Hellschreiber

What it is and how it works

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After 1945 most of the world news agencies adopted the Siemens-Hell system for both overseas and domestic news distribution. It was adapted by Siemens to other alphabets such as the Cyrillic script, in which Russian and some Slav languages are printed, and by the Chinese for transmitting the ideograms of Chinese and other Asiatic languages (see Fig 1(f)). In the 'fifties Siemens produced a page-printing *hellblatteschreiber* which was used extensively in western Europe during the post-war years, and the Siemens-Hell-Schreiber GL, a start-stop system evidently intended as a competitor to the rising popularity of the Baudot-coded radio teleprinter. The GL system survives to this day and is used commercially on wire circuits in Germany, and by amateurs. It was perhaps a foregone conclusion that one day the Hellschreiber would be out-moded. Essentially a strip printing system, it was eventually out-performed by the Baudot-coded radio teleprinter, which by the early 'sixties had become firmly established as a page printing system with the added benefits of frequency-shift keying and protective devices.

Introduction

Considerable interest has been aroused in recent years, particularly among amateurs in Europe, in the direct printing telegraph system known as Hellschreiber, or, to give it its correct name, Siemens-Hell-Schreiber. This upsurge of interest in what might be described as an out-moded means of transmission began in the mid-'seventies when a number of amateurs acquired or unearthed pieces of ex-second-world-war German military equipment. Subsequently other amateurs began to study the principles of the Hellschreiber, and soon found ways of adapting it to the ubiquitous microprocessor. No one seems to know why the Hellschreiber system failed to attract the attention of amateurs much earlier—it was used extensively for over 30 years in various types of radio communication, referred to in text books [1], and given a full description in at least one journal as early as 1948 [2].

However, the present growth of interest in the subject has prompted amateur radio magazines to publish information on the Hellschreiber and on the way in which it is being used by amateurs in The Netherlands, West Germany and France [3]. One might therefore ask: "What is there in the Hellschreiber system that has attracted the amateur at this late stage?" and "How does the system compare with other printing telegraphs?" The object of this article is to explain the Hellschreiber system of transmission, to describe its advantages and limitations and thereby to enable the reader to answer these questions.

History

Siemens-Hell, the name by which the Hellschreiber system generally became known and further contracted into "Hell", was devised by Dr Rudolf Hell and developed by a company of that name in Germany in the early 'thirties. The patents of the system were later made available to Siemens-Halske of Berlin, and the equipment was subsequently manufactured by them and marketed world-wide under the name Siemens-Hell. As well as taking the first syllable of the name from that of its inventor, the full name "Hellschreiber" is the German word for "clear writer".

When first launched upon the communications world it was particularly attractive for its simplicity; the receiving mechanism had only two major moving parts and, furthermore, could be plugged into the most elementary type of radio receiver. For this reason it was ideally suited to the transmission of news despatches and multi-destination radio news broadcasts, and by the outbreak of the second world war a number of world news agencies had adopted the system for world-wide distribution of their material. From 1939 to 1945 Germany's Hellschreiber transmission dominated Axis news from the war areas; the official news agency operated an almost day-long service in German for domestic newspapers, while other subsidiary news agencies broadcast Hellschreiber transmissions in several languages to many parts of the world.

As might be expected, Siemens-Halske were quick to appreciate the possibilities of Hellschreiber in other branches of telecommunications, and by 1935 the company had developed a portable Hellschreiber transceiver, the *feldfernschreiber* or "field telegraph writer". Information published at the time described this equipment as "suited to use by the military or police for transmitting written messages over temporary telephone or power lines and radio circuits." The *feldfernschreiber* eventually became a standard unit of the German armed forces, and they were manufactured in large numbers in Germany and in other parts of occupied Europe almost until the end of hostilities.

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General

Before describing the Hellschreiber system and making comparisons with other systems, the main features of its closest rival, the teleprinter, should be briefly considered. As many will know, the teleprinter is a digitally-encoded system. Each transmitted letter consists of an even-length group of five impulses or elements, usually of 20ms duration, and designated "marks" or "spaces". Some are grouped together in blocks, but each is preceded by a "start" pulse of one "space" element and finished by a "stop" pulse usually of 1·5 "mark" elements. The receiving mechanism is at rest until the start pulse is received; it is then put into motion. As the signal train arrives, each element is examined in turn and, finally, the receiving machinery is set up to print the received character. If an element is not "seen" by the receiving interrogator, the wrong letter is printed; or if the missing group is a "shift" signal the machine will stay on "letters" when "figures" is intended. It is therefore essential that each coded letter group is received undistorted, and to this end much effort is directed both in the signal path and in the terminal circuitry and printer mechanism.

By contrast, Hellschreiber is not a digitally-encoded system. Each letter is transmitted as a picture consisting of a train of "mark" and "space"

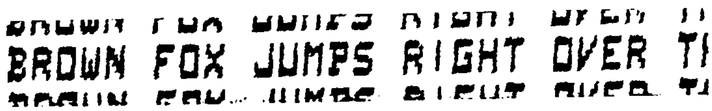


Fig 1(a). Transmitter and receiver running at approximately the same speed

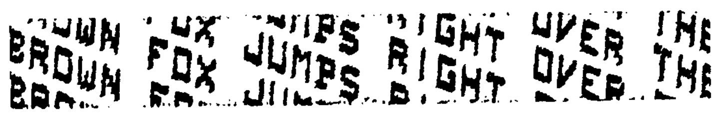


Fig 1(b). Receiver running slow

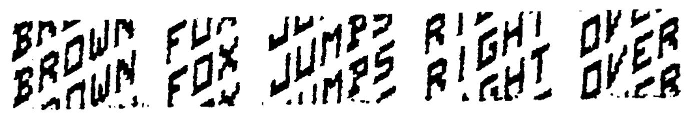


Fig 1(c). Receiver running fast

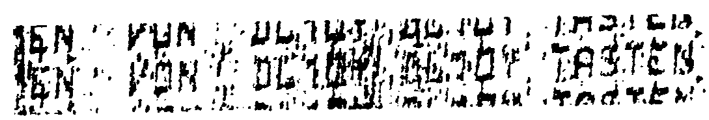


Fig 1(d). QRM on DL1OY in QSO with PA0OB on 7,033kHz

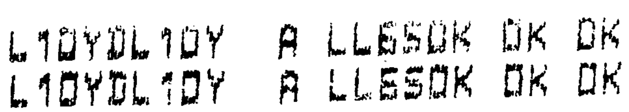


Fig 1(e). Computer-produced signal from DL1OY using an Apple 2

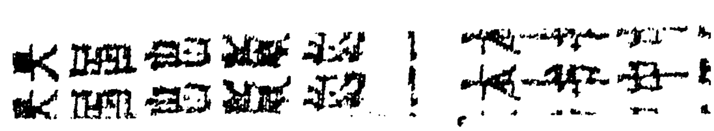


Fig 1(f). Hellfax from Peking received by ZL1BAD and processed before printing at G5XB. Frequency 14,140kHz impulses which are synthesized in the receiver into a mosaic of black and white elements on a grid of closely-spaced parallel lines. There are no "start" or "stop" elements, and many signal elements may be lost or blurred without serious consequences.

This gives rise to one of the most attractive features of the Hellschreiber system, its relative immunity to the effects of circuit noise and interference. Such intrusions in a Hellschreiber radio circuit merely produce a fuzzy background, never the wrong letter, or figures instead of letters, or vice versa. In a sense this makes use of the human eye's ability to select intended information in the same way that the ear is able to pick out a weak morse signal from heavy interference. Another useful feature of the Hellschreiber system is its speed tolerance. The transmitting or receiving speeds can vary as much as plus or minus 5 per cent (this will be explained later). Some machines had belt drive!

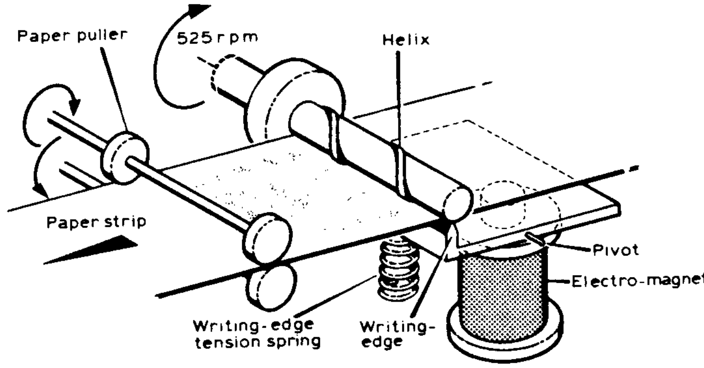


Fig 3. Working parts of the Hellschreiber printing head

Character generation

Mention has already been made of the Hellschreiber letter synthesis, and Fig 2(a) illustrates how this synthesis is produced. Each letter or character received is formed as a mosaic on a matrix or frame of seven vertical lines each having 14 picture elements. The first and seventh lines are left blank to give letter spacing, and the first, second, thirteenth and fourteenth elements in each line are normally left blank to give spacing at the top and bottom of each character. Exceptions to this element-blanking rule occur with numerals such as 3 and 5. An example of this is shown in Fig 2(a). The object of this irregularity is to avoid ambiguity, since a reader of the printed text would not easily mis-read a 3 with its tail below the line for a 5 with its top or hat above the line. It should also be noted that although there are 14 picture elements to each line they are never transmitted singly. This is an important feature which will be explained later.

It will also be seen from Fig 2 that although the mosaic is of seven-line construction—it is called a seven-line Hellschreiber—the active elements of each character or letter are formed within a five by five domain. The shaded areas in the drawing correspond to a "mark" signalling condition and the unshaded areas to "space". Note also that in the drawing the lines are numbered from left to right, the normal progression of printing or writing, while the picture elements are numbered from bottom to top since, as will be described later, this is the way in which the letters are formed in the receiving process. For example, the letter D is sent by the mechanism originating a serial train of impulses or elements corresponding to the shaded areas of the diagram at Fig 2(b). At the receiver the impulses are formed into the letter D by a scanning action. The full range of characters is shown in Fig 2(c).

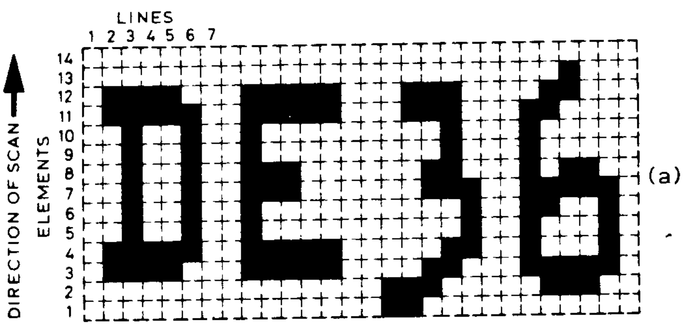
Writing

The Hellschreiber receiving mechanism shown in Fig 3 is about the simplest device, apart from the human hand with pen and ink, for printing capital letters, numerals and the necessary punctuation signs. The working parts are a revolving helix inked by an idling felt roller, a signal-operated writing edge and a pair of knurled wheels driven through gearing arranged to pull a paper strip or tape between the helix and writing edge.

When a succession of current impulses corresponding to the pattern of a letter train is fed to the printing magnet, the writing edge is moved rapidly up and down, lifting the paper into contact with the helix. The letter is then written by the resulting action of the helix. The pitch of the helix is designed to print a double row of characters as shown in Fig 1(a). It is this feature of the Hellschreiber system which obviates the need for precise speed control. Fig 1(b) and (c) show the effect of small speed discrepancies; the line of printing merely runs up or down, always leaving one clear letter on the tape. In practice the speed of the transmitting machines may differ by as much as 5 per cent without seriously affecting the legibility of the copy.

Sending

Two methods were used to generate Hellschreiber signal trains. The mechanics of the first system involved a tape head having sensing "peckers" similar to those of the present-day teleprinter senders, the tape interface being the standard Baudot-coded five-hole type. The peckers sensed a character and then released the clutch of a rotating cam assembly which opened and closed contacts in conformity with indentations on its



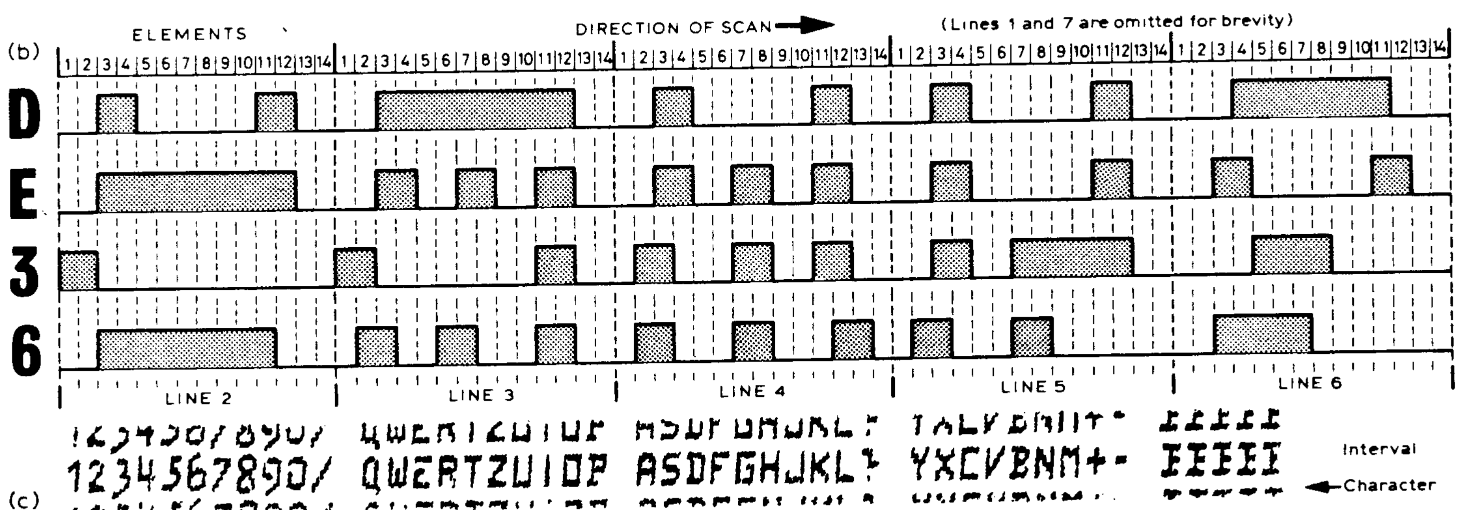
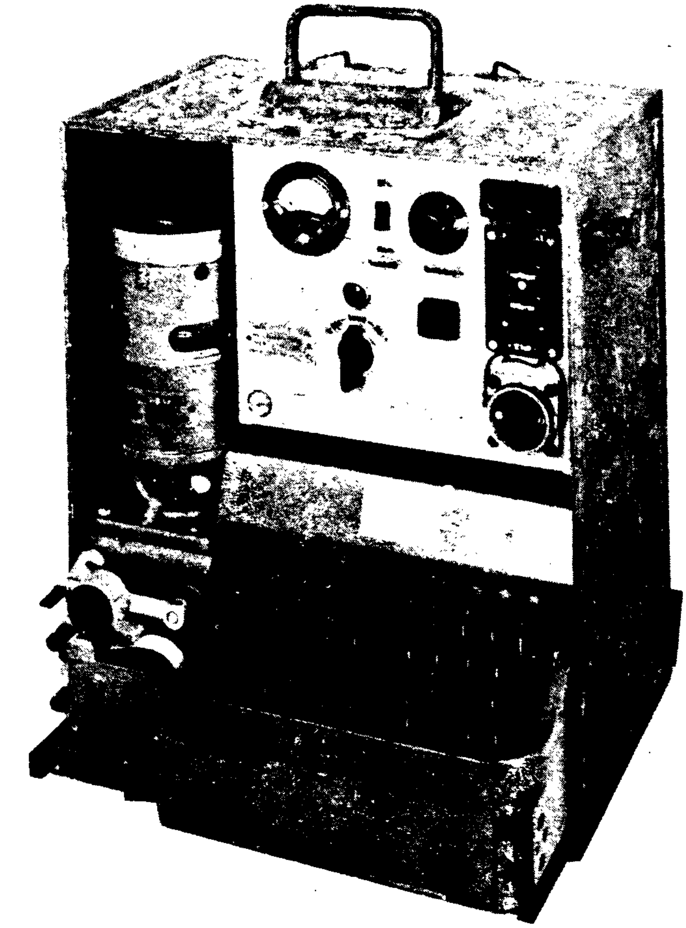


Fig 2. Method of character synthesis: (a) matrix diagram of typical letters and numerals; (b) element trains necessary for their formation; (c) Hellschreiber character font



Siemens *Feldfernschreiber*. *Photo:* Science Museum

circumference. This method, with variations, was used for all commercial equipment throughout the Hellschreiber's working life. It was particularly suitable for the transmission of multi-destination messages and press agency broadcasts, because it made possible tape editing and the repetition of material for secondary destinations, as well as the additional facility of sending traffic in either or both the Hellschreiber or teleprinter modes. The speed was five characters per second or approximately 50wpm.

The second system, which survives today in the German army *feldfernschreiber* machines used by amateurs, produces character trains directly from a keyboard. In these machines the signals are derived from a rotating drum or commutator having on its surface a track of insulated metal segments corresponding to the matrix coding for each character. Depressing a key causes a contact to drop onto the drum for one revolution, thus making an electrical circuit and so producing the appropriate pulse train. Each key has an interlock to prevent the signalling of another character before the preceding one has been completed. Operation of these machines is essentially at cadence speed of 2·5 characters per second or 25wpm.

Throughout the Hellschreiber's working life, transmissions were mostly operated on the "keyed tone" or "keyed carrier" principle, sometimes simultaneously. This keying mode (A1, A2 and A3) allowed the use of the simplest of terminal units, such as the connection of the printing electromagnet, via a metal rectifier, directly into the loudspeaker sockets of a broadcast receiver. At the other end of the scale the more elegant terminal devices boasted an audio bandpass input filter, a two-stage amplifier, clipping and agc, bridge-type metal rectification and further dc amplification.

The Siemens *feldfernschreiber,* mechanical details

So far as is known, the only mechanically-operated Hellschreiber equipment of the standard seven-line type in use today is the ex-German army *feldfernschreiber,* the general construction of which can be seen in the photograph. It is perhaps a tribute to the design and manufacturing skills of the Siemens factories that so many of these machines have withstood the ravages of time and, with renovation, are still in use.

As the photograph shows, the equipment is in two parts, a keyboard and receiving module and a terminal unit. The rotating mechanism is powered by a 12V dc motor generator which generates a 165–180V dc supply for the terminal unit from a second winding and commutator, as well as mechanical power for the commutator drum and helix assembly. These rotating parts are driven through a gearbox which has precision-hobbed silent-running-helical and worm gears, all running on ball-races.

A valve is used to regulate the speed of the motor-generator; this is effected by passing the anode current of the regulator valve through a second field winding to act as a brake. Centrifugally-operated contacts on the armature shaft open and close the valve's grid circuit, thus varying the anode current and thereby the speed. Although, as stated earlier, accurate speed control is not essential to the system, the regulation obtained by this means is better than 0·5 per cent. Motor-generator brushes and governor contacts are fully rfi suppressed.

Terminal unit

The terminal unit comprises a 900Hz sine wave oscillator, a single-stage input amplifier, a full-wave copper oxide signal rectifier and a dc amplifier driving the electromagnetic printing head. It has three inputs, one for 800Ω unbalanced lines, another at 4,000Ω for input from a radio receiver, and a high level "listen" jack at the amplifier output. A fourth jack is provided in some models for direct connection to a balanced 800Ω telephone line. Two contacts of a 12-pin socket on the front panel break into the commutator circuit for low-level dc or tone keying. Local copy of the outgoing signals is obtained through an auxiliary winding on the input/output transformer. A simplified circuit diagram of the unit is show in Fig 4. The four valves are Telefunken RV12 P4000, the multi-purpose type commonly found in second world war German military equipment. It will immediately be obvious that the simple receiving mechanism can easily be copied by interested model-makers. For those who might be interested, the two-start helix rotates anticlockwise viewed from the driven end at 525rpm. A close-up of the printing head is shown in the photograph.

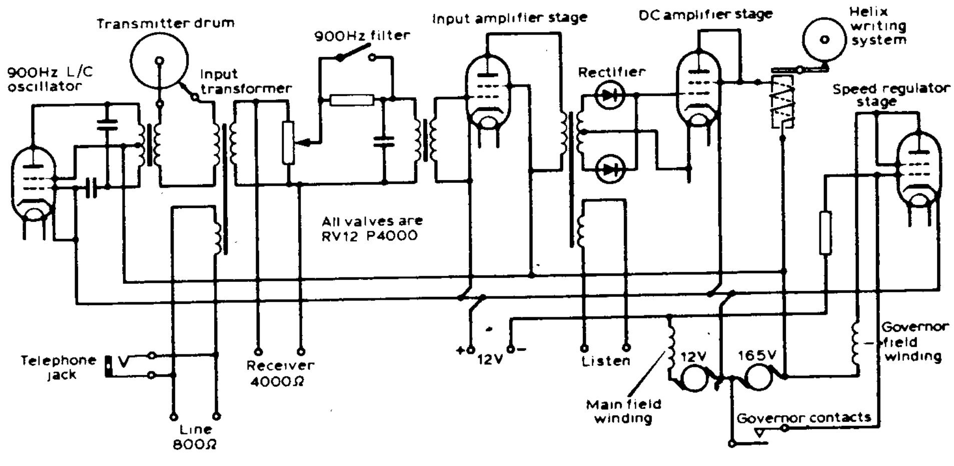
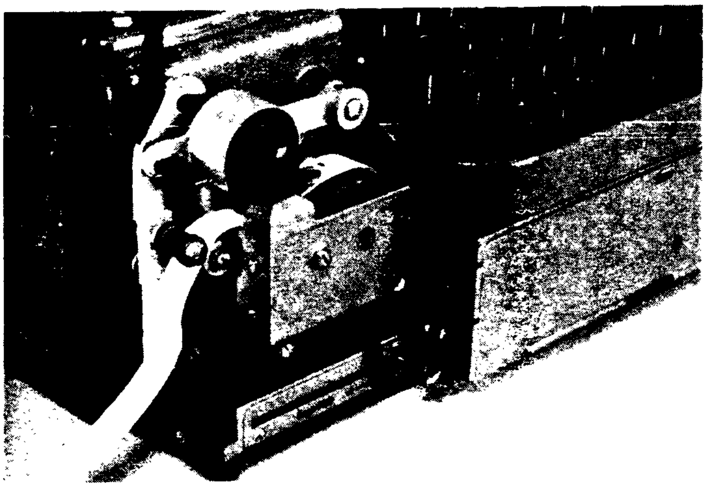


Fig 4. *Feldfernschreiber* terminal unit



Close-up of printing head. *Photo:* **Science Museum**

Bandwidth (how much?)

At this point it might be opportune to pose the question which many users and observers of the Hellschreiber system raised in its early years—"What is the bandwidth of a Hellschreiber signal?" and "How much of the spectrum does it occupy when transmitted over a radio circuit?"

As many amateurs of the 'thirties will remember, early Hellschreiber transmissions were often extravagant of bandwidth. In retrospect it is easy to see why this was so. Transmitters of that period were not so well frequency-controlled as they are today, and this led to the widespread use of A2 type emissions (interrupted continuous wave) and, in some cases, A3 (full carrier plus two sidebands). Then, as today, there were over-driven and over-modulated transmissions; and everyone knows how easy it is to produce a small family of spurious signals on either side of a parent signal. (The splatter produced by over-driven (non) linear amplifiers is a modern manifestation of the same condition.) The situation today is different. First, there are no commercial Hellschreiber transmissions except possibly in China; and second, amateur Hellschreiber communication is on-off keyed and most operators restrict their bandwidth to reasonable limits by one means or another.

So just how much bandwidth does a Hellschreiber signal need, and how much does it occupy in practice? The answer to this question is to be found in the International Radio Regulations, where the bandwidth necessary for any form of telegraphy is specified as the keying speed in bauds multiplied by a factor of three if signals are steady, or by five when the signal merit is poor. To see how this specification affects Hellschreiber it is necessary to review fundamental keying definitions. The baud, the basic unit of telegraph speed, is the duration of the shortest pulse or one code element per second. But a single code element must always be followed by a space, otherwise no intelligence would be transmitted. It is obvious therefore that one cycle of keying is equal to two code elements. Telegraph keying is ideally a square wave, but it has long been recognized that a wave shape somewhat short of the ideal and containing only the third harmonic plus the fundamental is perfectly satisfactory for good communication. This is the reason for the factor of three in the International Regulations.

The shortest signalling pulse of the present-day amateur Hellschreiber transmissions is 1/49 of a complete letter frame—remember, Hellschreiber picture elements are always sent in pairs. The baud speed is therefore computed by multiplying the figure of 2·5 characters a second by 49, which is 122·5 bauds. Since one cycle of keying must always consist of two elements, a mark and a space, the keying bandwidth is one half of this value, ie or 61·25Hz or, after applying the factor of three to preserve a reasonably shaped square wave, 183·75Hz. However, when this waveform is made to modulate a carrier wave, a further factor of two is introduced because, like any other form of modulation, two sidebands are created. Thus the radio frequency bandwidth is twice the keying bandwidth, or 365·3Hz. This is approximately 0·125 of the bandwidth taken up by a well-engineered A3j ssb voice transmission although about 25 per cent wider than the 246Hz of an expertly tailored 45·5 baud, 170Hz shift amateur teleprinter signal (see "Appendix").

How well the computed figure for Hellschreiber bandwidth is realized in practice depends on the type of keying used and the steps taken by the system designer to shape the applied keying waveform. Amateur Hellschreiber transmissions are invariably on-off keyed and, when investigated spectrally, few have exceeded the computed bandwidth; in fact some signals have exhibited a narrower bandwidth of some 200–300Hz with no loss of intelligibility resulting from the element distortion produced by the unduly soft keying.

Construction

As mentioned earlier, the European amateurs' interest in Hellschreiber began in 1976 and 1977 when a number of the German army *feldfernschreiber* machines were rescued from scrap heaps and elsewhere in Holland and West Germany and restored to their original condition. The source of these machines having dried up—they are much-sought-after collectors items—many amateurs have turned to constructing them. The simplicity of the receiving mechanism has been particularly attractive to the do-it-yourself types, and many receive-only devices have been constructed from the junk box. In 1942 the author built a receiver from the remains of a morse inker and a helix fabricated from a brass cylinder to which short pieces of steel piano wire were sweated. A collection of Meccano gears completed the picture. Some 10 years later a similar machine was seen at a hobbies exhibition.

More recently the West German and Dutch amateur fraternity have turned their attention to the microprocessor, and several have written programs for the Apple 2 computer. No doubt many others will soon be working on the TRS80 and the PET! As with the mpu-driven "driven" Baudot-coded rtty systems, the operation is paperless. The signal trains are derived from a type of ASCII-to-Hellschreiber converter and received on an ASCII-driven vdu display. What could be simpler?

An appraisal

Some may feel that the relatively slow speed of amateur Hellschreiber signals (25wpm) may limit it as a viable system of communication. But if instead of speed the criterion of comparison is made one of accuracy, the Hellschreiber system compares very favourably with the 5U teleprinter. For example, a single incorrectly-received element in the case of a 5U coded signal will alter a transmitted character completely or transpose a shift signal to the opposite case. On the other hand an incorrectly received Hellschreiber letter element will only result in a blurred outline—never the wrong letter.

Although no authentic records of the Hellschreiber's interference avoiding properties are known to exist, a listener to the signals of the European net on 3·5, 7 and 14MHz will be left in no doubt as to the validity of the claim. Many signals monitored during the past three years have at times been so weak or overlaid with various types of interference that they are rendered inaudible and yet capable of being selected by the eye. A good example of this is seen on the tape of DL1OY in QSO with PA0AOB in Fig 1(d).

This article may have left some important questions unanswered, and the future of Hellschreiber—if it has a future—in doubt. But at least it may have stirred someone's grey matter, as indeed the author's was stirred when he first bumped into the Hellschreiber system in 1941, and again in 1977 when the familiar sounds from a machine at PA0AOB unexpectedly came popping out of a receiver at G5XB.

Bibliography

[1] *Telegraphy,* Freebody.
[2] *Funk-Praxis* Vol 1, Nr 14, December 1948.
[3] *Ham Radio* December 1979, Evers, PA0CX.
[4] "Technical Topics", J. P. Hawker, *Rad Com* February 1980, pp 154–5.

Appendix

The necessary bandwidth for F1 type emissions is determined according to International Radio Regulations as follows:

(1) Bandwidth $= 2{\cdot}6D + 0{\cdot}55B$ for $1{\cdot}5 < \frac{2D}{B} > 5{\cdot}5$

or

(2) Bandwidth $= 2{\cdot}1D + 1{\cdot}9B$ for $5{\cdot}5 \leqslant \frac{2D}{B} \geqslant 20$

where B = Telegraph speed in bauds
D = 0·5 times the frequency shift

For 45·5 baud 170Hz shift $\frac{2D}{B} = \frac{170}{45{\cdot}5}$ or 3·7

Clearly formula (1) applies.

$\therefore\ 2{\cdot}6D = 221$
$0{\cdot}55B = 25$
246Hz.