IT'IS FOUNDATION
2017

Cover: NEUROMAN "Functionalized Anatomical Models for Studying EM-Neuronal Dynamic Interactions"

ANOTHER SUCCESSFUL YEAR

In 2017, the IT'IS Foundation has achieved important milestones in both of its primary research areas, namely electromagnetics and precision medicine.

Since the onset of the wireless revolution in the late 1980s, we have worked closely with academia, governments, regulators, and industry to develop the scientific basis and tools needed to assess the exposure and risks associated with the first (1G) through fourth generations (4G) of wireless technologies – first at D-ITET of the ETH Zurich, and since 1999 as the IT'IS Foundation. In 2015, we initiated several research projects related to body-worn transmitters that operate at frequencies above 6 GHz, to close important gaps that might delay the rapid market introduction and thorough risk assessment of currently emerging 5G technologies. Our most recent achievements include the development of instrumentation for demonstrating compliance with exposure guidelines of devices operating at millimeter wavelengths, even in the close near-field of transmitters (page 12), and we have solved five of the most urgent scientific and engineering problems for evaluating exposures at 6 – 10 GHz (page 13).

IT'IS continually maintains and extends its library of computational human and animal models to empower *in silico* design, optimization, and evaluation of medical devices. The basis of the virtual population (ViP) was established 20 years ago with the development of anatomical head models to access the variability of wireless exposure as a function of anatomy. The current ViP library – consisting of 24 high-resolution, full-body anatomical models – is used for a variety of applications. In this respect, two recent achievements of considerable importance should be mentioned: 1) We have successfully requested funding for the project NEUROMAN "Functionalized Anatomical Models for Studying EM-Neuronal Dynamic Interactions" from the Swiss Commission for Technology and Innovation (CTI) and the Korea Institute for Advancement of Technology. For the project, we are partnering with two leading Korean medical universities to develop the "Korean Couple" (based on the Korean visual male and female models), and the first monkey computational anatomical model created thus far. Most importantly, NEUROMAN will be a major step towards functionalization of our ViP models with the addition of neuromodulation capabilities (see cover) in addition to the already widely-used perfusion functionality. 2) The second major achievement is the successful development of a multi-resolution registration algorithm capable of morphing a high-resolution, highly detailed model into arbitrary body shapes. Apart from creating broader anatomical variability at low cost, the new method constitutes a major step towards the creation of full-body models of individual patients with only a few mouse-clicks and the promise of *in silico* based precision medicine (page 16).

Another very important success story is the award of the project "Open Online Simulations for Stimulating Peripheral Activity to Relieve Conditions (o^2S^2PARC)" funded by the U.S. National Institutes of Health (NIH) (pages 14 – 15). With o^2S^2PARC, we aim to build a freely accessible interactive online platform for simulating neuromodulation of the complex human peripheral nervous system. This project will consolidate all of the tools and knowledge of SPARC and those developed in our collaborations with research groups and industry in the field of neuro-modulation: e.g., the project "Restoring locomotion in paraplegic patients based on targeted epidural electrical stimulation)" funded by EUROSTARS and our joint research on noninvasive deep-brain stimulation via delivery of temporally interfering electric fields with the Massachusetts Institute of Technology (USA) and Imperial College London (UK). o^2S^2PARC will also open the door to evaluate, explore, and develop future computer technologies that have the potential to be a technology shift for complex multi-physics simulations.

IT'IS owes its success to the commitment, intelligence, agility, and creativity of our hard-working staff (page 5) as well as to our dedicated network of partner universities and research institutes in Switzerland and abroad (page 10). Special thanks go out to the members of the Foundation Board (page 4) for their continuous commitment in guiding us to select the most promising research projects. We happily welcome Prof. Lukas Novotny, who will further strengthen and broaden our engagement with the ETH Zurich, as the 11th member of the Board. We are also extremely grateful to our many sponsors and donors (Page 9) who generously support us in the pursuit of our goals, especially CTI, the Swiss National Science Foundation (SNSF), the EU Commission, and the U.S. National Institutes of Health (NIH).

Zurich, January 2018 Prof. Niels Kuster

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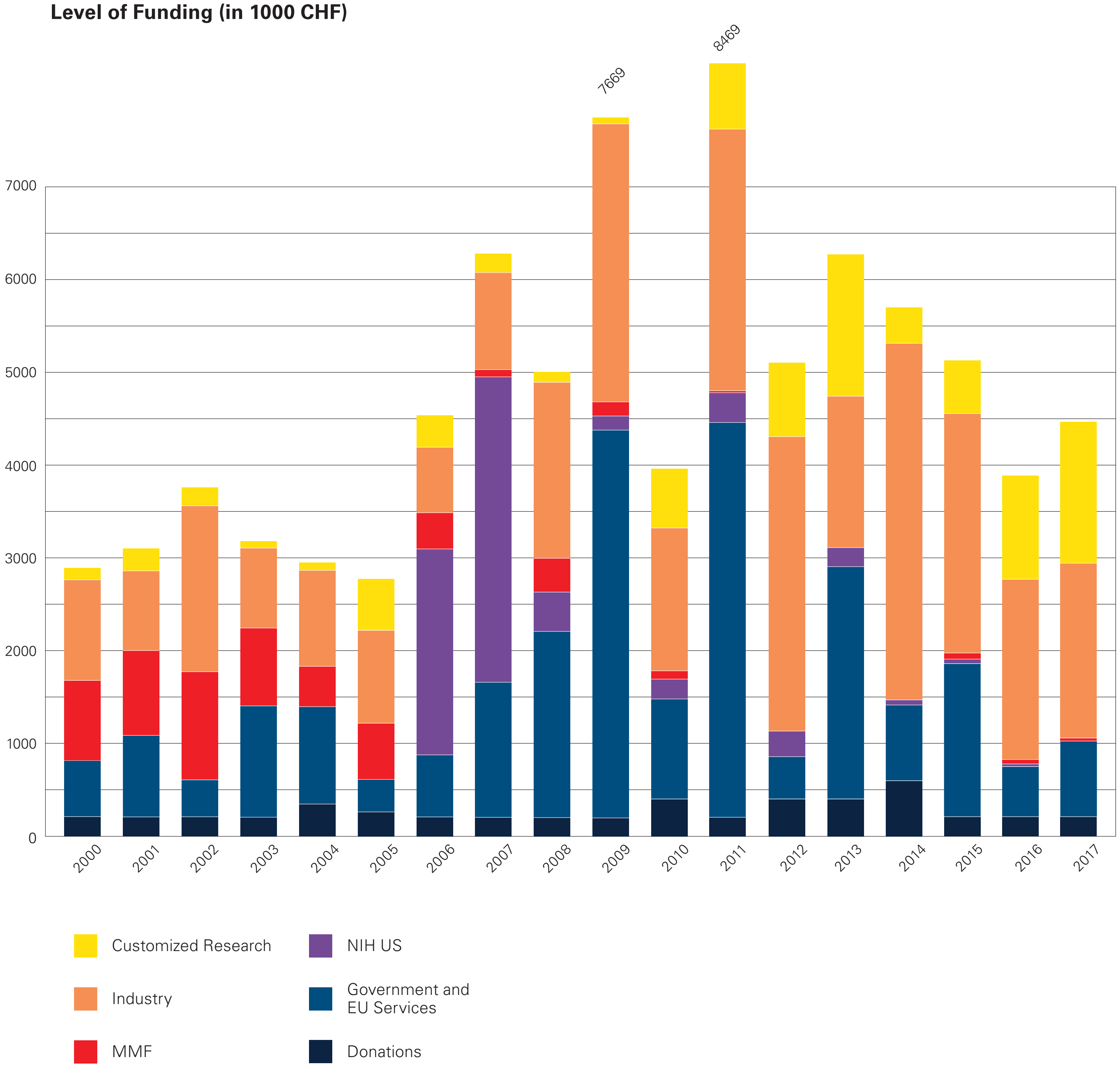
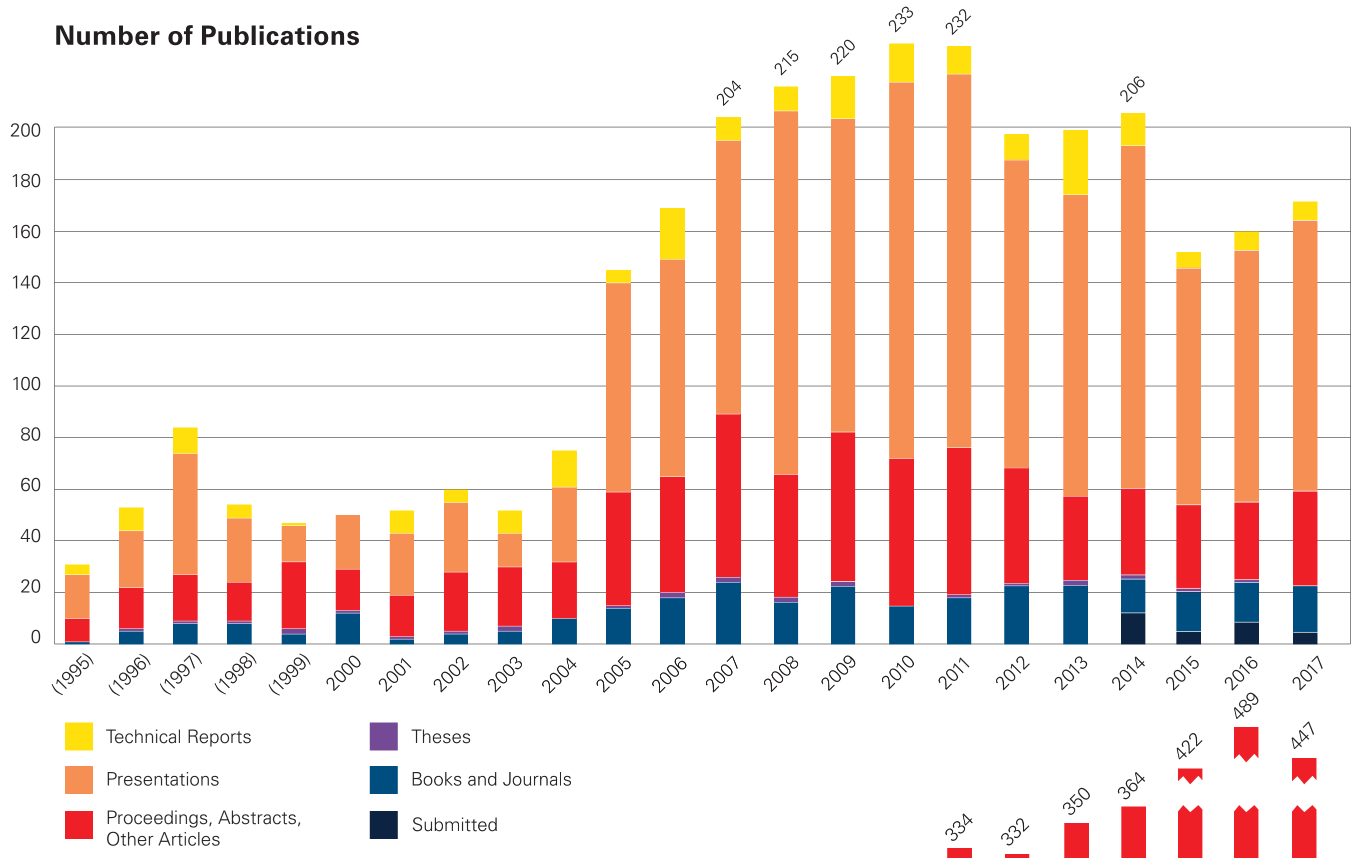
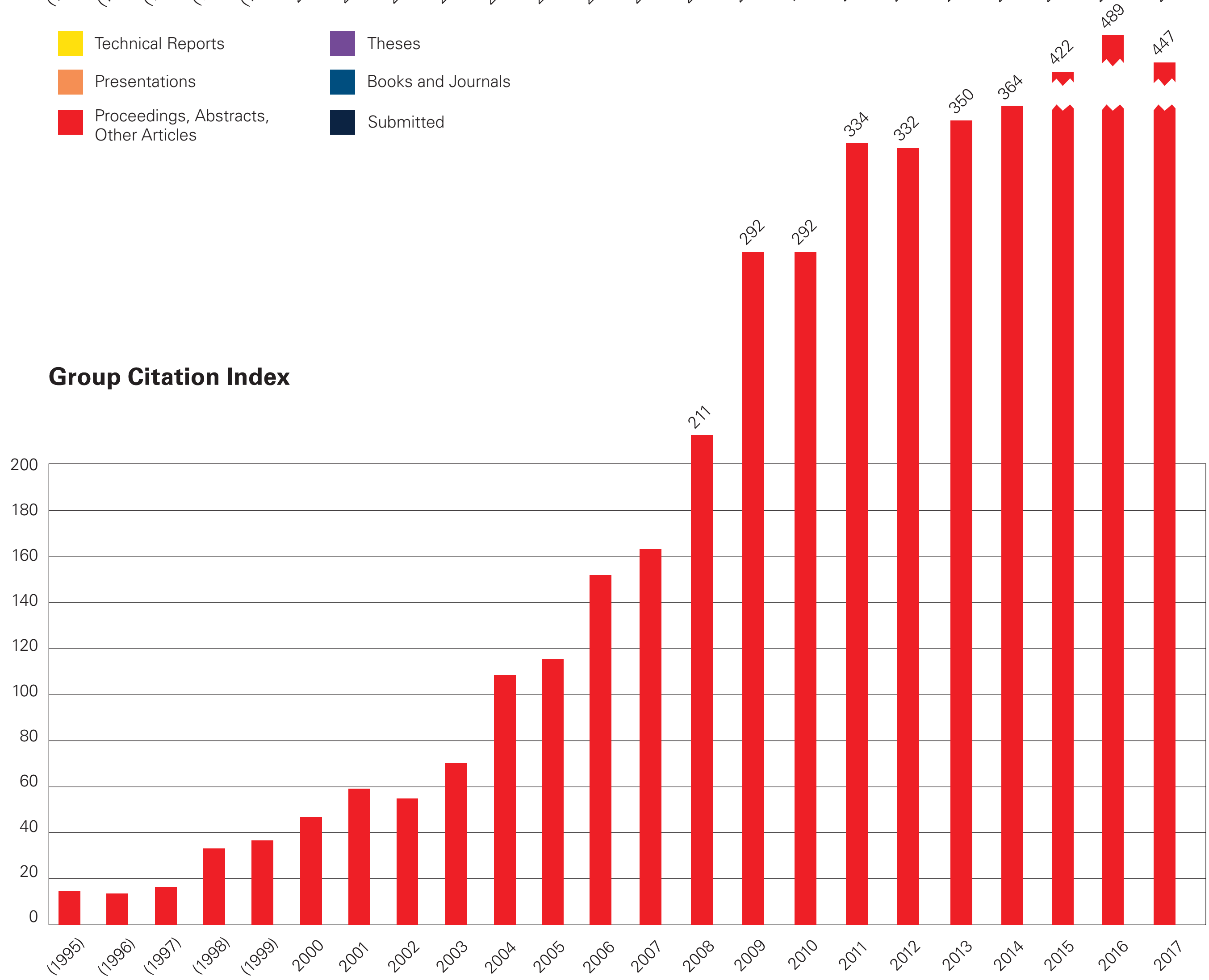


KEY FIGURES

Number of Publications



Group Citation Index



Years in parentheses (1993–1999) show citation development while at ETH, before IT'IS was established as an independent foundation.

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Biotronik, DE
Draeger, DE
Forschungs- und Technologiezentrum der Deutsche Telekom, DE
Incos Boté Cosmetic GmbH, DE
Kathrein-Werke KG, DE
Pfisterer International AG, DE
Roche Diagnostics, DE
Siemens AG, DE
T-Mobile International AG, DE
TÜV SÜD Auto Service GmbH, DE
SYNOSTE, FI
Healtis, FR
Image Guided Therapy, FR
Orange S.A., FR
Oticon Medical, FR
Sorin CRM/LivaNova, FR
THESS, GR
Istituto Di Ricerche Biomediche "Antoine Marxer" S.p.A., IT
MEDICO SpA., IT
TILAB SpA., IT
Alnair Labs, JP
ARIB – Association of Radio Industries and Businesses, JP
Mitsubishi, JP
NTT Communications, JP
NTT DoCoMo, JP
Toshiba, JP
HCTM, KR
G-Therapeutics, NL
Philips Medical Systems, NL
Vratis, PL
Ericsson Radio Systems AB, SE
Torptronics Engineering AG, SE
Volvo Car Corporation, SE
IndexSAR, UK
Vodafone, UK
York EMC Services, UK
Abbott (former St. Jude Medical Inc.), US
AGC Automotive, US
AT&T, US
Boston Scientific, US
CTIA, US
Exponent Inc., US
GE Healthcare, US
Imricor Medical Systems, US
Intel Corp., US
Mainstay Medical, US
Micro Systems Engineering Inc., US
Motorola, US
MRI Interventions Inc., US
National Instruments, US
Nevro Corporation, US
Qualcomm, US
SeboTek Hearing Systems, US

** For more information about individual departments, please consult https://www.itis.ethz.ch/who-we-are/partners/*

PROJECTS

EM Technology

TD SENSOR	Development of time-domain near-field field sensor technology
OH4VNA	Development of a miniature optically-fed electrical measurement head for a vector network analyzer
ICEy-RE	Implementation and validation of a novel dual near-field EMC/EMI and radiated emission testbed
WPT/P11	Development of test equipment and software to show compliance with electromagnetic safety guidelines for wireless power transfer systems

EM Exposure and Risk Assessment

sXc, sXv, sXh	Development of optimized exposure systems for bio-experiments from static to GHz fields
sXv – NTP/NIEHS-II	Development, manufacturing, installation, and detailed dosimetry of the NIEHS *in vivo* follow-up studies
FP7 GERoNiMO	Novel methods for generalized electromagnetic field research
ANIMEX	Development, manufacturing, installation, and detailed dosimetry of a reverberation chamber-based exposure system for INERIS
CREST	Characterization of radiofrequency exposure due to novel usage scenarios or new technologies for mobile communications devices
BfS Ex-Mice	Dosimetric assessment on detailed anatomical mice models of radiofrequency exposure
EPIRADIOMEM	Investigations of the effect of LTE 4G signals on cognitive functions, such as memory and its underlying epigenetic regulation
MICEV	Development of metrology techniques to advance inductive power transfer for charging electric vehicles

IT'IS for Health

CLS - o^2S^2PARC	Establishment of an interactive, freely accessible online platform for simulating peripheral nerve system neuromodulation/stimulation
CLS - FUS	Transcranial Focused Ultrasound; Sonoknife; Liver motion during FUS interventions
CLS - V&V40	Development of novel concepts for verification and validation of computational life science software platforms and their applications
ViP 4.x	Development of the next generation of high-resolution anatomical models
ViP - NEUROMAN	Functionalized anatomical models for studying electromagnetic-neuronal dynamic interactions
ViP - P/VM/M	Development of novel posers, of methodology for enhanced volume meshes of anatomical structures and of a physically-based morphing tool
MRI - MRIneo	Development of magnetic resonance imaging exposure risk probability for fetuses and newborns based on local temperature safety considerations
MRI - MRInext	Development of tools to morph anatomical models to patient anatomies for in silico personalized radiofrequency exposure assessment
MRI - Implant Safety	Improved procedures and instrumentation for MR-safety evaluation of medical implants
MRI - ULF NMR	Development of numerically validated magnetic resonance imaging coil and electric phantom models, and optimization of neuronal current imaging with ultra-low field nuclear MR
AneuX	Development of predictive tool to use shape as biomarker for aneurysm disease
PerfusImaging	Establishment of a metrological framework for blood perfusion measurements of impaired heart tissues by means of medical imaging technology
RESTORE	Development of a patient-specific system based on targeted epidural electrical stimulation to restore locomotion in paraplegic patients
HT-KSA/UHZ/ETHZ	Development of novel hyperthermia hardware and treatment planning software for human applications
MagnetoTheranostics	Early detection and treatment of prostate cancer lymph node metastases with nanomagnetite particles (Swiss-NanoTera project)
REPLICATIONS	Validation and mechanistic investigation of modulation-specific cellular electromagnetic effects published by Zimmermann et al.
STANDARDIZATION	Participation in regulatory activities of standards committees and governments

INSTRUMENTATION FOR COMPLIANCE TESTING OF 5G MOBILE DEVICES

With demand for ever greater bandwidths, emerging 5G mobile communication systems are likely to bring millimeter-wave technologies into mobile devices. The latest implementation plans feature frequency ranges mainly around 28 – 65 GHz.

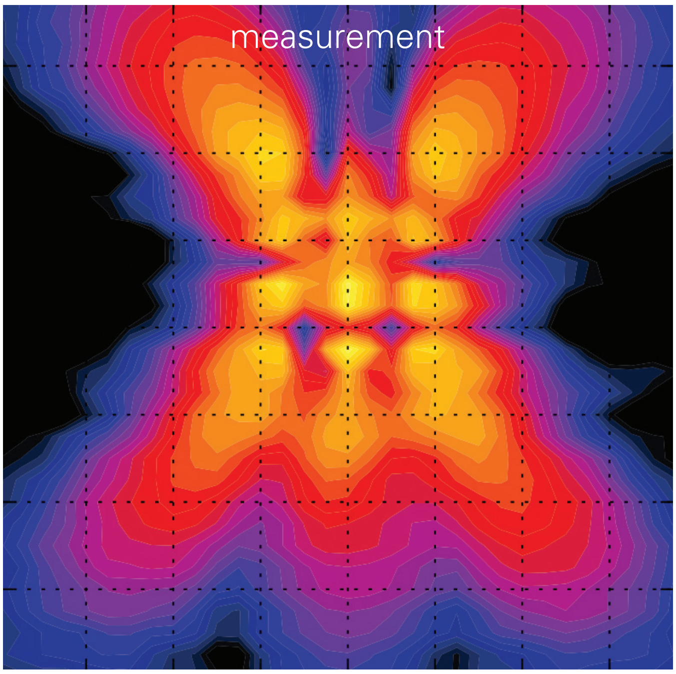
Human exposure to millimeter wave sources has so far been considered only for the far field, i.e., at distances larger than a few wavelengths, which imposes several potential threats regarding the introduction of 5G technologies: 1) current safety guidelines lack the scientific basis for localized sources (see page 13), and 2) measurement equipment for testing the compliance of 5G millimeter wave devices with regard to current safety guidelines (i.e., the spatially averaged power flux density incident to human skin that requires the knowledge of the Poynting vector in the reactive near-field) is lacking.

Together with our industrial partner, Schmid & Partner Engineering AG (SPEAG), we developed a novel electric near-field probe that is small and spherically isotropic with negligible scattering for frequencies up to 110 GHz. The probe is based on the pseudo-vector design invented by IT'IS in the late 1990s. The great advantage of the design is that it can be realized within a very small volume, allows compensation for field distortions, and derives not only the amplitude but also the electric (E-) field polarization ellipses with the highest precision. The EUmmWV2 probe meets the specifications for accurate assessment between 750 MHz – 110 GHz and enables accurate measurements as close as 2 mm to the surface of the transmitter when positioned by SPEAG's DASY6 or ICEy near-field scanning systems. We further developed a novel calibration setup that allows traceable calibration of the probe up to 110 GHz, with an uncertainty of <1 dB.

The determination of the Poynting vector requires knowledge of both the E-field and magnetic (H-) field amplitudes and phases. Reconstruction of these quantities, which are constrained by Maxwell's equations, is feasible from E-field measurements only. Until now, this has been successfully demonstrated only in the far and intermediate field zones. To overcome this limitation, we developed a novel phase reconstruction approach based on plane-to-plane (PTP) reconstruction algorithms and the E-field polarization ellipse information of the EUmmWV2 probe. The robustness and accuracy of the reconstruction algorithm have been analyzed and optimized for distances of a fraction of a wavelength. A comprehensive set of realistic exposure conditions has been simulated to evaluate the accuracy of the reconstruction algorithm. For distances greater than $\lambda/5$, the error of the spatially-averaged peak incident power density is found to be less than 0.5 dB, and, for $\lambda/2$, even below 0.2 dB.

The abovementioned efforts are complemented by the development of a comprehensive set of millimeter-wave verification and validation sources. The verification sources are based on horn antennas; for validation, we have developed sources with more complex near-field patterns, including horn-fed slot arrays and cavity-backed slot-fed dipole arrays.

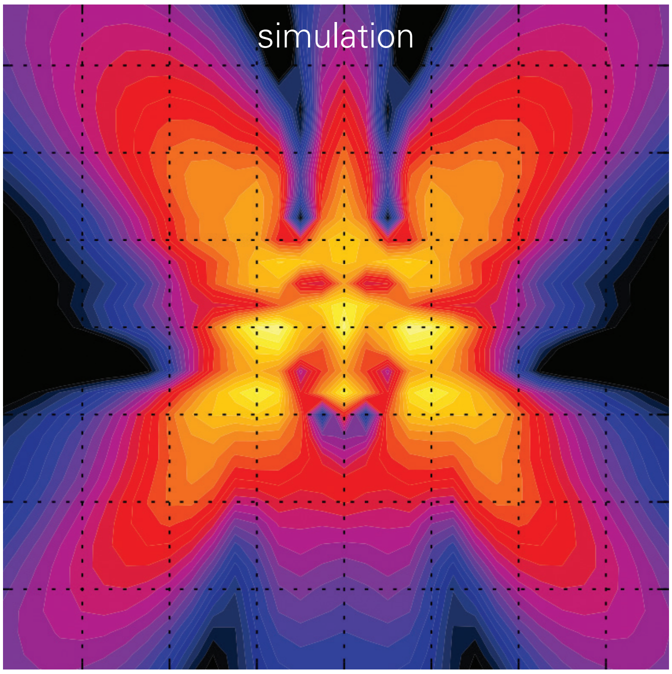
Thanks to our concentrated research efforts, SPEAG's DASY6 and ICEy became the first 5G near-field compliance test solutions to be rapidly adopted world-wide by the industry.



TOWARDS SCIENCE-BASED EXPOSURE ASSESSMENTS OF 5G TECHNOLOGY

International guidelines for electromagnetic (EM) exposure safety cover the frequency range from DC to 300 GHz, even though the literature for science-based risk assessment at frequencies above the Industrial-Scientific-Medical (ISM) band at 2.45 GHz is very sparse. The IT'IS Foundation initiated multiple projects to close major gaps regarding the coupling of incident fields with the human body. The projects were focused on the investigation of 1) the dependence of the coupling on the skin model, 2) the transition between safety thresholds based on specific absorption rate (SAR) and power density, 3) the most appropriate averaging volume for SAR, 4) averaging area for power density as a function of frequency, and 5) the maximum averaging time.

In the first project, we reviewed the literature regarding the ranges of thicknesses and the electric and thermal properties of the skin layers to identify their impact on coupling, energy deposition, and the resulting thermal effect. We found that reflections due to dielectric contrast, standing wave effects, poor cooling in the unperfused epidermis, and the insulating effect of subcutaneous fat tissue are the most important factors. Based on these results, we derived conservative parameters of skin tissue models as a function of frequency.



The objective of project 4 was to determine the antenna aperture, and the antenna-body distance, and the maximally allowable averaging area for incident power that guarantees that the temperature increase is below a threshold target (e.g., 1° C) as a function of the frequency. This analytical approach involves Green's function of the Pennes bioheat equation, as well as a model of near-field and far-field focus width. A variety of archetypical antennas, including dipole, slot, patch, and focused arrays of these, were considered.
The analytical model was successfully validated against detailed computational models of a wide range of antennas, e.g., single elements and arrays. Results reveal a strong dependence of the allowable averaging area at low frequencies, while demonstrating that the averaging areas defined in the current standards are too large to yield a conservative estimate of the temperature increase for localized exposure.

In the fifth project, we investigated pulsed and modulated EM exposures via computation of a surrogate quantity for thermal tissue damage according to the CEM43 model. Broadband wireless devices operating at above 10 GHz may transmit data in bursts of a few milliseconds to seconds. Even when the time- and area-averaged power density values remain within acceptable safety limits for continuous exposure, these bursts may lead to short temperature spikes in the skin of exposed people.
We developed a novel analytical approach to pulsed heating to investigate the peak-temperature-to-average-temperature ratio, as well as resulting tissue damage, as a function of the pulse profile. The results reveal that the current safety guidelines are not sufficiently robust and conservative, such that the peak-to-average ratio of 1000, as tolerated by the ICNIRP guidelines (1998), may result in permanent tissue damage, even after short exposures.

o^2S^2PARC

In recent years, the increased understanding of the nervous system and human electrophysiology, along with the continuous development of innovative neuro-engineering solutions, has opened exciting new avenues for medical devices that actively influence neural function to impact organ physiology and treat a variety of diseases. In 2013, the British pharmaceutical company GlaxoSmithKline used the term "electroceuticals" to describe the use of primarily electromagnetic (but also ultrasonic, optic, and mechanical) devices that affect organ function and relieve conditions through neural stimulation. Since then, the terms "bioelectronics" and "bioelectric medicine" – with similar meanings – have been introduced. Tiny electronic implants have been proposed for treatmet of chronic diseases such as diabetes, asthma, hypertension, gastrointestinal diseases, Parkinson's disease and many more, including even immune-response diseases such as arthritis. Multiple devices are under development, and first devices, mostly based on traditional technology for cardiac or spinal cord stimulation, have already been approved by regulators for, e.g., stimulation of the vagus nerve to treat depression as well as epilepsy.

Electroceuticals have enormous potential to complement pharmaceutical and surgical approaches permitting targeted and personalized therapies that directly affect and exploit the innate physiological function of organs and the controlling function of the autonomic nervous system. Similar approaches are used in the field of neuroprosthetics, which is concerned with the direct modulation of nerve function to compensate for lost sensory or motor function. Emerging applications include retinal implants to provide vision, prosthetic limbs and devices that are controlled through the patients' nervous system and/or restore lost tactile and other sensory functions, spinal cord and peripheral nervous system stimulation to provide locomotion to paraplegics, and many more.

Selective neuromodulations (stimulation or blocking) are currently investigated with regard to the treatment of obesity, Alzheimer's disease, migraine, addiction, heart failure, and other conditions, thus illustrating the potential of electroceuticals and at the same time the importance of achieving targeted, functionally selective neuro-

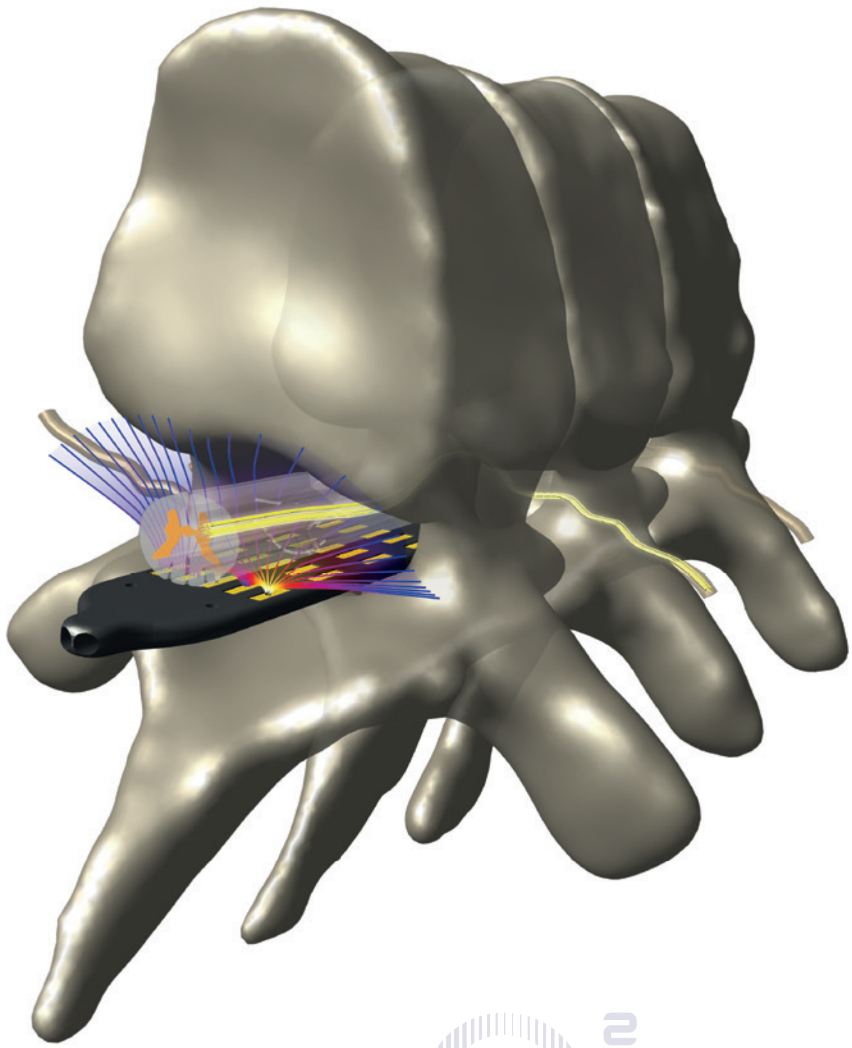
OPEN ONLINE SIMULATIONS FOR STIMULATING PERIPHERAL ACTIVITY TO RELIEVE CONDITIONS

modulation, while avoiding adverse side-effects. We have recently received an award from the U.S. National Institutes of Health (NIH) to enable and accelerate the development of electroceuticals and neuroprosthetics by establishing and maintaining a unique neurosimulation platform within NIH's Stimulating Peripheral Activity to Relieve Conditions (SPARC) program. Specifically, IT'IS will be the central hub for hosting and connecting simulations across the whole SPARC community.

The aim of **o²S²PARC** – **O**pen **O**nline **S**imulations for **S**timulating **P**eripheral **A**ctivity to **R**elieve **C**onditions – is to establish a comprehensive, freely accessible, intuitive, and interactive online framework capable of hosting and connecting simulations to create predictive, multiscale, multiphysics models spanning from modulation sources acting at feasible access points to organ functional responses. To achieve this, the platform will comprise both state-of-the art and highly detailed animal and human anatomical models with realistic tissue property distributions that make it possible to perform simulations ranging from the molecular scale up to the complexity of the human body.

o²S²PARC will provide users with an interactive approach to effectively develop, extend, validate, certify, document, store, share, and apply models, explore the impact of stimulation parameters, and create predictive, multi-scale, multi-physics models for a wide range of scenarios. One of the core elements of the platform is a set of novel neuro- and physiology-functionalized human and animal anatomical models (called NEUROCOUPLE and NEUROFAUNA, respectively). The models will allow simulation of *in vivo* fields generated by implanted or external stimulators, elucidation of the resulting neuromodulations, and assessment of the changes induced in organ physiology. The powerful and flexible simulation platform, developed according to open-source philosophy, will enable users to: 1) connect existing and/or novel computational (*in silico*) models to perform studies, 2) easily integrate new structures (e.g., nerve microstructure) into the anatomical models, and 3) generate new computational services, simulation studies, and anatomical models that can be shared with other users and researchers according to project-specific requirements.

The development and implementation of the platform is anticipated to run for five years with a total budget (internal and external funds) of over US$10 million.

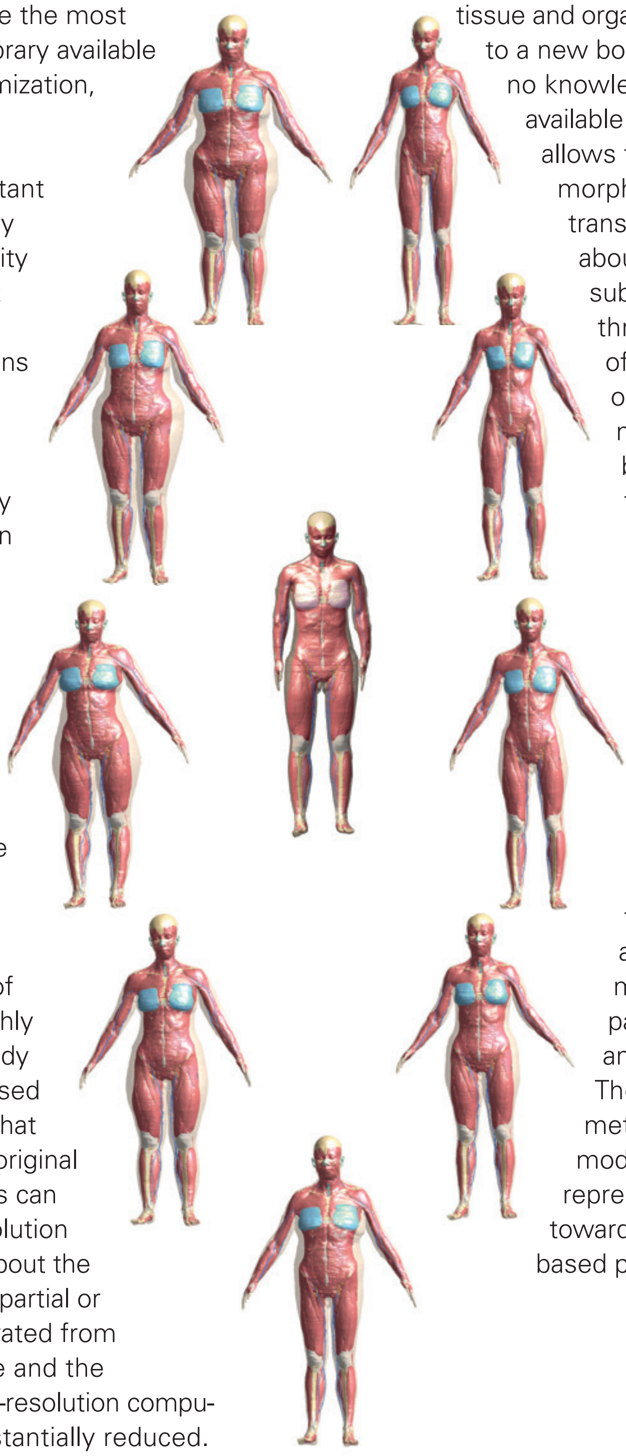


PERSONALIZATION OF COMPUTATIONAL ANATOMICAL MODELS – A REGISTRATION APPROACH

The first computational anatomical model project at IT'IS was initiated 20 years ago. Since then, our Virtual Population (ViP 3.x) has become the most detailed and validated model library available for *in silico* device design, optimization, and evaluation.

Although the ViP covers important parts of the population diversity (such as gender, age, and obesity levels) and is currently the best available representation of patient and consumer populations analysis of variability might require a broader and more continuous spectrum of individual anatomies, particularly as a larger library will strengthen the analysis and reduce the risk of underestimated effects of anatomical features.

Unfortunately, the standard approach to the creation of anatomical models through image segmentation of 3D medical image data is very time consuming. To overcome this drawback, IT'IS has recently developed a multi-resolution registration algorithm capable of morphing a high-resolution, highly detailed model into arbitrary body shapes. The approach can be used to generate complete models that preserve the properties of the original mesh. High-quality registrations can be obtained even with low-resolution targets for which information about the internal anatomical structure is partial or missing (such as models generated from laser-scan data). Thus, the time and the effort required to generate high-resolution computational phantoms can be substantially reduced.



The novel registration method finds a path to mapping from an existing anatomical model with detailed tissue and organ segmentations (the "template") to a new body shape, for which little or no knowledge of tissue distributions is available (the "target"). The mapping allows the template model to be morphed to the target anatomy by transferring detailed knowledge about internal structures to the target subject. The algorithm consists of three main steps: 1) registration of the body surface, 2) estimation of the thickness of the subcutaneous fat and position of skeletal bones in the target, and 3) the construction of a complete mapping that includes all internal structures.

While the method can already be used to capture gross anthropometric characteristics, such as body shape (height, weight, chest/hip circumference, etc.), it is not yet sufficiently informed about the shapes and positions of internal organs. In the future, the approach will be applied to 3D medical image data, making it possible to obtain fully patient-specific computational anatomical models within minutes. The IT'IS vision to apply this methodology to create full-body models of individual patients represents a fundamental step towards the realization of *in silico* based precision medicine.

CUSTOMIZED RESEARCH

The IT'IS Foundation offers state-of-the-art research, hardware and software development, and regulatory-grade safety assessments for partners in industry and government. Our offerings range from design support and product compliance certification to multi-physics physiological simulations.

Electromagnetic Near-Field Evaluations
IT'IS is the world leader in electromagnetic near-field measurements and simulations: induced fields (E, I, <1 kHz – 10 MHz, e.g., wireless power transfer systems), specific absorption rate (SAR, 100 kHz – 10 GHz), and power density (PD, 6 – 300 GHz).

Exposure Systems
IT'IS designs and develops customized exposure systems for *in vitro, in vivo,* and human studies on interactions of electromagnetic fields with living tissue.

MRI System Safety Solutions
IT'IS develops methodologies for assessment of health risks due to magnetic resonance imaging (MRI) exposure and performs customized safety evaluations of MRI exposure scenarios.

MRI Implant Safety Evaluations
IT'IS performs safety evaluations of passive and active medical implants and studies the fundamental mechanisms of interactions of such implants with MRI-induced fields. IT'IS also offers its expertise to develop customized solutions for mitigation of risk for MRI scanning of patients at 1.5T, 3T, and beyond.

In- and On-Body Antennas
IT'IS designs customized, electrically small, safety-compliant antennas, with optimized link budgets for in- and on-body use, and validates their functionality in realistic complex environments.

Tissue Models
IT'IS collaborates with academic groups and hospitals to maintain an up-to-date database of material parameters of biological tissues, and to develop new tissue models for customized applications.

Experimental Phantoms
IT'IS develops standard and customized homogenous or multilayer phantoms for evaluation of over-the-air (OTA) performance, SAR, optimization of on-body and implant transceivers, and validation of simulations.

Functionalized Human and Animal Anatomical Models
IT'IS owns, maintains, and extends the Virtual Population (ViP 3.x), the most comprehensive suite of high-resolution functionalized whole-body computational human anatomical models for biomedical modeling and safety assessment. IT'IS also develops customized human and animal models through imaging and segmentation and by using our posing, morphing, and personalization tools.

Computational Life Sciences
IT'IS combines expertise in computational engineering, tissue modeling, functionalized computational phantoms, and regulatory processes and standards to support design, optimization, and analysis of diagnostic and therapeutic applications.

Neuronal Stimulation
IT'IS uses its expertise in neuronal modeling within complex anatomy to support the development, optimization, and evaluation of efficacy and safety of electroceuticals.

Precision Medicine
IT'IS develops customized computational treatment planning tools for therapeutic applications for hyperthermia, ultrasound, and neuromodulation treatment modalities.

INFRASTRUCTURE

Dosimetric, Near-Field, and EMC/EMI Facilities

Semi-Anechoic Chamber
This shielded, rectangular chamber has the dimensions 7 × 5 × 2.9 m (L × W × H). It is equipped with a reflecting ground plane floor, and half of its walls are covered with electromagnetic absorbers. The chamber contains an integrated DASY6NEO system and can be utilized for all research activities involving dosimetric, near-field and far-field evaluations, the optimization and synthesis of handheld devices, body-mounted transmitters, implants, desktop applications, micro-base and pico-base station antennas, exposure setups, calibration procedures, EMI tests, MRI safety tests, compliance testing of implants, etc.

Two Reverberation Chambers
The Blue and NIEHS ***reverberation*** chambers have the dimensions 4 × 3 × 2.9 m and 3.7 × 2.2 × 2.7 m (L × W × H), respectively. Both chambers are equipped with two mechanical stirrers each and provide controlled and consistent environments for EM emissions and immunity testing, as well as shielding effectiveness and susceptibility testing of electromagnetic equipment.

Facility for Dosimetric Compliance Testing
IT'IS shares a facility with Schmid & Partner Engineering AG, which meets the requirements for dosimetric evaluations. The documentation of Class C accreditation has been completed.

Technical Equipment and Instrumentation

Spectrum and Network Analyzers
1 HP 8753E Network Analyzer, 30 kHz – 6 GHz
1 HP APC 85033B Calibration Kit
1 Rohde & Schwarz FSP Spectrum Analyzer, 9 kHz – 30 GHz
1 Rohde & Schwarz ZVA24 Vector Network Analyzer, 10 MHz – 24 GHz
1 Rohde & Schwarz ZVA50 Vector Network Analyzer, 10 MHz – 50 GHz
1 Rohde & Schwarz ZV-Z52 Calibration Kit

Signal Generators and Testers
3 Agilent 33120A, Waveform Generators
1 Agilent 33250A, Waveform Generator
1 Agilent E8251A Signal Generator, 250 KHz – 20 GHz
3 Anritsu 3700A
2 Anritsu MG3700A
1 HP 8647A, Signal Generator 250 KHz – 1000 MHz
1 Rohde & Schwarz CMU200
1 Rohde & Schwarz CMW500
1 Rohde & Schwarz CTS55, Digital Radio Tester
1 Rohde & Schwarz SMIQ02B, Signal Generator
2 Rohde & Schwarz SML02, Signal Generators
1 Rohde & Schwarz SML03, Signal Generator
1 Rohde & Schwarz SMT06, Signal Generator
1 Rohde & Schwarz SMU200A, Signal Generator
1 Rohde & Schwarz SMY02, Signal Generator

DASY, cSAR3D, EASY4MRI, MITS, PiX
1 INDY (3 year old child head) Phantom
1 ISABELLA (6 year old child head) Phantom
1 METROLAB, THM 1176, Magnetic Field Sensor
1 SPEAG AMIDV2, Audio Magnetic Field Probe
1 SPEAG AMIDV3, Audio Magnetic Field Probe
3 SPEAG ASTM Phantoms
1 SPEAG cSAR3D System (2 Flat, 2 Head and 1 Quad)
2 SPEAG DAE4, Data Acquisition Electronics
4 SPEAG DAEasy4MRI, Data Acquisition Electronics
1 SPEAG DAK 12/3.5/1.2E
2 SPEAG DASY6NEOs
4 SPEAG EASY4MRI
1 SPEAG EE3DV1, E-Field Probes
1 SPEAG EE3DV3, E-Field Probes
1 SPEAG EF3DV6, E-Field Probe
2 SPEAG ELI4 Phantoms
2 SPEAG ER3DV6, E-Field Probes
1 SPEAG ET1DV4, Dosimetric Probe
2 SPEAG ET3DV6, Dosimetric Probes
1 SPEAG EU2DV2, Probe
1 SPEAG EX3DV3, Dosimetric Probe
3 SPEAG EX3DV4, Dosimetric Probes
1 SPEAG H1TDS7zV1, H-Field Time Domain Sensor
1 SPEAG H1TDSxV1, H-Field Time Domain Sensor
4 SPEAG H3DV6, H-Field Probes
3 SPEAG H3DV7, H-Field Probes
1 SPEAG HAC RF Extension
1 SPEAG HAC T-Coil Extension
1 SPEAG HU2DV1, Probe
1 SPEAG SAM V6.0 Phantom
3 SPEAG T1V3LA, Temperature Probes
2 SPEAG T1V3, Temperature Probes
1 SPEAG T1V3LAB, Temperature Probe
1 SPEAG ES3DV2, Temperature Probe
1 SPEAG TSIL, Temperature Probe
1 SPEAG ICEy
1 ZMT MITS 1.5 with Phantoms
1 ZMT MITS 3.0 with Phantoms
1 ZMT MITS Gradient
1 ZMT PiXE64/128

1 SPEAG D900, Validation Dipole
1 SPEAG D835, Validation Dipole
1 SPEAG D1640, Validation Dipole
1 SPEAG D1800, Validation Dipole
1 SPEAG D1900, Validation Dipole
1 SPEAG D5GHz, Validation Dipole
1 SPEAG CD835V3, Validation Dipole
1 SPEAG CD1880V3, Validation Dipole
1 SPEAG CD2450V3, Validation Dipole
1 Log-Periodic Antenna (650 – 4000 MHz)
2 Generic Phones (835/1900 MHz)

Meters
3 Agilent 34970A Data Acquisition Units
2 Agilent E4419B, 4 HP 8482A, Power Meters
1 Handyscope HS3 Data Acquisition Unit
1 Handyscope HS4 Data Acquisition Unit
3 HP 436A, 3 HP 8481A, Power Meters
1 Magnet Physik FH49 – 7030, Gauss/Teslameter
2 Rohde & Schwarz NRP2 Power Meters

Amplifiers
1 Amplifier Research 10S1G4A, Amplifier, 800 MHz – 4.2 GHz
1 Kalmus 717FC RF Power Controller, 200 – 1000 MHz
1 LS Elektronik 2450 Amplifier, 400 W / 900 MHz
3 LS Elektronik 2449 Amplifiers, 200 W / 900 MHz
2 LS Elektronik 2448 Amplifiers, 60 W / 900 MHz
3 LS Elektronik 2452 Amplifiers, 200 W / 1800 MHz
1 LS Elektronik 2451 Amplifier, 60 W / 1800 MHz
1 LS Elektronik 2447 Amplifier, 5 W / 1800 MHz
2 LS Elektronik 2780 Amplifiers, 40 W / 2140 MHz
8 Mini-Circuits Amplifiers, ZHL42, 700 – 4200 MHz
2 Mini Circuits Amplifiers, ZVE-8G, 2 – 8 GHz
1 Nucletudes ALP336 Amplifier, 1.5 – 2.5 GHz
2 Ophir 5141, 700 MHz – 3 GHz

Other Equipment
8 Maury 1878B, 3-Step Tuners
1 Narda EHP-50 EM Field Probe Analyzer, 5 Hz – 100 KHz
1 Narda ELT-400 Magnetic Field Probe, 1 Hz – 400 KHz
1 Siemens, Universale Messleitung, (0.5) 1 – 13 GHz
2 SPEAG Dipoles SCC34 Benchmark
3 SPEAG, SHO V2 RB, RC &RP, OTA Hand Phantoms
6 Validation Dipoles D835, D900, D1640, D1800, D2450, D5GHz

Computers
51 Mobile Workstations/Laptops, 8/16/32 GB RAM;
from Acer, Apple, Asus, Dell, HP, IBM, Lenovo

48 Desktop Workstations/Computers, 8/16/32/48 GB RAM RAM;
from AXE, Dalco, Dell, HP, custom built

14 HPC Workstations/Servers, >=64GB RAM; 2/4/8x NVIDIA GPUs,
from AXE, Dalco, custom built

9 Servers + Network Data Storage, ~400TB; from Dalco, QNAP

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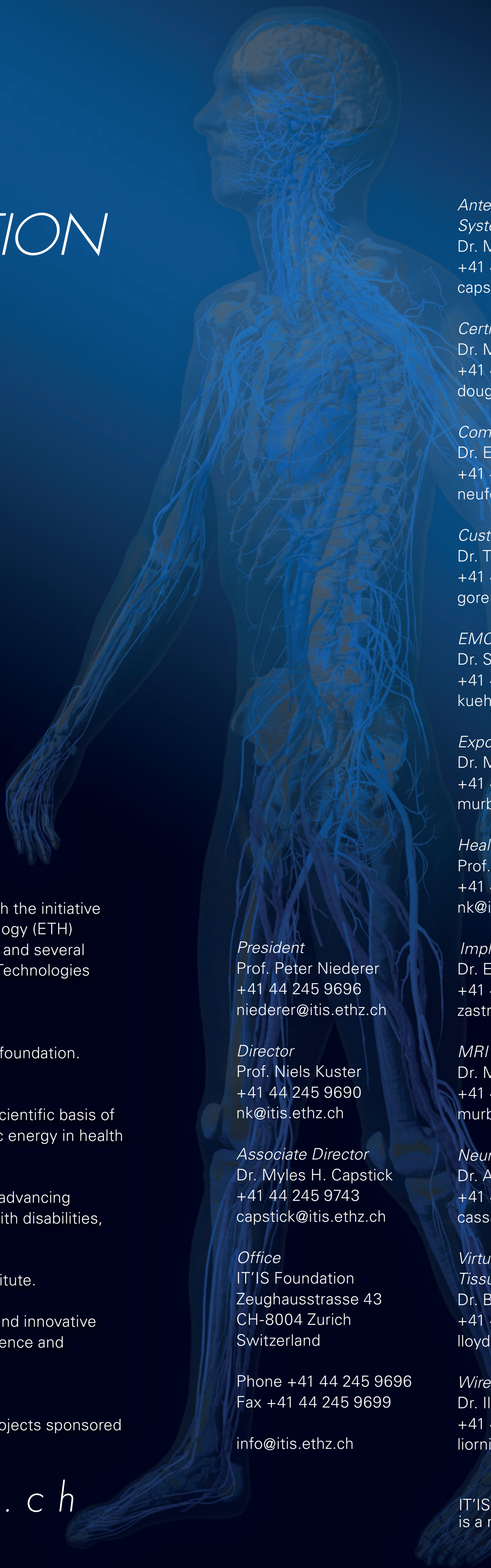

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The IT'IS Foundation was established in 1999 through the initiative and support of the Swiss Federal Institute of Technology (ETH) Zurich, the global wireless communications industry, and several government agencies. IT'IS stands for "Information Technologies in Society".

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