

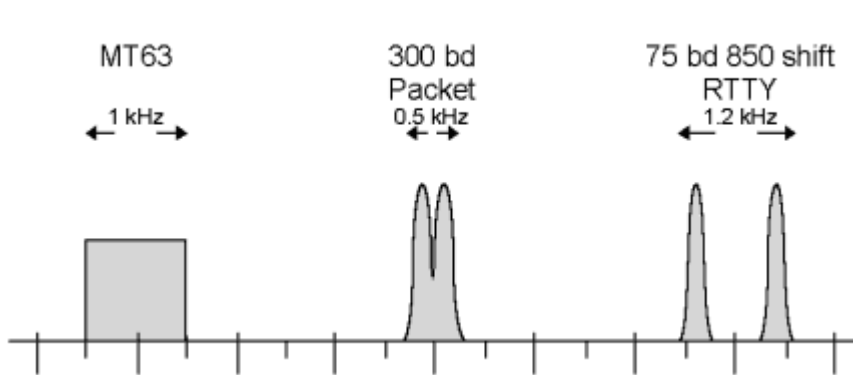
# DIGITAL COMMUNICATIONS

by AD5XJ Ken

## Disclaimer:

These are my comments on digital communications and are not necessarily all there is to know on the subject. As with everything computer related – there are at least six ways to do the same thing. Given this caveat, let me say this is opinion and not the complete story. I only relate to you my experience of 5 or more years using digital modes to give you the benefit of my experience. I will leave the rest for you to research as you see fit.

## PACTOR I



PACTOR (*Latin for: The mediator - contracted from PACket and amTOR*) is a radio modulation mode that uses Frequency Shift Keyed (FSK) modulation or audio frequency shift keying (AFSK). PACTOR was developed in Germany by Ulrich Strate (DF4KV) and Hans-Peter Helfert (DL6MAA) of Special Communications

Systems GmbH (SCS) and released to the public in 1991. PACTOR is an evolution of both Amtor and packet radio, hence the name PAC-TOR. It was developed in order to improve the reception of digital data when the received signal was weak or noisy. PACTOR combines the bandwidth efficiency of packet radio with the Cyclic Redundancy Check (CRC) and Automatic Repeat reQuest (ARQ) error recovery of AMTOR. Amateur radio operators were instrumental in developing and implementing this new digital mode. PACTOR is most commonly used on frequencies between 1 MHz and 30 MHz but theoretically can be used on any amateur frequency where digital communications are allowed. The illustration shows the spectral content of a PACTOR transmission. Notice this is very similar to other 2FSK modes like RTTY, AMTOR/SITOR and G-TOR. The illustration is of PACTOR II, but the PACTOR I waveform is very similar. PACTOR I provides reliable communications with only 170-200 Hz required for the 2FSK transmission scheme at a character rate faster than RTTY and AMTOR.

The PACTOR protocol allows a much higher throughput than AMTOR/SITOR/GTOR, and packet (150 and 300 baud modes on HF) with the efficient error correction and data transparency of packet radio. One should not, however, be under the impression that PACTOR is just a combination of packet radio and AMTOR/SITOR. Although essential parts of both systems have been included, such as data integrity (by using CRC error checking), and multi-frequency data elements from packet radio, and the synchronous transmission format and short block lengths (compared to packet radio) of AMTOR/SITOR, a fully new concept has also been included from the very beginning. For the first time in amateur radio, in-line data compression can be used to markedly increase the effective transmission speed so long as it complies with current FCC guidelines. Also the use of memory ARQ in PACTOR I is a milestone in amateur radio, although it has been known for a long time in the commercial sector.

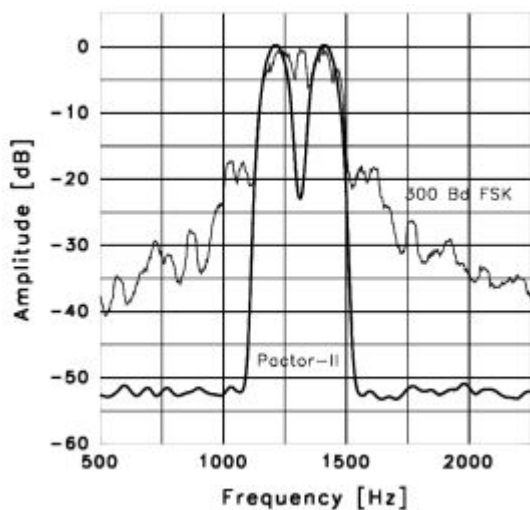
Previously it has been very difficult, or impossible, to apply the concept of memory ARQ in amateur

radio. The use of memory ARQ is the main reason that PACTOR does not lose the link under bad conditions. With memory ARQ, defectively received packets or blocks are not just simply thrown away. They are stored and added to other defective packets, until enough data is collected in memory to reconstruct the original packet, and thus keep the link during operation. The new WinMor protocol will incorporate a similar strategy to provide robustness to its platform.

PACTOR has established itself as a standard for AFSK radio message transport on shortwave amateur and marine radio. PACTOR makes it possible to utilize an almost ideal combination of simple AFSK modulation and ARQ protocol for robust error detection and data throughput. Generational improvements to PACTOR I include PACTOR II and PACTOR III, which are capable of higher speed transmission. These newer versions are used mostly by amateur radio operators to transfer large binary data files and to accomplish transparent Internet E-mail access over shortwave. PACTOR is also used by the SailMail network for e-mail transfer over Marine radio frequencies

HF data transmission by radio amateurs usually use medium power (typically 100 watts or less) over all distances. Such distances over hostile radio paths require that special attention be paid to the rate at which data is repeated, and to error correction methods. To reduce the amount of data sent, in-stream data compression and CRC is utilized, along with memory ARQ. By combining these open technologies, PACTOR achieves a power efficiency much greater than that of older protocols such as packet, AMTOR or RTTY (RTTY has no error correction methods of its' own only CRC error detection). PACTOR I has a very narrow audio spectrum waveform and can occupy the same band space as analog 300 baud packet.

To date, there is only one soundcard software program that can both transmit and receive PACTOR I – “hf”, as it is called, available only on some Linux platforms. There are several that can decode PACTOR I signals in receive only mode (ARQ). Those programs are known as MultiPSK (Windows), Fldigi (Linux, Windows), and MixW (Windows with the addon, plugin module). These programs do not allow software connection to email client programs directly, but text can be cut and pasted when necessary. There is great promise that WinMor will be a soundcard based mode that will surpass PACTOR I and will be free for general amateur use.



## PACTOR II

The PACTOR-II protocol is essentially based on the Level-I standard, consisting of a synchronous half-duplex ARQ protocol.

New, however, is the ability to choose four different data speed steps, so that a greatly improved adaptability is obtained.

The modulation system used for PACTOR-II is based on DPSK (differential phase shift keying) which leads to a very narrow spectrum, virtually independent of the data rate. The robustness of the DPSK modulation qualifies itself noticeably

higher at lower information speeds in comparison to FSK. The illustration shows the audio spectrum use in comparison to 300 baud packet FSK.

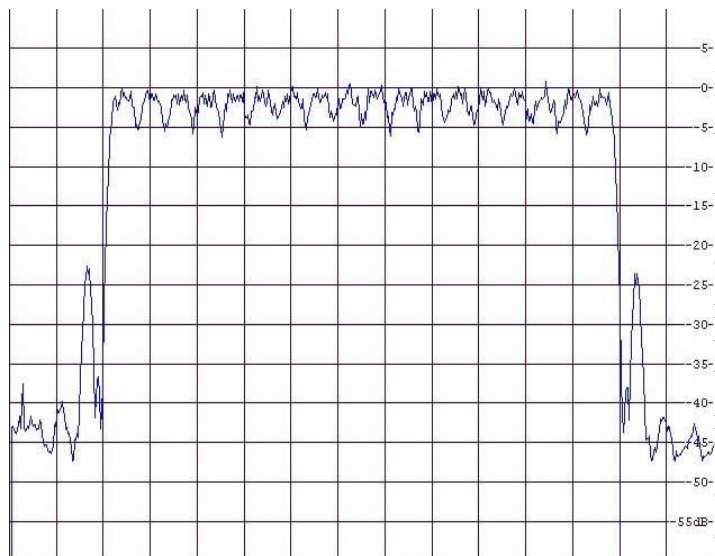
Being more robust than PACTOR I, PACTOR-II uses high performance convolutional coding, that is

evaluated with a real Viterbi decoder in the data receiver. This is a common method for multi-frequency error-correcting protocols today. The high correction capability of the decoder allows not only links with extremely weak or noisy signals, but also, with more normal signals, enables short error bursts, or fadeouts, to be entirely ignored, and a repetition of that packet is not required. This is especially important with PACTOR-II, as the protocol allows switching to a triple cycle length if there is enough data in the transmit buffer. The relatively long resultant data packet would be very prone to impulse errors from clicks or atmospherics (QRN), if not for the highly effective error correction designed.

As with the Level-I protocol, PACTOR-II uses hardware based Huffman coding for text compression on a packet by packet basis. As an alternative, PACTOR-II can also use pseudo Markov coding (also hardware based) as a compression method. Known as PMC, it has been developed by SCS, and increases the throughput of plain text by a factor of 1.3 compared to Huffman coding. The PTC-II modem hardware examines each packet individually to see if it would be faster to send it using Huffman, PMC, or normal ASCII transmission. There are thus no disadvantages incurred by using PMC when using the internal compression provided by the PTC-II. There is a total of 6 different compression variations available for use. The SCS PTC-II modem checks each packet automatically, and then chooses the best compression method for transmitting the data.

Additionally, PACTOR-II uses "run length coding", so that sequences of repeated characters, (e.g. underlining, or columns in graphics), may be transmitted very efficiently. With "run length coding", the system does not transmit each character individually, instead a sample character is sent, followed by the required number of same. Maximum net throughput with in-line data compression: approx. 1200 Bit/sec.

In certain configurations, Pactor II and III utilizes proprietary data compression technology which may be used by the unscrupulous to try to conceal the nature of the transmission. This is illegal on ham radio but it is possible with the SCS modems.



### **PACTOR-III**

Almost all current PTC modems currently available are upgradeable to use PACTOR-III via a software update. PACTOR-III is included as an option in the standard PTC-II firmware. To use PACTOR-III both, transmitting and receiving stations, must support PACTOR-III. If you are a mobile station transmitting to a land based station, both mobile and land stations must be in PACTOR-III mode in order to benefit from the higher data rates PACTOR-III offers.

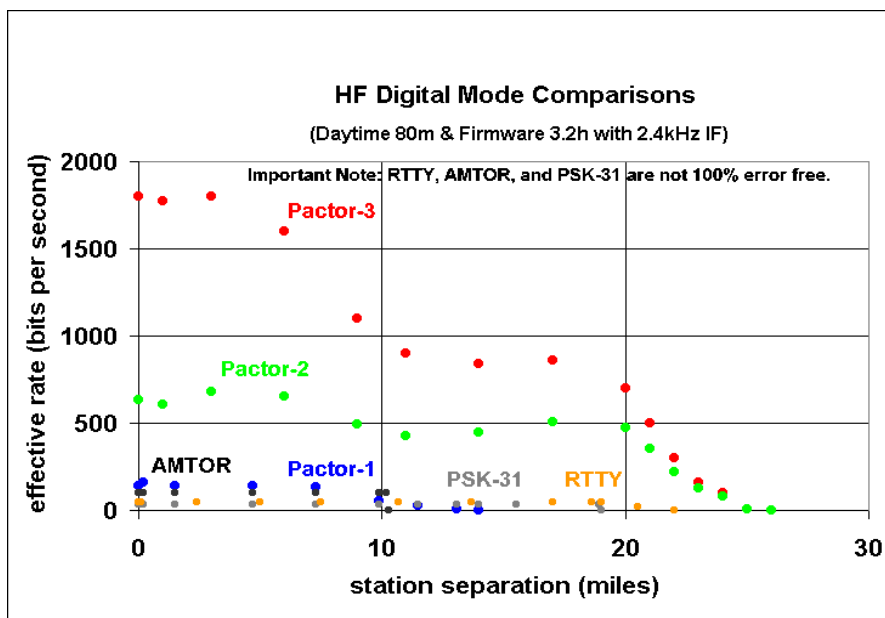
The calling modem uses the PACTOR-I FSK connect frame to be compatible with the lowest level. The called modem then answers and the modems negotiate to the highest possible level both modems are capable of. If one modem is only capable of PACTOR-II, then the 500 Hz PACTOR-II mode is used for the session. With the PTC-II MYLevel command, a user may limit a modems highest mode. An example: a user may set MYL to "1" and a PTC modem will only make a PACTOR I connection, set to "2" and PACTOR I and II connections are

available, set to "3" and PACTOR I through III connections are enabled. The default MYL is set to "2" with the current firmware and with PACTOR III firmware it will be set to "3". If a user is only allowed to occupy a 500 Hz channel, MYL can be set to "2" and the modem will behave like PACTOR-II firmware.

Maximum occupied bandwidth: 2.4 kHz @ -40 dB, audio passband: 400-2600 Hz. The illustration is of the PACTOR III signal at maximum data rate. The scale is 0-3000 Hz.

Notice that the slope of the leading and trailing passband waveform is very steep by design. This requires very high quality audio passband amplifiers and filters to interpret the signal accurately. Some older radios may have too much ringing in the filters or too broad a slope to provide accurate and reliable results. Most modern, solid-state, digital radios are capable of good to excellent results.

Maximum net throughput with proprietary hardware based in-line data compression is approx. 5200 Bit/sec according to the manufacturers web site.



PACTOR III modems are specifically able to use a combination of different data rates, compression methods, internal modulation modes, and error detection/correction methods to quickly adapt to widely varying conditions. There are up to 6 different data rates, four compression methods, and three error correction/detection methods that can be used in any combination. As mentioned earlier, the PACTOR III to PACTOR III connection protocol starts with the base

PACTOR I mode to establish a link and progressively increases the transmission rate to find the best throughput for channel conditions. Using a combination of variable length packet headers, 16-bit CRC error checking, memory based ARQ, adaptive channel audio equalization, DBPSK, and DQPSK, PACTOR III achieves higher robustness at the low SNR edge compared to PACTOR II. On an average channel, PACTOR III is around 3.5 times faster than PACTOR II. On good channels, the effective throughput ratio between PACTOR III and PACTOR II can exceed 5.

The in-line data compression provided by the PTC modems is especially useful for applications which do not allow off-line (file) compression, e.g. email via TCP/IP, etc. However, it is a proprietary compression method and is not widely accepted by some countries as an acceptable compression method. US amateurs should not use the built in compression of the SCS modems, but rather use the compression methods provided by PACLINK and AirMail in all modes including PACTOR I, in order to comply with the spirit of FCC Part 97 and OSEHP guidelines on data encryption.

The illustration shows how effective PACTOR III connections of moderate quality are over other modes. All modes are on 80m in the daytime (moderately poor conditions). Stations separation miles should not be take too literally as an indicator of performance on HF as this graph pertains to specific tests for comparison purposes only.

The negatives of PACTOR II and III are:

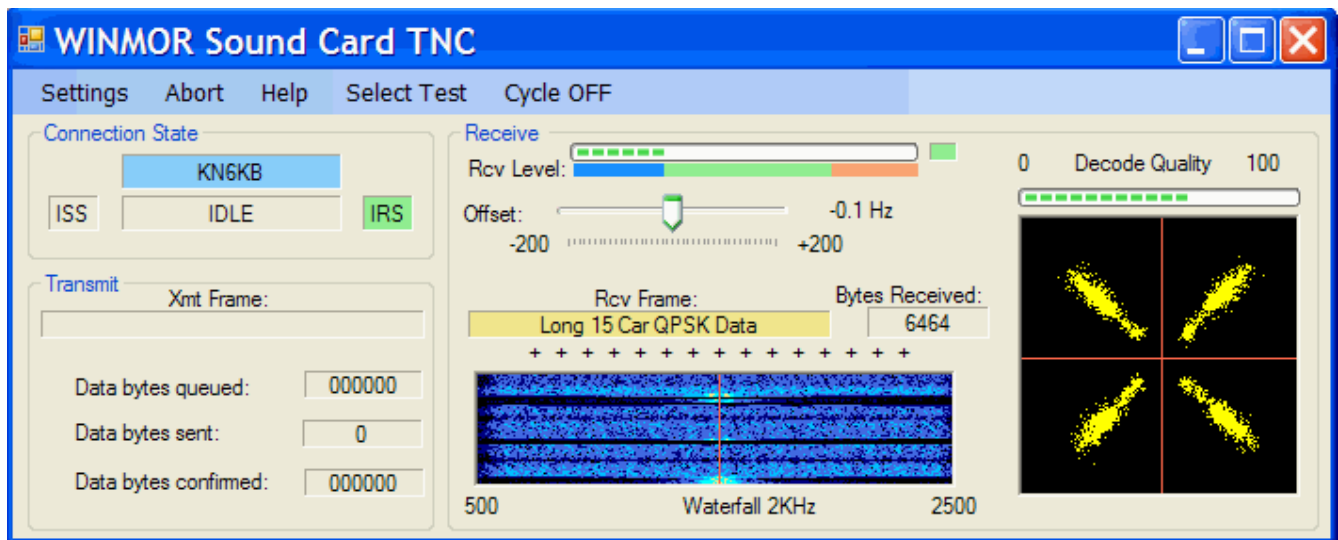
- Cost is an important consideration when choosing PACTOR II and III equipment. PACTOR I is open technology and used modems can be purchased for PACTOR I (e.g. the Kantronics KAM XL and later models of the AEA PK232 modem) in the \$50-\$150 price range and are in ample supply. Only one soundcard software solution currently transmits and receives PACTOR I – “hf” for Linux. The two enhanced modes, PACTOR II and PACTOR III, are much faster but have been kept proprietary by the German company, SCS, that developed PACTOR. As a result, SCS is the only source for modems capable of these modes. The price of these modems (in some cases as much as a recent model HF radio) discourage many potential users. WinMor is due for release soon and should address this concern as it is promised to be released for the public domain for free and exceeds PACTOR I in performance. It is unclear whether it will be for the Windows market only or will be multi-platform in its initial release.
- As wireless Internet connections become commonplace, including satellite Internet service providers and WiFi, users are finding that other reliable ways to communicate that are less costly than proprietary hardware.
- Like all digital radio modulation modes, PACTOR transmissions have the potential to disrupt other modes of communication on the same or nearby frequencies because of bandwidth considerations in data segments of each band, and unattended automated operations. Good operating practices must be followed to avoid potential interference. SCS modems have the ability to detect activity before transmitting but it is an operator selected option. Previously, PMBO operators had this feature turned off. Now the use of this feature is more widely accepted and may be in widespread use soon if not already.

## WINMOR

WINMOR, by Rick Muething KN6KB of the Winlink Development Team, is a new HF radio transmission protocol for the Winlink 2000 system. WINMOR was introduced at the 2008 ARRL / TAPR Digital Communications Conference in Chicago on September 26-28, 2008. Unlike PACTOR II and III, only a simple computer soundcard-to-radio interface is required, and it will run as a "virtual TNC" with PackLink and RMS software. Also unlike PACTOR, it will be fully documented and without restrictions or license issues preventing anyone from using the protocol in other software. It will have at least three modes, ranging from 200 to 2000 Hertz in bandwidth, and will provide raw speeds ranging from 125 to at least 1875 bits per second. This rivals PACTOR II under some conditions.

WINMOR will *NOT* replace PACTOR but be used in addition to PACTOR. The RMS HF servers will be able to operate BOTH WINMOR and PACTOR (1-3) but not simultaneous connections. While WINMOR may not equal PACTOR II and PACTOR III in total performance it will provide lower cost, higher performance and more robustness than PACTOR I. The primary applications will be for those lower usage Emcomm applications which have trouble justifying the high cost and low utilization of the PACTOR II and PACTOR III modems.

This is a screen shot of the WinMor test panel provided in PacLinkW 9.1.0.3. WinMor is being intensely tested by Rick Muething KN6KB and other Alpha level testers to get RMS servers to link with WinMor, PACTOR, and Packet. A Beta test group has been established for when RMS servers are operating reliably with WinMor.



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Just stay with us for more next month on other interesting digital modes. We will have something for you as we go along. If you missed some of this, I will make a printed version available if you email me a request.

I am also a technical specialist so you can email me with your technical questions and problems as well.