Hellschreiber
An old mode still has performance that's hard to beat
Part I—History and description

Murray Greenman ZL1BPU

Tired of the noise on the low HF bands? Interested in QRP? LF operation? Digital operation on noisy bands, net operation? Digital modes for your ALIVO transceiver? Digital Hellschreiber is the answer!

Part I of this series describes the development of Hellschreiber and, in simple terms, the technical details of this uncomplicated but interesting digital mode. Part II describes how you can easily get on the air with Hellschreiber—probably with equipment you already own. Part III will have all the technical analysis stuff that digital mode aficionados enjoy.

What is Hellschreiber?

Hellschreiber (Heh writing) was invented by Rudolf Heh around 1927, the same year the BBC was founded, as a way of reliably sending text under poor radio conditions. Hellschreiber has nothing to do with the underworld, as the word "Heh" means "bright". At the time, teleprinting as we know it was still in its infancy and, due to the limited capabilities of contemporary electronics, was not usable by radio, was complex and required large heavy equipment. Rudolf Heh's simple system was, therefore, quite different and revolutionary. The Heh system sent text in a similar way to facsimile—it scanned the text and sent it as dots, in fact just like dots sent to a dot matrix printer.

![Image of a dot matrix printer]

The wartime Siemens and Halske manufactured machines were about the size of a large typewriter, and contained a small motor and a drum with contacts on it; one ring of contacts representing each letter or number. The drum rotated once for every key pressed, then stopped and the contacts keyed a simple CW transmitter. The printer in the unit contained a solenoid, operated by a valve amplifier from the audio tones received from a CW receiver. The solenoid tapped on the back of a strip of paper whenever a dot was received. Above the paper was a rotating spiral, rather like a worm gear, tipped with ink, which scanned the paper strip, the same paper then widely used to print telegrams. This article concentrates on "modern" digital Hellschreiber, but a very good description of the mechanical machines was published in Ham Radio Magazine in December 1979. The original article and most of the pictures are available on the internet. [See also Radio Bygones, No 51, February/March 1998—Editor.]

Technical description

Characters were sent as "dot matrix" dots, one pixel (picture element) at a time. The transmitter scans up each column, and across the character columns, one dot at a time. In Figure 1, the magnified pixels are numbered in the order transmitted. The black pixels are transmitted as Morse key-down, and the white spaces are key-up, like the spaces between Morse code dots. The pixels are higher than they are wide. In the traditional mechanical system, they were printed by a tiny hammer tapping the back of a slowly moving roll of paper above which a small worm gear coated with ink. The worm rotated every 57.12 ms, or 1050 rpm, and the movement of the paper caused the characters to lean forward slightly, like italics.

![Figure 1. Character slant due to paper movement.]

The original character set was very limited, just upper case letters, numbers and very few punctuation characters, but there is no reason why more characters could not be used. Some compromises would need to be made due to the low resolution; lower case descenders, in such characters as p and q would require some ingenuity. The beauty of the system is that no matter what characters are sent, they will be faithfully reproduced, as the receiver has no concept of character set, language or character length. It is possible, for example, to include extra long characters, or use a proportional font.

Many modern digital Hellschreiber systems include a double width transmit system (each column sent twice), which is much easier to read when conditions are very bad, although the character transmission rate is halved. See the example below:

![Example of double width transmission]

Some programs also include the ability to average the repeated columns of double width printing to reduce the effects of noise. Other systems use double width as "upper case", although the characters are all upper case already!

In the traditional German Feld-Heh system, the characters were sent with a pixel rate of 122.5 Hz, each pixel occupying 8.16 ms, creating a seven by seven dot matrix. This is the standard still most used today. The transmitter carrier was keyed in an on-off fashion, like CW, and the resulting signal was about 400 Hz wide, similar to 45 baud RTTY or CW at 80 wpm. The data throughput was much lower, at 2.5 characters per second, compared with six characters per second for 45 baud RTTY and about 6.5 characters per second for 80 wpm CW. In performance Hellschreiber can be compared with 30 wpm CW, which has a similar data throughput.
The Feld-Hell system had no synchronization mechanism, simply relying on the pixel rate being similar at each station. (The old machines had a rheostat for adjustment of motor speed.) With seven pixels per character column, of which five printed, and seven columns per character, including the inter-character space (five columns print), each character therefore took 8.16 x 7 x 7 ms = 400 ms to transmit. Put another way, 122.5 Hz + 7 = 17.5 columns/second, and 17.5 cols/sec + 7 = 2.5 characters/second.

Because there was no synchronization, if there was a difference between the sampling rate at the receiver and the pixel scanning rate at the transmitter, the text would slant up or down, and therefore tend to cut the characters in two. The solution was very simple—the Feld-Hell system transmits each character once, but the receiver printed it twice, with one image above the other, but using a two-turn inked helix. In this way, if the synchronization was out, the characters could still be read. If the rates were very different, the text would slope uphill or downhill, but still be readable. You can see this in the examples.

There are other newer but less frequently used systems such as Hell-GL and Hell-80, which use synchronization. Hell-GL, developed commercially, uses synchronization bits at the start of each character, while Hell-80 is an amateur adaptation using asynchronous data start and stop bits. These systems are much more prone to errors, and neither of these systems has any advantage over RTTY on HF, although the Europeans use them on VHF. The original Feld-Hell system is today still the favourite for HF.

Digital Hellschreiber

Modern computer generated Hellschreiber is typically transmitted by keying an audio tone on and off, and controlled by computer. This tone is then fed to an SSB transmitter. For transmission and reception a simple interface is all that is required. For (sampling theory) reasons that experts will understand, incoming pixels are sampled for display at least twice the pixel rate. The best systems average several samples per pixel (a technique called oversampling) and display the result as varying levels of grey, depending on the confidence of whether the pixel was a dot or not. This makes the text much easier to read because it tends to suppress noise. The following example is from software by Henk PA3BQs.

![Image]

The transmitter duty cycle is very low. In the drawing in Figure 2, the word "HELL" consists of 7 x 7 x 4 = 196 pixels. Only 44 of these are actually transmitted—22.5 per cent duty cycle. Most SSB transmitters will send forever under these circumstances, as the duty cycle is similar to voice. I estimate the CW duty cycle for 1:1 dot/space weighted characters to be about 40-50 per cent.

While Hell might appear to have very poor throughput compared with other modes, it is outstanding in its most suited application—low power and portable communications using simple equipment on noisy bands, which is exactly what the system was developed for in the first place. Because reading the received text is left to the eye and brain, which are superior pattern detectors, significant numbers of errors are easily tolerated without affecting the readability of the text. In fact, up to about 20 per cent of the pixels can be wrong before the eye and brain refuse to recognize familiar characters.

Despite the noise, the signal is still very readable. When received with the best software, it is impossible to tune in a signal weak by ear, because it is possible to distinguish the terms of the signal in the eye. Fortunately, tuned eye is easy.

Hellschreiber is also suited to languages based on other characters—Arabic, Hebrew, even Chinese. Hellschreiber running at higher speeds is equivalent to Hellschreiber HF for many years—today on our amateur bands we have recently heard commercial FSK Hellschreiber at area of 3.4 MHz, but the baud rate is different to Feld-Hell.

It is possible to operate Feld-Hell under similar conditions and in similar bandwidths to CW. In effect, Hell is one of few simple modes available to the amateur and can be tuned down into the noise and still be fully readable. Hellschreiber should attract the attention of:

- QRP and portable operators—it's compatible with your new ALIVO transceiver.
- MF and low HF operators—avoid the noise, have readable digital QSOs.
- LF (170 kHz) or lower enthusiasts—what better way to key their transmsitors?

Now that every amateur shack is equipped with a personal computer (yours likely uses the equipment requirements for operating Hellschreiber are minimal. You probably have everything except the software. All you need is:

- DOS-based PC, preferably 280 or better
Hellschreiber
An old mode still has performance that's hard to beat
Part II—getting on air
Murray Greenman ZL1BPU

PART I described the development of Hellschreiber and gave technical details of this simple but interesting digital mode. Part II of the series describes how you can easily get on the air with Hellschreiber—probably with equipment you already possess.

Software
There are several programs available, but I would recommend getting started with the simplest to use software, from Sigfus Jonsson LA0BX. This will work with a very simple Hamcomm style modem, and needs no more than a DOS-based PC. Like many communications applications, it will not work in a Windows 95 DOS box, but often does work in full screen mode, although the timing may not be reliable. However, the LA0BX software will work in DOS from Windows 3.1.

The LA0BX program has minimal instructions, but few are needed, and the configuration file is easy to understand and alter to suit your station. Most examples in this article were transmitted and received by the LA0BX software. The software will display multiple lines of Hell text on the screen and allows the operator to send standard Feld-Hell signals and CW ID. The transceiver is fully controlled from the keyboard. The latest version of the LA0BX software, called HS.C9709.zip, is only about 85 K bytes and can be downloaded from the SARTG FTP site, or via the LA91HA Hellschreiber page. If you find it difficult to obtain the software, send me an SASE containing a PC formatted blank 3.5" disc. Alternatively, email me at greenbaa@link.co.nz

The software is free for non-profit use.

Computer
The computer requirements are minimal. You need a PC—and that's about it! Sigfus recommends a 286 or better, and a serial port or parallel port is required, plus CGA display or better. I have used the LA0BX software successfully on the following computers:

- No-name Pentium II 233 MHz with 3 MB 5e S/VGA
- IBM PS/Note 486/25 laptop with mono VGA
- HP200LX palmtop (10 MHz 80186 processor, 640x320 mono CGA)

The palmtop and an ALIVO transceiver would make the ultimate portable digital station. The HP200LX must run the LA0BX software without the graphical interface—in native DOS mode.

Connecting up the LA0BX software
Sigfus intentionally kept his manual as short as possible (to make sure you would read it!), but there are one or two things that should have been mentioned that affect amateurs interested in building their own interfaces. The software can use a standard Hamcomm or JVFAX interface, provides power for the interface from the computer serial port, and expects to use the signals shown in Table 1.

To use your interface for HFFAX, EKSSTV, Pasokon TV Lite, MSCAN, JVFAX and so on, you need also to connect the receiving limiter output to the R1 signal. LA0BX expects this signal on DSR, so for compatibility, connect it to both pins.

If you plan to use your interface and LA0BX software with an SSB transceiver, no modifications are required. If a CW transceiver is the target, the keying input can be driven by the Hamcomm PPT circuit, by moving the anode of the diode that goes to the base of the PPT transistor from RTS to TXD. Use the VOX in the rig to turn the transmitter on and off. Alternatively, build a copy of the PPT circuit especially for CW, and connect it to the TXD signal. In Figure 1 is a design capable of keying a JA transmitter. It is possible to key a high-speed relay using the Hamcomm PPT circuit. The pull-in and drop-out times of the relay should be less than 0.2 ms, or the dots will be difficult to read.

To operate the interface with an ALIVO transceiver, you will need to provide high current keying transistor like the Darlington design shown in Figure 1. You will need a manual transmit/receive changeover, as the standard ALIVO has no relay (now there's a good idea!).

Setting up the LA0BX software
To set up the software on your PC, start by "unzipping" the LA0BX program into a new directory, and then configure the software files to suit your installation. Table 2 shows the files you will find in your directory.

<table>
<thead>
<tr>
<th>Table 1: LA0BX signals</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal</strong></td>
<td><strong>DB9</strong></td>
</tr>
<tr>
<td>DSR</td>
<td>6</td>
</tr>
<tr>
<td>RI</td>
<td>9</td>
</tr>
<tr>
<td>TXD</td>
<td>3</td>
</tr>
<tr>
<td>RTS</td>
<td>7</td>
</tr>
<tr>
<td>DTR</td>
<td>4</td>
</tr>
</tbody>
</table>

Receive data from Hamcomm limiter, Alternative Hamcomm input (used by WEFAX and SSTD, etc.), Transmit audio (in TXD2 mode), Transmit keying (TXD0 mode), Press-to-talk signal to transceiver, interface power (-9 V), Interface power (+9 V).

<table>
<thead>
<tr>
<th><strong>Table 2: LA0BX files</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HS.CFG</strong></td>
</tr>
<tr>
<td><strong>HS.ESE</strong></td>
</tr>
<tr>
<td><strong>HSMAN.ENG</strong></td>
</tr>
<tr>
<td><strong>MESS</strong></td>
</tr>
<tr>
<td><strong>CONTEST.TXT</strong></td>
</tr>
<tr>
<td><strong>HSMAN.NOR</strong></td>
</tr>
<tr>
<td><strong>LPT_INTF.TXT</strong></td>
</tr>
<tr>
<td><strong>MODEM.ENG</strong></td>
</tr>
<tr>
<td><strong>MODEM.NOR</strong></td>
</tr>
<tr>
<td><strong>REF.TXT</strong></td>
</tr>
</tbody>
</table>

Station configuration file, LA0BX DOS executable (the program), English language manual, Canned messages: bag messages, station ID, etc. Information about the annual HF contest, You never know when you might need the manual in Norwegian... The L9201 modem and use of the LPT port. Simple LA0BX modem and COM port information in English, Simple LA0BX modem and COM port information in Norwegian, Bibliography of reference information available about Hellschreiber.
Table 3. Software configuration in HS.CFG

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT4</td>
<td>Interrupt for COM1 (use INT3 for COM2).</td>
</tr>
<tr>
<td>COM1</td>
<td>Selected COM port (use COM2 for COM2).</td>
</tr>
<tr>
<td>BONW</td>
<td>Black on white display—probably more readable than white on black on most PCs. Sets CW ID speed.</td>
</tr>
<tr>
<td>CW14</td>
<td>Suitable upper limit of software bandpass filter.</td>
</tr>
<tr>
<td>UF1100</td>
<td>Suitable lower limit of software bandpass filter.</td>
</tr>
<tr>
<td>LF800</td>
<td>Detector sensitivity.</td>
</tr>
<tr>
<td>SP1100</td>
<td>Speaker on.</td>
</tr>
<tr>
<td>TXD2</td>
<td>Speaker tone frequency (near Tx frequency). 960 Hz Tx tone on TXD pin.</td>
</tr>
</tbody>
</table>

You need not worry about the LA08X or LA920 problems unless you are interested in playing with the software and experimenting with it. The Hamcom interface works quite well enough in the HS.CFG. Edit this file with a DOS text editor such as notepad, don't use a word processor! Most of the information in this file is comment, and the important lines (recognized by the software) start with a "#" symbol. The list of parameters in Table 3 assumes that you are using the port COM1 serial port, an ATASCII transmitter, and have your narrow CW filter for use on 960 Hz received tones.

If you plan to use a CW transmitter, change to TXD0 and modify your Hamcom interface as described in the previous chapter (the transmitter won't appreciate timing the audio tones at 960 Hz), and you may find it difficult to see a 1715 Hz received signal with your CW filter. This will matter if you don't mind using the RTT to offset the received signal.

Before you try transmitting, edit the file MESS with a text editor, and add all your standard station information and logging requirements. It is wise to leave ALT F8 and ALT F9 blank, as they are not used at all. If you intend to change to CW receive, get confused in the middle of the QSO. You can use the function keys by embedding them in these messages, unfortunately, although some can embed them in the transmitting keyboard buffer. The experimental version of the MESS software which I am developing provides optional commands in the MESS file and allows you to set up a "beacon" mode with CW and MESS ID.

The commands F8, F9, and F10 are for use from the keyboard, during a QSO. These keys are used to transmit commands to the software. I have found it convenient to complete your QSO, then switch to CW to send your call-sign, then switch to receive, and then:

... so, over to you Fred, G0PPG de ZL1BPU AR K <F8> de ZL1BPU <F9>

The commands ALT F8, ALT F9 and ALT F10 are the equivalent of the previous commands. While the other station is transmitting, you can start filling your buffer, and when it is your turn, press ALT F10 to transmit at the start of the buffer. This is just as simple as typical RTTY operation.

Interface

The simple Hamcom or JVFAX modem (it has one op-amp and one transistor) will allow the software to detect on/off keying of the transmitted signal because the LA08X software uses a clever digital signal processing technique. That the LA08X Bell program uses the Hamcom modem is good news, because this same hardware permits operation on RTTY and AMTOR (using Hamcom software), as well as FAX (using PC HFifax or JVFAX) and SSTV (using MSCAN, EZSSTV, Pasokon TV Lite or JVFAX). If you operate any of these modes using a Hamcom interface, you now have no excuse not to run Hellschreiber!

For miniaturation addicts, the Hamcom interface can easily be built inside a DB25 connector, but it is equally useful in a small desktop box, which gives you the opportunity to include extra features. A complete schematic and excellent layout program for the interface can be found at http://www.b3000cb.com/~tnsay/bar avoidance.htm

My Hamcom interface- like interface is built into an existing modem, which already has the power supply, the limiter circuit, some useful band-pass filtering and a very good transmitter low-pass filter. It also has tuning meters, and allows audio to an external speaker, to be turned on and off, so you can hear what you are doing, when you need to.

Many other amateur modems, such as RTTY units (Maplin TU1000, BARTG Mut-tyter, AF4Z Multi-modem and others) have PC compatible signals, and may be modified to provide both receive and transmit operation on Hamcom compatible programs. Take the output of the slicer to the PC COM port R1 and DSR inputs, and connect the COM port TXD line to the transmit tone filter in place of the existing tone generator, via a switch, so you can still operate RTTY if the need arises.

There is also a fairly simple specialized Hell modem designed by LA08X. I have the schematic of some very high performance grey-scale modem designs by PA9DF, SASE if you are interested. If you wish to use an SCS PTC-II Pactor controller for high performance Hell without making any modifications to the unit, contact Wilbert ZL2BSJ for information.

Receiving Hellschreiber

Connect your Hamcom modem to the PC and the radio, and after setting up the software, as described above, run the file HS.EXE from DOS.

To adjust the receiver, set the audio gain until occasional noise dots appear on the screen. You will find that very little audio is required. If you can't find any Hellschreiber signals (no surprise!), practise by tuning in a CW signal (CW signals print what looks like bar codes). Hellschreiber signals are easily identified—they have a purr-purr sound like bursts of high speed Morse, and are distinctly different to other digital modes, largely because Hell uses a single tone system. Once a signal is received, tune across it carefully, for best (brightest) copy, and if necessary adjust the audio and RF gains for best printing. If the signal is strong, it is best to use very slow AGC or wind back the RF gain to defeat the AGC, which may otherwise cause noise to appear between characters.

On weak signals, experiment with RF and audio gain for best printing. If the signal is subject to rapid fading, you may need to adjust the gain occasionally during an over to achieve best results. Hell is subject to some interesting multi-path and fading distortion effects. For example, it is not uncommon for occasional characters to appear to have their pixels splashed all around where they should be, as they arrive by different paths and therefore at different times. Observe the first "E" in the following sample.

B E N N I N G T O  E V E N  M E A N I N G T O

Rapid fades can cause the loss of one or more characters as the AGC catches up.
Observe the loss of two characters, and nearly a third, in the next sample.

The ideal AGC would have about 500 ms attack and 500 ms decay. On 80 m it is normal for copy to deteriorate as the evening progresses, due to multi-path timing distortion. This effect is well-known to RTTY and AMTOR operators. On 40, 30 and 20 m copy is generally much less affected—the biggest problem is that occasionally letters print on top of themselves due to long path and short path reception. Another interesting effect on the higher bands is a “wave” effect, as a weak signal fades in and out over a few seconds.

The performance of your receiving equipment will be considerably enhanced if you use a 500 Hz bandwidth filter. The digital filter in the software has very steep skirts and performs very well, but if you set the bandwidth too narrow, it will make the signals difficult to tune. I recommend most of the time in this mode, i.e., with SSB filter in the transceiver and 500 Hz wide software filter, because it allows you to listen to adjacent signals. The disadvantage of the software filter or an external audio filter is that a strong signal within the receiver pass-band will pump the AGC and seriously affect copy of a weaker Hell signal. The only answer to this is a narrow IF filter.

Few transceivers allow the CW filter to be selected in SSB mode. If yours does not, you will need to switch back and forth from SSB to CW on transmit and receive. There is a simple modification to the Kenwood TS-430S which places the CW filter in the SSB Narrow position—allowing 800 Hz centre frequency to be used on upper sideband and 2.1 kHz centre frequency on lower sideband—ideal for Hell-schreiber and RTTY respectively. The filter centre frequency must match the filter in the LA0BX software. Adjusting the tuning becomes critical as the characters run together. If you don’t have, or

can’t use a CW filter, experiment with pass-band tuning.

Because of its narrow bandwidth and off-keying, it is legitimate to operate Hell-schreiber in the CW section of most bands, but in keeping with its “data” designation, it is probably best to keep the data segments, at least on 80 m and 40 m. The European calling frequencies are 3558 kHz and 7035 kHz. There is operation in Europe on Sundays at 1230Z on 80 m, 1530Z on 40 m, and VR2DSG works Europeans at 0200Z on 14061 kHz, although these times and frequencies are changing all the time. A good place to look for local, ZL and VK, Hell-schreiber operation is just above the CW segment on 80 m, say 3358 or 3630 kHz. “Look for” is the operative term, because the signals are difficult to identify if they are weak. A weekly Hell net is under discussion and is likely to be 3558 kHz Fridays at 0800-0900Z.

Transmitting Hell-schreiber

Before you transmit, tune up the transmitter with carrier, then make final adjustment of audio gain (or transmitter drive) by sending CW from the LA0BX software. This is important because the duty cycle of Hell-schreiber is low and it is tempting to override the transmitter. The oscilloscope picture of the offered received signal (below) clearly shows the low duty cycle of the transmitter. Two short words (about 10 seconds) are shown, and the signal was 59+ copy at a range of about 40 km.

If you are using a CW or homebrew transmitter, check the keying waveform of the transmitter. If the transmitter uses VOX or is capable of full break-in, it is not so important if the first character after sending starts is lost, but the transmitter must send each following dot with a pulse width of at least 3 ms. There will be delay between the keying signal and the RF output, but the RF signal should be similar to the keying signal. The ARRL-accepted standard of 3 ms rise and fall time for CW transmitters (to avoid key clicks) may be too slow for Hell-schreiber—around 1 ms would be better. Some CW transmitters may need modification for high speed transmission, but there should be no such trouble with SSB transmitters. Remember that the keying speed is equivalent to 80 wpm Morse. With the transmitter on dummy load, tune across the signal and check for clicks and excessive bandwidth.

Once you have set the audio level correctly by sending CW, you can change to Hell and, without changing the settings, you are ready to put out a call. When you do, observe that the transmitter average power level is much lower, and the transmitter barely gets warm. If you use a CW transmitter, perhaps an old valve one, tune it up for maximum CW (even get the plates to glow!), and it will be happy sending Hell without distress.

When you call CQ or make a test transmission, always include a CW ID after the transmission, so that other amateurs will know what is going on. Hell-schreiber is not that difficult to operate—use a Voice ID as well. The point is that you will have a chance to pass on to others who listen the news with this fascinating old mode.

While it is possible to operate Hell with good conditions under an SSB QSO, not something to do on purpose. Choose a clear frequency in the data segment (suggested 3610-3630 kHz on 80 m). Carriers or CW signals within a few hundred Hertz of the received frequency are seriously effective copy if they are strong enough to capture a limiter. It won’t matter if you have local noise on the frequency, but it will make keying signals difficult. Call for Hell for at least a minute or two, remember, when you are in sending characters, nobody will know that you are using the conventional CW and RTTY shortcuts and operating procedure. It should be possible to operate full break-in Hell, but I have not yet seen software that supports the ability to listen between words. You software experts—writing!

Advanced techniques

A number of amateurs have contacted, both on air and via email, are using developing Digital Signal Processing techniques to receive the transmit Hell. One good example is a program called EVMHell, written for the Motorola 56002 Evaluation Module by Doug Brauning N1OWU. Another is an elegant technique being developed by PA2DQ, which uses a PIC processor to digitize the received signal at high speed, while taking all the timing problems away from the PC. Both of these systems exploit grey scale display and proportional transmit fonts. The weak signal performance of these systems is better than the LA0BX software. I am hoping for someone to quickly develop a system using the onboard sound card to demodulate the received signal.

In a subsequent article I hope to discuss the technology.
PART I described the development of Hellschreiber and gave technical details of this simple but interesting digital mode. Part II of the series described how to get on the air with Hellschreiber. Now we will look at some properties of the signal and discuss some important recent developments.

Bandwidth

It is widely believed that CW occupies no bandwidth, although this is not actually so since the signal occupies a bandwidth related to the signalling speed. In this respect, Feld-Hell is like high-speed CW, 80 wpm CW in fact. The greatest instantaneous bandwidth requirement is for alternate black and white pixels, at 122.5 bits/sec, or 61.25 Hz, the same as a string of dots at 80 wpm. This causes sidebands spaced 61.25 Hz down from the carrier, and will be about 40 dB down at the tenth sideband. The 30 dB bandwidth (5 S points down on the carrier) will be 612.5 Hz, as shown in Figure 1.

<table>
<thead>
<tr>
<th>Mode</th>
<th>AGC</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 wpm CW</td>
<td>4 dB</td>
<td>30 dB</td>
</tr>
<tr>
<td>Feld-Hell</td>
<td>24.5 Hz</td>
<td>245 Hz</td>
</tr>
<tr>
<td>MT-Hell (see later)</td>
<td>61.25 Hz</td>
<td>612.5 Hz</td>
</tr>
<tr>
<td>RTTY (50 baud)</td>
<td>100-200 Hz</td>
<td>200-400 Hz</td>
</tr>
<tr>
<td>AMTOR (100 baud)</td>
<td>200 Hz</td>
<td>500 Hz</td>
</tr>
<tr>
<td>HF Packet (300 baud)</td>
<td>400 Hz</td>
<td>700 Hz</td>
</tr>
</tbody>
</table>

Table 1

These days it is relatively easy to measure keying bandwidth using a PC, even if each individual spur cannot be seen due to lack of spectrum analyzer resolution. The spectrum analyzer I use is Spectrograph 4.2.2a, which uses the PC to transmit CW or Feld-Hell data elements as short 8 ms, the transmitter key speed must be high. Commercial transmitters softened keying edges to minimize clicks in CW mode, provide creditably clean but may not be suitable for transmitting Hellschreiber. ARRL recommend 3 ms transmission time and fall time for slow-speed CW which is a significant portion of the Hell time! Slower response to continuous carrier prior to high speed keying...

Figure 2

In a Break-In article many years ago, an excellent series of drawings showed the bandwidth occupied by various signals, and showed that a CW signal displays a peaked spectrum with sidebands at the keying rate, just like Figure 5. Most of the other modes portrayed in the article were FSK, and exhibit a flat top or double peaked characteristic.

Figure 1

We can update that article for Hellschreiber related Sound Card for input. Figure 2 is a 256 point FFT (Fast Fourier Transform), averaged over 32 measurements to smooth the noise, and shows a 32 wpm string of CW dots.

The spectrum analyzer was fed from a Collins 32S-1 receiver on LSB with a 2.4 kHz filter, via a transformer-coupled high-pass filter with 300 Hz cut-off to reduce the hum. The receiver RF gain was backed off to disable the AGC and limit background noise. The transmitter was a homebrew, VFO-controlled, QRP rig on dummy load at 3.6 MHz. The equipment was adjusted to 0 dB on a con-

Figure 3

The best way to get around this is to use an SSB transmitter, partly because the time of the transmitter is shorter (under 1 ms) and partly because the key clicks (which will be generated) can be lim-
ited to a 2.4 kHz bandwidth. This is how the LA0BX software operates. Before you operate Feld-Hell with your trans-
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In a Break-In article many years ago, an excellent series of drawings showed the bandwidth occupied by various signals, and showed that a CW signal displays a peaked spectrum with sidebands at the keying rate, just like Figure 5. Most of the other modes portrayed in the article were FSK, and exhibit a flat top or double peaked characteristic.

We can update that article for Hellschreiber related Sound Card for input. Figure 2 is a 256 point FFT (Fast Fourier Transform), averaged over 32 measurements to smooth the noise, and shows a 32 wpm string of CW dots.

The spectrum analyzer was fed from a Collins 32S-1 receiver on LSB with a 2.4 kHz filter, via a transformer-coupled high-pass filter with 300 Hz cut-off to reduce the hum. The receiver RF gain was backed off to disable the AGC and limit background noise. The transmitter was a homebrew, VFO-controlled, QRP rig on dummy load at 3.6 MHz. The equipment was adjusted to 0 dB on a con-

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Figure 1

The best way to get around this is to use an SSB transmitter, partly because the time of the transmitter is shorter (under 1 ms) and partly because the key clicks (which will be generated) can be limited to a 2.4 kHz bandwidth. This is how the LA0BX software operates. Before you operate Feld-Hell with your transmitter, it is a good idea to check or adjust its keying waveform with an oscillo-

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scope, comparing the trans-
mmitter with Figure 3.

There is a cunning tech-
nique employed in the tradi-
tional mechanical Feld-Hell
machine which limits the mini-
mum pulse width to 8 ms
able providing 4 ms resolu-
Hential. I omitted this from the
description in Part 1 to limit
the reader's confusion. The
font is designed so that the
characters have 4 ms resolution,
or rather 8 ms, for appro-
prop character shape, but
the 4 ms pulses are never
transmitted alone, for exam-
ple in the right of a "B" there
are two 12 ms pulses (each 1.5
dots). The purpose of this
restriction is not only to
produce key clicks, it also
restricts the minimum size of
pulses that the mechanical
reception equipment need
respond to, and helps the
transmitter generate reason-
able pulses despite slow key-
ing.

The waterfall plot
The spectral display (for
example, in Figure 2), is an
excellent tool which displays
signal strength vertically, and
frequency horizontally. How-
ever, it does not tell the whole
story, as well as clicks and
blips, there are many things
that are right to see with a
conventional spectral display.
This is the time to roll out the
second weapon, the waterfall
display, which portrays signal
strength vertically, time hori-
izontally, and signal strength
at brightness or colour. The
second card waterfall plot is
a real-time spectrumogram and
is usually the most important
feature of the Radio test tool
developed since the Grid Dip
Meter. With a waterfall dis-
play, FSK keying, key clicks,
blips, blips and distortion are
demystified. Figure 4


Figure 4.

Decisions, decisions
In Part 1 of this series I
touched on the problem that is
common to all digital modes:
what is there a data bit, and
what is it? To refresh your
memory, I quote:

"It has always been a prob-
lem with automatic recep-
tion, that the equipment
must decide in real time
when a data bit occurs,
and what the data bit is.
Both of these properties
are subject to transmission
path errors, and conse-
quently the equipment is
prone to making errors."

A good digital communi-
cation system should either:

- make highly accurate deci-
sion (TYPE A), or

- avoid making decisions at all!

In a noisy HF environment,
particularly where simple
equipment is an important fac-
tor, the latter approach—I call
it TYPE B—is a much simpler
approach to take, and quite
appropriate for casual QSOs
and nets.

This decision process
applies to all digital modes,
and most modes attempt to
take the first approach. Mak-
ing highly accurate decisions
is important where the data
transmission controls equip-
ment without human opera-
tors, for example operating
radio bulletin boards or
repeaters. However, for
person-to-person random
QSOs, the alternative (no
decisions) approach is entirely
appropriate and much sim-
pler. Of course, CW addicts
have known this for years. It is
also recognized that error cor-
correction and detection processes
occupy a significant propor-
tion of useful transmission
bandwidth that could well be
used to provide redundancy
to enhance the noise tolerance
of the radio circuit, and so avoid
needing error correction! CW
and Hall are unique among
digital modes in taking the
TYPE B approach, by avoid-
ing making decisions in elec-
tronics. FAX and SSTV have
some similar properties, but
are considered to be analogue
modes.

In the example below, the
timing is out by more than two
per cent. If individual bits of


two facets. When refers to syn-
chronism—deciding when
there is a data bit, which is no
simple matter when the radio
path length can vary by as
much as the length of many
bits. What refers to whether
the information in the radio
channel at the time a decision
needs to be made is data 1,
data 0, or noise. Almost all
data systems are synchron-
nous or asynchronous. In syn-
chronous systems the data is
sampled at fixed times relative to a
reference (which may be trans-
mitted ahead of the data, as it
is in Packet radio, or at the
start of a frame, as it is in
AMTOR and PACTOR). In an
asynchronous system, data is
sampled at fixed times relative
to the start of the data word
(as it is in RTTY). All of these
modes experience the what
and when problem, because
each data bit transmitted is
subject to the vagaries of the
ionosphere. For human read-
ability, a non-synchronous
mode would be ideal.

Feld-Hell is a step in this
direction. First of all, Feld-Hell
is uniquely quasi-synchronous.
This means that the receiving
equipment should try to be in
step with the sending equip-
ment, but the information
is not lost if it is not quite in step.
Rudolf Hall achieved this with
two clever mechanisms: printing
data when it arrives, and
providing immunity to term-
ing errors.

First, the pixel is printed
when it arrives, so it isn't
sampled as such. Both mechanical
RTTY machines and com-
puters used for RTTY have
to sample the incoming data bit
at a fixed time (typically in the
middle of the expected bit),
whereas the old Feld-Hell
machine simply prints a dot
when it gets the data—even if
it is late or early. No time
decision is made. Secondly,
the timing is relatively unin-
important, because if the equip-
ment gets out of step, the
effect is to cause the charac-
ters to move up or down, or
ultimately, to slant up or
down.

In the example below, the
timing is out by more than two
per cent. If individual bits of
data arrives seriously out of time, which they will if the propagation path changes due to ionospheric multi-path effects, pixels will be scattered, the quasi-synchronous nature of Feld-Hell causing the print to be not easily readable. This is what happened to the “1” in my call-sign in the next example.

A mechanism related to the what process, which should be employed by Feld-Hell, is the use of “fuzzy” logic. In other words pass on information to the reader based on the likelihood of there being a data bit, rather than make a firm yes/no decision. This technique is used in multi-tone and grey-scale versions of Hell. Probability, over-sampling and averaging are the techniques which can make the most spectacular improvement to reception. The following samples were both generated from a tape recording of OH/DK42C transmitting Feld-Hell on 20 m. First, as received by the LA0BX software, with its fixed bit decisions and quasi-synchronous timing:

Second, a sample made by Rob ZL2AKM by post-processing the data from the same recording, using over-sampling, averaging, and grey-scale to portray probability (see Table 2).

In a couple of places in this article, you will have spotted references to “MT-HELL”. This is the secret weapon of the Hell-schreiber world — multi-tone Hell-schreiber.

Now that you have been introduced to the spectrogram, the next issue will discuss MT-Hell, sending encoded text in the frequency domain and the advantages this has. New Zealand now has a score of Hell users, and several already operate frequency domain Hell!

If you are interested in experimenting with DSP, want to talk digital, have any questions, or want to hear MT-Hell, send me a note. I recommend that you join the irregular net on 3560 LSB at around 0830-0930z week nights. Friday night is the ZL Hell Raisers’ net, and a good opportunity for a Hell contact with VK. All the software you will ever need for Hell is available on my web site, or failing that, by sending me a floppy disk and an SASE.

For more information visit my web site at: http://members.zoon.com/zl1bpu/contents.html

References
2. Spectrogram 4.2.4 or Win95 or WinNT, is freeware by R. S. Hume rehorne@msn.com and is available for download at http://www.monumental.net/rehorne/gram.html. Highly recommended for any radio signal analysis.

CQ Calling all newly-licensed radio amateurs

If you gained your licence within the past 12 months and would like to introduce yourself to the ZL amateur radio community through Break-In please fill in the form below and send it, with a photograph of yourself (optional, include SASE) you want it returned to: The Editor (New Hams), Break-In PO Box 1733, Christchurch

Please type or print clearly

Call-sign __________________________

Date gained licence __/__/____

Family Name ______________________________

Given names ______________________

Address _______________________________________

Age group (optional): under 20 yr [ ] 20-40 yr [ ] 40-60 yr [ ] over 60 yr [ ]

Are you a member of a local radio club? [ ] [ ]

Name ________________________________

Which aspect of the hobby interests you most?
1. ________________________________
2. ________________________________
3. ________________________________

Any other comments or information ________________________________

8
PART I described the development of Hellschreiber and gave technical details of this simple but interesting digital mode. Part II of the series described how to get on the air with Hellschreiber. Part III dealt with signal analysis and digital philosophy. Now we will discuss some important recent developments.

At the risk of being suspected of an "April Fool's" joke, I would like to conclude this article with an introduction to sending text in the frequency domain. Up until recently, all Amateur transmissions, including Hellschreiber, took place in the time domain. Even if different frequencies were used (FSK), the transmissions remained in the time domain, and were decoded in the time domain. However, it is quite possible to transmit signals in the frequency domain. Digital HF users may be aware of frequency domain modes such as Piccolo, and there are phase domain examples as well (PSK31, Clover). These phase and frequency modes are (according to my definition) TYPE A communications systems. A few amateurs, G3PLX, G3PPT and myself are working with sending text as a frequency domain TYPE B transmission. The aim is to free the text transmission from all time domain-related effects, of course including interference and most importantly, freedom from ionospheric propagation timing distortion, which affects Feld-Hell and has such a disastrous effect on RTTY, even when signals are strong.

The secret to analyzing text signals in the frequency domain is good Fast Fourier Transform software, with a display of frequency against time—the waterfall display again! Frequency domain transmission can be likened to the chirping of birds or the noises of whales—they make no sense to humans, but when displayed on a spectrograph, which displays frequency against time, recognizable patterns are visible. The same applies to sending text as tones. If you have a spectrogram program, try whistling different notes, with some practise, you might be able to whistle your name! (Jack is difficult, but Jill is easy.)

This is exactly the technique used to generate frequency domain text, which we call Multi-Tone Hellschreiber, or MT-Hell, because of its historical association with Feld-Hell. The MT-Hell signals are generated as a series of chirps, and may contain more than one tone (frequency) at a time. There is no amplitude information, except that when there is no tone, there is no dot. We have evolved two systems—concurrent C/MT-Hell, and sequential tone S/MT-Hell, which are largely compatible with the same receiving software. Most of the work so far has been done using sophisticated DSP hardware and up to 16 concurrent tones. I have been working with seven sequential tones, a system I call MOSIAC II, which sends text using a simple DOS PC program. I use GRAM and a PC sound card to receive.

This example shows C/MT-Hell, generated using sound card software by G3PPT. It has upright characters and sharp, thin text. The next sample is S/MT-Hell generated by my MOSIAC II, and has slightly taller, fatter text, which slopes to the right.

Both systems use seven tones with the same tone spacing, and were recording using the same GRAM settings. The images have not been enhanced, enlarged or touched up in any way. Some distortion and noise surrounding the text in the above examples can be attributed to keying rate sidebands and clicks. There are also mathematical shortcomings in the FFT technique which cause similar effects. With a fast enough PC, and the right windowing technique, these artefacts can, to a large extent, be controlled by choosing the correct settings.

Most received noise is in the amplitude domain, which contributes significantly to the noise rejection properties of frequency domain reception. In addition, in-band interference such as signals, splatter, and lightning crashes have very little effect on the readability of MT-Hell text. I have demonstrated this by sending a QRP MT-Hell signal between the tones of an amateur RTTY news bulletin transmission on 80 m—with good readability! The following picture demonstrates this.

The ragged block marks top and bottom are the 170 Hz shift RTTY signal, and the MT-Hell text in the centre is clearly visible. With the ear, all that could be heard was the RTTY station. The MOSIAC II transmission is a mere 50 Hz wide, transmitted at 10 pixels per second, or about one character per second.

Because MT-Hell operates in the frequency domain, there is no notion of synchronism, no need to match transmit and receive tone frequencies or even pixel rates at each end of the communications path. Thus the timing requirements are very relaxed, as can be seen in the following example, where two completely different transmission techniques, at different speeds, are decoded at the same time!

Relaxed timing also frees MT-Hell from time-of-arrival errors caused by the ionosphere. Even variations in timing caused by the computer operating system has negligible effect.

It has been found that the pixel tone spacing (Hz) should approximately match the pixel rate (pixels/sec) for the best compromise of readability. This places the first keying sideband under the adjacent pixel and minimizes the pixel structure. (Helps the characters look smooth rather than dotty.) This approximate one-to-one aspect ratio is really all that defines the timing of the characters.

Unlike Feld-Hell (amplitude keyed Hellschreiber), there is no need to display each character twice to combat bad character synchronism—because there is no concept of synchronism! MT-Hell is truly non-synchronous (look back at the table of properties). Tuning is uncritical, and although the transmitted signal is generally less than 200 Hz wide, there is no need for a narrow filter. Interfering signals have minimal effect on copy, unless they are that much stronger than the wanted signal that the receive gain is affected by AGC action.