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INCLUDING A SELECTED IMPI 53 PAPER

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Test Set for Dielectric Measurements of Double Layer Laminates#

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#A paper awarded the best student presentation prize at IMPI 53, Las Vegas, 2019

1 Introduction

Different types of synthetic leather (SL) are widely used as decorative materials for surface coating in the automobile industry. Hot melt bonding is the usual method to fix the decorative material (the decorative leather) to the substrate (typically polymer blend material) surface. The hot melt adhesive is located between the coating and the substrate surface. Temperatures of about 80 °C are typical activation temperatures for hot melts adhesives. Microwave heating is a flexible, less time consuming and more energy efficient heating method as compared with conventional heating methods [1]. This is because of the volumetric and selective heating characteristics of the microwave heating. Particularly, the selectivity of microwave absorption, according to the loss factor of materials, allows a unique temperature distribution, which is not possible if using conventional heating methods. However, successful microwave heating of a coating-adhesive-substrate sandwich structure requires a detailed knowledge of the dielectric properties of the materials used. The following chapters introduce a test-set that allows for dielectric characterization of thin layers and laminates, respectively.

2 Methodology

For the design of an appropriate test set, the cavity perturbation method was chosen. Since the synthetic leather has a relatively low dielectric loss factor [1], a cavity with a quality (Q-) factor above 1000 is required. At this place, a cylindrical cavity, which contains an equatorial split [2-3], is used. This enables measurements of flat samples positioned parallel to the cavity ends that occupy all the cavity cross-section. The cavity design allows the excitation of the TE_{111} mode at 2.45 GHz and provides an unloaded Q-factor of about 12000. The TE_{111} mode is chosen, because it provides a maximum electric field in the cavity center [4]. At the same time, the wall currents are parallel to the sample and cavity cut. Thus, a perturbation oriented along the cavity radius will not cut the surface currents. It minimizes the change of the electric field profile inside the cavity compared with an unsplit resonator. A small lab jack with a micrometer screw in combination with an appropriate cavity holder enables the precise adjustment of the distance between both resonator parts.

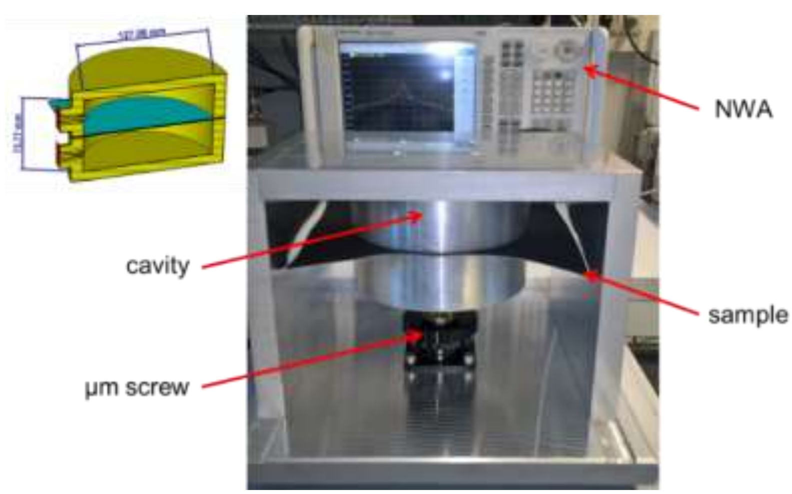

Figure 1. Measurement setup.

This measurements setup, as shown in Fig. 1, allows the precise dielectric characterization of synthetic leather with and without glue. In this connection the synthetic leather is point wise coated with glue (see [1]). A full-wave 3D electromagnetic model of the experimental setup was developed to explore the influence of the adhesive, covering the wrong side of the synthetic lether, on the total permittivity.

The calibration of the system requires the full-wave 3D electromagnetic field simulation as well. Here CST Microwave Studio is used. The calibration was made for a full range of the expected dielectric properties and thicknesses of the coating material, from 0.5 mm up to 2 mm.

3 Results

Two successive measurements were carried out for the dielectric characterization of the double layer material. In the first measurement the dielectric properties of the synthetic leather without glue was characterized. The leather thickness was estimated to be about 1 mm (±0.05 mm). The corresponding dielectric properties of the measured leather samples (both with and without an adhesive layer), which are different in color, are presented in Table 1 (Synthetic leather (gray), synthetic leather (beige) and synthetic leather (black)).

Table 1. Measured dielectric properties

Material	ϵ’	tanδ
SL gray	1.87	0.020
SL beige	1.88	0.021
SL black	1.89	0.021
SL+Glue 1 with 2% C	2.05	0.050
SL+Glue 2 with 2% C	2.07	0.053
SL+Glue 1 with 4% C	2.13	0.068
SL+Glue 2 with 4% C	2.11	0.075
Glue 1 with 2% C	8.04	0.391
Glue 2 with 2% C	9.04	0.388
Glue 1 with 4% C	12.05	0.437
Glue 2 with 4% C	11.04	0.534

Moreover, the effective permittivity of the black synthetic leather, covered by different kinds of glue, was measured (Table 1, Synthetic leather black + Glue 1 with 2% carbon, Synthetic leather black + Glue 2 with 2% carbon, Synthetic leather black + Glue 1 with 4% carbon and Synthetic leather black + Glue 2 with 4% carbon). The adhesive mass fraction was estimated to be about 3.2 weight percent. By using the density of the glue, the dot-wise adhesive volume was approximated by a homogeneous layer with an effective thickness of 0.08 mm. Based on this estimated effective glue thickness, the effective dielectric properties of the glue was estimated with the post processing tool ‘Extract Material Properties from S-Parameters’ in CST Microwave Studio (see Table 1, glue 1 and glue 2 with 2 and 4 weight% carbon blend, respectively) The accuracy of the estimated properties strongly correlates to the sample thickness. An estimated uncertainty in the calculated effective glue thickness of ±12 % leads to a measurement error of ± 12 % for the permittivity and ± 15 % for the loss factor of the glue, respectively.

4 Conclusions

In the present work, a test set for dielectric characterization of thin multilayer materials at 2.45 GHz was designed. This design is based on a TE_{111} cylindrical resonator with an equatorial slit. The full wave numerical simulations enabled the calibration of the measuring system in the full range of dielectric properties of the materials under test. The dielectric properties obtained for synthetic leather agree well with the data measured with the cavity perturbation approach in a TE_{104} cavity reported in [1]. However, the hot melt permittivity evaluated with CST post-processing routine results in values which are a factor of 4 higher as compared with the ones reported in [1]. This may be explained by the different preparation methods of the measured samples. In [1] the sample was a compact from dried adhesive powder that, typically, never reaches full density, therefore permittivity is underestimated. Here errors occurred due to the assumption of an effective glue layer.

Acknowledgement

The German Federal Ministry of Economic Affairs and Energy (BMWi) fund this research and development project within the 6. Energy Research Program (funding number 03ET1576A) and managed by the Project Management Jülich (PTJ).

For further reading

1. Soldatov, S.; Meiser, J.; Lepers, B.; Link, G. and Jelonnek J.; Microwave assisted bonding of synthetic leather to plastic substrates. In *3rd Global Congress on Microwave Energy Applications. Cartagena, Spain*, 25-29 July 2016
2. Janezic, M. D.; Kuester, E. F. and Jarvis, J.B.; Broadband complex permittivity measurements of dielectric substrates using a split-cylinder resonator. *Microwave Symposium Digest, 2004 IEEE MTT-S International*, 2004, **3**, 1817-1820.
3. Mohd. A.T.; Mohd Salleh, M. K. and Zan, M. M. M.; Air-Filled Circular Cross Sectional Cavity for Microwave Non-Destructive Testing. *International Journal of Mechanical and Mechatronics Engineering*, 2008, **2** (6), 809-814.
4. Nesbitt, A.; Navabpour, P.; Degamber, B.; Nightingale, C.; Mann, T.; Fernado, G.; Day, R. J.; Development of a microwave calorimeter for simultaneous thermal analysis infrared spectroscopy and dielectric measurements, *Meas. Sci. Technol.* 2004, **15**, 2313-2325.

About the authors

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Sergey Soldatov received the Dipl.-Ing. degree in experimental nuclear physics and plasma physics from MEPhI (Moscow) and Ph.D. degree from National Research Center "Kurchatov Institute". From 1994 to 2005 as an expert in microwave diagnostics he was involved in fusion plasma experiment at TOKAMAK-10 (Moscow) and later (2005-2011) at TEXTOR (Jülich, Germany). Since 2011, Sergey Soldatov is a leading researcher in the Institute for Pulsed Power and Microwave Technology at Karlsruhe Institute of Technology (KIT), Germany. He specializes in design and development of microwave applicators for thermal material treatment as well as microwave sustained plasma systems. His research interest covers also plasma diagnostics, antenna systems, dielectric characterization and multi-physics simulations.

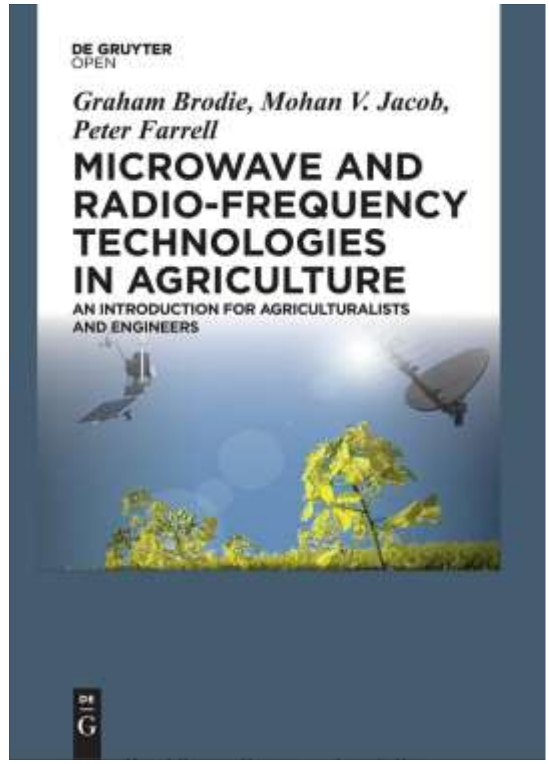
Guido Link received the Dipl.-Phys. and Dr. rer. nat. degree in physics from the Technical University Karlsruhe, Germany in 1990 and 1993, respectively. His diploma thesis and graduate research was devoted to the frequency and temperature dependent dielectric characterization of low loss ceramics and ionic crystals. Since 1993, he has been working at the Karlsruhe Institute of Technology, Germany (former Forschungszentrum Karlsruhe) in the field of high power microwave and millimeter-wave processing of materials, plasma chemistry, system and process design and dielectric characterization as a team leader at the Institute for Pulsed Power and Microwave Technology.

John Jelonnek received the Dipl.-Ing. and the Dr.-Ing. degree in electrical engineering from Hamburg University of Technology (TUHH), Germany, in 1991 and 2000, respectively. At TUHH he developed rigorous self-consistent analyses for gyrotron oscillators, in the frequency and in the time domain (slow- and fast-time scales), with a particular focus on the rigorous time-domain simulation of gyrotron operation at mismatched conditions and injection locking. From 1997 to 2011, John Jelonnek was working in several different leading positions at the industry. Since 2011, John Jelonnek is the Director of the Institute for Pulsed Power and Microwave Technology (IHM) at Karlsruhe Institute of Technology (KIT), Germany. Both, research and development of high power microwave sources, with a particular focus on fusion gyrotrons, and application of microwaves to energy efficient industrial processes using dielectric heating and microwave plasma are in the focus. Research and development in pulsed power technologies range from the development of high power sources to applications in the fields of materials processing and bioelectrics. John Jelonnek is a Professor of high-power microwave technologies at KIT.

Scientific Book Review

A review by Cristina Leonelli

Title: Microwave and Radio-Frequency Technologies in Agriculture-An Introduction for Agriculturalists and Engineers
Authors: Brodie, Graham / Jacob, Mohan V. / Farrell, Peter
Book Format: eBook (PDF)
https://www.degruyter.com/view/product/466435
Publication Date: November 2015
ISBN code: 978-3-11-045540-3



How could microwave and radio-frequency technologies be applied successfully to agriculture? Three Australian professors, namely Graham Brodie, Mohan V. Jacob and Peter Farrell, have provided a comprehensive treatise of what is possible to be done by microwave and radio-frequency systems to further enhance the agricultural industry. These suggestive answers to our question are collected in the 369 pages book titled: "Microwave and radio-frequency technologies in Agriculture - An Introduction for agriculturalists and engineers" published by De Gruyter in 2015 as an open access e-book. The book is divided into 4 sections, each of which is further divided into a number of chapters; the four sections are: General introduction, Non-destructive characterization using electromagnetic waves, Dielectric heating, and finally Automatic data acquisition and wireless sensor networks.

Electromagnetic waves, as the authors point out, do offer a good means of solving problems such as crop drying, quarantine and biosecurity, moisture monitoring, radar imaging, GPS geographic information, weed management, treatment of animal fodder, wood modification, MW extraction, thermal processing of biomasses, animal tracking systems and much more.

The authors have collected their personal experiences and report the findings of their colleagues in well-matched chapters where the beginner and the expert equally can find interesting novelties and original approaches.

This book is of considerable interest to investors in emerging technologies as well as MW and RF development specialists and industrialists.

Ricky's Afterthought:

Elevator Pitch

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I bet most of you reading this piece would not know what an elevator pitch is. Or do you? Even though you may not know what it means I bet you have exercised it in one form or another in your daily business be it in academe or industry.

Let me elaborate. There are many stories about how the elevator pitch came into being but the one that seems most credible goes like this. An individual who worked as Director of Quality at International Telephone and Telegraph had some radical ideas for changing some functions that were held at the company but could not pin down the CEO in order to inform him of his plans as he was always going from section to section or in and out of the building. So he drafted a paragraph, made up of a few sentences, which described in stark terms what he had in mind. He then decided early in the morning to wait around the headquarters' elevator (lift in English and *ascenseur* in French) knowing that within a span of less than half an hour the CEO would enter the building and head for the elevator to take him to his penthouse office. At a particular day he saw the CEO approach the elevator and luckily he entered it on his own so the Director of Quality followed him in. As soon as the elevator started its upward trajectory he made his pitch to the CEO. By the time it took to reach the penthouse the CEO was so convinced that he asked the Director of Quality to present his ideas to all the Section Managers. So the concept of the elevator pitch was born. It has to contain all the important elements of the scheme, it has to attract and maintain the attention of the listener and it must be anything between 15 seconds and 2 minutes.

Another story which goes around is that a Senior Editor of Vanity Fair, the popular magazine of culture, fashion and current affairs, wanted to pitch various story lines to the Editor in Chief but could never find her in one place as she was always on the move. So the Senior Editor would join her in the elevator knowing he had up to a minute to put his ideas across. So goes an alternative explanation of how the elevator pitch was created.

Thus, elevator pitch has become the 'go to' catch phrase in many walks of life from engineering to politics and from literature to sporting activities. Assuming you wrote a book and you wish to convince the publisher to accept it. So you prepare a two to three sentence elevator pitch with all the important elements of what you are writing.

Now that you have read the above I bet you have exclaimed, "Of course I used such a pitch at my interview". For example, for university staff, the head of your department may ask how you would convince the students to follow your course and not any of the competitive courses given by your colleagues. In simple terms, you prepare an elevator pitch, which encapsulates all the essential elements of your course and why the students should follow it. If electro-technology is your particular option you emphasize that fossil fuels are running out and electricity should be seriously considered particularly if it is produced by renewables energy and not a gas-fired power station.

In its most generic form the key elements of an elevator pitch should include:

- Definition of the problem
- Offer a solution
- Who are you targeting?
- Knowing your competition?
- Costs and milestones

Take the case of trying to convince a manufacturer of textile packages to use RF in part of the company's operations and you do not have all day to do so. Brevity is masterful in such situations, so you prepare an elevator pitch, which may take the following form next time you accidentally meet the technical manager and have minutes at your disposal, or you shadow him/her at a convention you know they frequent:

"You are drying your packages using steam or hot air but it takes too long and it needs a lot of space. The solution is to use a hybrid system, where you could use mangling (mechanically squeezing the moisture off) followed by conventional energy to reach, say down to 20-10% moisture depending on the type of textile, and finally remove the rest of the moisture down to equilibrium by using RF in a compact and safe unit which would repay itself in 2 years based on an increased production of 5%."

Well, I wonder how many times marketing engineers used such an elevator pitch to convince textile manufacturers to adopt RF in their operations? Judging by the thousands of RF textile dryers that have been installed in industry during the past 40 years, I would suggest countless times.

Similar elevator pitches have been used for tempering of frozen foodstuffs using microwaves or for drying of pharmaceuticals under vacuum using microwaves or welding of plastics using RF.

Wishing you all the best with your elevator pitches!

Highlights of the 53rd Annual Microwave Power Symposium (IMPI 53)

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The 53nd Annual Microwave Power Symposium (IMPI 53) held in June 18-20, 2019 at the Caesars Palace in Las Vegas, Nevada, USA (Fig. 1) gathered about 120 attendees from 18 countries. IMPI 53 program featured 65 presentations on a wide range of high power microwave applications with a growing focus on solid-state microwave amplifiers. Furthermore, a record number of 19 companies presented their products at the industrial exposition.

During the welcome reception Jennipher Marshall-Jenkinson, MTA-UK was featuring a very interesting live microwave cooking demonstration. Further social events have been two networking luncheons and a Group Dinner at Pizzeria Monzu.

Figure 1. Caesars Palace, Las Vegas

A new event was the Exhibitor Spotlight that started beforehand the welcome reception where each exhibitor performed booth side demonstrations.

Figure 2. Exhibition

A strong focus of most exhibitors was on the solid-state amplifier (SSA) market. The latest news in this sector stretched from the development of new high power 1-stage Push-Pull 500 watt RF transistor for the 2.45 GHz ISM band from AMPLEON to complete custom-made systems based on SSA. For example, Huber+Suhner impressed with a modified domestic microwave oven (see Fig. 3), operated with a 250 W SSA at 2.45 GHz. A novel compact waveguide, partially filled with a dielectric material, transmits the microwave power into the microwave chamber. Furthermore, a smartphone app allows controlling the SSA frequency while an array of polychrome LEDs fixed in a Plexiglas plate indicate field polarization and strength of the excited cavity mode by colour and luminosity, respectively.

Figure 3. Huber+Suhner: domestic microwave oven with a solid-state amplifier as power source

Dr. Kenneth Foster, Professor of Bioengineering at the University of Pennsylvania, and Michael Wolf, Founder of the Smart Kitchen Summit, delivered the two Keynote talks. Invited papers were delivered by Dr. Klaus Baumgaertner of Muegge GmbH, Dr. Eleanor Binner of the University of Nottingham, Mr. Christopher Hopper of IBEX and Dr. Alain LeBail of ONIRIS. Dr. Klaus Werner, former Executive Director of the RF Energy Alliance, led a panel discussion focused on IMPI's newly formed Solid State RF Energy Section and their plans for the future.

From the oral presentations, one of my highlights was the talk given by Kenneth Kaplan from Cellencor, Inc entitled 'Utilizing Independent Parallel Outputs from High Power Solid State Microwave Generators' where a high power and high-temperature patch antenna design with a balloon shaped radiation pattern has been introduced.

There were three awards. Petra Kumi (Worcester Polytechnic Institute, USA) was granted an honorable mention. Ali Taqi (University of Nottingham, UK) was awarded the best oral paper and myself the best presentation for which we were both given a one-year student membership to IMPI as well as a cash prize.

Dr. Juan Anguilar-Garib, University of Nuevo Leon was chosen to be the 35th Fellow of IMPI and was handed a commemorative plaque.

During the closing ceremony on June 20th, it was announced that the location of IMPI54 will be the historic DeSoto Hotel in downtown Savannah, Georgia, USA and will take place from June 15-17, 2020.

For further reading:

http://impi.org/wp-content/uploads/2019/07/Wave-Newsletter-July-2019_Final-1-1.pdf

About the authors

Vasileios Ramopoulos received the M.Sc. degree in electrical engineering from Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, in 2014. At KIT, he is involved in the research and development of in-situ dielectric measurements systems and microwave applicators for industrial microwave processing.

Upcoming Events

The 17th International Conference on Microwave and High Frequency Heating: AMPERE 2019 is the largest event in Europe dedicated to scientific and industrial applications of microwave and radiofrequency power systems. The conference presents the status and trends in the multidisciplinary fields of microwave and radiofrequency heating, dielectric properties, material processing, high power systems and technologies.
The AMPERE conference is a unique opportunity for the presentation and discussion of the most recent advances in the microwave technology and its applications. The conference provides many opportunities to researchers and engineers from academia and industry to exchange innovative ideas, networking, discuss collaborations and to meet with international experts in a wide variety of specialties of microwave and high frequency technologies at both scientific and industrial scale.

Website: http://ampere2019.com/

Materials Science & Technology 2019

Processing and Performance of Materials Using Microwaves, Electric and Magnetic Fields, Ultrasound, Lasers, and Mechanical Work – Rustum Roy Symposium

29th September – 3rd October, Portland, Oregon, USA

This symposium focuses on the discovery of novel processing methods, manufacturing, and performance of materials systems under the influence of microwaves, electric and magnetic fields (ac or dc), laser, ultrasound and mechanical energy. The symposium explores the fundamental science and mechanisms underlying these processing methods. Phenomena where electric and magnetic driving forces are coupled with mechanical and chemical effects will be emphasized especially at the system level. Sessions at the symposium will cover but not limited to the following topics: (i) Microwave Materials Processing, (ii) Electric Field Assisted Sintering, (iii) Phenomena in Li+ Batteries, (iv) Biological Phenomena in Electric and Magnetic fields, and (v) Microstructure Evolution and Phase Transformations under the influence of Electric and/or Magnetic fields.

Website: http://www.matscitech.org/2019-technical-program/

4th Global Congress on Microwave Energy Applications

The Global Congress on Microwave Energy Applications (GCMEA) is the "Olympic Event" for worldwide researchers and engineers working on the relevant fields of microwave/RF power applications. It happens every 4 years in a different continent. Sichuan University together with the China Association of Microwave Power Applications (CAMPA) is pleased to announce that the 4th GCMEA will be kindly hosted in Chengdu, Sichuan, China during Aug. 17-20, 2020.

Chengdu is the capital city of Sichuan Province, with a history of more than two thousand years and many cultural relics. It is usually associated with many tags, such as "the homeland of pandas", "city of gastronomy" and "tourist resort". Being an international city, people can take a comfortable and nonstop travel to Chengdu from all around the world.

The scope of the Conference is concentrated on microwave energy applications, and includes:

- Microwave/RF plasma
- Microwave/RF chemistry& metallurgy
- Microwave/RF chemical engineering
- Microwave/RF applications in environment engineering
- Microwave/RF applications in medicine and biology
- Microwave/RF assisted materials science and engineering
- Microwave/RF assisted food science and engineering
- Interaction mechanism of Microwave /RF and substances
- Dielectric and magnetic properties measurement
- EM modeling and numerical techniques
- Design of microwave/RF applicators and components
- Microwave/RF sources and power supply
- Microwave chemistry devices and working stations
- Microwave/RF processing design and optimization
- Microwave/RF industrial equipment and scale-up
- Industrial applications of microwave /RF energy
- Radiation safety and standards
- Other relevant topic

General Chair: Prof. Kama Huang (Sichuan Univerisity)
Venue: The CYNN Hotel - 69, North Kehua Road, Chengdu, 610023, China.
Email: microw_chem_eng@126.com
Website: http://campa.com.cn/4gcmea/

About AMPERE Newsletter

AMPERE Newsletter is published by AMPERE, a European non-profit association devoted to the promotion of microwave and RF heating techniques for research and industrial applications (http://www.AmpereEurope.org).

Call for Papers

AMPERE Newsletter welcomes submissions of articles, briefs and news on topics of interest for the RF-and-microwave heating community worldwide, including:

- Research briefs and discovery reports.
- Review articles on R&D trends and thematic issues.
- Technology-transfer and commercialization.
- Safety, RFI, and regulatory aspects.
- Technological and market forecasts.
- Comments, views, and visions.
- Interviews with leading innovators and experts.
- New projects, openings and hiring opportunities.
- Tutorials and technical notes.
- Social, cultural and historical aspects.
- Economical and practical considerations.
- Upcoming events, new books and papers.

AMPERE Newsletter is an ISSN registered periodical publication hence its articles are citable as references. However, the Newsletter's publication criteria may differ from that of common scientific Journals by its acceptance (and even encouragement) of news in more premature stages of on-going efforts.

We believe that this seemingly less-rigorous editorial approach is essential in order to accelerate the circulation of ideas, discoveries, and contemporary studies among the AMPERE community worldwide. It may hopefully enrich our common knowledge and hence exciting new ideas, findings and developments.

Please send your submission (or any question, comment or suggestion in this regard) to the Editor in the e-mail address below.

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