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June 27, 1969

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CHIRPED HANDCLAPS

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June 27, 1969

One morning last December as I was jogging on the outskirts of Stockholm my path led me past the wall of a large factory. Following an impulse, I clapped my hands and listened. Instead of the expected echoing handclap I heard what at first seemed to be a sparrow emitting a swiftly descending chirp. After several more claps and chirps I realized that it was no sparrow--besides, where was the echo?

For the next few minutes I jogged back and forth in front of the factory clapping and listening. For every clap there was a chirp. I realized with astonishment that it was as if the handclap were being Fourier-analyzed and the high frequency components echoed back to me sooner than the low frequency. But how? Finally I noticed that the factory wall was not flat but was made of corrugated metal, the evenly spaced vertically oriented corrugations having a horizontal spacing between neighboring corrugations of about 10 cm. Therein lay the explanation.

The chirping of my handclap is explained as follows: The corrugated wall is an effective diffraction grating for sound waves. At a given angle of incidence, two neighboring corrugations give constructive interference for that wavelength for which the distance from me to one corrugation is less than that to the next by one half wavelength. As the

angle of incidence increases, the wavelength for constructive interference increases. Also, the distance from me to the wall segment increases, so that the time delay increases. Thus I hear a descending chirp.

An alternative (but equivalent) explanation is as follows: Rather than thinking of the corrugated wall as performing a Fourier analysis of the handclap into various wavelengths, which then interfere constructively for the appropriate wavelength, think instead of each corrugation as simply reflecting the sharp handclap back to me with a time delay corresponding to the distance to the corrugation. My ear then receives a rapid sequence of reflected claps from successive corrugations. Thus I hear a note having frequency $\nu_0 = 1/T$, where T is the time interval between two successive reflected claps.

Now a question for the student: Do you expect the corrugated-wall grating to diffract only in zeroth order (specular reflection) and first order (down-and-back path difference of one wavelength), or instead, should second and higher order also contribute significantly? In other words should I hear not only a "fundamental chirp," $\nu = \nu_0$, but also a "first octave chirp," $\nu = 2\nu_0$, as well as higher overtones? (Assume the shape of the corrugations is approximately sinusoidal.)

Although I discovered "chirped handclaps" in Stockholm I have since found that any large corrugated building will work.[1] I have also learned that workers in optics use an analogous method to chirp a pulsed light beam. They use two parallel plane gratings in tandem so that after the beam has zigzagged (via two reflections) through the system the beam is parallel to its original direction, with longer wave-

lengths suffering a longer time delay than shorter. (The reflections are not specular but are of first order; thus longer wavelengths travel over longer paths.) One can run this process backwards, starting with a laser-produced frequency-modulated chirped light pulse having longer wavelength at the beginning of the pulse than at the end. After two reflections from the tandem gratings the longer wavelengths are delayed more than the shorter, so that the longer emerge at the same time as the shorter. Thus the pulse is compressed in time, or "dechirped." In this way subpicosecond pulses can be obtained.[2] That is like jogging backwards past the Stockholm factory, whistling an ascending sparrow chirp, and hearing an echoing handclap.

I am happy to thank Margareta Westman for her warm hospitality to my wife Bev and me in Stockholm.

References

1. Good examples are Bldg. 46 at Lawrence Radiation Laboratory, Berkeley, and a warehouse at Seventh and Parker Streets, Berkeley.
2. R. A. Fisher, P. L. Kelley, and T. K. Gustafson, Appl. Phys. Letters 14, 140 (1969).

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