IP400 and the
Digital Future of Amateur Radio

Jim Fisher Memorial Digital Network Association (JFMDNA)

Steve Stroh N8GNJ 2025-04-21

Steve Stroh N8GNJ
Editor, Zero Retries

- Licensed in 1980s - Packet Radio made Amateur Radio *interesting!*

- Moved to WA in 1987, fell in with Puget Sound Amateur Radio TCP/IP Group.

- Group put up multiple, networked 9600 bps bit regen TCP/IP *data* repeaters.

  - With an Internet gateway!

- Learned TCP/IP well enough to talk my way into a SysAdmin job

- Began writing a column in Boardwatch magazine about Broadband Wireless Internet Access using Part 15 wireless devices; one of the first to discuss Wireless ISPs.

Zero Retries Newsletter
Why *another* Amateur Radio Newsletter?

- Back in the day… TAPR PSR, Packet Radio Magazine, Digital Digest, *and QST* (regular articles on Packet Radio).

- Cool stuff that I *knew* was happening in the 2020s wasn't being covered in Amateur Radio media.

- Amateur Radio was *much* cooler, hip, happenin'… *relevant* than what was being shown.

- Substack platform - newsletters via email - came along making ZR possible.

- Zero Retries is a love letter to Amateur Radio, paying forward what Amateur Radio had done for me. Zero Retries 0000 published July 9, 2021.

What's with the name "*Zero Retries*"?

Better than N8GNJ's newsletter on data communications and other interesting things in Amateur Radio.

- In Amateur Radio Packet Radio, a data transmission is divided into "packets" and each packet is tagged with a "checksum" that is unique to that packet.

- When the packet is received, the receiving station compares the checksum to the data received. If the checksum is correct the packet is assumed to be good.

- If the checksum is not correct, the receiving station sends a request to re-transmit the packet (a Retry).

- Thus Zero Retries is the ideal state of a packet radio data transmission. I strive to explain things well.

- Name was created by Budd Churchward WB7FHC for the now-defunct NAPRA.

Zero Retries "Secrets"
Just things I've learned

- I have a different "editing" approach than most newsletters. If I know of an interesting topic but can't find anyone to write it up, I'll do the research and write it up myself.

- In the 21st century, requiring payment content for activities like Amateur Radio doesn't work.

  - Paywalls make content invisible and thus irrelevant.

  - QST's competition isn't piracy, it's Surrey Amateur Radio Communications' The Communicator.

    - PDF, free via web download, over 100 pages, bimonthly

- Zero Retries is free!

- No concern for email subscription churn; subscribers (mostly) come, some unsubscribe.

Always play for those five
Don Lancaster, beloved technology author:

Many years ago, I was at a rock concert. The opening act was a single flute player standing solo in front of the closed stage curtains. His job was to warm up the audience for the high priced talent that was to follow. He was good.

But as he went along, the musical vibes got stranger and stranger, then totally bizarre. He was playing **chords** on his flute. Combined with utterly unbelievable riffs. Much of the audience got impatient and bored at what seemed like a bunch of gawd-awful squawks.

Then I happened to notice a friend beside me who had both been in and taught concert band. He was literally on the edge of his seat. He turned to me and slowly said **"you… can't… *do*… that… with… a… *flute*"**.

Of the thousands and thousands of people in the theater audience, at most only five realized they were witnessing a once-in-a-lifetime performance of the absolute mastery of a difficult and demanding instrument.

Always play for those five.

I write Zero Retries for those "five", like me, who like to do data, space, microwave, and other technical activities in Amateur Radio.

New Types of Amateur Radio Operators
Generally, more technical

- Examples - Engineering student, software developer, hacker, maker, open source advocate

- Interested in decentralized radio communications. Example - Meshtastic on LoRa.

- More transactional - Amateur Radio isn't an activity unto itself; they want to use Amateur Radio to learn radio technology, experiment, and have fun.

- Internet natives - Internet is just infrastructure, like previous generations take grid power for granted.

- Happy with Technician privileges, don't see a lot of value in big HF station / antenna.

- Much more interested in digital (data) operation. They text a lot more than they talk.

- Mobile device is primary casual interface (rather than desktop). *Where's the app?*

- Example - getting licensed at DEFCON or GNU Radio Conference.

Mission Creep of Zero Retries

Show Amateur Radio as relevant by highlighting the things they're interested in.

- Discovered that there are a lot of existing Amateur Radio Operators that weren't happy with the lack of coverage of data modes and other Zero Retries Interesting topics.

- Document for posterity that there is a lot of technological innovation happening now in Amateur Radio.

- Zero Retries mostly covers what others are doing. I just expose it more widely outside their silos. Examples:

  - AREDN - Microwave networking by Amateur Radio for the unique needs of Amateur Radio.

  - Amateur Radio GEO payload for the Western Hemisphere (bit of a lonely quest at the moment).

  - VARA FM - 25 kbps robust data in a standard VHF / UHF FM voice channel.

  - GNU Radio - not Amateur Radio (exclusively) but lots of crossover for Software Defined Radio.

- As a mostly solo publication, I have the freedom to say what I think needs to be said, and dive as deep as I think a subject needs (often, multiple articles).

Example of Mission Creep of Zero Retries
M17 Project

- M17 Project is digital voice for VHF / UHF

- Implemented entirely as Open Source, including CODEC - Codec 2

- Designed *by* Amateur Radio (Wojciech "Woj" Kaczmarski SP5WWP) *for* Amateur Radio

- Very well thought out specification, digital voice *and* data

- Had been evolving slowly as a series of individual elements

  - Linking between M17 hotspots, repeaters supported in Brandmeister

  - Incorporated into the MMDVM as a supported mode

  - M17 data supported in Mobilinkd TNC 3 and TNC 4

  - Modified portable radios

  - Module 17 Modem

Example of Mission Creep of Zero Retries
M17 Project - continued

- I began studying M17 and trying to explain it in Zero Retries

- As part of my study, I concluded that M17 had all the pieces for a complete ecosystem to go mainstream.

- Published that conclusion in Zero Retries and M17 found some new energy from Zero Retries readers.

- I started an email list - m17-users

- Connect Systems created the first radios that incorporated M17 out of the box

- M17 Foundation created in Poland

- First M17 Conference to be held in Poland this September

- Biggest takeaway from discussing M17 in Zero Retries was that there was a large community that decided to get involved in M17 solely because it was open source. They were not interested in DMR, SF, D-Star because of the proprietary CODEC.

Other Zero Retries Mission Creep
If it interests me, there's a lot of others.

- Before deep dive on M17, had done a similar deep dives:

  - MMDVM-TNC - little known advanced data mode being developed

  - VARA FM - fast, robust data mode (25 kbps) for VHF / UHF

  - Concluded that for best success, projects / systems need dedicated advocacy groups to evangelize them. Regular mentions of developments in Zero Retries helps. Examples:

    - AREDN

    - APRS - APRS Foundation

    - TAPR - Packet Radio

    - FreeDV

    - WInlink - Amateur Radio Safety Foundation

Future of Amateur Radio
Yet another mission creep of Zero Retries

- Amateur Radio, and especially US Amateur Radio needs a new focus.

- Increasingly, Amateur Radio isn't needed for emergency communications.

  - EMCOM is often useful, especially for personal emergency communications.

  - But, served agencies don't need Amateur Radio nearly as much:

    - Starlink (Mini)

    - Iridium (new sats)

    - FirstNET

    - Mobile phone to satellite (soon!)

Future of Amateur Radio
New mission?

- What society / industry / government needs *badly* is more radio technology expertise.

- SDR is the wave of the *present*, and US doesn't have nearly enough expertise.

- Need to promote Amateur Radio to university students, hackers, makers, IT personnel, software developers, etc. and make Amateur Radio seem relevant to them.

- Make room for open source / community software development model. Those SDR experimenters need somewhere to do their experiments

  - Staying in unlicensed bands is like learning programming on a Sinclair ZX-80 - possible, but hard, and "stunts" your learned expertise.

  - If Amateur Radio doesn't adapt to this, it could become the (unlicensed) Citizens Experimental Radio Service.

- China is starting to make their own unilateral standards. Can the US afford to be passive customers of a Chinese developed variant of Wi-Fi? Cheaper, no royalties, no US brand, Africa, Asia are bigger markets than the US.

Amateur Radio Regulatory Reform
(Yet *another* morph of Zero Retries)

- Advocate for regulatory (FCC, Part 97) reform for technical specifications better for data communications.

- FCC Docket 16-239 - eliminate the symbol rate for HF bands (legalize PACTOR 4 modems).

  - Finally completed by FCC in 2024.

  - FCC asked "should we do the same in VHF / UHF bands?

  - Filed comments - Heck YES!

- FCC Docket 24-240 - Reconfigure 902-928 MHz for NextNav

  - Filed comments - Technical reasons why FCC shouldn't do what NextNav wants.

- FCC Docket 25-133 - Any FCC rules we should delete?

  - Filed comments on a number of deletions in Part 97 that would encourage innovation and experimentation.

Transition Between Zero Retries and IP400 Network Project

Five higher speed data systems; all have tradeoffs

- AREDN - 10s of Mbps *on microwave*.

- Icom D-Star DD mode - *Proprietary* 128 Kbps *on 1240-1300 MHz*.

- New Packet Radio - up to 1 Mbps on 420-450 MHz (*requires 1 MHz*).

- VARA FM - up to 25 kbps on standard VHF / UHF channel (*proprietary*).

- 802.11ah / Wi-Fi HaLow - 902-928 MHz (Amateur *or unlicensed*.

SuperPeater Thought Experiment
A number of trends converged

- The new type of Amateur Radio Operator coming into Amateur Radio that preferred data, VHF / UHF, open source information.

- Many, most repeaters have gone quiet (unused).

- Increase in data modes, but using simplex connections, few networks, just hubs like Winlink Radio Message Servers.

- Feasible to add data capabilities to repeaters, just no blueprint on how.

  - Data over repeaters makes it easier to use data, just as repeaters make it easier to use voice.

SuperPeater Thought Experiment
Technical Ideas

- Cross-band makes a lot of sense

  - Repeater receives multiple inputs on different bands

  - Repeater receive multiple modes, including data, digital voice (especially M17)

  - Repeater transmits a single high speed data stream

  - For users, "choose an input" makes it easy / inexpensive to "transmit with what they've got".

  - User can use receive high speed data stream with inexpensive SD Receiver + Raspberry Pi.

  - Use Multi Mode Digital Voice Modem (MMDVM)

  - Include *MMDVM-TNC* advanced *data* mode

SuperPeater ideas got the attention of Martin Alcock VE6VH

Was working on an improved repeater controller with data

- VE6VH was developing with *data* radio chipsets to do higher speed data in the Amateur Radio 420-450 MHz (70 cm) band.

- We began talking about our respective ideas for enabling repeaters for data.

- I pointed out that the biggest issue in SuperPeater concept was lack of a *good user **data** radio*; using FM radios with modems wasn't great.

- VE6VH said that data radio chipsets could easily do what was needed.

- Thus the IP400 (*I*ntelligent *P*rotocol on ***400*** MHz) Network Project was born in January 2025.

Other Inspirations / Factors for IP400
Other influential factors to start IP400

- AREDN works great - *if* you can do microwave.

- New capable radio chipsets for *fast data* (not "walkie talkie" chipsets).

- VE6VH projects are sponsored by Alberta Digital Radio Communications Society.

- We are evangelizing IP400 in Zero Retries.

  - Messaging: ***IP400 is Packet Radio Revolution of the 21st Century***.

- Minimum viable product is low risk, first hardware in Summer 2025.

- Will showcase IP400 at Zero Retries Digital Conference in September.

IP400 Technical Details

- Fast data - 100 kbps minimum, and faster.

- Simple – Ethernet / Wi-Fi / USB in, radio out. Think Ethernet cable and Ethernet switches.

  - Transparent, lightweight protocol, encapsulation will allow backwards compatibility like AX.25.

- No modems - modulating in the radio domain, not audio domain. Not an "audio mode".

- Mesh networking, taking cue from AREDN's conversion to Babel.

- Development plan includes a repeater module.

IP400 has a longer term development plan
OFDM - Secret Sauce to future Amateur Radio data technology

- Orthogonal Frequency Division Multiplexing

  - Subcarriers, subcarriers, subcarriers

  - Redundant data across subcarriers

  - Forward Error Correction in each subcarrier.

- Martin and I bonded over his former employer and one of my early interview subjects.

- They demonstrated the power of OFDM in dealing with multipath and reliable service on unlicensed spectrum.

- OFDM is actually an old technology. At the time of the interview 20 years ago now, they said they were doing OFDM 20 years before that… but each radio required a VAX minicomputer to do the necessary computation to manage the subcarriers. Now we have cheap FPGAs.

What is IP400?

- A project to explore digital networking in the 400 MHz band
- Spectrum is underutilized with mostly repeaters and links
- Repeaters are becoming silent, spectrum is wasted
- Band has good propagation and penetration characteristics
- Use off the shelf modem components for 400 MHz
  - Higher orders of modulation and bit rates (4FSK, OFDM)
  - Compliant with current rules in most countries
  - Adaptable rates depending on data demand
- Minimum bit rate goal of 100Kb/s, and upwards
- Max Bandwidth goal of ~2.5 MHz

Raspberry Pi HAT node

- Pi Zero HAT format, supports most Raspberry Pi
- Built in linear power supply
  - Optionally powers raspberry Pi Zero, 2 and 3 series
  - Pi 4 series and above requires larger power supply
- SMA screw-type antenna connector
- Drive for external power amplifier
- UAR/T and SPI connection to Raspberry Pi
- Console using minicom and ttyAMA0
- Flash and EEPROM updaters
- Supports external ST-Link debugger
- Can support an external GPS receiver
- Coming soon!
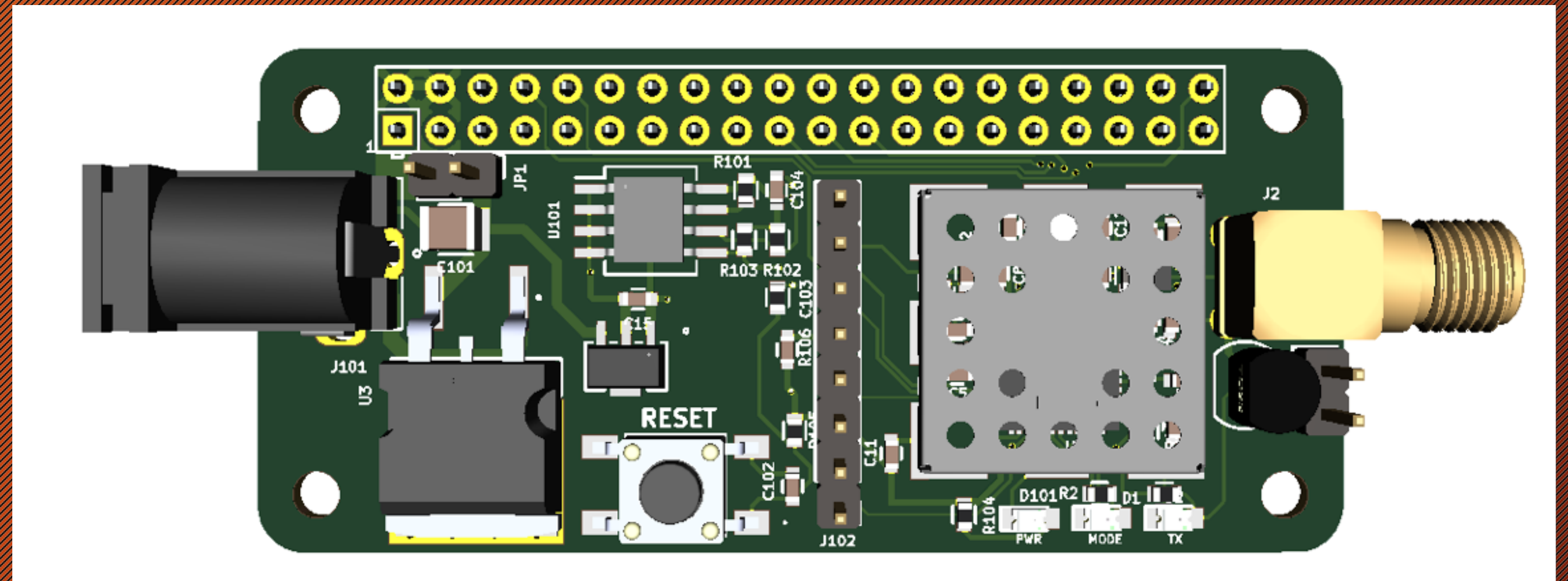
IP400 Protocol

- 802.15.4 compliant physical layer
- 2 carrier schemes utilized:
  - LCD is 100Kb/s 4FSK in 80 KHz BW
  - 4FSK up to 600Kb/s and 400 KHz B/W
  - OFDM using 232 carriers up to 5.8MB/s
- FSK carrier is always present
  - Beaconing and mesh table building
  - Link establishment and control
  - Compressed audio and telemetry
- BW Expanded for data sessions
  - High speed data and video traffic
  - Connect/Transfer/Teardown

IP400 Channel Utilization
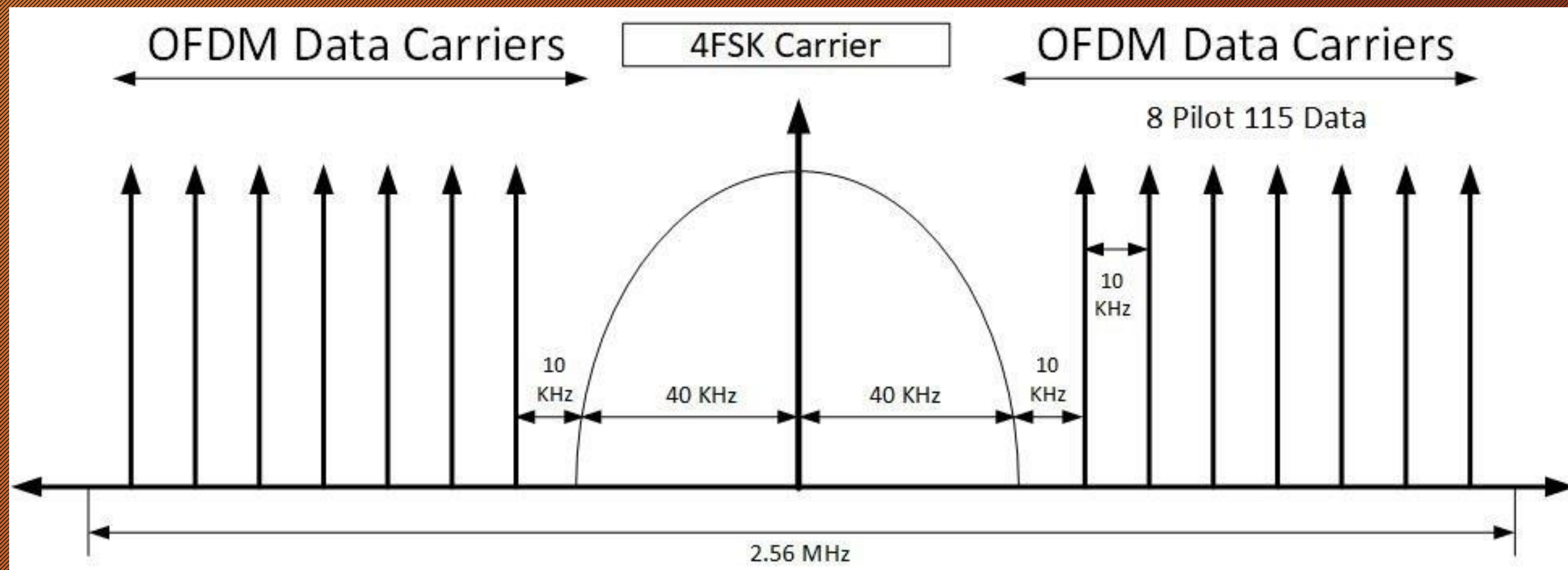
Digital Library of Amateur Radio & Communications
I really, really love DLARC

- Project of the Internet Archive (parent of Wayback Machine).

- Worldwide library for Amateur Radio (and loosely related communications).

- More than 1M items, all free to read, most free to download. A lot of DLARC material *has never been online* before DLARC.

- Fantastic technical resource - inspiration for ideas we tried, things we accomplished. Examples - TEXNET, PACSAT, Packet Radio Magazine, many microwave conferences, AMSAT's ORBIT magazine, etc.

- Funded by a grant from ARDC. A second ARDC grant in 4/2025 funds DLARC for an additional two years.

Amateur Radio Digital Communications
I really, really love ARDC

- Angel funding for Amateur Radio

- Amateur Radio was allocated a Class A IPv4 address block (44.x.x.x) in the very early days of the Internet.

- ARDC was formed as a formal group to administer (and protect) 44Net *for Amateur Radio*. The vultures were circling!

- ARDC decided that they could sell 4 million IPv4 addresses with very little impact to Amateur Radio.

- Sale was > $100M and was prudently invested, resulting in an annual endowment.

  - ARDC's major activity is now disbursing grants to Amateur Radio, education, and R&D.

  - Now has the funds to implement substantial improvements in 44Net infrastructure and focused management.

- My pitch is that ARDC has two major volunteer committees:

  - Grants Advisory Committee

  - Technical Advisory Committee

  - Call for volunteers goes out at the end of each year - please consider volunteering!

Zero Retries Digital Conference 2025
Saturday September 13, 2025 in Everett, Washington

- ARRL and TAPR, then TAPR sponsored annual Digital Communications Conference - *the* R&D conference for Amateur Radio.

- 2022 was the last in-person TAPR DCC.

- Annual, national in-person technical meeting for Amateur Radio is important!

- Tina KD7WSF and I decided to start a new Digital Conference (eventually).

- GNU Radio Conference 2025 is being held in Everett, WA in September, so we decided to "tag on" to GRCon 2025 with ZRDC the following Saturday.

- Carefully curated Zero Retries Interesting agenda.

Further reading…

- Zero Retries Digital Conference 2025 - https://www.zeroretries.org/p/conference

- IP400 Network Project - https://adrcs.org/adrcs/ip400-network-project/

- IP400 Github repository - https://github.com/adrcs/ip400

- IP400 email list - https://groups.io/g/ip400

- M17 Project - https://m17project.org/

- GNU Radio - https://www.gnuradio.org/   Conference - https://events.gnuradio.org/event/26/

- DLARC - https://archive.org/details/dlarc

- Amateur Radio Digital Communications (ARDC) - https://ardc.net

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Free (as in beer)

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Questions?