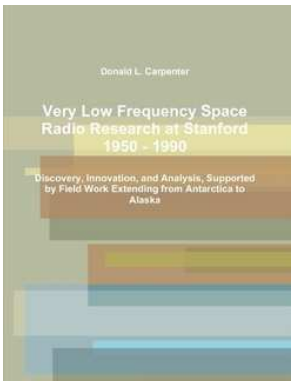
Title: ***Very Low Frequency Space Radio Research at Stanford 1950 – 1990: Discovery, Innovation and Analysis, Supported by Field Work Extending from Antarctica to Alaska***



Author: D. Carpenter
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Length: 215 pages, no index, 12-page bibliography
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Availability: Hardcover 53 USD, softcover 50 USD, copies may be ordered from: http://www.lulu.com/shop/donald-carpenter/vlf-history/hardcover/product-22497227.html
Reviewer: Whitham D. Reeve

Very Low Frequency Space Radio Research at Stanford 1950 – 1990 recognizes the work of Robert Helliwell who founded the Stanford University VLF Group and was its director for four decades from 1950 to 1990. Helliwell was the author of the classic ***Whistlers and Related Ionospheric Phenomena***, originally published by Stanford University Press in 1965; it was republished by Dover in 2006 and is still available [Helliwell]. Carpenter worked with Helliwell and made significant contributions to a chapter in Helliwell's book. The author also was closely associated with the research activities of Stanford's VLF Group during much of the time period covered.

The book reviewed here is not a primer. Readers already familiar with Earth's naturally occurring radio phenomena called *whistlers*, *auroral chorus* and *auroral hiss* will benefit the most. The natural radio phenomena in question occur below about 100 kHz in the low frequency (LF, 30 to 300 kHz), very low frequency (VLF, 3 to 30 kHz) and ultra-low frequency (ULF, 300 to 3000 Hz) bands but, as the book's title indicates, they are lumped under the category of *very low frequency*. Anyone interested in the history of radio research at these lower frequencies and the people involved in that research will enjoy reading this book.

Whistlers are impulsive radio phenomena produced by lightning discharges that travel into Earth's ionosphere and radiation belts where they interact with free electrons. These interactions force the radio waves to follow the geomagnetic field lines of force. As a whistler propagates, its frequency components travel at different speeds, dispersing or spreading out the impulse and making it sound like a descending whistle in a receiver. A typical whistler begins as a high audio frequency tone, dropping to as low as 1 kHz in about 1 s, more or less. Studies of whistlers and related phenomena are used to learn about Earth's ionosphere and radiation belts.

I was especially interested in the book because Alaska is mentioned in the subtitle plus I also have a copy of the Dover edition of Helliwell's book. Carpenter's book contains an extensive bibliography and 256 photos and diagrams and is mostly in chronological order. There are many gray-scale images of paper charts and reproductions of black-and-white and color photographs, all of which are of surprisingly high quality.

Very Low Frequency Space Radio Research at Stanford 1950 – 1990 generally is focused on operations by Stanford University in California, but Stanford had (and still has) extensive radio research field operations all around the world, particularly Antarctica and Alaska, including places in Alaska I have been to many times but never knew had radio research installations. Stanford also participated in related space radio research using data from purpose-built satellite observatories and sounding rockets. These field operations and their associated logistical problems are described throughout the book, making it very interesting reading.

Although the phenomena mentioned above occur naturally, it was found that they could be induced and affected by man-made activities. These includes nuclear explosions and terrestrial and spacecraft transmitters such as the now famous HAARP (High Altitude Auroral Research Project) facility near Gakona, Alaska (and vilified extensively by the aluminum foil helmet crowd), the US Navy's VLF transmitters used for submarine communications and other purpose-built transmitting stations.

The author describes transmitters built at field stations in Antarctica that used wire antennas tens of kilometers long, which were either laid on the ice or erected above it. One such antenna was a 33.5 km long dipole powered by a 100 kW transmitter on loan from the US Navy. This antenna was laid on the ice to lower its Q (quality factor) and, thus, increase its bandwidth. The system was used to probe the D- and E-regions of the ionosphere in the 3 to 30 kHz frequency range. I was particularly interested in this setup because in the late 1960s/early 1970s (about the same time frame as these Antarctica experiments) I maintained high frequency (3 to 30 MHz) transceivers and resonant dipole wire antennas that were used by mountain climbers of what was then called Mount McKinley north of Talkeetna, Alaska (it was renamed Denali in fall 2015). My brother-in-law, Don Sheldon, would fly the climbers to a base camp near the mountain and take care of other logistical details. He loaned them the radios, antennas and a car battery, which the climbers hauled up the mountain (!) for emergency and logistical communications with Sheldon in Talkeetna. The climbers were instructed to lay the antennas on the ice, and I recall this worked quite well.

Another dipole antenna at Antarctica was 21.2 km long. It was installed on supports 16 m above the snow and resonant at 5.1 kHz. This antenna had an estimated efficiency of 4% at 6 kHz. The transmitter was hand-keyed in Morse code with 0.5 s dots and 1.5 s dashes. These signals were received at Roberval, Quebec Canada, near the geomagnetic conjugate location in the northern hemisphere. Besides these VLF experiments at Antarctica, the author also describes measurements in Hawaii of nuclear blast effects from the Starfish Prime explosion in 1962 that was detonated 400 km above Johnston Island, a distance of about 1500 km from Hawaii.

In conclusion, although this is a somewhat expensive book for casual readers, it contains very interesting narratives and many interesting anecdotes along with a wealth of strip-chart data for VLF researchers and enthusiasts. Readers of this book also may be interested in ***Radio Nature*** by Renato Romero, a non-technical book about similar subjects written for radio amateurs [Romero]. I reviewed this book in Radio Astronomy in 2013 [Reeve].

Citations:

[Helliwell] Helliwell, R., Whistlers and Related Ionospheric Phenomena, Dover Publications, 2006

[Reeve] Reeve, W., Review of Radio Nature, *Radio Astronomy*, July-August 2013, available here: http://www.reeve.com/Documents/Book%20Reviews/Reeve_BookReview_RadioNature.pdf

[Romero] Romero, R., Radio Nature, Radio Society of Great Britain, 2010

Reviewer - Whitham Reeve is a contributing editor for the SARA journal, *Radio Astronomy*. He worked as an engineer and engineering firm owner/operator in the airline and telecommunications industries for more than 40 years and has lived in Anchorage, Alaska his entire life.