Fundamentals and Geophysical Application of Imaging Radar Systems

Syllabus

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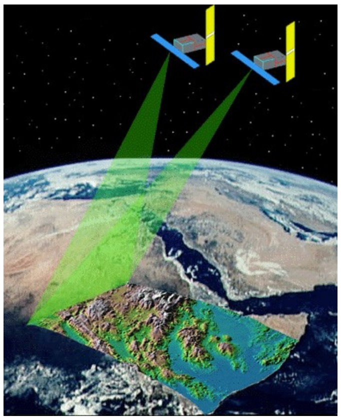
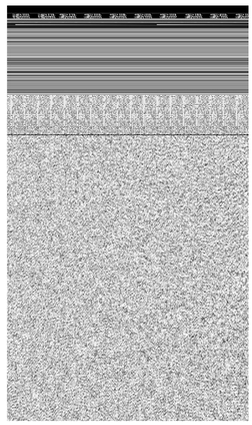
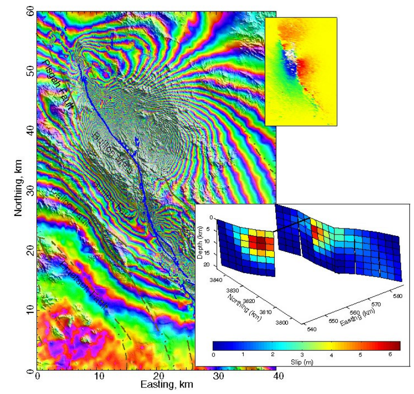


From instruments



to raw data



to images

General Information

Location :
Salvatori Seminar Room
South Mudd Building, Third Floor
Caltech Campus
Northeast corner of California and Wilson

Dates:
Oct. 23-Nov. 3, 2023

Times:
8:30-11:30 Lectures
1:00- Homework/Computer Lab

Intended audience:

This class is aimed at advanced students and radar professionals interested in the physical principles and signal processing and analysis needed to understand and work with radar remote sensing data.

Course goal:

The material presented here enables attendees to derive most properties of radar echoes from first physical principles, and to be able to design and implement processing code that generates high-resolution images from the raw measurements. In addition, you will be able to use multiple channel systems to produce higher order data products such as interferometric and polarimetric analyses. Finally, you will be able to apply these products to a diverse set of geophysical applications.

Course description:

Radar has evolved from a largely military detection system into a sophisticated three dimensional imaging tool with hundreds of applications ranging from commercial aviation to fundamental research in the earth and planetary sciences. The ability to measure and map surface topography and crustal change at unprecedented levels over large areas is fundamentally altering the way in which we can measure and model the processes, natural and man-made, that effect our environment. The interaction of EM waves with different surface types provides a basis for analyzing echoes to discern, for example, the structure of vegetation canopies or surface roughness. In this course we will investigate how radar images are formed and manipulated, as well as applications of the systems. We will be presenting radar as a signal processing problem, rather than the traditional approach as an instrumentation problem, acknowledging the importance of digital computer algorithms in modern radar systems. The first half of the course will be largely devoted to radar image formation, and topics will include system design, range and azimuth processing algorithms, and processor design. In the second half of the course we examine scattering from natural surfaces, polarimetric radars-- which are particularly suited to the study of vegetation cover--, plus the increasingly important field of radar interferometry. Interferometric radar techniques, which have formed a large part of radar-related research over the past 30 years, provide a means to characterize very small changes or motions on the Earth over large areas.

The course will be presented in a lecture/seminar style. Mornings will consistent largely of interactive lectures, while the afternoons will entail a computer exercise to give experience with implementation of the material presented in class. The afternoons will be augmented with guest lectures from senior radar scientists and engineers in order to present diverse ways to look at the problems.

Our approach will be to have students create their own codes to solve each day’s problem, building on the previous days’ exercises to create a full data flow. Lecture notes will be available online, and special handouts will also be distributed from time to time. Cooperation on the exercises is encouraged, with TA support to help with debugging problems quickly. We can grade you if you like but we want everyone to earn an A+ grade(!)

Day	Topic	Lectures	Handouts	Homework
1	**Basic Concepts and Notation**	What is an imaging radar ? System design principles Radar equation	*Handout 0* *Handout 1* *Handout 2* *Handout 3* *Handout 5* *Handout 6*	*Homework 1*
2	**Range modulation processing**	Radar as a signal processing problem Range processing and matched filters Pulse compression System impulse response FFT implementations	*Handout 7* *Handout 10* *Handout 11* *Handout 12*	*Homework 2* *"ersdata" data file*
3	**Doppler viewpoint**	Image formation Real aperture and unfocused processors Range-Doppler system design	*Handout 14* *Handout 14a*	*Homework 3* *"ersdata.hw3" data file*
4	**SAR Processing**	Synthetic aperture technique System impulse response Azimuth correlator design	*Handout 15* *Handout 17* *Handout 19* *Handout 20*	*Homework 4* *"ersdata.hw3" data file (same as hw 3)*

5	**Range migration processing**	Focusing and autofocus algorithms Doppler tracking and filtering Multilook processing	*Handout 22* *Handout 25* *Handout 27*	*Homework 5* *"simlband.dat" data file*
6	**Back projection methods**	Coherent summation viewpoint Motion compensation Geocoding	*Handout 45* *Handout 46* *Handout 49*	*Homework 6 1-d* *"alossim_1d.dat" data file* --------------------------- *Homework 6 Advanced* *"alosraw.dat" data file* *"alos.position" data file* *"alos.dem" data file* *"alos.dem.rsc" data file* *"alos.xyz" data file*
7	**Radar/surface interactions**	Scattering mechanisms and models Kirchhoff facet models Bragg scattering Volume scattering	*Handout 28* *Handout 31* *Handout 50*	*Homework 7* *"hw7prob1a.txt" table* *"hw7prob1b.txt" table* *"hw7prob1c.txt" table*
8	**Polarimetry**	Polarized radar waves Polarizations signatures and diffuse scattering Scattering from vegetation	*Handout 51*	*Homework 8*

		Radiometric calibration Geometric distortion		
9	**Interferometry**	Interferometric radar Image registration Baseline determination Surface topography Surface velocities / ocean currents Crustal deformation	*Handout 32* *Handout 33* *Handout 34* *Handout 37* *Handout 38* *Handout 39* *Handout 40* *Handout 42* *Handout 43* *Handout 44* *Handout 52*	*Homework 9* *"slc1.dat" data file* *"slc2.dat" data file* *"slc.dem" data file* *"slc.baseline" data file*
10	**Application examples**	Ecosystems Cryosphere Solid Earth NISAR applications community	*Handout 47* *Handout 48*	

REFERENCES

Several books which may serve as useful references are listed below.

Bracewell, R. N., The Fourier Transform and Its Applications, McGraw-Hill, New York, 2nd edition, 1986.

Carrara, W.G., R.S. Goodman, and R.M. Majewski, Spotlight Synthetic Aperture Radar: Signal Processing Algorithms, Artech House, Norwood, MA, 1995.

Cook, C.E., and M. Bernfeld, Radar Signals, Academic Press, New York, 1967.

Curlander, J.C. and R.N. McDonough, Synthetic Aperture Radar, Wiley Interscience, New York, 1991.

Elachi, C., Introduction to the physics and techniques of remote sensing, Wiley, New York, 1987.

Elachi, C., Spaceborne Radar Remote Sensing: Applications and Techniques, IEEE press, New York, 1988.

Goodman, J.W., Introduction to Fourier Optics, McGraw-Hill, New York, 1968.

Kraus, J.D. Radio Astronomy, McGraw-Hill, New York, 1966. (Later editions good also)

Peebles, P.Z, Radar Principles, Wiley Interscience, New York, 1998.

Press, W.H., B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling, Numerical Recipes in C, the Art of Scientific Computing, Cambridge University Press, New York, 1988. (Any of the Numerical Recipes series will have useful algorithm information)

Sabins, F., Remote Sensing, 3rd ed., Freeman, New York, 1996. Soumekh, M., Fourier Array Imaging, Prentice Hall, Englewood Cliffs, New Jersey, 1994.

Skolnik, M.I., Radar Handbook, McGraw-Hill, New York, 1970.