The Inverse Doppler effect: Researchers add to the bylaws of physics

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What if the speed of light is a constant only most of the time? What if gravity sometimes pushed instead of pulled? Scientists are increasingly asking what would seem like far-out questions regarding the laws and rules of physics after discovering conditions and materials where the rules don't quite apply.
Take the Doppler effect.

The Doppler effect is in use everywhere, everyday. Police use it to catch speeders. Satellites use it to track space debris and air-traffic controllers use it to monitor aircraft. The Doppler effect explains why the pitch changes from high to low when a police siren passes you on the street. As the siren moves toward you, it is catching up to and compressing the sound waves it produces, thus the higher pitch. When it passes, the sound expands to fill the increasing space between you and the noise. The sound waves are longer and the pitch is lower.

The inverse Doppler effect is not something you can hear, but understanding it could one day lead to important advances in optics and communications equipment.

Predicted in the 1940s, the inverse Doppler effect was first observed in 2003 by British researchers Nigel Seddon and Trevor Bearpark using an experimental magnetic, nonlinear transmission line sketched out by Avenir Belyantsev and Alexander Kozyrev in 2000. This nonlinear transmission line is a synthetic structure that allows electromagnetic waves to propagate along it in a new fashion.

In the experiment, a pulse of current fed into the line acts as the moving "siren" or shockwave. It generates a radio frequency (RF) signal but as the pulse recedes, the spacing between the peaks and troughs in the waves tighten rather than loosen: the inverse of the Doppler effect. That's just the opposite of what happens with sound waves when a siren passes you.

Reporting in the May 20 issue of the journal *Physics Review Letters*, University of Wisconsin-Madison Research Associate Alexander Kozyrev and Electrical and Computer Engineering Professor Dan van der Weide prove how an RF signal moving through this special transmission line can reverse itself and fall in sync with the shockwave in order to realize the inverse Doppler effect. They demonstrated that the shift arises from a complex and remarkable spatial structure of waves propagating along the line.

Normally consisting of only one spatial period, the considered system exhibits multiple spatial periods enabled by the periodicity of the nonlinear transmission line structure. Their explanation may point the way toward making materials in which this new effect can operate.

"There are now emerging a whole class of experiments, and theories to back them up, that involve the creation of materials that support electromagnetic wave propagation in ways that are not observed in nature," van der Weide says. "In other words, it's turning nature on its head. Some might ask, 'If you can only do this in artificial material, what good is it?' The answer is that we might be able to create materials that could support this type of effect for light or other electromagnetic waves. The larger point is that physicists are starting to challenge what were thought to be the basic laws of nature."

In 1968, Russian theorist V.G. Veselago predicted that materials could be engineered to interact with their environment in the opposite of how natural materials react. In 2000, researchers at the University of California-San Diego (UCSD) confirmed this, creating what's known as the first "left-handed" material.

In nature, all materials appear to obey the "right-hand rule." If the fingers of the right hand represent the waves' electric field, and if the fingers curl around to the base of the hand, representing the magnetic field, then the outstretched thumb indicates the direction of the flow of power. But the UCSD team created material that caused fields to move to the left even though the electromagnetic energy moved to the right. Light waves produced by such material should also produce an inverted Doppler effect. Van der Weide's group, in collaboration with researchers at MIT and the University of Delaware, is also exploring left-handed media.

"This is kind of the tip of the iceberg in terms of discovering things that we've held to be inviolable. We're finding they can, in fact, be violated under certain conditions," van der Weide says. "Can we build structures that would support that kind of thing? The answer appears to be yes."

Source: University of Wisconsin-Madison