**Before The**
**Federal Communications Commission**
**Washington, D.C. 20554**

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| In the Matter of: | ) | |
| | ) | |
| The Amendment of Part 97 of the | ) | |
| Commission's Amateur Radio Service Rules | ) | |
| to Permit Greater Flexibility in | ) | |
| Data Communications | ) | WT Docket No. 16-239 |
| | ) | |
| | ) | RM-11708 |
| By: Loring Kutchins | ) | |
| President, | ) | |
| Amateur Radio Safety Foundation, Inc. | ) | |
| For the Entire Board of Directors | ) | |
| (See Appendix 1) | ) | |
| | ) | |
| _____ | ) | |

**Comments in Support and Rebuttal of Opponent's Arguments**

## 1. Amateur Radio Safety Foundation, Inc. (ARSFI)[1]

ARSFI provides for the formation, training, maintenance, and testing of volunteer licensed amateur radio public and emergency services and networks using state of the art communications technology. These serve the public by facilitating emergency, health, or welfare communication in times of disaster or other communications emergencies. The primary project of ARSFI is the Winlink Global Radio Email® system (winlink.org). ARSFI supports the day-to-day costs of running Winlink and projects to develop and improve radio telecommunications technologies.

The Amateur Radio Safety Foundation was incorporated January 1, 2006, as a non-profit Florida Corporation; Federal ID Number 20-5586920. This corporation is a NON-PROFIT PUBLIC BENEFIT CORPORATION and is not organized for the private gain of any person. It is organized under the Non-Profit Public Benefit Corporation Law for public and charitable purposes. The purpose for which the corporation is organized is to transact any lawful business for which Non-Profit corporations may be organized under the laws of the State of Florida, as they may be amended from time to time and under Section 501(c) 3, Internal Revenue Code. ARSFI has no employees, and services are provided entirely by volunteers.

## 2. Introduction

Members of this Board of Directors are unanimously in support of the Commission's proposal and encourage the elimination of the outdated and symbol rate limits.

Opponents to WD Docket No. 16-239 have responded to internet and social media campaigns led by Theodore Rappaport, resulting in a multitude of comments that echo false or misleading technical points, driven by highly emotional arguments about "national security, crime and terrorism". We address these arguments with the documented realities of science and logic in hopes that the Commission will find them balanced, informed, and trustworthy counterpoints for good decision making.

## 3. The HF Symbol Rate Limitation in § 97.307(3) Should be Removed

The current 300 baud symbol rate limitation was instituted around 1980 by the Commission as a mechanism to manage HF digital modes (both FEC and ARQ) that would be compatible with typical HF signal widths in use. The most common amateur HF digital modes in use then were AMTOR (similar to SITOR), later refined as Pactor 1 and HF packet (300 baud FSK). Since then, technical advancements in modulation, coding technology and Digital Signal Processing (DSP) now make it possible to implement significantly faster, more robust digital protocols with better spectrum efficiency (e.g. PSK31/63, MT63, Pactor 2, Pactor 3, WINMOR, ARDOP, VARA, Pactor 4, and other popular amateur modes). These modes are possible and affordable due primarily to the significant advancements in digital signal processing, cost reductions in computers, sound cards, and DSP processing chips since the original 300 baud symbol rate restriction was instituted. So, in 2018, the symbol rate limit is a deterrent to advancing the radio art now that modern encoding techniques are available.[2]

A more appropriate mechanism for managing these amateur modes would be to use a specific and more relevant metric such as occupied bandwidth. The Commission has used this approach in some of the emission types in § 97.303 and § 97.221. Adopting this approach has several advantages:

*Promotes advancement of the radio art*

The Commission's rules define the purposes of the Amateur Radio service. One of them is to advance the radio art.[3] The current limitation has set the US well behind other countries in the development of more efficient HF radio protocols. Now there is little incentive to develop better protocols. Improved coding theory, DSP hardware and software now allow more efficient spectrum utilization, but the current rules minimize incentives to bring them into existence. The fact is, better, more efficient HF modems are possible while keeping signal widths manageable in other ways than limiting symbol rate.

*The Increase of spectrum efficiency (bytes/minute/Hz)*

More data sent in less time in the same occupied bandwidth allows more stations to use the same occupied spectrum in time (higher bytes/minute/Hz). This reduces band congestion. Higher symbol rates in advanced ARQ modes that adapt to a rapidly changing propagation channel allow this. Examples:

—Pactor 4 (not permitted because it exceeds 300 baud) has over twice the spectrum efficiency as Pactor 3 (which conforms to the 300 baud restriction) while occupying slightly less than the same bandwidth.[4]

—Mil STD 188 110B and similar STANAG modes provide an efficient mechanism for transmitting up to 6400 bits/sec in a 2600 Hz bandwidth using a single 2400 baud carrier with 16QAM modulation. This detailed and publicly documented protocol, with its optional encryption layer disabled for amateur use, would provide another effective, efficient and proven protocol for amateur use that would ease band congestion, not worsen it.[5]

*Intercommunicate more efficiently with countries that already permit digital protocols without symbol rate restrictions.*

Canada, Mexico and Central America and most of the world already fill our airspace with signals using modern modes not permitted in the US—with no more signal width than Pactor 3 and with double the spectral efficiency. The International Telecommunications Union (ITU) has undertaken a project to expand Pactor 4 Winlink gateway stations in Guatemala, Costa Rica, Dominican Republic, and Nicaragua to bring superior contingency communications to the region.[6] They would depend upon US resources in large disasters and interoperable, efficient communications means are needed. And the reverse is also true. Interoperability is certainly key in either direction.

*Remove the need for Special Temporary Authority (STA) during major events.*

Following recent hurricanes, the FCC saw the need for Pactor 4 and granted STAs for each occurrence as it was needed.[7] There are no other competing digital systems with Winlink's scale of use and real, demonstrated results, ranging from hurricanes to the recent California wildfires. Whatever the emergency, today's needs dictate being able to quickly send large volumes of data without error.

Efficient protocols being available full time is more effective than temporary STAs. With the permanent elimination of the symbol rate restriction, individuals will be inclined to make the investment in protocols like Pactor 4, and equipment will be set up and tested in advance of need. Expensive and Mil-grade modems are difficult to justify for only short-term use.[8]

**4. Fact-Checking the Opponents**

The following opponent arguments have nothing to do with the symbol rate question and thus, are not related to Docket No. 16-239. Nevertheless, we address these repeated false and uninformed comments.

*The Winlink system can be used by terrorists and criminals, and poses a threat to national security*.

FALSE OR EXTREMELY UNLIKELY. Concerning Theodore Rappaport's letters, campaigns, and ex parte filings, removing the 300 baud limit is not especially related to any increase in national security problems. The airwaves are not exclusively US airwaves, so while the Commission can control radio operators within the US, that is not a wholly practical solution. Next, anyone who wants to threaten national security will surely flaunt the law, regardless. Finally, anyone who really wants to send secret messages undetectably will first choose to use another less public radio service where self-monitoring does not exist and where encryption is common and expected, e.g. common smart phones or computers over the internet. Why would a terrorist use thousands of dollars' worth of radio equipment to communicate securely when it can be better done with the phone in his pocket? Removing the 300 baud limit does not prevent any of this from happening.

Concerning security and self-monitoring by the Winlink system, all new participant call signs to the system are automatically checked for a valid license. Daily automated reports of the few that fail automated vetting are sent to our administrators to investigate. Annual license validity checks are made after the initial validation. This is done for all and not just US-licensed users against the FCC database. The Winlink system also requires password-protected call sign login to eliminate the ability to breach the system by someone trying to pirate a valid call sign. Gateway frequencies are checked often for compliance with § 97.221. Abuse of any kind is spotted within hours and warned or cut off. Messages sent and received on the Winlink system are also made visible from the master database to sysops as a means of independently monitoring content, call signs, etc. In nineteen years of operation only one case of suspected terror threat was turned over to the FBI and cleared.[9]

We believe in self-monitoring in the amateur spirit of self-regulation. We believe the sizable participating Winlink amateur community—with the help of smart automation—is doing that job better than if less knowledgeable operators participated on-air. Over 2500 active (more are inactive at any instant) and licensed sysops outnumber the ARRL's volunteer monitors plus they focus exclusively on the digital band segments we use.

Theodore Rappaport and the opponents he informs offer an emotional, layman's conjecture in their assertions that hard-to-monitor, advanced digital protocols used in the amateur radio service will encourage crime, terrorism, and are a threat to national security. They clearly do not know what monitoring routinely occurs, and are thus not qualified to judge. Rappaport himself has never held a Winlink account or ever used one to learn, or to rationally evaluate it. The same is true for almost all of the commenters Rappaport has inspired.

In his letter to the Commissioners, November 10, 2018, including email communications with Eric Burger, FCC CTO,[10] Theodore Rappaport implied that 'Winlink" was a protocol, stating, "Winlink, ARDOP, WINMOR are proprietary and undocumented." Actually, Winlink is not a mode or protocol but is a system that is agnostic to the modes and radio protocols it uses. We use both the most efficient and cost-effective radio modes and protocols to satisfy many different levels of the amateur community. There is a mode for those who wish to participate in experimenting and development of the radio art (ARDOP), those who can't afford advanced hardware modems (WINMOR, ARDOP and VARA) and those only interested in applying the highest performance to contingency communications and more demanding missions (Pactor 3, and 4 where permitted). All protocols are documented to a level allowing independent development of compatible software or firmware.[11]

All such comments and emotional predictions should be disregarded by the Commission and not allowed to color a rational decision-making process.

*ARC modes can't be monitored on-air by the amateur community at large.*

FALSE. ARQ modes can be monitored by both commercially available hardware and software.[12] Amateur use of ARQ modes dates back to the early days of AX.25 packet (circa 1980). As with any successful monitoring, this requires certain skills and knowledge of the signals, proper equipment/software, and a readable signal.

It is also worthwhile noting that in the Winlink system (and most other ARQ message forwarding systems) header information including call sign exchanges, supported forwarding protocol modes and traffic proposed for transfer (message ID and size) are not compressed and transmitted using plain text, making them easier to decode with simple unconnected monitor modems or software.[13] A terrorist or criminal certainly would not want to be identified this way. Opponents conveniently ignore this.

*Compression techniques are proprietary and equivalent to encryption.*

FALSE. ARQ protocols sometimes use data compression (e.g. FBB B1 circa 1986 and Winlink B2F circa 1999) which use publicly posted specifications. These historical and easily used compression and decompression techniques (similar to familiar computer "zip" files) are NOT encryption and can significantly improve spectrum utilization (2:1 is typical with text messages). They are routinely used by the amateur community worldwide. The Winlink system uses ONLY B2F protocol with LZH compression/ encapsulation.[14] Any other available compression techniques (public or proprietary) are not supported by Winlink and are disabled in any terminal node controllers or modems by the current software used in the Winlink system.[15]

All modern sophisticated digital transmissions can be difficult but not impossible to monitor. It is our opinion that it is normally not practical to expect a layman or the amateur community at large to monitor third-party communications via these transmissions. To expect so is also not relevant, and does not present a danger because other, much more efficient means of inspecting and monitoring are at work daily. Messages are retained for inspection as well. Nothing in the Commission's rules requires third-party monitoring, and it will become ever more difficult to monitor as digital transmission techniques become more sophisticated. See also the discussions immediately below.

*Winlink messages are not available for public review.*

FALSE. All email transiting the Winlink system is kept for 21 days after delivery and can be inspected on request by anyone with good reason. Over 2500 sysops routinely inspect their own gateway station's traffic. Administrators have access to all messages with powerful search and filtering tools. Winlink's terms and conditions remind users that there is absolutely no privacy on amateur radio, as well as the prohibitions of content and other limitations per the Commission's rules.

§ 97.305(b)(3) states that one can use entirely proprietary (but still not encrypted) communications so long as there is a record of communication. Since we make messages available for inspection as required, that it is hard to intercept a radio communication is irrelevant for both discovery and enforcement purposes. This rule is very important for the future of evolving digital modes, as they will certainly become for a layman increasingly more difficult and/or expensive to intercept over the air. Almost exclusively the radio art will advance in the digital realm, not the analog one.

*Winlink uses Pactor (SCS) proprietary compression.*

FALSE. SCS modems that run Pactor allows the native compression schemes to be switched off. Winlink software disables native compression when modems are initiated. Messages are compressed before transmission by Winlink's publicly documented B2F protocol with LZH (or LZHUF) compression. The computer code for this is in the public domain and is posted online.[16] Messages are later decompressed when received. This process shrinks most messages by up to 50% with text and more or less with other file types, reducing the time needed to transmit messages significantly. Source code for both compression and decompression methods are readily available on the Internet.[17]

Users outside of Winlink can use Pactor modems with it's proprietary compression.[18] In this case they join the ranks of other permitted systems like D*Star, Fusion, DMR (DVI voice codec) and a few others. To our knowledge none of these other systems using proprietary codecs or compression— and that are hard to intercept by a layman without proprietary equipment or software—have been challenged as a threat to national security.

*Winlink users operate out-of-band and use P4 illegally.*

Legal Pactor 4 gateway stations in Mexico, Canada, the Caribbean, and Central America are commonly mistaken for US Winlink stations. Though the large Winlink community actively self-monitors in the spirit of amateur radio, we cannot speak for these and other actors on the bands using the same protocols in systems like NTSD (Radio Relay International), HF-ALE, and others. These are also commonly mistaken for US Winlink stations.

Transient frequency or mode errors that might appear on the published, live RMS Channels list online[19] are usually the result of a sysop's typo when configuring his station. These errors are caught by other sysops or administrators and corrected within a reasonable time. Their appearance on the list for a short time does not mean that actual transmissions in violation are in progress from the affected gateway station. This is another example of participating operators' self-regulation.

Rappaport and his followers frequently cite incorrect signal widths (occupied bandwidth) for Pactor 2. It is the same as Pactor 1: 450Hz. Pactor 1, Pactor 2 and many other digital protocols, including CW and RTTY, are allowed outside the § 97.221 sub-bands, even if unattended. Although protocols using greater than 500 Hz are also allowed outside the § 97.221 sub-bands if they are attended by a control operator, they are not normally used this way. In our experience, wide-signal protocols are wasted on slow keyboard-to-keyboard, human-speed applications, and should be used only by unattended stations and client stations that communicate in an automated fashion. Rarely would one use an ARQ protocol for peer-to-peer transmissions outside the § 97.221 sub-bands, and if done as permitted, control operators are present on both sides to judge interference issues.

*Pactor signals cannot coexist with other signals.*

In a shared-frequency, un-channelized service like amateur radio some interference is inevitable (in fact, unintentional interference is common), so one should not expect clear frequencies like in other radio services. Pactor 1, 2 and 3 have co-existed with other signal types for over 16 years without "terrible" interference. Other similar protocols like Clover, have been tolerated well among other signals for longer. Interference within the § 97.221 sub-bands is certainly not like contesting, DX pileups, or other common activities that cause interference to everyone on the bands.

*With passage of NPRM 11708, new wide-band data will become commonplace and will run roughshod over existing narrowband amateurs.*

This NPRM proceeding does not change the § 97.221 sub-bands, and Winlink stations using wide-band modes will remain within their isolated spaces. Winlink stations

operating outside the § 97.221 sub-bands do so lawfully using modes of less than 500Hz occupied bandwidth. With this proposed change, nothing changes with respect to Winlink station operations or for any other similar transmissions. I**t is a technical fact that eliminating the symbol rate limit to encourage the use of better protocols will increase spectrum utilization (faster speeds with same or less signal width) and substantially reduce the potential for unintended interference.** This is demonstrated daily in every other country outside the US where the symbol rate limitation does not exist.

*Winlink was designed for secure commercial and government maritime mobile radio systems.*[20]

FALSE. This has been grossly misrepresented by Rappaport. Winlink is a wholly amateur radio development that began as the brainchild of Victor Poor (deceased), who has been honored as a pioneer of microprocessor development. Victor Poor was an avid amateur radio operator and sailor. While sailing, Poor wanted a better way to communicate with those around him. In 1985 this led him to develop the original IBM-PC DOS-based computer program, *APlink* (AMTOR-Packet Link). Poor then surrounded himself with a like-minded group of radio amateurs, and acting as architect, he and the group developed what became Winlink. Both of these systems automatically store and forward messages between amateur radio stations and have been in continuous use on the amateur bands. Though it has inspired independent commercial products and services, Winlink remains to this day written, managed, and maintained by a group of volunteer amateur radio operators and supported by a public-benefit non-profit entity.[21] It is in daily use by over 25,000 amateur operators.

**5. Needed: Control of Occupied Bandwidth**

Opponents fear incompatibility between wideband protocols in the same band space as very narrow ones. This is a justified concern. Capping maximum bandwidth for digital modes at 2.8 kHz as the ARRL proposed, is a good temporary measure until rebalancing of the digital band plans can be properly accomplished.

**6. Conclusion**

The Board of Directors of ARSFI strongly supports the removal of the 300 baud limitation on HF data. The change will improve the bands by easing congestion and improving data transfer efficiency.

For now and for expediency in the absence of regulating our bands by bandwidth, we also agree with the ARRL and see the need for a 2.8 kHz bandwidth limitation on wide bandwidth digital signals.[22] This will alleviate immediate fears about interference and be compatible with the HF emissions in use today, while still encouraging advancement of

the radio art. We understand that other changes are needed and must be incremental. This should be considered in a separate NPRM.

While opponents often take aim at Winlink's global use of Pactor 1-4, the effects of this symbol rate proposal goes beyond Pactor. It deals with all other existing protocols, and will affect those not yet developed.

While not directly related to the symbol rate question, we are very concerned about possible consequences should the Commission succumb to the national security arguments. Opponents urge the Commission to disallow from the ham bands advanced digital modes that are impractical, proprietary, or prohibitively expensive to intercept by a third party. Damaging consequences are likely, including a significant economic impact on a number of small entities in the amateur radio market. It would remove many popular products and services from the amateur bands including Winlink and D-Star, Fusion, HF-ALE, AMTOR, Clover, as well as digital voice modes that use proprietary codecs and firmware, and are hard for a layman to intercept without some level of proprietary hardware, firmware or software. Moreover, permitting hard-to-intercept modes on VHF/UHF while not on MF or HF is inconsistent to opponent arguments about national security. DHS NCC SHARES, FEMA and other state and local civil authorities and NGO critical infrastructure partners rely on licensed amateur radio operators as experts in operation and HF knowledge and as stewards of their stations. If the Commission cuts off amateurs from hard-to-monitor data protocols, you starve the federal government from its operating resources for DHS NCC SHARES, and other programs at various levels of government. This directly opposes two important purposes of the amateur radio service: to expand the existing reservoir of trained operators, and to enhance the value of the service, particularly with respect to emergency communications. Reply comments by John O'Conner, Director, National Coordinating Center for Communications, DHS, details the importance of amateur radio in such government service.[23] Heeding these arguments would set back amateur radio to 1980 in its mix of available modes and technologies. Digital activities are the growth area in amateur radio and should not be impeded. And last, it would directly offend the Commission's own stated purposes of the Amateur Radio Service.[24]

**Appendix 1** — *The Board of Directors of the Amateur Radio Safety Foundation, Inc.*

All Directors of the Amateur Radio Safety Foundation, Inc. are members of the *Winlink Development Team*, who have created and maintain the Winlink system and Winlink software.

**Loring Kutchins** is licensee of amateur radio station W3QA, first licensed in 1965. Retired from a career in analytical instrumentation and digital data handling, as a software author, and as an entrepreneur of successful computer- and laboratory-oriented startups. Product Specialist and Manager at Bausch & Lomb Applied Research Laboratories for the Inductively Coupled Plasma Quantometer. Vice President, Dynamic Solutions, Inc. Vice President, Millipore Corporation Dynamic Solutions Division. Co-

founder and President, Business Partnerships, Inc. Founder and President, Listing Systems, Inc. President of the Amateur Radio Safety Foundation, Inc. Member of the Board of several holding companies, community organizations and nonprofits. Volunteer licensing Examiner. Active as a North Carolina AUXCOMM volunteer for State and local emergency communications and for DHS NCC SHARES.

**Gerald F. (Rick) Muething, Jr. PE**, KN6KB, was first licensed in 1962 and holds a BSEE (Honors) from University of Cincinnati and a MSEE (High Honors) from Northeastern University with specialties of Computers and Communications. Mr. Muething is the current Secretary/Treasurer and one of the founders of the Amateur Radio Safety Foundation Inc. He has worked for RL Drake Co, Raytheon, Honeywell, Itek, and founded two successful silicon valley startups. Mr. Muething is author of amateur digital modes SCAMP, WINMOR, and ARDOP and has presented numerous papers on Amateur Radio Protocol development.

**Tom Lafleur,** KA6lQA, was member of the technical staff at U.S. Navy Electronics Laboratory (NELC), doing radio propagation and solar-geophysical research. Founder of GNAT computer, an early microcomputer company. Director of R&D at Digital Research, an early microcomputer operating system company (CP/M). VP Engineering at M/A Com-Linkabit, developing advanced satellite communication systems and forward error correcting modem. VP Engineering, QUALCOMM. Development team member of OmniTracks mobile communication system. Senior member of the engineering and management team for the development for the Globalstar satellite network. Senior member, engineering council, and General Manager of a QUALCOMM European joint venture. Co-founder and CTO of Rhythm's Net Connection an early DLS firm. Co-founder, CTO and Member of the Board of DriveCam (now LYTX, Inc.). Member of the Board of Directors of several startups and nonprofits.

**Steve Waterman**, K4CJX, has held an amateur radio license since 1955. Retired from a career as VP of Telco Research Corporation, an independent telecommunications software and network design business, and VP of New York, New England Telephone Exchange (NYNEX), a Regional Bell Operating Company. Currently, an active volunteer for civil authorities and their critical infrastructure partners, including: *DHS NCC SHARES*, SHARES Data Working Group, DHS NCC SHARES Winlink radio email system's administrator. *FEMA* Region IV Regional Communications Coordinating Working Group (RECCWG), Chairman for their Auxiliary Communications Working Group Committee. Tennessee Emergency Management Agency (*TEMA COMU). TN Homeland Security District 5 Communications Committee. Williamson County, TN, EMA Reserves. Assistant Director. ARRL Delta Division*. *Amateur Radio Safety Foundation, (ARSFI)* Immediate past president. He currently spends his time supporting Winlink, worldwide, both on the Amateur spectrum, and for government agencies at all levels.

**Lee Inman**, amateur radio license K0QED since 2002, holds a Bachelor of Science degree in Electrical Engineering. Retired from the US Air Force in 1991. During his final years in the Air Force Lee taught physics, chemistry and computer science courses at the US Air Force Academy. His second career centered around software engineering and telephony systems research and development. Lee is a member of the Board of

Directors for the Amateur Radio Safety Foundation, Inc. and is an active member of the Winlink development and management teams.

**Tom Whiteside** is licensee of amateur radio station N5TW, first licensed in 1995. He retired as an IBM Development Vice President responsible for IBM's Power and PowerPC Microprocessor Development. Previously, he was a Vice President at Silicon Graphics where he was President of their MIPS Technology Microprocessor subsidiary. He has served in various roles in the ARRL's Amateur Radio Emergency Service (ARES) including as the Section Emergency Coordinator of the South Texas Section. He is currently a board member of the Amateur Radio Safety Foundation, Inc.

**Phil Sherrod** is licensed as Extra Class W4PHS. Phil is a Volunteer Examiner, and teaches the General Class and the math portion of the Extra Class licensing classes. BA in physics and math from Vanderbilt University. Chief of Software and Programming at Vanderbilt University Computer Center. Phil started his own software company in 1975, developing two multi-user operating systems (TSX-Plus and TSX-32), Internet service provider software, and a very popular Usenet newsgroup reader. Phil developed the DTREG (www.dtreg.com) predictive modeling software that builds statistical-mathematical models using neural networks, support vector machines, polynomial networks, and other types of models. DTREG is in use at more than 100 government research labs, universities, and commercial companies and other programs are in use at over 100,000 sites. For Winlink Phil developed the "hybrid" network that forwards messages via an HF MESH network if the Internet is not available. Phil is active in DHS NCC SHARES, the Tennessee Emergency Management Agency Communication Unit, and the Williamson County, Tennessee Reserve Team.

**Scott K. Miller**, K6SKM, is a successful entrepreneur and IT engineer with over 35 years of experience in the high-tech industry. While specializing in computer networking he is also a respected engineer in cybersecurity, datacenter design, and IT systems architecture. Past employers include M/A-COM, QUALCOMM, Cisco, Sempra, SPAWAR, Department of Defense, BT Global Services, and a number of start-up companies. He is currently President and owner of American Radio in San Diego, CA which provides LMR and IT solutions to government, utilities, and commercial entities. He currently serves as a Director on the Amateur Radio Safety Foundation, Inc. Board of Directors.

**Afternotes**

1. https://arsfi.org. A profile of the nonprofit entity is available at https://www.guidestar.org/profile/20-5586920

2. Today, HF data communications usually happens using audio tone modulation and transmitting audio using suppressed-carrier single sideband equipment designed for voice signals. These techniques have evolved to where information may be contained within ham transmitter passband filter widths of up to 2.8 kHz even with symbol rates

well above the current 300 symbols/second limitation.

Here is a more thorough explanation the benefits and challenges of single-carrier high baud rate modulation. First a brief review of some important communication basics.

A) Channel Capacity. A brilliant Bell Labs Engineer (Claude Shannon) came up with a (now famous) equation that related the true channel capacity of a given channel to the Signal to Noise in the channel. This allows the calculation of the maximum possible channel capacity (bits/sec per Hz of bandwidth) that can be sent. While you can never actually reach this limit with modern modulation and error coding techniques, you can get quite close (within a few tenths of a dB). In ham radio you can approach this limit on VHF/UHF/Microwave but are usually at least a few dB less on HF due to disturbed propagation on typical channels like selective fading, static crashes, etc).

B) Shannon's equation is based on a few simple parameters:

1) The Noise level in the channel bandwidth usually referred to No. The math works well for simple white (Gaussian) noise but is not easy for other noise or fading (aurora, static crashes, etc). P4 and some other high symbol rate modes do use some "sounding" of the channel to try and correct for some of this.

2) The transmitted Energy/bit in the signal usually referred to as Eb. This is calculated from three important parameters:

a) The Peak power available from the transmitter. (e.g. 100 watt PEP)

b) The Peak to average power ratio or PAPR (How "pulsy" is the modulating signal). A pure sine wave has a low PAPR of 2.0. Most digital signals have PAPRs from 3-10. Lower is better because it allows a given transmitter (e.g. a 100 W PEP) to provide more energy/per bit.

c) The modulation scheme (PSK, QAM, FSK, number of OFDM carriers, and symbol rate), which determines how bits are modulated. The more bits per "symbol" the lower the Energy per bit (assuming using the same transmitter). The faster the symbol rate the lower the Energy per bit. The more carriers the lower the energy per bit (assuming again the same transmitter)

All the above is very well documented (including Shannon's original 1948 paper). It is covered in the introduction to advanced undergraduate- or graduate-level communications courses. See http://math.harvard.edu/~cfm/home/text/others/shannon/entropy/entropy.pdf.

C) Multi-carrier modulation (often called OFDM for Orthogonal Frequency Diversity Modulation). This well understood and well-used approach breaks the digital data in to "parallel streams" and modulates multiple carriers one for each digital stream. This has some nice advantages but also some trade-offs. OFDM is used heavily (HF UHF/VHF/Microwave) because it can send more data with lower symbol rates making them easier

to encode and decode especially in the presence of white noise or other interference (e.g. multipath or aurora). Good examples of HF modes using OFDM are Pactor 2, 3, MFSK, WINMOR, ARDOP, VARA and many others. The lower symbol rate (per carrier) allows easier decoding in channels with noise and distortion such as multipath.

BUT... there is a trade-off:

Multiple carriers generate higher PAPR (the combined waveform is more "pulsy"), so this limits the total Energy available from the transmitter (which is almost always peak power limited). The net Energy from the transmitter (which must be spread over all the bits being sent) is lower than it would be with a single carrier (which could use all the available power to the PEP rating of the transmitter). It is this total Energy per bit / Noise or Eb/No that must abide by the "Shannon Limit". The bottom line is a single carrier can better use the available transmitter power BUT it is harder to decode without powerful DSP and error correction coding. This means that complex and powerful computations must be applied to the signal before transmission, the channel must be modeled and compensated for, and the received signal decoded with more complex DSP and advance error correction decoding. Pactor 4 and some of the more advanced schemes of STANAG and Mil Std 188 use these techniques and this allows sending more data per second for a specific bandwidth given the available transmitter power. Unfortunately for US amateurs, these improved throughput (bits/sec/Hz) modes usually exceed the current (circa 1985) max symbol rate (baud) limit of 300 on amateur bands.

Important Note: The symbol rate does affect bandwidth in a similar way as multiple carriers do but multiple carriers (with their significantly higher PAPR) reduces the total energy available from a given transmitter and hence have a lower Eb/No. and therefore must have a lower Shannon capacity (and therefore less theoretical throughput).

Today's advanced DSP and error coding techniques and low cost computers make these more complex and higher performance modes possible and have been widely used in both HF and VHF-Microwave applications.

3. See 47 C.F.R. § 97.1(b)

4. See WT Docket No. 16-239 NPRM RM-11708 at 6. Compared to OFDM-type modems (Pactor 3), serial modems like Pactor 4 provide more throughput under adverse HF signal conditions using identical power and bandwidth, and lower crest factor, and produce lower IMD3 spurious transmissions in case of non-linear class A/B or B power amplifiers. (See Hans-Peter Helfert email in reply to Scot Stone regarding Pactor 3 and 4, filed November 7, 2018.),
see also https://www.scs.ptc.com/en/PACTOR-4.html

5. Mil-Std-188-110B Appendix C. http://hflink.com/standards/MIL_STD_188_110B.pdf

Commercial HF modems including MilStd 188/STANAG
General Reference: http://www.rfwireless-world.com/Vendors/HF-radio-modem.html
SCD Pactor 4 DR-7400, DR-7800 http://www.farallon.us

Mil Std 188 (STANAG) modems:
https://www.codanradio.com/product/3212-7200-bps/
https://www.rapidm.com/
https://www.rockwellcollins.com/Products-and-Services/
http://www.milspec.ca/modems/rf-5710.html
Software implementation of Mil Std 188-110A:
https://www.tapr.org/pdf/DCC1999-FederalStandard1052Modem-N4HY.pdf

6. The ITU began a project with the help of Mexico's FMRE in 2017 to strengthen emergency telecommunications throughout the Americas. Funded by the ITU and located at government or public institutional sites, in 2018 Winlink gateway stations in Costa Rica, the Dominican Republic, Guatemala, and Nicaragua came online. https://winlink.org/sites/default/files/itu_continues_strengthening_emergency_telecommunications_in_the_americas-converted.pdf

7. Special Temporary Authority permitting Pactor 4 use was granted for the period after Hurricane Lane in Hawaii, and Hurricane Florence in the Carolinas: http://www.arrl.org/news/fcc-grants-temporary-waiver-for-hurricane-lane-relief-efforts, http://www.arrl.org/news/fcc-grants-arrl-temporary-waiver-request-to-permit-pactor-4-use-in-hurricane-relief

8. New SCS Pactor modems that support Pactor 4 cost between USD $1498 and over $2000. Used units on the market are exceedingly rare, and when available rival the costs of new amateur radio transceivers. They are justified and used mainly by those in the amateur radio community who are serious about high performance, have a demanding mission, or participate in government service with DHS NCC SHARES, MARS, local emergency management, or similar programs. They are also frequently purchased for government-owned stations that are operated by trained amateur licensees.

9. December 27, 2013, we reported to the FBI a message posted on a popular internet email group where the writer claimed to have certain knowledge of suspicious terrorist activity using Winlink. The FBI accepted the evidence, investigated and later reported back that the writer admitted his claims were without merit. The second-hand evidence he presented was dismissed as well. Copies of correspondence are available for inspection by the FCC.

10. Theodore Rappaport, Notice of ex parte, email communications with FCC CTO Dr. Eric Burger from November 8-11, 2018.

11. ARDOP documentation: https://winlink.org/content/ardop_overview
ARDOP specifications and detailed documentation is at https://ardop.groups.io/g/developers/files and https://winlink.org/content/ardop_dicumentation
WINMOR documentation: https://winlink.org/content/winmor_documentation
VARA documentation: https://rosmodem.wordpress.com

Pactor 2, 3, 4 documentation and information on advanced data compression: https://www.scs-ptc.com/en/Downloads.html

12. There are several sources of commercial software that allow third-party interception of communications of Pactor 3 and Pactor 4 communications:
http://www.hoka.com/products/code300-32-options/pactor-iii-hoka.html
http://www.wavecom.ch/content/ext/DecoderOnlineHelp/default.html#!worddocuments/pactoriii.htm
https://saab.com/globalassets/comercial/land/istar/medav-radio-monitoring/demodulators-and-decoders--vd-technology.pdf

All SCS Pactor modems also have an internal command, MONitor, that allows the modem to be used with appropriate software to demodulate and print received characters in clear text ARC mode. See page 69 of the manual at https://www.p4dragon.com/download/SCS_Manual_PTC-IIIusb_4.1.pdf

The use of these products for this purpose also requires knowledge of the protocol used and encapsulated message and it's treatment, and the development skill to apply them successfully.

13. ID's call signs, forwarding protocol, and message proposals with message ID's are always sent uncompressed in plain text on most message systems and can easily be monitored with amateur modems (both hardware and DSP software with an appropriate sound card interface) by placing them in monitor or FEC unconnected mode and setting the receiver to the correct frequency. Some software and hardware sources:
http://www.w1hkj.com/index.html
http://www.hamuniverse.com/hfdigitalmodessoftware.html
https://www.dxsoft.com/en/products/truetty/
https://timewave.com/product-category/amateur-radio/
https://www.scs-ptc.com/en/Home.htm
http://www.cruisersforum.com/forums/f13/inexpensive-pactor-1-text-only-email-from-the-high-seas-12055.html
http://www.hoka.com/products/
http://www.tigertronics.com/sl_soft.htm

Example: A Pactor 3 connection signal is monitored using a SCS PTC-II modem, amateur HF transceiver, antenna, computer, and interconnecting cables. Running the free Airmail client software configured for the PTC-II modem and radio, start a terminal window. The modem should be initiated and success displayed in the terminal. From the 'MODE' menu select the following items: Pactor 3, Monitor mode, and Keyboard mode. Tune the signal carefully and the modem's display and Airmail terminal window will print callsigns of both connected stations and the connection negotiation information prior to transferring compressed messages via the ARC mode. Clear, undistorted reception of both station's signals is required.

14. FBB B1 specifications: http://www.f6fbb.org/protocole.html#version1 and Winlink B2F specifications, including information on compression used in Winlink: https://

www.winlink.org/B2F
This is the same actual public LZW compression algorithm as FBB B1 has used since the 80s in packet bulletin boards.

15. https://winlink.org/B2F

16. https://winlink.org/B2F

17. https://github.com/arsfi, https://github.com/tyll/tinyos-2.x-contrib/blob/master/eon/eon/src/util/lzss-c/lzhuf.c, or https://winlink.org/B2F

18. https://www.p4dragon.com/download/PACTOR_Advanced_Data_Compression.pdf

19. A current public list and world map of Winlink Radio Mail Server stations (also known as 'gateways') is at: https://winlink.org/RMSChannels

20. Theodore Rappaport, Ex parte notice, letter to the Commissioners of November 10, 2018. He states, "…Pactor and Winlink, ARDOP, Winmor, STANAG, and other HF transmission schemes that use controlling software (e.g. Winlink, which was designed for secure commercial and government maritime mobile radio systems)…"

21. A short history of the Winlink project is published online at https://winlink.org/content/winlink_history

22. See Petition at 11, and see WT Docket No. 16-239 NPRM RM-11708 at 6.

23. John O'Connor, Reply Comments, PS Docket 17-344. https://ecfsapi.fcc.gov/file/102221867611691/DHS%20NCC%20Reply%20Comments%20FCC%20PS%20Docket%2017-344%202017%20Hurricane%20Season.pdf

24. See 47 C.F.R. § 97.1(a), (b), and (d)