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<th>N° PROYECTO</th>
<th>1095018</th>
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<td>TÍTULO PROYECTO</td>
<td>STUDY OF MIMO AND &quot;NETWORK MIMO&quot; COMMUNICATION SYSTEMS: CHANNEL MODELING, EFFICIENT ANTENNA ARRAYS AND MODULATION/CODING</td>
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<td>INVESTIGADOR(A) RESPONSABLE</td>
<td>RODOLFO JUAN FEICK LAUDIEN</td>
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<tr>
<td>CIUDAD</td>
<td>VINA DEL MAR</td>
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<td>REGIÓN</td>
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### OBJETIVOS

Cumplimiento de los Objetivos planteados en la etapa final, o pendientes de cumplir. Recuerde que en esta sección debe referirse a objetivos desarrollados, NO listar actividades desarrolladas.

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<th>N°</th>
<th>OBJETIVOS</th>
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<th>FUNDAMENTO</th>
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<td>1</td>
<td>Perform wideband 1x4 MIMO channel measurements for outdoor-indoor scenarios using the existing channel sounder.</td>
<td>TOTAL</td>
<td>This objective, was completed in the last year using a different approach than originally envisioned. The modification of the narrowband channel sounder for wideband measurements would have demanded work and costs beyond the allocated resources and budget. In addition it would have interfered with other ongoing work. Therefore wideband measurements were performed using a Vector Network Analyzer (VNA) with sequential positioning of the antennas, which corresponds to a sequential wideband MIMO measurement, rather than a simultaneous one as had been planned. We also used wideband channel sounding equipment capable of simultaneously measuring narrow- and wideband power.</td>
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<td></td>
<td>Configuration of the Anechoic Chamber for measurements at up to 10 GHz.</td>
<td>TOTAL</td>
<td>The measurements with the small anechoic chamber built with modest funding of previous and the present projects have resulted in the superior chamber inner-outer isolation, up to 45 dB in the frequency band 0.8-6.0 GHz. During the experiments we found that the absorbing material of the chamber and the better electromagnetic isolation would be essentially preserved with a frequency increase of up to 10-12 GHz. For such higher frequencies, however, the relative characteristic size of the AUT (Antenna Under Test) relative to the wavelength becomes much smaller for the given chamber size and use of the same absorbing covering. This means that the chamber will serve effectively for such higher frequencies but only for smaller antennas and antenna arrays. With the new VNA acquisition, the structural and instrumental configuration of the chamber measurement set-up became adequate for work at much higher frequencies.</td>
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<td></td>
<td>Design and study compact omnidirectional and/or directional antennas and MIMO arrays.</td>
<td>TOTAL</td>
<td>The work on compact communications antennas is currently continuing in two directions: (i) Design and study of printed X antenna elements and fabrication them by means of modern LTCC technology at the National University of Singapore (NUS). The joint study on our two-port X directive antennas for polarization-diversity applications is based on our two ISI publications in the J. of Microwave and Optical Technology Letters (June 2009 and December 2010) (ii) Study of backfire antennas for much higher microwave and millimeter-wave frequencies for future communications pico-cell systems. This is a new path of our recently started work on low-terahertz backfire and Fresnel lens antennas. In support of the work on channel sounding, sleeve-dipole antennas and arrays of such antennas for frequency bands around 3.5 and 5.5 GHz were designed and measured in the anechoic chamber</td>
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<tr>
<td><em>4</em></td>
<td>Perform indoor “Network MIMO” indoor channel measurements. Measure wideband response using sliding window correlator. Measure angular spread using virtual arrays and directive antennas.</td>
<td>TOTAL</td>
<td>During the last year of this project the measurement capabilities of the 4-channel sounder were extended to 12 channels using a linear array with antennas sequentially switched among the sounder channels. Phase coherence between the channels was to be preserved in order to be able to perform vector channel-gain measurements. In addition it was required that the transmitter be connected to a movable antenna and that transmissions at various positions be synchronized with the sequential switching process at the receive end. The above required quite extensive and time-consuming modifications to the sounding equipment, which were successfully completed in December 2011. Since then an extensive measurement campaign was initiated aimed at evaluating MIMO capacities vs. Beamforming in a wide range of femtocell-type settings.</td>
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<tr>
<td><em>5</em></td>
<td>Process collected statistical data and formulate channel models for specific short range (&lt; 200m) outdoor- indoor and indoor scenarios. Compare MIMO and beamforming performance from the measured data</td>
<td>TOTAL</td>
<td>This objective is closely related to the previous one. A paper describing the effect of using low altitude base stations to deliver fixed wireless service to homes in areas where placement at lamppost level altitudes is not desired or possible was submitted to the IEEE Transactions on Wireless Communications and has been accepted for publication.</td>
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<tr>
<td><em>6</em></td>
<td>Setup SDRs for SISO and MIMO measurements and for modulation/coding tests in real channels</td>
<td>TOTAL</td>
<td>Extensive work was performed in adapting the SDRs to channel measurements, particularly for Relay Channels. This proved far more complex than originally envisioned, as the considerable flexibility of the SDRs also entails the careful selection of a wide range of user-defined options. A fully automated measurement procedure has now been completed. This involves the simultaneous operation of 2 SDRs one as a relay and the other emulating a user terminal, both receiving from a single base station. A reliable time-synchronization procedure had to be developed to allow correlating data received from both SDRs. An extensive measurement campaign in a range of urban settings is currently underway using theses elements. As discussed in the previous report, the collaboration has involved scientists at Bell-Labs and through them researchers at Rutgers-Winlabs, who will use the same type of devices.</td>
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<td>Objective</td>
<td>TOTAL</td>
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<tr>
<td>Measure MIMO channels for diverse antenna choices, positions and polarization configurations using SDRs in outdoor and outdoor-indoor urban settings. Use of SDRs with realistic modulation and coding schemes in fading channels</td>
<td>This objective that started in the second semester of the project was approached using SDRs as well as previously designed channel sounding systems. CW measurements were performed as the link budget for wideband work proved to be too limited. The purchase of power amplifiers allowed extending the range. Relay and Remote Radio Head (RRH) type links were measured in urban settings. A paper with the results was submitted to IEEE Transactions on Wireless Communications. It is currently being modified to comply with the reviewer's suggestions.</td>
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<tr>
<td>Configure Anechoic Chamber as Reverberation Chamber. Design and study of two-port compact antenna elements for MIMO antenna arrays.</td>
<td>The microwave measurement chamber was completed during 2011 with the financial support of this project. This chamber simulates the multi-reflection electromagnetic dynamics in usual and MIMO inside and outside mobile scenarios. For measurements of mobile antennas and handheld communications devices in more realistic situation a Standard Anthropomorphic (SAM) Head and Hand models have been acquired for installing inside the reverberation and anechoic chambers. The chamber evaluation, equipment and calibration are under way and some measurements on antenna gain, handheld radiation power, and radiation patterns with the presence of SAM elements have been completed.</td>
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<td>Process collected statistical data and formulate channel models for outdoor and outdoor-indoor scenarios considering ranges of up to 3km.</td>
<td>This objective, which spanned the project’s duration, resulted in a paper on the effect of pedestrian traffic on the channel dynamics. This paper was published in the journal IET Communications.</td>
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<td>Find the expression for the PDF of the bits’ metrics and compare them with simulation results, evaluate the impact of adopted simplifications. Evaluate the impact of the Gaussian approximation of the small number of interferers. Characterize the most significant events and find their probabilistic description.</td>
<td>This work was completed as part of the collaboration between INRS and the UTFSM. The M. Sc. student Victor Nunez was tutored in his thesis by Dr. Leszek Szczuczinski and the Ph. D candidate Alex Alvarado studying at Chalmers University. During 2011 a new M. Sc. student initiated work under the guidance of Dr. Szczcinski, investigating the possibility of improving transmission rates using adaptive modulation and coding (AMC) in combination with the ARQ protocol.</td>
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Otro(s) aspecto(s) que Ud. considere importante(s) en la evaluación del cumplimiento de objetivos planteados en la propuesta original o en las modificaciones autorizadas por los Consejos.
RESULTS OBTAINED:
For each specific goal, describe or summarize the results obtained. Relate each one to work already published and/or manuscripts submitted. In the Annex section include additional information deemed pertinent and relevant to the evaluation process. The maximum length for this section is 5 pages. (Arial or Verdana, font size 10).

The following are the results of the third year for Fondecyt Project 1095018.

STUDY OF MIMO AND "NETWORK MIMO" COMMUNICATION SYSTEMS: CHANNEL MODELING, EFFICIENT ANTENNA ARRAYS AND MODULATION/CODING
Where appropriate we mention previous work to clarify the context of the last year’s development. The specific topics are presented as in the original project submission. As in any scientific project, in several cases work progressed along slightly different lines than envisioned 4 years ago. However this did not affect the achievement of the general objectives, as confirmed by the considerable number of accepted publications related to the various subject matters.

Confirmation documents for the reception/publication of papers related to this work are included in “ANNEXES”.

Perform wideband 1x4 MIMO channel measurements for outdoor-indoor scenarios using the existing channel sounder.
This objective, which was formulated for years 1 and 2 and 3, was completed in the last year using a different approach than originally envisioned. The modification of the narrowband channel sounder for wideband measurements would have demanded work and costs beyond the allocated resources and budget. In addition it would have interfered with other ongoing work. Therefore wideband measurements were performed using a Vector Network Analyzer (VNA) with sequential positioning of the antennas, which corresponds to a sequential wideband MIMO measurement, rather than a simultaneous one as had been planned. We also used wideband channel sounding equipment capable of simultaneously measuring narrow- and wideband power. The formulation of a wideband channel model capable of predicting fade depth as a function of bandwidth had already resulted in a paper presented at the international conference (PIMRC 2010, Istanbul). A follow-up journal paper is currently being completed.

Configuration of the Anechoic Chamber for measurements at up to 10 GHz.
The measurements with the small anechoic chamber built with modest funding of previous projects and modified during the last years have resulted in improved chamber inner-outter isolation, up to 45 dB in the frequency band 0.8-6.0 GHz. During the experiments we found that the absorbing material of the chamber and the better electromagnetic isolation would be essentially preserved with a frequency increase of up to 10-12 GHz. For such higher frequencies, however, the relative characteristic size of the AUT (Antenna Under Test) relative to the wavelength becomes much smaller for the given chamber size and use of the same absorbing covering. This means that the chamber will serve effectively for such higher frequencies but only for smaller antennas and antenna arrays.

With the new VNA acquisition (R&S Model ZVL 9 kHz-13.6 GHz), the structural and instrumental configuration of the chamber measurement set-up became adequate for work at much higher frequencies.

Design and study compact omnidirectional and/or directional antennas and MIMO arrays.
The work on compact communications antennas is currently continuing in two directions:
(i) Design and study of printed X antenna elements and fabrication them by means of modern LTCC technology at the National University of Singapore (NUS). This work was planned during the October 2011 visit of our research partner Dr. Y. X. Guo from the RF & Microwave Group. The joint study on our two-port X directive antennas for polarization-diversity applications is based on our two ISI publications in the J. of Microwave and Optical Technology Letters (June 2009 and December 2010)
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completed and presented at the 2011 European Microwave Conference, Manchester, UK under the partial support of the present project.

In support of the work on channel sounding, sleeve-dipole antennas and arrays of such antennas for frequency bands around 3.5 and 5.5 GHz were designed and measured in the anechoic chamber.

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**Process collected statistical data and formulate channel models for specific short range (< 200m) outdoor-indoor and indoor scenarios. Compare MIMO and beamforming performance from the measured data**

This objective is closely related to the previous one. A paper describing the effect of using low altitude base stations to deliver fixed wireless service to homes in areas where placement at lamppost level altitudes is not desired or possible was submitted to the *IEEE Transactions on Wireless Communications* and has been accepted for publication.

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**JOURNAL PAPERS (YEAR 3):**


**CONFERENCE PAPERS (YEAR 3):**

2. Rodríguez, JM.; Hristov, HD.; Grote, W., “Fresnel Zone Plate and Ordinary Lens Antennas Comparative Study at Microwave and Terahertz Frequencies” *41st European Microwave Conference (EuMC) 2011*. 


OTHER ACHIEVEMENTS OF THE PROJECT:
- Research visit(s) to other institution(s).
- Outreach activities related to the project’s main topic.
- Any other contribution, not addressed elsewhere, that you consider important.

The maximum length for this section is 1 page. (Arial or Verdana, font size 10).

During May 2011 the Principal Investigator of this project completed a two week research stay at Bell-Labs, Alcatel Lucent. During this stay the now accepted paper on low-altitude base stations was revised and diverse research topics were discussed. A very important activity during this stay was the formulation of the continuation of the current research activity. The resulting proposal was approved as a new 3-year Fondecyt Project, to begin in April 2012.

In October 2011 a one-day international workshop on wireless communications was organized at Universidad Técnica Federico Santa María, as one of the scheduled activities of the closely related Anillos ACT-53 project. Researchers of this Fondecyt project, including the collaborators from INRS Dr. Leszek Szczecinski and from Cambridge University, Dr. Alex Alvarado, actively participated in this event, which attracted a large audience of academics and graduate students from other Chilean universities.

The participation of many undergraduate and graduate students is considered particularly relevant as it has motivated many of them to seek participation in the research activities of this and of related projects.
COOPERACIÓN INTERNACIONAL

N° Proyecto: 1095018
Nombre Colaborador (a) Extranjero (a): REINALDO VALENZUELA
Afiliación Institucional Actual: BELL LABORATORIES, LUCENT TECHNOLOGIES

Describa las actividades realizadas y resultados obtenidos. Destaque su contribución al logro de los objetivos del proyecto. Si es pertinente, indique las publicaciones conjuntas generadas, haciendo referencia a lo informado en la etapa Productos. Agregue en la etapa anexos la información necesaria.

Dr. Valenzuela continued his collaboration with this and with related projects during 2011.

His visit in September involved various activities:

1.- Revision of a journal paper, now accepted for publication in the IEEE Transactions on Wireless Communications, as reported elsewhere.

2.- Evaluation of preliminary results of outdoor-indoor and outdoor-outdoor MIMO measurements. Definition of contents for future research papers on this subject.

3.- Definition of objectives for ongoing work on Relay links and Femtocells.

Dr. Valenzuela’s insights have as always proved to be very valuable and have contributed very significantly to the successful publication record.

PRODUCTOS

ARTÍCULOS
Para trabajos en Prensa/ Aceptados/Enviados adjunte copia de carta de aceptación o de recepción.

N°: 1
Autor (a)(es/as): Feick, R.; Ahumada, L.; Carrasco, H.
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<td>Rodríguez, M.; Feick, R.; Carrasco, H.; Valenzuela, RA.; Derpich, MS.; Ahumada, L.</td>
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<tr>
<td>Nombre Completo de la Revista :</td>
<td>IEEE Transactions on Wireless Communications</td>
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<td>Título (Idioma original) :</td>
<td>Wireless Access Channels with Near Ground Level Antennas</td>
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<td>ISI</td>
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Nombre Completo de la Revista: IEEE Transactions on Wireless Communications
Título (Idioma original): Empirical Evaluation of Achievable Cellular Throughput Gains of Remote Radio Heads in Urban Environments
Indexación: ISI

Nº: 4
Autor (a)(es/as): Ahumada, L.; Feick, R.; Valenzuela, RA.; Gallardo, M.; Derpich, MS.; Carrasco, H.

Otras Fuentes de financiamiento, si las hay:
Fondecy 1110355, 3100109, Anillo ACT-53, STIC-AMSUD

Envía documento en papel: sí

Archivo(s) Asociado(s) al artículo:
Empirical_Evaluation_Achievable_Cell.pdf
Email_Review_Empirical_Eval_Achievable.pdf


text from the document
CONGRESOS

Nº : 1
Autor (a)(es/as) : Ahumada, l.; Feick, t.; Valenzuela, RA.; Gallardo, M.; Derpich, MS.; Carrasco, H.
Título (Idioma original) : Empirical Gains Achievable with Low Altitude Remote Radio Heads in Wireless Urban Links
Nombre del Congreso : IEEE International Conference on Communications (ICC SmallNets)
País : CANADA
Ciudad : OTTAWA
Fecha Inicio : 10/06/2012
Fecha Término : 15/06/2012
Nombre Publicación : IEEE ICC 2012
Año :
Vol. :
Nº :
Páginas :
Envía documento en papel : si
Archivo Asociado : RRH-Final.pdf

Mail_Aceptación_Empirical_Evaluation_Achievable.pdf

Nº : 2
Autor (a)(es/as) : Rodríguez, JM.; Hristov, HD.; Grote, W.
Título (Idioma original) : Fresnel Zone Plate and Ordinary Lens Antennas Comparative Study at Microwave and Terahertz Frequencies
Nombre del Congreso : 41st European Microwave Conference (EuMC)
País : REINO UNIDO DE GB E IRLANDA DEL NORTE
Ciudad : Manchester
Fecha Inicio : 10/10/2011
Fecha Término : 13/10/2011
Nombre Publicación : Procedings of the 41st European Microwave Conference
Año : 2011
Vol. :
Nº :
Páginas : 984-897
Envía documento en papel : si
TESIS/MEMORIAS

Sin información ingresada.

ANEXOS

A continuación se detallan los anexos físicos/papel que no se incluyen en el informe en formato PDF.