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A tribute to Robert Helliwell (1920–2011)

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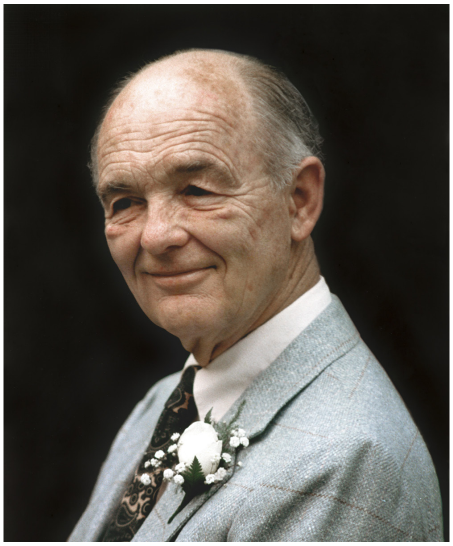

Robert Helliwell

Robert (Bob) Helliwell, radio science pioneer and global leader in the study of the propagation of whistler mode waves, a class of waves that propagate in space plasmas, died on 3 May 2011 at the age of 90.

During World War II, Helliwell worked at Stanford University to improve understanding of the effects of Earth's ionosphere on radio communications. He sought to lower the frequencies being used to sound the ionosphere, operating a spark transmitter at 100 kilohertz. Such a transmitter was unacceptable to the Federal Communications Commission (FCC) because of its potential for wideband radio interference, but Helliwell succeeded in disguising it as an "experimental impulse transmitter." To probe the lowest layers of the ionosphere, he began experiments with impulsive signals from distant lightning in the audio frequency range, ultimately stumbling on the whistler mode wave phenomenon, with its characteristic gliding tone variation in propagation velocity with frequency, to which he then devoted his decades-long research career.

Helliwell was one of a small number of investigators worldwide undertaking experiments to test and extend the remarkable findings of L. R. O. Storey, who as a doctoral candidate at Cambridge University in 1953 had explained whistlers as plasma waves launched by lightning. These waves can penetrate the ionosphere and be guided for thousands of kilometers along the Earth's magnetic field lines to the opposite hemisphere, thus serving as remote probes of the plasma density along field lines.

Helliwell became one of those early scientists who, prior to the satellite era, realized that the Earth's plasma envelope extended to great altitudes and that it could be probed by means of tape-recorded broadband audio recordings at ground stations. His long and productive research career evolved in ways that reflected his interest in the sensitivity of whistler mode signals (whether originating in lightning or man-made sources or occurring spontaneously in space) to both cold, dense background plasma and hot, tenuous plasma of the radiation belts. While he saw the cold plasma as the propagation medium controlling the dispersion properties of the waves, he also recognized that, because of their subluminous phase velocities, the waves could exchange energy and momentum with radiation belt particles.

Upon the discovery in 1962, largely by his group, of the phenomenon of very low frequency (VLF) emissions triggered in space by fixed-frequency signals from U.S. Navy communications transmitters, Helliwell was consumed by a desire to understand and explain this apparently simple phenomenon. Until the end of his career, and even beyond his retirement in 1990, he was captivated by the intricate features of artificially triggered VLF emissions and by their similarity to the whistler mode noise bursts called chorus that appear to arise spontaneously in space or through interaction with other waves. He insisted that there had to be a simple explanation for this phenomenon that nature exhibits so simply and beautifully, and he kept searching for this solution, brushing aside intricate plasma models and simulations.

The experiments that Helliwell and his students undertook led to the construction of a network of ground receivers during the International Geophysical Year (1957–1958) that extended from Alaska to the Antarctic. The ground station network formed the basis for the first essentially global mapping of Earth's cold plasma envelope, with its most prominent feature, the abrupt magnetic field–aligned drop in density known as the plasmapause, which was identified by D. L. Carpenter. The research also provided the material for Helliwell's highly influential 1965 monograph *Whistlers and Related Ionospheric Phenomena*.

Realizing that above the ionosphere there exists a rich family of "nonducted" whistler mode waves that do not penetrate to ground receivers because they do not become trapped within the "ducts," or density irregularities that follow the curvature of the Earth's magnetic field, Helliwell worked with colleagues at Stanford Research Institute on the pioneering Orbiting Geophysical Observatory (OGO) satellite series of the 1960s. These scientists measured geophysically important new varieties of lightning-induced whistlers, transmissions from powerful communications transmitters, and naturally occurring discrete and diffuse VLF emissions. Important new results were obtained by Helliwell's students in several areas involving ray-tracing analysis of whistler mode propagation.

In this period, Helliwell and his associates were already considering the possibility of active experiments in which whistler mode wave injection might be used both to reduce and to increase radiation belt particle energies through resonant interactions in which the wave and particle velocities are matched in a way that allows for wave-particle energy exchange. Altering radiation belt particle energies could provide a means of reducing danger to astronauts and satellite assets during periods of enhanced radiation levels. The transmitter at Siple Station, Antarctica, an engineering marvel, was established in 1973. For almost a decade prior to its closing in 1988, Siple Station hosted crossed horizontal dipole transmitter antennas 42 kilometers long mounted over an Antarctic ice sheet 2 kilometers thick. Designed and operated by Helliwell's students and staff, these antennas generated transmissions in the low-kilohertz range which were received in the Northern Hemisphere conjugate region near Roberval, Quebec, and produced a rich reservoir of information on what came to be called the coherent wave instability (CWI). In a CWI, weak narrowband waves (<10-hertz bandwidth) from Siple Station propagating along magnetic field–aligned paths regularly underwent fast temporal amplitude growth of the order of 30 decibels before saturation of the growth process, broadening of the wave spectrum, generation of sidebands, and triggering of discrete emissions that rose or fell in frequency with time occurred. One after another, the complexities of the VLF growth and triggering phenomena were revealed in beautifully designed experiments, so much so that in this one field, experiment was well ahead of theory and continues to be so.

Bob Helliwell's contributions as a researcher, teacher, and member of the science and engineering communities were many. At Stanford he fostered a strong sense of group loyalty and a collegial atmosphere in which members were able to work with a large measure of independence. He authored or coauthored more than 130 papers and supervised the work of 44 doctoral students. He fostered wide-ranging collaborative investigations, including many at Siple Station. In 1972 he received the Appleton Prize from the International Radio Science Union (URSI) for outstanding contributions to ionospheric research. He was a Fellow of both the Institute of Electrical and Electronics Engineers and AGU, and he also served as president of AGU's Solar Terrestrial Relations section. He was a member of the National Academy of Sciences and chaired several committees for the National Research Council of the National Academies.

Bob Helliwell's legacy continues through the work of his many former students and of the Stanford VLF Group, now under the leadership of U. S. Inan. The sense of group loyalty, work ethic, and love of science fostered by Bob Helliwell is destined to continue for many years to come.

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