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Marlene H. Dortch
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Subject:
RM-11831 (NYU Petition for Declaratory Ruling)
WT Docket No. 16-239

Dear Ms Dortch,

This letter is being filed to support the RM-11831 Petition for Declaratory Ruling by NYU. I respectfully ask the Commission to adopt the Petition for Declaratory Ruling by NYU, and address the issues of transparency and openness regarding digital modes of transmission on the amateur radio bands as outlined in that filing. This letter also addresses related issues of spectrum allocation relevant to narrowband and wideband HF amateur radio transmissions that create compatibility challenges. I respectfully ask the commission to reject WT Docket No. 16-239. Findings on key technical issues are included in this letter showing why these steps are needed.

Amateur radio has been important to me for almost 50 years and became my ticket to a rewarding career and a great hobby as it has for many. I strongly believe it continues to have much to offer to students as well as others, and my concern here is to strengthen the future of amateur radio. My first call was WN3PKU as a novice at age 13 in 1970. About 8 months later I passed the Advanced Class exams, and later as a high school senior I passed the Extra Class exams as well as the First Class Radiotelephone exams. That enabled me to work at radio and TV stations and pay for much of my college education in Electrical Engineering. That would not have happened without amateur radio. My background in amateur radio was important to obtaining a position at AT&T Bell Labs in the Cellular Engineering Systems Group in January 1979, almost 5 years before the very first commercial cellular systems went on the air in December of 1983. I worked in wireless R&D for over 35 years and was honored with IEEE Fellow, AT&T Fellow and Broadcom Fellow awards and the opportunity to perform research and product development on cellular technology from the first generation through 2G, 3G & 4G. Many of the fundamental technologies used in 3G & 4G cellular modems are similar to the technologies used in wideband digital HF modems such as adaptive modulation and coding, channel

equalization using single carrier or OFDM processes, source compression, and DSP capabilities using general purpose architecture, FPGA's or custom data-paths. Of course, cellular modems now run at rates over 1 Gbps and use many additional technologies such as MIMO, strong encryption, advanced power management capabilities, and include extremely complex software protocol stacks. It is good to see connections between some of the most advanced wireless capabilities on earth such as cellular modems and amateur radio with wideband digital modems. Amateur Radio continues to evolve and perhaps faster than ever before. The intent of supporting openness and transparency, even with complex digital technology, is to make sure the hobby is accessible to everyone and that it serves the public well including providing a valuable path for students in STEM careers.

The ARRL Eastern Massachusetts Group says this on their website: "…Winlink transmissions are nearly impossible to intercept,…" [1] But the ARSFI, SCS, Gordon L. Gibby, John Huggins, and others claim that Winlink and PACTOR are completely open and documented in the public domain. Here is an expanded quote: "All communication is error corrected, and heavily compressed, allowing fairly fast file transmission. A side effect of this compression is that Winlink transmissions are nearly impossible to intercept, exceeding HIPA (Health Insurance Portability and Accountability Act of 1996) standards." Other organizations make similar statements. Large groups of amateur radio operators involved in packet data communications and emergency communications have clearly believed for a number of years, that Winlink transmissions using PACTOR modems are almost impossible to intercept. If so, this would fall short of openness and transparency.

HF packet data modem technology advances the state of the art substantially and using such technology for emergency purposes is a very valuable capability. However, such capabilities still need to provide technology openness and transparency. They also need to use spectrum in a compatible way with other technologies. I do not believe that there needs to be a conflict between openness and transparency for amateur radio and emergency communications. These issues can be solved.

In this letter, it will be shown that there are multiple layers of obstacles to reading transmissions by PACTOR 2, 3 & 4 modems by 3rd parties except to use modems supplied only by SCS, and that there are further obstacles to reading messages using Winlink with PACTOR 2, 3 & 4, WINMOR, ARDOP and VARA modems that are not part of a point-to-point transmission using these technologies. Any one of these obstacles is a severe problem for monitoring these transmissions by other amateur radio operators. Together they form a daunting barrier. Together they explain why the ARRL Eastern Massachusetts Group and many others believe "that Winlink transmissions are nearly impossible to intercept." Unfortunately, they are not wrong. I would prefer that they were wrong, but it is not the case.

SCS claims in their Oct 22, 2019[2] dated filing that:

"PACTOR 3 and PACTOR 4 are sufficiently documented within the scope of the legal requirements."

Gordon L Gibby states the following in his Oct 31, 2019 dated filing[3] on page 12:

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[1] https://ema.arrl.org/ares/winlink-2000/

[2] https://ecfsapi.fcc.gov/file/1105087415643/SCS_letter_ScotStone_FCC_22102019_1%20(1)%5B523%5D.pdf

“ARRL: "This is a one-stop Web site for technical characteristics called for in FCC rules § 97.309(a)(4), which reads:(4) An amateur station transmitting a RTTY or data emission using a digital code specified in this paragraph may use any technique whose technical characteristics have been documented publicly, such as CLOVER, G-TOR, or PacTOR, for the purpose of facilitating communications. Documentation should be adequate to (a) recognize the technique or protocol when observed on the air, (b) determine call signs of stations in communication and read the content of the transmissions. " The list includes 3 versions of PACTOR as well as WINMOR and many other techniques. http://www.arrl.org/technical-characteristics Apparently Rappaport et al., find the ARRL's documentation insufficient.”

Unfortunately both of these statements are falsified by an examination of the provided documents. It is noted that reference 3 uses inaccurate text for FCC § 97.309(a)(4). Here is the correct text:[4]

“(4) An amateur station transmitting a RTTY or data emission using a digital code specified in this paragraph may use any technique whose technical characteristics have been documented publicly, such as CLOVER, G-TOR, or PacTOR, for the purpose of facilitating communications.”

It will be shown that the provided information falls far short of “documented publicly” that is required. The missing information combined with the complexity of the Pactor-2, 3 and 4 modems renders information transmitted by Winlink using PACTOR-2, 3 & 4 modems unreadable by even those most highly skilled in the art unless one obtains a hardware or software modem from SCS.

Russell Lawrence credits the following to Loring A. Kutchins, ARSFI President: [5]

“The facts are these: There is no such thing as ‘effective encryption’ and dynamic compression is not encryption, yet the opposition ignores this and continues to spread false information otherwise. State-of-the-art data compression is employed in many digital signals to optimize spectral efficiency. Further, Winlink messages sent over the air can be more conveniently read by any licensed amateur for the purpose of self-policing using our online ‘Message Viewer’ linked from the main page of winlink.org*. There is no* 'intent to obscure meaning'*. Messages can be easily read for full meaning both on-air and on-line. Making all this moot is this: Over-the-air monitoring of Winlink PACTOR 1-3 signals by third party eavesdroppers have been demonstrated and documented using free software available for download from* https://p4dragon.com/en/Downloads.html *See the video at* http://www.philsherrod.com/Winlink/Winlink_monitoring2.mp4 *for proof. On-air copying of other modes only requires adequate software that can be developed using publicly documented technical details of the mode in question, as was done for the PACTOR software mentioned above.*

The petition should be dismissed because there is no need for the ruling demonstrated by the petitioners. The current rules are adequate to enable self-policing of digital modes on the amateur bands.”

Loring A. Kutchins understands that digital modes for HF must be publicly documented sufficiently to allow:

“On-air copying of other modes only requires adequate software that can be developed using publicly documented technical details of the mode in question, as was done for the PACTOR software mentioned above.”

The public documentation is available for PACTOR or PACTOR-1. It is not for PACTOR-2, 3 & 4 in sufficient detail to satisfy Loring A. Kutchins’ statement. Perhaps the statement can be clarified for the meaning of “PACTOR”.

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[3] https://ecfsapi.fcc.gov/file/1031895715302/InconvenientObservations.pdf
[4] https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=0c987e01edd9b2f7042c4edd92e736f6&mc=true&n=sp47.5.97.d&r=SUBPART&ty=HTML#se47.5.97_1309
[5] https://www.fcc.gov/ecfs/filing/1113400313887

There appear to be several sources of very expensive recon equipment intended primarily for law enforcement that can decode-only PACTOR 1, 2, 3 & 4 packets (this does not address issues of adaptive compression and ARQ combined with adaptive modulation and coding over typical HF channels as used by Winlink protocols discussed in section 3), but these are not relevant for the amateur radio community, and they do not address the issue of fully documenting these technologies for transparency.

On the one hand, SCS claims (reference 2):

"PACTOR 3 and PACTOR 4 are sufficiently documented within the scope of the legal requirements."

But SCS says in their filing that

"This software called "PMON for Raspberry Pi2" is now freely available, see also our press release attached to this letter."

While this is helpful, albeit only after there have been years of complaints about openness, it still falls well short of the FCC requirements. An executable image and installation package with operation documentation is provided, but no source code is provided which would allow ham radio operators to actually understand many critical details of PACTOR-2, 3 & 4 transmissions. To be clear this does not provide sufficient documentation, and especially it does not provide sufficient documentation to be able to read messages independently. It merely provides a sole source decode capability in a closed box.

Gordon L. Gibby believes that the ARRL website documents the PACTOR modems with sufficient detail for documentation compliance including specifically the ability to read messages. But Gibby treated the modem as a closed box himself as did others, using a modem provided by SCS for his demonstrations, and he merely asserts that the ARRL website provides adequate documentation. It does not. It falls woefully short of meeting that requirement as will be shown in detail in Section 1. Gibby focused only on the Winlink compression component which is implemented outside of the PACTOR modem, but the PACTOR modem itself is a daunting barrier except to use an SCS supplied modem.

Section 1 provides details on key missing information in the public documents necessary to decode PACTOR-2, 3 and 4 signals. Section 2 discusses the incompatibility problems of sharing spectrum between narrowband signals and wideband signals. In particular, PACTOR-4 would introduce spread spectrum techniques into the HF amateur radio bands which is in violation of existing regulations. And Section 3 clarifies the major barriers to decoding messages by 3rd parties associated with dynamic compression and ARQ based systems especially when combined with adaptive modulation and coding using typical HF channels. Section 4 provides a detailed analysis of recent experiments by Gordon L. Gibby & John Huggins to monitor Winlink over PACTOR-3 transmissions. It is found that these experiments in fact justify the view that: "…Winlink transmissions are nearly impossible to intercept,…"

1 – The Issue of Key Specifications Missing in Public Documents for PACTOR-2, 3 and 4

PACTOR modems use a number of advanced technologies to enhance performance or to facilitate the functions of a complex modem. Indeed some of those techniques can significantly improve performance, but when they are not specified in the public domain in detail sufficient for implementation by those skilled in the art, they are a very strong barrier to 3rd party implementation due to the complexity involved which has sufficient dimensionality to make reverse engineering impractical in the amateur radio community. These techniques are also found in cellular and WiFi data modems and others but are specified in many hundreds of pages to thousands of pages by the relevant standards groups. One technique which has been discussed is ARQ. Another technique is channel coding, but not just fixed channel coding, adaptive channel coding is used. A related technique is code puncturing which involves the removal of redundancy bits using patterns which may be complex and/or non-obvious. Another technique is adaptive modulation. Sometimes binary modulation may be used and sometimes QPSK may be used in PACTOR-3 as well as other levels of modulation in PACTOR-4. The adaptive modulation may also include adapting the number of OFDM tones and/or the baud rate. Yet another technique is the use of bit interleaving over data blocks. Bit interleaving mixes the positioning of bits within a frame so that error bursts which locally corrupt a number of bits will be scattered across the Viterbi convolutional channel decoder input to reduce overloading it with too many errors within its working region. Many of these adaptive techniques are often referenced jointly as **adaptive modulation and coding.** Used together they allow a wireless link to increase the bit rate to some high-speed maximum under good conditions, and to lower the bit rate using increasingly robust modulation and coding under adverse or low SNR conditions so that connections still operate albeit with reduced throughput.

The PACTOR-2, 3 & 4 modems use these techniques, but many critical details are not documented in the public domain. The ARRL website Technical Description for PACTOR-3 references: ITU Recommendation ITU-R 1798 "Characteristics of HF radio equipment for the exchange of digital data and electronic mail in the maritime mobile service," starting on page 40 of the document.[6] This document does provide many details of the PACTOR-3 modem and is over 100 pages in size. Nevertheless some of the most critical details of the modem design are not provided, rendering the document unusable for actually implementing a working decoder for PACTOR-3, and hence this does not satisfy:

"An amateur station transmitting a RTTY or data emission using a digital code specified in this paragraph may use any technique whose technical characteristics have been documented publicly,…."

Among the missing details for PACTOR-3 modems are the method and bit patterns of the bit inter-leaving used in conjunction with convolutional channel coding to enhance performance. The words "interleaving" or "de-interleaving" only appear several times in the document and then simply to say that these procedures are performed. No significant detail is provided. There are many kinds of interleaving algorithms that have been proposed and studied in the wireless industry. The result is essentially a fixed scrambling algorithm over 100's to 1000's of bits that makes the data unintelligible

[6] https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.1798-1-201004-I!!PDF-E.pdf

without having information on the type of interleaving or scrambling algorithm that is used along with any related parameters. This missing information alone makes 3rd party decoding or implementation a very daunting task. There is information available for PACTOR-2 & PACTOR-4 for the interleaver on SCS' website.[7] [8] It should be noted that PACTOR-2 uses 4 different settings of a critical interleaving parameter. Perhaps this is just an oversight in providing critical design detail, but it is a major barrier for 3rd parties.

A second critical area of missing detail for PACTOR-3 modem are the details for puncturing of the convolutionally encoded data to obtain channel coding rates higher than a natural rate of ½ (2 bits of encoded data for each bit of information). By eliminating some of the encoded bits at the transmitter prior to transmission, rates between ½ and 1 such as 2/3, 4/5, 8/9,… can be achieved to send more user data when channel conditions are favorable than for rate 1/2. At the receiver the punctured bits which may use a complex pattern over the block of data are reinserted into the data stream just prior to decoding with a conventional ½ rate Viterbi decoder with erasure symbols. This is common practice in the industry, but the critical information is the detailed and complex pattern of the puncturing bits. This has similar issues to interleaving in terms of complexity and impact on transparency. If this information is missing, the unknown puncturing makes 3rd party decoding almost impossible. The authors of ITU-R 1798 acknowledge that this information is missing on page 40 when they describe puncturing: "Prior to the transmission, certain bits of the rate 1/2 encoded bit stream are "punctured", i.e. deleted and thus not transmitted." The "certain" bits are not documented. They also comment" "The coding gain of a "punctured" code nearly matches the coding gain of the best known specific rate 3/4 or 8/9 codes with a comparable constraint length, provided that the puncture pattern is chosen carefully." There is no information on how the puncture pattern is chosen carefully for PACTOR III. In reference 7, there is some information on puncturing regarding PACTOR-2, but it is incomplete and is missing a mapping function between a puncturing vector and non-punctured codewords. In reference 8, the puncturing for 5/6 rate which is used for PACTOR-4 appears to be reasonable documented, but the puncturing for PACTOR-3 which uses rate 3/4 and rate 8/9 does not appear to be documented anywhere.

A third area which appears to have missing detailed information is the complete functionality of the packet headers as discussed in section 1.6 pages 43 and 44 of the ITU PACTOR-3 document. The headers are important for a number of critical functions such as Speed Level (modulation and coding). For example, this text is on page 44: "The remaining tones 1-4, 6-11 and 13-18 are preceded by constant headers that characterize the respective tones without transferring any additional information. They support frequency tracking, memory-ARQ, the listen-mode and the detection of the speed levels 5 and 6." But the detailed mapping of these signals into functionality is not provided. Hence a 3rd party attempting to decode PACTOR III packets without using an SCS provided hardware or software modem faces a daunting task of attempting to decode the packet headers with incomplete information before getting to the previously mentioned obstacles of puncturing and interleaving where the key information may be missing or is ambiguous.

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[7] https://www.p4dragon.com/download/PACTOR-2%20Protocol.pdf
[8] https://www.p4dragon.com/download/PACTOR-4%20Protocol.pdf

A fourth area where there is missing detail is for modulation symbol mapping for Pactor-4. Reference 8 provides drawings of BPSK, QPSK, 8-PSK, 16-QAM and 32-QAM, all which are used adaptively by PACTOR-4. But no table or other specification is provided showing how the points in each constellation maps into a stream of 1, 2, 3, 4, and 5 bits respectively. There is a short discussion on “symbol mapping” but the key information is actually not provided. This issue is easily addressed in other places in the wireless industry, but since it is not provided here, it is a significant barrier.

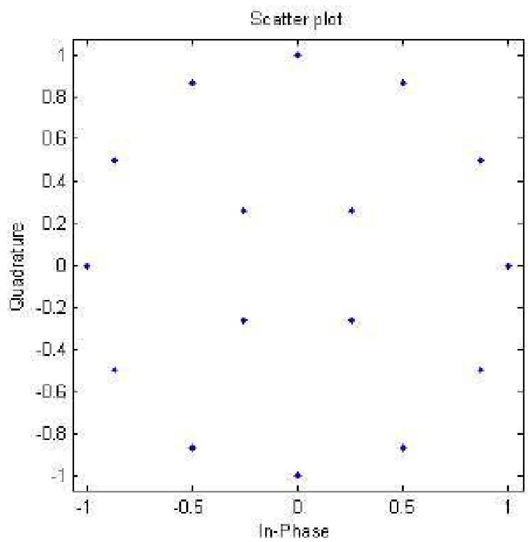

Figure 9.4: 16-QAM

This is the diagram provided in reference 8 by SCS to document 16-QAM and its mapping. Unfortunately the mapping of each constellation point to 4 bits is not provided. Also this is a not the most common form of 16-QAM, which is square placing 4 x 4 points at equal spacing, but it instead places 4 points on an inner circle and 12 points on an outer circle to achieve some benefits in distances between points relative to average power and hence in bit error rate for a given SNR. But there are many ways to map these points into groups of 4 bits which are not revealed. As is known by those skilled in the art, the topic of M-QAM constellation design and mapping to bits has been an area of advanced research for a good many years in order to optimize decoded bit error rate or possibly block error rate. This mapping information is missing for at least 8-QAM, 16-QAM and 32-QAM for PACTOR-4. The mapping information is well known to be a key part of modem design, but is omitted in the documentation for PACTOR-4.

The claim that

“PACTOR 3 and PACTOR 4 are sufficiently documented within the scope of the legal requirements.”

is not accurate. Perhaps SCS simply does not realize that a number of key information areas have been omitted in the documents, or perhaps SCS retains certain trade secrets of PACTOR modems. If this is

related to trade secrets, this not only retains any related intellectual property, it makes amateur radio operators 100% dependent in practice upon SCS to decode and to use PACTOR compatible transmissions on the airwaves. This sort of practice has long since been abandoned for commercial systems requiring interoperability such as Cellular, Wi-Fi, Bluetooth, NFC and many others. Full disclosure of technologies that will be used (but not necessarily implementation distinctions) is the practice, and intellectual property is handled under the conditions of full disclosure. Without full disclosure of the technology sufficient to support interoperability or 3rd party implementation, compliance with FCC § 97.309(a)(4) is not possible. If the parties wish to retain technology as trade secrets that are necessary to implement 3rd party modems, they should seek relief from compliance with FCC § 97.309(a)(4). While some of the missing information is limited in scope, taken together, the list of missing information (which is likely to also be incomplete) is a serious barrier to any 3rd party implementation.

I do not want to suggest that it is desirable or workable to move to some kind of standards process along the lines of IEEE or 3GPP for amateur radio digital transmission technologies, although open cooperative processes are sometimes used to develop amateur radio technologies. It should be noted that early and 1st version documents of open commercial wireless standards almost always are missing critical details, and filling those holes can involve years of effort and review/input by many companies and many engineers due to the very high complexity. In the case of closed and single entity development of complex radio technologies, especially complex software and DSP intensive technologies, there is a similar problem, and fully documenting the technology is not a small task. It is difficult to actually provide a fully accurate description of these technologies, due to the complexity, but this also provides an opportunity to conveniently omit critical information lost in many pages of otherwise useful and interesting detail. For amateur radio use, it behooves such entities to create some process that can work for them and for the amateur radio community where missing design and specification information necessary to decode signals on the amateur radio bands can be added to the publicly available documents. I am not aware of such a process for PACTOR-2, 3 and 4. I am open to correction or a response that such a process will be created. Until then and until these issues are addressed, compliance with openness is missing.

2 - Compatibility of Narrowband and Wideband Modes

The compatibility of narrowband and wideband modes in the same spectrum needs very careful consideration. Ron Kolarik writes

> "The mode that's received the most attention in these proceedings, Pactor 4, is specifically designed to overcome narrow band interference. In other words, Pactor 4 is capable of taking over any spectrum it wishes, at any time. The current Pactor 3 implementation also has the ability to override almost any other signal to make a connection, apparently has no effective means to determine if a channel is already occupied, and what limited "channel busy detection" is available is easily defeated or ignored."[9]

While it is desirable to minimize segmentation of the radio spectrum to the extent feasible, when major issues of incompatibility arise, segmentation of spectrum is the known solution.

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[9] https://ecfsapi.fcc.gov/file/12300483528083/Adjit%20Pai%20cover%20letter.pdf

SCS' own descriptions of their modems provide insight into this issue:

"In the PACTOR-2 system, the transferred information is swapped from one channel (tone) to the other in every cycle. Unlike FSK systems, the link is thus not blocked when strong narrow band QRM completely overpowers one channel (e.g. CW or carriers), but only its maximum speed is reduced".[10]

Even in PACTOR-2, features where developed and indeed optimized to overpower narrowband signals. It does not appear that PACTOR-2 adapts to reduce interference to others, but instead uses message repetition across its 2 tones combined with coding to overcome lost data. The statement indicates that the data rate is cut in half with interference from one strong narrowband interferer, so the channel occupancy is also doubled in time and hence the duration of the QRM/interference for a given amount of data. For PACTOR-3, this is only described this way:

"At low SNR, PACTOR-3 achieves a higher robustness compared to PACTOR-2."

PACTOR-3 uses up to 18 tone OFDM. A narrowband interferer may impact only a single tone or perhaps several tones. Channel coding can efficiently suppress the impact of such narrowband interference allowing the PACTOR-3 modem to efficiently continue transmissions while the narrowband CW or data signal may be rendered unusable. PACTOR-4 uses a single carrier approach, but employs modulation adaptation with modulation spreading up to a factor of 16x (12 dB of gain) and at the lowest rate mode a Chirp function with a factor of about 10x which combines with spreading over 2 tones to provide spreading and gain of about 20x. In addition, the modem includes 6 auto-notch filters to suppress narrowband interference. The result is that a PACTOR-4 modem can operate under conditions where the interference may be much stronger than the desired signal. On the other hand, a narrowband signal such as CW or RTTY or even PSK31 are essentially limited to using narrowband filters and require a useful positive SNR within that filter's bandwidth for successful operations.

The use of signal spreading by PACTOR-4 up to factors of 16x to 20x in order to obtain processing gains of 12 to 13 dB in bandwidths of 2.4 KHz is a major concern. The FCC does not allow SS operations in the HF bands, and for excellent reasons that are fundamental and remain true to this day.[11][12] Even for VHF and UHF bands, SS signals are only allowed to transmit at modest power levels of 10 watts PEP.[13] Yet PACTOR-4 will introduce a form of SS signals into the HF bands at the full legal power limit of 1500 watts PEP. The spreading of low-bit rate signals of 100 bits-per second to occupy bandwidths of 2400 Hz combined with the techniques employed is clearly an introduction of SS signals into the HF bands. This property is a key concern that PACTOR-4 signals can easily overpower and are in fact designed to overpower narrowband signals. While the intent may be to make PACTOR-4 extremely robust to interference, the resulting side effect is to overpower other signals.

Sending level 1 uses "chirp". Chirp is an old and well known form of SS where a transmitter sweeps the carrier frequency across some much wider bandwidth than the basic bandwidth of the signal. At the receiver, the sweep is undone followed by normal filtering and data demodulation, decoding,.... SL1 has a baud rate of only 100 symbols/sec, but each of 2 tones are swept over about 1 KHz or 10x compared to the symbol rate over the course of about 3.5 seconds for a data packet. In this way any narrowband interference only corrupts the signal locally in time over a packet and most of the packet

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[10] https://www.p4dragon.com/download/PACTOR-2%20Protocol.pdf
[11] FCC §97.305 Authorized emission types
[12] FCC §97.311 SS emission types
[13] §97.313 Transmitter power standards (j)

can be received interference-free and then decoded successfully with error correction and redundancy in the coding. Of course this creates interference over 10x the bandwidth compared to a non-swept carrier. Furthermore the data is repeated on 2 tones. Together the effective spreading is about 20x.

Sending levels 2 & 3 use direct sequence spreading with a factor of 16x which spreads the bandwidth by 16x while Sending level 4 uses direct sequence spreading with a factor of 8x. This is documented in Table 2.1 on page 3 of the Technical Description of PACTOR-4 provided by SCS on their website. The actual direct sequence spreading sequences are shown on page 8 in sets of 16 & 8 complex numbers used to multiple the data symbols and directly expand the symbol rate by 16x and 8x respectively which corresponds to direct sequence spread spectrum. The terms “spread spectrum” and “direct sequence” do not appear in the document although “spread”, “spreading factor”, “spreading sequence” and “chirp” do appear. Those familiar with SS will recognize that in this context these terms are referring to spread spectrum using direct sequence and chirp technologies.

The argument can be made that this SS property is important to ensure that critical emergency information can be transmitted. But then this introduces a severe situation of incompatibility and unfairness in using the spectrum. Will Spread Spectrum (in this case with spreading factors up to 20x and processing gains of 13 dB) now be allowed on the HF bands? How much spreading is OK and can this be increased to 40x, 80x,… only limited by the operating band with possible rule changes? If SCS and potential PACTOR-4 users wish to introduce SS technology into the HF bands, they must seek a change to FCC regulations that permit SS only above 220 MHz. Are they willing to limit the power levels of such transmissions to 10 watts PEP as is required by FCC part 97 (see reference 13)? This limitation is applicable to PACTOR-4 due to the usage of spreading factors up to 20x laying aside the separate prohibition on SS below 220 MHz for amateur radio bands (see reference 11).

Claims that this is not actually SS since the bandwidth is limited to less than 2.8 KHz would not be correct, since these modes are transmitting with user data rates similar to those commonly used for existing narrowband data transmissions (100 to 400 bps), but spread the signals out over bandwidths 5x to 20x in width using well known SS techniques of direct sequence spread spectrum and chirp spread spectrum. Previously it was determined that modems called CHIP and ROS were not legal in the USA due to the use of SS even though the bandwidths occupied were less than 2.8 KHz similar to SSB, and even though the frequency hopping and direct sequence spreading used in those modems was performed within the audio signal prior to coupling to the audio of a conventional SSB transceiver.[14] A different finding for PACTOR-4 which includes SS in sending modes 1 to 4 would be in direct conflict with the earlier determinations on CHIP and ROS.

The use of SS in sending levels 1 to 4 especially results in severe incompatibility in tolerance to interference by new wideband modems compared to narrowband signals as well as non-compliance with regulations on SS. The wideband modems use advanced technologies, including Spread Spectrum, to suppress narrowband interference that only corrupts a small portion of their total bandwidth, while the narrowband technologies have no similar option. Hence these wideband signals can and will if permitted overpower narrowband signals. This severe incompatibility is best addressed by segmentation of the operating bands as has been noted and has been done for decades between legacy narrowband (CW and RTTY) and wideband modes (voice), although the issues are not identical. It should be noted that PACTOR-2, 3 & 4 modems are likely to also cause issues in band segments used for

[14] https://forums.qrz.com/index.php?threads/ros-and-chip-deemed-illegal-below-222-mhz-for-u-s-amateurs.238581/

SSB and other voice modes.   But PACTOR-4 introduces clear issues of non-compliance with limitations on SS signals. PACTOR-3 also employs methods to overpower narrowband signals, but has more limited capabilities than PACTOR-4 simply adapting for sending level 1 to 2 widely spaced carriers with repetition and coding across those carriers.

Activity Detection, AD (or Listen Before Talk, LBT) is considered critical for ACDS operations to manage the potential for harmful interference by automatic transmitters. One of the first rules an amateur radio operator learns is that one must listen carefully to a frequency for any existing activity before transmitting to avoid causing interference. Of course these rules are bent to some degree in DX pileups and in contests where the activity can be described as "radiosport", but even there, amateurs are expected to follow rules and to minimize interference. Unfortunately AD is complicated by a number of complex issues including at least: 1) the hidden node problem; 2) split frequency operations; and 3) the plethora of waveforms and protocols now available to radio amateurs. Together they mean that automated AD is very challenging to perform effectively. Because of this, mixing narrowband and automated wideband digital modes in the same band segments creates significant problems and potential for harmful interference when there is significant activity.

The activity detector for PACTOR is described as follows: "An occupied channel is defined as all signals that are audibly distinctly different from noise, but, however, having a speed < 250 Baud. Packet-Radio (300 Baud) is virtually ignored. Furthermore, strong carriers on the channel are NOT evaluated as Channel busy."[15]   This is probably out-of-date since as stated, this AD would not detect PACTOR-4 signals. Very basic details are not included such as a description and parameters of the memory in time of the activity detector. Does it listen for ¼ second or 10 seconds,….? What is the nature of spectrum analysis or correlation analysis that appears to be performed? No information on performance is provided such as SNR and average time required to detect CW, SS, RTTY or another PACTOR signal. Certainly the use of an AD is preferred, but the available information is very limited and suggests limitations in performance.

The hidden node problem is related to the issue that interference from TX2 causes harm at the receiving end of a link from TX1 to RX1, But TX2 can only hear signals from TX1 (you cannot hear a receiver!). Radio amateurs are very familiar with hearing just one side of a conversation (Phone, CW or conversational digital) on 20 meters, and they know that if they are aware that another amateur radio station which they heard previously is likely to be listening on that frequency during gaps in what they can hear from the one side, that they should not transmit because they will cause interference. In this case, the radio amateur decoded the situation including the meaning of words from earlier transmissions which they could hear to realize that the channel is still busy even though they hear nothing. This procedure is not easily performed by AD's for ACDS.   The hidden node problem is very well known by the WiFi community as well as others, but the WiFi groups have developed special protocols using Ready-to-Send (RTS) and Clear-to-Send (CTS) messages to help mitigate this problem. With this protocol, a station that is about to receive a long message, transmits a short CTS message indicating that it will be listening immediately to receive the long message for a specified period of time. This allows a receiver which may be harmed by interference due to the hidden node problem to instruct potential interferers to wait till that period of time has passed before attempting any transmissions and thereby avoiding harmful interference. There is no such protocol for amateur radio, hence the hidden node problem is problematic for ACDS, but it is especially problematic for mixing narrowband and automated wideband digital signals such as ACDS. It is also problematic to mix SSB with ACDS. Human

[15] https://www.p4dragon.com/download/SCS_Manual_PTCplus.pdf

operators listen to the content of conversational messages to perform functions manually that are similar to RTS and CTS, often implying the status of others without explicit information. This is very important to mitigate interference. AD's for ACDS are unlikely to perform similar functions.

Split frequency operation is common on the amateur radio bands for managing pileups and interference. This creates a severe problem for AD. Consider a situation where a CW or RTTY operator transmits in a 3 to 10 second period on 14.100 MHz, and he listens for incoming signals on 14.105 MHz where transmissions may also be 3 to 10 seconds in length. Similar split frequency operation is possible and occurs for narrowband digital and SSB. The split frequency operation is typically explicitly indicated by the calling station. How does an AD process such signals? It is unlikely to decode the contents of the messages in the plethora of modes used on HF and understand that even though there are long periods of inactivity on each frequency, it cannot consider the frequencies inactive. It could use very long in time power averaging or power peak detection sliding window algorithms,…., but then the ACDS transmitter may find that it is almost always blocked from using any channel. Split frequency operation strongly complicates activity detection and adds to the issues of sharing band segments with ACDS.

Due to the special problems presented by these wideband signals and due to the issues of ACDS operations. I support the proposal to require CW ID's at least every 10 minutes for these operations which would be similar to requirements for SS transmissions at VHF and UHF frequencies. Automated CW readers are readily available. This is especially relevant since PACTOR-4 includes SS modes of operation and is proposed for operations in HF frequency bands, but it is also important for any ACDS operation since there is a minority of amateurs equipped to monitor even the station ID's and these operations include methods of operation that may be unfriendly in terms of interference.

Any expansion of band segments for wideband digital modems should be substantially limited, especially for ACDS, and many amateurs believe that ACDS operations should be limited to the existing specified band segments. Unfortunately, wideband HF modem technology encourages those skilled in the art to introduce SS modes into those modems as a means of combating and overpowering other signals, especially narrowband signals. This happened before with CHIP and ROS. It has happened again with PACTOR-4 sending levels 1 to 4. While PACTOR-4 clearly uses SS technology based on the language and documentation, it is possible to introduce techniques where the language and documentation are less clear on the usage of processes to achieve SS-like results. This problem is very unlikely to be addressed by any constraint other than emissions bandwidth constraints combined with band segment limitations for wider bandwidth signals. Therefore, I urge the Commission to reject WT Docket No. 16-239.

Section 3 – Barriers to Decoding Digital Signals that use Dynamic Compression and ARQ

Gordon L. Gibby performed an experiment to demonstrate 3rd party decoding of Winlink data transmissions using PACTOR.[16] It is important to note that Gibby used a closed box PACTOR modem supplied by SCS, and his experiments did nothing to address the many previously cited issues on full and open documentation of the methods and means used by PACTOR-2, 3 & 4 modems sufficient to enable amateur radio operators to monitor such transmissions short of obtaining an SCS modem. He also did not address the issue of wideband PACTOR-3 and PACTOR-4 signals overpowering narrowband signals using a multiplicity of advanced techniques especially designed to efficiently perform such operations,

[16] https://ecfsapi.fcc.gov/file/109191626613689/InconvenientTruths.pdf

including the use of spread spectrum technology below 30 MHz contrary to allowed emissions types. The following applies also to Winlink messages over WINMOR, ARDOP, VARA,…. Even though the modems themselves may or may not be fully disclosed in the public domain.

Gibby asserts on page 8:

"The technical characteristics of the PACTOR system have been published and unquestioned for years. They were sufficient for more than one competitor to replicate them. This makes it difficult to understand how they might be considered secretive.. ."

Notice that no distinction is made here between PACTOR, PACTOR-2, PACTOR-3 and PACTOR-4. The only references to PACTOR generations to be found in the document are in references from other documents. Almost all agree that generation 1 of PACTOR was documented sufficiently for 3rd parties to implement decoders and that that indeed happened. But this document does not distinguish between the generations of PACTOR and may be just referring to generation 1 of PACTOR in most places. As found in Section 4 analysis, it appears though that PACTOR-3 modems were used in these experiments with signals sent between Texas and Florida.

Gibby focused on the issue of decoding Winlink messages at protocol levels above the physical modem level, and particularly on the issue of the interaction of ARQ and dynamic compression obscuring messages for any 3rd party listener not party to participants in a point-to-point transmission. The claim is that it is quite easy for a 3rd party to decode such messages, although Gibby does express amazement as to why this has not been done earlier in the course of almost 2 decades. With detail to follow, the answer is that those skilled in the art realize that such a method of monitoring these communications will perform so poorly as to be deemed essentially useless. The Winlink organization implicitly supports this position when they say that the best way to monitor messages is not over the air but by interrogation of Winlink servers. So why bother to engage in such a capability or product when it is clear that the result will be most unsatisfactory, albeit with some effort it will sometimes be possible to decode short messages or snippets of messages?

Winlink and ARRL entities have sometimes smeared the distinction between adaptive compression and encryption.[17] In this document, users are advised: "US amateurs should not use the built in compression of the SCS modems,….. in order to comply with the spirit of FCC Part 97 and OSHEP guidelines on data encryption." In this case the issue was the lack of details on the adaptive compression algorithm itself which was obscuring the data content, even though there is no intentional/actual encryption. Since this document was released, SCS in 2018, provided a document on the PACTOR-2, 3 & 4 compression algorithms.[18] The algorithms are optimized for text and use fixed tables which would avoid the catastrophic failure characteristic of adaptive compression upon a single error. This demonstrates a path to avoid the problems of monitoring Winlink & similar transmissions combined with adaptive modulation and coding and ARQ over HF channels provided there is full transparency on the methods actually used. It is described as follows:

"The information sending system (ISS) automatically checks, whether one of these compression modes or the original ASCII code leads to the shortest data package, which depends on the probability of occurrence of the characters. Hence, there is no

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[17] http://www.laarrl.org/pdfs/digital_comm3.pdf
[18] https://www.p4dragon.com/download/PACTOR_Advanced_Data_Compression.pdf

risk of losing throughput capacity. Of course, PACTOR is still capable to transfer any given binary information, e.g. programs or picture and voice files. In case of a binary data transfer, the on-line data compression normally switches off automatically due to the character distribution. An external data compression in the terminal program is usually performed instead."

Regarding non-text message content, best practices, voice, image and video coding are relevant. LZHUF coding will not provide significant further compression of standard voice, image and video coded content. Standard PDF, JPEG, JPEG2000, PNG,…. images are already highly compressed. That is a key feature of the standards. Further compression (especially lossless compression like LZHUF) is very limited in removing additional redundancy. Furthermore, the image compression standards are much more efficient for image compression than LZHUF for coding uncompressed images since they use 2-dimensional spatial coding instead of only 1-dimensional spatial coding and algorithms selected especially for that purpose. The same is true for efficient voice coders such as G.728, G.729, AMR,…. and video coders such as H.264, MPEG,…. Regarding text and text formats, some text formats such as Microsoft Word, Google Docs,…., typically expand the size of text content by an order of magnitude while straight text or even Microsoft Notepad are much more efficient for simple text. Any use of text source that expands file size by an order of magnitude on emergency channels, especially low bit rate HF channels is very poor practice. Image use should be minimized and used only for critical information and coded using efficient methods such as PDF, JPEG,…., not LZHUF. I am puzzled by suggestions that LZHUF is critical for efficient transmissions for systems using HF digital modems. Its usage has some convenience, but best practices, usage of readily available and highly efficient voice, image and video coding,….. are far more important, and text can be readily compressed using fixed tables, even at L1/L2 protocol levels as described in the SCS document on compression, by using an encoder which adapts between text compression and clear uncompressed packets and is documented.

Gibby to some extent acknowledges the very poor performance that can be expected for a 3rd party listener by recommending diversity reception with receiving antennas possibly spaced a number of miles apart. And he showed in this own experiments that even with fairly strong signals without significant interference, that once a message reaches a significant length, that failure to decode is almost always the result. Surely there were multiple attempts to send the longer messages and all failed in these experiments. Hence the conclusion by many amateur radio operators, including the ARRL EMA group that, "…Winlink transmissions are nearly impossible to intercept,…" This does not say impossible, but it does say nearly impossible. In fact, under less than strong clear channel conditions, failure to decode longer messages is likely even with multiple diversity sites. The behavior then under typical HF channel conditions seems similar to the behavior with unknown adaptive compression which LARRL deemed a problem.

A key issue here is radio propagation and fading over HF channels and how that interacts with ARQ, **adaptive modulation and coding**, and adaptive compression. I believe almost everyone agrees that once a 3rd party loses a single packet during a long transmission which uses ARQ and adaptive compression, that the rest of the message is 100% obscured for any practical purpose (not to disallow the usage of future extreme computing techniques which by searching very high order coding spaces might recover from even this situation although the order of such spaces is incredibly high). This is because adaptive compression continually modifies the compression tables based on the transmitted

user data which includes the length in bits of the table pointers, so loss of modem data obscures all future user data in quite complex ways.

What about the likelihood of a 3rd party losing a packet? SCS brushes off this issue by saying:

"Reading is only a matter of SNR."[19]

They compare the situation to SSB:

"Such techniques would also be required of voice transmission monitoring if one wishes a 100 % monitor despite recurrent fading."

But SSB does not behave anything like ARQ with adaptive compression. In the case of SSB, a short burst of interference or a short fade only causes momentary loss of information, and everything that follows the short burst is then fully readable. But for the case of ARQ with adaptive compression, everything that follows the short burst is lost. The remainder of the transmission is 100% obscured. So such a comparison is not appropriate. SCS acknowledges this issue:

"The only real drawback is the lack of "late entry capability". Decoding will be performed properly until there is a gap in the input data stream. Missing data in the received data stream thus (with current technology) leads to an abort of decoding."

Yet SCS down plays this as a minor issue and says perhaps you should add diversity to reduce the problem. Amateur Radio operators know that significant fading and intermittent interference is the norm on HF bands, not the exception. However, neither SCS nor Gordon L Gibby discuss the nature of **adaptive modulation and coding** and its interaction with fading and ARQ with adaptive compression which together dramatically increase the likelihood of loss of data by a 3rd party and the likelihood of this happening quite early in any transmission.

Adaptive modulation and coding is now widely used in wireless technologies. As explained earlier, this allows a wireless link to increase the user bit rate to some high-speed maximum under good conditions taking advantage of high SNR by adding less redundancy to the data & using more complex modulation & sensitive constellations, and to lower the bit rate using increasingly robust modulation and coding under adverse or low SNR conditions so that connections still operate albeit with reduced throughput. Periodic receiver to transmitter feedback with information of channel quality is used to facilitate adaptation. SCS' documentation on PACTOR-3 shows bit error rates of 1% occur at about -8 dB SNR for speed level 1 and about +9 dB SNR for speed level 6 or with about 17 dB difference in SNR capability. For adaptive modulation and coding modems, block error operating points of 1% to 10% are generally used to maximize throughput while constraining latency due to packet repeats. But this means that the signals can and are designed to tolerate packet loss even at high SNR as normal operating conditions. SCS documentation on PACTOR-4 shows that it has 10 speed levels as compared to only 6 speed levels in PACTOR-3, and PACTOR-4 also introduces modulations up to 32-QAM compared to only QPSK for PACTOR-3 as well as SS for the low SNR speed levels. The additional speed levels are used to expand the range of adaption both on the low and high ends of SNR, and it appears the modem is functional from as low as -19 dB SNR to as high as almost +17 dB SNR with a difference in SNR > 35 dB.

[19] https://ecfsapi.fcc.gov/file/1105087415643/SCS_letter_ScotStone_FCC_22102019_1%20(1)%5B523%5D.pdf

A good source for information on HF fading can be found in an ITU paper.[20] They show that the typical HF channel spends 10% of the time in down-fades that are greater in attenuation than 8 dB and 10% of the time in up-fades that are greater than 5 dB for short term fading, or a 13 dB difference between the 90th percentile and the 10th percentile (see page 307). They also discuss some measurements showing mean value of fading rates of about 11.25 per minute or about every 5 seconds (page 305).

Suppose a 3rd party is attempting to monitor Winlink transmissions using PACTOR-4 modems and has a strong signal around S9 and with about 20 dB SNR which are good conditions on the HF bands. And suppose the two parties to the radio link message transmission have somewhat weaker signals around S7.5 or about 10 dB weaker and with about 10 dB SNR's. You would think that the 3rd party would have no problem decoding messages, and decoding lengthy messages since they have a stronger and higher SNR signal (on the average) than for the desired receiver. This is not true!! Based on the ITU data, a difference in fading between the links will typically encounter a fading difference between them of over 10 dB within a small number of seconds, and the probability of this not occurring becomes exponentially smaller with the passing of time. Once the local signal difference in fading exceeds about 10 dB, or the difference in average SNR between the links, where the desired path is in an up-fade and hence has good SNR and the 3rd party monitor is in a down-fade and hence has reduced SNR, the desired path then has better SNR than the 3rd party path for a short period of time. At that point the **adaptive modulation and coding** will continue to act to choose a speed level that is just good enough to close the path from the transmitter to the desired receiver to maximize speed perhaps with some margin for error. But it probably will not be good enough to close the path to the 3rd party monitor which for a short period of time has a lower SNR than the desired receiver even though it enjoys a 10 dB advantage in average SNR over the long term. Upon losing a single packet at that point, all following user or carried data is lost (cannot be decoded) for the duration of the transmissions even though most packets may be successfully decoded at the physical layer.

The problem is that a monitoring station must have an extreme advantage on the average in SNR and/or a very clean channel in order to monitor Winlink over PACTOR-2, 3 & 4 for significant periods of time compared to the desired path. This is rare in practice. Stated another way, the packet error rate must asymptotically approach zero for the monitoring station for it to decode messages. Furthermore, even if that criterion is satisfied, there is no option to decode part or most of a message if the very beginning of a message is missed due to acquiring a signal. Pactor-4 in particular would appear to require an extreme advantage in average SNR due to the very wide dynamic range of its adaptation and its ability to take advantage of high SNR's with 32-QAM and light channel coding to increase transmission rates which then makes the associated packets quite sensitive to any small disturbance for decoding by a 3rd party. These issues explain why Gordon L. Gibby suggests diversity reception, and was unsuccessful in decoding longer messages even using PACTOR-3.

There is no mystery on why it is easy to find claims that Winlink using PACTOR modems is almost impossible to decode by 3rd parties and even claims that it exceeds HIPA requirements. There is much truth in such claims when one studies how HF fading, **adaptive modulation and coding**, ARQ and

[20] https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-P.266-7-1990-PDF-E.pdf

adaptive compression interact to very quickly render attempts to decode a message a failure under most conditions for messages of significant length.

There are readily known solutions to these problems, so there is not a need for fundamental innovation to address them. As has been previously discussed, fixed codebook compression would eliminate the problem of the compression codebook changing when losing a single packet. If Winlink is implemented to allow independent decoding of the user data for each packet using fixed codebooks, this problem is solved. This is a well known technology and there is no barrier to its usage & advantages of fixed compression could be enjoyed. With this step, ARQ does not need to be eliminated for transparency, and so reliable communications is not harmed, provided the ARQ transparently repeats any lost packets or portions of lost packets. Modest losses in efficiency due to fixed codebook compression should be acceptable to achieve transparency and eliminate the issue of a single packet loss rendering a transmission non-decodable. This would eliminate a key issue behind the claim that Winlink is almost impossible to intercept. According to filings by the ARSFI, compression is disabled in PACTOR modems for Winlink systems, and compression apparently occurs in servers or other equipment outside of PACTOR, so it appears that this issue can be addressed in the software for those systems.

Section 4 – An Analysis of Recent Experiments to Monitor Winlink Over PACTOR-3 Messages

In reference 16, Gordon L. Gibby provides details on his experiments to monitor and decode Winlink over PACTOR modems. Gordon does provide significant detail on his experimental setup including detailed logs of messages and modem packets, locations of stations, and the equipment. The experiments are not sufficient to derive statistic results or probabilities of performance. Here is part of one of his captures using PMON to monitor PACTOR with an SCS modem:

###PAYLOAD_END
þú
###PLISTEN: Level: 3:
###STATUS: SL: 4, CYC: 0, RQ: 0, REV: 0, LSB: 0, dF: 14.3, CRC: 8C8A, FRCNT: 3,FRNR: 48
###PAYLOAD1: LEN: 117, TYPE:
8###PAYLOAD2:1E,C9,BC,73,82,A2,73,99,E0,03,78,11,F3,0B,F3,93,9A,05,75,C4,EC,1B,5B,02,D4,10,0A,83,
BF,46,8F,E4,84,A1,19,4D,26,8C,9B,FA,2A,CA,8B,58,59,A9,48,D2,C4,CC,C8,AD,0B,AE,38,E2,6C,28,41,DF,1C
,3A,01,0F,FD,24,1B,E5,21,A0,D1,D7,79,5E,35,B6,AA,B8,B0,FC,EB,F4,29,08,E4,18,B1,8A,92,45,ED,50,01,29
,A4,93,C8,50,29,12,66,53,63,CA,73,73,29,40,1D,58,07,64,83,01,6D,91,FC

###PAYLOAD_END
þú
###PLISTEN: Level: 3:
###STATUS: SL: 4, CYC: 0, RQ: 0, REV: 1, LSB: 0, dF: 14.2, CRC: B620, FRCNT: 0,FRNR: 49
###PAYLOAD1: LEN: 115, TYPE: 8
###PAYLOAD2:3B,A3,F3,D9,58,69,4A,18,2F,44,A0,28,0F,E1,EC,CF,1D,DF,F1,57,AC,90,75,F1,F0,1A,C8,02,F
A,49,C4,D3,12,62,7A,24,95,33,86,CB,25,C2,E1,4D,14,41,6F,48,71,E6,47,04,4E,8B,3A,AF,1D,6B,87,EB,7F,A

9,4D,5D,C3,E3,D9,FC,F9,EF,EC,FA,7F,FA,9F,03,C4,35,64,BD,B2,C6,2E,77,98,DF,DF,73,96,7E,AA,7F,3E,E9,CB,0A,38,96,CF,DD,17,C9,FC,96,E5,1E,1C,5B,24,8A,2D,F5,C0,ED,F0

PMON is documented here: https://www.scs-ptc.com/repo/packages/PMON_Manual.pdf

This indicates PACTOR-3 (###PLISTEN: Level: 3:) was used in these experiments which sent messages from Texas to Florida. Looking at the results in Appendices 1 to 4, where each Appendix documents the details of all packets sent corresponding to a single overall user message, I find that the highest sending level ever used is SL5, but packets sent with SL5 are not decoded properly by the monitoring station due to their sensitivity to noise and interference. SL6 or the highest rate mode is never used. SL5 has a bit error rate of 1% at only 6.5 dB SNR, while SL6 has a bit error rate of 1% at only 8.5 dB SNR. This indicates that the desired link may have had a best case SNR of only about 10 dB SNR. Probably the SL adaptation allows a few dB of margin before switching from one mode to a higher mode, so it might require something over 10 dB SNR to switch to SL6, but it should not require a huge margin. It appears to be the case that the connected link may have generally experienced poor to moderate quality. This causes most of the data to be very strongly coded and robust, allowing a monitoring station with a good average SNR (good clean signal) to successfully decode several short messages. There is failure for the one and only example of a longer message, and the failure starts exactly when the transmitter switched to a higher sending level (SL5) that carries more data and is less robust to noise and interference.

Please see the following detailed analysis of the Appendices in reference 16 :

Appendix 1: The SL is 3 or 4 for user data. The very first packet is SL 5 but with no data payload. This packet may be used to sound the channel for quality or other startup purposes. After it is sent, the modem goes to SL 3 and finally to SL 4 for several packets. This suggests that the connected SNR is poor to moderate in quality on the level of only 0 to 10 dB. See the PACTOR-3 technical description & the packet error plots (the plot is below for convenience). It is also possible that for short messages, that the PACTOR-3 adaptation algorithm is conservative and simply favors the lower SL's. The effect is the same however. Most of the packets are sent with very strong and robust coding. No data payload is sent with SL5 or SL6. There are only 8 packets in the entire message. And the total transmission time may only be 15 to 30 seconds, so this may not go into even a first fade at a monitoring station. The author indicates that the signal at the monitoring station sometimes approached S9 which he showed is a fairly strong signal close to -70 dBm on his equipment or approaching 25 to 30 dB average SNR since the noise floor approaches -100 dBm. This suggests that the monitoring receiver may have had about a 20 to 30 dB average SNR advantage over the desired receiver in this test (or at least what SNR was required) since the mode adaptation selected a mode only requiring around 0 to 10 dB SNR, but the monitoring receiver enjoyed an SNR of 25 to 30 dB.

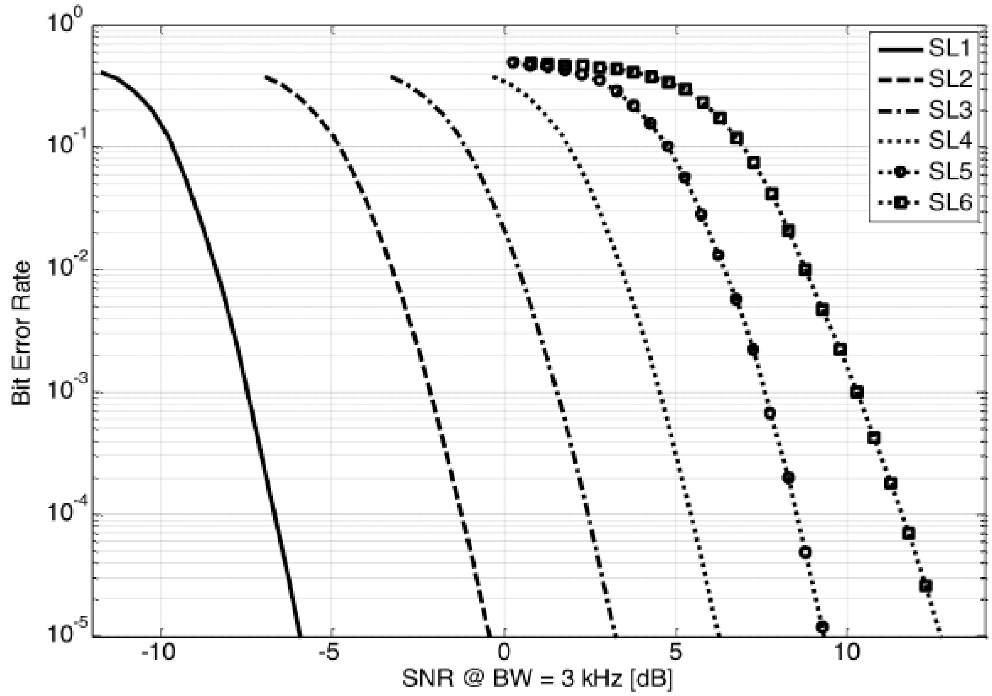

Figure 4: Bit error rate for the different speed levels with respect to the channel SNR

This is the bit error rate for the different sending levels of the PACTOR-3 modem. The capability of error correction (FEC or Forward Error Correction) may be in the range of 1% to 10% which determines the packet error rate. A conservative bit error rate of 1% is considered here which should allow successful decoding in all modes although the difference in SNR between 1% and 10% is only about 1.5 dB for each sending level.

Appendix 2: The situation is similar to Appendix 1. The file is a bit longer. Almost all data is sent with SL3 and SL4. There is one case of user data payload being sent with SL5. There is no usage of SL6.

Appendix 3: The situation is similar to Appendices 1 & 2. Most of the data is sent with SL3 & SL4.

Appendix 4: This is the case of a longer (but still only moderate length) message and also one where Gibby had major difficulty in decoding the message. He never successfully decodes this message. He proposed RX diversity to help with this problem, but he does not actually implement it. It must be noted that this is a failure to decode a moderately longer message, even under a somewhat controlled over-the-air situation and where the monitoring station appears to enjoy a significant SNR advantage over the desired receiving station. Gibby suggests that there were also poorer conditions for this case at the monitoring station. But this is the stress test and the case which most directly addresses the issue of "…Winlink transmissions are nearly impossible to intercept,…" The SL starts at SL3 and SL4, and then eventually moves to SL5. On frame number 82, exactly when the sending modem switches from SL4 to SL5, the monitoring receiver misses its first packet. This is only about 10 packets into the message. All

user data after this was lost by the monitoring station, even though it is shown that most packets that follow are decoded successfully by the modem at the physical layer, the user data they contain is obscured by the resulting failure of adaptive decompression which follows due to sensitivity to losing a single bit or a single packet. In fact, Gibby shows that a number of errors occur after this at the monitoring station, each one would independently obscure all data following such packet losses, but the first error only about 10 packets into the exchange obscures all following data itself. This examination explains why Gibby could not decode this message. This message actually sends a number of packets using SL's up to at least SL5, but even here SL6 is never used. If the desired link had enjoyed a bit better signal quality such that SL6 was used for some packets, early failure by the monitoring station is even more likely.

Taken together, Gibby's experimental results over-the-air on 20 meters (but with significant control of the overall situation) and a careful analysis of those results strongly support the view that Winlink over PACTOR is almost impossible to intercept. Decoding brief snippets of messages or very short messages may sometimes be possible, and under conditions of very strong advantage in the signal quality for a monitoring station versus a desired receiving station, the odds of decoding improve. Gibby was successful in decoding messages in Appendices 1, 2 & 3 in that document under the 3 joint conditions: 1) robust coding for the data possibly due to poor SNR at the desired receiver; 2) a strong clean signal at the monitoring station; and 3)fairly short messages with a few lines of text. If any one of these conditions are not met, the result quickly becomes failure to decode. Appendix 4 in that document shows what can normally be expected in attempting to decode messages (failure). It should be noted that PACTOR-4 extends the adaptation of the sending levels both higher and lower in SNR requirements compared to PACTOR-3. This means that this problem will be amplified substantially for PACTOR-4. Other modems such as VARA with 11 levels of adaptation will yield similar results with adaptive compression such as LZHUF.

For someone so inclined, there is an obvious method to render the possibility of short messages being intercepted useless, just send a longer message and embed any sensitive information in the last section of the longer message. With average fading rates of about 5 seconds on the HF amateur bands, sending 15 to 60 seconds of non-sensitive data initially in a message followed by any sensitive data will result in a high probability of failure to decode the data by any monitoring 3rd party. If you are still nervous about interception, simply make the section of non-sensitive data longer, because the probability of interception asymptotes to zero exponentially with time for typical HF channels even with clear channels due to fading and noise. One way to make this more efficient is to cluster or bundle groups of messages into single large messages.

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 it. This is not discussed in the reference. His own experiments show the combined effect of adaptive modulation and coding with HF fading channels and adaptive compression and ARQ where packets sent at sending levels higher than 4 (sending levels 5 or 6) are lost by the monitoring station with catastrophic decode failure then resulting.

The effect is to send some packets at high sending levels on up-fades on the connected link, but which are then highly exposed to interference and noise at the monitoring station due to the adaptive modulation and coding choosing a high throughput sending level during periods of high SNR on up-fades at the connected station. The highly exposed packets are likely at some point to fail to decode at the monitoring station as the reference shows. It is the combination of evolving advanced technologies along with fading wireless channels which has made interception increasingly impractical to almost impossible.

Other experiments by John Huggins show decoding of Winlink over PACTOR-3 modems using an SCS supplied hardware modem.[21] It appears the operating stations are all located close to each other and should have excellent signals operating on 80 meters. In fact the connected stations are only about 2 miles apart, possibly using 100 watts of TX power. In those experiments the connected stations are N2LEE and KM4HRR located east of Dulles Airport. The monitoring station appears to be located at KX4O about 30 miles away.

An analysis of the provided logs shows that all of the transmissions between these connected stations are limited to sending levels 1, 2 and 3 using PACTOR-3.[22] Sending levels 4, 5 and 6 are never used. The data shows toggling between SL2 and SL3 indicating a quiescence point was reached with these 2 levels. This indicates that the SNR at the receiving connected station may be only in the 0 to 5 dB SNR range or that something else is constraining the sending level. Given that the connected stations are only about 2 miles apart and operating on 80 meters, and that the receiving station is a Winlink node, the signals received there should be capable of supporting SL5 or SL6 with no problem. The Gordon L. Gibby tests showed that the connected link moved to SL5 for the longer message on Texas to Fla transmissions on 20 meters where the monitoring station failed to decode. So why are the Huggins experiments limited to SL3?

In any case, limiting the transmission modes to SL3 or lower means that an SNR of only around 0 dB is needed to decode messages. It is likely that signal levels far exceeded S9 at the monitoring station and also exceeded 20 dB SNR, providing an extreme SNR advantage (or equivalent due to SL constrained to 3 or less) for the monitoring station, even though it is further away than the connected station. Conditions at the connected and monitoring stations and other information for the experiments are not provided in the references, but the constraint on sending level at only 3 is clear in the data and information on station locations is provided by call signs.

Paul Newland suggests that there are many factors which may make monitoring amateur radio transmissions difficult for a 3rd party and that "dynamic compression" is just another factor.[23] I respectfully disagree with this conclusion when adaptive modulation and coding is combined with ARQ & dynamic compression and then operations are over typical fading channels. Adaptive modulation and coding is not addressed and its impact combined with these other technologies is not considered. Other known and deployed combinations of technologies in the amateur radio bands do not result in

[21] https://ecfsapi.fcc.gov/file/1073182572879/KX4O_Demonstration_OTA_Winlink_Decoding.pdf
[22] https://www.hamradio.me/graphs/WinlinkTests/Examples_of_Partial_Decodes/
[23] https://www.fcc.gov/ecfs/filing/1114793710210

catastrophic decode failure for all following data upon the loss of a single bit or single packet at the monitoring station where the data packets are transmitted with adaptive modulation and coding which dramatically enhances the probability of packet failure for a monitoring 3rd party for typical HF conditions. As was shown, this is a problem even for situations where the monitoring 3rd party station enjoys a significant SNR advantage on the average over the connected stations due to HF fading characteristics.

Together, the Gibby and Huggins experiments are consistent with and confirm the issue that extreme SNR advantage or other similar conditions/constraints are needed to successfully decode Winlink over PACTOR-3 messages (which will be exacerbated by PACTOR-4). And that long messages are increasingly difficult (exponentially) to decode with length**.**

Conclusion

I found upon inspection of the available public documents that PACTOR-2, 3 & 4 provide significant information on their design and operation, but a number of critical details are missing that are major barriers to 3rd party implementation. It is only practical to decode PACTOR-2, 3 & 4 messages using a closed box SCS supplied hardware or software modem (baring intense reverse engineering efforts to determine the missing design information in available documents). This issue of transparency should not be difficult to address, but probably requires some process for 3rd parties to identify missing information and for such missing information to be added to the public documents. The existing status violates requirements on transparency (see FCC § 97.309(a)(4) on requirements for documentation).

I also found that existing wideband HF modems such as PACTOR-3 and PACTOR-4 use very strong narrowband interference suppression and management technologies which give them a huge advantage in any interference situation. PACTOR-4 even includes spread spectrum modes with spreading factors up to 20x equivalent or 13 dB processing gain in violation of prohibitions on SS in HF amateur bands by the FCC (see FCC §97.305 Authorized emission types). This means that such wideband signals can and will overpower narrowband signals if allowed to occupy the same spectrum, especially for ACDS. Hence wideband digital signals in the HF amateur bands must be carefully constrained to appropriate segments of the bands and constrained in bandwidth, but not until transparency is adequately addressed.

An examination of the interactions of HF channel fading characteristics**, adaptive modulation and coding**, ARQ, and adaptive compression, found that only under conditions of extreme signal SNR advantage or equivalent conditions would a monitoring 3rd party be able to fully or mostly decode Winlink over PACTOR, WINMOR, ARDOP or VARA messages for messages of significant length. This provides substantial support for the claims that: "…Winlink transmissions are nearly impossible to intercept,…" (see reference 1) There are reasonable and documented methods that the relevant parties could engage to address this issue and support independent per packet decoding by 3rd parties or similar characteristics to address the issue that the loss of a single modem packet renders all following user data 100% obscured (see pages 13 & 14)

Experiments by Gordon L. Gibby were analyzed in detail as well as analysis of experiments by John Huggins. The results agree clearly with the previous paragraph. Gibby was unable to decode

moderately long messages even with controlled over-the-air conditions on 20 meters. He was able to decode several short messages under 3 joint conditions: 1) robust coding for the data by the transmitter possibly due to poor/moderate SNR at the desired receiver; 2) a strong clean signal at the monitoring station; and 3) fairly short messages with a few lines of text. The suggestion to use RX diversity to mitigate (but not solve) this problem is not implemented. Earlier experiments by John Huggins show that an unknown issue constrained the PACTOR-3 modem to only use the 3 most robust modes of the modem in spite of the connected link operating over only about 2 miles with possibly 100 watts on 80 meters. That combined with operating over very short distances and probably very strong signal conditions means that the experiment does not represent typical conditions. Overall these results support the view that: "…Winlink transmissions are nearly impossible to intercept,…" These results do not materially change this understanding.

HF packet data modem technology advances the state of the art substantially and using such technology for emergency purposes is a valuable capability. The findings and comments here are not intended to stand in the way of such innovation nor to hinder emergency services, but are intended to improve clarity on the current status of relevant technical and transparency issues; to provide some paths to correct problems of compliance; and to achieve spectrum allocations in the public interest.

I respectfully urge the Commission to adopt the RM-11831 Petition for Declaratory Ruling by NYU, and to reject WT Docket No. 16-239.

Respectfully submitted,

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