

**GEOL 702h – Geophysics – Remote Sensing for Geoscience Applications  
Imaging Radar**

**COURSE SYLLABUS – Spring 2002**

**Course Credits: 3 semester hours, 2 hours of lecture and 3 hours of lab per week**

**Instructor: Dr. James V. Taranik, Regents Professor  
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Laxalt Mineral Research 356A  
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Available for consultation by e-mail appointment.**

**Program Assistant: Ms. Lori Rountree, LME 302, 784-6261, [lori@mines.unr.edu](mailto:lori@mines.unr.edu)**

**Classroom: LMR 356A**

**Laboratory: Arthur Brant Laboratory for Exploration Geophysics, LMR 360**

**Times: Lecture; 1:00 – 1:50 hrs, MW. Lab; days and hours by arrangement.**

**COURSE DESCRIPTION**

This course reviews fundamental principles of aerospace remote sensing in the microwave portions of the electromagnetic spectrum. Students learn how the energy-path concept provides a model for understanding the properties of the sources of microwave electromagnetic radiation and the transmitting media. Concepts of frequency, wavelength and phase learned and the properties of microwave energy are understood by students. Students learn the phenomenology of atmospheric effects is to develop an understanding of the effects of atmospheric scattering, absorption, polarization, and ionospheric and tropospheric decorrelation on microwave energy propagated to and received from the Earth's surface.

Students learn radar system parameters are reviewed including: Earth curvature, orbit characteristics, the Radar Equation, definitions, radar operation, phase noise, polarization, radar resolution, illumination geometry and landscape geometry, image geometry and inherent distortions, and speckle in radar imagery. Environmental and target parameters learned including: concepts of roughness, geometry of targets, resonance, dielectric constant, surface and volume scattering, signal penetration and signal enhancement. Interpretation techniques, procedures and aids are reviewed, including: interpretation keys, merged radar sets, multifrequency-multipolarization radar analysis, filters and enhancements, manual versus computer assisted interpretation.

Students learn basic radargrammetry including: basic radargrammetry equations, projection equations, relief displacement, matching radar images and digital terrain models, geometric rectification, stereoscopic radar analysis, and parallax radargrammetry. Students learn concepts and applications of radar polarimetry are reviewed including: polarimetry in nature, basic equations of radar polarimetry, antenna

concepts, target concepts, optimum polarization for maximum power, co-polarization and cross-polarization, and geoscience applications of radar polarimetry.

Students learn concepts of imaging radar interferometry including: overview of interferometry principles, interferometric topographic mapping, velocity mapping, change mapping and geoscience applications, including earthquake hazard and event analysis, volcanic hazard detection, glacier and ice movement, landslide and erosion detection, etc. Students construct radar interferograms using the SUN – Solaris 8 radar image processing workstation with JPL ROI\_PAC software in the Arthur Brant Laboratory for Exploration Geophysics.

Students study the physics of surface scattering, reflection, of microwave EMR by major classes of earth surface materials, with emphasis on the physical and electrical properties of minerals and consolidated rocks, unconsolidated rock-weathering products, soils, and coatings and alteration products that occur with these materials.

Sensor technology is reviewed in terms of microwave physics and antenna technology. Students gain an understanding of the models used to characterize radar backscatter to understand how microwave EMR, measured by airborne and spaceborne radar antennas, is formatted to data. Concepts of radiometric and geometric adjustments to microwave data are applied by students. Spaceborne radar systems are reviewed including: SEASAT-A, SIR-A, SIR-B and SIR-C/X-SAR, Kosmos, Almaz, ERS-1 and ERS-2, J-ERS-1, and RADARSAT. Aircraft radar systems are reviewed including: AirSAR, C/X SAR, E-SAR and STAR-1.

Students learn how to conduct ground-based field and laboratory studies of common rock materials and their associated rock alteration products to develop an appreciation of the microwave attributes of natural resource types measured with aerospace remote sensing techniques. Microwave data analysis techniques are introduced over known geology in the Great Basin. The cost-effectiveness of radar imagery is compared to optical imagery and thermal imagery for natural resources investigations..

## **COURSE EMPHASIS**

**Course Notebook: 15%, constitutes the textbook for the course.**

**Mid-Term Examination: 15%, a take-home examination, open book, open notes.**

**Term Project: 30%**

**Oral Presentation on term project: 15%**

**Final Examination: 25%, closed book 2 hour exam.**

## **COURSE NOTEBOOK**

This course has no course textbook, however students are expected to develop their own course textbook through lecture notes taken in class, notes taken from assigned readings and notes taken from reference materials that students wish to include on their own initiative. Please **do not** just copy references from this course for your notebook!

Your interpretations of the key points in these references are what should constitute most of your notebook. An important part of the notebook is a comprehensive list of references, appropriate to each major subject, and including references you may find beyond those assigned during class. The notebook will be professionally prepared, including carefully illustrated diagrams. It will be appropriately footnoted to acknowledge sources of information, and it will be organized in a three-ring binder. These notebooks will be graded for completeness and neatness. Notebooks submitted by students may be retained by the instructor and the information contained in the notebooks will not be subject to copyright by the student. The instructor reserves the right to use materials from the submitted notebooks for future classes. Some of the material in the submitted course notebooks may be placed, in condensed form, on the World Wide Web for the use of all students.

## **TERM PROJECT**

The term project will involve student laboratory research on characterizing geoscience problems in terms of the kinds of microwave attributes that can be detected and mapped with aerospace remote sensing data. Students in the class are encouraged work as a team to acquire radar image data, over a geological problem area for analysis with ENVI, ER-Mapper and/or JPL ROI-PAC software. Term projects must be approved by the instructor and should be arranged during the first week or two of instruction.

We have developed a technique for documenting the steps students might utilize in computer analysis of remote sensing data in their term projects. This documentation takes the form of saving the computer screen showing the procedures used. This type of documentation should be utilized in an appendix at the end of the report. Powerpoint illustrations and image data acquired and processed in the course of the term project should be provided to the instructor in the form of a CD-ROM, or 100 MB ZIP Disk as appropriate. Large data sets may have to be archived on our Peerless 20GB removable drives. Students are encouraged to consider publishing their term reports after suitable peer review. The instructor will be pleased to assist in any publication effort.

The methodology for term projects will take the form of (1) definition of a project, (2) identification of suitable data and development of a general outline to be submitted to the instructor for his review, (3) expansion of the project outline, with key references noted, after project work is underway (graded), (4) preliminary results and findings submitting as a topic sentence outline for the proposed project report. The topic sentence outline and bibliography will be evaluated for completeness and they will be graded. The final report is due typewritten, in professional style on the last day of the course. Late reports will be downgraded accordingly. Incompletes are strongly discouraged and must be adjudicated with the instructor.

## **ORAL REPORT**

The oral report will be a professionally prepared talk that uses “MS Powerpoint” for original figures and diagrams. Figures and diagrams from reference sources must be carefully documented. The oral report will be presented as a 20 minute presentation with

5 minutes for questions and answers, in a manner similar to that in a professional association meeting. The class will participate in the evaluation of the presentation, in terms of its organization, style and content. These talks are designed to improve student communication skills and to prepare students for professional life. The oral reports will be given at the end of the course and students may invite guests to attend.

## COURSE SCHEDULE

- January 23, 2002 – Hand out syllabus and assign readings. Reading assignments  
Wednesday (1) for next two weeks: Reference 1, 2, 3 entire paper; Reference 4 (131 – 140).
- January 25, 2002 – Laboratory. Continue assigned readings on electromagnetic  
energy, the radar spectrum, history and development of radar for  
geologic applications. No formal lecture, independent study on  
assigned Readings. **Begin definition of a term project.** Instructor  
will be available for discussions on candidate term projects (356  
LMR 10:00AM – 12:00AM). Make an appointment. E-mail:  
jtaranik@mines.unr.edu and/or jvtaranik@cs.com
- January 28, 2002 - No Class. Jim in Toronto, Canada for Newmont Mining  
Monday Corporation Board Meeting. Introduction to the microwave  
electromagnetic spectrum. Theory of electromagnetic radiation.  
Electromagnetic waves and wave interactions. Read Reference 4  
(pp. 140 – 155).
- January 30, 2002 - No class, Jim in Toronto, Canada. Newmont Mining Corporation.  
Wednesday Reading assignment for 28 Jan: Reference 19, (16 - 42). Reference  
19
- February 1, 2002 - Laboratory. **Define Term Project.** Meet with the  
Friday instructor as appropriate (365 LMR 10:00 – 12:00). Make an  
appointment. E-mail: jtaranik@mines.unr.edu and  
jvtaranik@cs.com
- February 4, 2002 - **Hand in Term Topic and brief outline.** The Radar Equation  
Monday Fundamental system and target parameters that influence radar  
power return. Radar system imaging geometry. Incident  
angle, look angle, look direction (azimuth angle), local slope angle,  
effect of position and range on incident angle. Concepts of  
foreshortening, slope compression to a point and layover.  
Concepts of slant range and ground range. Concept of squint and  
Azimuth angles.
- February 6, 2002 - Lecture. **Term project proposals handed back.** Radar operation.  
Wednesday (4) Real Aperture Radar and Synthetic Aperture Radar. The radar

Electromagnetic spectrum and aircraft and spacecraft imaging  
Radar systems. Concept of polarization, linear polarization,  
elliptical polarization and circular polarization. Radar resolution,  
resolution in range, resolution in azimuth. Swath angle, near-range  
far-range. Ground-range and slant-range presentations. Layover  
and depression angle, radar shadow, depression angle and shadow.

- February 8, 2002 - Friday  
Laboratory. Continue readings, independent work on term project.  
Meet with instructor as appropriate. Make an appointment.  
Reading Assignment for 11 Feb: Reference 4, (155 – 181),  
Reference 19, (43 – 62),
- February 11, 2002 - Monday (4)  
Lecture. Introduction to radar parallax and stereoscopy. Concepts  
speckle and number of looks. Concept of target roughness,  
microscale roughness (tone), mesoscale roughness (texture),  
macroscale roughness (topographic effects). Geometry of targets,  
corner reflectors. Bragg scattering (resonance). Electrical  
properties of targets (dielectric constant).
- February 13, 2002 - Wednesday (5)  
Lecture. Introduction to surface and volume scattering. Signal  
penetration. Signal enhancement. Multipolarization and  
Multifrequency radar.
- February 15, 2002 - Friday  
Laboratory. Interpretation techniques and procedures for  
monochromatic imaging radar. Use of interpretation keys: texture,  
tone, shape, size, shadow and pattern approach. Concept of pattern  
recognition, radiometric patterns, landscape patterns, surface cover  
and landform patterns. Interpretation of color radar imagery.  
Work on data sets in LMR 360 ABEL lab. Meet with instructor  
As appropriate regarding questions on readings and/or term  
project. Reading Assignment for 18 Feb: Reference 7, (184 –  
269), Reference 8 (if available from Library).
- February 18, 2002  
HOLIDAY, No Class
- February 20, 2002 - Wednesday (6)  
Lecture. Radargrammetry. History of radargrammetry. Projection  
equations. Relief displacement. Projection of radar imagery onto  
a spherical planet. Attitude and motion compensation. Matching  
radar images and DEMs. Radar stereo, same side stereo, opposite  
side stereo, shallow and steep look angles, crossing orbits stereo,  
parallax radargrammetry.
- February 25, 2002 - Monday (7)  
Lecture. Radargrammetry continued with examples. **Hand in  
Term Project expanded outline.** This outline should be a general  
outline of the term project showing, scientific questions to be

addressed, research methodology, data to be utilized, results expected and key references to be utilized. (graded).

- February 27, 2002  
Wednesday (8) Introduction to Polarimetry. Target concepts. Independent readings on geologic applications including: playas, alluvial fans, sand dunes and moraines, sedimentary rock formations, and lava flows. Soil moisture estimation, snow hydrology and flood mapping. Instructor at JPL INSAR Conference in Pasadena. Reading assignment for this block: Reference 6, (566 – 629).
- February 22, 2002 -  
Friday Laboratory. Interpretation techniques for stereo radar images. Reading assignment for 4 Feb: Reference 9 (270 – 358), Reference 18. Laboratory. Interpretation techniques for polarimetric imagery. Continue independent readings. Instructor at INSAR Conference in Pasadena. Reading assignment for 4 Mar: Reference 10, (359 – 406).
- March 4, 2002 -  
Monday (8) Lecture. Introduction to imaging radar interferometry. History of the technique. Fundamental principles, spatial baselines, temporal baselines, mixed baselines. Interferometric mapping, single-pass interferometry, two-pass interferometry. Reading Assignment for 6 March: References 11, 12, 13 and 16.
- March 6, 2002 –  
Wednesday (9) Lecture. Imaging radar interferometry continued. Systems for topographic mapping, aircraft single pass systems, two-pass satellite systems, Shuttle Radar Topographic Mapping (SRTM). Velocity mapping and change mapping.
- March 8, 2002 -  
Friday Laboratory. Laboratory on interpretation on radar interferometric image data. Reading assignment for 11 Mar: Reference 27, (406 – 433)
- March 11, 2002 -  
Monday No class. Take Home Mid-Term Examination handed out. Hand in topic sentence outline with key references and data sets to be used for term project (graded)
- March 13, 2002 -  
Wednesday No class. Jim at AAPG meeting in Houston. Work on Mid-Term.
- March 15, 2002 -  
Friday Laboratory. Examples of soil moisture and soil salinity imagery analysis available in lab.
- March 18, 2002 -  
Monday No class work on take home examination.

March 20, 2002 - Wednesday	Work on take-home examination. No class. Jim at National Space Grant Director's Conference in Washington, D. C.
March 22, 2002 Friday	<b>Hand in take-home examination</b> to Lori Rountree at beginning of lab period. Instructor in Washington D. C.
March 25, 2002 - Monday. (11)	Lecture, Review of Mid-Term examination
March 27, 2002 - Wednesday (12)	Lecture. Case histories in the applications of imaging radar to geology. SEASAT radar.
March 29, 2002 - Friday	Laboratory, <b>Hand in term project topic sentence outline.</b> This outline is graded and is comprehensive.
April 8, 2002 - Monday (13)	Lecture. Case histories continued. Shuttle Imaging Radar SIR-A, B.
April 10, 2002 - Wednesday (14)	Lecture. Case histories continued. SIR-C/X-SAR
April 12, 2002 - Friday	Laboratory. Continue work on term projects. Instructor available for consultation.
April 15, 2002 - Monday (15)	Lecture. Case histories continued.. SIR-C/X-SAR
April 17, 2002 - Wednesday (16)	Lecture. Case histories continued. ERS-1,2, Radargrammetry and interferometry. Introduction to RadarSat.
April 19, 2002 - Friday	Laboratory. Continue work on term projects. Instructor available for consultation.
April 22, 2002 - Monday	No class, at AAPG Annual Meeting, Instructor at AGI Foundation Board Meeting in New Orleans, LA. Work on term projects.
April 24, 2002 - Wednesday	No class, at AAPG Annual Meeting. Work on term projects.
April 26, 2002 - Friday	Laboratory. Continue work on term projects. Instructor available for consultation.
April 29, 2002 - Monday	<b>First 3 Student Presentations on Term Projects.</b>

May 1, 2002 Wednesday	<b>Second 3 Student Presentations on Term Projects..</b>
May 3, 2002 Friday	<b>Term Projects due.</b> Hand in to Lori Rountree. <b>Additional Student Presentations, if necessary.</b>
May 6, 2002 Monday	Lecture, review for final examination, last class
May 8, 2002 Wednesday	Final preparation day, no class.
May 13, 2002 Monday	<b>Final Examination</b> , Room LMR 356, 1200 noon – 2:00PM Hand in examination and <b>Course Notebook due</b> to Lori Rountree.

## READINGS

1. Jenson, H., Graham, L. C., Porcello, L. J., and Leith, E. H., 1977, **Side-Looking Airborne Radar**: in Scientific American, Vol. 237, No. 4., pp. 84 – 95.
2. Elachi, C., 1980, **Spaceborne Imaging Radar: Geologic and Oceanographic Applications: in Science**, Vol. 209, pp. 1073 – 1082, 5 Sep. 80.
3. MacDonald, H. C., 1980, **Techniques and Applications of Imaging Radars**: in Remote Sensing in Geology, Chapter 10, pp. 297 – 336, Siegal and Gillespie Ed., John Wiley and Sons, New York.
4. Lewis, A. J., Henderson, F. M., and Holcomb, D. W., 1998, **Radar Fundamentals: The Geoscience Perspective**: in Principles and Applications of Imaging Radar, Manual of Remote Sensing, Third Edition, Vol. 2, Chapter 3, pp. 131 – 181.
5. Ford, J. P., et. al., 1998, **Radar Geology**: in Principles and Applications of Imaging Radar, Manual of Remote Sensing, 3<sup>rd</sup> Edition, Vol. 2, Chapter 10, pp. 512 – 565.
6. Lewis, A. J., 1998, **Geomorphic and Hydrologic Applications of Active Microwave Remote Sensing**: in Principles and Applications of Imaging Radar, Manual of Remote Sensing, Third Edition, Vol. 2, American Society of Photogrammetry and Remote Sensing, Chapter 11, pp. 566 – 629.
7. Leberl, F. W., 1998, **Radargrammetry**: in Principles and Applications of Imaging Radar, Manual of Remote Sensing, Third Edition, Vol. 2, Am. Soc. of Photogrammetry and Rem. Sens., Chapter 4, pp. 183 – 269.

8. Leberl, F. W., 1990, **Radargrammetric Image Processing**: Artech House, 595 p.
9. Boerner, Wolfgang-Martin, et. al., 1998, **Polarimetry in Radar Remote Sensing; Basic and Applied Concepts**: in Principles and Applications of Imaging Radar, Manual of Remote Sensing, Third Edition, Vol. 2, Am Soc. of Photogrammetry and Rem. Sens., Chapter 5, pp. 270 – 358.
10. Madsen, S. N., and Zebker, H. A., 1998, **Imaging Radar Interferometry**: in Principles and Applications of Imaging Radar, Manual of Remote Sensing, 3<sup>rd</sup> Edition, Vol. 2, Am. Soc. of Photogrammetry and Rem. Sens., Chapter 6, pp. 359 – 406.
11. Massonnet, D., et. al., 1993, **The Displacement Field of the Landers Earthquake Mapped by Radar Interferometry**: in Nature, Vol. 364, pp. 132 – 142.
12. Massonnet, D., et. al., 1994, **Radar Interferometric Mapping of Deformation in the Year After the Landers Earthquake**: in Nature., Vol. 369, pp. 227 – 230.
13. Zebker, H., and Goldstein, 1986, **Topographic Mapping from Interferometric SAR Observations**: in Jour. Of Geophys. Res., vol. 91, B5, pp. 4493-4499.
14. Zebker, H., et. al., 1994a, **Accuracy of Topographic Maps Derived from ERS-1 Interferometric Radar**: in IEEE Trans. Geoscience and Remote Sensing, Vol. 32, No. 4, pp. 823 – 836.
15. Zebker, H., et. al., 1994b, **On the Derivation of Co-seismic Displacement Fields Using Differential Radar Interferometry**: in Jour. Geophys. Res. Solid Earth, Vol. 99, No 10, pp. 19617 – 19634.
16. Zebker, H., et. al., 1994c, **Mapping the World's Topography with Radar Interferometry**: in Proc. IEEE, Vol. 82, No. 12, pp. 1774 – 1786.
17. Zebker, H. A., van Zyl, J. J., and Elachi, C., 1990, **Polarimetric SAR Applications: in Radar polarimetry for geoscience applications**, F. T. Ulaby and C. Elachi editors, Artech House, Inc, 364 pp.
18. Zebker, H. A., and van Zyl, J. J., 1991, **Imaging Radar Polarimetry: A Review**: in Proc. IEEE, Vol. 79, pp. 1583 – 1606.
19. Trevett, J. W., 1986, **Imaging Radar for Resources Surveys**: Chapman and Hall, New York.
20. Curlander, J. C., and McDonough, R. N., 1991, **Synthetic Aperture Radar, Systems and Signal Processing**: John Wiley and Sons, New York.

21. Elachi, C., 1987, **Solid-Surface Sensing: Microwave and Radio Frequencies: in Introduction to the Physics and Techniques of Remote Sensing**, Chapter 6, pp. 161 – 272.
22. Beal, R. C., DeLeonibus, P. S., and Katz, I., 1981, **Spaceborne Synthetic Aperture Radar for Oceanography**: Johns Hopkins University Press, Baltimore, MD.
23. MacDonald, H. C., and Waite, W. P., 1971, **Optimum Radar Depression Angles for Geological Analysis**: in *Modern Geology*, Vol. 2, pp. 179 – 193.
24. MacDonald, H. C., 1969, **Geologic Evaluation of Radar Imagery from Darien Province, Panama**: in *Modern Geology*, Vol. 1, pp. 1 – 63.
25. Wing, R. S., **Structural Analysis from Radar Imagery of the Eastern Panama Isthmus: Part I and 2**, in *Modern Geology*, Vol. 2, pp. 1 – 21 and 75 – 127.
26. Dellwig, L. F., 1969, **An evaluation of multifrequency radar imagery of the Pisgah Crater area, California**: in *Modern Geology*, vol 1, pp. 65 – 73.
27. Dobson, M. C., and Ulaby, F. T., 1998, **Mapping Soil Moisture Distribution with Imaging Radar**: in *Principles and Applications of Imaging Radar, Manual of Remote Sensing*, 3<sup>rd</sup> Edition, Vol. 2, Chapter 8, pp. 407 – 433.
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31. Rosen, P. A., Hensley, S., Joughin, I. R., Li, F., Madsen, S. N., Rodriguez, E., and Goldstein, R. M., 1999, **Synthetic Aperture Radar Interferometry**: in *Proc. Of IEEE, Geoscience and Remote Sensing Society* (submitted for publication).
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35. Masonnet, D., and Feigl, K. L., 1998, **Radar interferometry and its application to changes in the earth's surface**: Reviews of Geophysics: Vol. 36, pp. 441 - 500.
36. Gabriel, A. K., Goldstein, R. M., and Zebker, H. A., 1989, **Mapping Small Elevation Changes Over Large Areas: Differential Radar Interferometry**; in Jour. Of Geophys. Res., Vol., 94, No. B7, pp. 9183 – 9191.
37. References on InSAR processing software:
- The Alaska SAR Facility: <http://www.asf.alaska.edu>
- JPL's ROI-PAC processing software:  
[http://www.seismo.berkeley.edu/~dschmidt/ROI\\_PAC/](http://www.seismo.berkeley.edu/~dschmidt/ROI_PAC/)
- Atlantis Scientific's Webpage: <http://www.atlsci.com>
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