
Dr. Anthony Freeman

**Work Address:**

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Experience: over 25 years of experience as a researcher, manager, earth observation system designer and engineer, teacher, project leader and task leader. Positions held and responsibilities are listed below:

Program Manager, JPL [2004-present]: manager of the Earth Science Research and Advanced Concepts Office (830). JPL has a broad portfolio of Earth Science missions and instruments and this office is responsible for all of JPL's future work in this area, including new science, technology and

missions, covering all parts of the Electromagnetic spectrum. FY '09 funding stands at \$59M (up by more than 130% compared with FY '05), with additional authority over discretionary spending (internal investment). Current workforce stands at ~170 scientists and engineers. Office reviews and signs off on 150-200 research proposals to NASA per annum. Responsible for coordinating JPL's response to the NAS Earth Science and Applications decadal survey, released in 2007.

Section Manager, JPL [1999-2004]: manager of the Mission & Systems Architecture section (311). The section employs over 150 engineers and is responsible for leading up to 100 advanced mission studies per year and for developing the architecture of all new JPL missions, for both Planetary and Earth Science investigations. Section is also responsible for leadership in program and project system engineering, cost estimation, project planning and collaborative engineering at JPL. Architect of several new mission concepts and proposal lead for several large (\$300-600M) planetary missions. Architect and owner of the mission and systems architecture process, which is the pre-phase A system design methodology at JPL.

LightSAR Radar System Manager, JPL [1996-1999]: responsible for the design and technology development for a lightweight, capable, polarimetric, multi-mode spaceborne Synthetic Aperture Radar (SAR), known as LightSAR, for science and commercial use. Managed the development of prototype hardware through a partnership between JPL and industry. Hardware was flight-tested on an airborne platform. Served as radar instrument lead for 4 innovative L-Band and P-Band SAR mission concepts (valued at over \$100M) 3 of which were proposed to NASA and one to ESA.

Group Supervisor, JPL [1995-1996]: leader of a team responsible for the development and wide dissemination of SAR data products to the broadest possible spectrum of users. This activity expanded JPL's user base, distributed over 30,000 copies of an innovative educational CD-ROM to educators and others worldwide, created a world-class web site and helped stimulate advocacy for NASA to fund pre-Phase A LightSAR studies. Team won NASA's first ever group achievement award for Outreach.

Group Supervisor, JPL [1993-1995]: leader of a team responsible for SAR data calibration, SAR system design and applications. Team was the first to calibrate a multi-frequency polarimetric spaceborne SAR (SIR-C). Team was also first to propose using JERS-1 for basin-wide mapping of inundation in the Amazon to NASDA, which began in 1995. Group was funded at over \$2.5M per annum.

Group Leader, JPL [1988-1993]: lead a team responsible for system design, development and implementation of end-to-end calibration algorithms for airborne and spaceborne SAR systems. The team were the first to calibrate ERS-1 and JERS-1 SAR data, and NASA/JPL AIRSAR data.

Member of Technical Staff, JPL [1987-1988]: responsible for radar systems engineering and end-to-end calibration of the first polarimetric, multi-frequency NASA/JPL AIRSAR system and for the development of innovative calibration techniques for the NASA/JPL SIR-C radar.

GEC-Marconi Research Centre, UK [1982-1987]: researcher and team lead responsible for the development of novel algorithms for airborne SAR systems and in defining ERS-1 data quality.

Education:

University of Manchester, UK	B.Sc in Mathematics (Hons.)	1976-1979
University of Manchester, UK	Ph. D. in Astrophysics	1979-1982
Thesis topic: Chemical Equilibrium Models of Interstellar Gas Clouds		

Research: Current research interests address the next generation of SAR missions and include characterization of the ionosphere using SAR polarimetry, understanding of scattering from vegetation canopies, subsurface scattering characterization, SAR calibration and system design. Publications describe new scattering models for polarimetric SAR data, a new, lower-cost approach to SAR antenna design, and the discovery of a new temple and other archaeological features at the ancient Cambodian city of Angkor. Other career highlights as a researcher include:

- Co-investigator on a NASA radar sounder to map the base of the major ice sheets, funded by NASA
- A novel implementation of a wide-swath SAR using a reflector antenna (SweepSAR)
- Development of a novel algorithm for correction of Faraday rotation in polarimetric SAR data (the ‘Freeman method’)
- Several ground-breaking algorithms for polarimetric and radiometric SAR calibration
- Development of new approaches for modeling and analysis of multi-freq., polarimetric SAR data (including the ‘Freeman-Durden Decomposition’)
- Member of the AIRSAR, SIR-C and SMAP science teams
- First multi-season mapping of inundation over the entire Amazon Basin using SAR data in 1995/6
- Design of several innovative, lightweight, low-power SAR systems
- New approaches for MTI, motion compensation and geometric correction in airborne SAR data

Publications: has published over 40 refereed journal papers, 120 conference papers, and 2 book chapters on Synthetic Aperture Radar and related topics. Currently editing a book on next-generation SAR System concepts.

Teaching: - has organized and taught many remote sensing short courses to literally hundreds of engineers, scientists and managers over a 25-year period. Consistently ranked very highly in student evaluations, and placed in the top 10% of lecturers at UCLA Extension for 5 years. Currently teaching Systems Engineering for Caltech, and ASTE-553 – a graduate-level class on Remote Sensing Systems from Space at USC.

Awards: awarded the NASA Exceptional Service Medal for calibration of SIR-C mission data, several NASA Group Achievement Awards, numerous NASA new technology awards, and holder of 2 patents

Memberships: Fellow, IEEE (2000); Professional Member, Remote Sensing Society of Great Britain

Professional Activities:

Participant, Oceans 2025 National Academy Workshop, Irvine, CA, January 2009

Mission concept reviewer for JPL, ESA and CSA

Member, Technical Committee and Session Organizer for many IGARSS and SAR-related conferences

Chairman, the international CEOS SAR Calibration Working Group (1989-96)

Associate editor and reviewer for IEEE Transactions on Geoscience and Remote Sensing (GRS)

Chair of GRS technical committee on Data Standards and Distribution (1995)

Gave invited tutorials on SAR topics at IGARSS '98, '99 and '00.

Reviewer for several professional journals and Ph. D. Theses at several universities around the world

Other Interests: Soccer; running; reading history; hiking; travel

Publications:

Refereed Journal publications:

1. Lasne, Y.; Paillou, P.; Freeman, A.; Farr, T.; McDonald, K.C.; Ruffie, G.; Malezieux, J.-M.; Chapman, B.; Demontoux, F.; Effect of Salinity on the Dielectric Properties of Geological Materials: Implication for Soil Moisture Detection by Means of Radar Remote Sensing, *Geoscience and Remote Sensing, IEEE Transactions*, Vol. 46, Issue 6, pp. 1674 – 1688, June 2008
2. Freeman, A.; Response to “Corrections to ‘Calibration of Linearly Polarized Polarimetric SAR Data Subject to Faraday Rotation’”, *Geoscience and Remote Sensing, IEEE Transactions on*, Vol. 46, Issue 4, Part 2, pp. 1279 – 1279, April 2008
3. Freeman, A., Fitting a two-component scattering model to polarimetric SAR data from forests, *IEEE TGRS*, VOL. 45, NO. 8, pp. 2583-2292, August 2007
4. Jezek, K.C., E. Rodriguez, P. Gogineni, A. Freeman, J. Curlander, X. Wu, J. Paden, and C. Allen. Glaciers and Ice Sheet Mapping Orbiter Concept. *J. Geoph. Res – Planets, , J. Geophys. Res.*, 111, E06S20, doi:10.1029/2005JE002572, 2006.
5. Campbell, B.A., T. Maxwell, and A. Freeman, Mars orbital SAR: Obtaining geologic information from radar polarimetry, *J. Geophys. Res.*, 109, doi:10.1029/2004JE002264, 2004.
6. Lasne, Y., Paillou, P. Freeman, A. and Farr, T., A Phase Signature for Detecting Wet Subsurface Structures Using Polarimetric L-Band SAR, *IEEE TGRS*, VOL. 42, NO. 8, AUG. 2004.
7. Freeman, A., “Calibration of Linearly Polarized Polarimetric SAR Data Subject to Faraday Rotation,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. 42, no. 8, pp. 1617–1624, 2004. Gogineni
8. Freeman, A. and Saatchi, S., “On the Detection of Faraday Rotation in Linearly Polarized, L-Band SAR Backscatter Signatures”, *IEEE Transactions on Geoscience and Remote Sensing*, vol. 42, no. 8, pp. 1607–1616, 2004.
9. Jun Liu; Kuga, Y.; Ishimaru, A.; Xiaoqing Pi; Freeman, A.; Ionospheric effects on SAR imaging: a numerical study, *Geoscience and Remote Sensing, IEEE Transactions on*, Vol. 41, Issue 5, Part 1, pp. 939 – 947, May 2003
10. Siqueira, P., Hensley, S., Shaffer, S., Hess, L., McGarragh, G., Chapman, B., and Freeman, A., A Continental-Scale Mosaic of the Amazon Basin Using JERS-1 SAR, *IEEE Trans. on Geoscience and Remote Sensing*, Vol. 38, No. 6, pp. 2638-2644, Nov. 2000.
11. Rosenqvist A., Shimada M., Chapman B., Freeman A., De Grandi G.F., Saatchi S. and Rauste Y. "The Global Rain Forest Mapping project - A review". *International Journal of Remote Sensing*, Vol. 21, No. 6&7, pp. 1375-1387, 2000.
12. Freeman, A., Johnson, W. T. K., Jordan, R., Huneycutt, B., Hensley, S., Siqueira, P. and Curlander, J. C., “The Myth of the Minimum SAR Antenna Area Constraint”, *IEEE Trans. on Geoscience and Remote Sensing*, November 1999.
13. Freeman, A. and Durden, S., “A Three-Component Scattering Model for Polarimetric SAR Data”, *IEEE Trans. on Geoscience and Remote Sensing*, Vol. 36, No. 3, pp. 963-973, May 1998.
14. Moore, E. H. and Freeman, A., “Circular sites at Angkor: a radar scattering model”, *Journal of the Siam Society, Bangkok*, Vol 85, Parts 1 & 2 (1997), pp. 107-119, 1997

15. Freeman, A., Evans, D., and van Zyl, J. J., SAR Applications in the 21st Century, AEU - International Journal of Electronics and Communications, Vol. 50, pp. 79 - 84, March 1996.
16. Freeman, A., Cruz, J., Alves, M., Chapman, B., S. Shaffer and Turner, E., SIR-C Data Quality and Calibration Results, IEEE Trans. Geosci. Remote Sensing, vol. 33, no. 4, July 1995.
17. Sarabandi, K., L. Pierce, M.C. Dobson, F.T. Ulaby, J. Stiles, T.C. Chiu, R. De Roo, R. Hartikka, A. Zambetti, and A. Freeman, Polarimetric calibration of SIR-C using point and distributed targets, IEEE Trans. Geosci. Remote Sensing, vol. 33, no. 4, July 1995.
18. Shimada, M. and Freeman, A., A Technique for Measurement of Spaceborne SAR Antenna Patterns Using Distributed Targets, IEEE Transactions on Geoscience and Remote Sensing, Vol. 33, No. 1, pp. 100-114, January 1995.
19. Zink, M., Ottl, H., and Freeman, A., Design of a Monopulse SAR System for the Determination of Elevation Angles in SAR, IEEE Transactions on Geoscience and Remote Sensing, Vol. 32, No. 6, pp. 1198-1200, November 1994.
20. Sarabandi, K., Pierce, L.E., Oh, Y., Dobson, M.C., Ulaby, F.T., Freeman, A. and Dubois, P.C., Cross-calibration of JPL AIRSAR and truck-mounted polarimetric scatterometer, IEEE Transactions on Geoscience and Remote Sensing, Vol. 32, No. 5, pp. 975-985, September 1994.
21. Kwok, R., Rignot, E., Way, J., Freeman, A. and Holt, J., Polarization signatures of frozen and thawed forests of varying environmental state, IEEE Trans. on Geoscience and Remote Sensing, Vol. 32, No. 2, pp. 371-381, March 1994.
22. Freeman, A. Villasenor, J., Klein, J.D., Hoogeboom, P. and Groot, J.S., On the use of Multi-frequency and polarimetric radar backscatter features for classification of agricultural crops, International Journal of Remote Sensing, vol. 15, No. 9, pp. 1719-1812, 1994.
23. Freeman, A., An algorithm for estimating the noise levels in polarimetric SAR image data, International Journal of Remote Sensing, vol. 15, No. 9, pp. 1791-1798, 1994.
24. Freeman, A. and Zink, M., An Application of the Monopulse Principle to determining Elevation Angles in SAR images, IEEE Trans. on Geoscience and Remote Sensing, Vol. 32, No. 3, pp. 616-625, May 1994.
25. Zink, M., Olivier, P. and Freeman, A., Cross-calibration between Airborne SAR Sensors, IEEE Trans. on Geoscience and Remote Sensing, Vol. 31, No.1, pp. 237-245, January 1993.
26. Freeman, A., SAR Calibration: An Overview, IEEE Trans. on Geoscience and Remote Sensing, Vol. 30, No. 6, pp. 1107-1121, November 1992.
27. Freeman, A., van Zyl, J.J., Klein, J.D., Zebker, H.A. and Shen, Y., Calibration of Stokes and scattering matrix format polarimetric SAR data, IEEE Trans. on Geoscience and Remote Sensing, Vol. 30, No. 3, pp. 531-539, May 1992.
28. Freeman, A., A New System Model For Radar Polarimeters, IEEE Trans. on Geoscience and Remote Sensing, Vol. GE-29, No. 5, pp. 761-767, Sept. 1991.
29. Klein, J.D. and Freeman, A., Quadpolarization SAR Calibration Using Target Reciprocity, Journal of Electromagnetic Waves & Applications, Vol. 5, No. 7, pp. 735-751, 1991.
30. Freeman, A., Shen, Y. and Werner, C., Polarimetric Radar Calibration Experiment Using Active Radar Calibrations, IEEE Trans. on Geoscience and Remote Sensing, Vol. GE-28, No. 2, March 1990, pp. 224-240.
31. Sheen, D. R., Freeman, A. and Kasischke, E. S., Phase Calibration of Polarimetric Radar Images, IEEE Trans. on Geoscience and Remote Sensing, Vol. GE-27, November 1989, pp. 719-731.
32. Freeman, A. and Curlander, J. C., Radiometric Correction and Calibration of SAR Images, Photogrammetric Engineering & Remote Sensing, September 1989.

33. Blacknell, D., Freeman, A., Quegan, S., Ward, I.A., Finley, I.P., Oliver, C.J., White, R.G. and Wood, J.W., Geometric Accuracy in Airborne SAR images, IEEE Trans. on Aerospace and Electronic Systems, Vol. 25, No.2, pp. 241-258, March 1989.
34. Blacknell, D., Freeman, A., White, R.G. and Wood, J.W., The prediction of geometric distortion in airborne SAR imagery from autofocus measurements, IEEE Trans. on Geoscience and Remote Sensing, Vol. GE-25, No. 6, pp.775-782, Nov. 1987.
35. Freeman, A. and Currie, A.C., Synthetic Aperture Radar Images of Moving Targets, GEC Journal of Research, Vol. 5, No. 2, pp. 106-115, 1987.
36. Millar, T. J., Williams, D.A., Jones, A. P. and Freeman, A., Chemical Evolution in Local Interstellar Molecular Clouds, in 'Nearby Molecular Clouds', ed. G. Serra, publ. Springer-Verlag, Lecture Notes in Physics No. 237, 1984.
37. Nejad, L. A. , Millar, T. J. and Freeman, A., Chemical Modeling of Molecular Sources III: C₃H Formation in IRC+10216, M.N.R.A.S., vol 208, 1985.
38. Millar, T. J. and Freeman, A., Chemical Modeling of Molecular Sources II, M.N.R.A.S., vol 207, No. 2, pp. 425-432, 1984.
39. Millar, T. J. and Freeman, A., Chemical Modeling of Molecular Sources I: TMC-1, M.N.R.A.S., vol 207, No. 2, pp. 405-424, 1984.
40. Freeman, A. and Millar, T. J., The Formation of Complex Molecules in TMC-1, Nature., vol 301, No. 5899, pp. 402-4, 1983.
41. Freeman, A. and Williams, D.A., Vibrationally Excited Molecular Hydrogen in Circumstellar clouds and the Interstellar CH⁺ Abundance, Astrophys. and Sp. Sci., 83, 417, 1981

Articles submitted to refereed journals:

1. Freeman A., Raney R. K. and Jordan R. Improving Range Ambiguity Performance in Quad-pol SAR, accepted for publication in IEEE GRSL, April 2009.
2. Truong-Loi, ML., A. Freeman, P Dubois-Fernandez, Estimation of soil moisture and Faraday rotation from bare surfaces using Compact Polarimetry, submitted to IEEE GRSL in September 2008
3. Lasne, Y.; Paillou, P.; Freeman, A.; Farr, T.; McDonald, K.C.; Ruffie, G.; Malezieux, J.-M.; Chapman, B.; Study of Hyper-Saline Deposits and Analysis of their Signature in Airborne and Spaceborne SAR Data: Example of Death Valley, California, submitted to IEEE TGRS, Dec 2008.

Books/Book Chapters:

1. Freeman, A. and Rodriguez, E. (editors), SAR Systems of the 21st Century, textbook to be published by Artech House, 2010
2. Freeman, A., Calibration, SARs, in Encyclopedia of Remote Sensing, publ. Springer 2009
3. Moore, E., Freeman, A. and Hensley, S., Spaceborne and Airborne Radar at Angkor: Introducing New Technology to the Ancient site, in Remote Sensing in Archaeology, ed. Wiseman, J. and El-Baz, F., publ. Springer 2007.

Patents:

1. Synthetic Aperture Radar (technique for correcting geometric distortions in processed SAR images), Freeman et al, UK patent application no. I/7253/MRC, 1987.
2. Airborne SAR system for determining the topography of a terrain, Zink, M., Ottl, H. and Freeman, A., US Patent No. 5,489,907, February 6, 1996

Other contributions (selected):

1. Freeman A., V. Zlotnicki, T. Liu, L-L. Fu, B. Holt, R. Kwok, S. Yueh, I. Fukumori, J. Vazquez, D. Siegel, G. Lagerloef, White paper on “Ocean Measurements from Space in 2025”, National Academy Oceans 2025 workshop, Irvine, CA, January 2009.
2. NASA Earth Science and Applications from Space Strategic Roadmap: Exploring our Planet for the Benefit of Society, Strategic Roadmap Committee #9, May 2005 (<http://www.spaceref.com/news/viewstr.html?pid=16754>)
3. Freeman, A., Trimble, J., O’Leary, E., Erickson, K., Alves, M., Chapman, B. and Crandall, K., Seeing Earth in a New Way: The SIR-C Education Program Post-launch CD-ROM, Vol. SIRCED02, Jet Propulsion Laboratory, 1995.
4. Drinkwater, M. and Freeman, T., “A Brief History of Time”: A decade of the IGARSS Soccer Phenomenon, IEEE GRS Newsletter, Issue #108, Dec. 1998.

Conference papers/presentations (selected refereed or invited):

1. Freeman, A., G. Krieger, P. Rosen, Younis, M., W. T. K. Johnson, Huber, S., R. Jordan, and Moreira, A., SweepSAR: Beam-forming on Receive using a Reflector-Phased Array Feed Combination for Spaceborne SAR, to appear in Proc. Radarcon ’09, Pasadena, CA, May 2009.
2. Freeman, A., On the Design of Spaceborne Polarimetric SARs, to appear in Proc. Radarcon ’09, Pasadena, CA, May 2009.
3. Johnson, W. T. K., Rosen, P., Hensley, S., and Freeman, A., Radar Design for the DesdynI Mission, to appear in Proc. Radarcon ’09, Pasadena, CA, May 2009.
4. Jezek, K., Gogenini, P. Rodriguez, F., Hoch, A., Wu, X., Sonntag, J., Rodriguez, R, and Freeman, A., Global Ice Sheet Mapping Observatory: Airborne Experiments, to appear in Proc. Radarcon ’09, Pasadena, CA, May 2009.
5. Dubois-Fernandez, P., Freeman, A., Truong-Loi, M-L., Pottier, E., The conformity coefficient or how to explore the scattering behaviour from compact polarimetry mode, to appear in Proc. Radarcon ’09, Pasadena, CA, May 2009.
6. Lasne, Y.; Paillou, P.; Freeman, A.; Chapman, B.; SAR Imagery Applied to the Monitoring of Hyper-Saline Deposits: Death Valley Example (CA), to appear in Proc. Radarcon ’09, Pasadena, CA, May 2009.
7. Freeman, A., Pi, X. and Chapman, B., Calibration of PolSAR polarimetric data, Proc. PolinSAR 2009, Frascati, Italy, January 2009.
8. Freeman, A. et al, DESDynI – A NASA Mission for Ecosystems, Solid Earth, and Cryosphere Science, Proc. PolinSAR 2009, Frascati, Italy, January 2009.
9. Raney, R. K. and Freeman, A., Hybrid-Polarity SAR Architecture, Proc. PolinSAR 2009, Frascati, Italy, January 2009.
10. Dubois-Fernandez, P., Angelliaume, S., Truong-Loi, M-L., Freeman, A., Pottier, E., POLINSAR at Low Frequency and Ionospheric Effects, Proc. PolinSAR 2009, Frascati, Italy, January 2009.

11. Freeman, A., Dubois-Fernandez, P., and Truong-Loi, M., Soil moisture estimation from Compact Polarimetry – a viable alternative for SMAP, Proc. Microwave Land Hydrology Workshop, Oxnard, CA, <http://microwave-workshop.jpl.nasa.gov/Posters/>, October 2008.
12. Freeman, A., et al, Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI), Proc. EUSAR 2008, Friedrichshafen, Germany, June 2008
13. Freeman, A., Polarimetric radar scattering models and vegetation structure, presented at the NASA Vegetation 3-D Structure and Biomass Workshop, Charlottesville, Virginia, February 2008.
14. Freeman, A. "Faraday rotation and interferometric/polarimetric SAR - four years on," in Proceedings ASAR/CEOS Workshop. Vancouver, BC, Canada: Canadian Space Agency, 2007.
15. Freeman, A., K. Jezek, E. Rodríguez, P. Gogineni, J. Curlander, X. Wu, C. Allen, J., Ledford, J. Sonntag, W. Krabill, The Global Ice Sheet Mapping Orbiter (GISMO) – mission concept and instrument development, ACRAS Workshop, British Antarctic Survey, Cambridge, UK, May 2007.
16. Freeman, A., “Observing climate change from space”, Keynote address at the Hydrogen and Fuel Cells 2007: International Conference and Trade Show, Vancouver April 2007
17. Freeman, A. “International Polar Year,” presented at ASAR 2005 Workshop. Montreal, Canada: Canadian Space Agency, November 2005.
18. Freeman, A., “Earth science at JPL”, JPL Industry Day, Pasadena, California, April 18, 2006
19. Freeman, A., Hensley, S. & Moore, E. 1998. Radar imaging methodologies for archaeology: Angkor, Cambodia, Conference on Remote Sensing in Archaeology, Boston University Department of Archaeology and Remote Sensing Center, 11-19 April 1998.
20. Freeman, A., Chapman, B., Siqueira, P. and Holt, J., “Mapping Inundation in the Amazon - the JAMMS project”, Proc. IGARSS ‘98, Seattle, WA, July 1998.
21. Freeman, D. Evans and J. J. van Zyl, “SAR Applications in the 21st Century”, Proc. EUSAR ‘96, Konigswinter, Germany, pp. 25-30, March 1996
22. Freeman, E. Caro, R. Jordan, Y. Kim, J. Klein, Y. Lou, Y. Shen, S. Shaffer, C.Y. Chang and F. Stuhr, “Lessons learned from the first two SIR-C missions - an engineering perspective”, Proc. EUSAR ‘96, Konigswinter, Germany, pp. 37-40, March 1996
23. Freeman, A., Imaging Radar as a Mapping Tool, California Map Society Meeting, Jet Propulsion Laboratory, January 1996.
24. Freeman, A., The Role of Imaging Radar in Forest Management, Society of American Foresters Meeting, Portland, Maine, 1995.
25. Evans, D. and Freeman, A., Future Directions For Synthetic Aperture Radar, in Proceedings of "Land Satellite Information in the Next Decade" ASPRS Conference, Tyson's Corner, Virginia, September 1995