Amateur Radio Digital Modes

An introduction to PSK31, MFSK16, MT63, and Hellschreiber

John DeGood NU3E

Trenton Computer Festival

Sat 5 May 2001

Acknowledgement: figures and illustrations from http://www.qsl.net/zl1bpu/

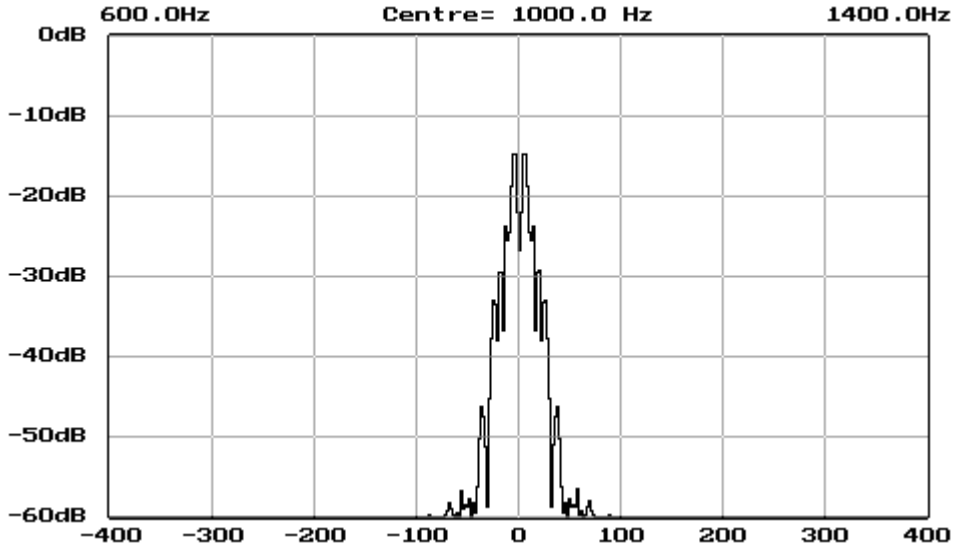
PSK31

- Invented by Peter Martinez, G3PLX
- First PC soundcard version 26 Dec 1998
- Intended for live keyboard-to-keyboard QSO
- Uses varicode character coding for 50 wpm
- Easy to use and monitor
- Gives very good copy under low Eb/No numbers and is thus suitable for QRP

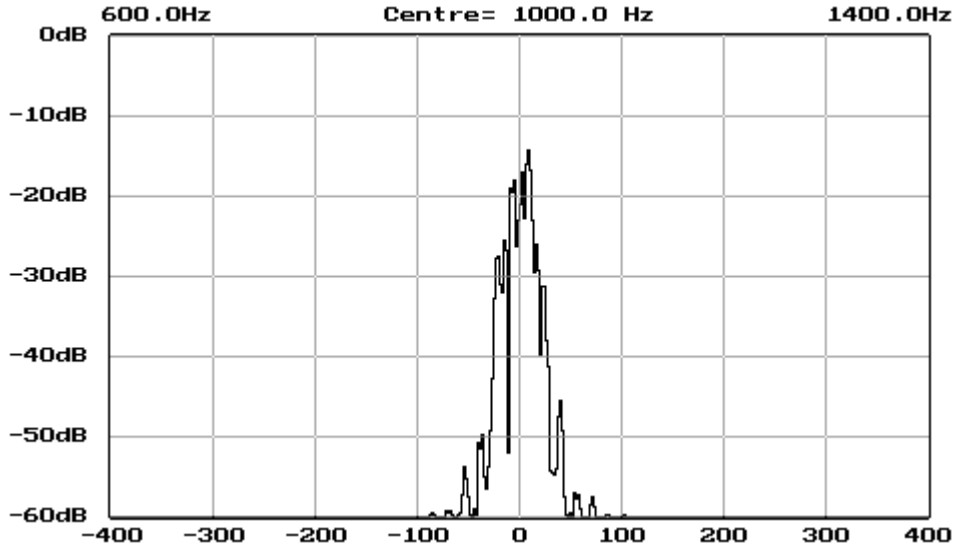
PSK31 (continued)

- Instead of using FSK or on/off keying, uses BPSK or QPSK with a Viterbi decoder
- Is available for free for many platforms, including Windows with soundcard
- Uses advanced DSP and narrow bandwidth (31.25 Hz) techniques
- Tx duty cycle is 50% idle, 90% maximum
- The greatest activity is around 14070.15

Bandwidth



BPSK



QPSK

Spectra obtained with EvmSpec (from PSK31 homepage)

PSK31 Operation

- BPSK is generally used for calling CQ and routine operation
- QPSK gives much better performance with fading and flutter
- QPSK has an 800 msec one-way delay, or 1.6 sec round-trip
- PSK31 requires a synth or stable VFO rig
  - BPSK tuning needs to be within 8 Hz
  - QPSK tuning needs to be within 4 Hz

MFSK16

- Sequential transmission using 1 of 16 tones
- Developed by Murray ZL1BPU and Nino IZ8BLY
- IZ8BLY Stream software was first implementation (June 2000)
- High rejection of pulse and broadband noise due to narrow receiver bandwidth per tone

MFSK16 (continued)

- Low baud rate for sensitivity and multi-path rejection - data bit rate higher than symbol baud rate
- Constant transmitter power
- Tolerance of ionospheric effects such as doppler, fading and multi-path

MFSK16 Characteristics

- Symbol Rate = 15.625 baud
- Channel Data Rate = 15.625 x $\log_2 16$ = 15.625 x 4 = 62.5 bps
- User Data Rate = 62.5 x 1/2 (FEC RATE) = 31.25 bps
- Text Throughput (CPS) = 31.25 / 10 (Varicode) = 3.125 CPS
- Text Throughput (WPM) = 3.125 x 60 / 6 = 31.25 WPM
- 316 Hz bandwidth

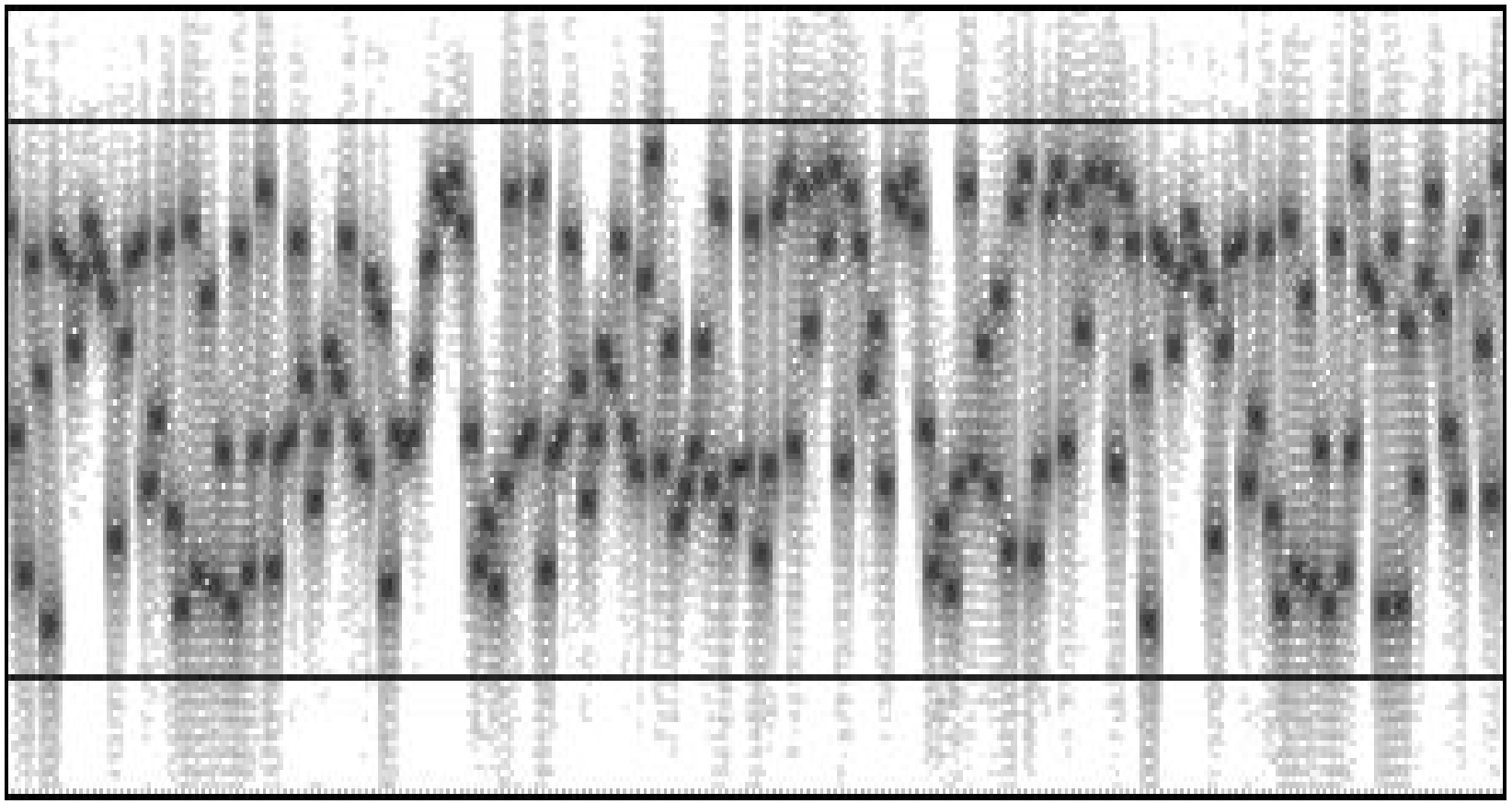
History of MFSK Over Radio

- LMT (France) ca. 1935
- DTMF (Bell Labs)
- Coquelet, i.e. “Rooster” (Belgium) ca.1954
- Piccolot (Britain) ca.1957

Disadvantages of MFSK16

- It is important that the radio transceiver be very stable, and also that it has very small frequency offset between transmit and receive (preferably less than 5 Hz).
- MFSK uses more bandwidth for a given text speed than a 2FSK or PSK system, but by the same token it is therefore more robust.

Spectrogram of an MFSK16 Signal



MT63

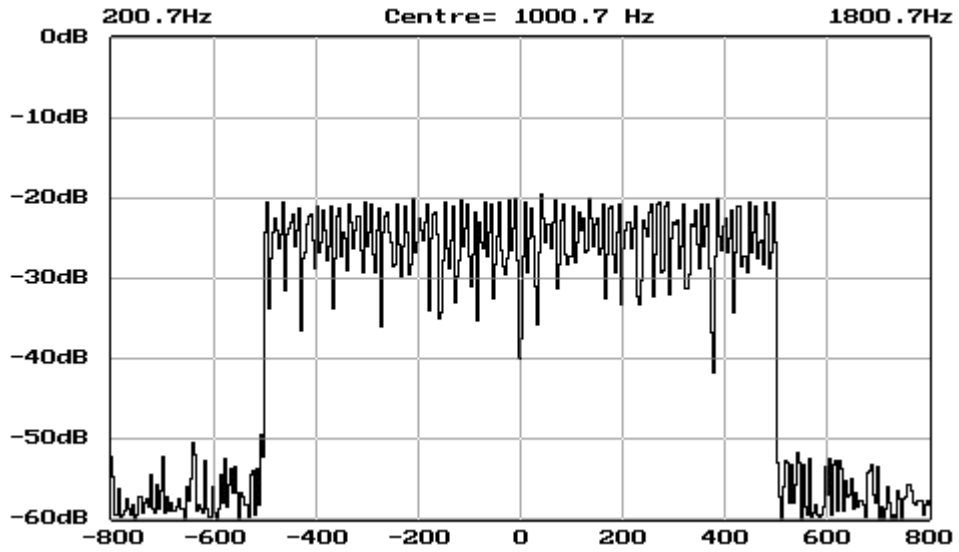
- Developed by Patwel Jolocha SP9VRC
- Encodes information using 63 modulated tones
- Sounds unusual, like a roaring noise
- No connection process, as in AMTOR, Packet, or PACTOR
- Outstanding performance when conditions are both weak and unstable.

MT63 (continued)

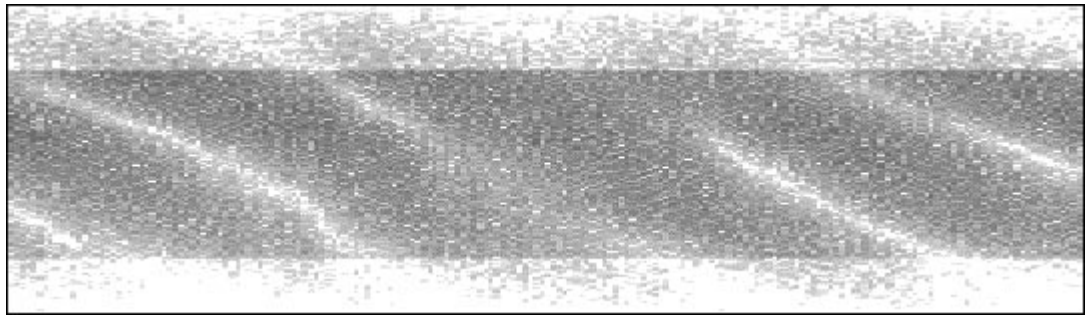
- Spreads signal in time (several seconds) and space (500-2000 Hz)
- Forward Error Correction (7-bit ASCII encoded into 64 bits using a Walsh function) can result in 100% copy even if 25% of a character is obliterated
- Clumsy (slow) operation due to FEC delay
- Very aggressive: causes interference to other modes, but itself is little affected by other modes

MT63 Characteristics

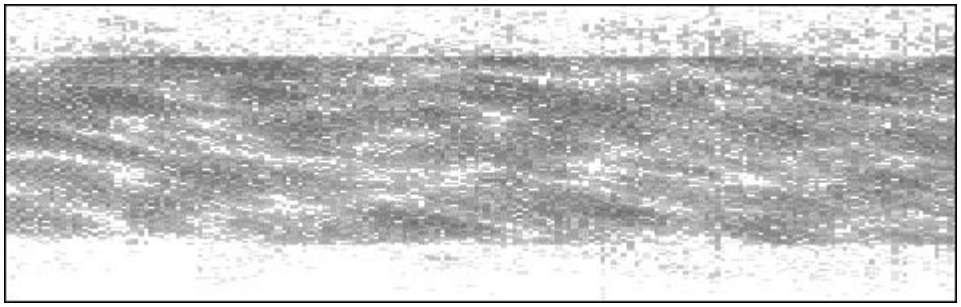
Bandwidth	Audio Range	Symbol Rate	Char Rate	Interleave/char
500 Hz	500-1000 Hz	5 baud	5 char/sec	6.4 or 12.8 sec
1000 Hz	500-1500 Hz	10 baud	10 char/sec	3.2 or 6.4 sec
2000 Hz	500-2500 Hz	20 baud	20 char/sec	1.6 or 3.2 sec



100% Copy in Presence of Complex Fading with MT63



10 Watts on 14 MHz



50 Watts on 3.5 MHz

Hellschreiber (Hell Writing)

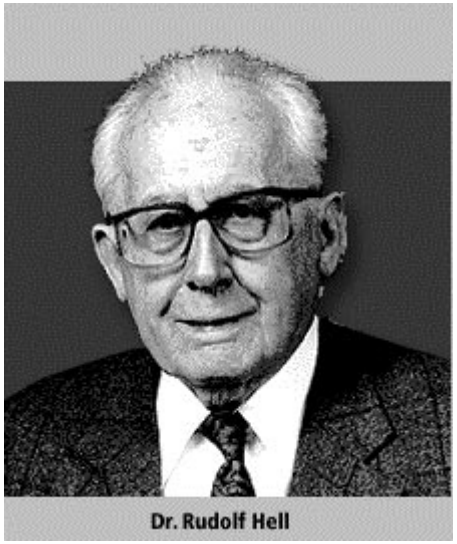
- Patented by Rudolf Hell in 1929
- Used by the German Condor Legion during the Spanish Civil War (1933). During WWII, Hellschreiber was widely used for field portable military communications.
- Still used today in the original format
- Visually readable mode
- Most DX on 14063 kHz - 14070 kHz

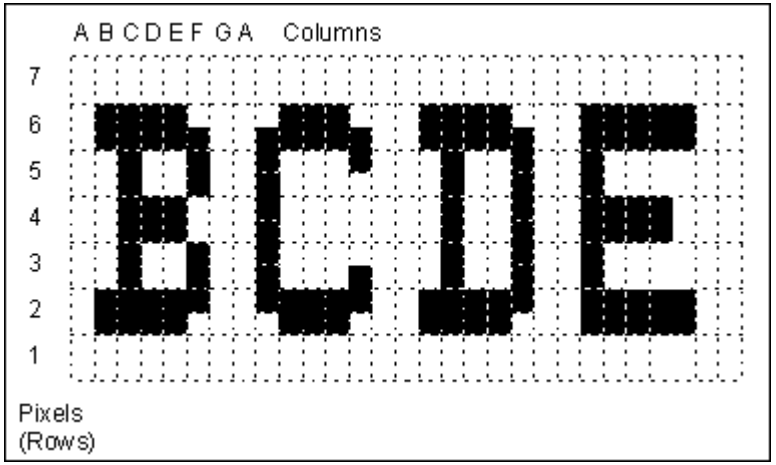
Feld-Hell (Field Hell)

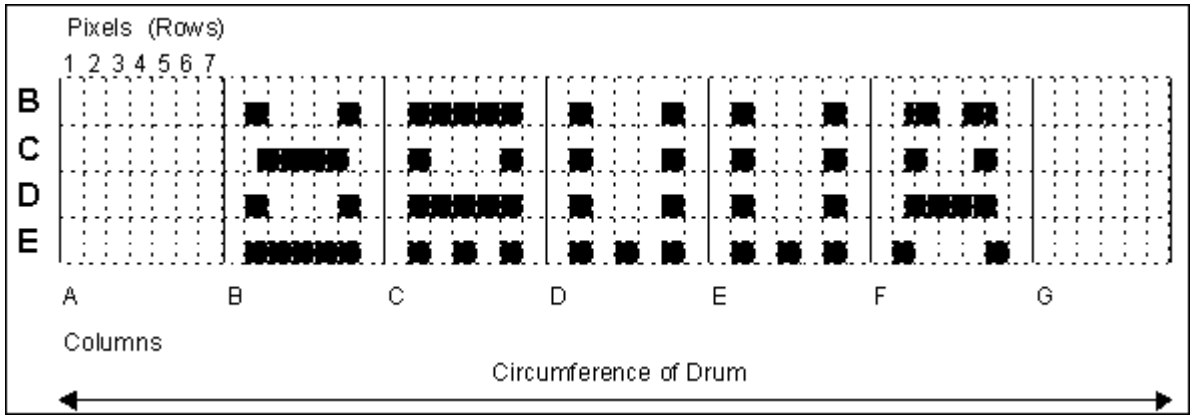
- Feld-Hell characters are sent as a series of dots at 122.5 pixels/sec, using a CW transmitter or by sending tones to an SSB transmitter.
- Black dots are represented by a CW dot (key down), and white spaces by a space as long as one dot (key up).
- Low duty-cycle: ~22%

The Siemens & Halske A2 Feldfernschreiber (1944)

Feld-Hell 7x7 Character Set


Dr. Rudolf Hell

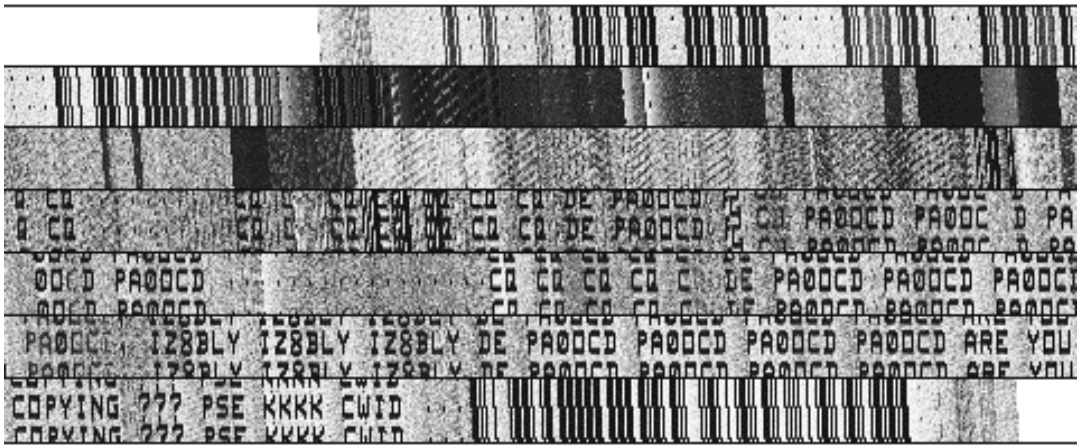


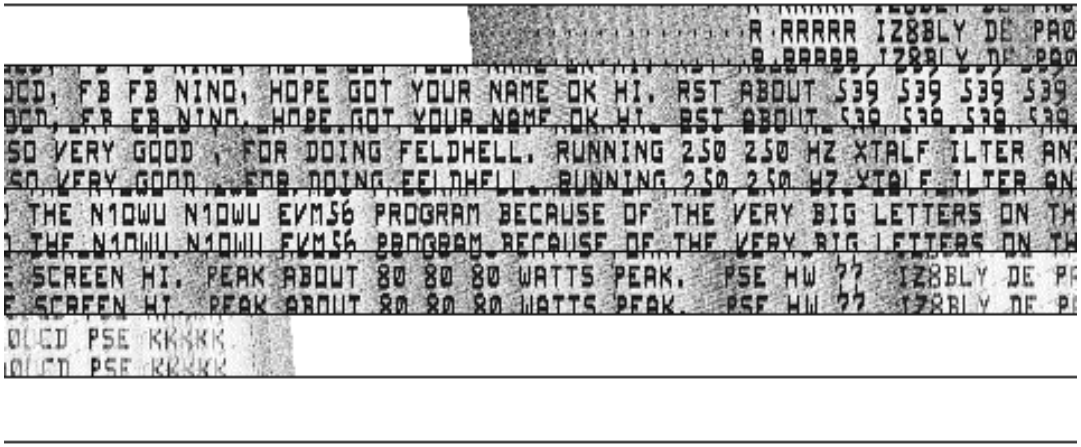


Feld-Hell Timing

- Each character takes 400ms. Since there are 49 pixels per character, each pixel is 8.163ms long. The effective baud rate is 1/8.163 ms = 122.5 baud, and the throughput is 2.5 characters/sec, or about 25 WPM.
- Raised cosine filtering results in 2 * 122.5 = 245 Hz bandwidth.

The First IZ8BLY Feld-Hell QSO January 1, 1999





PSK-Hell

- Recently invented by Murray ZL1BPU and implemented by Nino IZ8BLY.
- Uses Differential Phase Shift Keying, which relies on detection of a change in phase. One state (black) is defined as no change in phase from one dot to the next, while the other state (white) is defined as a reversal of the carrier phase from the previous dot.

PSK-Hell (continued)

- Matrix is only 7 x 6, seven columns of six dots (42 dots). This reduction in dots per column allows a lower baud rate (105 baud) for the same column rate and text speed as Feld-Hell.
- High Tx duty-cycle: ~90%

MT-Hell (Multi-Tone Hell)

- Each row of dots or pixels in the character is at a different frequency, with quite different (much relaxed) timing, and thus is transmitted in the frequency domain.
- Since columns are always sequential, there is no notion of synchronism in MT-Hell.
- Reception of MT-Hell requires a technique called the Fast Fourier Transform to convert the signal back into a human readable form.

C/MT-Hell

- C/MT-Hell or Concurrent MT-Hell uses many tones (seven or more), which are often transmitted at the same time.
- C/MT-Hell has the following potential advantages:
  - Speed, since several dots can be sent at the same time
  - Better readability, since more dots provide better resolution
  - Better looking text, since the characters need not slope and many fonts can be used

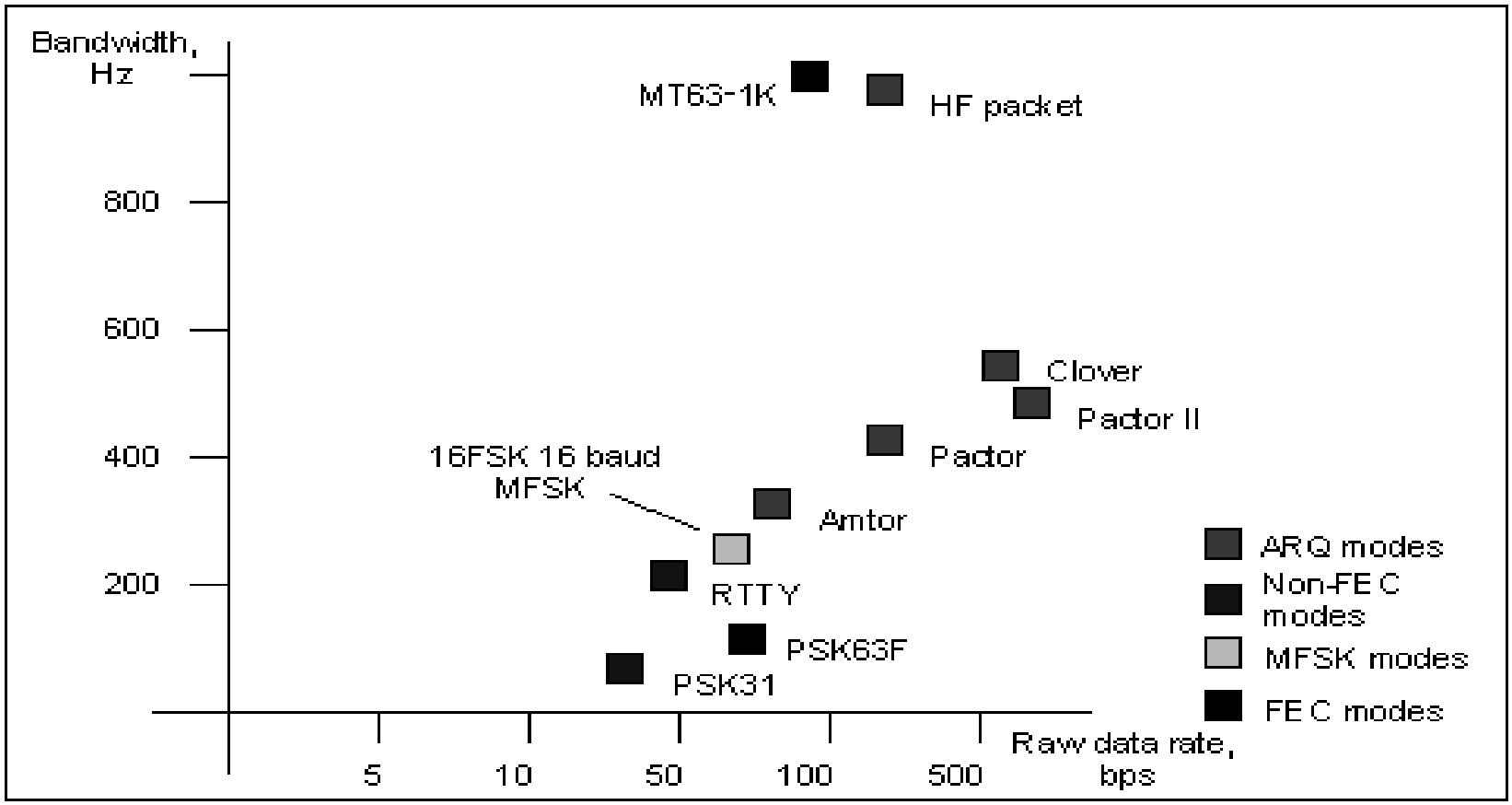
S/MT-Hell

- S/MT-Hell or Sequential MT-Hell uses only a few tones, typically five or seven, but never more than one at a time.
- S/MT-Hell advantages:
  - Weak signal performance, since all the transmitter power is applied to a single dot
  - High efficiency: since the transmitter need not be linear, Class C transmitters can be used
  - Very simple transmitter requirements - easily adapted to QRP and LF transmitters
  - Simple signal generation with a PC, even via the PC speaker or a Hamcom interface

Appearance of Hell Modes

- Feld-Hell text is usually very sharp and may lean slightly to the right, and is always double printed.
- Sequential MT-HELL text leans strongly to the right, and may have a dotty (pixellated) appearance.
- Concurrent tone MT-HELL has very detailed characters, and is always upright (unless the user has chosen an italic font!)

Bandwidth vs Data Rate Comparison



Summary

- PSK31 is the fastest growing mode in amateur radio.
- MFSK16 and MT63 are not widespread. The wide bandwidth of MT63 is controversial.
- Hellschreiber activity in the USA is limited, but it is a popular mode in Europe.
- PSK, MFSK16, and Hell to a lesser extent, are great for QRP and restricted antenna installations due to great performance with low Eb/No.

Amateur Radio Digital Mode Information Resources

- Official PSK31 Homepage
  - http://aintel.bi.ehu.es/psk31.html
- Fuzzy Modes (and MT63) Web Site
  - http://www.qsl.net/zl1bpu/
- Digipan PSK31 Software
  - http://www.digipan.net/
- Hellschreiber, MFSK16, and MT63 Software
  - http://iz8bly.sysonline.it/
- Slides of This Presentation
  - http://www.nerc.com/~jdegood/tcf2001.pdf