Before the Federal Communications Commission
Washington DC 20554

In the Matter of:

Amendment of Part 97 of the Commission's Amateur Radio Service Rules to Reduce Interference and Add Transparency to Digital Data Communications; to Permit Greater Flexibility in Data Communications

RM-11831; WT Docket 16-239

Reply Comments of Philip R Karn, Jr KA9Q, President, Amateur Radio Digital Communications Inc (ARDC)

This is a reply in opposition to comments filed in support of New York University (NYU) Petition for Declaratory Ruling Regarding Amateur Radio Communications, WT Docket No

16-239 et al, by Nelson Sollenberger, KA2C.[1] They supplement our earlier comments in reply to those of Rappaport and NYU.

Background

I write these comments both individually and as President of Amateur Radio Digital Communications, Inc (ARDC), introduced in my previous comments as a nonprofit foundation dedicated to furthering the educational potential of amateur radio through the development of digital communications technology.

Although I do not know him personally, Mr. Sullenberger and I seem to be roughly the same age with similar backgrounds. I also began as a radio amateur in high school, earned money during college as a broadcast engineer, and spent my career in professional communications R&D, first for Bell Labs, then for Bell Communications Research (Bellcore) and finally for Qualcomm Inc, from which I retired in 2011 as a Vice President-Technology. One apparent difference is that I specialized in systems engineering and in protocols above the physical layer from the link through transport levels. But Qualcomm gave me an excellent education in digital radio modulation, error correction, spread spectrum, power control and other advanced techniques that are now standard in the cellular industry. As an aside, I invented the RTS/CTS method he mentions on page 11 that became part of the WiFi standard. I originally conceived it for amateur packet radio.

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[1] https://ecfsapi.fcc.gov/file/113087596430/FCC%20letter%2016-239%20Dec%202019-2.pdf

Completeness of Air Interface Documentation

Mr Sullenberger goes to elaborate lengths to show that the later Pactor modems are not publicly documented in sufficient detail to permit independent interoperable implementation. This is both true and *completely irrelevant* for this proceeding, as shown by the fact that the Commission explicitly accepts the use of G-TOR and CLOVER, neither of which is fully documented either. As explained in our earlier comments, we must carefully distinguish between what we'd all *like* to have (completely open and non-proprietary air interface specifications with multiple free implementations) and what's actually necessary to monitor communications (at least one publicly available, albeit proprietary, hardware or software product with a "monitor mode").

We must repeat our earlier point that an unnecessarily strict legal requirement for full public disclosure of an air interface would sweep well beyond Pactor. For example it would outlaw all three digital voice systems currently used on the amateur bands: D*Star, Fusion and DMR. All three use voice compression (codecs) proprietary to Digital Voice Systems Inc (DVSI). They're only available as hardware produced by DVSI, and are not publicly documented. As long as SCS, the owner of Pactor, produces a hardware modem with a "monitor mode" (and they do), there can be no proper legal distinction between it and a DVSI codec. Ban Pactor for lack of full documentation and you necessarily also ban D*Star, Fusion and DMR.

We reiterate that the best answer to proprietary air interfaces on the amateur bands is to develop superior open-source alternatives and persuade amateurs to use them. Supporting such efforts is one of ARDC's primary goals. A legal "fix" is simply not required.

Narrowband/Wideband Compatibility

Mr Sullenberger complains that a "wideband" mode like Pactor can resist narrowband interference, but a narrowband signal cannot resist interference from a wideband signal. This is not completely true: only that fraction of the wideband signal power falling within the bandwidth of the narrowband signal will interfere with it, so the narrowband signal also enjoys a degree of process gain. Furthermore, wideband signals need not have uniform power spectral density; for example, it is common practice with OFDM to use a "water filling" algorithm to allocate less power to sub-channels with poorer signal-to-noise-and-interference ratios. This automatically reduces interference to any narrowband signals. Since wideband signals can be more tolerant of channel impairments such as selective fading, they can be more power efficient, thus further reducing interference to co-channel narrowband signals. (Automatic power control by *all* modes would go a long way to reduce interference on the amateur bands but make monitoring more difficult. This is just one example of how spectrum efficiency[2] and "monitorability" are in fundamental conflict.)

But to the extent that Mr Sollenberger's statement is partly true, it simply underscores the inherent disadvantages of narrow signals. The rules should recognize the fundamental physics and mathematics of communications and allow radio amateurs to strive toward those theoretical limits without being hampered by unnecessary regulations.

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[2] "Spectrum efficiency" is *not* defined merely in terms of bits per second per hertz of bandwidth. It must also account for power efficiency, i.e., resistance to noise and interference, as this also reduces interference to others. The famous Shannon-Hartley Law shows that there is a fundamental tradeoff between occupied bandwidth and power efficiency. Real-world practice bears this out.

I could have a fine academic debate with Mr Sollenberger on the exact semantics of "spread spectrum". For example, I would argue that declaring "spread" any signal occupying more than, say, 2 Hz of bandwidth per bit/s of data rate is much too simplistic. Adding forward error correction makes a signal wider, but this is not usually considered "spreading". Nor is it spreading to use modest additional bandwidth to facilitate symbol timing or to compensate for common channel impairments such as multipath,[3] even with techniques like chirping. The true spread spectrum systems with which I am familiar[4] all have bandwidth expansion ratios of 100:1 (20 dB) or more, not the relatively small ratios in Pactor at its lower data rates.

But in the real world, contrary to Mr Sollenberger's claim, a signal no wider than standard SSB voice can hardly qualify as "spread spectrum" in any meaningful way regardless of its structure. The "true" information rate in human speech is quite low,[5] and SSB encodes it in a remarkably power- and bandwidth-inefficient way by modern digital standards.[6] So is SSB a form of "spread spectrum" that should also be banned from the HF amateur bands?

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[3] Multipath propagation by the ionosphere on HF is ubiquitous. It causes "frequency selective fading" that can completely take out a narrowband signal for a time. Retransmission (ARQ) and/or strong forward error correction (FEC) can overcome this with time diversity, though in practice many amateurs using narrowband schemes simply increase power. HF selective fade nulls are usually much narrower than 2.8 kHz, so the use of that bandwidth additionally provides significant "frequency diversity" for FEC to help overcome selective fades without increasing power.

[4] Qualcomm CDMA digital cellular and the Global Positioning System, among others.

[5] A typical English speaker talks at 125 words/minute. At an average of 5 letters per word, that's 10.4 letters per second or less than 100 bits/sec even without (dynamic) text compression, which would further cut the data rate by a factor of 2-4 or more. That's slower than even the slowest Pactor 4 data rate that Mr Sollenberger complains about.

[6] This is just one reason why modern digital communication schemes like Pactor are vastly superior in relaying "record traffic", e.g., formal emergency messages, than traditional amateur methods using voice or Morse Code.

Dynamic Compression

Mr Sollenberger presents another elaborate argument to show that third parties who don't benefit from the error controls enjoyed by the intended receiver will see errors in compressed data streams that render the rest of the stream unreadable.[7] While largely correct, we have never denied this either! We have only pointed out that this is just one of many examples of the absolutely fundamental tension between spectrum efficiency and monitorability.

Mr Sollenberger makes an interesting concession along these lines:

> "Gibby explains that adaptive compression and ARQ have been used on amateur radio links for many years. So why is there now concern? But early implementations of adaptive compression and ARQ did not include adaptive modulation and coding or used very limited forms or [sic] it."

Indeed, Mr. Sollenberger then correctly shows that adaptive coding and modulation (ACM) complicates third party monitoring when dynamic compression is in use. We have never denied this either; it is yet another example of the inherent tradeoff between spectrum efficiency and monitorability. But why does he single out dynamic compression when, as he admits, there was no problem with it until the advent of ACM, which he apparently supports?

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[7] The unreadability extends only to the end of the current compression "session". For practical reasons, applications of dynamic compression sometimes periodically reset the compression algorithm state, e.g., at the end of a message, a series of messages or a transmission. After a reset, decompression can resume at a 3rd party monitoring station regardless of any earlier channel errors. However, a reset does decrease compression efficiency by an amount depending on the algorithm, data statistics and the frequency of reset.

Mr. Sollenberger asserts that static (rather than dynamic) compression will solve the problem. But not only is static compression *significantly* less efficient on many real-world data files,[8] Sollenberger is simply *wrong* in his assertion! ACM, which he seems to like, will make it much more difficult for third parties to monitor *any* kind of data, compressed or not. The fundamental feature of ACM is the fine-tuning of the signal so that it is just barely receivable by the intended station. It closely resembles automatic power control (APC) in this respect, whether or not APC is explicitly performed.[9] Stations trying to monitor a well-designed adaptive coding and modulation scheme may well receive *nothing at all*[10] unless their channel to the transmitter is at least as good as between the transmitter and intended receiver. This is yet another example of the efficiency/monitorability tradeoff, which extends far beyond the use of dynamic data compression.

Alternatives for Off-Air Monitoring

So how can more spectrum-efficient methods be monitored without impairing the ability of amateurs to use them? ARFSI has already implemented one such scheme: an Internet site open to the public where traffic can be inspected. This is by far the easiest and most effective way to meet the spirit of the rules, especially with a network as large and complex as Winlink with radio

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[8] Mr Sollenberger seems unaware that modern dynamic compression algorithms monitor their own performance, and will "get out of the way" (not attempt to compress) if it doesn't produce any benefit (e.g., if the data is already compressed). This permits them to be simply left on all the time.

[9] Both ACM and APC vary the transmitted energy per user data bit to keep the received energy per bit at the intended receiver just above the required threshold. APC does this by varying the transmitter power while keeping the data rate constant. ACM varies the user data rate while keeping the transmitter power constant. The occupied bandwidth is often also kept constant, with more bandwidth-efficient techniques at higher data rates. At lower rates, more power-efficient techniques are used that reduce the receiver bit energy threshold. Pactor is an excellent example. ACM and APC are sometimes combined.

[10] Efficient coding and modulation exhibits a "cliff" effect, as predicted by information theory. Signals just above the threshold produce perfect copy and signals below the threshold produce nothing at all. The difference can be as small as 1 decibel or even less.

links all over the world. But for some reason it does not satisfy the proponents of the NYU/ Rappaport petition. Indeed, they keep moving their goalposts to exclude every concession that has been made to them.

But it is worth exploring an option for off-air monitoring that Sollenberger et al does not consider. This is the already extensive network of general purpose software defined radios established by individual amateurs and publicly available over the Internet. For example, the website http://www.sdr.hu currently lists 491 receivers all over the world, most on the HF bands.[11] Many amateurs find them extremely useful in receiving signals that they cannot receive directly due to bad propagation, high local noise levels or simply a lack of appropriate equipment (especially antennas). By selecting a suitable receiver close to a transmitting station, that station can be monitored regardless of its transmission format, as long as it fits within the receiver bandwidth (i.e., the 2.8 kHz occupied by SSB).

Summary and Conclusions

Although Mr Sollenberger clearly has impressive technical credentials, his analyses miss the forest for the trees. Although we would all prefer that every air interface used on the amateur bands be completely non-proprietary with multiple open-source implementations, that is not necessary for signal monitoring. All that is required is that monitoring hardware and/or software, proprietary or not, be available on the market. This is the case for Winlink/Pactor. A legal requirement for fully open documentation would sweep far more broadly than Pactor and ban

[11] I run two web-connected receivers myself in San Diego, California.

other digital formats used on the ham bands, e.g., D*Star, Fusion and DMR, where there have been no complaints about the ability to monitor.

We have never claimed that a sophisticated communication scheme like Winlink/Pactor is easy to monitor. Indeed we have stressed the inherent conflict between “monitorability” and spectral efficiency that will apply to other advanced amateur communication schemes as they are developed. Winlink/Pactor just happens to be the first to attract controversy, but it is ARDC’s mission to encourage the development of other advanced digital communication systems.

The Commission has always wisely encouraged its licensees, including amateurs, to pursue spectral efficiency, and changing the amateur rules to make “monitorability” a paramount requirement would necessarily thwart this goal. The existing rule that defines encryption as an “intent to obscure meaning” already addresses the issue. It has withstood the test of time as technology develops.

Nor can the developers of efficient technologies such Winlink/Pactor be responsible for users who mistake its sophistication for secrecy mechanisms. This misconception is so common among computer users as a whole that computer security professionals (such as myself) have a mantra: **Security through obscurity does not work!** Effectively obscuring the meaning of a communication is actually very hard. It’s much more than just throwing a cipher like AES into your system. Very careful attention must be paid to the subtle details of key management, especially side channels and clever man-in-the-middle attacks. It is because I am so familiar in my professional work with how hard it is to do encryption properly that I take great exception to

Rappaport's misleading and inflammatory phrase "effectively encrypted". Something is either encrypted or it's not, and Winlink/Pactor is not encrypted.

We again respectfully urge the Commission to dismiss RM-11831 and the Rappaport/NYU petition and reaffirm the "intent to obscure meaning" provision in the current amateur rules.

Respectfully submitted,

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