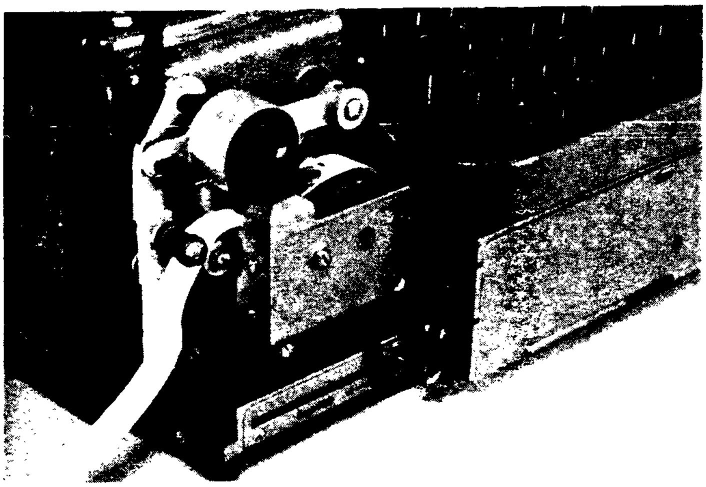

Close-up of printing head. *Photo:* **Science Museum**

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

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Appendix

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

(1) Bandwidth $= 2\cdot6D + 0\cdot55B$ for $1\cdot5 < \frac{2D}{B} > 5\cdot5$

or

(2) Bandwidth $= 2\cdot1D + 1\cdot9B$ for $5\cdot5 \leqslant \frac{2D}{B} \geqslant 20$

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

For 45·5 baud 170Hz shift $\frac{2D}{B} = \frac{170}{45\cdot5}$ or 3·7

Clearly formula (1) applies.

$\therefore 2\cdot6D = 221$

$0\cdot55B = 25$

246Hz.