Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of:	)	
	)	**RM-11306**
	)	
Amendment of Part 97 of the Commission's	)	
Rules Governing the Amateur Radio Services	)	
	)	
By	)	
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	)	

REPLY TO THE COMMENTS OF HOWARD TELLER, KH6TY.

The following is my reply, submitted in accordance with 47CFR§1.405(b).

1. Background and Introduction

As one who is interested in the "wide band" digital data modes, and *as the inventor of the PACTOR data transfer protocols,* which are widely used in the Amateur Radio Service, I want to generally address some inaccurate statements regarding the efficiency of current "wide band" digital data modes, and use the mode that I developed[1], PACTOR-III, as a specific example since it was used for inaccurate Comments to the FCC for RM-11306.

I have been the holder of an Amateur Radio license (highest German license class) since 1981, and am an active radio Amateur. I originally majored in the natural sciences, with an emphasis in chemistry and electrochemical measuring systems, at the Technical University of Munich. I have been working on the theory of HF communications systems and implementing the latest algorithms using Digital Signal Processing (DSP) for HF modems since DSP has been a known vehicle for such experimentation and development.

[1] Regardless of any financial interest I may have from the development of the PACTOR protocols, the facts of their performance are still the same.

I offer these replies not only to the specifics involved with the current PACTOR protocols, but also to maintain some integrity of accuracy regarding the *overall development* of high-speed data transfer protocols. I wish to let the FCC know that serious progress has been made in the advancement of such protocol development within the Amateur Radio Service, and has sense permeated throughout the communications industry. With this reply, I also wish to support the American Radio Relay League in their attempt to provide the opportunity for advanced digital communications development in the US through RM-11306.

2. Original Comments and Corresponding Replies

Mr. Teller:

> "The most advanced HF data transfer mode currently available is Pactor-III, in daily use for over 92 % of Winlink Email transfers, and utilizing a maximum bandwidth of 2400 Hz when run on the highest speed. Pactor-III is capable of a speed of 225 characters per second over a wired network, but, according to the statistics at http://winlink.org/status, only achieves and average speed of 15 characters per second on HF circuits."

Reply:

1. The maximum effective throughput of PACTOR-III is 2722 bits per second (340 bytes per second) *without* data compression. For plain text message transfers, usually automatic data compresssion is applied (e. g. Pseudo Markov Compression) and the effective maximum speed frequently (depending on the 1- or 2-dimensional Entropy of the actual text) exceeds 600 characters per second.

2. The maximum bandwidth of PACTOR-III is 2200 Hz at -25 dB. The -40 dB bandwidth (2400 Hz) has no relevance if standard amateur transceivers with a third order intermodulation distance of less than 30 dB are used.

3. According to Mr. Steve Waterman, WinLink system administrator, the mix of PACTOR-I, PACTOR-II, and PACTOR-III is different each day. The figure "92 %" is obviously only a snap shot and cannot be used for general calculations.

4. It is impossible to derive accurate PACTOR-II/III throughput figures from a generalized mixed-mode statistics.

   Stating that PACTOR-III "only achieved an average speed of 15 characters per second <u>on HF circuits</u>," is misleading and does not provide reasonable information about the real performance of the waveform/protocol. Such generalized throughput figures can only serve as a <u>*relative*</u> measure of the overall network performance, but reflect poorly on the technical performance of the utilized physical protocols. How the average channel utilization of a network or the antennas of the mobile users are

improved, is quite a different technical issue, and is not related to the general performance of the underlying transport protocols on the physical layer.
The statistics used by Mr. Teller do not reveal anything about the message overhead, the average signal-to-noise-ratio (SNR), the PACTOR-I/II/III mix, and a reasonably informed engineer will know this.

PACTOR-III achieves a much higher throughput than "15 characters per second" assuming average Amateur signal. This statement can easily be illustrated: 15 characters per second (without data compression) translates to 120 bits per second. PACTOR-III already achieves this low throughput well below an SNR of 0 dB @ 3 kHz noise bandwidth (reference) under all typical channel conditions (e.g. ITU-R F.520 "good", "moderate", and "poor" channel models). SNR's below 0 dB @ 3 kHz noise bandwidth are significantly worse than the average SNR of typical Amateur Radio signals, for example, analog voice contacts (SSB) are hardly possible at such low SNR's.

Obviously, I have conducted multitudinous on-the-air throughput measurements on both PACTOR-II and PACTOR-III. For instance, transferring a 37 kByte plain text file on 3.6 MHz during night time (this usually is the "worst case" for HF modems because of high multipath delay spread and Doppler spread) over a distance of 600 km took only 2.7 minutes. This test utilized 50 Watts average power (RMS) and a 2x12 m long V-dipole 10 meters above the ground. The effective throughput (with compression) corresponded to 228 characters per second.

The results of my throughput measurements are consistent, clear, and in marked contrast to the "average throughput" figures for PACTOR-II/III estimated by Mr. Teller. The average effective speed of PACTOR-III on real-world channels and average signal conditions (50 Watts, dipole) typically varies between 150 and 500 characters per second (with compression), depending on the quality of the channel (delay spread, Doppler spread, burst errors, and other sources of noise). PACTOR-III is highly adaptive and auto-adapts to varying channel conditions.

These field measurements show that when using equal power, PACTOR-III is approximately 3.5 times faster than PACTOR-II. Thus, as PACTOR-III only occupies roughly 5 times more bandwidth than PACTOR-II, it is evident that PACTOR-III has a better average spectral efficiency than PACTOR-II and leaves a much smaller "footprint". The speed factor easily exceeds 5 at the *same power per bandwidth* since then the SNR has to be lowered by 7 dB (10*log(5)) for the throughput comparison in the case of PACTOR-II.

Accurate throughput comparisons between modems are only possible under a controlled environment, i. e. under known, repeatable channel conditions and a given SNR. I have also conducted numerous throughput tests in the laboratory, using an ionospheric simulator. The results obtained under these controlled laboratory conditions closely correlate with the results obtained during on-the-air testing:

I want to present a few results obtained during PACTOR-III tests in the labaratory, using SCS PTC-IIpro modems, latest firmware version 3.6. The noise power is normalized to a bandwidth of 3 kHz, the signal power is the true in-packet RMS power:

SNR:	-3 dB (signal 0.5 S-units below the noise):	
Throughput:	AWGN channel:	317 bps, 39.6 Bps, 75.3 cps.
	ITU "poor" channel:	159 bps, 19.9 BPs, 37.8 cps.
SNR:	+12 dB (signal only 2 S-units above the noise):	
Throughput:	AWGN channel:	2107 bps, 263 Bps, 500 cps.
	ITU "poor" channel:	900 bps, 112 Bps, 214 cps.

(bps = bits per second, Bps = bytes per second without compression, cps = characters per second with automatic compression, compression factor 1.9.)

Mr. Teller:

"The Pactor-II mode, requiring a lower bandwidth of 450 Hz, also used daily by Winlink, achieves an average speed on HF circuits of only 10 characters per second, comparing to a speed of 50 characters per second on a wired circuit."

Reply:

1. The maximum effective throughput of PACTOR-II is 589 bits per second (73.6 bytes per second) *without* compression and can exceed 130 characters per second if automatic data compression is applied.

2. PACTOR-II throughput figures derived from the generalized mixed-mode statistics are as inaccurate and useless as the corresponding PACTOR-III throughput figures as discussed above.

Mr. Teller:

"The main limiting factors on HF that prevent high-speed data transfer are fading, noise, and interference requiring too many necessary repeats of data blocks in order to achieve the error-free transfer needed for data transfer, and severly limiting the achievable speed of data transfer on HF in actual practice."

Reply:

PACTOR-III was especially designed for high-speed data transfers on difficult HF channels. It applies state-of-the-art pulse-shaped Orthogonal Frequency Division Multiplexing (OFDM) coping very well with high delay spreads and Doppler spreads introduced by time-varying multipath channels. Powerful Convolutional Coding (k=7 and k=9) with full-frame interleaving generally improves the weak-signal

performance, and especially, the robustness against burst-errors and short fadeouts. Even in the case of retries, no power is wasted, as all packets are combined (termed "Memory-ARQ") until the SNR of the resulting "super packet" is sufficient for the Viterbi decoder.

Mr. Teller:

"Even the best engineering to date has been unable to achieve high-speed error-free data or multimedia transfer on HF…"

Reply:

Effective throughput figures of more than 2400 bits per second in a 3 kHz HF channel have been common for more than 20 years (well recognized modems from Harris, Rohde & Schwarz, and others.). Digital Radio Mondiale (DRM) and STANAG 4539 are only two examples of numerous modern HF systems achieving up to 9600 bits per second within 3 kHz of occupied bandwidth at relatively low SNR's, quite close to the Shannon bound. Nevertheless, improvements are still possible.

Mr. Teller:

"The current Part 97 regulations limit the symbol rate to 300 baud on the HF bands, and recently it has been shown that higher baudrates are counterproductive, because lower baud rates are necessary for high sensitivity and multi-path rejection. Therefore, there is no overriding need to eliminate the 300 baud limitation on symbol rate, as the ARRL proposes."

Reply:

There are many serial-tone HF modems utilizing high baudrates, e. g. 2400 symbols per second. Strong multipath distortions of relatively short symbols are cancelled with the aid of so-called adaptive equalizers. As serial-tone waveforms show some advantages compared to low baudrate parallel-tone modems (e.g. OFDM) in the high throughput region (>2 bit/Hz), these waveforms should also be generally permitted on Amateur Radio bands. Apart from the increased processing complexity, there are no drawbacks compared to parallel-tone modems. Obviously, with current and future technologies, occupied bandwidth is the major consideration, and not symbol rate.

3. Conclusion

Contrary to the statements of Mr. Teller, high-speed data transfers on voice-bandwidth HF channels are feasible and already in common use. There is no need for discriminating voice-bandwidth error-free data modes on Amateur Radio bands. These waveforms and protocols are a viable part of modern HF communications and offer the opportunity for further improvements and entirely new applications.

At the present time, there is again rapid development in HF digital radio protocols by several companies, including the German PACTOR modem manufacturer Special Communications Systems, SCS[2] that I am associated with. More advanced HF digital radio protocols, developed by companies and/or Amateurs, will definitely appear in the Amateur Radio Service provided that there is ample frequency spectrum in which to operate. In order for the US Amateurs to enjoy these newer modes as their overseas Amateur counterparts, the FCC Part 97 rules will need to be changed to encourage the development and implementation of these modes in the US. I therefore encourage the commission to adopt RM-11306 and specifically delete Part 97.221(c) to encourage the development of newer communications protocols.

Respectfully,

Hans-Peter Helfert, DL6MAA

[2] SCS - Special Communications Systems, Roentgenstrasse 36, 63454 Hanau, Germany