

Let's See you in Hell!

It is old or new? Digital or analog? Either way, it's a Hell of a good time!

When you need to send text by radio the common method is to use software to assign strings of bits (1s and 0s) to represent each letter of the alphabet, as well as numbers and punctuation. The software shuffles this data into whatever coding scheme you decide to use and a soundcard or modem translates the result into frequency- or phase-shifting audio tones. Apply these tones to a transceiver and they become RF signals.

At the receiving end a modem processes these signals back into data. Software interprets the data and "decides" which characters will be displayed according to the constraints of the code.

PACTOR, Clover, G-TOR, PSK31, packet and RTTY all use variations of this fundamental approach to transmitting and receiving information. But, as the proverbial saying goes, there is more than one way to skin a cat!

Hellschreiber—Seeing is Believing

Let's begin with text, but instead of assigning groups of 1s and 0s to represent the characters, the actual *shapes* (fonts) of the

characters themselves are translated into various combinations of tones (as well as precisely timed intervals of silence). At the receiving end the software merely decides whether the pixels on a particular area of the screen should be dark or light, thereby "painting" the text on the monitor as it is received. The eyes and brain of the operator perform the final interpretation.

Sounds like an advanced technique, doesn't it? Would you believe that this method of text transmission was invented more than 70 years ago?

Hellschreiber (a German-language pun¹) was the name Rudolf Hell² gave to his invention in 1929, and it was soon in widespread use for press, diplomatic and military traffic. The equipment was simple, and at the time, both cheaper and more reliable

than 5-level code teleprinters. A military version, the *Feldfernschreiber*, or field teleprinter, was widely used during World War II by the Germans, and later by the Swedish and Czech forces. The *Feld-Hell* machine was very simple, required nothing more than a CW transmitter and receiver for radio use, and performed well with the low-power transmitters and broad receivers of the time.

But surely Amateur Radio is all about developing new technology. We should be exploring new modes, rather than revisiting this old stuff, right? Well, yes, and no. Of course there are plenty of new techniques to be explored (PSK31 is a current example), but old technology should also be understood and appreciated—and improved upon. After all, Morse is still in widespread use, and it dates from 1838!

Hellschreiber has some important fea-

¹Notes appear on page 00.



Picture of a 1944 Feldfernschreiber, thanks to Dick, PA0SE.

What is a Fuzzy Mode?

A Fuzzy Mode is specially designed for human readability, using digital, analog or DSP techniques. For best performance, a Fuzzy Mode must:

- Be *uncoded*. That is, each character or symbol must be sent complete.
- The equipment *must not make timing decisions*.
- The equipment *must not make state decisions*.

An uncoded mode like Hell is not affected greatly by noise because the redundant information in the complete character ensures that it will be recognized. Coded modes such as RTTY can lose synchronization or have one character changed to another by noise or interference.

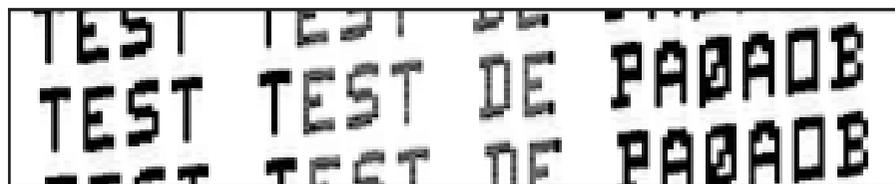
Data should be presented as it is received so that incorrect timing decisions are avoided. The transmission path will cause the signal phase to vary, and often the transmitter signal phase is unknown. In computer Hell this is achieved by oversampling.

A Fuzzy system will present the user with an indication of the probability of each element (e.g. as a gray-scale), rather than make hard (yes/no) decisions. This allows the eye or ear to assess each element in conjunction with the others more effectively.

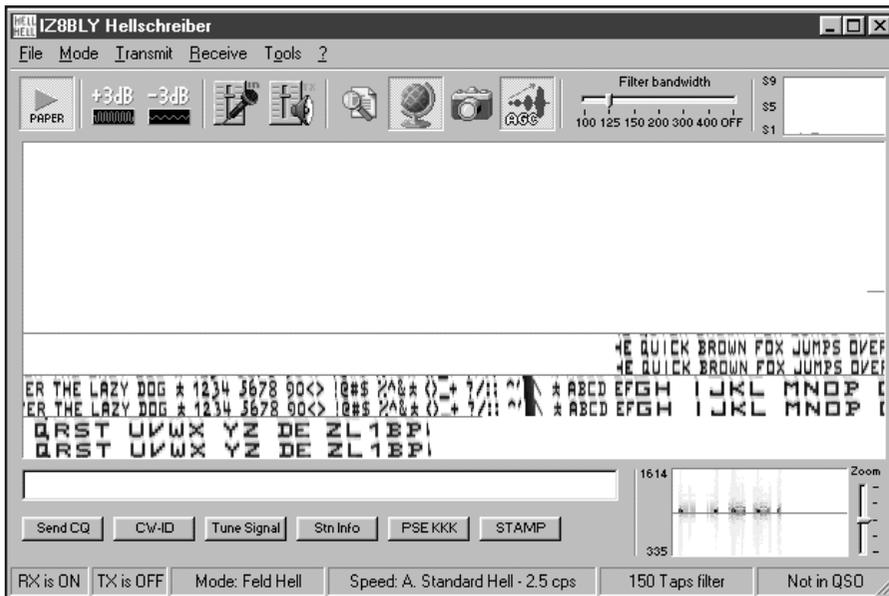
HF FAX (ignoring the starting sync pulses) is a Fuzzy Mode—so are Feld-Hell, MT-Hell and Duplo Hell. Can you think of any others? Experts consider Morse to be a natural language, rather than a code. This makes Morse a Fuzzy Mode!



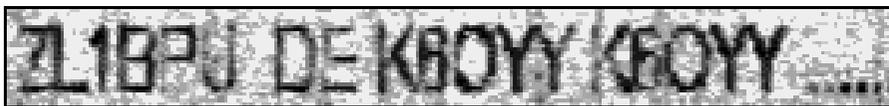
Figure 1— Illustration of multi-path reception—3.5 MHz, 300 km range.



Arie, PA0AOB, using a 1944 Feldfernschreiber.



The IZ8BLY display screen with tuning indicator (bottom right corner).



Jim K6OYY transmitting C/MT-Hell using the G3PLX MT-Hell software.

tures, and we have recently added Digital Signal Processing (DSP), to elevate Hellschreiber to a high-performance DX mode. The most common type of Hellschreiber in use on the amateur bands today is Feld-Hell. Feld-Hell characteristics include on-off keying, quasi-synchronous operation, a double printing strategy to counter signal phase and speed uncertainty. The special text font, readable under poor conditions, was designed for minimum bandwidth.

Feld-Hell transmits text in a similar manner to the printing of a dot-matrix printer. Where a black dot is required, the CW transmitter is keyed, while nothing is sent for white. The timing needs to be reasonably accurate. The characters are built by scanning up each column of the character from left to right. If the speed is slightly off, the text will climb uphill or slide downhill, because there is no synchronization. The characters occupy approximately a 5 × 5 dot area in a 7 × 7 field. The dot rate is 122.5 baud, a leisurely 2.5 characters/second or about 25 WPM. The transmitter duty cycle of this simple facsimile/digital mode is about 21%.

Soon after the war, Dutch and German amateurs discovered that Feld-Hell equipment was very simple to operate, and performed better than RTTY on the lower bands. Unfortunately few machines survived the war, so although there was a surge in interest in the '80s, due in part to magazine articles³ and the appearance of personal computers,⁴ it was only the dedicated

Europeans who kept the mode alive. Now, however, the new breed of PC equipped *Hell Raisers* have revived and enhanced this interesting, high-performance mode.

Software

The first DOS PC software for Feld-Hell, by Sigfus LAØBX,⁵ is still widely used, particularly by those who choose to use older PCs or operate portable. Recently it was realized that DSP could transform Hellschreiber into a highly sensitive mode, resistant to many forms of interference. I have to take some of the blame for this, and I was the one who coined the term *Fuzzy Modes* to describe radio modes that are not really digital, nor completely analog, but provide important advantages of both by being human readable.⁶

The first important improvement to Hell was to use a gray-scale display (rather than strictly black-on-white) for reception. This significantly improves weak-signal readability. Doug, N1OWU and Peter, G3PLX used the Motorola DSP56002EVM evaluation module for DSP signal processing, while software for PC soundcards by Lionel, G3PPT and Nino, IZ8BLY now performs DSP inside the PC.

Not for Technophobes!

What do we use DSP for? Let's follow the receiving system in the IZ8BLY software. First the receiver audio is digitized by the PC sound card, and the data is filtered in software using a Finite Impulse Response (FIR) bandpass filter with adjust-



Ever worked CN8? You can on Hell!



The print quality of the 1937 Radio Printer was good even with fading.

able bandwidth (down to 100 Hz), centered on 980 Hz (the operating tone frequency). The signal is then down-sampled and demodulated, using modulus addition and division, to provide an averaged and denoised sample representing the actual signal power at four times the dot rate. The sample is represented on the screen as a gray-scale picture element, giving the text a vertical resolution of 28 picture elements (pixels). The signal power also operates a digital AGC system, which controls a multiplying factor applied to the incoming train of sample data. The digital AGC has adjustable attack and decay. Finally, the signal is tuned in on a Fast Fourier Transform (FFT) waterfall plot tuning display.

On transmit, the signal is generated as a series of wave-table sounds. Each dot is phase synchronous, and generated mathematically as a 980 Hz sine wave. The program generates and stores the wave sounds for each character in the character set, letters, numbers, symbols and a few small graphics. Any *Windows* font can be used, even high-resolution fonts with rendered corners (yes, the software actually transmits gray-scale dots!). Special Hell fonts are carefully designed to transmit dots in a time interval no shorter than 8 ms, which limits the bandwidth while retaining higher resolution. The wave sounds for these Hell fonts are passed through a raised cosine envelope shaper, (multiplying the sine wave samples with a raised cosine) which shapes each group of dots to limit the keying bandwidth.⁷ During transmit, characters from the keyboard buffer cause the appropriate wave sounds to be written to the sound card where they are timed and restored to analog form for transmission. The transmitter software runs at the same time as the receiver software, so the system can operate *full duplex*.

Now who said Hell wasn't high tech?

Performance

Fortunately, you do not need to understand how it works to enjoy this mode. Simply install the software, connect up your rig (probably the same cables you use for PSK31 and SSTV), set the signal levels and away you go! Hell is a rag chewer's mode—and a delight to use. It is as slick to operate as RTTY or Morse. It is not quite as sensitive as PSK31, but is much easier to tune, and is tolerant of drift. I hesitate to compare the performance with Morse, but I know brass pounders who appreciate Hell because it gives them the same operating feel that Morse does—you can see and hear

Is Hellschreiber Permissible Under Part 97?

FCC regulations are normally straightforward in terms of classifying amateur transmission modes. One need only determine the emission designator and then review Section 97.3(c) to determine which emission type applies: CW, data, image, MCW, phone, pulse, RTTY, SS or Test. Discussions with FCC staff concerning the legality of Hellschreiber resulted in the following classification, based on the determination of the proper emission designator. The legality of other amateur modes should be determined by the same method.—Chris Imlay, W3KD, ARRL General Counsel

Is Hellschreiber a facsimile or a direct-printing telegraph system?

The 1929 Hellschreiber (now known as “Feld-Hell” or “Field-Hell”) is a facsimile device for transmitting text, originally to be printed on tape. It can be transmitted using the emission designators A1C (Double sideband, a single channel containing quantized or digital information without the use of a modulating subcarrier, facsimile), F1C (Frequency modulation, etc. as above), or J2C (Single sideband, suppressed carrier, a single channel containing quantized or digital information with the use of a modulating subcarrier, facsimile). While permissible within Part 97 Rules as facsimile operating on frequencies where “image” emission is authorized (where phone, SSTV or fax is permitted), this may not be welcomed by other amateurs using the rather narrow frequencies normally used for image communications.

An alternative is to consider Hellschreiber as a direct-printing telegraph system and operate it in the RTTY/data segments of the HF bands (where it is already in use). Perhaps little known is the ITU definition of *facsimile*, namely: “A form of telegraphy for the transmission of fixed images, with or without half-tones, with a view to their reproduction in a permanent form.” So, it can be operated under these emission designations: A1B (Double sideband, a single channel containing quantized or digital information without the use of a modulating subcarrier, telegraphy for automatic reception), F1B (Frequency modulation, etc., as above), or J2B (Single sideband, suppressed carrier, a single channel containing quantized or digital information with the use of a modulating subcarrier, telegraphy for automatic reception.)

The multi-frequency versions of Hellschreiber can be operated under the above emission symbols F1C, J2C, F1B and J2B. Because only one frequency is transmitted at a time and there is only one stream of information, the second character 7 (for two or more channels containing quantized or digital information) does not apply. A1C or A1B would not be usable because these designate simply on/off keying. F1C or F1B would be possible if the different tones caused different frequency shifts.

Bottom line: US amateurs may transmit Hellschreiber in the RTTY/data segments using single-sideband transmitters. J2B is the appropriate emission symbol.—Paul Rinaldo, W4RI, ARRL Technical Relations Manager

the signal interacting with the ionosphere. (I am careful to say “Morse,” not “CW,” because Feld-Hell is *also* CW!)

For digital modes, HF operating presents a variety of challenges: interference, poor propagation, fading, multi-path, noise, lightning static, polar flutter and high transmitter duty cycles. HF is a challenge for Feld-Hell, too, but not to such a great extent.

For example, Hell is reasonably sensitive; it is resistant to most interference except zero-beat carriers. It is readable through fades thanks to gray-scale display, sensitivity and the human ability to recognize characters in noise. Unlike RTTY it cannot print wrong characters or lose synchronization on noise or lightning static. Hell is also immune to the effects of polar flutter.⁸ And thanks to the low duty cycle, the transmitter stays cool!

Multi-path reception can be a problem, but is useful as a fascinating propagation indicator. In Figure 1 ZL1AF’s signal has a weak echo about 16 ms after the main signal. This delay is equivalent to 4800 km, so just where has the signal been all that time?

Feld-Hell is a relatively narrow band mode, so you can use a CW filter. The modern software is capable of around 350 Hz bandwidth if adjusted correctly. Me-

chanical machines and some older software have wider signals. The spectrum shape is the same as high-speed Morse.

Getting Started

Visit the Fuzzy Modes Web site⁹ and download the software that suits your computer. There is good software for DOS and for Windows 95/98/NT. There is even software for the Macintosh.¹⁰ I recommend the IZ8BLY software,¹¹ which is the most advanced and offers all other “Fuzzy” modes as well. On the Web site there is a wealth of information about operating this software, how to make the cables, and other operating advice.¹² The IZ8BLY program even has help files in English, German, Italian, Czech and Spanish.

Need an Elmer to help you on the air? Check out the Hell Call Book¹³ for a Hell Raiser near you. There is also a Hell e-mail reflector (mailing list)¹⁴ where you can ask questions or set up skeds. Small pictures of received signals are often exchanged, which is something you can’t do with RTTY!

Operating

The best place to get started is on 80 meters at night, where you can learn to operate, give and receive advice. Here sig-

nals are strong, but the noise is even stronger! Hell performs very well on 80 meter, typically around 3.580 MHz, and you will see plenty of ionospheric effects—fading, multi-path reception and lightning noise. DX isn’t bad either—1000-km contacts are routine, and 3000-km not unusual. From the eastern US, transatlantic contacts should be possible.

At present most of the DX is on 20 meters, from 14.063 MHz upward. Other frequencies to look at are 7.035, 10.135, and 21.063 MHz. On 20 meters DX is excellent and copy is very good. Most stations run about 50 W, and many even less. High power and expensive antennas are not required.

There are contacts to be made any time of day when the conditions are reasonable. Hams in more than 50 countries operate Feld-Hell, including some relatively rare ones such as 3D2, 5N0, ZF, PJ2 and CN8 for example. There are more than 300 Hell Raisers active at present, a large proportion of them in Europe. Feld-Hell is new to the DX scene, so many HF operators have yet to discover the delights of this simple mode. The ARRL DXCC currently counts Hell contacts as RTTY contacts.

Other Options

I mentioned that there are other Hell modes. Most of these are older modes that offer no advantage over Feld-Hell. One interesting mode demonstrated in 1937¹⁵ used seven concurrent tones to portray different horizontal line segments making up each character.

Peter, G3PLX, improved this mode, using 16 tones and an FFT receiver. We now call it Concurrent Multi-Tone Hell, or C/MT-Hell. It is less sensitive than Feld-Hell, but the FFT receiver is remarkably immune to all kinds of interference, since reception is in the frequency domain and most interference is in the time/amplitude domain. C/MT-Hell works well on the lower bands, is narrow band (200 Hz) and free of keying sidebands because the keying is at column rate rather than dot rate.

Another multi-tone system, Sequential Multi-Tone Hell or S/MT-Hell, is a relative newcomer. It is like a combination of Feld-Hell and MT-Hell. The dots are sent in a pattern, like Feld-Hell, but each row of dots is sent with a different tone frequency. The FFT receiver is able to reconstruct the characters without them looking excessively dotty. The biggest advantage of S/MT-Hell is that it can be transmitted with a Class C (nonlinear) CW transmitter, whereas all the other modes require a linear SSB transmitter. It is a challenge to transmit S/MT-Hell with good clarity, because the keying sidebands become visible within the character matrix.

The latest “designer” Hell mode is IZ8BLY’s Duplo-Hell. This mode is closely related to Feld-Hell, but two columns of dots are transmitted at the same

time, using two different tones. The same typing speed as Feld-Hell is achieved by sending the dots for twice as long. This has two important effects: (1) The noise rejection is enhanced even further, and (2) the multi-path echoes are reduced by a factor of two. Duplo-Hell is great for low-band DX. The received signal looks as sharp and clear as Feld-Hell, but can have a slight dotted effect due to selective fading. The spectrum of Duplo-Hell is little wider than Feld-Hell.

Summary

Hell is a new/old mode with plenty to offer the HF operator. It does not require high power, is simple and inexpensive to use, and gives great performance. Hell is a Fuzzy mode, kinda' digital, yet mostly analog, uses DSP, and makes use of the human eye and brain to do even more signal processing. It does not suffer from noise-related errors like other digital modes. It is fun to use and there is excellent freely available software.

I look forward to *seeing* you in *Hell!*

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Notes

¹Hellschreiber is a pun devised by Rudolf Hell based on his last name and the nature of the mode itself. Hellschreiber translates to "light recorder" (and "helles Schreiben" means "bright writing").

²A biography of Rudolf Hell is available on the Web at: http://www.lhag.de/company_int/rudolf.html.

³"The Hellschreiber—a Rediscovery" by Hans Evers, PA0CX, *Ham Radio Magazine*, Dec 1979. Numerous articles in Dutch by Dick Rollema, PA0SE, and others, 1979-1982.

⁴An Apple II Hell program developed by Klaas, PA0KLS, in 1980.

⁵HS-V9709.ZIP by LA0BX is available at <http://www.qsl.net/z11bpu/FUZZY/software.html>.

⁶See the sidebar "What is a Fuzzy Mode?"

⁷If the envelope of a dot has a cosine shape, there is only one pair of keying sidebands.

⁸Disturbance of the ionosphere near the poles causes effect phase, frequency and amplitude flutter on signals passing through it.

⁹<http://www.qsl.net/z11bpu/FUZZY/software.html>

¹⁰<http://www.blackcatsystems.com/software/multimode.html>

¹¹Nino's Web site is <http://www.freeweb.org/varie/ninopo/radio/Hell/index.htm>. The software is also available at <http://www.qsl.net/z11bpu>.

¹²See "Getting Started" at <http://www.qsl.net/z11bpu/FUZZY/starting.html>.

¹³<http://www.freeweb.org/varie/ninopo/radio/Hell/callbook.htm>

¹⁴<http://www.onelist.com/subscribe.cgi/Hellschreiber>

¹⁵"Seven Frequency Radio Printer", Devaux and Smets, *Electrical Communication* 1937. (Available in edited form at <http://www.qsl.net/z11bpu/FUZZY/LMT.html>.)