

Some Digimodes through different Channels

Nils Schiffhauer, DK8OK, ©2012

Nine popular chat-modes had been put through four different ITU-channels.¹ Those channels were provided by PathSim² of AE4JY.

The ITU channel models do refer to the so-called “Watterson Model” of the ionosphere.³ They consider *four different ways of a signal through the ionosphere*, modulating the original signal in time, frequency and phase. However, the *resulting signal* (“envelope”) can largely be simulated by combining just two “channels”, differing in delay, Doppler spread, and frequency offset.

This model is available in some categories, referring to latitudes (Low, Mid, High) as well as different conditions (Quiet to Disturbed). A special model for short-range shortwave communications (NVIS) has been added.

Watterson’s paper has been transferred – including even some figures, as e.g. his *Fig 8* (see right, but taken from ITU publication) – into the official CCIR-, and then ITU Recommendations. Watterson et al. are summing up:

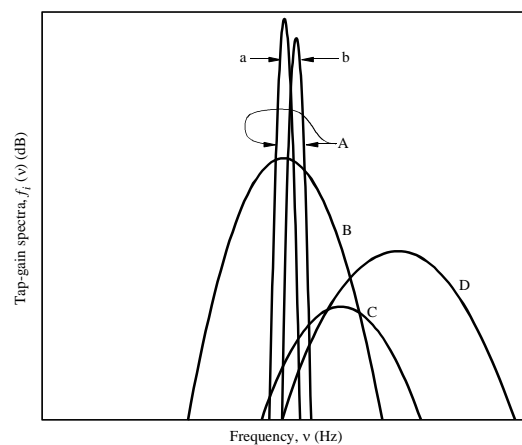
“Since other measurements and analyses have shown HF modal components usually exhibit Rayleigh fading, and since components with time spreads comparable to the measured paths are common, it appears reasonable to assume that the stationary channel is valid for practical bandwidths for a large percentage, if not a majority, of typical HF ionospheric channels.”⁴

The most sophisticated software for this channel model has been written by W7AY, dubbed “cocoaPath” (Mac).⁵ It offers a deliberate number of paths for one signal and, most important, even *different attenuations* for each of the paths. This compensates for two shortcomings of the ITU model, namely its unnatural deep fades, plus it’s restriction to only two paths of one signal.

Another software comes from DL6IAK, the “Ionospheric Simulator”.⁶ As each of the three software provides adding noise (AWGN), this additionally features also the addition of impulses to simulate shortwave even more realistic.

Both PathSim and cocoaPath do provide an excellent introduction into the world of ionospheric simulators, and how to forge them into software.⁷

FIGURE 1
Example power spectra for the multipath components of a CW signal



A: Path 1 (1E mode, a and b represent magneto-ionic splitting)
B: Path 2 (1F mode)
C: Path 3 (Mixed mode)
D: Path 4 (2F mode)

1487-01

¹ http://www.itu.int/dms_pubrec/itu-r/rec/f/R-REC-F.1487-0-200005-1!!PDF-E.pdf

² <http://www.moetronix.com/ae4jy/pathsim.htm>

³ Watterson et al.: Experimental Confirmation of an HF Channel Model. IEEE Transactions of Communication Technology, Vol. COM-18, No. 6, December 1970, pp. 792 - 803

⁴ *ibid.*, p. 802

⁵ <http://www.w7ay.net/site/Applications/cocoaPath/index.html>

⁶ <http://dl6iak.etonlein.de/projects/2000-11-15.htm>

Although I recommend W7AY's software, all 180 measurements had been done with PathSim – just for the reason to stick to one operating system – namely Windows 7/64 Professional.⁸ This was needed to ease the following time-consuming workflow a bit:

- A text of 1000 characters was made, including pangram “The quick brown fox ...” (QBF, recommended by ITU-T Rec. R.52 for exactly this purpose), together with all numbers, a CQ DX Call and some lyrics of “Johnny B. Goode” by Chuck Berry.⁹
- This was coded directly to a WAV-file by Fldigi multimode software by a team around W1HKJ.¹⁰ As PathSim accepts only WAV files of 8 kHz/16 bit, those modes automatically produced at 11,025 kHz had been resampled to 8 kHz by Steinberg's WaveLab 7.¹¹
- The WAV file was sent through the different channels, modeled by PathSim according to IT-R F.1487. In order to scan the most important paths, I opted to Mid-latitudes “Moderate”, “Disturbed” and “Disturbed-NVIS” (covering more than 50% of amateur's communications and emergency, I presume) plus High-latitudes “Disturbed” (for polar paths). There was also added noise (AWGN), resulting in signal-to-noise ratios (SNR) from +6 dB to -15 dB within a 3 kHz channel.
- Those WAV files were decoded in Fldigi's file modus within a 3 kHz sonagram (“waterfall”).
- Eventually, input and output were automatically compared by VE3NEA's software “RTTYCompare”.¹²
As it does only accept the Baudot code set, non-Baudot characters had before been stripped by “MorseCAT”.¹³
- For me, the most important result comparing the performance of different digimodes under different conditions was the “Character Error Rate – CER”, easily provide as percent of the whole file by RTTYCompare.
These figures have been categorized into up to 10 % CER (“good copy”, green), 11 to 30 % CER (“difficult copy”, yellow), and over 30 % CER (“impossible copy”, red); arithmetically rounded.¹⁴
- The findings are presented in a self-explaining EXCEL sheet, see the following pages.

Using ITU model “Quiet”, resulted in large CERs even at just an SNR of -6 dB, confirming the unnaturally deep fading of this model. These results therefore were regarded useless and had been omitted.

As the performance of a mode has also to be seen in respect to its bandwidth and speed, plus depending on the decoding software, you'll find two diagrams dealing with these factors on page 7.

Thanks to all, who provide that software! And especially thanks to Kok Chen, W7AY, who get me on the track to think more about digimodes.

Any comments & critics welcomed: Nils.Schiffhauer@t-online.de

⁷ <http://www.moetronix.com/ae4jy/files/pathsimtech100.pdf> and <http://www.w7ay.net/site/Applications/cocoaPath/Contents/users.html>

⁸ ☹ A rather dull OS with many and often unrepeatable surprises.

⁹ Chess 1691, 1958. It's also part of Voyager's „Golden Record“: <http://voyager.jpl.nasa.gov/spacecraft/music.html>

¹⁰ <http://www.w1hkj.com/Fldigi.html>

¹¹ <http://www.steinberg.net/en/products/wavelab/start.html>

¹² <http://www.dxatlas.com/RttyCompare/>

¹³ <http://www.morsecat.de/download.html>

¹⁴ Following a convincing suggestion of ZL1BPU: <http://www.gsl.net/zl1bpu/>

	<i>ITU-R F.1487 Mid-latitudes, Moderate conditions</i>				
<i>SNR in 3 kHz</i>	<i>6 dB</i>	<i>-6 dB</i>	<i>-9 dB</i>	<i>-12 dB</i>	<i>-15 dB</i>
Modes					
BPSK31	1,3	9,1	16,5	29,1	45,6
Contestia 8/500Hz	0	2,8	9,3	26,8	60,4
Domino EX11	0,9	11,3	16,8	25,7	41,9
MFSK16	0	2,1	11,3	40,8	
MT63 1000 Hz	0	3,5	34,0		
Olivia 8/500 Hz	0	0,4	3,5	17,3	41,6
RTTY 45.45/170 Hz	7,3	31,4			
Thor11	0	1,3	11,2	31,3	
Throb 2	0,6	4,0	15,7	17,6	34,5

	<i>ITU-R F.1487 Mid-latitudes, Disturbed conditions</i>				
<i>SNR in 3 kHz</i>	<i>6 dB</i>	<i>-6 dB</i>	<i>-9 dB</i>	<i>-12 dB</i>	<i>-15 dB</i>
<i>Modes</i>					
BPSK31	4,7	14,1	21,6	35,0	
Contestia 8/500Hz	0	1,7	7,9	24,3	61,5
Domino EX11	4,4	10,2	17,8	29,5	47,2
MFSK16	0	1	8,6	49,5	
MT63 1000 Hz	0	0,6	23,1	76,1	
Olivia 8/500 Hz	0	0,4	3,2	8,6	32,9
RTTY 45.45/170 Hz	11,5	40,0			
Thor11	0	3,2	11,2	35,7	
Throb 2	4,7	10,9	19,8	28,5	35,7

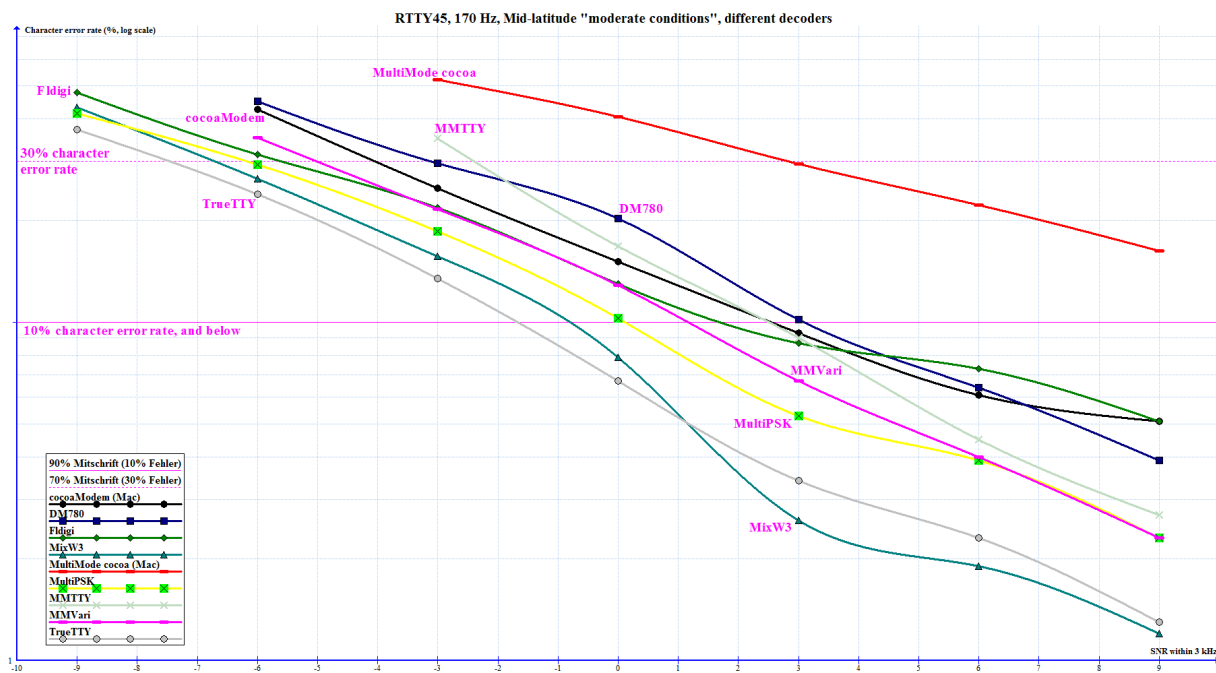
SNR in 3 kHz	ITU-R F.1487 Mid-latitudes, Disturbed NVIS				
	6 dB	-6 dB	-9 dB	-12 dB	-15 dB
<i>Modes</i>					
BPSK31	7,9	15,9	24,3	37,5	
Contestia 8/500Hz	0	2,2	7,7	27,7	68,3
Domino EX11	2,3	10	19,8	30,1	47,0
MFSK16	0,3	0,4	11,4	49,4	
MT63 1000 Hz	0	0,7	34,8		
Olivia 8/500 Hz	0	0,7	1,9	14,0	40,5
RTTY 45.45/170 Hz	8,6	37,4			
Thor11	0	4,1	17,8	53,3	
Throb 2	19,1	22,6	22,8	28,8	35,9

	<i>ITU-R F.1487 High-latitudes, Disturbed conditions</i>				
<i>SNR in 3 kHz</i>	<i>6 dB</i>	<i>-6 dB</i>	<i>-9 dB</i>	<i>-12 dB</i>	<i>-15 dB</i>
<i>Modes</i>					
BPSK31	100				
Contestia 8/500Hz	0	0	3,8	24,3	100
Domino EX11	100				
MFSK16	5,5	36,2			
MT63 1000 Hz	100				
Olivia 8/500 Hz	0	0	0	9,7	48,3
RTTY 45.45/170 Hz	15,7	47,1			
Thor11	100				
Throb 2	100				

Right: The performance of a mode at a given SNR is mostly a trade-off between bandwidth and speed, see figure below. It shows the ITU bandwidth for each mode¹⁵ and the typing speed¹⁶. To calculate the typing speed in characters/minute, I took the time of one transmission of 1000 characters and calculated it. This also includes e.g. overhead in some modes.



Below: Also decoders – and to a part: coders¹⁷ – do play an important part when comparing the performance. To get an overlook, some multimode decoders for PC (DM780, Fldigi, MixW3, MMVari, MultiPSK) and Mac (cocoaModem, Multimode cocoa) have been tested as well as two mode-dedicated software (MMTTY, TrueTTY¹⁸) as well. These tests were performed by playing the WAV file via a virtual soundcard – VAC on the PC, Soundflower¹⁹ on a MacBook Air. This comparison concentrates on RTTY 45,45/170 Hz under channel model “Mid-latitudes, Moderate conditions” only (SNR +9 to -9 dB in 3 dB steps). SNRs, resulting in a character error rate of more than 50%, have been omitted from the figure.



¹⁵ Mostly drawn from the collection of W1HKJ: <http://www.w1hjk.com/FldigiHelp-3.21/Modes/index.htm>

¹⁶ Usual typing speed on a keyboard varies from 115 (slow) to 200 (fast; mine being over 250) characters per minute, see: http://en.wikipedia.org/wiki/Words_per_minute#cite_note-multiple-2. But: Most of the digital communications in ham radio is exchanging prepared macros at *maximum speed of the used mode*. Characters per minute divided by 5 equals words per minute (wpm).

¹⁷ W7AY's cocoaModem provides the cleanest RTTY signal found.

¹⁸ In their appearance: <http://www.hrdsoftwarellc.com/>, <http://www.w1hjk.com/Fldigi.html>, <http://mixw.net/>, <http://hamsoft.ca/pages/mmvari.php>, http://f6cte.free.fr/index_anglais.htm, <http://www.w7ay.net/site/Applications/cocoaModem/index.html>, <http://www.blackcatsystems.com/software/multimode-cocoa-beta.html>, <http://hamsoft.ca/pages/mmtty.php> and <http://www.dxsoft.com/de/products/truetty/>

¹⁹ <http://software.muzychenko.net/eng/vac.htm> and <http://soundflower.en.softonic.com/mac>