

# MFSK for the New Millennium

Following in the wide wake of digital-mode revolutionary PSK31, MFSK (in its myriad flavors) is raising the digital performance bar ever higher. And, like PSK31, all you need to get into the action is a computer, a sound card and a free download. Try the newest super-RTTY for yourself!

Over the past two years, digi-mode DXers have had access to “designer” digital modes that offer greatly improved HF performance when compared to “classic” RTTY. The best-known “RTTY replacement” is probably PSK31, which is a great DX performer with high and low power alike. Several landmark PC programs for PSK31 are now available and have recently been reviewed in many Amateur Radio magazines.<sup>1,2</sup>

Unfortunately, none of these digital modes—PSK31 included—has been able to counter *all* of the problems prevalent on HF. The list of troubling phenomena includes multi-path reception, Doppler flutter and severe lightning and man-made noise (common on 160 to 40 meters). To counter these effects, some hams have resorted to “fuzzy” image modes such as Feld-Hell and PSK-Hell.<sup>3</sup> I can now report that major progress has been made in solving *all* of these problems with a true digital mode.

The new mode is MFSK16, and it uses techniques from the '60s and the latest advances in digital signal processing to provide truly remarkable results. MFSK16 won't replace PSK31 completely, although it provides a viable alternative when other modes won't get through. It could replace RTTY, however, and by the time you read this you may have already heard its distinctive sound on the bands.

## History

The first multi-tone data mode wasn't digital—it was “fuzzy.” The LMT Seven Tone Radio Mode<sup>4</sup> dates from 1937 and

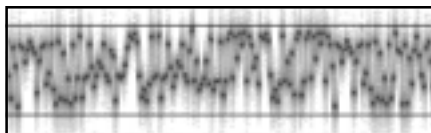


Figure 1—An MFSK16 spectrogram (the horizontal lines are 300 Hz apart).

was used to portray text as images, rather like Hellschreiber. The best known examples of digital MFSK (Multi-tone Frequency-Shift Keyed) modes are Piccolo<sup>5</sup> and Coquelet<sup>6</sup>, which both date from the early 1960s.

MFSK is really a type of super-RTTY, and it's difficult to understand why hams didn't adopt it (or adapt it) years ago. The MFSK technique was developed during the heyday of HF teleprinter communications as a way to combat multi-path propagation problems and provide reliable point-to-point communications with relatively simple equipment. Piccolo, for example, was used on diplomatic links between England and Singapore, and typically provided good copy for an hour after RTTY links had faded out. The technology was then electromechanical, but several key principles were recognized and exploited at the time:

- Performance (reduced error rate) improved as the number of tones used increased.
- Performance was best when the least number of symbols<sup>7</sup> was used to represent each transmitted text element.<sup>8</sup>
- In systems that used special integrating detectors, tones spaced as closely as the baud rate could be uniquely detected without cross-talk.

Piccolo and Coquelet both used two

symbols per text character—compared to 7.5 for RTTY and 3 to 12 for PSK31. MFSK16 uses only *one* symbol per signaling element! With MFSK, the baud rate (the rate at which symbols are transmitted) is quite a bit lower than the text rate because each symbol carries more information in its frequency properties than RTTY or PSK. Although it is somewhat confusing, this technique has an advantage because “longer” symbols are easier to detect in the presence of noise, they have a narrower bandwidth and are much less affected by multi-path timing errors.

Piccolo originally used as many as 32 tones, but the most common form used six. Coquelet generally used 12 tones. MFSK has recently been tested with as many as 64 tones, although the released version, MFSK16, uses 16 tones and the weak-signal variant, MFSK8, uses 32.

The integrating detector used in Piccolo was a milestone in FSK detection techniques in its day.<sup>9</sup> Without going into great detail, narrow active filters with very high gain were used to detect each tone. By carefully choosing the baud rate and tone-channel spacing and resetting the filters at the start of each symbol period it was possible to reliably detect very weak tones without cross-talk. In fact, the response of the adjacent channels produced a null at the sampling point. This helped with noise rejection and prevented energy resulting from ionospheric effects on one tone from appearing in the next channel.

With the advent of satellite communications and high-speed ALE (Automatic Link Establishment) systems, these older commercial MFSK modes have largely fallen into disuse. The concepts and the

<sup>1</sup>Notes appear on page 36.

technology are still viable, however, and should be of great interest to radio amateurs faced with the age-old problems of multi-path, Doppler instability and interference.

## The New Approach

In searching for a better way to hold reliable long-path QSOs, I looked at what made copy difficult with existing modes and what could be done about it. It was obvious that phase-shift keying (PSK), unless relatively high speed, wasn't practical. The incidental phase errors introduced by an unstable ionosphere (particularly in polar regions) typically exceed the phase modulation of the signal. Frequency-shift keying (FSK) and on-off keying also perform poorly, but principally because the arrival time of signals vary, often by as much as five to 10 ms, depending on the path, and perhaps by as much as 30 ms between long and short paths. This interval is longer than the signaling duration of a 22-ms RTTY symbol—and multi-path reception is the reason why so many RTTY signals, even strong signals, don't print reliably.

While casting around for a better method, I revisited the MFSK techniques mentioned previously. At the same time I also reviewed the advances made in modern PC and sound card DSP technology, which were light years ahead of 1960's hardware, especially in compactness and simplicity. Putting these together, I had all the necessary building blocks to replicate and enhance the old MFSK modes using nothing more than a PC with a sound card!

I decided to kick things off by sending a specification for the new mode to a bunch of DSP, coding and software experts, and a remarkable collection of ideas and offers of assistance resulted. Nino Porcino, IZ8BLY, of Hellschreiber and MT63 fame, quickly turned the specification into reality. The result has been tested thoroughly in real and simulated conditions. The first QSO using this new mode (between Nino and myself) was over an 11,000-mile long-path connection on 17 meters. We had 100% copy using 25 W and dipole antennas—so the specification can't be too far off the mark!

That amazing day was June 18, 2000, and since then we have been in communication using this mode almost every day. Most days we work 20 or 17 meters using as little as 5 W.

As with the popular PSK31, all you need to run this amazing new mode is a Pentium-class PC with a sound card and a couple of simple cables. You could even use it with the QRP transceiver designed by Dave, NN1G.<sup>10</sup> The first software for MFSK16 is called *Stream* and is available



Figure 2—*Stream* in the MFSK16 mode.

from the MFSK Web site<sup>11</sup> or from IZ8BLY.<sup>12</sup>

## The Signal

What does this new mode consist of? Well, there are 16 tones—sent one at a time—at 15.625 baud and spaced 15.625-Hz apart. Each tone represents four binary data bits. The transmission is 316-Hz wide and has a ITU-R specification of *316HJ2B*.<sup>13</sup> It's exactly like RTTY, but with 16 closely spaced tones instead of two wider-spaced tones. With a bandwidth of 316 Hz, the signal easily fits through a narrow CW filter.

The tones are continuous phase keyed, which eliminates keying noise, and the phase information can be used to determine tuning and symbol phase. Figure 1 shows an MFSK16 spectrogram (the horizontal lines are 300-Hz apart).

Unlike Piccolo or PSK31, no special arrangements are made to transmit symbol timing, which can be recovered from the inherent properties of the signal. One critical factor, like RTTY, is that the signal is of constant amplitude and does *not* require a linear transmitter to maintain signal purity.<sup>14</sup> Unlike SSB and PSK31, overdriving the transmitter will *not* make an MFSK16 signal any wider.

To ensure that text is received with an absolute minimum of errors, the new mode incorporates an excellent forward error-correction (FEC) technique using *Viterbi* decoder routines developed by Phil Karn, KA9Q, and a clever self-synchronizing interleaver developed for MFSK by IZ8BLY. The typing rate, even with FEC, tops 40 WPM. This speed is achieved by efficient coding techniques, including a varicode similar to PSK31, which provides an extended ASCII character set.

Finally, the receiver detector uses a synchronous Fast-Fourier-Transform (FFT) routine, a DSP technique that exactly models the original Piccolo integrating detector. The FFT also provides phase information, automatic frequency control (AFC) and a "waterfall" tuning display.

The filter provides 4-Hz channels and is easily able to separate the 16 closely spaced tones.

The signal has an amusing musical sound, is quite narrow, is clean to tune across and not unpleasant to listen to. The sound is certainly better and the bandwidth narrower than many HF modes in use today.

## First Impressions

Downloading the software and installing it is very simple. The "help file" is also available as separate download, so you can read that before you install the software. Figure 2 shows *Stream* in MFSK16 mode.

At first glance the software is well laid out and similar in appearance to *IZ8BLY Hellschreiber* or *MT63*, which isn't surprising, considering its origin. It has a generous collection of tools along the top of the screen, separate transmit and receive windows, a good collection of definable "macro" buttons and an excellent "waterfall" tuning display. Along the bottom is a list of settings and parameters, plus the date and time. There is also a drop-down log window for automatic logging and insertion of QSO information and a useful "QSP" window for relaying incoming text.

Nino's software actually includes *three* new modes! The default mode is MFSK16 (16-tone, 16-baud MFSK with FEC). Next is a slower, but more sensitive, variant called MFSK8 (32-tone, 8-baud MFSK with FEC). Both modes share the same 300-Hz bandwidth, but sound quite different. The other new mode is Nino's PSK63F, which is a 63-baud PSK mode that's similar to PSK31, but faster and with full-time FEC. PSK63F has about a 100-Hz bandwidth.

The MFSK and PSK modes are complementary, as Nino's new mode is great for short-path DX and local QSOs. You'll have no trouble telling them apart, and no trouble telling Nino's PSK63F from PSK31 because it is twice as wide. As a standard of comparison [and perhaps the ultimate in convenience—*Ed.*], the software includes PSK31 as well!

*Stream* is quite simple to use—start typing and it transmits; press F12 to end the transmission. The challenge comes in getting a signal lock. It takes some skill and a certain amount of patience to learn how to properly and efficiently tune an MFSK signal. I'm confident you'll agree that the results are worth the effort.

Because the tones are closely spaced and the filters quite narrow, you *must* have a stable transceiver and you *must* use software tuning—not transceiver tuning and certainly not the RIT! The software tunes up and down in 1-Hz steps. Click on the waterfall, with its zoom

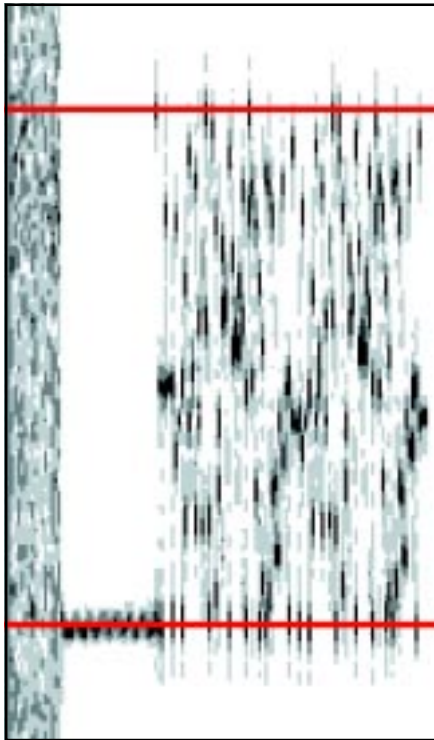


Figure 3—The *Stream* waterfall display in 3X zoom

function, for exact tuning.

The software's AFC is good, but you need to be within about 5 Hz of dead center to get a good response. The AFC works on the idle tone, which appears at the start of every over and also during transmission. Whenever the AFC is active, the Phase Scope comes alive. You can also manually tune by clicking on the waterfall display in just the right spot or by using the Up/Down frequency buttons to tweak the tuning.

There's an interesting display alongside the Phase Scope that shows the Symbol Clock Alignment. This display is a great indication of ionospheric stability! The Bit Shape display is a small oscilloscope that shows what the symbol sync is working with (this is a type of correlator).

Tuning is done using an excellent waterfall display. Figure 3 shows this display in 3X zoom mode. Under the lower horizontal line (red on the screen) you'll see a broad band towards the left. This is the idle carrier, the lowest of the 16 tones. This carrier is transmitted briefly at the start of each over and returns at the end, or whenever the operator stops to think. To tune the signal correctly, center the red line on this carrier and the AFC will keep it there. During the over you'll see little black vertical stripes all over the waterfall, with gray "side-lobes" above and below. These are the transmitted symbols, and once again, you can adjust the software tuning so the red line centers on the

## Is it Legal?

MFSK16 uses publicly available software, and the source code, algorithms and codes are all public domain.<sup>15</sup>

In that sense the mode is open, unencrypted and publicly available. In fact, users with the ability could write their own versions. I hope that other versions will appear, including a *Linux* version.

According to Chris Imlay, W3KD, ARRL General Counsel,<sup>16</sup> the legality of new modes in the USA should be determined by reviewing FCC Part 97, section 97.3(c), to determine which emission type applies (based on the emission designator, in this case F1B). This is the same emission designator as RTTY. According to both Chris Imlay and Paul Rinaldo, W4RI (ARRL Technical Relations Manager), MFSK16 meets the FCC requirements for a legal HF digital mode.

Of course, *where* to operate the new mode also depends on its emission type. MFSK16 calling frequencies on DX bands are 10.147 MHz USB (indicated dial frequency—that's 10.148 MHz idle carrier), 14.080 MHz USB, 18.105 MHz USB and 21.063 MHz USB.—ZL1BPU

lowest of these symbols. Unfortunately, while this is easy when the signal is already tuned, finding the correct spot on a weak signal during a transmission isn't so simple and takes a little practice.

Once you've found the right spot, almost-perfect text will start to appear on the screen, delayed by three to four seconds as the data trickles through the error-correction system and appears one or two words at a time. You'll soon get used to that.

The mode is a delight to use once you learn to tune it. The typing speed is fast and, while transmit-receive changeover isn't as fast as RTTY or Hellschreiber, it's fine for conversing and net operations.

## Performance

Well, this *is* the telling factor, isn't it? For short-path QSOs out to 8000 miles (with no polar propagation), MFSK16 works fine but you may find PSK31 easier to use. If you're interested in QRP, MFSK16 appears to be the hands-down winner. Over long-path and polar routes—and when conditions are really nasty—MFSK16 stands alone. It keeps giving almost perfect copy when signals are barely audible, have bad fades, noticeable Doppler, multi-path distortion and even QRM. High power *isn't* necessary.

MFSK16 is also probably the best mode yet for digital work on the lower bands. If you are into traffic handling or sending bulletins on 80 or 40 meters, give this mode a try. It just doesn't give up! 80 meters is especially prone to multi-path, as RTTY and Feld-Hell users know. On nighttime 80-meter QRP circuits, MFSK16 will work over thousands of miles with 90% perfect copy! As a bonus, lightning effects are largely ignored.

Although not noticeably better on the low bands, MFSK8 is great to have when the band starts to die. It's definitely more sensitive than MFSK16 and, although tuning is very tight and typing speeds are down to 25 WPM, it will allow you to com-

plete that difficult QSO with almost perfect copy.

PSK63F, on the other hand, is quite the reverse. Although not very good on long path, it's sensitive (almost as good as PSK31) and fast (40 WPM). Thanks to FEC, it provides error-free copy most of the time. It's also very easy to tune, as it's wider than PSK31 and has excellent AFC performance. PSK63F is also minimally affected by Doppler and drift problems. It's good for short-haul DX and would be great on VHF.

*Stream* has been tested on an ionospheric simulator by Johan Forrer, KC7WW, and the results bear out the practical experience. Moe Wheatley, AE4JY, has run sensitivity tests that place MFSK16 on an equal footing with PSK31 in white noise. As testing proceeds, speed and tone tweaks may produce improved performance or even new modes.

Feedback from users shows that sensitivity and the ability to cope with poor conditions are unsurpassed. MFSK16 is also useful on VHF—it's not affected by aircraft reflections and is great for DX because of its inherent sensitivity. Karl Schneidhoffer, HA5CAR, is even using it on 23 cm. Here are some quotes from users:

"Great—just great!"—*Iván, LU3OK*

"Bob, K4CY, appeared out of the noise. A good QSO followed. Band propagation not ideal at this time"—*Victor, G3GK*

"It's got one strong receiver/decoder, doesn't it? I was getting 70%+ copy on signals that wouldn't even change the shade of gray on the waterfall!"—*Gordon, N5AJF*

"Hey guys—great mode! Works well down into the noise for me. Andy (KBØEOQ) and I went to the 5-W area for a bit last night and I still pulled him in when QSB took him below my QRN level and audibility"—*Gary, AGØN*

"Conditions were slow QSB and aircraft reflections. Tuning stability not too much of a problem. Signals were about



S1 or below”—Terry, GØEZY (100 mile path on 2 meters)

“I worked RTTY since about 1978, but gave it away. Copy not very good except when signals are strong. It’s the same with PSK—no good at all on really long DX contacts. This mode is much, much better.”—Frank, ZL2BR

### Try It Yourself!

At press time the only publicly released software available for MFSK16 is *Stream* by IZ8BLY. It’s completely free and fully functional, and can be downloaded from numerous places on the internet.<sup>17</sup> *Stream* requires at least a Pentium 100 PC with a 16-bit sound card and *Windows 9x* or newer. Other versions will hopefully follow. You can subscribe to the MFSK16 support group by sending an e-mail to [MFSK-subscribe@egroups.com](mailto:MFSK-subscribe@egroups.com).

If you’re already set up for PSK31, you only need to download *Stream* and you’re ready to go. Even if you’ve never

tried sound-card-based digital communication software before, you’ll be surprised at how easy it can be. The *Stream* help files will tell you how to connect the necessary audio and keying cables between your computer and your radio. You’ll find these files in the “Help” folder that is created when you install *Stream*.

This month you’ll have a chance to test the performance of MFSK16 during the W1AW HF Digital Run. See the announcement elsewhere in this issue for details.

### Notes

<sup>1</sup>Steve Ford, WB8IMY, “PSK31 2000,” *QST*, May 2000.

<sup>2</sup>Jack Heller, KB7NO, “Inside MIXW32,” *73 Amateur Radio Today*, Jul 2000.

<sup>3</sup>Murray Greenman, ZL1BPU, “Let’s See you in Hellschreiber,” Jan 2000.

<sup>4</sup>See [www.qsl.net/zl1bpu/Fuzzy/LMT.html](http://www.qsl.net/zl1bpu/Fuzzy/LMT.html).

<sup>5</sup>Developed by H. K. Robin and J. D. Ralphs, et al, for the British Foreign and Commonwealth Office.

<sup>6</sup>Developed in Belgium by ACEC and used by

French and Belgian police.

<sup>7</sup>The smallest signaling entity of a digital mode.

<sup>8</sup>Article (in French) in *ACEC-Revue*, No. 3.4, 1970.

<sup>9</sup>H.K. Robin, OBE, et al, “Paper 204E,” published in *Proc IEE*, Vol 110, No. 9, Sep 1963.

<sup>10</sup>Skip Teller, KH6TY, and Dave Benson, NN1G, “A Panoramic Transceiving System for PSK31,” *QST*, Jun 2000.

<sup>11</sup>[www.qsl.net/zl1bpu/MFSK/](http://www.qsl.net/zl1bpu/MFSK/)

<sup>12</sup>[space.tin.it/computer/aporcino](http://space.tin.it/computer/aporcino)


<sup>13</sup>See FCC Part 47, paragraphs 2.201 and 2.202.

<sup>14</sup>Distortion in sound card or transmitter audio stages can still lead to undesirable images of the signal above and below the correct one.

<sup>15</sup>[www.qsl.net/zl1bpu/MFSK/Documents.html](http://www.qsl.net/zl1bpu/MFSK/Documents.html)

<sup>16</sup>See “Is Hellschreiber Permissible Under Part 97?” *QST*, Jan 2000, p 54.

<sup>17</sup>For example, from [www.qsl.net/zl1bpu/MFSK/software](http://www.qsl.net/zl1bpu/MFSK/software) or [www.egroups.com/files/MFSK](http://www.egroups.com/files/MFSK). At time of writing the latest version is *StreamSetup085.EXE*, [www.qsl.net/zl1bpu/MFSK/software/StreamSetup083.EXE](http://www.qsl.net/zl1bpu/MFSK/software/StreamSetup083.EXE).

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## NEW BOOKS

### A FAMILY AFFAIR: THE R. L. DRAKE STORY

By John Loughmiller, KB9AT

Published by Technical Support Group, 15 Saddle Ridge Trail, Alexandria, KY 41001-9105; tel 859-635-6487; [home.fuse.net/tsg/](http://home.fuse.net/tsg/). First edition, softcover, 305 pages, 8½ × 11 inches with black and white illustrations. \$29.95 plus shipping and handling.

Reviewed by Steve Ford, WB8IMY  
QST Managing Editor

I must confess at the beginning that I bring a special bias to this review of *A Family Affair: The R. L. Drake Story*. I was an employee of the R. L. Drake Company in the mid-1980s. So, when I received a copy of the book by John Loughmiller, KB9AT, I approached it with some trepidation. Would Loughmiller accurately portray the Drake Company that I knew?

As it turns out, Loughmiller’s chronicle of Drake’s history is honest and on target. He has carefully researched his subject, spinning a fascinating story that rises above a mere collection of historical facts. At the heart of *A Family Affair: The R. L. Drake Story* are the recollections culled from a number of former employees who have since retired or otherwise moved on. At times the tone of the book is almost gossipy, but not in a negative sense. It treats the reader to inside glimpses of life at the company that would otherwise have vanished into the

mists of time. You feel like the proverbial “fly on the wall,” privy to private conversations and “unusual” episodes (failed designs, labor union bickering, interpersonal conflicts—it’s all there). Because none of the juicier items come from my time with the company, I can’t vouch for their accuracy first hand, but I knew the individuals involved and the stories certainly have a strong ring of truth.

I found only one of the anecdotes to be a little off target. On page 27 there is the story of a “Hint & Kink” item published in the February 1969 *QST* concerning a method for cleaning a badly contaminated radio by flushing it with water and baking out the residual moisture in an oven. A teenage TR-3 owner attempted this, but used too much heat. The results were disastrous. When the boy’s mother complained to Bob Drake, he fixed the radio free of charge. According to the book, the advice was an early *QST* April Fool joke. In reality, it wasn’t, but it is true that Bob Drake carried a grudge for *QST* for a long time thereafter.

Like many good historical works, *A Family Affair: The R. L. Drake Story* has a tragic rise-and-fall structure, beginning with the company’s birth under the direction of Bob Drake, along with the birth

of receivers and transmitters that were destined to become legendary. You witness the ascension of Drake’s Amateur Radio line up to and including the development of the famous TR-7 transceiver. You also witness Drake’s exit from the Amateur Radio stage as the rig that was to become the TR-8 is crated and sent to storage, never to exist beyond a prototype.

Loughmiller’s writing is outstanding, a cut above most of the material you find in the Amateur Radio press. Thanks to his compelling narrative, *A Family Affair: The R. L. Drake Story* is quite a page-turner. The story pulls you along like a well-crafted fiction novel.

The Drake story itself comprises about half of the book. The remaining half is devoted to technical information about various Drake products. It is an invaluable encyclopedia of modifications, hints and tips.

*A Family Affair: The R. L. Drake Story* is a must-have for Drake aficionados, but it has an appeal that reaches beyond die-hard devotees. The story that unfolds in the book is a microcosm of the history of Amateur Radio itself. It is a somewhat cautionary tale that John Loughmiller has woven in an entertaining, informative style. 