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ALL FOR ONE, AND ONE FOR ALL

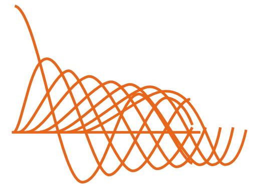
horizons mission: the people who make it happen

FUTURE FUELS

EXPANDING OUR KNOWLEDGE OF WATER

High-precision measuring instruments in the air: the Channel Sounder in the hangar at the DLR site in Oberpfaffenhoffen before its installation in the Falcon research aircraft.

TRACKING RADIO WAVES



When information is transmitted by radio – whether for communications, position determination or authentication – it must reach its destination reliably and be received correctly. Also, in view of increasing levels of automation, ever-increasing importance is attached to having reliable communications links between various systems. To open up new frequency bands or make better use of existing ones, DLR researchers are surveying radio channels with a special instrument that covers all areas of research – the Channel Sounder. Work on the use and development of this indispensable measuring instrument began 15 years ago.

The Channel Sounder analyses the propagation of radio signals – for the best reception

Uwe-Carsten Fiebig and Thomas Jost

Everyone has experienced hearing their voice reflected from the face of a nearby mountain, with the typically long echo. The mountain scenario is an expanded version of what we hear in an empty room. Why is that? Nature provides the answer; these sound waves are reflected off of the walls. These types of reflections are greatly dependent on the wall characteristics – including their dimensions, the material they are made of and the roughness of their surfaces. If there are strong echoes, anyone listening to a spoken voice will have difficulty understanding what is being said.

Similar effects are experienced with the transmission of radio waves. In most cases, electromagnetic waves reach the receiver not only through the direct path of propagation – meaning the line-of-sight connection between the transmitter and the receiver – but also via reflections or echoes. At the receiver, the direct signal has the reflected signals superimposed on it; this causes distortions of the direct signal and, in turn, an erroneous reception of the transmitted information bits. The quality of reception is determined by the transmission channel, which defines the characteristics of propagation between the transmitter and the receiver.

When new radio systems are being developed, it is important to have precise knowledge of the transmission channel – that is, the propagation conditions. These conditions are dependent on many parameters, such as the frequency and bandwidth of the transmitted signal; the physical environment in which the radio system is operated; and the relative speed and separation distance between the transmitter and the receiver.

Researchers examine the transmission channel characteristics through the use of a 'Channel Sounder'. This measuring instrument consists of a transmitter that sends out a known test signal, and a receiver that records the signal in a highly accurate way. The evaluation of the data acquired makes it possible to achieve a precise mathematical definition of the transmission channel. The researchers construct a model of the propagation characteristics – the 'channel model'. This model provides the basis for designing and optimising radio systems, as well as for computer simulations of their transmission quality.

The Channel Sounder in operation – transmitter (left) and receiver unit (right).

In the first satellite Channel Sounder campaign, the receiving unit moved through Munich city centre in a measurement bus.

During the first measurement campaign, the transmitting unit was on an airship.

The Channel Sounder in DLR's Dornier Do 228-101 (D-CODE) research aircraft

Travelling across land, sea and air

Whether investigations are needed for satellite navigation, aircraft radio, maritime communications, vehicle-to-vehicle communications, or radio systems on trains, the Channel Sounder has an extremely diverse range of applications. Researchers at the DLR Institute of Communications and Navigation have already carried out numerous measurement campaigns to record the propagation characteristics of many different transmission channels. Modifications had to be made to the Channel Sounder to open up new frequencies. The Channel Sounder was originally designed only for the measurement of transmission channels with a carrier frequency of 1.51 GHz (L band), with a bandwidth of 100 MHz. With time, its range of capabilities has been expanded to include several carrier frequencies in the VHF frequency range, and in the S band and C band sections of the spectrum. Aviation, satellite navigation, as well as road, rail and maritime transport are all areas of research in which regular breakthroughs have been made in the field of radio transmission thanks to the researchers' campaigns.

In the Channel Sounder's first practical application in 2002, DLR researchers surveyed the propagation conditions affecting satellite navigation. The accuracy of GPS receivers is greatly dependent on the transmission channel because the signals have to travel over a long distance, and can – in cities, for example – experience strong reflections off of buildings. The transmission system sent the test signals not from a satellite but from an airship that was parked in a position several hundred metres above, while the measurement bus carrying the receiver unit drove through the streets of Munich and recorded the signal. Working on the basis of the measurements gathered, researchers were able to achieve an unprecedented level of detail in defining the propagation phenomena that satellite navigation signals are subjected to. The researchers noticed strong signal echoes in streets with a lot of building development; these echoes had a remarkably long duration. In such cases, a navigation receiver's position error may lead to a deviation of more than 50 metres from the true location.

At the Institute, new methods were subsequently developed to significantly reduce the effects of multiple-path propagation affecting a navigation receiver – with the result of providing far more accurate position determination. The channel model that was developed has been standardised in the Radiocommunication Sector of the International Telecommunication Union (ITU-R), a special organisation within the United Nations dedicated to the technical aspects of telecommunications.

From 2008 to 2010, in a range of different measurement programmes, DLR researchers expanded the use of the Channel Sounder to investigate the propagation conditions for signals reaching a mobile receiver within a building – either from a satellite or from a mobile radio base station. Measurements confirmed that signals would pass through windows (if not metal-coated), walls and even concrete ceilings to reach the interior of the building. But within the building, the signals become greatly attenuated and reflect off walls, doors and fixtures. Navigation is extremely difficult in such a multipath environment. Deeper inside the building, the received signals become so weak that it is impossible to achieve reliable position determination on the basis of satellite signals.

In a subsequent measurement programme, researchers showed that C band signals experience much greater attenuation as they enter a building than signals in L band. Accordingly, the advantages of potential broadband navigation signals in C band can only be exploited outdoors, and not inside buildings. Indoor applications tend to require lower-frequency signals. A comparison between transmission channels in L band and C band is necessary to decide whether the next generation of Galileo signals should be broadcast at different frequency ranges.

In 2003, the Channel Sounder was used in an aviation application to survey the transmission channels within an aircraft cabin. These transmission channels are important for aircraft manufacturers when they wish to replace cable-based communications with radio links. It was possible to determine which areas of the cabin could easily receive radio signals, learning in the process that there are many points (typically surrounded by metal) where the radio signal experiences severe attenuation or is not received at all. In 2007, the scientists investigated the transmission channel between the apron control tower and aircraft at Munich Airport. What they used was not an aircraft but a measurement bus, with which they tested various scenarios on the runway – both during the day and at night. A typical airport architecture – with its wide-open spaces and large buildings – is a recipe for changing behaviour in the transmission channels. This channel exhibits very strong, long-lasting echoes, together with signal shadowing near the positions where aircraft are parked. The channel model, as developed, takes these characteristics into account, with the result that DLR was able to adapt the new AeroMACS radio standard, which is designed for transmission between control towers and aircraft or vehicles on the ground, to these conditions.

The Channel Sounder's travels included airborne operations, as in a 2009 measurement campaign conducted in order to investigate the radio channel between two different aircraft using a carrier frequency of 250 MHz. The aircraft flew over a range of land surfaces, such as bodies of water, fields, forests and conurbations. The signal reflected from the ground proved to be exceptionally strong – to such an extent that it equalled the intensity of the direct signal. The direction in which the antenna was pointed was sufficient to make the reflected signal even more powerful than the direct signal in the case of some aircraft banking manoeuvres. The disruptive effect caused by the reflected signal can be markedly reduced by employing an equaliser.

Traffic applications

Rail transport is another area of application for the measuring instrument. In addition to a measurement campaign conducted on two trains (DLR Magazine 151/152 presented an article on this topic), the DLR measurement team investigated the transmission channel between two vehicles while both the transmitter and the receiver of the Channel Sounder were in motion. On the basis of the results achieved, the researchers were able to develop a model that incorporated the constantly changing transmission characteristics arising between moving vehicles. This model will be used to optimise vehicle-to-vehicle communications technology.

Future for good reception

Many new questions will await future scientists at the Institute of Communications and Navigation. These questions may include investigating higher bandwidths and other frequency ranges, as well as whether it is necessary to survey channel characteristics that were not previously relevant or even impossible to examine. Using a new Channel Sounder that is scheduled to go into operation in 2018, it will be possible to rely on ultra-wideband signals with a bandwidth of up to 1 GHz to improve the resolution of echoes. In addition, the researchers will be able to increase the measurement rate in order to capture higher-frequency Doppler effects. Composite antennas for both the transmitter and the receiver will also be supported by the new Channel Sounder. As a result, the foundations for good reception and reliable transmission technology have been laid.

Uwe-Carsten Fiebig heads the Communications Systems Department. One of the department's core competencies is the analysis and modelling of the propagation characteristics of radio signals for space, aeronautics, transport and maritime security applications. **Thomas Jost** has been a leading scientist in the field of radio wave propagation for many years and has been responsible for the Channel Sounder in almost all measurement campaigns.

During a measurement campaign in 2014, during which the researchers examined the radio link between a ship and the mainland, the receiving antenna was installed on the Warnemünde lighthouse. In 2016, one team recorded the transmission channel between two ships (DLRmagazine 148/149 reported about this).

In two moving high-speed trains, DLR experts investigated the propagation of radio waves for train-to-train communication in Italy.

About DLR

DLR, the German Aerospace Center, is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (Headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Göttingen, Hamburg, Jena, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington DC.

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DLR Department of Public Affairs and Communications
Linder Höhe, D 51147 Köln
Phone +49 (0) 2203 601-2116
E-mail kommunikation@dlr.de
Web DLR.de
Twitter @DLR_en

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Cover image
6 June 2018: A Soyuz MS-09 rocket brings Alexander Gerst and his team to the International Space Station. The horizons mission begins. On the ground, a much larger team ensures that the mission is successful.
Image: ESA / S. Corvaja

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