

# Compact HF Antennas: Fundamental Design Considerations and Elementary Antenna Types



**Lecturer:** Nader Behdad

**Level:** Introductory

**Time:** Feb 8, 2025 4:00 PM to 6:00 PM Pacific Time (US and Canada)

## Abstract

The high-frequency (HF) band of the electromagnetic spectrum lies in the 3–30-MHz range and is characterized by electromagnetic waves with wavelengths in the 10-100 m range. Electromagnetic waves in this frequency band are widely used in communications, navigation, and scientific applications due to their unique propagation characteristics. HF waves can travel long distances through multiple reflections off the ionosphere and ground, enabling reliable skywave communication, which is critical for maritime, aviation, and military operations. This band is also used in amateur radio, international broadcasting, and emergency communication systems, offering a global reach. Additionally, HF is used in over-the-horizon radar systems for beyond line-of-sight monitoring and surveillance and in ionospheric studies to understand and predict space weather effects on radio propagation.

In this lecture, we will first have a brief review of the characteristics of the earth's ionosphere that are important to propagation of HF waves and discuss three important modes of propagation of electromagnetic waves at these frequencies. These include the ground wave, near vertical incidence skywave (NVIS), and long-range skywave. Subsequently, we will have a brief discussion on noise at the HF band and discuss the different sources of noise that are important to operation at these frequencies. Following this, we have a brief discussion of the fundamental limitations of electrically small antennas that become particularly important for antennas with physically constrained dimensions at the HF band. We will then discuss the principles of designing compact HF antennas. Particular emphasis will be placed on illustrating the effect of the presence of earth on the performance of vertically and horizontally polarized HF antennas as well as the challenges of designing impedance matching networks with reduced loss and enhanced power handling capability. We will also briefly discuss the fundamental design principles that can be used to achieve compact, directional antennas at the HF band. This lecture is meant to be educational and its target audience are first year graduate students or senior undergraduate students as well as practicing engineers who are not familiar with the basics of HF communications or challenges involved in designing HF antennas.

## Bio

Nader Behdad received the B.S. degree in Electrical Engineering from Sharif University of Technology in 2000 and the M.S. and Ph.D. degrees in Electrical Engineering from University of Michigan - Ann Arbor in 2003 and 2006, respectively. Currently he is the McFarland-Bascom Professor in the Department of Electrical and Computer Engineering of the University of Wisconsin-Madison. Dr. Behdad's research expertise is in the area of applied electromagnetics with particular focus on electrically small antennas, phased-array antennas, bio-electromagnetics, microwave ablation, microwave periodic structures, and high-power microwaves. He has 25 issued or pending U.S. patents in these areas. Dr. Behdad has served as a consultant on topics related to designing antennas and phased arrays to industry. He has also served as a consultant and an expert witness for different U.S. law firms on topics related to intellectual property disputes as well as cell phone record analysis and historical cell site analysis. Over the years, Dr. Behdad's research has been sponsored by various U.S. Federal agencies including the U.S. Navy, U.S. Air Force, U.S. Army, National Science Foundation, IARPA, and the Defense Health Agency among others.

Dr. Behdad has graduated 28 Ph.D. and 19 M.S. students so far and served as the research advisor of 34 other post-doctoral research fellows and visiting scholars. He is a fellow of the IEEE and received the Harvey D. Spangler Faculty Scholar Award, the H. I. Romnes Faculty Award, and the Vilas Associates Award from the University of Wisconsin-Madison. Dr. Behdad is also the recipient of the 2021 H. A. Wheeler Prize Paper Award, the 2014 R. W. P. King Prize Paper Award, and the 2012 Piergiorgio L. E. Uslenghi Letters Prize Paper Award of the IEEE Antennas and Propagation Society. In 2011, he received the CAREER award from the U.S. National Science Foundation, the Young Investigator Award from the United States Air Force Office of Scientific Research, and the Young Investigator Award from the United States Office of Naval Research. Dr. Behdad is serving as a member of the Fellow Election Committee of IEEE Nuclear and Plasma Sciences Society and served as the 2020 chair of the paper awards committee of the IEEE Antennas and Propagation Society. He also served as an Associate Editor for IEEE Antennas and Wireless Propagation Letters (2011-2015) and as the co-chair of the technical program committee of the 2012 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting.