RANKING DIGITAL MODES FOR A "STEALTH" QTH

by Ed Sack, W3NRG

Using the digital mode software "MultiPSK"[1] as our guide, we find that there are something like 40 different digital transmission modes available to the amateur radio operator. These modes range from the "historic" (Hellschreiber) to the "classical" (RTTY) to the "relatively recent" (example, OLIVIA.) The availability of software to transmit and receive these modes using the computer sound card has rapidly expanded their use in ham communications.

Some modes are more popular in one part of the world than another. Some are preferred by DXers and some are the every day vehicles for QRP stations. All have had their advocates at one time or another and many have undergone several revisions, as is common with most software development.[2] Most of the articles that discuss the performance of the various modes focus on their utility in DX (or EME[3]) work. We have not found much information which focuses on the ability of the mode to provide useful communications under the very marginal conditions that may occur in a "stealth" QTH where antennas are very limited and local noise conditions may be very severe.

The author attempts to enjoy his amateur radio operations under what might be described as "condo-stealth" conditions. Due to the steel stud construction of the building in which he operates *internal* antennas are essentially useless. The only external antennas that do not attract COA attention are short whips which may be attached to the condo balcony. To make the situation more challenging, the condo building itself sits in the midst of other steel frame structures of similar height. Hence, the "straight shots" for the antennas are in two open paths between the individual buildings. If not all of that was a sufficient challenge, there are some very significant sources of external interference within the line of sight from the QTH

Early tests when first relocated to this QTH indicated that PSK31 was one answer to the option of pursuing the hobby, or not. As time went on, it seemed appropriate to question whether one of the other digital modes would be even more successful under our local conditions. The availability of multi-mode software suites such as MixW and MultiPSK suggested that experiments could be made to evaluate some or all of the many modes they offer.

In order to pursue that question in a more orderly manner, it was necessary to consider criteria for ranking the modes under our particular circumstances. While far from being the only options, it seemed that the bandwidth utilized, the throughput time for a given message and the reception accuracy were pretty fundamental. All other things considered, narrow bandwidth would be preferred since narrow filters could prevent strong local signals from interfering with the reception. Shorter throughput times reduced the chance for periodic pulse signals to knock out portions of the message. The inherent ability of the mode to be decoded under "invisible in the waterfall" conditions was also considered to be a major plus.

At the outset we must qualify our experiments as *"W3NRG QTH specific."* We do not have an RF laboratory or unlimited equipment. The receiving computer is what it is. The receiving sound card is what it is. The physical surroundings are what they are. However, we think that the relative performance of the modes we report here may be a guide to others who are trying to accomplish meaningful digital hamming under difficult conditions.

As a first step, we measured the throughput time for a prepared message (macro) to be "transmitted" for each of the approximately 40 modes (and varieties) available in the MultiPSK software. The macro was long enough that a hand-held stop watch gave reasonable accuracy. These measurements, which range from a message time of about 5 seconds to over a minute are probably accurate to +/- a second. The absolute values of the measurements are not important. Only the relative length is indicative. Note that in those modes where there are settings options (eg. Olivia, Domino EX, etc.) we used the default settings in the MultiPSK software and noted the setting after the name of the mode in our tables.

Table I shows the relative throughput times for the modes that were measured. The transmission times range from a several seconds, as exhibited by BPSK125 and QPSK 125 to over a minute for PSKAM10.

We did not attempt to make our own measurements of bandwidth. Instead we used the values given in the excellent HELP files that come with the MultiPSK application. Again, the absolute values are less relevant than the relative values. Table II gives the bandwidth numbers as reported in the MultiPSK HELP files. These numbers range from 40 Hz for PSK10 to over 1000 Hz for mode 141A.

While there are many other ways of "weighting" and ranking these numbers, we decided to use the *product* of the throughput time and the bandwidth as a first indicator of relative performance. The reasoning was that lower bandwidth with shorter throughput time seemed to indicate more efficient code than higher bandwidth with longer throughput time. Table III gives that product for the modes evaluated. Note again that it is only the relative values that may be significant.

The bandwidth - throughput time products in Table III range from the low thousands for the familiar PSK modes to five figures for some of the higher bandwidth modes. That immediately led to the question, "Is using more bandwidth for slower message transmission necessarily indicative of greater immunity to message errors?" An argument often presented for some of the slower/high bandwidth modes is that they are more immune to fading or multi-path or other propagation related challenges to successful QSOs.

Here is where we probably really "jumped into the deep end of the pool." We have endeavored to measure the throughput accuracy of the various modes under "very marginal" conditions. By "very marginal" we mean conditions where the signal is "down in the noise." Another way of characterizing these conditions could be "signal almost invisible in the waterfall."

Since it was unlikely that we would find all of these modes present on the band at any one time and since attempts to find fellow hams at a distance with the time to labor through the experiments with us did not immediately succeed, we decided to attempt to set up a "test range" within the confines of our condominium.

Setting up the *transmission* end of the "range" was fairly straightforward. The transmitting setup included a Windows XP computer connected to an Icom 706MKIIG through a USB Interface II. The 706 was, in turn, connected via an antenna tuner and a 60 foot run of coax to a 10 meter Hamstick temporarily mounted on the condo balcony railing. We operated the Icom at its lowest power level and cranked back the audio output from the computer to "just a whisper."[4]

The *receiving* setup presented much more of a challenge. First of all, we had to be sure that the signal being received was coming through the receiving antenna rather than the power lines. From our "days in the screen room" we knew that signals over more than one path can really confuse things. In

NAME	P/FSK	RTime
QPSK125	PSK	4.46
BPSK 125	PSK	5.00
PSK220F	PSK	5.80
RTTY75+SYNOP	FSK	7.44
RTTY 75	FSK	8.07
QPSK63	PSK	9.12
BPSK 63	PSK	9.88
AMTOR FEC	FSK	10.48
RTTYM	FSK	10.52
RTTY50+SYNOP	FSK	11.27
DOMINO EX 11	FSK	11.84
RTTY 45	FSK	12.19
HELL 80	FSK	13.24
CONTESTIA 32-1k	FSK	13.45
CHIP64/128	PSK	13.52
PSK 63F	PSK	16.56
MT 63 1k	FSK	17.00
141A	FSK	17.23
MFSK 16	FSK	18.14
BPSK 31	PSK	18.49
PACTOR 1 FEC	FSK	18.70
QPSK31	PSK	18.87
PAX2	FSK	19.16
DOMINO F	FSK	19.32
PSKAM50	PSK	20.95
PSKFEC31	PSK	22.59
FM HELL	FSK	26.15
PSK HELL	FSK	26.64
FELD HELL	FSK	28.33
MFSK 8	FSK	30.09
OLIVIA 32-1K	FSK	30.58
PSKAM31	PSK	33.45
PSK10	PSK	34.91
THROBX	FSK	35.14
THROB2 bd	FSK	36.11
PSKAM10	PSK	103.55

Table I - Relative Transmission Times
RTime in seconds

NAME	P/FSK	BWidth
PSK10	PSK	40
PSKAM10	PSK	50
THROB 2 bd	FSK	72
BPSK 31	PSK	80
QPSK31	PSK	80
PSKAM31	PSK	80
THROBX	FSK	94
FM HELL	FSK	130
PSK 63F	PSK	140
QPSK63	PSK	160
BPSK 63	PSK	160
PSKFEC31	PSK	160
PSK HELL	FSK	170
DOMINO EX 11	FSK	194
DOMINO F	FSK	213
PSKAM50	PSK	260
FELD HELL	FSK	300
MFSK 16	FSK	316
MFSK 8	FSK	316
QPSK125	PSK	320
BPSK 125	PSK	320
PSK220F	PSK	430
CHIP64/128	PSK	580
RTTY75+SYNOP	FSK	600
RTTY 75	FSK	600
RTTYM	FSK	600
RTTY50+SYNOP	FSK	600
RTTY 45	FSK	600
PACTOR 1 FEC	FSK	600
AMTOR FEC	FSK	800
HELL 80	FSK	800
MT63 1k	FSK	1000
PAX2	FSK	1000
CONTESTIA 32-1k	FSK	1000
OLIVIA 32-1k	FSK	1000
141A	FSK	2000

Table II - Reported Bandwidths
BWidth in hz

addition, we had to find a place in our condo where the signal being received was small enough that reception was truly "marginal."

We elected to eliminate the second path problem by using battery power for both the receiver, an Icom IC-R10 and the computer, a Dell Inspiron 7000 laptop. We kept the cable between the two as short as possible. As best we could tell, we were successful. With the stub antenna disconnected from the R10 there was no indication that any of our test transmissions were being detected.

Because of the use of steel studs in the interior walls and rebar and mesh in the exterior walls and floors, each room acts a bit like an imperfect Faraday cage. That is bad news when it comes to the use of indoor antennas but good news in terms of the opportunity to provide a convenient test range. We found a "test location" for the receiving setup in the condo where the signal strength of our test transmissions was truly marginal. Only a very robust mode would provide 100% good copy at the receiving setup.

Another advantage of the location we chose for the receiving setup was that there was an open hallway between it and the "ham shack." We could, therefore, use a remote access computer program[5] to view and control the transmitting computer via a second computer at the receiving site. That way we could select the mode, set the format for the macro for that mode, check the transmitter audio drive and initiate the test transmission without having to run back and forth to the transmitting setup.

Table IV shows the percent (stated as a decimal) "copy" of the transmitted message reported correctly on the receiving setup computer screen. The percents shown are "eyeball estimates." In the table, a "1" means that the copy was perfect, while a decimal rating of 0.45 indicates that slightly less than half of the transmitted symbols were properly reproduced.

Transmission of a fixed macro was repeated several times for each mode and a separate reception percent then recorded for each transmission. We found that the test results were reasonably reproducible and grouped around an average that was then transferred to this table. Periodically an earlier test would be repeated to see if there was any "drift" in the results over time. We did not find any.

Three modes Domino EX, FM Hell and Olivia all exhibited such accurate copy in repeated tests that we assigned them the value of 1 (or 100%). As the table shows, the copy accuracy for other modes ranged on down to very low levels of copy, or no copy at all.

Naturally we were concerned about the "low copy" and "no copy" results. Were there other factors in the experimental setup which were causing those modes to show poorer results in our tests? What about computer speed? Were some modes being disadvantaged by the relatively slow speed (by current standards) of the Inspiron 7000 notebook?

In an attempt to answer that question, we substituted a Compac laptop (1.7 GHz CPU clock) for the Inspiron laptop (250 MHz) and repeated many of the experiments. (We adjusted the gain in the Compac audio input until the test transmissions of modes such as Domino EX, PSK31 and RTTY 45 exhibited the same copy accuracy as had been recorded using the Inspiron computer.) We then retested the modes that had shown "low copy" or "no copy" in the tests with the Inspiron computer. We did not get any improvement in the results.

Another advantage of redoing many of the tests with a second computer was that a different "sound card" was in play. The sound card in the Inspiron uses an ESS chip set. The "sound card" in the Compac employs a Conexant chip.

Having already offended some by the use of the bandwidth - throughput time product for a first ranking of mode performance, we went on to create a second ranking that factored in the "Copy" number for performance ranking of the modes. In Table V, the BWxRT number is divided by the Copy number expressed as a decimal. Our argument is that a ranking that favors the combination of narrow

NAME	P/FSK	BWidth	RTime	BW_X_RT
PSK10	PSK	40	34.91	1396
QPSK125	PSK	320	4.46	1427
QPSK63	PSK	160	9.12	1459
BPSK 31	PSK	80	18.49	1479
QPSK31	PSK	80	18.87	1510
BPSK 63	PSK	160	9.88	1581
BPSK 125	PSK	320	5.00	1600
DOMINO EX 11	FSK	194	11.84	2297
PSK 63F	PSK	140	16.56	2318
PSK220F	PSK	430	5.80	2494
THROB 2 bd	FSK	72	36.11	2600
PSKAM31	PSK	80	33.45	2676
THROBX	FSK	94	35.14	3303
FM HELL	FSK	130	26.15	3400
PSKFEC31	PSK	160	22.59	3614
DOMINO F	FSK	213	19.32	4115
RTTY75+SYNOP	FSK	600	7.44	4464
PSK HELL	FSK	170	26.64	4529
RTTY 75	FSK	600	8.07	4842
PSKAM10	PSK	50	103.55	5178
PSKAM50	PSK	260	20.95	5447
MFSK 16	FSK	316	18.14	5732
RTTYM	FSK	600	10.52	6312
RTTY50+SYNOP	FSK	600	11.27	6762
RTTY 45	FSK	600	12.19	7314
CHIP64/128	PSK	580	13.52	7842
AMTOR FEC	FSK	800	10.48	8384
FELD HELL	FSK	300	28.33	8499
MFSK 8	FSK	316	30.09	9508
HELL 80	FSK	800	13.24	10592
PACTOR 1 FEC	FSK	600	18.70	11220
CONTESTIA 32-1k	FSK	1000	13.45	13450
MT63 1k	FSK	1000	17.00	17000
PAX2	FSK	1000	19.16	19160
OLIVA 32-1k	FSK	1000	30.58	30580
141A	FSK	2000	17.23	34460

Table III - Relative Bandwidth Throughput Time Product

NAME	P/FSK	Copy
DOMINO EX 11	FSK	1
FM HELL	FSK	1
OLIVIA 32-1k	FSK	1
RTTYM	FSK	0.97
MFSK 8	FSK	0.95
PSK10	PSK	0.93
DOMINO F	FSK	0.92
THROBX	FSK	0.91
PSKFEC31	PSK	0.9
PSKAM50	PSK	0.9
CONTESTIA 32-1k	FSK	0.9
BPSK 31	PSK	0.87
MFSK 16	FSK	0.87
PSKAM10	PSK	0.85
PSK 63F	PSK	0.83
PSKAM31	PSK	0.83
QPSK31	PSK	0.5
RTTY 45	FSK	0.45
PSK HELL	FSK	0.17
BPSK 63	PSK	0.13
THROB 2b	FSK	0.1
RTTY50+SYNOP	FSK	0.07
FELD HELL	FSK	0.07
RTTY75+SYNOP	FSK	0.03
QPSK63	PSK	0.02
BPSK 125	PSK	0.01
QPSK125	PSK	0
PSK220F	PSK	0
CHIP64/128	PSK	0
PAX2	FSK	0
HELL 80	FSK	0
RTTY 75	FSK	0
AMTOR FEC	FSK	0
MT63 1k	FSK	0
PACTOR 1 FEC	FSK	0
141A	FSK	0

Table IV - Message Copy

bandwidth, short transmission time and best possible copy "fits" our search for a good digital mode for a "stealth" QTH.

Of course Table V has to be used with reference to the data in the previous tables. As example, PSK10 shows well because of its narrow bandwidth and acceptable copy numbers but is probably too slow in general ham application to justify its being a "first choice" under most conditions.

On the other hand, Domino EX provides a respectable combination of all of the factors as does BPSK31. Certainly no one has to encourage the ham community to utilize BPSK31 today. Its utility as a

NAME	P/FSK	BWidth	RTime	BW_X_RT	Copy	[BWXRT]/Copy
PSK10	PSK	40	34.91	1396	0.93	1502
BPSK 31	PSK	80	18.49	1479	0.87	1700
DOMINO EX 11	FSK	194	11.84	2297	1	2297
PSK 63F	PSK	140	16.56	2318	0.83	2793
QPSK31	PSK	80	18.87	1510	0.5	3019
PSKAM31	PSK	80	33.45	2676	0.83	3224
FM HELL	FSK	130	26.15	3400	1	3400
THROBX	FSK	94	35.14	3303	0.91	3630
PSKFEC31	PSK	160	22.59	3614	0.9	4016
DOMINO F	FSK	213	19.32	4115	0.92	4473
PSKAM50	PSK	260	20.95	5447	0.9	6052
PSKAM10	PSK	50	103.55	5178	0.85	6091
RTTYM	FSK	600	10.52	6312	0.97	6507
MFSK 16	FSK	316	18.14	5732	0.87	6589
MFSK 8	FSK	316	30.09	9508	0.95	10009
BPSK 63	PSK	160	9.88	1581	0.13	12160
CONTESTIA 32-1k	FSK	1000	13.45	13450	0.9	14944
RTTY 45	FSK	600	12.19	7314	0.45	16253
THROB 2 bd	FSK	72	36.11	2600	0.1	25999
PSK HELL	FSK	170	26.64	4529	0.17	26640
OLIVA 32-1k	FSK	1000	30.58	30580	1	30580
QPSK63	PSK	160	9.12	1459	0.02	72960
RTTY50+SYNOP	FSK	600	11.27	6762	0.07	96600
FELD HELL	FSK	300	28.33	8499	0.07	121414
RTTY75+SYNOP	FSK	600	7.44	4464	0.03	148800
BPSK 125	PSK	320	5.00	1600	0.01	160000
QPSK125	PSK	320	4.46	1427	none	
PSK220F	PSK	430	5.80	2494	none	
RTTY 75	FSK	600	8.07	4842	none	
CHIP64/128	PSK	580	13.52	7842	none	
AMTOR FEC	FSK	800	10.48	8384	none	
HELL 80	FSK	800	13.24	10592	none	
PACTOR 1 FEC	FSK	600	18.70	11220	none	
MT63 1k	FSK	1000	17.00	17000	none	
PAX2	FSK	1000	19.16	19160	none	
141A	FSK	2000	17.23	34460	none	

Table V - Adding a Factor to Rank Bandwidth, Throughput Time and Copy

worldwide QRP DX vehicle is well established. Perhaps over time Domino EX will begin to be adopted as enthusiastically by the community as well.

What about the modes that showed very low to no "copy" in our tests (reference Table IV)? If our data is correct, we would not consider those modes for our "stealth" QTH. On the other hand, we have to assume that most of those modes work well under certain circumstances.

As a side experiment, we cranked up the output on the transmitting setup and repeated the copy tests on several of so called "no copy" modes. Two of them, PAX2 and CHIP64/128, which had shown "no copy" under our "marginal conditions" settings then exhibited 100% copy.

One of the observations we made during our tests was that a mode that made it easy to put the waterfall cursor on the proper point for copy to begin was likely to find favor under "marginal" conditions. Signals that are almost invisible in the waterfall are sometimes capable of good copy if either the operator or the software can find the proper point in the audio spectrum. When the energy of the signal in the waterfall is concentrated in a narrow line - as example with BPSK31 - we found it to be relatively easy to put the cursor on the point for best copy even when the software appeared to be a bit confused as to how to tune. On the other hand, when the signal was distributed over a larger portion of the waterfall - as is the case with some of the FSK modes, we found it possible to miss the chance for good copy unless some patience was exercised in moving the cursor up and down over the expected range.

CONCLUSIONS

It is truly a tribute to the hobby of ham radio that so much innovative software has been written for amateur digital mode operations. The creators of these programs who offer them at no cost to the amateur community deserve praise and recognition. Nothing we present in this article. should be interpreted as in any way demeaning the value of each and every of the available modes.

Judging by the articles and pamphlets on the topic, the issue of "stealth" condo (or homeowners association) hamming impacts a significant slice of the amateur radio community. Operating "QRP" with low visibility antennas is a way of life for these stations. We believe that the digital modes provide one answer to that challenge. Searching for the digital modes which appear to favor such operation becomes an important aspect of a solution. To the degree that the author's data is representative, those modes which lie at the top of the list in Table V would appear to be an excellent starting point for that search.

NOTES:

1. "MultiPSK," Steve Ford. QST, January 2004, page 55.
See also http://f6cte.free.fr/index_anglais.htm for the latest updates to the software and associated information

2. The HELP files that accompany the MultiPSK software include an excellent summary of the key aspects of the various digital modes under the heading "RX/TX modes, selection and their description." In addition, supporting information on most modes may be found on the internet by entering the mode name into a common search engine. See: http://sharon.esrac.ele.tue.nl/mirrors/zl1bpu/MFSK/Index.htm as an example.

3. A relatively new mode, JT65 (http://www.arrl.org/FandES/field/regulations/techchar/18JT65.pdf.), is reported to exhibit unusually good weak signal capabilities. However, to the best of our knowledge it is not yet being promoted as a general communications mode. We therefore did not attempt to include it in this study.

4. In setting up these experiments, we were mindful of a possible concern that we might cause some external interference during the time we were making the test runs. Several factors appeared to indicate that the chances of interference were very small. First of all the output power employed, as measured on an MFJ-904 combined SWR/Wattmeter, measured less than a 100 milliwatts (barely moved the forward power needle.) Second, we were able to monitor the waterfall on the "transmitting" setup between tests and could have discontinued the work if we saw any evidence of external signals. We saw none.

5. http://www.anyplace-control.com/