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Passive UHF RFID Tags, Systems and Applications

The rapidly increasing RFID market has generated a huge application pull towards passive RFID technologies, especially at UHF frequencies. The tutorial deals with low-cost passive RFID tag solutions at UHF frequencies based on both CMOS and SAW tags.

CMOS tags are advantageous for mass market applications, they are programmable during operation, smartness can easily integrated into them to deal with multi-tag scenarios, e.g., by using sub-carrier techniques such as digital mixing, they can run quite complex communication protocols, and, finally, they can come with additional integrated CMOS sensor functionalities and energy harvesting schemes.

On the other hand, SAW tags are advantageous for professional market applications because they can operate in harsh environments and at rather high temperatures. SAW sensor functionalities can be integrated and external sensors can be connected.

There are some basic differences between SAW tags and CMOS tags which greatly influences the system performance. CMOS tags are strongly non-linear, thus CMOS tag systems suffer from desensitization if strong interferes are present. The lower end of their dynamic range is determined by the required minimum converted DC voltage. Thus, CMOS tag systems are voltage-limited, i.e. their bottleneck is on the tag side. On the contrary, SAW tags are linear, thus the SAW tag systems' dynamic range is determined only by the reader's radar transceiver. So the sensitivity of the SAW tag system is determined by the required signal-to-noise ratio of the reader receiver which means that SAW tag systems are noise-limited, so that their bottleneck is on the reader side. Therefore, for given radio regulations SAW tags have the advantage over CMOS tags that they allow for a higher dynamic range of the system resulting in a higher read range.

SAW tags allow an easy integration of sensor functionalities, when physical or chemical effects are allowed to influence the propagation characteristics of the surface acoustic wave. SAW sensor tags use a reflective delay line, resonator, or impedance sensor setup to achieve the required accuracy and sensitivity range. Several application systems are presented which include wireless measurements of temperature, pressure, torque, acceleration, tire-road friction, magnetic field, and water content of soil. A discussion of further resonant structures which also could be used in a passive transponder system will close the presentation.

Biography: Leonhard Reindl received his Diploma in Physics from Technical University of Munich, Germany, in 1985 and his Dr. sc. techn. from University of Technology Vienna, Austria, in 1997. In April 1985 Dr. Reindl joined the surface acoustic wave group of the Siemens Corporate Technology Division, Munich, Germany. At Siemens Dr. Reindl contributed to the development of SAW convolvers, dispersive, tapped, and reflective delay lines. His primary interest was in the development and application of SAW ID-tag and wireless passive SAW sensor systems. In April 1999 Dr. Reindl joined the Institute of Electrical Information Technology, Clausthal University of Technology, where he became professor of communications

and microwave techniques. In May 2003 he accepted a full professor position as the chair for Electrical Instrumentation at the Institute for Microsystem Technology (IMTEK) at the University of Freiburg, Germany. Dr. Reindl is member of the IEEE, of the TPC of the IEEE Frequency Control Symposium, and of the German biannual Symposium Sensoren und Messsysteme. He has been elected member of the AdCom of the IEEE UFFC society in 2005 to 2007. He holds more than 30 patents on SAW devices and wireless passive sensors and has authored or co-authored more than 150 papers in this field.

Robert Weigel was born in Ebermannstadt, Germany, in 1956. He received the Dr.-Ing. and the Dr.-Ing.habil. degrees, both in electrical engineering and computer science, from the Munich University of Technology in Germany, in 1989 and 1992, respectively. From 1982 to 1988, he was a Research Engineer, from 1988 to 1994 a Senior Research Engineer, and from 1994 to 1996 a Professor for RF Circuits and Systems at the Munich University of Technology. In winter 1994/95 he was a Guest Professor for SAW Technology at Vienna University of Technology in Austria. From 1996 to 2002, he has been Director of the Institute for Communications and Information Engineering at the University of Linz, Austria. In August 1999, he co-founded DICE – Danube Integrated Circuit Engineering, Linz, meanwhile an Infineon Technologies Design Center which is devoted to the design of mobile radio circuits and systems. In 2000, he has been appointed a Professor for RF Engineering at the Tongji University in Shanghai, China. Also in 2000, he co-founded the Linz Center of Competence in Mechatronics, meanwhile also a company. Since 2002 he is Head of the Institute for Electronics Engineering at the University of Erlangen-Nuremberg. He has been engaged in research and development on microwave theory and techniques, integrated optics, high-temperature superconductivity, SAW technology, digital and microwave communication systems, automotive EMC. In these fields, he has published more than 650 papers and given about 300 international presentations. His review work includes international projects and journals. In 2002, he received the German ITG Award, and in 2007 the IEEE Microwave Applications Award. Dr. Weigel is a Fellow of IEEE, a member of the Institute for Components and Systems of The Electromagnetics Academy, and a member of the German ITG and the Austrian ÖVE. He serves on various editorial boards and has been editor of the Proceedings of the European Microwave Association (EuMA). He has been member of numerous conference steering committees. Currently he serves on several company and organization advisory boards. He is an elected scientific advisor of the German research Foundation DFG. Within IEEE MTT-S, he has been Chair of the Austrian COM/MTT Joint Chapter, Region 8 Coordinator and, during 2001 to 2003 Distinguished Microwave Lecturer. He is an AdCom Member and Vice-Chair of MTT-2 Microwave Acoustics.

Jochen Eßel is Senior Scientist at the Institute for Electronics Engineering at the University of Erlangen-Nuremberg, Germany. Currently, he is leader of a research group designing passive CMOS RFIDs and is working towards his Dr.-Ing. degree. His research interests include the design and characterization of nonlinear analog integrated circuits at radio frequencies and at

ultra low power levels. His project is part of a cooperation between the University of Erlangen-Nuremberg, the University of Hannover, Siemens, and Infineon Technologies.