Professor Heinz Mathis discusses how, whether for use in space or at home, his early attraction to wireless technology has led to a lifelong zeal for developing mobile communication solutions.

Could you begin by explaining what led you to the field of applied sciences and, more specifically, satellite and radio technology?

I finished my degree in electrical engineering with a focus on communication technology more than 20 years ago. I’ve always had a fascination for anything ‘wireless’. Through the jobs I held in industry, I became familiar with digital radio technology and paging systems, and then about 12 years ago, I learned about a Swiss company that produces satellite navigation solutions. The most interesting aspect of satellite navigation is that it shares technology with wireless communications but has a completely different purpose.

Your group has designed a Global Positioning System (GPS) logger for use by elite triathletes in training. What were the requirements set out at the beginning of this project?

We had some experience with position logging from a letter logger project some years earlier. The letter logger had to be very light, flat and energy-efficient to run over several days. Additional requirements in the GPS logger were effective waterproofing, ease of use and increased accuracy.

As a device used by athletes who rely on exact measurements, how accurate is this technology?

Although today’s standalone GPS technology is capable of accuracy to within a few metres, we had to use additional sensors such as accelerometers in our loggers in order to improve it further. For our purposes, water is the trickiest environment. We realised that fixing the logger on the athlete’s back, where it stays during the whole race including the cycling and running sections, does not work well when immersed in water during swimming. When attached to the swimmer’s goggles, the results are much better, but then two devices are required. In the end, the achieved accuracy depends on the amount of post-processing computation. Currently, we are identifying other areas in sports that could also benefit from a 23 g light GPS logger.

For the Virtual RADAR project, your group designed technology aimed at improving the safety of public transport. Why did you decide to use the Global System for Mobile communications (GSM)?

For the pilot case study, the project chose a bus company in a remote valley in Switzerland that only possesses a single-lane path with few crossing options. Our challenge was to develop a system with low running costs. The cost of satellite communications was prohibitive then and still is. At the time of installation, there was nothing else but GSM around and even that was expensive. One of the central ideas was to transmit as little data as possible without compromising safety.

What else can GPS be used for?

It is possible to envisage many interesting applications, but the question often boils down to how precise it is. We are therefore actively involved in making GPS receivers more accurate. In particular, indoor situations are proving a formidable challenge to the field of signal processing. One approach is to include other satellites, such as Russia’s Global Navigation Satellite System (GLONASS) or Galileo but, being of the same type of signal, this is only partially helpful. Another idea is to include broadcast signals such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB), or wireless signals such as GSM, Universal Mobile Telecommunications System (UMTS) or Long Term Evolution (LTE). In particular, LTE – the technology that is being rolled-out currently – has a good time base and is particularly suited for positioning applications.

Have you made any progress in developing novel space technologies?

About a year ago, the Swiss Federal Institute of Technology (ETH) in Zurich approached us to help build a microsatellite. The idea of the project CubETH is to produce a Cubesat – a cubic satellite that can navigate and perform attitude determination using only commercial off-the-shelf components. The satellite has an edge length of only 10 cm but must be powered autonomously by solar panels and contain all communication equipment as well as scientific instruments. Furthermore, it must withstand the vacuum, radiation and fast temperature cycles of space. We are working hard on the issue of properly placing antennas, both in simulation and in building measurement models. And, we are excited about the fact that the satellite will be launched in two or three years.
Calibrating communications

At the Institute for Communication Systems in Switzerland, a team developing wireless solutions to communication challenges is applying its collective expertise to overcome difficulties in a broad range of fields, from satellite positioning to surgical procedures.

In the guise of smartphones, tablets, laptops and home computers, wireless technology is a familiar feature in everyday life for many people in the modern world. Indeed, from standalone computer mice to the measuring capacities of satellites, the applications of wireless technology can be seen almost anywhere.

At the Institute for Communication Systems (ICOM) in Switzerland’s University of Applied Sciences Rapperswil (HSR), Dr Heinz Mathis, Professor of Mobile Communications and Head of ICOM, leads a team consisting mostly of electrical engineers in developing wireless communication solutions within a broad range of projects. The groups’ successes include Global Positioning System (GPS) loggers used by triathletes in preparation for the 2012 Olympics and electronic learning aides for use in lectures, but with a desire to tackle new problems, these are just a few examples among the Institute’s diverse portfolio of wireless solutions.

Safety at the pass

Heading into the remote valleys just south of Switzerland’s border with Austria, the isolation of the local communities provides a perfect backdrop to roadtest the Virtual RADAR project. As an evolution of existing technologies, Mathis has designed a system capable of decentralised fleet management. Current systems are routinely employed by taxi firms; for example, incoming messages of client pick-up times are relayed between the taxi and a human operator who mediates all information. However, Virtual RADAR proposes a method that circumvents the need for a human operator altogether: a computer capable of handling all incoming and outgoing messages, and broadcasting to every device in the fleet. In this case, the messages are the whereabouts of a local Swiss bus service, providing drivers with information about other vehicles in the area and passengers with a real-time public transport map; a useful tool where buses are the sole means of transport for local residents.

Using a palmtop computer with GPS and Global System for Mobile communications (GSM) capability mounted onto the bus, the vehicle transmits its ID number through an internet operator, down to a server and vice versa. At any time, an interested individual can look up the movements of any bus on a web map in real-time. To meet the project’s needs, Mathis used a sophisticated device with a GPS receiver, General Packet Radio Service (GPRS) modem, user-friendly display and additional sound device in case the screen cannot be seen.

Operating on a 13 km stretch of narrow, winding trail, the bus route is divided into waypoints at which the vehicle’s information is transmitted via the server to the rest of the fleet. A hazardous journey at times, the implementation of Mathis’ device has proved a success and popular with the vehicle’s operators in negotiating blind bends. As Mathis states: “At least one case was reported when a near collision was avoided thanks to the system”.

Precision in position

Navigating vehicles in the Swiss countryside is one thing, but built-up areas pose a different sort of challenge. Finding oneself in the urban canyons created by terraced skyscrapers or simply by being indoors, satellite navigational blind spots can occur resulting in GPS outages. Indeed, as Mathis explains: “One of the difficulties of indoor situations is the multipath environment that you have to resolve”. However, by combining GPS with
INTERNATIONAL INNOVATION

WIRELESS COMMUNICATION AND SATELLITE NAVIGATION

OBJECTIVES

To develop new technology to improve wireless communication and satellite navigation via a range of projects on topics including transport, educational tools and sporting activities.

KEY PARTNERS

ETH Zurich
AO Research Institute (ARI), Switzerland
u-blox

KEY COLLABORATORS

For a full list of ICOM team members, please visit: www.icom.hsr.ch/Team.8604.0.html?&L=4.

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PROFESSOR HEINZ MATHIS received an MSc in Electrical Engineering from ETH Zurich in 1993 and a PhD from the same university in 2001. From 1993-97, he held jobs as a DSP and RF engineer with different companies in Switzerland and the UK. He is currently Professor of Mobile Communications at the University of Applied Sciences Rapperswil, Switzerland. His research interests include signal processing for wireless communication and navigation systems.

GSM technology, Mathis has shown that it is possible to obtain a full three-dimensional (3D) fix in the best scenario, while in instances of total GPS outage one may still arrive at a fix of feasible precision.

A factor that makes GSM an attractive solution to GPS service decline is its ability to produce highly accurate real-time measurements. Although base transceiver stations (BTSs) enable wireless communication between a network and the relevant software, the network between different stations is often not synchronised. In lieu of synchronisation, GSM maintains its accuracy by measuring the time differences between various transceiver stations using location measurement units (LMUs).

Instead of incorporating the LMU concept at a later stage in the hybrid system’s development, however, Mathis has built the idea into its core function. The hybrid approach to positioning technology means the system can scan for GSM stations while GPS signal is available. By comparing the time offsets between the GSM stations and the more precise GPS, a model of time difference can be derived for every BTS whereby pseudoranges may be obtained in the case of a GPS outage. When a full 3D fix is not an option, the hybrid GPS/GSM system can still find a position with an accuracy of 70-200 m. With no registration requirements, the attractiveness of Mathis’ technology for a wide range of operators is further underscored by the fact that the need for roaming contracts is negated.

RECORDING REPAIR

With a self-confessed fascination for all types of wireless technology, it is of little surprise that Mathis is equally comfortable working on devices for medical applications as he is on positioning systems. At the AO Research Institute (ARI) in Davos, Switzerland, the Biomedical Services Programme has been working closely with ICOM to develop a wireless aid for easing the daily routine of surgeons. Although the idea is not entirely novel, the AO Fracture Monitor is distinct from its competitors in several ways. Comprising a data logger, which consists of a sensor and an electronic unit, the device is only a fraction larger than a single Swiss Franc coin, making its implantation relatively straightforward.

While a corrective implant, such as a bone plate, stabilises the broken bone, the data logger transmits information of the healing process through a wireless receiver to the physician’s computer. Such accurate data about the patient’s stages of repair can be interpreted more precisely to decide on the correct course of care, making the lives of the surgeon and the patient markedly simpler. Unlike other technologies attempting to monitor fractures, the ICOM-led design allows the ARI’s device to continuously record the patient’s activity in detail for up to four months. As first preclinical animal studies are currently underway, the fracture monitor’s performance remains to be seen, but clinical handling trials for external fixator treatment have already been arranged for the first rounds of human testing.

NO STOPPING

Often using pre-existing products off the shelf, Mathis’ work tweaks the capabilities already there in order to improve the scope of the technology. This philosophy allows the team to make quick gains in areas where they see a need. Despite the success of many of his projects, Mathis does not push commercialisation because the lure of a new project always holds the glimmer of exciting opportunities. As he relates: “My group likes innovative challenges – we are interested in the feasibility of something but then we move on, trying out new things”.

The wireless voting device developed by Mathis and his collaborators is an educational tool to help teachers learn about the progress of their students. It brings the feeling of a quiz show into the classroom.