

# CURRICULUM VITAE OF FABRIZIO PANCALDI

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# 1 Short Curriculum Vitae

## 1.1 Personal details

Place of birth: Modena  
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## 1.3 Academic career

- [1992-97] He attends the Istituto Tecnico Industriale Provinciale “E. Fermi” of Modena. He receives the Diploma di Perito Capotecnico in Elettronica e Telecomunicazioni with the mark 60/60.
- [1997] He enrolls at the course of Electrical Engineering (under the old educational ordination, *vecchio ordinamento didattico*, VOD) at the University of Modena and Reggio Emilia.
- [2002] He receives the Dr. Ing. degree in Electrical Engineering with the mark 110/110 and *honors*. His Master Thesis is entitled “Frequency Domain Equalization”.
- [2002] He is qualified to the professional activities in the wide area of engineering.
- [2003] He is awarded with a scholarship for the PhD course on Information Engineering at the University of Modena and Reggio Emilia.
- [2006] On March 2006 he receives the PhD degree on Information Engineering from the Department of Information Engineering at the University of Modena and Reggio Emilia, defending his thesis entitled “Models and Algorithms for Wireless Communications Systems”.
- [2006-today] Since the 1st of March 2006 he is an Assistant Professor at the Department of Science and Methods for Engineering of the University of Modena and Reggio Emilia.

## 1.4 Teaching activities

Since the academic year 2005/2006 he gives the course of “Communication Network” (60 hours of lecturing) at the BS degree course of Business Engineering. In the academic years 2006/2007, 2007/2008 and 2008/2009 he gave the course of “Networking Techniques”; in the academic years 2009/2010 and 2010/2011 he was co-responsible of the course “Distributed Systems for ICT” (54 hours of lecturing), holding this course from 2011/2012 to 2019/2020. Both courses belong to the MS degree course in Business Engineering. In the academic years 2018/2019 and 2019/2020 he gave the course “Final Synthesis Lab 2 - Educational technology innovation - Systems and communications for educational smart objects” (30 hours of lecturing) in the MS degree course of Innovation Design. From the academic year 2021/2022 he is co-responsible of the course “Embedded Systems” (54 hours of lecturing) in the MS degree course of Mechatronic Engineering. From the academic year 2023/2024 he is co-responsible of the course “Smart Systems for Data Acquisition” (27 hours of lecturing) in the MS degree course of Digital Automation Engineering.

## 1.5 Research activity

His research activity is focused on the following fields:

- Digital radio communications, with particular emphasis on channel equalization, statistical channel modelling, space-time coding, channel estimation and clock synchronization.
- Powerline communications, with particular emphasis on channel equalization, statistical channel modelling, channel estimation, channel coding and adaptive modulation.
- Indoor localization systems based on inertial measurement units (IMUs), radio devices operating at 169 MHz and radio equipment working in the ISM band at 2.4 GHz.
- Medical equipment, with particular emphasis on the diagnosis of
  - ✓ Lung diseases, like for instance pulmonary fibrosis secondary to rheumatoid arthritis, interstitial lung diseases secondary to Sjogren syndrome, **unusual interstitial pneumonia caused by COVID-19**. The diagnosis technique is based on the digital signal processing of lung sounds acquired through an electronic phonendoscope.
  - ✓ Disorders of the scleroderma spectrum related, for instance, to the Raynaud syndrome. He diagnostic technique is based on computer processing of images taken at the nailfold.
  - ✓ Hair and scalp diseases, like for instance androgenetic alopecia, alopecia areata, telogen effluvium. The diagnosis technique is based on the digital signal processing of images of hair and scalp acquired through a smartphone or tablet.
- Diagnosis of ball bearings through vibration analysis.
- Analysis of the stability and comfort of aerial cyclo-pedestrian walkways.
- Rover and drones with autonomous driving.

Moreover, he carries out a technical-practical activity for the development of

- **Mesh networks** operating in the ISM band at 2.4 GHz.
- **Powerline modems** operating in the FCC band 3-500 kHz.
- **Inertial localization** systems.

- **Radiolocalization** equipment operating at 169 MHz and 2.4 GHz.
- **Electronic phonendoscope** for the automatic diagnosis of pulmonary diseases through the analysis of lung sounds. This new electronic phonendoscope is currently developed in collaboration with the Italian company Redox srl and is endowed with MEMS microphone, accelerometer, BLE connectivity toward a tablet or smartphone, capability of edge computing and connection to the cloud.
- **Electronic dermatoscope** for the automatic diagnosis of diseases affecting hair and scalp. This new electronic dermatoscope is capable to process the images acquired through commercial photocameras coupled with an optical system suitably developed for this application.
- Systems for **automatic drug management and administration**.
- **Magnetic docking and undocking systems for drones** from moving vehicles.

He is co-author of the book entitled “Wireless Communications: Algorithmic Techniques” published in 2013 by the publishing house John Wiley & Sons.

He is co-author of 35 technical papers appeared or forthcoming on international journals, he is co-author of 2 manuscripts currently under review on or preparation to international journals, he is co-author of 21 papers presented at international conferences, he holds the intellectual property of 3 international patent and 2 Italian patents. Two Italian patent applications have been filed.

His publications are summarized as follows:

- 1 book
- 35 technical papers appeared or forthcoming on international journals
- 2 manuscripts currently under review on international journals
- 21 papers presented at international conferences
- 5 patents
- 2 Italian patent application have been filed

He is reviewer of the following international journals:

- *IEEE Transactions on Communications*
- *IEEE Transactions on Wireless Communications*
- *IEEE Transactions on Vehicular Technology*
- *IET Communications*
- *IEEE Transactions on Aerospace and Electronic Systems*
- *IEEE Access*
- *IEEE Journal of Communications and Networks*
- *Elsevier Physical Communication*
- *EURASIP Journal on Wireless Communication and Networking*
- *Elsevier Computers in Biology and Medicine*
- *Elsevier Mechanical Systems and Signal Processing*

- *Biocybernetics and Biomedical Engineering*
- *EAMBES Biomedical Signal Processing and Control*
- *IFAC Engineering Applications of Artificial Intelligence*

He has been reviewer for the following international conferences:

- *IEEE Global Communications Conference*, years 2005, 2007, 2008, 2009 and 2013.
- *IEEE International Conference on Communications*, years 2004, 2006, 2007, 2008 and 2009.
- *IEEE Vehicular Technology Conference 2005*
- *IEEE Wireless Communication and Networking Conference*, years 2007, 2010 and 2012.
- *IEEE International Symposium for Wireless Pervasive Computing*, years 2007, 2008, 2009 and 2010.
- *IEEE Symposium on Personal, Indoor, Mobile and Radio Communications*, years 2010, 2011, 2013, 2023, 2024.

He has been the *Publication Chair* at the *IEEE International Symposium for Wireless Pervasive Computing 2010*.

He has been *track chair* at the *IEEE-EMBS International Conference on Biomedical and Health Informatics 2022*.

He is *Member* of the *Institute of Electrical and Electronics Engineers (IEEE)* since 2004 and he is *Senior Member* of the IEEE from 2022.

## 1.6 Organizational activity

<b>2007–2012</b>	Representative of Assistant Professors in the Engineering Faculty Council – Headquarter located in Reggio Emilia.
<b>2006–2019</b>	Member in the Council of the International Doctorate School in <i>Information and Communication Technology (ICT)</i> .
<b>2007-2019</b>	Supervisor of 4 PhD students at the International Doctorate School in ICT
<b>2008-2010</b>	Representative for the development of the ICT area at the Department of Science and Methods for Engineering.
<b>2009-2017</b>	Co-responsible for the internationalization of the International Doctorate School in ICT.
<b>2015-today</b>	Representative of Assistant Professors at the Department of Science and Methods for Engineering.
<b>2015- 2019</b>	Member of the Junta at the Department of Science and Methods for Engineering.
<b>2017-2018</b>	Member of the Commission for the celebration of twenty years from the foundation of the Department of Science and Methods for Engineering.
<b>2019-today</b>	Faculty Advisor of the Project RED ( <a href="https://projectred.it">https://projectred.it</a> )

## 2 Research activity

In this Section the research activities accomplished by Dr. Fabrizio Pancaldi are shown. In particular, the scientific works are described referring to the international journal and conference publications listed in Section 7. Then, the technical-practical activity of applied research is illustrated. Finally, the international scientific collaboration and the international research project in which Dr. Fabrizio Pancaldi is involved are pointed out.

### 2.1 Research activity

Dr. Fabrizio Pancaldi has been working in the wide area of digital communications, with particular emphasis on both radio communications and *powerline communications* (PLC). Recently Dr. Fabrizio Pancaldi is applying the knowledge devised in the broad field of digital signal processing to solve multidisciplinary problem, especially in the field of biomedical engineering, mechanical engineering and civil engineering.

In the field of radio communication, his research activity is focused on the following themes: (a) channel equalization for single-carrier wideband digital communication systems; (b) statistical modelling for directional channels; (c) space-time coding for communication systems employing continuous phase modulations; (d) cooperative communication techniques for ad-hoc networks; (e) design of *ultrawide band* (UWB) communication systems.

In the field of PLC, his research activity is focused on the following themes: (a) statistical channel modeling; (b) noise modelling; (c) development of a channel sounder based on high performance FPGAs; (d) channel estimation; (e) channel equalization; (f) bit and power loading.

In the field of localization for indoor scenarios, his research activity is focused on the following themes: (a) radiolocalization based on the *received signal strength* (RSS) embedding the knowledge of the map of the propagation environment; (b) inertial localization embedding the knowledge of the map of the environment.

In the field of medical equipment, his research activity is focused on the following themes: (a) automatic non-invasive diagnosis of interstitial lung disease secondary to rheumatoid arthritis based on the processing of lung sounds acquired through auscultation; (b) automatic non-invasive diagnosis of interstitial lung disease secondary to connective tissue disease based on the processing of lung sounds acquired through auscultation; (c) automatic non-invasive diagnosis of interstitial pneumonia secondary to COVID-19 based on the processing of lung sounds acquired via auscultation; (d) automatic diagnosis of disorders belonging to the scleroderma spectrum through computer processing of nailfold images (videocapillaroscopy); (e) automatic diagnosis of androgenetic alopecia and telogen effluvium through commercial smartphones or tablets and a suitably designed software.

In the field of vibration analysis, his research activity is focused on the following themes: (a) condition monitoring and predictive maintenance of rotating machines; (b) statistical modelling of machine noise; (c) analysis of the stability and comfort of aerial walkways.

In the field of systems and subsystems for autonomous drones and rovers, the research activity concerned the design and development of a magnetic platform for docking and undocking drones on a moving vehicle.

### 2.1.1 Frequency domain channel equalization

This research activity concerns the study of channel equalization techniques for single carrier systems. Firstly, *single-input single-output* (SISO) systems adopting linear modulations have been taken into account. The first step has been introducing a new matrix description of block channel equalization in the frequency domain. This has enabled the derivation of two different *conventional* equalization schemes: a *linear equalizer* (LE) and a *decision feedback equalizer* (DFE). It has been proved that fractional sampling can provide an energy saving of some dB with respect to the classic symbol sampling. As far as the new DFE is concerned, a novel technique (based on the Levinson-Durbin algorithm) for computing the equalizer tap coefficients has been introduced; the new algorithm is characterized by a limited computational complexity and a limited memory usage with respect to the other DFEs available in the technical literature. Then, the derived equalizer have been set in a coded architecture in order to obtain two different *turbo equalization* schemes. Numerical results have shown that the turbo DFE can provide an appreciable energy saving with respect to the turbo LE at high *signal-to-noise ratio* (SNR).

The new approach has been applied to *multiple-input multiple-output* (MIMO) systems adopting linear modulations. The basic idea consists of combining space-time coding with frequency domain equalization, with the aim of jointly exploiting spatial and frequency diversity. In the field of conventional equalization, a LE and a DFE have been derived. Numerical results have evidenced the advantages provided by the novel equalizers with respect to the other equalizaer available in the technical literature. Then the LE and the DFE have been set in an iterative architecture for turbo equalization, yielding two innovative equalization/detection schemes. Numerical results have pointed out the appreciable energy saving which can be achieved jointly exploiting spatial and frequency diversity with respect to classic SISO systems.

The theory of equalization based on filtering, in principle developed for linear modulations, has been generalized for *continuous phase modulations* (CPM). Through the Laurent decomposition, the CPM signal has been represented as a sum of linearly modulated signals, and algorithms for block equalization in the frequency domain have been derived. The frame format has required a detailed study, since the cyclical extension, necessary for frequency domain equalization, cannot disrupt the phase continuity of the transmitted signal. Both a LE and a DFE have been derived. Numerical results have shown the appreciable energy saving offered by the DFE with respect to the LE; moreover, it has been proved that CPM transmitted over a frequency selective channel can be detected with a limited computational complexity. A turbo equalization scheme has been derived, however, satisfying performance has not been achieved because of error propagation phenomena entailed by the intrinsic memory of CPM.

**Publications:** [J.1], [J.2], [J.4], [J.5], [C.1], [C.2], [C.3], [C.6].

*Note:* The work [J.5], published on September 2008, was in the list of the 100 most popular IEEE papers until August 2009.

### 2.1.2 Statistical modelling for mobile radio channel selective in time, frequency and space

Novel models characterized by a reduced dimensionality have been developed for the mobile radio channel. Such models allow to represent the randomness of the time continuous filtering effect of the channel as the effect of a finite number of Gaussian random variables. Therefore, these models permit to describe, simply and with an arbitrary accuracy, a mobile radio channel with given statistical properties. The derivation of such models is based on the approximation of the correlation integrals, which represent the statistical properties of the channel, with numerical integration techniques like, for instance, the so called Gaussian quadrature rules. This approach

allows to model the selectivity of the channel in time, frequency and space; in particular, directional channels (representing the spatial dependence through two angular variables, the elevation and the azimuth) have been modelled. Computer simulations have shown that a significant accuracy can be achieved in the representation of a radio channel at the price of a limited computational complexity.

**Publications:** [J.3], [C.4], [C.5].

### 2.1.3 Noncoherent receivers for continuous phase frequency shift keying

The problem of space-time coding for noncoherently detected modulations have been taken into account; in particular, *continuous phase frequency shift keying* (CPFSK) has been considered. Three “optimal” criteria, in terms of achievable minimum error probability, have been introduced for the construction of space-time block codes. Then the optimum noncoherent receiver has been derived and the related performance has been obtained both analytically and numerically. It has been proved that the new codes can achieve the well known *full diversity*. Systems having two transmit antennas and any number of receive antennas have been accurately studied. It has been observed that the energy loss involved by noncoherent detection ranges from 4 to 6 dB with respect to coherent detection; however, the appreciable simplicity of the proposed receiver entails a significant application relevance.

**Publications:** [J.6], [C.7].

### 2.1.4 Cooperative communications in *ad hoc* networks

Two different *ad hoc radio* network architectures have been developed. The new idea consists of adopting cooperative transmission diversity techniques. In practice, the nodes of the network can “help” the source of information relaying the data packets towards the destination.

The first scheme is based on *orthogonal frequency division multiple access* (OFDMA), where distinct subcarriers are assigned to different users in order to avoid *multi-user interference* (MUI). The relaying is performed through a double string topology which allows to employ space-time coding between couples of relays. Moreover, the proposed architecture adopts an approach based on the idea of *utility* in order to derive a distributed routing algorithm. Cross layer optimization of the transmission technique provides a better energy efficiency and a more balanced use of the resources in the network (thus increasing the average lifetime) with respect to traditional solutions.

In the second ad-hoc network model the terminals are endowed with a single antenna, which is then “shared” with the other transceivers to form a distributed virtual array. Resorting to a modern approach based on noncooperative game theory, a distributed strategy for information relaying has been derived; in particular, the transmission strategy stems from the classic *transmit selection diversity* (TSD) where the transmission antenna is selected among the virtual array rather than among the antennas array belonging to a single terminal. In this way multi-user diversity is exploited to generate spatial diversity. The proposed scheme outperforms the similar systems available in the technical literature in terms of both throughput and energy efficiency. Since the strategy is simple and distributed, the proposed solution lends itself to a practical implementation.

**Publications:** [J.7], [J.8], [J.9], [C.8], [C.10].

### 2.1.5 Indoor radio localization

Multipath propagation of radio waves in indoor scenarios involves localization errors which are not tolerable in modern applications, especially when the *received signal strength* (RSS) is employed for ranging. To cope with this issue, various algorithms have been devised to mitigate the effect of the time dispersion of the ranging signal and then to appreciably improve the accuracy of positioning.

The first approach is based on a cooperative clustering technique which allows the identification of the set of agents whose ranging measurements (accomplished on the basis of the RSS) can be combined to refine the estimation of the distance between the agents and the anchor. Numerical simulations have shown that the ranging error can be significantly reduced with respect to classical single user systems.

In the second algorithm the distance between agent and anchor is estimated on the basis of the *time of arrival* (TOA) of the ranging signal. In particular various characteristics of the received waveform are exploited to mitigate the *non line of sight* (NLOS) bias, i.e. the extra delay entailed by physical obstructions (typically walls) on the propagation of the electromagnetic wave associated with the ranging signal. Numerical and experimental results have shown the capability of the devised algorithm to improve the accuracy of localization with respect to other technique suitable to NLOS mitigation.

Then the knowledge of the map of the environment in which localization signals are acquired has been exploited to cancel out, at least to some extent, the degradation in localization signals originating from their propagation through physical obstructions, so that a new unified statistical model for the signals acquired in map-aware localization systems based on time-of-arrival, time-difference-of-arrival or RSS techniques has been proposed and experimentally validated. However, the performance improvement is achieved at the price of an increase in the computational complexity of optimal estimation algorithms, since numerical integration of non-linear functions or search of minima in non-linear and non-convex constrained optimization problems are required; in particular, for large maps, the complexity of these algorithms may become prohibitive. Hence, optimal estimators for map-aware localization systems have been derived, numerical techniques for their implementation have been discussed and their computational complexity has been analysed; as a consequence, two novel sub-optimal variations of such estimators have been proposed to perform, in terms of accuracy, very close to their optimal counterparts, in spite of a much lower computational complexity. Numerical and experimental results have evidenced an accuracy better than 4 m even employing low-cost hardware (the retail cost of the setup is below 1000 euros).

**Publications:** [J.9], [J.12], [J.17], [J.18], [C.9], [C.13], [C.14], [C.15], [C.19].

### 2.1.6 Reduced complexity receivers for UWB applications

In impulse radio (IR) *ultra-wideband* (UWB) systems, each user is endowed with a code suitable to separate its own signal from those generated by the other users of the system. If appropriately designed, such codes can yield to data rates slightly different, i.e. a *rate division multiple access* (RDMA) system can be artificially generated, where distinct users are characterized by different data rates. The first result of this promising approach is the design of a multi-user receiver involving a limited computational complexity. This receiver embodies a novel fine clock synchronization algorithm and a novel multi-user channel estimator. Numerical results have shown that the designed channel estimator can handle 4 users simultaneously operating within the same band without introducing a relevant error floor. Although the considered radio channel is severely frequency selective, the computational complexity of the multi-user channel estimator increases only linearly with the training symbol block. Similar results have been obtained for the clock synchronization algorithm, in fact the sampling phase of the analogical to digital converters at the

receiver is properly compensated even over frequency selective fading, whereas the computational complexity is very limited, increasing only linearly with the preamble length.

**Publications:** [J.11], [C.12], [C.13].

### 2.1.7 Statistical modelling for PLC channels

The knowledge acquired in the field of radio communications has been applied to PLC. In order to design an efficient transceiver, it is of fundamental importance the knowledge of the impedance matrix of the channel; however, the presence of time-varying power loads prevents to devise a reliable channel estimation through traditional methods. Moreover, the power networks in the houses are installed by personnel not always adequately qualified, hence the power grids of similar building can appreciably differ.

For these reasons a channel sounder suitable to measure the characteristics of the powerline channel in the band 0.1 – 30 MHz has been developed. The information provided by the channel sounder is particularly useful for the design of the analogical front-end of PLC transceivers. Furthermore, the data extracted through the developed instrument have been employed to devise various novel mathematical tools suitable to model both the time-variant frequency response and the noise properties of the powerline channel. In particular it has been shown that the powerline channel can be accurately described as a linear periodically time-varying (LPTV) system involving a very limited computational complexity.

The novel LPTV model has been exploited to devise: (a) a new channel estimation algorithm characterized by a better accuracy with respect to its counterparts appeared in the technical literature; (b) a new zero-forcing (ZF) channel equalizer offering better performance with respect to its conventional counterpart; (c) a new bit and power loading algorithm which allows to increase the spectral efficiency of PLC with respect to other techniques available in the technical literature.

**Publications:** [J.10], [J.13], [J.14], [J.16], [J.19], [J.20], [J.21], [J.22], [C.16], [C.17], [C.18].

### 2.1.8 Medical equipment: electronic stethoscope for the automatic analysis of lung sounds

*Interstitial lung disease* (ILD) represents one of the most frequent manifestations in connective tissue diseases and significantly influences the prognosis of patients. In practice, the lung parenchyma is replaced by fibrotic tissue with a reduced capability to exchange oxygen and carbon dioxide between blood and air. In case of ILD, life expectation is dramatically reduced to a few years, leading to death for respiratory failure. Currently, *computer tomography* (CT) represents the gold standard for the diagnosis and characterization of ILD. However, CT is not suitable for screening campaigns since patients undergo to high radiological exposure, costs are unsustainable for the sanitary system and waiting times for all rheumatological patients would be unacceptable.

Recently, a close correlation has been observed between pulmonary fibrosis and velcro crackles. In particular, the velcro noise generated in the lung parenchyma has been independently associated with different radiological patterns, namely honeycombing, ground glass and traction bronchiectasis. Besides, the sound marker has been exploited to automatically detect pulmonary fibrosis secondary to rheumatoid arthritis and ILD in patients with connective tissue diseases, such as primary Sjogren syndrome.

In symptomatic patients, COVID-19 is characterized by a high percentage of cases of severe interstitial pneumonia requiring assisted ventilation and hospitalization. A peculiar characteristic of COVID-19 interstitial pneumonia is the absence of any symptomatology or semeiological relevant findings, even if the pulmonary involvement is severe. The result is a sudden functional decay in

the absence of significant clinical prodromes; this complicates patient monitoring, particularly at home. Recent studies have proved that CT is able to predict the severity of the disease, but the technical time necessary for its execution, the number and the difficulty in mobilizing patients, makes this approach unfeasible for screening.

The collaboration between physicians and engineers at the University of Modena and Reggio Emilia has led to the following results:

1. An electronic phonendoscope has been designed and developed to: (a) digitally acquire lung sounds; (b) process the acquired data and automatically detect pathological lung sounds according to the developed algorithms; (c) transfer data to a commercial smartphone or tablet through a USB connection or Bluetooth Low Energy (BLE) link; (d) provide ancillary services useful for the physician; (e) upload to the cloud all or part of the acquired data according to the law in terms of privacy.
2. Two software applications have been developed. In practice, patients are auscultated with an electronic phonendoscope and the audio files are processed on a common personal computer with the developed algorithms. The software applications quantitatively analyze lung sounds and infer the presence of lung complications. The results have been published on international journals and showed a diagnostic accuracy of 83.9% on patients with rheumatoid arthritis, of 82.6% on patients with connective tissue disease and of 75% on patients with interstitial pneumonia secondary to COVID-19.
3. A new pipeline based on deep learning for the detection of interstitial lung diseases secondary to connective tissue diseases has been developed. The diagnostic accuracy is 93%. A new software based on the deep learning pipeline is under development. The new software will be able to support rheumatologists in raising the diagnostic suspicion of interstitial lung diseases in patients affected by connective tissue diseases. This software can pave the way for a vast screening campaign of interstitial lung diseases in patients affected by autoimmune diseases.
4. A new pipeline based on deep learning algorithms has been developed to detect auscultations that do not contain useful information for the diagnosis of interstitial lung diseases secondary to connective tissue disease. The diagnostic accuracy obtained by combining the algorithm for detecting lung sounds that do not contain useful information with the algorithm for detecting interstitial lung disease secondary to connective tissue disease is 97%. A new software is under development; its scope consists of signaling the need to repeat the auscultation when lung sounds do not contain useful information for the diagnosis of interstitial lung disease.
5. The patent has been filed and other patents lying in the same field are in preparation.
6. The DiCoSound-ER project has been co-funded by the region Emilia-Romagna and the private company Redox srl (<http://www.redoxprogetti.it/>). The project has recently yielded a new tool suitable to non-invasive screening of interstitial pneumonia secondary to COVID-19. This invention can be interpreted as a new electronic phonendoscope capable of automatically detecting pathological lung sounds resulting from SARS-COV-2 interstitial pneumonia.

**Publications:** [J.23], [J.24], [J.25], [J.26], [J.27], [J.30], [J.31], [J.33], [J.35], [C.19], [P.4].

2.1.9 Medical equipment: electronic dermatoscope for the automatic analysis of the scalp through images

Alopecia is a widespread process of decreasing the quality and quantity of hairs, eventually up to the complete disappearance of the hair itself and the respective bulb. There are many forms of alopecia; in some cases, the etiology is partially or completely known, while in other cases it is predominantly unknown. In many cases a strong marker of alopecia is the miniaturization of the hair, so along with the “normal” hair there are also the so-called "vellus hair", hair with a markedly inferior diameter.

The multidisciplinary collaboration between dermatologists and engineers has led to the development of a non-invasive tool for the automatic diagnosis of alopecia. The tool is based on the acquisition of images through a suitable optical system and a common smartphone or tablet. The developed software allows to detect and quantify the miniaturization process of the hair. Our instrument is currently able to guarantee a reliability close to that of a dermatologist specialized in trichology.

**Publications:** [J.35], [P.5].

### 2.1.10 Condition monitoring of ball bearings

Ball bearings are the most common solution to constrain a rotating element to the frame. Ball bearings consist of 4 elements, namely inner ring, outer ring, cage and balls. In practice, the balls are exploited to transfer the forces between the inner ring and the outer ring and to provide a rotating contact without slipping between the shaft and the fixed structure. Unfortunately, the continuous contact between the elements leads to wears and breakages. In fact, some estimates evidence that 50-60% of machine downtime is entailed by wear and tear of the bearings. Therefore early detection of bearing failures is of great importance in every industrial plants.

A worn and/or broken bearing yields vibrations that can be considered different and "anomalous" with respect to the natural "machine noise". In particular, the vibrations of the mechanical system can be measured with a suitably positioned accelerometer; the stemming signal is cyclostationary in the presence of damage to the bearing.

The collaboration with mechanical engineers at the Department of Sciences and Methods for Engineering has led to the development of a new bearing damage detection algorithm based on the statistical definition of cyclostationarity. Experimental measurements have shown that the new algorithm is able to significantly outperform the classical counterparts available in the technical literature. Furthermore, the developed algorithm is intrinsically robust with respect to machine noise and involves a modest computational complexity, making this solution compatible with current commercial electronic devices.

A new model for machine noise has been developed to quantitatively compare the performance of different algorithms for condition monitoring and predictive maintenance of ball bearings. Such a model has been devised and validated through experimental measurements. Numerical results have evidenced that various algorithms well known in the technical literature, like for instance envelope detection, spectral kurtosis and spectral correlation, behave in a significantly different way in distinct scenarios.

**Publications:** [J.28], [J.32], [J.34], [C.20].

### 2.1.11 Analysis of stability and comfort in aerial cyclo-pedestrian walkways

Cycle and pedestrian walkways are widespread infrastructures that allow to cross both natural obstacles (rivers, gorges, ...) and other structures of anthropogenic origin (roads, railways, ...). these walkways are light and lean infrastructures capable to carry very limited loads, in the order of 400-

500 kg/m<sup>2</sup>. An emblematic example is the “Millenium Bridge” in London, where “lightness” was the key word behind the design. Following its opening in 2000, the walkway was crossed by thousands of pedestrians, but after only two days it was closed due to the effects of resonance and vibration that were not adequately considered and analyzed in the design phase. An important aspect of cycle and pedestrian walkways is, in fact, to guarantee "human comfort", where comfort for pedestrians is closely connected to the possible deformations and vibrations of the structure itself. Vibrational phenomena usually do not compromise the structural safety, however appreciable oscillations can induce feelings of discomfort and fear in people in transit. As a consequence, the analysis of vibrations and oscillations in cycle and pedestrian walkways is of fundamental importance to avoid situations of malaise and panic that might lead to an uncontrolled escape.

Dr. Fabrizio Pancaldi collaborates with civil engineers at the University of Modena and Reggio Emilia for the development of statistical models for pedestrian walking suitable to the study of stability and comfort of walkways. The new statistical model is capable to capture both the intrapersonal and interpersonal variability of pedestrian walking. It has been shown that a more accurate model can have an impact of up to 20-30% on the analysis of the forces and vibrations that come into play in the dynamic analysis of the stability and comfort of walkways.

**Publications: [J.29].**

#### 2.1.12 Medical equipment: system for automatic drug management and administration

The invention consists of a computerized system suitable to the management and administration of drugs. The system is composed of a mobile device, a fixed charging station and one or more optional devices (heart rate and blood pressure measuring device, smartphone, tablet, computer, ...). The portable platform represents the heart of the system, which is responsible for notifying the user of the types and dosages of drugs to be timely taken during the day via acoustic and visual signals. The mobile platform also guarantees the correct storage of medicines in a non-domestic environment within separate, recognizable and easily accessible slots. The data regarding the consumption of medicines and health parameters can be sent to a smartphone application and/or to a web page that can be consulted from any computer connected to the Internet. The fixed platform can be programmed according to the user's specific drug therapy and carries out the task of automatically filling the medicines into the portable dispenser in quantities appropriate to the daily requirement. The "target" beneficiaries of the system are hypertensive patients, who can have access to a self-organised portable dispenser which guarantees the conservation of blister-packed medicines and makes the pills available at the correct times and dosages in relation to the therapeutic plan. The system can be interfaced with a blood pressure monitor wearable on the wrist. This enables the remote control of the acquisition, storage and processing of data within a dedicated application on a smartphone.

Dr. Fabrizio Pancaldi is co-author of the related Italian patent application.

**Publications: [P.6].**

#### 2.1.13 Rovers and drones

The invention consists of a magnetic platform for docking and releasing drones from a moving vehicle. The proposed solution offers multiple advantages: (a) power consumption only in the dynamic phases of switching between docking and release (no power consumption in static conditions); (b) reduced electromagnetic disturbances; (c) reduced overall dimensions.

Dr. Fabrizio Pancaldi is co-author of the related Italian patent application.

**Publications:** [P.7].

## 2.2 Experimental activity

Dr. Fabrizio Pancaldi performs a technical-practical activity for the development of equipment characterized by a strong practical interest. The most relevant results of this laboratory activity are: (a) a narrowband PLC system; (b) a channel sounder suitable for powerline channel working in the band 0.1 – 30 MHz; (c) a self-organizing mesh network operating in the 2.4 GHz; (d) an inertial localization system particularly suitable for indoor scenarios; (e) a radio localization system for indoor scenarios operating at 169 MHz; (f) electronic phonendoscope for non-invasive automatic diagnosis of pulmonary fibrosis, interstitial lung disease and interstitial pneumonia; (g) electronic dermatoscope for non-invasive automatic diagnosis of androgenetic alopecia and telogen effluvium based on images taken with a smartphone or tablet; (h) system for the automatic drug management and administration; (i) magnetic platform for docking and releasing drones from a moving vehicle.

## 2.3 Scientific collaboration

Dr. Fabrizio Pancaldi currently collaborates with the Foundation for Research and Technology of Hellas (FORTH, Greece) and with the Technical University of Crete (TUC, Greece) under the supervision of Prof. Michalis Zervakis. The research groups operating at TUC and FORTH have strong experience in the field of artificial vision of biomedical images and in the field of clinical engineering. In particular, the collaboration concerns the development of a tool (hardware and software) capable of recognizing and measuring capillaroscopic changes caused by scleroderma spectrum disorders, in particular systemic sclerosis (SSc) and dermatomyositis (DM).

Dr. Fabrizio Pancaldi has been involved in the “Network of Excellence in Wireless COMMunications”, denoted with NEWCOM++ (contract number 216715). The scope of NEWCOM++ was to strengthen the integration among European research groups in the field of mobile radio communication systems beyond the third generation (3G). The reference website is [www.newcom-project.eu](http://www.newcom-project.eu). The NEWCOM++ project has been funded by the European Community within its 7FP. The research activity of Dr. Pancaldi is carried out at the University of Modena and Reggio Emilia, in the framework of the *Consorzio Nazionale Interuniversitario per le Telecomunicazioni* (CNIT), which is one of the most active members of the NEWCOM++ consortium.

From 2004 to 2008, Dr. Fabrizio Pancaldi collaborated with the University of Texas (Dallas, Texas, USA) and with the University of Waterloo (Waterloo, Ontario, Canada) for the study of channel equalization techniques.

From 2010 to 2013, Dr. Fabrizio Pancaldi collaborated with the University of Christchurch (New Zealand) for the preparation of the book "Wireless Communications: Algorithmic Techniques" published by the John Wiley & Sons publishing house.

## 2.4 International research projects

From February the 3rd of 2003 to December the 15<sup>th</sup> of 2003 and from March the 1<sup>st</sup> of 2004 to June the 30<sup>th</sup> of 2004, Dr. Fabrizio Pancaldi worked as research technical collaborator at the

Department of Information Engineering, University of Modena and Reggio Emilia; he was involved in the project entitled “Space Time codING for Reconfigurable wireless Access sYstems”, (STINGRAY – contract number: IST-2000-30173) funded by the European Community within its 5FP. The project was successfully completed on June 2004; the reference website is <http://stingray.intranet.gr>.

His research activity was focused on the investigation of novel statistical models for *multiple-input multiple-output* (MIMO) channels and on the development of the related channel simulator in C language.

During his research work he has established connections with the other partner of the project, namely INTRACOM S.A. Hellenic Telecommunications & Electronics Industry (Peania, Greece), Institute of Accelerating Systems and Applications (Athens, Greece), Technical Research Centre of Finland (Oulu, Finland) and National Technical University of Athens (Athens, Greece).

Since 2018, Dr. Fabrizio Pancaldi has been collaborating with the Technical University of Crete (TUC, Greece) and the Foundation for Research and Technology of Hellas (FORTH, Greece) on the development of algorithms for the analysis of capillaroscopic images. In fact, it has been shown that various physical parameters of superficial capillaries (number, size, shape, ...) are related to scleroderma spectrum disorders, in particular systemic sclerosis (SSc) and dermatomyositis (DM). The scope is providing quantitative support to the qualitative classification made by rheumatology specialists. The expected results are: (a) quantitative definition of a relationship between the physical parameters of the superficial capillaries and the various rheumatic diseases; (b) algorithms for the automatic classification of capillaroscopic images suitable to assist rheumatologists in the diagnosis of rheumatic diseases.

**Scientific results: [J.36], [T.1].**

## 2.5 National research projects

Since September 2004 to June 2005 Dr. Fabrizio Pancaldi worked at the Department of Information Engineering, University of Modena and Reggio Emilia, within the research project entitled “*Wideband Wireless Local Area Network*” (WWLAN). The reference website is <http://wwlan.alespazio.it>.

The project was co-funded by Alenia Spazio S.p.A and S.Paolo IMI S.p.A on behalf of *Ministero dell’Istruzione dell’Università e della Ricerca* (MIUR); the University of Modena and Reggio Emilia was involved as *third part*. The project started in July 2004 and finished in July 2005.

The scope of the project was to investigate a multi-segment system – wideband terrestrial wireless network, wideband satellite network, terrestrial cellular network– to be deployed in three different scenarios; the target consists of providing a *wideband wireless local area network* (WWLAN) integrated with wide area networks, like a satellite or a terrestrial network.

In particular, the activity accomplished by Dr. Pancaldi was focused on the analysis of signalling formats suitable to the considered scenarios, and on the development of channel equalization and clock synchronization algorithms for doubly selective channels.

Since 2014 Dr. Fabrizio Pancaldi has been collaborating with pulmonologists, rheumatologists and radiologists at the university hospital of Modena (Italy). The scope of the collaboration consists of the development of a new tool for the automatic detection of *interstitial lung diseases* (ILDs) secondary to chronic diseases like *idiopathic pulmonary fibrosis* (IPF) and *rheumatoid arthritis*

(RA). Basically, the tool can be interpreted as a new electronic phonendoscope capable to analyse the lung sounds and detect pathological conditions. The project was partially funded by the University of Modena and Reggio Emilia through a suitable fund for research. The access to the fund is on a competitive basis and relies to external per review. The budget of the project was 80,000 euros.

The scientific, technological and socio-economic impact of the invention is disruptive. In fact, the only drug currently available on the European market capable of counteracting IPF is pirfenidone, which has proved effective in slowing the progression of the disease only at an early stage. Considering the incidence of IPF on the Italian population, new cases of IPF in Italy are between 4200 and 6000 per year, of which only 45% are diagnosed within the first year of the onset of symptoms. Indeed, the number of early diagnoses of IPF could be significantly increased through a screening campaign launched on all people over 65 who go to the general doctor for various reasons. Potentially, every year in Italy, the life of a number of people between 1890 and 2700 could be save or their living conditions could be definitely improved. In addition, the incidence of RA (about 450,000 patients in Italy) prevents screening using *high resolution computer tomography* (HRCT), also considering the impossibility of predicting the onset of ILD and therefore the need to perform multiple HRCTs throughout the patient's clinical history. As a consequence, a non-invasive and low-cost screening method is needed to allow the selection of patients that have to undergo an HRCT for further investigation. Such a tool should be part of the technical equipment of every rheumatologist, allowing effective monitoring of the patient, minimizing exposure to ionizing radiation and reducing public spending on improper HRCT requests. In this context, **the new tool developed by Dr. Fabrizio Pancaldi represents the enabling technology for the improvement of the ILD diagnosis process, since auscultation is absolutely NON-INVASIVE for the person and at LOW COST for the Sanitary System (SS).**

A further social impact of the new tool consists of the possibility to monitor the follow up of fibrosing lung diseases objectively and non-invasively. Currently, the progression of the disease is essentially demanded to the sensitivity of the specialized doctor, since the HRCT cannot be repeated over short time supports. On the contrary, the new tool allows to objectively and punctually monitor the follow up of the disease regardless of the experience and/or skills of the medical staff, with appreciable advantages for both patients and sanitary system.

Given the high cost of hospitalization and maintenance of hospitals, a "home care" application, in which the patient himself records the lung sounds (possibly with the help of a family member) while the tool automatically uploads the related file, can be of great help. In fact, on the one hand the patient can stay comfortably at home, while, on the other hand, the doctor can earn detailed information about the follow up of the disease. Consequently, the discomfort for the patient is very limited, whereas the cost for the sanitary system is reduced.

The recent COVID-19 pandemic has shown that interstitial pneumonia is the main cause of death in symptomatic patients and is frequently complicated by respiratory distress syndrome requiring hospitalization and assisted ventilation. The ability to early identify patients with pulmonary involvement becomes therefore essential to discriminate who requires hospitalization and in-depth clinical monitoring.

Dr. Fabrizio Pancaldi is the principal investigator of the DiCoSound-ER project co-funded by the region Emilia-Romagna and by the private company Redox srl (<http://www.redoxprogetti.it/>) in 2020 .The project has recently yielded to a new tool for non-invasive screening tool of interstitial pneumonia secondary to COVID-19. This invention can be interpreted as a new electronic phonendoscope capable to automatically detect pathological lung sounds resulting from SARS-COV-2 interstitial pneumonia.

The health and social impacts expected from the project includes

- early and immediate identification of people with COVID-19 interstitial pneumonia, reducing the need to systematically request chest HRCT;
- the optimization of the distribution of patients in healthcare facilities and in home isolation;
- potentially, a reduction in deaths from respiratory distress syndrome not promptly identified.

Therefore, the figures that can benefit from the tool are

- local doctors who must decide whether to send to a health facility for further information or to maintain home isolation of a patient positive for the SARS-COV-2 virus, with or without respiratory symptoms;
- healthcare personnel working in advanced facilities who must decide whether to request a chest HRCT for a patient positive or suspected positive to COVID-19;
- all those who care people with suspected symptoms to COVID-19 in home isolation.

# 3 Teaching activity

Dr. Fabrizio Pancaldi gives various courses at the Department of Sciences and Methods for Engineering, University of Modena and Reggio Emilia (Italy). For each academic year, the given courses, the hours devoted to the teaching activity and the rating of the teacher are reported, respectively. All the courses given by Dr. Fabrizio Pancaldi are mandatory in the related BS and MS degree courses.

## 3.1 Academic year 2024/2025

### 3.1.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Embedded Systems**; the teaching load amounts to **54 hours**.
- **Smart Systems for Data Acquisition**; the teaching load amounts to **27 hours**.

### 3.1.2 Ratings

- **Communication Networks**; satisfaction indicator: the course ended in December 2024 and the related indicators are not available yet.
- **Embedded Systems**; satisfaction indicator: the course will be given starting from March 2025.
- **Smart Systems for Data Acquisition**; satisfaction indicator: the course ended in December 2024 and the related indicators are not available yet.

## 3.2 Academic year 2023/2024

### 3.2.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Embedded Systems**; the teaching load amounts to **54 hours**.
- **Smart Systems for Data Acquisition**; the teaching load amounts to **27 hours**.

### 3.2.2 Ratings

- **Communication Networks**; satisfaction indicator: 100%.
- **Embedded Systems**; satisfaction indicator: 68%.
- **Smart Systems for Data Acquisition**; satisfaction indicator: 78%.

## 3.3 Academic year 2022/2023

### 3.3.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Embedded Systems**; the teaching load amounts to **54 hours**.

### 3.3.2 Ratings

- **Communication Networks**; satisfaction indicator: 93%.
- **Embedded Systems**; satisfaction indicator: 89%.

## **3.4 Academic year 2021/2022**

### 3.4.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Embedded Systems**; the teaching load amounts to **54 hours**.

### 3.4.2 Ratings

- **Communication Networks**; satisfaction indicator: 94%.
- **Embedded Systems**; satisfaction indicator: 86%.

## **3.5 Academic year 2020/2021**

### 3.5.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.

### 3.5.2 Ratings

- **Communication Networks**; satisfaction indicator: 90%.

## **3.6 Academic year 2019/2020**

### 3.6.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.
- **Final Synthesis Lab 2 - Educational technology innovation - Systems and communications for educational smart objects**; the teaching load amounts to **30 hours**.

### 3.6.2 Ratings

- **Communication Networks**; satisfaction indicator: 87%.
- **Distributed ICT Systems**; satisfaction indicator: 88%.
- **Final Synthesis Lab 2 - Educational technology innovation - Systems and communications for educational smart objects**; the satisfaction indicator is not available for this course.

## **3.7 Academic year 2018/2019**

### 3.7.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.
- **Final Synthesis Lab 2 - Educational technology innovation - Systems and communications for educational smart objects**; the teaching load amounts to **30 hours**.

### 3.7.2 Ratings

- **Communication Networks**; satisfaction indicator: 91%.
- **Distributed ICT Systems**; satisfaction indicator: 76%.
- **Final Synthesis Lab 2 - Educational technology innovation - Systems and communications for educational smart objects**; the satisfaction indicator is not available for this course.

## **3.8 Academic year 2017/2018**

### 3.8.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

### 3.8.2 Ratings

- **Communication Networks**; satisfaction indicator: 91%.
- **Distributed ICT Systems**; satisfaction indicator: 95%.

## **3.9 Academic year 2016/2017**

### 3.9.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

### 3.9.2 Ratings

- **Communication Networks**; satisfaction indicator: 94%.
- **Distributed ICT Systems**; satisfaction indicator: 100%.

## **3.10 Academic year 2015/2016**

### 3.10.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

### 3.10.2 Ratings

- **Communication Networks**; satisfaction indicator: 96%.
- **Distributed ICT Systems**; satisfaction indicator: 100%.

## **3.11 Academic year 2014/2015**

### 3.11.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

### 3.11.2 Ratings

- **Communication Networks**; satisfaction indicator: 90%.
- **Distributed ICT Systems**; satisfaction indicator: 100%.

### 3.12 Academic year 2013/2014

#### 3.12.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

#### 3.12.2 Ratings

- **Communication Networks**; the teacher rating is 8.07 over 10.
- **Distributed ICT Systems**; the teacher rating is 8.91 over 10.

### 3.13 Academic year 2012/2013

#### 3.13.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

#### 3.13.2 Ratings

- **Communication Networks**; the teacher rating is 7.56 over 10.
- **Distributed ICT Systems**; the teacher rating is 9.00 over 10.

### 3.14 Academic year 2011/2012

#### 3.14.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **54 hours**.

#### 3.14.2 Ratings

- **Communication Networks**; the teacher rating is 7.35 over 10.
- **Distributed ICT Systems**; the teacher rating is not available.

### 3.15 Academic year 2010/2011

#### 3.15.1 Courses

- **Communication Networks**; the teaching load amounts to **54 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **27 hours**.

#### 3.15.2 Ratings

The teacher ratings are not available.

### 3.16 Academic year 2009/2010

#### 3.16.1 Courses

- **Communication Networks**; the teaching load amounts to **60 hours**.
- **Distributed ICT Systems**; the teaching load amounts to **30 hours**.

#### 3.16.2 Ratings

- **Communication Networks**; the teacher rating is 9.14 over 10.
- **Distributed ICT Systems**; the teacher rating is 7.14 over 10.

### 3.17 Academic year 2008/2009

#### 3.17.1 Courses

- **Communication Networks**; the teaching load amounts to **60 hours**.
- **Networking Techniques**; the teaching load amounts to **60 hours**.

#### 3.17.2 Ratings

- **Communication Networks**; the teacher rating is 9.57 over 10.
- **Networking Techniques**; the teacher rating is 8.50 over 10.

### 3.18 Academic year 2007/2008

#### 3.18.1 Courses

- **Communication Networks**; the teaching load amounts to **60 hours**.
- **Networking Techniques**; the teaching load amounts to **60 hours**.

#### 3.18.2 Ratings

- **Communication Networks**; the teacher rating is 8.60 over 10.
- **Networking Techniques**; the teacher rating is 9.30 over 10.

### 3.19 Academic year 2006/2007

#### 3.19.1 Courses

- **Communication Networks**; the teaching load amounts to **60 hours**.
- **Networking Techniques**; the teaching load amounts to **60 hours**.

#### 3.19.2 Ratings

- **Communication Networks**; the teacher rating is 8.25 over 10.
- **Networking Techniques**; the teacher rating is 9.11 over 10.

### 3.20 Academic year 2005/2006

#### 3.20.1 Course

- **Communication Networks**; the teaching load amounts to **60 hours**.

#### 3.20.2 Rating

The teacher rating is not available for this academic year.

### 3.21 Project RED

Dr. Fabrizio Pancaldi is Faculty Advisor of Project RED ([www.projectred.it](http://www.projectred.it)) since 2019, year of birth of the project. The scientific/technical scope of the project consists of designing, developing, and implementing a rover for the exploration of Mars planet. The team of Project RED is currently composed by more than 50 students enrolled in the Department of Sciences and Methods for Engineering, however students coming from other Departments, like Economy and Geology, of the University of Modena and Reggio Emilia are also involved. Project RED has the ambitious goal of developing multidisciplinary skills in the broad fields of robotics, aerospace technology, earth science and business/managerial science. Professional profiles trained within the Project RED have a great value for private companies and the national industrial scenario in general. Project RED

competed in the European Rover Challenge (<https://roverchallenge.eu/>) 2021 with teams coming from all over the world. Project RED ranked 21<sup>st</sup> over 58 participants to the “on-site” competition, and ranked 9<sup>th</sup> on 38 participants to the “remote” competition. Project RED competed in the European Rover Challenge (<https://roverchallenge.eu/>) 2022 with teams coming from all over the world. Project RED ranked 16<sup>th</sup> over 64 participants to the “on-site” competition, and ranked 3<sup>rd</sup> on 28 participants to the “remote” competition. Project RED was one of the three teams capable to qualify and compete on both the “remote” and “on-site” competition. Project RED competed in the European Rover Challenge (<https://roverchallenge.eu/>) 2023 with teams coming from all over the world. Project RED ranked 9<sup>th</sup> over 88 participants to the “on-site” competition, and ranked 3<sup>rd</sup> on 54 participants to the “remote” competition. Project RED entered the “top 10” of physical rovers at the 2023 European Rover Challenge. Project RED competed in the European Rover Challenge (<https://roverchallenge.eu/>) 2024 with teams coming from 23 countries all over the world. Project RED ranked 21<sup>st</sup> over 69 participants to the “on-site” competition.

### **3.22 Other activities**

Dr. Fabrizio Pancaldi has been the supervisor of a large number of Bachelor’s and Master’s degree students in Electrical Engineering, Communications Engineering, Business and Management Engineering and Mechatronics Engineering. He has been the supervisor of 4 PhD students at the International Doctorate School in Information and Communication Technology, University of Modena and Reggio Emilia. He is currently the supervisor of 1 doctoral student at the Doctoral School in Industrial Innovation Engineering of the University of Modena and Reggio Emilia. He has been reviewer of various doctorate theses for both Italian and international universities.

# 4 Technological transfer and public engagement

Dr. Fabrizio Pancaldi cooperates with both small local enterprises and large enterprises of international relevance.

## 4.1 Technological transfer to enterprises

### 4.1.1 Cooperation with OCEM SpA located in Bologna and Augier Energy SpA located in Nice.

The enterprises OCEM SpA located in Bologna and Augier Energy SpA located in Nice work in the field of lighting plants, devoting particular attention to airport lighting. The research group of Dr. Pancaldi is involved in the design of communication systems suitable to the remote management of the lamps. Besides this activity, the idea of distributed terrestrial radar has been patented [B.1]. In particular, the system concerns the positioning of airplanes and airport vehicles on the basis of a wireless sensor network. Dr. Fabrizio Pancaldi holds the intellectual property of the patent; the details are available at the link (<http://www.wipo.int/pctdb/en/wo.jsp?WO=2009133102&IA=EP2009055128&DISPLAY=STATUS>).

### 4.1.2 Cooperation with TechImp SpA located in Bologna.

The enterprise TechImp SpA located in Bologna designs and develops electronic devices for the diagnosis of very high power electrical equipment. Dr. Fabrizio Pancaldi works as a supervisor for the development of radio frequency sensors and measurement equipment for the detection of partial discharges in *gas insulated systems* (GIS).

### 4.1.3 Cooperation with Hiscores s.r.l. located in Modena.

The enterprise Hiscores cope with the design, the development, the installation and the placing on the market of high technology equipment suitable to interact with firearms. Dr. Fabrizio Pancaldi and Dr. Rovati are involved in the design and the development of a virtual shooting range, where the target consists of a screen on which a fixed image or a movement video can be projected. The scope of the project is to develop the electro-optic instruments necessary to provide the interaction between the (true) projectile cutting the (virtual) target projected onto the screen.

### 4.1.4 Cooperation with Redox s.r.l. located in Reggio Emilia.

Redox s.r.l. (<http://www.redoxprogetti.it/>) is an enterprise working in the wide field of wireless communications as far as design, prototyping and production are concerned. Dr. Fabrizio Pancaldi has supervised the development of 6 new products:

- A Bluetooth intercom enabling the communication among 8 users simultaneously. This product is particularly suitable to groups of people doing the same activity, as for instance bikers, runners, ...

- An electronic board having dimension of few cm<sup>2</sup> and thickness of 1 mm capable to embed different types of sensors for endoscopic investigation of industrial machinery (<https://www.laboratoriomister.it/en/portfolio/micronet/>).
- A datalogger endowed with Bluetooth Low Energy communication for the acquisition of signals from inertial sensors. The scope of the device consists of condition monitoring of industrial machinery (the project is called SMEDIP and has been funded by Regione Emilia Romagna).
- A new generation of smart lamps for public illumination capable to automatically detect theft and damage to the system, as well as to locate citizens that have activated an alarm in dangerous situations (the project is called LAMPANET and has been funded by Regione Emilia Romagna).
- An electronic phonendoscope suitable to the acquisition and automatic detection of pathological lung sounds. The phonendoscope can be connected through a BLE link or USB connection to a tablet or smartphone (the project is called DICOSOUNDER, <https://dicosounder.it/en/project/>).
- A communication system based on 5G technology, both infrastructured and C-V2X, for the transmission of information aimed at assisted driving. The system is characterized by high data rate and very limited latency, takes advantage of MIMO technology for diversity detection and beamforming, enables the communication between vehicles (P2P communication) and between a vehicle and the infrastructure. The project is called 5GCAR and has been co-funded by region Emilia-Romagna (Italy). The reference website is <https://5g-car.it/progetto/>.

#### 4.1.5 Cooperation to the project “MICRONET” funded by Regione Emilia Romagna

MICRONET represents one of the four Strategic Projects funded by Regione Emilia Romagna. In practice MICRONET denotes a new platform for the control of *micro electro-mechanical systems* (MEMS) in consumer and industrial applications. This platform is encapsulated in a smart package suitable to be used in harsh environments. Dr. Fabrizio Pancaldi currently leads the development of the firmware for a pressure logger employed to monitor the absolute pressure in airtight packages filled with a fluid.

#### **4.2 Cooperation with Reggio Emilia Innovazione located in Reggio Emilia**

Reggio Emilia Innovazione (REI, <https://www.reinnova.it/>) was founded in 2003 under the push of the University of Modena and Reggio Emilia, the Province and the Municipality of Reggio Emilia, the Chamber of Commerce, Capitalia S.p.A. and the local entrepreneurial network. The business target is promoting and assisting applied research, technological transfer and services related to product development and certification. Both private enterprises and public organizations take advantage of the services provided by REI. Dr. Fabrizio Pancaldi led the Notified Body (NB) from 2007 to 2013 against the European Directive 99/5/EC concerning radio equipment and telecommunications terminal equipment. In practice, radio equipment can be placed on the European market provided that it is marked with the European Community mark, i.e. it complies to given essential requirements in terms of health and safety, electromagnetic compatibility and efficient use of the radio spectrum. In particular Dr. Fabrizio Pancaldi has dealt with Expert Opinions (EOs) according to Annex IV of the European Directive 99/5/EC for a wide class of radio devices, namely Bluetooth, WiFi, 2G, 3G, GPS, sub GHz communications in the ISM bands 433 MHz and 868 MHz.

### **4.3 Collaboration with the Province of Reggio Emilia**

Dr. Fabrizio Pancaldi has been appointed as member of the Provincial Council of Reggio Emilia for Television and Radio Broadcasting, according to Article 20 of the Regional Law n. 30 of 31/10/200, on the basis of the Enactment of the President n. 52 of 07/09/2010. Such Council is charged to supervise over the safety and the health of citizens and environment, as far as the installation and the maintenance for TV and radio broadcasting is concerned.

### **4.4 Articles in newspapers and television interviews**

The study on the new phonendoscope for the automatic diagnosis of fibrosing lung diseases has appeared in various local newspapers (Gazzetta di Modena, Resto del Carlino) and academic magazines (UNIMORE Focus, UNIMORE Symbols). Moreover, Dr. Fabrizio Pancaldi has been interviewed during a news bulletin at the local Modena television station QuiTV.

The study focused on the new electronic phonendoscope for the automatic diagnosis of the interstitial pneumonia secondary to COVID-19 has appeared on local newspapers (Gazzetta di Modena, Gazzetta di Reggio Emilia) and national newspapers (Resto del Carlino). The study has been disseminated also by the social media of region Emilia-Romagna and has been broadcasted by several local news programs.

### **4.5 Collaboration with REI Lab**

REI Lab was founded in 2017 under the push of the Industrial Association of the Province of Reggio Emilia to offer product testing and certification services. Dr. Fabrizio Pancaldi collaborates with REI Lab on various topics:

- regulatory assistance for the CE marking of radio products under the Radio Equipment Directive 2014/53/EU;
- design and development of new measurement chains for radio tests required by the product standards related to Radio Equipment Directive 2014/53/EU;
- design and development of an ultraviolet (type C) ray sanitizer for small objects of common use (keys and key rings, cards,...) with BLE connectivity to a tablet or smartphone.

### **4.6 Collaboration with Ente Certificazione Machine**

Ente Certificazione Macchine (ECM) was founded in 1998 and operates mainly in the sectors of certification and testing of industrial, medical, electronic and radio products. Dr. Fabrizio Pancaldi cooperates with ECM covering the roles of

- Technical Manager and member of the deliberation committee for the CE marking of radio products in accordance with the Radio Equipment Device (RED) Directive 2014/53/EU;
- Technical Manager and member of the deliberation committee for the CE marking of products in accordance with the Electro-Magnetic Compatibility (EMC) Directive 2014/30/EU;

Dr. Fabrizio Pancaldi has undertaken a qualification process in cybersecurity matters to appropriately deal with the Delegated Regulation 2022/30 which will come into force on 1 August 2025.

# 5 Consulting activity

Dr. Fabrizio Pancaldi performs his consulting activity in the wide areas of informatics, electronics and telecommunications.

## 5.1 Technical/legal consulting

### 5.1.1 Civil Lawsuit RG. N. 18762/08 pursued at the Tribunal of Bologna (Italy)

Dr. Fabrizio Pancaldi has been Plaintiff Technical Consultant (*Consulente Tecnico di Parte*, CTP) in the civil lawsuit RG. N. 18762/08 focused on a GSM telephone dialler for elevator applications.

### 5.1.2 Civil and Penal Lawsuits

Dr. Fabrizio Pancaldi has been Court Technical Consultant (*Consulente Tecnico di Ufficio*, CTU) for several civil and penal lawsuit at the courts of Modena and Bologna (Italy).

# 6 Management and Administration

## **6.1 Administration at the Municipality of San Cesario sul Panaro (Modena, Italy), 2019-2024**

From June 2019 to June 2024 Dr. Fabrizio Pancaldi held the role of Councilor at the Municipality of San Cesario sul Panaro with delegations to the environment, waste, new technologies and information systems.

## **6.2 Administration at the Municipality of San Cesario sul Panaro (Modena, Italy)**

Since June 2024, Dr. Fabrizio Pancaldi holds the role of Councilor at the Municipality of San Cesario sul Panaro with responsibilities for the environment, urban planning, ecological transition and new technologies.

# 7 List of Publications

## 7.1 Books

- [B.1] G. M. Vitetta, D. P. Taylor, G. Colavolpe, F. Pancaldi and P. Martin, **Wireless Communications: Algorithmic Techniques**, John Wiley & Sons, 2013.

## 7.2 Journals

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#### 7.4 Technical design notes

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#### 7.5 Patents

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Reggio Emilia (Italy), January 3rd, 2025

Fabrizio Pancaldi