/UHF Narrowbanding". <http://transition.fcc.gov/pshs/docs/summits/narrowbanding-2011/Mussenden-Roberto-Narrowbanding-FCC-Panel-01262011.pdf>

- [FCC 2011d] FCC, "Licensing and the Narrowband requirement". Presented by Tracy Simmons at FCC "Workshop on VHF/UHF Narrowbanding". <http://transition.fcc.gov/pshs/docs/summits/narrowbanding-2011/Simmons-Tracy-Narrowbanding-FCC-Panel-01262011.pdf>

- [FCC 2011e] FCC, Public Notice DA-1189: Wireless Telecommunications Bureau, Public Safety, and Office of Engineering and Technology Provide Reminder of January 1, 2013 Deadline for Transition to Narrowband Operations in the 150-174 MHz and 421-512 MHz Bands and Guidance for Submission of Requests for Waiver and Other Matters". July 13, 2011. Available online at: <http://transition.fcc.gov/Daily_Releases/Daily_Business/2011/db0713/DA-11-1189A1.pdf>.

- [NTIA 2011a] National Telecommunications and Information Administration (NTIA), Manual of Regulations and Procedures for Federal Frequency Management (Redbook), May 2011 Revision of the January 2008 Edition. Available online at: <http://www.ntia.doc.gov/page/2011/manual-regulations-and-procedures-federal-radio-frequency-management-redbook>.

- [NXDN] NXDN Forum website. <http://ww http://www.nxdn-forum.com/w.nxdn-forum.com/>.

- [Salo 2011a] Salo, Timothy J., "Wide-area Environmental Sensing and alerTing Networks (WESTnets) Requirements for Data Radios

- [Salo 2011b] Salo, Timothy J., "Future Very Narrowband Radio Requirements", presented at the National Hydrologic Warning Council 2011 Conference, May 9-11, 2011, San Diego, CA.

- [TETRA] TETRA Association, Web page, <http://www.tetramou.com/>.

5. Attachments

- "Future Very Narrowband Radio Requirements", presented at the National Hydrologic Warning Council 2011 Conference, San Diego, May 11, 2011.
- *Wide-area Environmental Sensing and alerTing (WESTnets) Requirements for Data Radios*
- Review Comments: *ALERT2 AirLink Protocol Specification*, (the ALERT2 modem)
- Review Comments: *ALERT2 MANT Protocol Specification*, (the ALERT2 multiplexing protocol)
- Review Comments: *ALERT2 Application Layer Protocol Specification*
- Additional Review Comments: *ALERT2 AirLink Protocol Specification*, (the ALERT2 modem)
- Data Radio Exerciser (DRE) source code

A. "Future Very Narrowband Radio Requirements"

"Future Very Narrowband Radio Requirements", presented at the National Hydrologic Warning Council 2011 Conference, San Diego, May 11, 2011.

B. *Requirements for Data Radios*

Wide-area Environmental Sensing and alerTing (WESTnets) Requirements for Data Radios, Version 1.1, March 16, 2011.

C. Review Comments: *ALERT2 AirLink Protocol Specification*

Review Comments: *ALERT2 AirLink Protocol Specification*, (the ALERT2 modem), January 19, 2011.

D. Review Comments: *ALERT2 MANT Protocol Specification*

Review Comments: *ALERT2 MANT Protocol Specification*, (the ALERT2 multiplexing protocol), January 18, 2011.

E. Review Comments: *ALERT2 Application Layer Protocol Specification*

Review Comments: *ALERT2 Application Layer Protocol Specification,* January 18, 2011.

F. Additional Review Comments: *ALERT2 AirLink Protocol Specification*

Additional Review Comments: *ALERT2 AirLink Protocol Specification*, (the ALERT2 modem), April 25, 2011.

G. Data Radio Exerciser (DRE) source code

Data Radio Exerciser (DRE) source code

This source code contains the following classes:

- DRE
- DREFrame
- Radio
- RadioSD170E