

Final project report

<i>Project ID</i>	2004/11.5
<i>Title</i>	Tecnologia per la Glaciologia in Antartide, progettazione e realizzazione di uno snowRADAR
<i>Principal investigator</i>	Achille Emanuele Zirizzotti
<i>Institution</i>	Istituto Nazionale di Geofisica e Vulcanologia Roma
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<i>Duration</i>	3 years
<i>Assigned funding</i>	170'000.00 Euro

Activities and results

The proposed project was the realization of a high resolution airborne RES "Radio Echo Sounding" system to investigate bedrock and isochronous horizons (internal layers) over a wide area of Antarctica. This radar allows establishing the variation of the rate of accumulation of ice on a large scale leading to a more accurate determination of the mass balance on Antarctica.

The proposed RADAR will add useful information to that obtained with the RES system in the past campaign, and will give useful information to the Glaciological scientific community.

The research priorities were:

- 1) the design and the planning of an airborne phase coded radar. The radar operate in the VHF-UHF frequency band and exploit the most advanced techniques of on-line elaboration of the echo signal.
- 2) The mechanical and electrical design of the antennas, installed under the wings of the airplane suitable for flight certification.
- 3) Realization, engineering and testing of the prototype of the system including antennas and its mechanical supports.
- 4) Final test of the complete system and getting certified for the flight.
- 5) First campaign of measurements.

The first three objective were achieved with the complete realization of the radar system in each components, in particularly: the design and realization of a bi-phase coded carrier generator (transmitter) with a programmable pulse repetition rate and pulse width. The radar works at two frequencies 150 MHz and 300 MHz with variable pulse length from 50ns to 2 μ s to achieve the adequate vertical resolution. The design and realization of several receivers for envelope and phase coded transmitted pulse. The demodulated envelope and quadrature components I and Q are compressed logarithmically before digitizing to maintain the necessary dynamic range. A special study was focused on the choice of the two wide bandwidth antennas (folded dipole with a gain of 6 dBi) that will be mounted under the wings of the aircraft. Besides the two channel 14 bit acquisition system sampling at 150MHz and allow the reconstruction of the phase changes due to the code for the following elaboration processes. The acquisition, elaboration, visualization and data storing program of the acquired radar traces, running in the acquisition computer of the Radar system, was realized in C language and directly drive the acquisition system. The program synchronize the radar trace with a GPS time marker for the radar traces localization. The airplane installation and certification for flight of the radar system were postponed due to the reduced Antarctica activities of Italian Antarctic project due to lack of funds.

However field test of the instrument were conducted on the Stelvio Alpine Glacier, and during the XXV Italian Antarctic Campaign 2009-2010. The radar was mounted on a Flex Mobile allowing ground based radar measurements. In particular in Antarctica the measurement were conducted close to the Epica drilling site at Concordia station. The scope of the survey was the realization of a high resolution bedrock map and electromagnetic stratigraphies of the internal layers of ice core. The designed airborne RES system with phase code radar exploit the most advanced techniques of on-line elaboration of the echo signal and lead to the request of an international patent in radar technique "Single Shot Complementary Code RADAR (SSCC RADAR) with QPSK modulation" " International Patent Application No PTC/EP2008/000480.

Products

A – papers in scientific magazines

1. Forieri Alessandro, Luisa Zucconi Alfredo Bini, Achille Zirizzotti, Frédérique Remy, Ignazio Ezio Tabacco "New bedrock map of Dome C, Antarctica, and morphostructural interpretation of the area ", *Annals of Glaciology*, Volume 39, 2004.
2. Frezzotti M., G. Bitelli, F. Coren, P. De Michelis, A. Deponti, A. Forieri, S. Gandolfi, V. Maggi, F. Mancini, F. Rémy, P. Sterzai, S. Urbini, L. Vittuari, A. Zirizzotti "Geophysical survey at Talos Dome (East Antarctica): the search for a deep new drilling site", *Annals of Glaciology*, Volume 39, p. 423, 2004.
3. I. E. Tabacco, P. Cianfarra, A. Forieri, F. Salvini, A. Zirizzotti (2006) "Physiography and tectonic setting of the subglacial lake district between Vostok and Belgica subglacial highlands (Antarctica) ", *Geophysical Journal International* 165 (3), 1029–1040 2006
4. Cafarella L., Urbini S., Bianchi C., Zirizzotti A., Tabacco I. E., Forieri A. (2005). "[Five subglacial lakes and one of Antarctica's thickest ice covers newly determined by Radio Echo Sounding over the Vostok-Dome C region.](#)" *Polar Research Letter*, 25(1), 69-73, 2006.
5. Urbini S., Cafarella L., Zirizzotti A., Bianchi C., Tabacco I. E., Frezzotti (2005). "Location of a new ice core site at Talos Dome (East Antarctica)", *Annals of Geophysics*, Vol. 49, n. 4-5 1133-1138 Aug 2006
6. E. Tabacco (2), C. Bianchi (1), J.B. Arokiasamy (1), L. Cafarella (1), U. Sciacca (1), A. Zirizzotti (1), E. Zuccheretti (1) "Italian RES investigation in Antarctica: the new radar system", *Terra Antarctica Rep.* 14/2008
7. P. Cianfarra, A. Forieri, F. Salvini, I. E. Tabacco, A. Zirizzotti "Geological setting of the Concordia Trench-Lake system in East Antarctica " *Geophysical Journal International* 2009 DOI: 10.1111/j.1365-246X.2009.04123.x. IF 2.112
8. Tabacco I. E., Cianfarra P., Forieri A., Salvini F., Zirizzotti A. "Physiography and tectonic setting of the subglacial lake district between Vostok and Belgica Subglacial Highlands (Antarctica)." *Geophysical Journal International Tectonics and Geodynamics* 2006, 165, 1029-1040. IF 2.112, All.2 Doc.1
9. Zirizzotti, A.; Baskaradas, J.A.; Bianchi, C.; Sciacca, U.; Tabacco, I.E.; Zuccheretti, E. "Glacio RADAR system and results" *Radar Conference, 2008. RADAR apos;08. IEEE Volume , Issue , 26-30 May 2008 Page(s):1 – 3 Digital Object Identifier 10.1109/RADAR.2008.472099*
10. Zirizzotti A., Cafarella L., Baskaradas J. A, Tabacco I. E., Urbini S., Mangialetti M., and Bianchi C., "Dry-wet bedrock interface detection by radio echo sounding measurements" *IEEE Transactions on Geoscience and Remote Sensing*, Volume 48, Issue 5 DOI:10.1109/TGRS.2009.2038900.

B – book chapters

1. [Zirizzotti, A.](#), [Urbini, S.](#), [Cafarella, L.](#), [Baskaradas, J. A.](#), "Radar systems for Glaciology" INTECH, 2010 Ch.9. ISBN 978-953-307-029-2.

C - proceedings of international conferences

1. [Forieri, A.](#); [Tabacco, I.](#); [della Vedova, A.](#); [Zirizzotti, A.](#); [de Michelis, P.](#) "Bedrock topography of Talos Dome and Frontier Mountain area", EGS - AGU - EUG Joint Assembly, Abstracts from the meeting held in Nice, France, 6 - 11 April 2003, abstract n.9951
2. [Frezzotti, M.](#); [Bitelli, G.](#); [de Michelis, P.](#); [Deponti, A.](#); [Forieri, A.](#); [Gandolfi, S.](#); [Maggi, V.](#); [Mancini, F.](#); [Rémy, F.](#); [Tabacco, I. E.](#); [Urbini, S.](#); [Vittuari, L.](#); Geophysical survey at Talos Dome East Antarctica: the search for a deep new drilling site", *Seventh International Symposium on Antarctic Glaciology, Annals of Glaciology*, vol. 39, p.423-432
3. A. Zirizzotti, C. Bianchi E. Tabacco, I. Fiorucci, M. Mangialetti, A. J. Baskaradas, A. Forieri, L. Cafarella, S. Urbini. "Sub-Ice Wet Surfaces and Lakes Observed in Dome C Area by Radio Echo Sounding System" *Geological and Geophysical investigations from the Transantarctic Mountains to Dome C* Genova 26 Settembre 2008.
4. A. Zirizzotti, C. Bianchi E. Tabacco, I. Fiorucci, M. Mangialetti, A. J. Baskaradas, A. Forieri, L. Cafarella, S. Urbini. "Sub-Ice Wet Surfaces and Lakes Observed in Dome C Area by Radio Echo Sounding System XXX SCAR Open science conference, 19 - 22 November 2008, St. Petersburg, Russia
5. M. Mangialetti A. Forieri, A. Zirizzotti, L. Cafarella, C. Bianchi, I.E: Tabacco, "Physical properties of the ice-bottom interface in DomeC area inferred from analysis of bottom radar echoes." *INTERNATIONAL SYMPOSIUM ON RADIOGLACIOLOGY AND ITS APPLICATIONS* Madrid, Spain 9–13 June 2008
6. A. Zirizzotti, J.A.Baskaradas, C. Bianchi, U. Sciacca, I. E. Tabacco and E. Zuccheretti, "Glacio RADAR system and results" *IEEE RadarCon2008 Rome*, 26-30 May 2008.
7. Zirizzotti A., Baskaradas J.A., Bianchi C., Sciacca U., Tabacco I.E., Zuccheretti E. "The Italian Radio Echo Sounding system : Improvement solutions.", P11B-0548 XXII AGU Fall Meeting S. Francisco 2007
8. Zirizzotti A., Arokiasamy J.B., Bianchi C., Cafarella L., Forieri A., Passerini A., Sciacca U., Tabacco I.E., Urbini S., Zuccheretti E. "The Italian Radio Echo Sounding investigation in Antarctica and last improvements of the RES system" *IUGG Perugia* 2007.
9. Urbini Stefano, Cesidio Bianchi, Lili Cafarella, Alessandro Forieri, Ignazio Ezio Tabacco, Achille Zirizzotti, Neal

Programma Nazionale di Ricerche in Antartide (PNRA)

- Young. "Results of the investigation on the Shackleton ice shelf area (Antarctica)" IUGG Perugia 2007.
10. Bianchi C., Cafarella L., De Michelis P., Tabacco I. E., Zirizzotti A., "Talus Dome (Antarctica) Radio Echo Sounding results". Open science conference, 26-28 July 04, Bremen.
 11. Zirizzotti A., Arokiasamy J.B., Bianchi C., Cafarella L., Forieri A., Passerini A., Sciacca U., Tabacco I.E., Urbini S., Zuccheretti E. "Italian Radio Echo sounding (RES) investigation in Antarctica" Open science conference, 26-28 July 04, Bremen.
 12. Forieri A., Zirizzotti A., Bianchi C., Passerini A. and Tabacco I.E.: "Database of Italian radar exploration (East Antarctica 1995-2003)" XXVIII SCAR Open science conference, 26-28 July 04, Bremen.
 13. Tabacco I E, Salvini F, Remy F, Cianfarra P, Zirizzotti A and Forieri A.: "Detection and characterization of subglacial lakes in Vincennes and Aurora Basins." XXVIII SCAR Open science conference, 26-28 July 04, Bremen.
 14. Baskaradas, J.A.; [Bianchi, C.](#); [Sciacca, U.](#); [Tutone, G.](#); [Zirizzotti, A.](#); [Zuccheretti, E.](#) "Modern Radar Techniques for Geophysical Applications: Two Examples ", Workshop on Radar Investigations of Planetary and Terrestrial Environments", February 7-10, 2005, Houston, Texas, abstract no.6006

D – proceedings of national meetings and conferences

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E – thematic maps

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F – patents, prototypes and data bases

1. Zirizzotti A. E., Bianchi C., Baskaradas, J.A., "Single Shot Complementary Code RADAR (SSCC RADAR) with QPSK modulation" International Patent Application No PTC/EP2008/000480.

G – exhibits, organization of conferences, editing and similar

H - formation (PhD thesis, research fellowships, etc.)

1. Alessandro Forieri "Elaborazioni dati radar"

Research unit

Zirizzotti Achille	Tecnologo	INGV
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Unit members:

Bianchi Cesidio	Dir. Tecnologo	INGV
Zuccheretti Enrico	Tecnologo	INGV
Sciacca Umberto	Tecnologo	INGV
Urbini Stefano	Tecnologo	INGV
Baskaradas J. Ariokasamy	Tecnologo	INGV
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Notes