Periodic Reporting for period 1 - SIW-SAT-ANTENNAS
(Circularly Polarized Antenna Arrays for Broadband Satellite Data Terminals Using Substrate Integrated Waveguides enhanced with Metamaterials)

Okres sprawozdawczy: 2015-06-16 do 2017-06-15

Podsumowanie kontekstu i ogólnych celów projektu

Mobile Satellite communications hold the promise that can fulfil the Digital Agenda 2020 objective for fast Internet everywhere by providing broadband communications regardless of the place and location.
The advent of mobile devices such as smartphones and tablets along with multimedia content continue to push technology forward. There are major efforts in launching new satellite systems in addition to existing ones that offer fixed satellite services. There is also a strong European interest area considering the Galileo system and the European Space Agency work on broadband global access networks. European regulators have recently agreed to harmonize the spectrum for Earth Stations on Mobile Platforms that will use parts of the Ka-Band. Mobile or transportable terminals require an antenna solution. Existing antenna choices come mostly in the form of reflector dishes. The use of compact, flat and lightweight antennas is a major facilitator for the adoption of such terminals.

The project addresses the problem of antennas and related components that are required for the mobile terminals which can operate in the millimeter wave bands. Furthermore, printed antennas at these frequencies can also be utilized for future research opportunities on other emergent millimeter wave applications such as 5G, gigabit Wifi, wireless energy harvesting. In this context, the major research objective is to develop printed antenna elements and arrays that can provide 1GHz bandwidth for the transmitter uplink (29-30 GHz) and 1GHz for the receiver downlink (19-20 GHz). It is proposed that Circular Polarization is to be used due to reduced losses for the signal propagation up to the satellite. The antennas are to be developed in Substrate Integrated Waveguide (SIW).

Complementary circuit components are investigated; waveguide transitions, power splitters and duplexers that constitute the feeding network. An additional objective, with interdisciplinary character, is the application of artificial intelligence algorithms to antenna design.

An important objective of the program is also the development of research management skills, supervisory skills and building collaborations with other research groups so that the fellow can arrive at a leading independent position.

In conclusion, new low cost and lightweight antennas and arrays have been produced that operate in two millimeter wave bands. These arrays, comprised of 16 elements, can form the basis for mobile terminals’ antennas.

A second contribution is the transfer of antennas designs to the field of energy harvesting. Furthermore, due to the background of the fellow, several activities have disseminated regulatory and standards knowledge in the research community. Work was also done towards the interdisciplinary application of a class of a new algorithms called evolutionary algorithms which were applied to printed antennas that can operate in millimeter waves.

In addition, the fellow was trained in research proposal writing and develop supervisory skills by having three students.

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Prace wykonane od początku projektu do końca okresu sprawozdawczego oraz najważniejsze dotychczasowe rezultaty

In Work Package (WP) 1, an antenna specifications study and updated literature survey including commercial products was produced.

In WP2, an antenna element comprised by two printed inclined slots was developed as the basic array unit.

In WP3, feeding network circuit elements were developed. Most notably, a novel SIW duplexer was able to separate 20GHz and 30 GHz signals with 1GHz bandwidth at each band.

In WP4, linear subarrays composed of four elements were implemented using WP2 and WP3 components.
Furthermore, the consequences of using a linear slot array in conformal geometries for a Multiple Input Multiple Output configuration were investigated. In WP5, a large interlaved subarray of 16 elements was developed. The design provides great flexibility and can be used as a building block for future work.

WP7 was about training activities. A Career Development plan (CDP) has been laid out in the first month to align the activities. Transferable skills developed are a) Research proposal writing (six national and European) b) Supervision of three students c) Networking in the academic world and companies (participation in 8 events and contacts with satellite operators).

Moreover, the researcher has attended seminars organized by the host institution, the IEEE and EU IPR Helpdesk Seminars on Intellectual Property issues.

WP8 was about dissemination and Outreach Activities. Out of this project, 21 publications have been produced or journals in the field and two major conferences were attended (EuCAP, PIMRC) where papers were presented.

The ITU Workshop on satellite communications offered an excellent opportunity to liaise with satellite communications operators. The researcher also presented to students during the Science Week outreach event in Catalunya a demonstration on antennas for mobile phone antennas utilizing an anechoic chamber. A website was developed in the end of year 1.

A liaison workshop was co-organized by the researcher in conjunction with the Marie Curie RISE program, EMERGENT. Two invited talks were presented on regulatory and standards aspects of sensors.

In WP9 (Management) two periodic reports were produced. The budget was allocated for online training, conferences and workshops and procurement of materials for fabrication and measurements.

The project has produced results beyond the state of the art that have been submitted in peer reviewed publications.

- **Antenna Elements in SIW for dual band operation**
  
The slot antenna element was designed for 20GHz and 30 GHz with the flexibility of producing both Right and Left Hand polarization. These results formed the basis of two conference contributions. Based on the design approach, these elements can be redesigned for operation at 60GHz for gigabit Wifi or 73 GHz for 5G.

  Apart from slot antennas, a SIW dual band antenna has been developed.

  - A SIW duplexer has been developed that forms the basic feeding component of the proposed interleaved antenna array
  - A SIW Interleaved Array design for K and Ka Band was realized with 16 pairs of antennas elements by exploiting the antenna element developed and the diplexer.
  - A new correlation coefficient was introduced that allows efficient introduction of slot antennas conformed in any curved which can find application in MIMO systems for WiGig and 5G.
  - Contributions to antennas design using computational intelligence by the application of evolutionary algorithms (EA) on the optimization of printed antenna designs and on the antenna selection problem.

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Innowacyjność oraz oczekiwany potencjalny wpływ (w tym dotychczasowe znaczenie społeczno-gospodarcze i szersze implikacje społeczne projektu)

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in multielement antennas.
• Contributions to antennas for wireless energy harvesting by characterizing experimentally slot antennas. Moreover, the possibility of harvesting energy from FM radio and mobile telephony was also characterized in the laboratory.
• A synthetic work has been produced that covered the regulations and standards in the field wireless power transfer.
Overall, the project has produced innovative antennas and a feeding network component which can be scaled and used as building blocks in emerging applications. The developed components are low cost, planar and lightweight.
Furthermore, a new correlation coefficient was proposed that opens the way for the use of slot antennas in MIMO conformal antennas.
In addition, contributions to interdisciplinary applications of evolutionary algorithms to antenna designs have been presented.
8 element SIW antenna subarray for 30 GHz

2x4 SIW antenna subarray for 20GHz
Duplexer realized in Substrate Integrated Waveguide Technology that operates at 20GHz and 30 GHz
4 element SIW antenna subarray for 20 GHz with excitation controlled polarization

Interleaved 2x8 antenna array for 20/30GHz realized in SIW technology

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