The bandwidth of a well-modulated feld-Hell signal

Abstract - The occupied bandwidth of signal from a Feld-Hellschreiber is discussed and tested. Earlier assumptions of a wider bandwidth has been falsified. FH also fits in 200 Hz bandplan.

Introduction

In the description of the feld Hell schreiber by the late Murray Greenman, ZL1BPU, [1], an assumption is made of the keying sidebands of 122.5 Hz as a result from the minimal pixel speed of 122.5 pixels/s (= baudrate). However, the minimal width of an "on" pixel is 8.16 ms and the minimal width of an "off" pixel is also 8.16 ms. So the configuration with the highest switching speed is that of the smallest "on" pixel, followed by an "off"pixel, and that repeating. In Figure 1 such an succession of shown on the upper part. Remember, those 8.16 ms wide pixels are composed by elementary pixels of 4.08 ms wide of which at least two are combined.

To limit the bandwidth of the transmitted signal the pulses as show in the upper part of Figure 1 should be smoothed. The optimal way is to give the flanks of the pulses the shape of a raised cosine. In Figure 1 this is shown in the lower part. We see that the "on" pixel the cosine shape does rise so that the maximum value is reached at the end of the smallest pulse length. A "off" pixel does it fall to zero again in the shape of an raised cosine. From the picture we may conclude that the apparent frequency of the cosine that appears is the inverse of the period time of the succession of an "on" and an "off" pixel. This period time is here 16.32 ms, so the frequency of the cosine, here called "pixel frequency f_{pixel} is 61.25 Hz. So the keying sidebands are not 122.5 Hz as Murray wrote, but 61.25 Hz. See also [2].

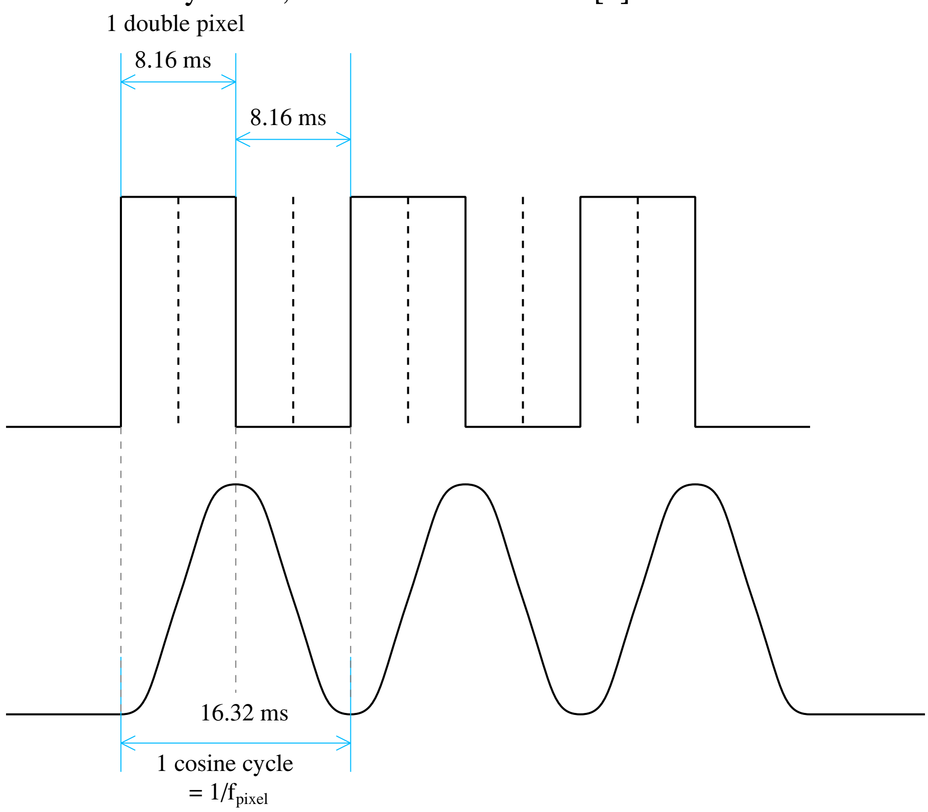


Figure 1.

The mathematics of the modulation on a carrier is below:

$$\begin{aligned} S(t) &= (\cos 2\pi f_{pixel} t + 1) * \sin 2\pi f_c t \\ &= \cos 2\pi f_{pixel} t * \sin 2\pi f_c t + \sin 2\pi f_c t \\ &= \frac{1}{2}\{\sin 2\pi (f_{pixel} + f_c)t - \sin 2\pi (f_{pixel} - f_c)t\} + \sin 2\pi f_c t \\ &= \frac{1}{2}\{\sin 2\pi (f_c + f_{pixel})t + \sin 2\pi (f_c - f_{pixel})t\} + \sin 2\pi f_c t \end{aligned}$$

Upper sideband *lower sideband* *carrier*

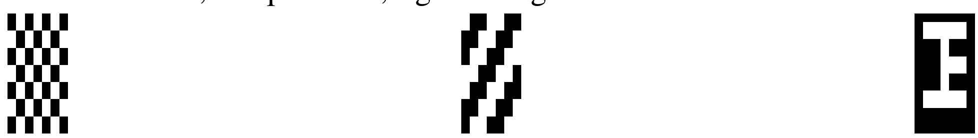
We see the the modulated bandwidth is twice the keying bandwidth, and that the sidebands are each 6 dB lower than the carrier strength.

Testing

Shaping the pulses with a raised cosine can in principle be done by an low-pass filter, but that is difficult to realise. An easier way is to digitally synthesize the shape. I have realized this in my All Mode HF Exciter, that is shown on my page on QRZ.COM. I used a 16 way analogue multiplier for this purpose.

For purpose of testing the bandwidth of the fel-Hell signals I took the 10.7 MHz IF output from the Exciter and lead that to my 2380/2382 Marconi spectrum analyser. This analyser has a minimum frequency resolution of 10 Hz.

To generate the 8.16 ms pixel sequences that gives a continuous 61.25 Hz keying pattern I made a special Hell character as shown in Figure 2, left. [In the software I use, written by PA3BEK, the Hell signal pattern is generated by scanning a small bitmap picture, "sprite". The sprites are selected by key strokes. As a user I can make my own Hell characters by adding or altering these sprites]. In the same way a test character was made with a 30.625 Hz pixel frequency, seem the middle test pattern 2. At last I used the test character which is on the original feld Hellschreiber, test pattern 3, right on Figure 2.



Test pattern 1.
Continuous 8.16 ms on
and 8.16ms off.

Test pattern 2.
Continuous 16.32 ms on
and 16.32ms off.

Test pattern 3.
Feld Hellschreiber
test character.

Figure 2. Test patterns.

Remark: the test patterns of 1 and 2 are not perfect: in between the end of one character to the next there is a phase jump, which has a minor influence on the spectrum as displayed.

Results

Photo 1 shows the measured spectrum when test pattern 1 is used. We see the sideband peaks at +/- 60 Hz, and they are 6 dB below the carrier strength. The next sideband components are more then 30 dB or more lower. The resolution bandwidth of the analyser is here 10 Hz.

Photo 2 shows this spectrum in combination with test pattern 2. Here the primary sidebands are at 30 Hz from the carrier. Third harmonics of these sidebands are visible at - 20 dB. These are still within the 200 Hz bandwidth as shown by the markers at +/- 100 Hz.

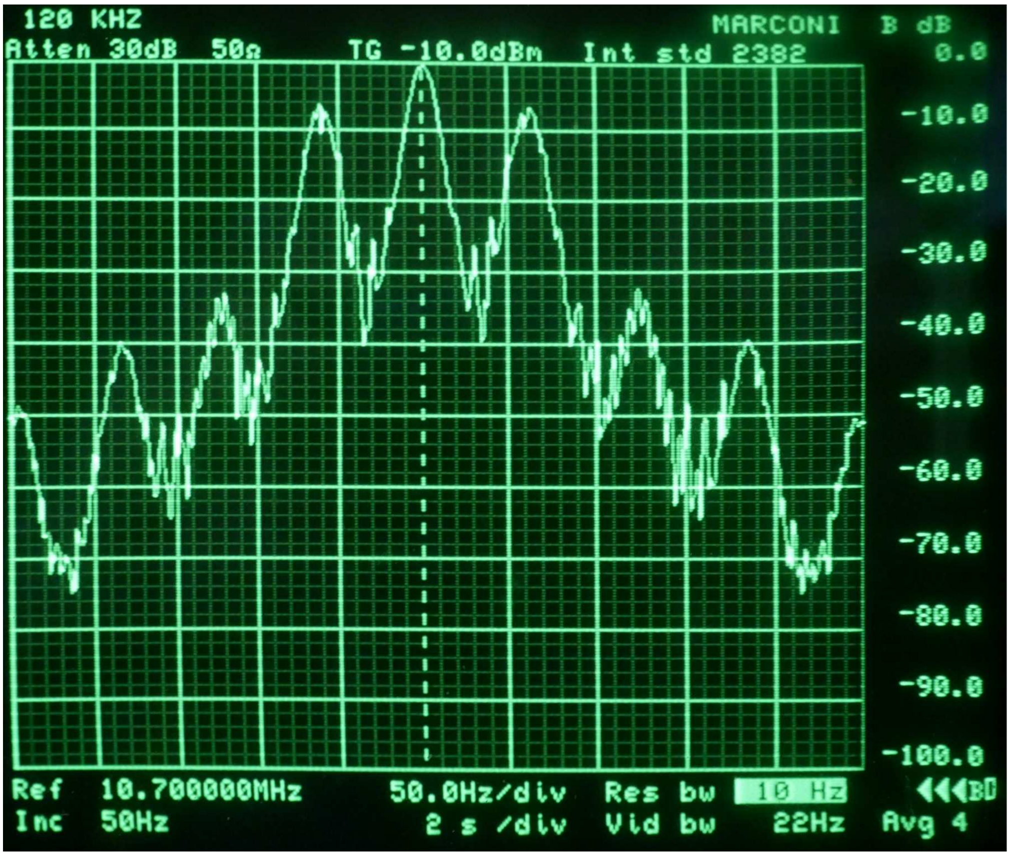
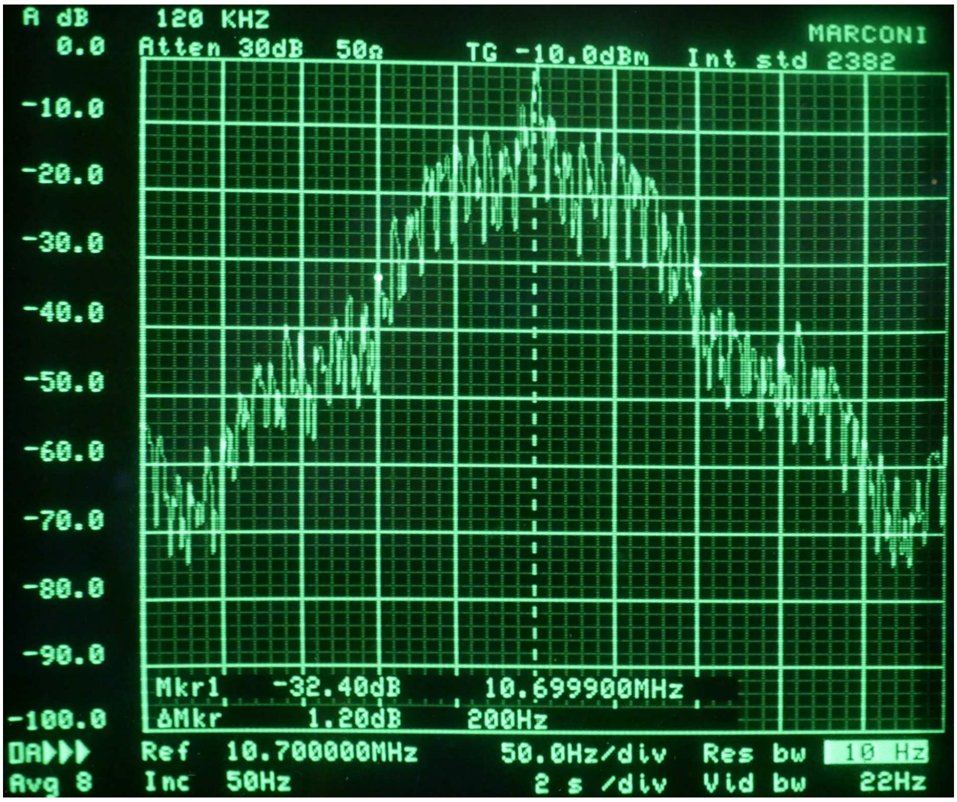
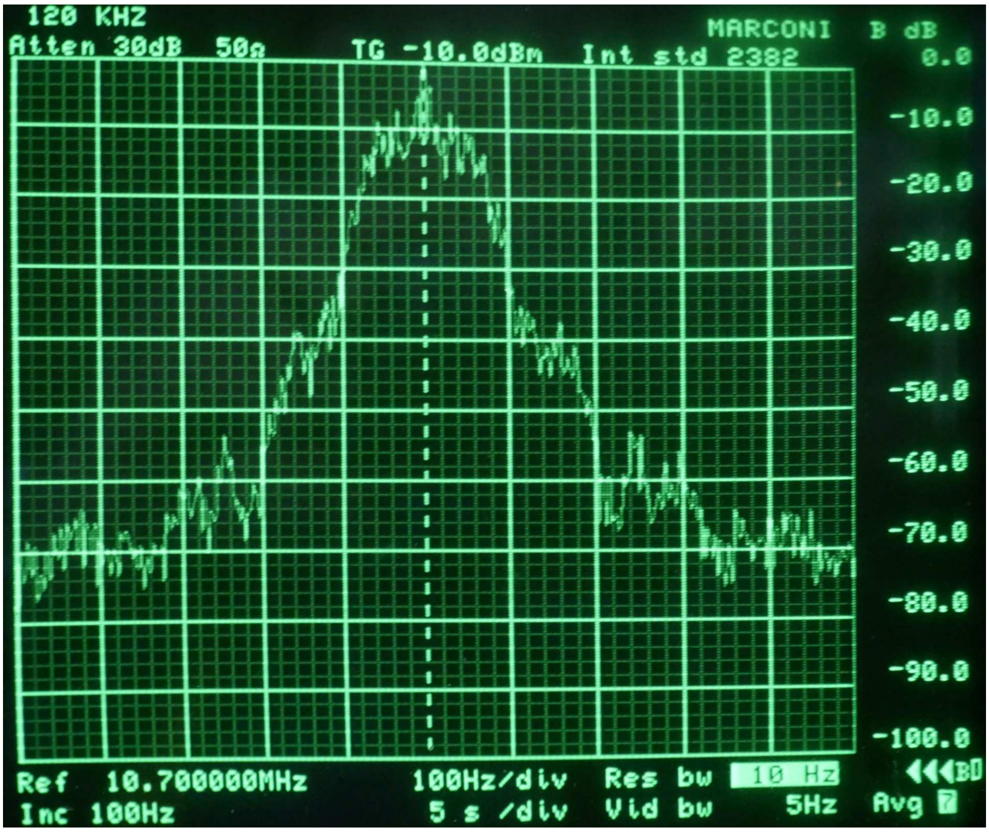


Photo 1. Test pattern 1.

Test pattern 2.



Test pattern 3.



Test pattern 3.

Most interesting is photo 3 wherein the original test character of the feld Hellschreiber is used. The carrier is again at 0 dB, and at +/- 100 Hz the sideband level has fallen to - 32 dB.

For showing the broadband roll-off of the spectrum in Photo 4 the span width of the analyser is broadened to 1 kHz, while transmitting the same feld Hell test character. We see that the roll-off continues wider from the carrier frequency.

We may conclude that a feld-Hell fits well in a 200 Hz bandwidth. This correspondents very well to my experiences with receiving feld-Hell signals with my Radio Modem, wherein quadrature detection is used in combination with switched capacitor low pass filters. The smallest bandwidth I can use without loss is 160 Hz.

Conclusion

The bandwidth of signals generated in the Feld-Hell mode is reasonably well limited to 200 Hz when use is made of raised cosine shaping of the pulses. This means that the feld Hell mode may be used in band segments with a bandwidth limitation of 200 Hz.

References

[1] Murray Greenman, ZL1BPU: https://www.qsl.net/zl1bpu/HELL/Feld.htm
[2] https://www.nonstopsystems.com/radio/hellschreiber-the-feld-hell.htm

Appendix

In 2010 I received an email from Murray Greenman. It is about his MSK Hell he developed. One of his arguments to use 105 baud MSK Hell that the bandwidth would be smaller and so would fit in a 200 Hz BW bandplan. Here he made wrong assumptions about the bandwidth of feld-Hell:

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From: <denwood@orcon.net.nz>
Subject: [Hellschreiber] New Hell software for LF/MF
Date: Fri, 29 Oct 2010 20:15
Source: mail

Hi,
Just to whet your appetite...

You might remember that the first use of Hell by radio was on LF, and it
pre-dated RTTY by many years! Since MSK is so effective on LF we thought we'd
revive Hell, combine it with MSK and give the world a new narrow-band,
sensitive chat mode for LF/MF.

Con ZL2AFP is (with my assistance) developing a new Hell program, designed
specifically for use on LF and MF. The modulation is MSK, and so the
bandwidth is very narrow and sensitivity very good. Speeds 105, 63 and 31
baud are offered. For comparison purposes, the program also offers Feld-Hell
mode (on-off keyed) with the same speeds.
On the 105 baud speed this software is completely compatible with IZ8BLY
Hellshreiber (in both FM-Hell and Feld-Hell modes) due to the use of a lower
resolution font.

The receiver offers an interesting eye diagram for tuning (like CMSK), and
TWO different detectors. The traditional ASYNC detector has best sensitivity,
but the new SYNC detector alternative (uses a Costas Loop demod similar to
CMSK) gives nice clear text with no wandering, provided there's not much
multipath.
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The 105 baud MSK-Hell 105 is just under 200Hz wide, so appropriate for use on 600m in ZL where the maximum transmission BW is 200Hz. The expected sensitivity of the MSK-Hell 31 is about -15dB S/N in 2.4kHz BW and the transmission is only 50Hz wide. It's not too difficult to tune, and the waterfall display is clear to see at the weakest levels.

My test signals using MSK-Hell 63 have been copied easily in VK2 (range 2200km) on 600m, so expect some good performance!

The new modes work on HF as well, but there's no reason to use the slower speeds and you will run into Doppler problems there. The new software offers nothing for HF operators that IZ8BLY Hell hasn't got (except the SYNC detector), but for LF/MF it's an important step forward.

The software is for Windows and will be on my web site soon,complete with help file. If you'd like to test a beta version, write to Con ZL2AFP (zl2afp at xtra dot co dot nz).

73,
Murray ZL1BPU/ZL1EE