Academic and Industrial Research Activities on RF and Microwaves in Latin America: An Overview

José E. Rayas-Sánchez and Zabdiel Brito-Brito

Department of Electronics, Systems, and Informatics, ITESO – The Jesuit University of Guadalajara
Tlaquepaque, Jalisco, 45604 Mexico
erayas@iteso.mx, zabdiel@iteso.mx

***Abstract* — In this paper, we present a comprehensive general view of the main academic and industrial research activities in the areas of RF and microwaves in Latin America. We provide a geographical perspective of the overall distribution of the main research and development clusters on RF and microwaves in this region. We make a summary of RF and microwave academic research in the following countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Nicaragua, Peru, Puerto Rico and Venezuela. Industrial research and development in RF and microwaves in Latin America is also briefly reviewed. We finalize by highlighting international research-funding programs currently available to support collaborations between Latin American institutions and those from other regions of the world, particularly with European countries.**

I. Introduction

In comparison with other technical fields, the areas of RF and microwave engineering and technology have traditionally required a very high level of specialization demanding solid academic formation in challenging subjects. Even though the high-frequency industrial sector is clearly expanding due to emerging new technologies, such as 5G and the internet of things (IoT) and space (IoS), the number of engineers working in these areas seems to be discordant with the above growing trend. For instance, the IEEE Microwave Theory and Techniques Society (MTT-S), perhaps the most influential professional and technical association worldwide in these fields, has experienced some small but steady decrease in membership since 2009 [1]. Naturally, most of the engineering, development, and research activities in RF and microwaves are currently realized in developed countries. All the above facts make clear the relevance of paying attention to geographical regions with high relative growth potential in this technical arena, such as Latin America [2]-[5]. Moreover, recent experiences [6], [7] seem to indicate that specific zones of Latin America have a great potential for accelerated growth in the areas of RF and microwaves, both in terms of new students' formation and industrial development, which in turn could enable a more harmonized economic development.

With the above motivation in mind, we present in this paper a comprehensive overview of the main academic and industrial research activities in RF and microwaves in Latin America. We first provide a geographical view of the general distribution of the main research and development clusters in RF and microwaves in this large geographical region. We next make a brief description of the most relevant RF and microwave academic research lines in the following countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Nicaragua, Peru, Puerto Rico, and Venezuela. Additionally, we briefly review the main industrial research and development in RF and microwaves in the region. Finally, we mention some international programs to support research collaborations between Latin America and other regions of the world, emphasizing those with European countries.

Fig. 1. Geographical distribution of main clusters of research activities in RF and microwaves in Latin America. Most relevant work in the field is realized in 7 countries (out of 26).

II. Geographical Distribution of RF and Microwave Development Poles in Latin America

Latin America encompasses an area of 19.2×10^6 km^2 with

TABLE I
LATIN AMERICAN COUNTRIES AND PRINCIPAL METROPOLITAN AREAS WITH OFFICIAL IEEE MTT-S CHAPTERS

Country	Main City	Chapter Name
Argentina	Buenos Aires	Argentina Section
Brazil	Belem	Centro-Norte Brasil Section
Brazil	Brasilia	Centro-Norte Brasili Section
Brazil	Rio de Janeiro	Rio de Janeiro Section
Brazil	Sao Paulo	South Brazil Section
Mexico	Guadalajara	Guadalajara Section
Mexico	Mexico City	Mexico Section
Mexico	Puebla	Puebla Student Chapter (BUAP)
Peru	Arequipa/Lima	Peru Section
Venezuela	Caracas	Venezuela Section

26 countries (20 sovereign states) and more than 626×10^6 inhabitants. However, most of the advanced engineering and industrial development is concentrated in less than half of those countries. A geographical perspective of the overall distribution of the main research and development clusters on RF and microwaves in Latin America is shown in Fig. 1. A more detailed view of their specific geographical distribution in Mexico is in [8]. It is seen that most relevant activities are allocated in 7 countries.

Another indicator of the level of activities and maturity in RF and microwaves in Latin America consists of the availability of IEEE MTT-S Chapters in the region. Table I shows the Latin American countries and main metropolitan areas with official IEEE MTT-S Chapters (some of them joint chapters). A total of 10 chapters have been officially formed, distributed in 5 countries.

III. RF AND MICROWAVE ACADEMIC RESEARCH

A. Argentina

Main research efforts in Argentina have been realized at the following organizations: Institute of Astronomy and Space Physics, National Technological University, National University of La Plata, National Commission of Space Activities. Principal topics are focused mainly on sensors, devices, filters, and radiometers [4], [9], [10].

B. Brazil

Most RF and microwave research is realized in the following institutions: University of Sao Paulo, National Institute for Space Research, Federal University of Rio Grande do Norte, Nuclear and Energy Research Institute, University of Campinas, Federal University of Santa Catarina, National Institute of Telecommunications, University of Brasilia, Federal University of Minas Gerais, Pontifical Catholic University of Rio, and Federal University of Parana. The research scope is quite broad, including antennas, power amplifiers, CAD techniques, EM field analysis, and photonic technologies [11]-[14]. Brazil organizes the International Microwave and Optoelectronics Conference (IMOC).

C. Chile

Most Chilean universities work primarily in topics related to remote sensing, antennas and propagation, and mobile radio communications. Those involved in microwave research are: University of Chile, Pontifical Catholic University of Chile, and Technical University of Federico Santa Maria [15]-[17].

D. Colombia

The National University of Colombia, the University of the Quindío, and the Pedagogical and Technological University of Colombia are the main universities involve in RF and microwave research. Antennas and propagation, filters, and power amplifier are the major research topics [18]-[20].

E. Mexico

Main research activities in RF and microwaves is realized at the *Centro de Investigación Científica y de Educación Superior de Ensenada* (CICESE) in Baja California; the *Instituto Nacional de Astrofísica, Óptica y Electrónica* (INAOE) in Puebla; the *Centro de Investigación y Estudios Avanzados* (CINVESTAV) in Guadalajara and Mexico City; the National Polytechnic Institute (ESIME-Zacatenco-IPN) in Mexico City; and at ITESO—The Jesuit University of Guadalajara. The main research areas include microwave devices, power amplifiers, CAD techniques, signal integrity and high-speed interconnect modeling [6], [21]-[23].

F. Peru

Main research has been done at Pontifical Catholic University of Peru, Catholic University San Pablo-Arequipa, and University of La Salle-Arequipa. It focuses in power amplifiers and microwave transistor modeling [24]- [26].

G. Puerto Rico

The research activities in RF and microwave are done essentially at the University of Puerto Rico at Mayagüez (UPRM), mostly in antennas and radar systems [27].

H. Costa Rica, Nicaragua, Ecuador, and Venezuela

Costa Rica, Ecuador, and Nicaragua have presented a research work for the IEEE SIGHT initiative, applying RF and microwaves to humanitarian problems [28], [29]. Ecuador is making research using microwave sensors [30] and links [31] related to rain process. Venezuela is making research in microwave devices at the Simon Bolivar University [32].

IV. INDUSTRIAL RESEARCH AND DEVELOPMENT

Industrial research and development in areas of high-frequency electronics, RF and microwave engineering is mainly realized by transnational companies in Latin America. However, the great majority of the engineers, researchers, and scientists hired by these companies are from Latin America, mainly from the local country.

Perhaps the most emblematic case in Latin America of a

high-tech company performing large volumes of advanced engineering (especially in electrical and EM validation of high-speed platforms), development, and research in RF and microwaves is Intel Guadalajara [33]-[35], which includes formal research facilities (Intel Labs Guadalajara). Some of this research is performed in collaboration with Mexican universities and research centers [36]-[43].

Continental Automotive is another prominent industrial case of advanced engineering, development, and research in RF and microwaves in Latin America [44], with operations in Guadalajara, Mexico (with 3 large industrial plants, one of them hosting an official research and development center), as well as in Sao Paulo, Brazil.

Other transnational companies that perform RF and microwave engineering in Latin America are: Nokia, with operations in Mexico City and Sao Paulo, Brazil, and NXP Semiconductors, with operations in Campinas, Brazil, and Guadalajara, Mexico.

Latin America has not been able to create a large amount of Latin American high-tech companies in these technical fields; just a few examples exist. For instance, Mixbaal [45], established in Guadalajara, Mexico, which designs and produces microwave radios for digital links, and Cormat [46],[47], established in Zapopan (Guadalajara), Mexico, which designs and produces RF electrotherapy equipment.

V. International Programs for Research Collaborations with Latin American Countries

A review of specific cases of research collaborations in RF and microwaves between Latin American institutions and those from other countries is in [48]. Here we describe international programs to support this kind of collaborations.

A. Horizon 2020

The European Community Horizon 2020 Programme [49], the largest European initiative for research and innovation, includes several topics that strongly encourage or require cooperation with non-EU partners in collaborative projects, targeting a specific country or region.

B. Erasmus+

This program aims "to support actions in the fields of Education, Training, Youth and Sport for the period 2014-2020" [50]. It considers a strong international dimension in the field of higher education (institutional cooperation and mobility). It is managed by the European Commission.

C. Iberoamerican Science and Technology Education Consortium (ISTEC)

ISTEC is a non-profit organization supporting science and technology in Latin America to improve local standards of living [51]. It facilitates collaborations (research projects, library interchange, advanced continuing education, and entrepreneurship) between Latin American academic institutions and research centers with industries and educational/research organizations in developed countries (mainly United States, Canada, Spain, and Portugal).

D. Specific National Programs

Many countries offer specific programs to support international research collaborations, for instance, the international programs of the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) [52]; the British Council Newton Fund [53]; the *Asociación Universitaria Iberoamericana de Posgrado* (AUIP) [54]; among others.

VI. Conclusion

A global summary of the main academic and industrial research activities in RF and microwaves in Latin America was realized in this article. We show a geographical perspective of the research and development clusters working on these technical fields. A summary of academic research by main country is provided. Industrial research and development is also considered. We finally mentioned international programs to support research collaborations with Latin American institutions.

References

[1] K. Wu, "President's column: reenergizing MTT-S membership," *IEEE Microw. Mag.*, vol. 17, no. 3, pp. 8-10, Mar. 2016.

[2] L. Rodríguez, M. Huerta, R. Alvizu, and R. Clotet, "Overview of RFID technology in Latin America," in *Andean Region Int. Conf.*, Cuenca, Ecuador, Nov. 2012, pp. 109-112.

[3] C. Tremola, M. A. Azpurua, E. Javier Paez, and G. Moruga, "Electromagnetic compatibility in Latin America - a technological and regulatory perspective," *IEEE Latin America Trans.*, vol. 11, no. 6, pp. 1307-1317, Dec. 2013.

[4] R. Murphy, R. Torres, J. E. Rayas-Sánchez, A. Reynoso, M. Maya-Sánchez, A. Henze, A. Zozaya, P. del Pino, J. Pena, and G. Rafael-Valdivia, "R&D in Latin America: RF and microwave research in Latin America," *IEEE Microw. Mag.*, vol. 15, no. 3, pp. 97-103, May 2014.

[5] R. Murphy, "A bird's-eye view of microwave R&D in Latin America," in *IEEE MTT-S Int. Microw. Symp. Dig.*, Phoenix, AZ, May 2015, pp. 1-3.

[6] J. E. Rayas-Sánchez, D. Pasquet, B. Szendrenyi, and M. S. Gupta, "MTT-S Mexico trip: addressing the RF and microwave community in Mexico," *IEEE Microw. Mag.*, vol. 16, no. 7, pp. 104-107, Aug. 2015.

[7] J. E. Rayas-Sánchez and G. E. Ponchak, "Conference report: first IEEE MTT-S Latin America microwave conference (LAMC-2016)," *IEEE Microw. Mag.*, vol. 18, no. ?, pp. ?-?, 2017 (accepted).

[8] R. Murphy and R. Torres, "MTT world: microwave engineering in Mexico," *IEEE Microw. Mag.*, vol. 11, no. 6, pp. 152–148, Oct. 2010.

[9] A. J. Venere, M. Hurtado, R. Lopez La Valle, and C. H. Muravchik, "New design of a variable impedance based on polarized diodes at microwave frequency," *IEEE Microw. Wireless Comp. Letters*, vol. 27, no. 5, pp. 470-472, May. 2017.

[10] S. Redzwan, N. B. Asan, J. Velander, D. Lee, M. D. Perez, M. Raaben, T. J. Blokhuis, and R. Augustine, "Frequency domain analysis of hip fracture using microwave split ring resonator sensor on phantom model," in *IEEE Asia-Pacific Conf. Applied Electromag. (APACE-2016)*, Langkawi, Malaysia, Dec. 2016, pp. 244-247.

[11] P. J. Castro, J. J. Barroso, J. P. L. Neto, and A. Tomaz, "Microwave propagation experiments on a gradient array of split-ring resonators," in *SBMO/IEEE MTT-S Int. Microw. Optoelectronics Conf. (IMOC-2013)*, Rio de Janeiro, Brazil, Oct. 2013, pp. 1-5.

[12] A. Cerqueira Sodre; N. Cañas-Estrada; D. F. Noque; R. M. Borges; S. A. S. Melo; N. G. Gonzalez; J. C. R. F. Oliveira, "Photonic-assisted microwave amplification using four-wave mixing," *IET Optoelectronics*,

vol. 10, no. 5, pp. 163-168, Oct. 2016.
[13] P. F. Maccarini, A. Shah, S. Y. Palani, D. V. Pearce, M. Vardhan, P. R. Stauffer, D. B. Rodrigues, S. Salahi, T. R. Oliveira, D. Reudink, and B. W. Snow, "A novel compact microwave radiometric sensor to noninvasively track deep tissue thermal profiles," in *2015 European Microw. Conf. (EuMC)*, Paris, France, Dec. 2015, pp. 690-693.
[14] R. A. Santos, A. C. Sodré and S. E. Barbin, "A low-profile printed antenna for UWB applications," in *Int. Conf. Electromagnetics Advanced Applic.* (ICEAA-2016), Cairns, Australia, 2016, pp. 905-908.
[15] M. Derpich and R. Feick, "On the second order power spectral statistics of wideband indoor microwave channels," in *IEEE Int. Symp. Personal Indoor Mobile Radio Comm.*, Istanbul, Turkey, Sep. 2010, pp. 335-340.
[16] A. Santamaria-Artigas, C. Mattar, and J. P. Wigneron, "Application of a combined optical-passive microwave method to retrieve soil moisture at regional scale over Chile," *IEEE J. Selected Topics Applied Earth Observations Remote Sensing*, vol. 9, no. 4, pp. 1493-1504, Jan. 2016.
[17] P. B. A. Fechine, H. H. B. Rocha, R. S. T. Moretzsohn, J. C. Denardin, R. Lavin, A. S. B. Sombra, "Study of a microwave ferrite resonator antenna based on a ferromagnetic composite," *IET Microw. Antennas Propag.*, vol. 3, no. 8, pp. 1191-1198, Dec. 2009.
[18] S. Bernal, F. Vega, F. Roman, and A. Valero, "A high-gain broad-wall slotted waveguide antenna array to be used as part of a narrowband high power microwaves system," in *Int. Conf. on Electromag. Advanced Applications (ICEAA-2015)*, Turin, Italy, Sep. 2015, pp. 618-621.
[19] R. Quaglia, V. Camarchia, M. Pirola, J. J. M. Rubio, and G. Ghione, "Linear GaN MMIC combined power amplifiers for 7-GHz microwave backhaul," *IEEE Trans. Microw. Theory Techn.*, vol. 62, pp. 2700-2710, 2014.
[20] S. J. Florez, "Multiband filters with elliptical and Gaussian dielectric resonators planar in microwave," in *IEEE Colombian Workshop Circ. Syst. (CWCAS-2012)*, Barranquilla, Colombia, Nov. 2012, pp. 1-6.
[21] A. Morales-Diaz, C. Gutierrez-Martínez, J. A. Torres-Fórtiz, J. M. Pérez, B. E. Méndez, and J. S. G. Romero, "Developing high-frequency electronics in Mexico: design and realization of microwave generators for potential applications on terrestrial and satellite radio link," in *IEEE ANDESCON*, Cochabamba, Bolivia, Oct. 2014, pp. 1-1.
[22] J. R. Loo-Yau, P. Moreno, J. A. Reynoso-Hernández, and M. C. Maya-Sanchez, "Microwaves research collaboration between Cinvestav-GDL and CICESE, two research centers in Mexico," in *IEEE MTT-S Int. Microw. Symp. Dig.*, Tampa, FL, Jun. 2014, pp. 1-4.
[23] J. E. Rayas-Sánchez and Z. Brito-Brito, "Research activities on computer-aided modeling, design and optimization of RF and microwave circuits at ITESO Mexico" in *IEEE MTT-S Int. Microw. Symp. Dig.*, Tampa, FL, Jun. 2014, pp. 1-3.
[24] Z. A. Khan, E. Zenteno, P. Händel, and M. Isaksson, "Digital predistortion for joint mitigation of I/Q imbalance and MIMO power amplifier distortion," *IEEE Trans. Microw. Theory Techn.*, vol. 65, pp. 322-333, 2017.
[25] G. Rafael-Valdivia and Z. Su, "Non-linear modeling for low and high power microwave transistors," in *2016 46th European Microw. Conf. (EuMC)*, London, UK, Oct. 2016, pp. 847-850.
[26] M. A. Martinez and M. A. Yarleque, "Gossip-based transmission algorithms performance in wireless sensor networks (WSN)," in *IEEE Int. Conf. Microw. Comm. Antennas and Electronic Syst. (COMCAS 2013)*, Tel Aviv, Israel, Oct. 2013, pp. 1-5.
[27] R. A. Rodriguez-Solis, J. G. Colom-Ustariz, S. Cruz-Pol, and L. Leon-Colon, "Microwave research at the University of Puerto Rico at Mayaguez" in *IEEE MTT-S Int. Microw. Symp. Dig.*, Tampa, FL, Jun. 2014, pp. 1-3.
[28] J. Jadan-Guerrero, L. A. Guerrero, and T. Sharma, "Improving the interaction of Down syndrome students through the use of RFID technology," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Puerto Vallarta, Mexico, Dec. 2016, pp. 1-4.
[29] J. C. C. Icabalzeta, G. E. D. Fernandez, and M. R. Arias, "Evaluation of non-ionizing radiation emitted by FM broadcasting and free-to-air TV systems in the municipality of El Crucero, Managua," in *IEEE Global Humanitarian Tech. Conf. (GHTC-2016)*, Seattle, WA, USA, Oct. 2016, pp. 731-737.
[30] E. A. Munoz, F. Di Paola, M. Lanfri, and F. J. Arteaga, "Observing the troposphere through the advanced technology microwave sensor (ATMS) to retrieve rain rate," *IEEE Latin America Trans.*, vol. 14, no. 2, 2016.
[31] B. Ramos, M. D'Amico, J. Santos, I. Nolivos, A. Manzoni, R. Ponguillo, J. Gámez, and T. Chavez, "Measuring rain with microwave links: A pilot experiment in Ecuador," in *IEEE-APS Topical Conf. Antennas Propag. Wireless Comm. (APWC-2015)*, Turin, Italy, Sep. 2015, pp. 171-174.
[32] A. Sucre-Gonzalez, F. Zarate-Rincon, A. Ortiz-Conde, R. Torres-Torres, F. J. Garcia-Sanchez, J. Muci, and R. S. Murphy-Arteaga, "A DC method to extract mobility degradation and series resistance of multifinger microwave MOSFETs," *IEEE Trans. Electron Dev.*, vol. 63, no. 5, pp. 1821-1826, May 2016.
[33] J. R. Camacho-Perez et al., "Intel Labs Mexico - Leading Industrial Research in Latin America," in *IEEE MTT-S Int. Microw. Symp. Dig.*, Tampa, FL, Jun. 2014, pp. 1-3.
[34] R. Astro and C. Franco, "Modeling linear VR for DDR4 termination scheme of ADDR/CMD/CTRL signals," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Pto. Vallarta, Mexico, Dec. 2016, pp. 1-3.
[35] D. M. Garcia-Mora, D. Garcia-Garcia, F. Yahyaei-Moayyed, J. C. Cinco-Galicia, C. R. Sanchez-Ortiz, and C. A. Sala, "Filter design methodology for low noise power domains in datacenter platforms," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Puerto Vallarta, Mexico, Dec. 2016, pp. 1-3.
[36] F. Rangel-Patino, A. Viveros-Wacher, J. E. Rayas-Sánchez, E. A. Vega-Ochoa, I. Duron-Rosales, and N. Hakim, "A holistic methodology for system margining and jitter tolerance optimization in post-silicon validation," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Puerto Vallarta, Mexico, Dec. 2016, pp. 1-4.
[37] A. Viveros-Wacher and J. E. Rayas-Sánchez, "Eye diagram optimization based on design of experiments (DoE) to accelerate industrial testing of high speed links," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Puerto Vallarta, Mexico, Dec. 2016, pp. 1-3.
[38] F. Leal-Romo, J. E. Rayas-Sánchez, and J. He, "Design of experiments implementation towards optimization of power distribution networks," in *IEEE Latin American Symp. Circuits and Systems Dig. (LASCAS 2017)*, Bariloche, Argentina, Feb. 2017, pp. 1-4.
[39] F. Rangel-Patino, J. L. Chávez-Hurtado, A. Viveros-Wacher, J. E. Rayas-Sánchez, and N. Hakim, "Eye diagram system margining surrogate-based optimization in a server silicon validation platform," in *European Microw. Conf. (EuMC-2017)*, Nuremberg, Germany, Oct. 2017, pp. 1-4.
[40] J. C. Cervantes-González, J. E. Rayas-Sánchez, C. A. López, J. R. Camacho-Pérez, Z. Brito-Brito, and J. L. Chavez-Hurtado, "Space mapping optimization of handset antennas considering EM effects of mobile phone components and human body," *Int. J. RF and Microw. CAE*, vol. 26, no. 2, pp. 121-128, Feb. 2016.
[41] F. E. Rangel-Patiño, J. L. Chávez-Hurtado, A. Viveros-Wacher, J. E. Rayas-Sánchez and N. Hakim, "System margining surrogate-based optimization in post-silicon validation," *IEEE Trans. Microw. Theory Techn.*, vol. 65, 2017 (accepted).
[42] D. M. Cortés-Hernández, J. Sánchez-Mesa, B. Galvez-Sahagun, and R. Torres-Torres, "Characterizing printed transmission lines from calculated frequency-dependent resistance and inductance and experimental propagation constant," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Puerto Vallarta, Mexico, Dec. 2016, pp. 1-4.
[43] R. R. Carlos, J. L. Naredo, R. P. Michel, and O. Longoria, "A high-speed interconnect model in s-domain," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Pto. Vallarta, Mexico, Dec. 2016, pp. 1-4.
[44] J. R. del-Rey, Z. Brito-Brito, J. E. Rayas-Sánchez, and N. Izquierdo, "Temperature effects in automotive-grade high speed interconnects," in *IEEE MTT-S Latin America Microw. Conf. (LAMC-2016)*, Puerto Vallarta, Mexico, Dec. 2016, pp. 1-4.
[45] Mixbaal, http://mixbaal.com/.
[46] Cormat, http://www.cormat.mx/.
[47] A. Corres-Matamoros, E. Martínez-Guerrero, and J. E. Rayas-Sánchez, "A programmable CMOS voltage controlled ring oscillator for radio-frequency diathermy on-chip circuit," in *Int. Caribbean Conf. Dev. Cir. Syst. (ICCDCS-2017)*, Cozumel, Mexico, Jun. 2017, pp. 1-4 (accepted).
[48] R. S. Murphy and R. Torres-Torres, "An overview of RF and microwave engineering research collaboration between Latin America and the rest of the world," in *European Microw. Conf. (EuMC-2016)*, London, UK, Oct. 2016, pp. 843-846.
[49] Horizon 2020, https://ec.europa.eu/programmes/horizon2020/en
[50] Erasmus+, http://eacea.ec.europa.eu/erasmus-plus_en.
[51] ISTEC, http://www.istec.org/.
[52] DFG, http://www.dfg.de/en/index.jsp.
[53] Newton Fund, https://www.britishcouncil.org/education/science/newton.
[54] AUIP, http://www.auip.org/es/.