

User antennas for internet everywhere via satellites

Abstract

Internet access everywhere is a fundamental need nowadays, and satellite systems play a specific role in all cases where terrestrial networks cannot offer a reliable connectivity. Efficient while low-cost terminals for users connected to satellites are compulsory, and this is finally one of the main condition for the viability of such systems. In the user terminal, its antenna front-end is the most critical sub-system, as in most cases it requires that a directive beam tracks one (or 2) satellite(s) over a very wide field-of-view, because either the user or the satellite is moving or even both simultaneously.

Trading the best solutions, building innovative efficient designs is a stringent challenge for antenna engineers. We will review designs based on electronic or mechanical steering, hybrid solutions (combining mechanical and electronic steering), and new concepts applied to these missions.

Graphical abstract



Recommended prerequisites

- Basic knowledge concerning Antenna properties
- Telecom link & Satellite communications basics (preferable, but not compulsory)

Learning objectives

- know the candidate antenna concepts for user terminals connecting to internet via satellites
- understand the severe constraints for such user antennas, and the main Pros/Cons of each antenna solution
- having discovered some innovative antenna designs able to meet the challenging requirements

Course outline

The short course will consist of slides presentations (alternating the 2 teachers), with the following content:

1/ Need for satellite systems enabling internet access anywhere in the world:

- where there is no efficient terrestrial network: small isolated, rural areas in most developed countries, and large ones in the 3rd world
- during long-travels in airplanes, high-speed trains, trucks, camping-cars ...

2/ Overview of various satellite systems enabling such ubiquitous internet access:

with few GEO* satellites, tens in MEO*, hundreds to thousands in LEO* ; present systems and those under-development ; in L, X, Ku, Ka bands ; comparing available overall throughput and constraints for the users.

3/ Technical challenges for User antenna front-end's connecting to such systems; they should combine high performances and low cost as consumer products:

- Simple but very cheap TX/RX front-end's for fixed users linked with GEO satellites
- Requiring to steer/scan their beam over a wide field-of-view for mobile users (on vehicles, aircrafts...); with added difficulty for most Ku-band systems, requiring linear polarisation alignment.
- Adding for users connected to MEO or LEO satellites, the need to switch instantaneously from one satellite of the constellation to another (handover).

4/ For each application (aeronautical, maritime, land-mobile), we will detail the various options for the antenna front-end:

- mechanical steering or full-electronic scanning
- hybrid antennas, combining mechanical steering over large angles, especially in azimuth, and electronic scanning within smaller angular domains, as in elevation and for fine tracking in both dimensions);
- innovative concepts: metamaterial-based, VICTS*, variably-biased liquid crystals, retro-directive antennas ...

We will present the best state-of-the-art worldwide:

- developments funded by ESA, and on-going in US (Thinkom, Kymeta ...) and Japan,
- addressing also briefly the technologies for amplifiers and control devices, part of the antenna front-end.

5/ We will conclude on the main trends, letting place to an open discussion between participants.

*GEO: Geostationary Earth Orbit, MEO: Medium Earth Orbit; LEO Low Earth Orbit; VICTS: Variably Inclined Continuous Transverse Stubs.

Instructor 1

Gerard CAILLE



➤ **Education**

- Ecole Polytechnique de Paris
- ENSEEIHT (Electronics & Telecom in Toulouse), microwave option

➤ **Industrial career**

(within Thomson, then Alcatel, then Thales companies, Space divisions):

- 1987-1994: design engineer for satellite active antennas
- 1995-98: Active Antennas group manager
- 1999-2014: TAS responsible for the Advanced Antennas Research, expert for Active Antennas.
- Retired from Thales in January 2015; now board member of SEE* Midi-Pyrenees, consultant on antenna design (short expertises for Thales Alenia Space, CNES etc) and expert for the Horizon Europe research program.

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➤ **Highlights**

- 1996-2001: Expert for SKYBRIDGE project (worldwide internet via LEO satellites), both for satellite antennas, and User terminal ones
- Crucial contribution to the design of STENTOR & ASAR active antennas
- Managed the Array Antennas activity within ACE (Antenna Centre of Excellence, 2002-2008)
- Author of a dozen of approved patents concerning antennas for Space systems, on-ground & on-board

➤ **Presentations in Conferences**

- Tutorial talks at JINAs (Journées Internationales de Nice sur les Antennes) from 1990 to 2004
- Responsible for Array Antenna sessions at EuCAP 2006-2007; oral presentations at most EuCAP conferences until 2014.
- "30 years of Agile Antennas design in Alcatel then Thales" 39th ESA Workshop on Reconfigurable Antennas, Oct. 2018

➤ **Teaching activities**

- Courses on Space Antennas in 2 engineer schools in Toulouse and in 3 adults training courses
- Conferences on 'internet via satellite' at XLIM (Limoges), ENSEEIHT (Toulouse) & *Rencontres Aérospatiales* (Toulouse), from 2015 to 2018.

*SEE: Société de l'Electricité, l'Electronique, des Techniques de l'Information et la Communication.

Instructor 2

Nelson J. G. Fonseca (Senior Member, IEEE) received the M.Eng. degree from Ecole Nationale Supérieure d'Electrotechnique, Electronique, Informatique, Hydraulique et Télécommunications (ENSEEIH), Toulouse, France, in 2003, the M.Sc. degree from the Ecole Polytechnique de Montreal, Quebec, Canada, also in 2003, and the PhD degree from Institut National Polytechnique de Toulouse – Université de Toulouse, France, in 2010, all in electrical engineering.



He currently works as an Antenna Engineer with the Antenna and Sub-Millimetre Waves Section, European Space Agency (ESA), Noordwijk, The Netherlands. Since November 2020, he has been holding an Honorary Appointment as Professional Fellow at the University of Technology Sydney (UTS), Ultimo, NSW. Australia. His current research interests include multiple beam antennas for space missions, beam-former theory and design, ground terminal antennas, transfer of technology to and from terrestrial systems, including 5G networks, and novel manufacturing techniques. He has authored or co-authored more than 270 papers in peer-reviewed journals and conferences and has over 50 patents issued or pending. Dr. Fonseca is serving as an Associate Editor for the IEEE Transactions on Antennas and Propagation and the IET Microwave, Antennas and Propagation, and as a Topic Editor for the IEEE Journal of Microwaves. He is also serving as Chair of the newly founded IEEE MTT-S Technical Committee 29 on Microwave Aerospace Systems. He is a board member of the European School of Antennas (ESoA) since January 2019 and is actively involved both as lecturer and as coordinator in courses related to space and ground antennas. He is the elected EurAAP Regional Delegate representing Benelux for the term 2021-2023. He received several prizes and awards, including the Best Young Engineer Paper Award at the 29th ESA Workshop on Antennas in 2007, an ESA Teamwork Excellence Award in 2020, multiple ESA Technical Improvement Awards, and the Best Applied Technology Antenna Paper Award at EuCAP 2022.

Key bibliography

- G. Caille : 'Internet par satellite partout dans le monde, y compris les avions, TGV...' ; Conférence du soir, ENSEEIH/SEE, Avril 2016
- G. Caille : 'Internet pour les passagers' ; Rencontres Aérospatiales, Toulouse Avril 2017
- N. J. G. Fonseca, P. de Maagt: "Satcom Ground, Segment Training: Terminal Antennas", Internal Training at the European Space Agency, 2016.
- H Zhou et al : "Evolution of Satellite Communication Antennas on Mobile Ground Terminals", Review article in International Journal of Antennas and Propagation, 2015.