On Rogue Waves (Wave Modulations)

According to Heraclitus, the advocate of change, nature loves to hide, for example, 30m waves. The study of huge sudden *rogue waves* by Chris Garrett and Johannes Gemmrich (PHYSICS TODAY, June 2009, page 62) describes a phenomenon that is difficult to reproduce in the laboratory and resistant to mathematical analysis. Relevant to this subject, I did extensive research in the 1980s-90s, which resulted in the Patent,[1] "Method for Producing Natural Motion." I also submitted to the USPTO a lengthy Report[2] to support and defend the Patent Application. In many tests, I produced *sudden extra-large* waves by straightforward modulation of waves, as described below. This has not been done before. Garrett, Gemmrich, fellow APS members and others may want to reproduce my results for rogue waves and other phenomena.

Here is a rough summary of the Patent: (1) Any body whatsoever can be induced to move in a straight line by the modulation of two or more standing waves within the body, (2) Stepping, or rhythmic, motion can be produced by "phase locking" the modulated waves in the body. Using the second mode on containers with water, the water executes a fascinating behavior – sudden extra-large waves.

First, it is best to produce linear motions with simple shapes (rectangular blocks, boxes, etc.) From my Report to PTO, (1) Mount 2 dc motors firmly symmetrically on the sides of the body, (2) Cross-wire the motors to rotate the shafts in opposite directions, (3) Attach equal unbalanced masses to the shafts of the motors, (4) Connect the motors to a power supply, or batteries. The mass of the rotating inertia elements can be 100th the total mass, or smaller. With a few tests, one can establish the following, from *Invited Talk*[3]: (1) The velocity is constant for a given frequency, (2) Terminal velocity is reached instantly, (3) There is a cutoff frequency below which motion does not occur, (4) There is a range of frequencies, f_{min} and f_{max}, within which velocity increases when the frequency is increased and vice versa. Motion diminishes rapidly beyond f_{max}.

To produce stepping motion, add another drive module (2 motors, batteries, electronics, etc.) above or below the first drive module. Turn both drives on at about the same frequency. Slowly vary the rotations on one drive module. You will see the body move in distinct steps, which can be controlled by varying parameters. Carefully observe the sudden start and stop of each step and the total dead stop between steps.

Get a Plexiglas, or other, square or rectangular container. Mount two drive modules on the sides, as described above. You can first move the container without water, and then add the water to see how the velocity varies with mass. When using only one drive module, notice the fascinating standing waves pattern that forms on the water surface – distinct square mesh for a square container, standing circular rings for a circular container, etc. You can vary the standing waves by changing parameters.

Finally, produce the stepping motion, as described above, in the Plexiglas model with water. You will see a sudden wave that rocks back and forth in the container. Adjust the frequency on one drive to change the rhythmic motion and build up the wave amplitude. Notice how the flat plane of the water surface remains intact as it oscillates higher and higher on the sides of the container. Use liquids of different density, etc.

Garrett and Gemmrich refer to tests in "a wave tank" to produce extra-large waves. These tanks are fixed structures and any tendency of the water to naturally modulate is squelched. In our case, the tank and the water are free to react to the applied pulses and resulting modulations; hence, linear motion, rhythmic motion, and infinite gaits and forms of motion. A more profound example is familiar to everyone; waves in strings fixed at both ends to rigid walls. I built cubical aluminum structures, attached four motors on the top (or side) aluminum angles, connected a string between each two motors with a small weight in the middle of each string, and activated the motors to produce the familiar fundamental mode in each string. By varying the frequency on one string, the aluminum structure moved in distinct steps. There are many experiments in many laboratories where the oscillators are fixed to rigid walls, ceilings, floors, or on lab benches. There is a new physics to be discovered in releasing the oscillators to produce motion.

Mechanical pulses generated by rotating unbalanced masses and deposited on the surface of a body produce wave trains that travel within the body, reflect from the boundaries, and form standing waves (clearly visible on the water surface in the Plexiglas container example). As a first approximation, consider two wave trains of equal amplitude, A, represented by the harmonics, $y_1(t) = A \cos w_1 t$ and $y_2(t) = A \cos w_2 t$. The resultant superposition, or modulation, of the two waves is $y(t) = A_{mod}(t) \cos w_{ave} t$, where, $A_{mod}(t) = 2A \cos w_{mod} t$, $w_{ave} = ½ (w_1 + w_2)$, and $w_{mod} = ½ (w_1 - w_2)$. This is the familiar *almost harmonic amplitude-modulated wave* with slowly varying amplitude $A_{mod}(t)$ and with fast driving frequency w_{ave}. The motion models move forward at the frequency w_{ave} and, with practice, the motion can be made to look smooth to the eye. It seems that the modulations produce a "motive force" that causes the bodies to move. From here, standard methods can be used to study the force, momentum, and energy involved.

The four motors in the above examples produce out-of-phase waves and many traveling, reflecting and standing waves. The many waves do not affect the basic mathematics. Take for example the transmission of one musical note on AM radio. The traveling AM radio signal is completely defined by the above equation for $y(t)$ for the musical note and the carrier frequency, or $V(t) = A_{mod}(t) \cos w_{ave} t$, where $V(t)$ is the transmitter driving voltage. If the radio station is transmitting a concert, then there are great many frequencies to handle; yet, the solution for $V(t)$ remains the same as above. The frequencies of all the sound waves are summed together in the $A_{mod}(t)$ term. Relevant formulas can be found in Crawford[4] and other textbooks.

The motions produced with the Invention are orthogonal to the exciting forces. This is contrary to what we learn and teach in physics and engineering and to common sense. Are there phenomena that support my claim? Garrett and Gemmrich describe how "*waves generated by a stone dropped in a pond*" produce a wave that "*appears on the inside of the ring of waves, travels through the ring, and disappears at the front.*" These wavelets travel in a direction orthogonal to the exciting agent, i.e., stones falling on the water surface. The wavelets, or wave packets, carry energy, which, if harnessed, can impart motion to a "freestanding" body. Another example is the Poynting vector, **S**, which results from the superposition of the electric vector **E** and magnetic vector **B**. The Poynting vector is perpendicular to the exciting agents, **E** and **B**, and it carries energy. There are other examples in nature.

The difficult part of my research was to produce distinct and repeatable steps. The steps occur when the driving harmonics are nearly equal, or, $w_1 \approx w_2$. This condition produces the familiar beat phenomenon. By holding the difference between w_1 and w_2 constant, we are "phase locking" the modulation of the waves. The near-perfect steps described above approximate the *ideal low-pass filter* behavior, where the magnitude of the output of the modulation is a "step of constant magnitude." From my Report to the PTO, "In Network Analysis,[5] Van Valkenburg points out that the "*ideal low-pass filter does not exist in nature,"* and he further comments on the Fourier analysis that the amplitude characteristic (i.e., perfect step) is not realizable by physical components." My stepping motion models attain the ideal low-pass filter behavior.

The rogue wave study shows more maddening mathematics (dispersion, nonlinear terms, instabilities, random superposition) and exasperating attempts to correlate analysis to tests. I spent years trying to produce and reproduce nearly perfect steps that link up to mathematics, and vice versa. I included dispersion, other material properties, geometry, boundary conditions and, even, temperature variations. I would produce perfect steps in one motion model late at night, but the steps would completely disappear the next day. The steps disappeared from motion models after a short drive in a car. Eventually, I realized that it was more effective to modulate the already modulated waves in a motion model. This step bypassed the complexities of wave mechanics. If the temperature changed slightly or greatly, I simply adjust the frequency of one drive to recover and repeat the steps over and over again. I could transport stepping models in a car or a plane and easily recover the steps. And models of whatever material executed the distinct steps.

Wave modulations within a body can produce linear motions, and higher-order modulations can produce near-perfect steps that can be derived with standard Fourier analysis. Remember, the second drive module modulates the already modulated waves of the first drive module. The huge sudden rogue waves could be the result of "higher-order modulation." The motion mechanisms can also be used to study hurricanes, tornados, earthquakes and other natural phenomena.

I strongly recommend the above procedure (especially, 2 drive modules with 2 motors each) be used to produce distinct steps, achieve repeatability, and correlate mathematics to tests.

Superposition, modulation, or dynamic coupling is not a new concept. Niels Bohr proposed a "coupling mechanism" in 1921 to explain quantum and atomic phenomena. Bohr's idea was that dynamic coupling occurs when waves impinge on "*an ensemble of harmonic oscillators*." Bohr discussed water waves and *the energy carrying wave packets* at length. From my Report to PTO, "After lengthy discussion with Heisenberg over a period of five years, Heisenberg said, "*I just wanted to forget about the wave packets and* *the waves*."[6] It appears that waves, wave packets and Bohr's virtual oscillators are important in modern physics.

In mid-1980s, I demonstrated linear and stepping motions to experts in DOD, though, at the time, the steps were random and difficult to reproduce. In 1998, I built, delivered and successfully tested for DARPA 10 remotely controlled motion models (black boxes). The black boxes moved on hard floors and carpets, through hallways and into, around, and out of offices. Subsequently, DOD contracted with others to use my motion mechanism to produce anti-gravity effects. These effects are not part of my Patent. Just before my Patent issued in November 2004, I had a massive congestive heart failure and I was in a coma for days in the hospital. I was given a few weeks to live then, and I relapsed again. My many motion models, countless hours of video chronicling the development of the invention went into storage boxes. Until I get to the boxes, I hope others will build the models described above to simulate and better understand *rogue waves*.

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[1] Abu-Taha, Ali F., "*Method for Producing Natural Motion*," Patent No. 6,826,449, Issue Date November 30, 2004, Application Date December 31, 1997. Available on uspto.gov.
[2] AbuTaha, Ali F., "*Wave-Induced Motion*," 2002, submitted to USPTO.
[3] AbuTaha, Ali F., Invited Talk, "*The Discovery of Self-Motion, or Natural-Mechanical-Quantum-Motion,*" The First Conference on Materials Science (CMSI), Mu'tah University, Jordan, 1-4 November 1997.
[4] Crawford, Frank S., Jr., "*Waves – Berkeley physics course – volume 3*," McGraw-Hill Company, New York, 1968. This textbook was an excellent companion throughout my development of "natural motion," and it contains well-thought out and wonderful examples of wave motions.
[5] Van Valkenburg, M.E., *Network Analysis*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1964, pp. 438-449.
[6] Miller, Arthur I., "*Imagery in Scientific Thought – Creating 20th Century Physics*," Birkhäuser Inc., Boston, 1984, p. 149.

Ali F. AbuTaha
aabutaha@aol.com
Manassas, Virginia