Comments on Patent Application 20040196910, Joseph Bobier, et al.

This patent application claims an invention based on a frequency-shift modulation scheme which the authors call Integer Cycle Frequency Hopping (ICFH). Since the technique of frequency-shift modulation has been known for decades, the unique part of this claim is the ICFH scheme. The modulation scheme is designed for transmitting and receiving binary-coded data over a radio-frequency link. This is accomplished by deviating the carrier frequency to represent either a one or a zero, depending on the chosen logic "polarity". Apparently, an important part of this claim is the concept of changing the frequency at zero crossings of the waveform; that is to say only after an integral number of cycles has been transmitted at the current frequency.

The following statement in the section of the Patent Application labeled Field of the Invention is *false*: "Specifically, the invention provides a modulated signal and method of modulation by which the spectral channel width occupied by the radio signal can remain very narrow even though the data bit-rate, which is used as the modulating signal, may be very fast, including data bit rate speeds up to and equal to the frequency of the carrier itself." Thus the main advantage, narrow bandwidth, claimed for the ICFH scheme is *nonexistent*. There exits a fundamental limitation in the transmission of information: the bandwidth of the signal must be at least as large as the bandwidth of the information being sent. It is usually a little larger, even in the most narrow-bandwidth modulation schemes. In addition, the following statement in the Abstract is misleading: "The spectral output of a transmitting device using this modulation scheme will be defined by the difference in frequency between the main carrier signal and the modulating frequency." In reality, the spectrum depends on both the difference in frequency and the modulation data rate.

The demonstration of the invalidity of the narrow-bandwidth claim requires the application of the Fourier transform to a mathematical representation of the signal, in order to compute the spectrum. Without including the mathematical details, a brief description of the situation follows.

Consider the representation of an ICFH signal in Figure 1, where *n* cycles of frequency f_0 are followed by *m* cycles of frequency f_1. It is not necessary that $n = m$, although that is a likely choice. It is assumed, however, that *n* and *m* are both integers, as required by the ICFH signal definition.

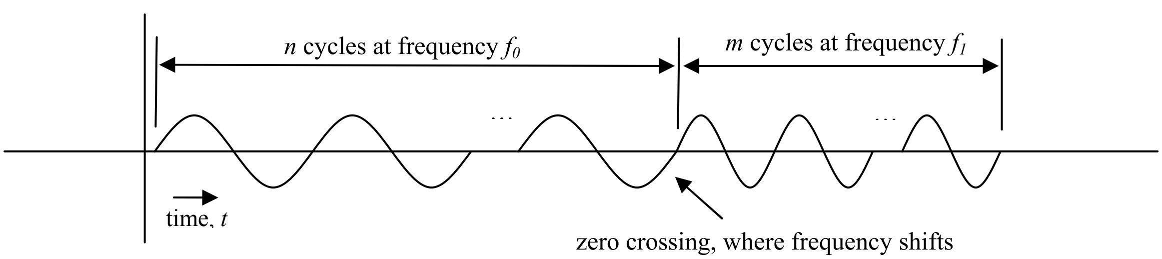

Figure 1 The ICFH waveform, showing the transition between binary states at a zero crossing of the waveform.

It should be noted that if $f_0 = f_1$, the signal *will* have a very narrow bandwidth, but the signal will be an unmodulated carrier containing no information. Thus, the non-trivial case is $f_0 \neq f_1$, and such a signal, capable of sending binary information, will have a wider bandwidth than the unmodulated carrier.

The bandwidth of the signal is dependent not only on the difference in the two frequencies, f_0 and f_1, but on the rate at which the frequencies are shifted, that is the data rate.

In reality, an ICFH waveform would encode some random pattern of zeros and ones. However, a conveniently simple ICFH signal is modulated with a repeating pattern of zeros and ones (0101010101…). This signal is periodic, repeating the same pattern over and over. A periodically modulated signal has a spectrum that consists of evenly space spectral lines centered on the carrier frequency. If the period of the modulation is *T* seconds, then the frequency spacing of the spectral lines is $\Delta f = 1/T$ hertz. For example, if $T = 1\ \mu\text{s}$, the spectral lines would be spaced at $\Delta f = 1\ \text{MHz}$ intervals.

The amplitude of the spectral lines depends on the additional details of the signal. In fact, the spectral lines are essentially discrete samples of a continuous spectrum that would be produced by a single period of the periodic signal transmitted alone. The shorter the duration of the single period, the wider is the continuous spectrum. The ICFH waveform with $n = m = 10$ has a much smaller period than a waveform with $n = m = 1{,}000$, and will therefore have a much wider spectrum. The proposed ICFH signal with $n = m = 1$, which the inventors imply would have a narrow bandwidth, will have the widest bandwidth of all.

The period of the modulation is determined by the choice of the integers, *n* and *m*, as well the frequencies f_0 and f_1:

$$T = \frac{n}{f_0} + \frac{m}{f_1} = \frac{mf_0 + nf_1}{f_0 f_1}.$$

The spectral lines will be spaced at

$$\Delta f = \frac{1}{T} = \frac{f_0 f_1}{mf_0 + nf_1}.$$

Now, the continuous spectrum of a single period of the signal goes to zero at certain values of *f*. In the special case when $f_0 = f_1$, only one of the samples occurs when the continuous spectrum is not zero. Thus, in this special case, the spectrum is a single line, and is very narrow. However, the signal contains no information, since the two states have the same frequency. When the two states have different frequency ($f_0 \neq f_1$), the signal can contain information, but in this case, many of the samples occur where the continuous spectrum is not zero, and the signal has significant bandwidth.

When f_1 differs from f_0 by only a tiny amount, the spectral lines have very low amplitude, and one might be fooled into believing the spectrum of the signal is narrow. However, if the spectrum is filtered so that there is only the strong central line, it will be indistinguishable from the case of $f_0 = f_1$, and any information is lost. The information is contained entirely in the small, but non-zero spectral lines on either side of the strong central line.