2016 Radio System Dev

Introduction and background

The year 2015 saw me get a ham license (AF7RQ) and a GMRS license (WQWR689). My initial motivation was to have some means to contact home from the woods while firewooding or hiking. Shortly thereafter, I also developed the desire to equip our personal vehicles with communications gear for emergency coordination. Finally, I asked the local authorities about how to participate in emergency response, and was asked to write a communications plan for the county. All three threads of activity have been pursued with respect to the challenges of the local mountainous topography.

In essence, all of my reasons to fiddle with radios can be summarized as wanting reliable communications between two or more points which are local (within the skip zone) and non-line-of-sight. Furthermore, while I can identify a handful of fixed places I want to communicate with, I also want mobile and portable communications which work anywhere in the woods: particularly deep in the draws and on the long roads replete with switchbacks which lead up to a ridge or hilltop. In general, I have found that I can contact any VHF/UHF repeater anywhere from ridgetops and hilltops, but the signal degrades very rapidly as the descent begins.

I spent the last half of 2015 learning about the approaches to communication used by hams and public safety agencies. A primary goal is to make sure that when I start parting with money, whatever equipment I get can be pressed into service in an emergency. Another goal is to figure out and propose a method to include hams in local emergency plans. The remainder of this document summarizes what I learned in 2015 and outlines some personal goals to focus my efforts in 2016. My description of what I learned by surfing the Internet should be taken to represent my current understanding, not unassailable fact. As of this writing, I have no actual experience with any of these topics. The point of this document is to select a few topics with which to obtain some experience with in 2016.

Background research summary

Hams and Public Safety

Local Voice Communications

Local voice communications for both hams and public safety are exclusively based on line-of-sight technologies. Public safety is almost exclusively VHF in Montana, while hams have substantial infrastructure built out in both the 2m and 70cm bands. Exceptions to the line-of-sight rule are very few and very limited.[1] Both hams and public safety have built out relay infrastructure consisting of

1 For example, with directional antennas, one can try to reflect a signal off of a hillside to hit a repeater, or try to exploit some knife edge diffraction over a ridgeline. To be successful, one must: a] have directional antennas; b] have a good mental handle of the geometry of the situation; and/or c] be lucky. Lining up one bounce proved beyond my ability when trying to set up a TV antenna on my house; two, three or four bounces is laughably impossible.

potentially linked repeaters, typically on the same developed hilltop sites. These have good to very good coverage of most of the I-90 corridor through the county, but the instant one strays into the woods, coverage can usually be characterized as lousy. Both hams and public safety can supplement this coverage with portable repeaters, but this may require sending someone to a hilltop well away from the area where coverage is desired, and can potentially create an "island" of communication which is not connected back to a dispatch center. Better than nothing, but not great.

Hams and public safety are compatible with respect to narrowband analog FM voice signals. Hams have a few unique and mutually incompatible approaches to digital voice, none of which are compatible with the APCO P25 family of standards public safety uses. Some hams do operate APCO P25 radios, but this is not mainstream digital voice on the ham bands. We are all very compatibly "conventional," but we are not compatibly digital. This presents a problem due to the limited range of narrowband analog FM signals compared to both wideband analog FM and narrowband P25 digital.

A prominent standard feature of P25 is "trunking": dynamically sharing a handful of fixed simplex and half-duplex (repeater) frequencies among a much larger set of "talkgroups". This makes better use of scarce spectral and physical resources, while insulating the users from the details of checking for, selecting and coordinating a clear frequency among those who need to talk. There is a statewide trunked system, but Mineral county public safety is not included. Various state agencies (highway patrol, department of transportation) are. The trunking controllers must never become inaccessible, lest the system collapse.

Broadband data

Both hams and the larger public safety community (not necessarily Mineral county) are dabbling with a transition from primarily analog-or-digital voice to primarily data (where voice is one data stream in a broadband channel, and arbitrary applications are supported via computer or smartphone). This transition also represents a move away from manually managing (i.e., coordinating; and for public safety, licensing) individual voice-sized channels to automatic partitioning of a wide bandwidth signal. These technologies are very much line-of-sight. Both hams and public safety are expected to hold on to their current land mobile radio equipment for quite some time.

Hams and public safety are not pursuing inter-operable transitions to broadband data. The highest profile and most widely deployed ham effort is based on the IEEE 802.11 (WiFi) set of standards. The ham solution is a type of Mobile Ad-hoc NETwork (MANET), which can organically coalesce into a connected network from a set of stations which can see one another. The National Public Safety Broadband Network (FirstNet) is based on 4G LTE cellular technology. The latter is designed for constant connectivity and central management, whereas the former is designed for detached operation and automatic distributed management. The two approaches could be viewed as complementary rather than interoperable, in that the amateur data network could be rapidly constructed to carry the backhaul for a FirstNet deployable. However, this has a major impediment with regard to the Part 97 exclusion of encryption.

At this point, it is unclear how public safety's LTE solution will operate if it cannot contact the centralized support functions located on the primary network. There are commercially available backpack-sized LTE solutions which self-organize into a detached LTE network, but these solutions accomplish this using vendor proprietary and incompatible means, so it is not possible to be generally confident that a random collection of FirstNet deployables available in an emergency will usefully cooperate to support the incident.

Interoperable HF for long distance communications

A technique called "Automatic Link Establishment" (ALE) is a tool for inter-operable HF radio communications. Stations continuously scan a set of predetermined frequencies between 2-10 MHz for activity. The frequencies are chosen to maximize the possibility that one of the bands will be open regardless of whether it is day or night, summer or winter. The stations occasionally perform "soundings" which provide current information on propagation conditions. To make contact, the calling station sends a digital message addressed to the desired party, using one of the unoccupied, prearranged frequencies deemed most likely to successfully reach the addressee based on recent sounding information. The (possibly unattended) receiving station acknowledges, and after a brief digital handshake, the link is considered established. The system can deliver digital messages, data, or can alert an operator that a voice (SSB) contact is desired. The contact takes place on the channel which was used to set up the call.

ALE has been standardized by the US Department of Defense and by the civilian side of the federal government.[2] Although hams do not normally use ALE, they have promulgated standards and operating procedures to use ALE within the ham bands.[3] ALE simplifies and makes more reliable the process of making contacts which depend on the current state of affairs in the upper atmosphere.

HF transceivers may use relays to switch among the bands on which they can operate. Some use solid state circuits to switch. Relays wear out faster than solid state devices. Used as an ALE transceiver, the switching circuitry is constantly active, and if mechanical switching devices are used, wear and tear on the transceiver may be excessive.

Link Quality Analysis (LQA) is used by ALE to measure the quality of received signals.[4] One can measure the bit error rate, the signal-to-noise ratio plus distortion (SINAD), or both. LQA measurements are taken passively (by listening to signals which just happen to be there) or actively (good practice is for all stations to transmit soundings once an hour).

Locating pre-existing ALE controllers may be something of a challenge. A few radios have embedded controllers and external hardware controllers are available from Harris and Rockwell. Software controllers are few. I found only two software packages which support this: PCALE and RFSM-8000. RFSM-8000 costs $300. PCALE is a free windows application. I was not able to locate source code.

The PCALE software describes the connection to supported radios. The signal follows the standard

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2 MIL STD 188-141, FED-1045 for calling and ALE, STANANG 5066 for interface to IP systems

3 http://hflink.com/alehamradio/, http://hflink.com/alehamradiousa/

4 https://en.wikipedia.org/wiki/Link_quality_analysis, https://en.wikipedia.org/wiki/SINAD, http://www.radio-electronics.com/info/rf-technology-design/rf-noise-sensitivity/sinad.php

audio pathways. Control of the radio (for scanning, tuning, PTT, etc.) is accomplished using a Computer Aided Tuning (CAT) interface. This is not a complete interface definition per se, but in general it is a low speed serial interface. In the old days, equipment required “level shifting” from RS232 levels. Currently, USB conversion cables are offered for sale. Connectors and pinouts on ham equipment are not constant from manufacturer to manufacturer.

While there is an iPhone app to decode ALE data, to my knowledge there is no ALE controller implemented for a smartphone/tablet platform. The PCALE controller works with compatible transceivers listed on the PCALE website.[5] There is an open standard for transmitting geolocation across ALE.[6] This is at least supported by PCALE.

Options for the lazy

Two-way radio communications requires participants who have access to the same bit of the EM spectrum. Within the context of personal preparation for coordination in an emergency, this means that all parties involved in the coordination need the same license, or a license-free option. The basic non-ham options are:

- CB: 12W PEP SSB max, 4W AM max, near the 10m ham band (~27Mhz), license-free, distance limit of 250km (155.3 mi)
- MURS: 2W max, near the 2m ham band (~151/154MHz); license-free
- GMRS: 50W max, near the 70cm ham band (~462/467 MHz); license costs ~$65, but requires no study, there is no test, and the license applies to all immediate family members (father, mother, son, daughter, sister, brother).

Locally, these are all line-of-sight solutions. CB has the potential to exhibit skip but has power and distance limits to mitigate that possibility. CB also has a very limited ground wave.

Enforcement concerning abuses of these radio services is lacking to nonexistent. However, the specter of being fined is always there, and likely depends on how disruptive the illegal use is, as well as who is being disrupted and how vehemently they are demanding satisfaction. Hunters using GMRS radios (which Fish and Game monitors) to locate game have additional problems unrelated to FCC enforcement if they are caught. Listeners could be anywhere, recording devices are ubiquitous, direction finding equipment is trivial to construct and operate, and fines are orders of magnitude more than the cost (if any) of the license. Wikipedia indicates that the FCC has turned renewed attention to enforcement actions concerning misdeeds in the neighborhood of the CB/ham 10 meter band/military frequencies called “freebanding”.

Most GMRS equipment is uncompromisingly lousy. “Bubblepack” equipment consisting of inexpensive and poor quality low power (5W or less) hand-held devices having permanently attached rubber duck antennas is the norm. According to the FCC website[7], Part 95A type-accepted devices

5 http://hflink.com/hardware/
6 http://hflink.com/alegpr/
7 FCC OET Authorization Search (https://apps.fcc.gov/oetcf/eas/reports/GenericSearch.cfm)

capable of more than 10W are few and old. Two Kenwood models in 2012, two more Kenwoods in 2010, followed by two others from various manufacturers in 2008, approximately 10 in 2007, and so on. The lack of options have led to an interpretation of the FCC rules to the effect that any radio which meets the technical standards specified in Part 95 is legal to use for GMRS[8]. In essence, this leads to the widespread practice of re-purposing Part 90 public safety or business radios programmed for GMRS frequencies and power levels, as the technical standards are nearly identical.

Long story short, none of my intended purposes would benefit from abusing these radio services, and if it turns out that GMRS plays a role, $65 for Jen's five year license is a pretty cheap insurance policy. As far as radio equipment goes, I will assimilate the interpretation that appropriately programmed Part 90 certified radios are OK.

An interesting note about GMRS is that there is a repeater in operation in the bitterroot valley (462.675(+) 141.3):

> *THIS REPEATER COVERS THE BITTEROOT VALLEY FROM LOST TRAILS PASS TO MISSOULA ON A 25 WATT MOBILE, IT HAS HAND HELD COVERAGE IN THE CENTRAL BITTEROOT CITIES OF HAMILTON, CORVALIS AND STEVI. And uses the 141.3 TONE FOR TRAVELERS...THANK YOU JIM...WQKU999*

Ham-only modes and techniques

This section summarizes some potentially useful things which hams do but which public safety doesn't do. These approaches have the most promise for addressing my intended use cases.

APRS and packet radio

Packet radio is a form of multi-hop relay implemented with a common simplex frequency shared by a network of nodes which store-and-forward digital packets, a process called “digipeating”. The network of nodes can intelligently route packets on an optimal path from a source to a destination. The Automatic Packet Reporting System (APRS) is a special type of packet network designed to widely disseminate messages. APRS, in effect, creates a near-real-time common operating picture available to everyone within range of the network. A national APRS frequency has been coordinated on the 2m band and is used to inform traveling hams of local repeaters, events, and weather conditions as well as the location and availability of other hams.

The information disseminated on this network generally does not have to move more than two hops before it encounters an “iGate”, which moves the packet over to the Internet. Certain types of packets, such as weather reports originating on the Internet, or messages destined for a local RF-connected participant, can move in the other direction (Internet to airwaves.) The effect is that RF-connected users have access to all local information in the APRS system, the system is globally connected via the Internet, and the local information finds its way into global, search-able archives.

APRS supports tracking in near-real-time. This means that items on the display are probably not more than ten minutes stale. It is not an up-to-the-minute, blow by blow account of activity. APRS also

8 http://www.buytwowayradios.com/blog/2012/06/using_a_business_radio_for_gmrs.aspx

supports delivery of short text messages. These messages can be addressed to a particular user, but they are not private: they are available to everyone else and archived in the global search-able database. Likewise with any other information, including your track.

APRS can also be used locally. By switching all participants to a different frequency not used nationally, a local APRS network can be created which contains only the participants who have switched. This is accepted best practice for supporting special events or emergencies, when there are a lot of APRS nodes in one place sending out a lot of messages.

Managing traffic on the network is a huge challenge with APRS. The tendency to promiscuously replicate information and relay to all listening parties (who then replicate the information and relay to all listening parties, who then....) means that the number of copies of the information increases geometrically with the number of hops. Limiting the number of hops information is allowed to take before it is no longer digipeated has become a key tool to alleviate congestion.

Advice on the web for setting up the mobile radio in the truck to digipeat the signal from my handheld may have application to getting simple text messages back to home while hiking in the woods. The home station could either receive messages via RF or via the Internet. Either way, the home station could sport a mapping display which tracks me and displays texts. There is also information about setting up a “fill-in” station, which can supplement areas of bad coverage by either digipeating APRS packets, transferring them to the Internet, or both.

Some mobile radios natively support APRS. They can display text messages and basic local information on their front panel, and if connected to a GPS, can display a map and report their position to others (possibly with intentionally degraded precision). APRSdroid is an application which runs on Android based smartphones and tablets. It can scan the APRS internet feed, or if connected to a radio via the headphone cables, can participate in the APRS RF network directly. The smartphone/tablet display and interface is generally superior to interfaces built into mobile radios. Any radio can be used. There is also a bluetooth interface[9] which allows a wireless connection between the smartphone and the radio (although this typically means that the bluetooth interface itself is attached to the radio with a rubberband and headset cables).

Near Vertical Incidence Skywave

Near Vertical Incidence Skywave (NVIS) is exactly what it sounds like: radio energy that is sent straight up instead of out toward the horizon. It uses frequencies which are reflected by the ionosphere (else the RF would just keep going out to deep space.) In this case, HF is used not for long distance communication (DX), but for local communication, within the skip zone. Antennas used for this mode are located closer to the ground than antennas used in the same band for DX (typical heights of 1/10th to ¼ wavelength from the ground). Lowering the antenna reduces the amount of energy sent to the horizon and redirects it upward. Standard HF mobile power levels (100W) are adequate to successfully operate this mode.

9 http://www.mobilinkd.com/

The advantage to using the ionosphere as a reflector for local communications is that the ionosphere is much much higher than the highest terrestrial obstruction. A fairly wide beam pointed up is even wider when it hits the ground, and generally covers everything in the local vicinity, regardless of what whimpy little mountains separate the two talkers. In other words, when the beam is coming essentially straight down, there's not much shadow. This is not a groundwave mode, this is line-of-sight reflected off of a high-altitude mirror: your signal is always at high noon on the equator.

Unlike a repeater, the ionospheric mirror is not “infrastructure”. It does not require maintenance. It does not require power. It does not require frequency coordination. Whereas a repeater supports a single conversation over its coverage area using two frequencies, NVIS opens (or closes) all possible channels in an entire band to direct simplex contact.

The frequencies used are typically between 2-10MHz. The 80m and 40m bands are most commonly open. It is important to have the flexibility to move to different bands in order to maximize the chances of having something work regardless of conditions. Higher frequencies become predictably less and less useful until there is roughly a zero percent chance of ever using this mode even under the most favorable conditions at ~30Mhz (10m band.) As with DX, the best frequencies to use change from season to season, day to night, with the sunspot cycle, and with current solar activity. Automatic Link Establishment (ALE) can be combined with the NVIS propagation mode to monitor current conditions and assist in selecting the best performing band.

NVIS communications are optimized if both stations are set up for NVIS communications (pointed up.) Configuring a station for NVIS communication reduces the noise level by pointing the antenna beam away from distant thunderstorms, which is a major source of noise in the HF bands. Chances of interfering with (or suffering interference from) distant stations is also reduced when the antenna beam is directed upwards.

The NVIS mode is limited to those hams licensed for the low HF bands. This excludes technicians, but general class and up are all in the game. I encountered a mailing list archive from ten years ago which referenced a Missoula County website with modeling results from a variety of NVIS antennas.[10] This web page no longer exists, but I was able to find it in the Internet Archives. The person who did the modeling was David McGinnis K7UXO.

Digital Voice (FreeDV/Codec2)

APCO P25 radios use the proprietary Improved Multi-band Excitation (IMBE) and Advanced Multi-band Excitation (AMBE) vocoders to digitize and compress voice data for transport across narrowband digital channels. These are standardized for P25 Phase 1 and 2 respectively. Digital Voice offered in commercially produced ham equipment licenses one or both of these vocoders. (This is not to say they are compatible: their methods for conveying digital information over the airwaves are fundamentally different.) The patents are expiring for IMBE, and open source implementations are starting to appear based on the information in the patents.

10 http://www.co.missoula.mt.us/acs/NVIS%20EZNEC.htm

A completely open source vocoder and digital transport has appeared, collectively known as FreeDV. This consists of a modem which name I never learned and a vocoder called Codec2. FreeDV is in use on the HF bands. The signal is designed to fit in the audio passband of the transceiver and therefore fit into a standard sized voice channel on the air. This is a "soundcard" mode which can be added to any HF rig via connection to a computer running the freely available software. There is also an open-source hardware implementation called the SM1000 Smart Mic.[11] It can connect to the HF (or VHF or UHF) rig with audio cables or you can hold it up to the speaker on the radio.

The primary advantage of FreeDV is that it allows clearer copy of weaker signals. Like all digital voice, it is perfect until it completely collapses. There are conditions under which it is advantageous to use analog SSB, however there are also conditions where the digital voice is preferred. Highly compressed digital voice contains artifacts which are annoying to some users. This is a subjective judgment that requires the user to gain some experience and make up their own mind.

Amateur radio broadband data

Unlicensed wireless networking equipment (wireless routers, access points, etc.) operate on the ISM bands at 900MHz, 2.4GHz, and 5GHz under FCC Part 15 rules. Hams are reprogramming this equipment to use ham frequencies and/or higher power. Using this modified equipment means that Part 97 rules apply to it's operation, and Part 97 is quite restrictive compared to Part 15. Part of the ham modifications ensure that identification requirements of Part 97 are met. Key features of this effort are very wide bandwidths (~20MHz or so) and high data rates (hundreds of megabits per second.) The efforts are focused in two projects, where one is really an outgrowth of the other:

1. High-speed multimedia (HSMM or broadband-hamnet), the original; and
2. Amateur Radio Emergency Data Network (AREDN), which forked HSMM and concentrates on emergency response.

Originally, the equipment used was the LinkSys family of wireless home routers, but recent development efforts, particularly with AREDN, have focused on the Ubiquiti line of inexpensive outdoor wireless equipment. The Ubiquiti equipment is typically built to be bolted onto towers, primarily to establish a large scale broadband infrastructure. Ubiquiti equipment is generally built to the highest Part 15 power limit because of the expectation that longer communication paths may be involved. The indoor home wireless equipment is not necessarily so beefy. Ubiquiti pursues a modular approach, where the radio can be connected to the most appropriate type of antenna, offering a selection of parabolic dish, sector and omni-directional antennas.

These approaches leverage the IEEE 802.11 family of standards, which were written with the expectation that all participants on the network are in the same structure and they can all "hear" each other. If this assumption holds true, then the devices can coordinate to avoid colliding on the air. Taking these devices outside and dispersing them widely tends to violate this assumption, which causes more collisions, retransmissions, lost packets, and lower data rates. Some of the Ubiquity equipment's firmware contains a proprietary algorithm which assigns each client a designated time slot to transmit,

11 http://www.rowetel.com/blog/?page_id=3902

reducing collisions and increasing data rate. This crafty approach is lost when the firmware is re-flashed. I do not recall a corresponding feature being present in the custom ham firmware. However, the chances that client devices will see each other can be increased by using a sector antenna at the access point. At least all the clients serviced by that radio will be roughly in the same direction from the access point.

Mobile components to such a network would tend to have omnidirectional antennas, while elements of fixed infrastructure would be set up to have omni, sector, or parabolic antennas. Fixed infrastructure sites in a well designed network will have one or more dedicated point to point links (providing backhaul) as well as one (omni) or more (sector) dedicated radios to serve clients in the area. The radios which serve clients would have to have firmware compatible with the mobile units, however the point to point links need only to be self-consistent and expose an Ethernet interface. The ham firmware is capable of leveraging an IP network to connect multiple access points, provided in this case by the point to point links.

Because these data networks operate using the Part 97 FCC rules for amateur radio, encryption is prohibited...sort of. One cannot use codes or ciphers to obscure the meaning of a communication. You can certainly use a cryptographic techniques in a well defined authentication process to avoid sending your password over the air in plaintext. The thinking behind this is that it will be obvious that an authentication is taking place, so the meaning is not obscured. The actual password itself is obscured, but it conveys no meaning. However, once the authentication is complete, the control channel can't obscure the commands and responses which are going back and forth. The one exception is control channels to orbiting platforms.

An accepted use of encryption (which is currently the limit to which the regulations may be stretched) is to require authentication for admission to the network, so long as admission to the network is generally available to all hams. As I understand it, all of the various schemes to require authentication for a WiFi network result in encrypted network traffic over the air. Thus, unlike the above, the communication channel remains encrypted over the air after the authentication takes place. The intent here is to exclude non-hams from accessing the ham network, mitigating the possibility that they would introduce traffic which would find it's way out a Part 97 transmitter. After all, some of the modified equipment is still operating on the same frequency as every wireless router in Best Buy, and is therefore visible to the general public.

Notwithstanding the above, the prohibition on encryption is the biggest Achilles heel of implementing a data network using Part 97 rules. Forbidding encryption conflicts with many best practices and entrenched policies related to managing digital infrastructure, eliminating many potential served agencies due only to the fact that they have adopted these best practices in a context where they are not forbidden. For example, all federal government websites are required to use HTTPS (encryption) for all connections by December 2016.[12] The feds are not leaders in this regard, as they note they are adopting this policy in order to keep pace with common practice in industry. The intent is not to erect a barrier to the publicly available information (many federal and commercial websites subject to this and similar

12 https://www.whitehouse.gov/blog/2015/06/08/https-everywhere-government

policies do not require a password), but rather to obscure who is accessing the information. It represents better privacy protection for those who access the sites. Likewise, it is common policy to require that laptops connected to an external network establish a Virtual Private Network (VPN) connection back to the company's or agency's intranet. Finally, the process of logging into a remote machine to do maintenance or update configuration nearly always involves an encrypted link: secure shell (SSH) for linux is intrinsically encrypted, devices offering web control almost invariably require HTTPS, and the various remote desktop protocols for GUI-only environments such as windows, also incorporate methods to protect the channel via encryption. All are designed to deprive the casual listener from knowledge of what is transpiring, and hence all are prohibited by Part 97. Most of these are entrenched, unassailable policies adopted by the agencies/organizations, or worse, they are required as a practical necessity (e.g., Forest Service email is only available from the intranet, so to get email, FS employees must VPN into the FS intranet. It is also likely that the email is only delivered to the laptop by "secure"/encrypted means.)

Perhaps the highest profile problem with the interplay between Part 97 rules and data is that Part 97 networks cannot transport backhaul data for FirstNet deployables under the current rules. FirstNet has a particular emphasis on security which would put it in violation of Part 97. If the network itself didn't, the applications running on the plethora of smartphones and laptops from served agencies would. Or the secure communications required by law enforcement and EMS would. Other than this little legal problem, the two approaches are technically quite complementary.

The encryption described above is forbidden, whereas encrypting the entire network is not. The latter categorically excludes non-hams, but allows all hams to view the traffic. The former excludes everyone not involved in the specific encrypted connection, such that none of the hams operating relay nodes can know what traffic they are relaying. FCC Part 97 is written to ensure that the amateur spectrum remains an open public resource, whereas digital networks (even personal networks) universally implement privacy and security protections. These two characteristics are in conflict. It is not merely that the FCC rules have been outpaced by technology. To resolve this will require rule-making actions by the FCC which strike a new balance between openness, security, and privacy. This will not be quick, easy, or painless transition away from self-policing amateur bands which are publicly accessible to anyone with a scanner, licensed or not. It is, however, necessary if amateur bands are to carry public safety data traffic in an emergency. The first step (rendering amateur data traffic inaccessible to unlicensed scanner-operating public) has already been taken without a rulemaking action, but this is about as far as "creative interpretation" can take us.

Sound card modes and mobile devices

A typical pattern with ham radio operation is that certain modes are implemented with a controller connected to the radio via audio cables. The controller is typically a desktop or laptop computer, although recently the controlling software for many of the modes has become available on specialized embedded devices (Arduino, Raspberry Pi, or custom: Mobilinkd or SM1000 Smart Mic), tablets and smartphones. Embedded devices, tablets and smartphones use much less power than laptops and desktops, allowing for extended operation on battery power. Because the connection from the radio to the controller just involves an audio signal, mobile computing devices can use either built in speakers and microphones or a wired connection to the headset jack. Smartphones and tablets include touchscreen interfaces, typically integrate an onboard GPS receiver, may support Bluetooth and USB connectivity to peripherals and can connect to the Internet via WiFi or cellular data if available. They also have a significant internal memory for data and installed applications.

“Controller” can simply mean that the device serves as a modem for a digital mode, manages file transfers, or can imply something more complex, like serving as a digipeater controller on a packet or APRS network. For most common modes and applications, programs exist on all common computing platforms: Windows, Linux, Max, iPhone, and Android. However, I have only located an ALE controller for the PC platform. This may indicate that some development is in order to support efficient battery powered ALE operation. In the interim, ALE operation can be supported by a laptop.

Portable power

The ham radio/emergency power standard connector is the Anderson Powerpole.[13] The local ham radio club says they have some in stock. Unless there is very good reason to deviate from this standard, everything requiring power in the emergency comm system should use these connectors.

Lithium ion batteries are becoming available for portable use. A two pound battery can sustain a 100W HF SSB mobile transceiver for two hours. These usually must be purchased as a pack, because the packs have integrated electronics which prevent over-charging, over-discharging, and bursting into flames. I believe the charging systems must also be designed for Lithium Ion batteries. I found a vendor of Lithium ion battery / charging systems on the web: http://www.batteryspace.com/lifepo4cellspacks.aspx. Buddipole.com sells Lithium Ion batteries and charger systems which already have powerpoles installed.

Lithium ion batteries cost more than lead acid, SLA, Gel cells, etc, but can be more deeply discharged more often, and need to be replaced less often. The effect is that their lifetime cost is much less than maintaining a portable power solution comprised of these other technologies. They are also lighter and more realistic to consider for backpack operation.

Goals and functional requirements

My personal goals for this year address my initial motivations for getting involved in radio. Namely: figure out a way to contact home from the woods, and determine the most appropriate way to get the vehicles (and people) set up for coordination in an emergency, with the constraint that those requiring coordination aren't going to be hams. The first steps will involve getting some experience with the things I was learning about in 2015.

Phoning civilization from the woods

For the general task of contacting civilization from the woods, two technologies present themselves:

13 http://www.andersonpower.com/us/en/products/powerpole/index.aspx

NVIS propagation for text messaging with my station at home (or voice contact with other hams, if the mode takes off), and APRS for tracking and text messaging. In general, I envision that the home station will be controlled by my ~10 year old desktop, hopefully running linux; while the mobile/portable stations will be controlled by my laptop and/or Android tablet(s)/smartphone(s). Ideally, a tablet/smartphone platform would include a compact bluetooth keyboard. These controllers will be connected to unmodified radio equipment via audio cables and perhaps through a serial control port. The focus will be on using what I have to avoid buying new, until the number of stations outstrips the equipment I have on hand.

The APRS tracking solution will be pursued first, with NVIS after. I have no HF equipment compatible with NVIS, but I do have 2m/70cm radios in handheld and mobile form factors.

Generic functional requirements of the “APRS tracking” solution:

- My truck should be capable of reporting position and sending text messages via APRS. It should also have a graphical map display.
- My truck should be capable of “digipeating” APRS position reports and text messages from my handheld radio.
- My handheld radio should be capable of reporting position and sending text messages via APRS, and should have a graphical map display.
- My house should be a “fill-in” station for APRS, in order to receive APRS packets via RF and make Alberton less radio lame.
- Something in my house should be capable of sounding an alert if a message is received from me, and Jen needs to know how to access my tracking data/messages via the web.

Generic functional requirements of the NVIS propagation solution:

- Since it may only be me, especially at first, the emphasis is on comprehensive ALE support and text messages between my home and the remote station.
- My house should be set up as an NVIS station
- I want to develop a transportable NVIS station, which perhaps needs to be unpacked and set up, but which is compact and lightweight: perhaps first a hardcase that fits in the truck, later an arrangement that fits on the motorcycle with my camping gear and finally a backpack sized solution with some room left for food, water, tent, sleeping bag. Can NVIS QRP?
- I would like to investigate setting the truck up as a mobile NVIS station, such that it can transmit when moving.
- When the house receives an ALE message, it should alert Jen, and she should know how to view it.
- If there's other people to talk to, I'd like to try messing with FreeDV over NVIS.

- “Home” ham equipment (NVIS and APRS stations, above), needs to be rapidly packed up into transportable form.

Emergency coordination with GMRS or CB

The primary use case for emergency coordination is: Collecting Jen's kids on the way through Missoula and coordinating a convoy down to her parents' place in Conner. Staying in contact when running into town is also a high priority (Alberton->Missoula or Conner->Hamilton). The fundamental constraint is that neither Jen nor Jen's family members are getting ham licenses.

Ideal functional requirements for the Emergency coordination system (experimentation will determine how realistic these are):

- Simplex vehicle to vehicle communication should be possible over fairly long distances in the valleys (from Missoula to Hamilton, Missoula to Alberton (or as close as we can get)).
- Vehicle to handheld communication between her and her children should work anywhere in Missoula.
- Handheld-to-handheld communication should work between her kids' apartments in Missoula.
- Vehicle parked at her parent's place in Conner should be able to talk to vehicle in Hamilton using simplex. Parked vehicle can use high gain directional antenna and temporary mast, and should be considered a temporary base station. If GMRS, parked vehicle at her parents' should be able to talk to vehicle anywhere in the bitterroot valley through the repeater.
- For GMRS, all vehicles and handhelds should be capable of using the repeater.

“Vehicle”, above, means my truck and Jen's SUV. Handhelds and chargers for all.

This year will see experimentation which should lead to identifying equipment which will suit these needs. Experimentation will be performed on ham bands near the GMRS or CB bands, at similar power levels with the same modulation schemes. Some experimentation, like testing simplex handheld performance around Missoula, may require Jen's help, and therefore actual GMRS equipment. No sense buying anything until I have a good idea of how well things will work.

Consolidated development plan

This section outlines a tentative plan to accomplish as many of the above goals as possible. Three stages are outlined which allow for a cumulative building of capacity which is reused in subsequent stages.

Stage One: APRS System

The APRS system requires that three APRS nodes be developed: 1] a “fill in” station at home; 2] a “relay”, digipeater node in the truck; and 3] a handheld/portable node for hiking.

The home system requires:

- The 2m mobile rig from the truck.
- An external antenna (roof or pole mount)
- A controller, interfaced to the 2m rig and running APRS software.

The truck system requires:

- A new 2m/70cm dual band mobile (uses existing antenna)
- A dedicated APRS controller. Should be able to: 1] operate as a regular APRS node when in motion, including a GPS and a display; 2] be configured to digipeat packets from the handheld when stationary (no screen or GPS required).
- Interface cables from the controller to the radio.

The portable system requires:

- My existing 2m/70cm hand-held (uses existing antenna)
- A dedicated, hand-held APRS controller which operates as a regular APRS node, including a GPS and display.
- Mobilinkd bluetooth interface to separate the user interface from the radio.

Stage Two: Coverage measurement

I am interested the the coverage afforded by the GMRS and CB radio services under specific circumstances. Coverage will actually be measured in ham bands spectrally adjacent to the radio services of interest, with the assumption that the ham-band measurements are applicable to the CB and GMRS services. Handheld devices will only be evaluated for 5W GMRS coverage, as I cannot imagine handheld CB (11 m wavelength) devices having antennas efficient enough to be a contender. Vehicle and base stations will be evaluated at the full power limit of the respective service. All devices will have typical, realistic antennas for the type of platform (handheld, vehicle, or base).

Measuring coverage involves four combinations of equipment: handheld to handheld; handheld to vehicle; vehicle to vehicle; and base to vehicle. Since there is only one ham involved, measuring coverage needs to be an automatic process. APRS would be a good choice if it can measure and log the link quality, as stage one develops significant APRS capability which can be reused. An alternative to investigate would be the Link Quality Analysis function of ALE. If neither will work, I will have to develop my own solution, likely with a custom Android app or custom firmware for something like the Mobilinkd or SM1000 Smart Mic.

The hand-held to hand-held paths will be evaluated only on the 70cm band and require:

- Two of the “portable systems”, described above; or
- One “portable system” and one “Truck system”, described above. “Truck system” set to 5W hand held power, and having a typical hand held antenna

The hand-held to vehicle path will be evaluated only on the 70cm band and requires:

- The “portable system” described above; and
- The “truck system” described above

The vehicle to vehicle path will be evaluated both on the 70cm and 10m bands, requiring:
- Two of the “truck systems” described above, on 70cm, set to 50W
- Two of the “truck systems” described above, on 10m, set to 12W SSB

The vehicle to base paths will be evaluated both on the 70cm and 10m bands, requiring:
- Upgrading the “home system” to operate on the 70cm band as well as the 10m band, capable of being adjusted to transmit at the relevant power limits.
- Ensure the entire “home system” for 70cm and 10m is portable, as it will need to be used to evaluate paths in Alberton and Conner.
- Install a 10m rig in the truck, interfaced to the ALE-or-APRS controller
- Install high gain antennas for 70cm and 10m at home (likely on a fiberglass mast)
- Install a typical mobile 10m monoband antenna on the truck

Stage Three: NVIS and ALE

Implementing a basic NVIS capability requires development of a home station and a transportable one. “Transportable” likely means a 100W mobile radio and antenna, capable of acting as a temporary base station. There is no initial requirement that the system operate while in motion. Both stations require an ALE controller, which may have been developed in Stage Two.

- The home station requires:
  - a transceiver capable of transmitting on several HF bands between 2-10Mhz at approximately 100W PEP SSB.
  - NVIS antennas on the supported bands, as well as a means of switching among them.
  - An ALE controller

- The transportable station requires:
  - a portable power source
  - a transceiver capable of transmitting on several HF bands between 2-10Mhz at approximately 100W PEP SSB.
  - Portable NVIS antennas on the supported bands, as well as a means of switching among them.
  - An ALE controller

Stage by stage buildout

The above functional requirements and development stages are summarized in Table 1. This table specifies requirements only. It does not necessarily indicate what devices should be purchased for what stage. It is intended to aid in “optimizing” my purchases. For instance, it makes little sense to purchase a 2m monoband transceiver for stage 1 when it is necessary to support 70cm in stage 2. Also, while the desktop may seem an attractive option for a home controller, a new tablet may be better suited to an 8 hour battery backup.

As far as ham radio goes, stages one and three represent capacities which I would like to develop, whereas stage 2 represents an activity having an end. Once stage two is accomplished, the ham equipment used can be released to other tasks. Stages one and three must be capable of simultaneous operation. In all three stages, it is desirable that the home station be rapidly transportable.

Table 1: Capacity building by stage. Table shows requirements of each stage and does not necessarily spell out what to buy when.

Stage	Platform	Item	Specification
1	Home/Base	Transceiver	2m@50W
		Antenna	2m outdoor antenna
		Controller	Desktop computer as APRS fill-in node
		Mast/Tower	Maybe
		Power	8 hour battery backup (controller + 5/5/90 radio operation)
	Truck	Transceiver	2m@50W
		Antenna	Larsen 2/70
		Controller	Tablet/Cell/Embedded
		Power	Aux battery (not vehicle battery) 8 hours unattended operation
	Handheld	Transceiver	2m@5W
		Antenna	Diamond SRJ77CA
		Controller	Tablet/cell/mobilinkd
		Power	Spare handheld battery, charger for controller
2	Home/Base	Transceiver	Stage 1 plus: 70cm@50W 10m@12W PEP SSB
		Antenna	Stage 1 plus: 70cm high-gain (yagi?) 10m high-gain (yagi?)
		Controller	Stage 1 plus: coverage measurement/sounding software
		Mast/Tower	Y
		Power	8 hour battery backup (controller + 5/5/90 operation all radios)
	Truck	Transceiver	Stage 1 plus: 70cm@50W 10m@12W PEP SSB
		Antenna	Stage 1 plus: 10m monoband mobile antenna
		Controller	Stage 1 plus: coverage measurement/sounding software
		Power	70cm: Stage 1 Aux battery 10m: Vehicle power
	Handheld	Transceiver	70cm@5W
		Antenna	Same as Stage 1
		Controller	Stage 1 plus: coverage measurement/sounding software
		Power	Same as Stage 1
3	Home/Base	Transceiver	Stage 2 plus: Low HF bands @ 100W
		Antenna	Stage 2 plus: NVIS antenna(s) for chosen low HF bands
		Controller	Stage 2 plus: ALE software
		Mast/Tower	Y
		Power	Same as Stage 2
	Transportable	Transceiver	Low HF bands @ 100W
		Antenna	Portable/Deployable NVIS antennas for low HF bands
		Controller	Tablet/Cell with ALE software
		Mast/Tower	Y
		Power	Aux battery 2-8 hours operation at 100W Generator

Fun (when work is done)

As if all these plans aren't enough to keep me out of trouble (and in the poor house) for the next five years:

- Participate in National Parks on the Air using HF ham equipment (if I get some). This would imply being able to configure my portable station for traditional DX or for NVIS.
- Establish some broadband capability with Ubiquiti equipment and AREDN or LTE and smartphones or both.
- Gain some experience with P25 operation.
    - Ad-hoc trunking:
        - Explore the notion of "tactical trunking": smart utilization of simplex frequencies and repeaters, with simple, portable infrastructural elements.
        - Explore the notion of "band trunking" for ham bands, with automatic contention resolution. Also applicable to ALE/NVIS: automatic handoff to a free channel which isn't the ALE channel.
    - Build a P25-based APRS, or investigate how P25 does location finding.