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Autor: Blondel, Enrico

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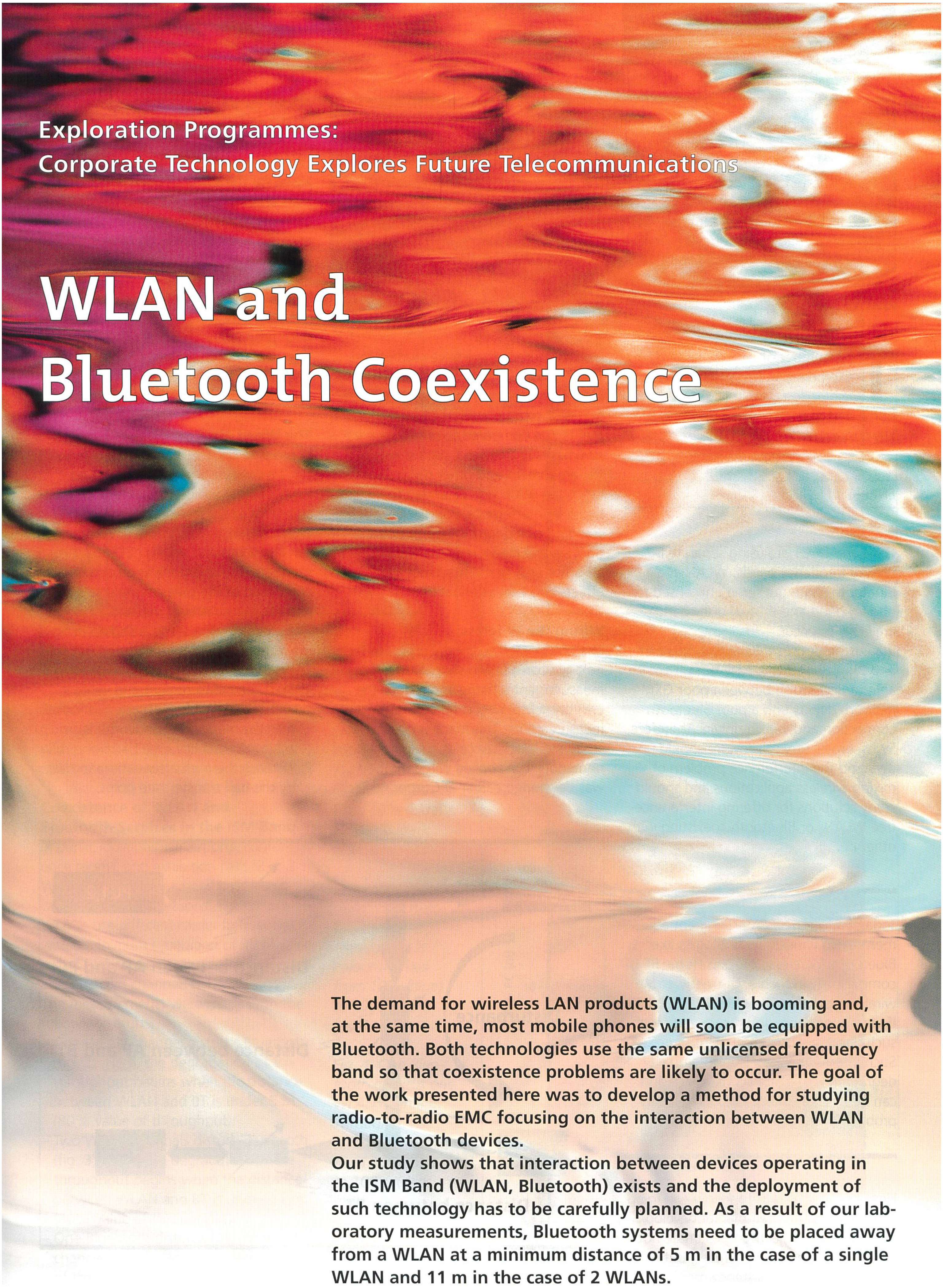

Exploration Programmes:
Corporate Technology Explores Future Telecommunications

WLAN and Bluetooth Coexistence

The demand for wireless LAN products (WLAN) is booming and, at the same time, most mobile phones will soon be equipped with Bluetooth. Both technologies use the same unlicensed frequency band so that coexistence problems are likely to occur. The goal of the work presented here was to develop a method for studying radio-to-radio EMC focusing on the interaction between WLAN and Bluetooth devices.

Our study shows that interaction between devices operating in the ISM Band (WLAN, Bluetooth) exists and the deployment of such technology has to be carefully planned. As a result of our laboratory measurements, Bluetooth systems need to be placed away from a WLAN at a minimum distance of 5 m in the case of a single WLAN and 11 m in the case of 2 WLANs.

The Programme "Electromagnetic Effects" investigates the electromagnetic compatibility (EMC) aspects of emerging telecommunication technologies and the biological effects of electromagnetic radiation. Necessary actions and guidelines are elaborated allowing Swisscom to improve quality of service and minimise installation and troubleshooting cost.
With its Exploration Programmes, Corporate Technology is exploring telecommunication technologies and new service possibilities with a long-term view of 2–5 years. Further, the expertise built up in the course of this activity enables active support of business innovation projects.

The number of wireless systems is exploding. In this situation, the use of compatible equipment at home and at the office is becoming a key success factor. While, for example,

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GSM and DECT are using separate licensed frequency bands, WLAN and Bluetooth share the same unlicensed frequency band and mutual disturbances are likely to occur.
If a customer uses a Bluetooth headset and the call quality is bad, he will not be able to distinguish between poor GSM network quality and a poor Bluetooth connection and will complain. Therefore, Swisscom as service provider should understand the interference problem of mixing wireless applications and should study solutions for offering interference-free WLANs or Bluetooth coexisting with other ISM devices.

Today, various new entertainment equipment using wireless technologies like Bluetooth, Wireless LAN and Home RF is commercially available. Currently, those wireless devices share the same 2.4 GHz ISM frequency band and coexistence of such devices causes mutual interference. Such interference can lead to a quality degradation of a Swisscom service and can be wrongly interpreted as a quality problem of the Swisscom network.

Hence, it is important to follow emerging technologies and their market development with the objective to estimate not only the business opportunities, but also related risks and coexistence problems.

For that purpose, we have studied the interference scenario with the support of laboratory measurements. After verification of the setup a series of measurements was compared to reference measurements in free field, data sheets of the equipment and other publications. Later, the setup was extended to include multiple interference. For a better understanding of indoor multipath propagation, several measurements were done in an office environment subject to fading effects and wall attenuation.

Wiring the Wireless

The EMC expert team at Corporate Technology succeeded to simplify the overall measurement scheme and reduce the environmental effects related to the measurements. This made it possible to study the interference as a separate phenomenon. The applied wired method was developed earlier at Corporate Technology for the first investigations of WLAN and was adapted to the problem to be studied.
The developed method can be generalised for the study of coexistence problems among other ISM band devices, for example Home RF. It generates the reference data, for example bit rate or packet loss, for planning a harmonised coexistence of Bluetooth and WLAN (IEEE802.11b). In addition, it provides the data to be introduced in the empirical indoor propagation models for the three typical Bluetooth and WLAN coexistence environments: office, home and public space.

The Wired Method

In order to provide an accurate criterion for the coexistence of Bluetooth and WLAN in real use cases, a reference measurement approach was developed first which is directly applicable to commercial Bluetooth and WLAN (IEEE802.11b) products. The reference approach is composed of the measurement setup and the measurement method.
The measurement setup is shown in figure 1. Measurements are carried out following three basic steps:

1. Start the measurement and verify it with a reasonable path attenuation so that the maximum bandwidth is achieved.
2. Increase the path attenuation and verify the half transfer rate point.

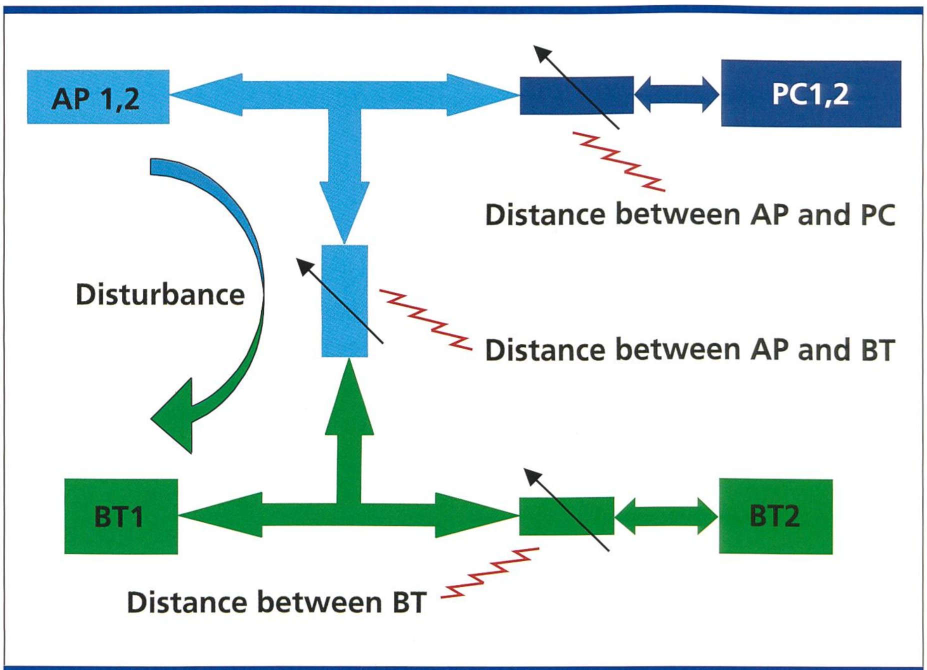

Fig. 1. Measurement setup.

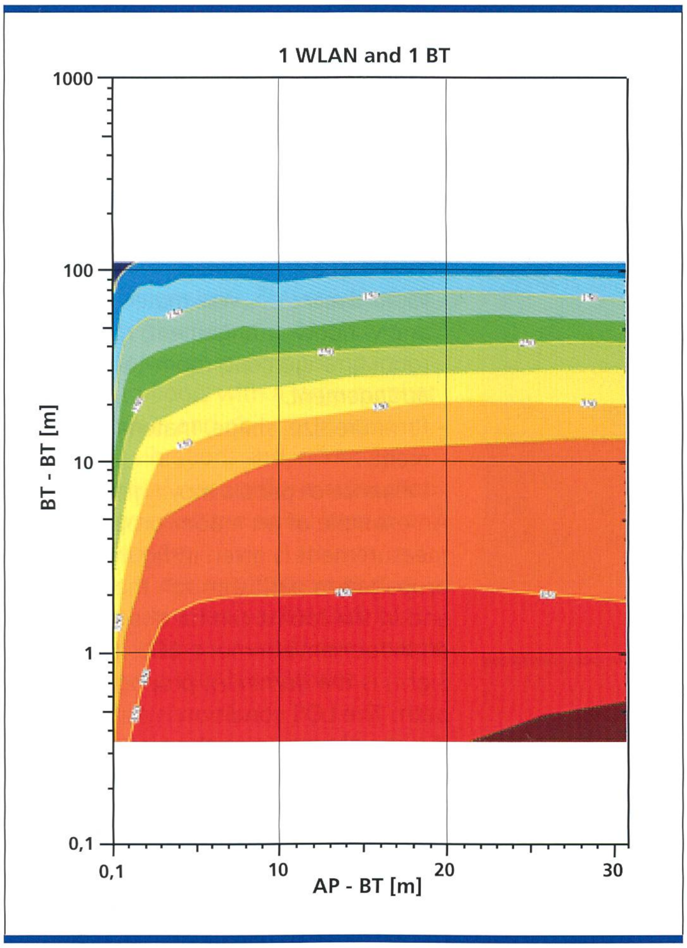

Fig. 2. One WLAN channel disturbs Bluetooth. Throughput is colour-marked from 10% (blue) to 100% (dark red).

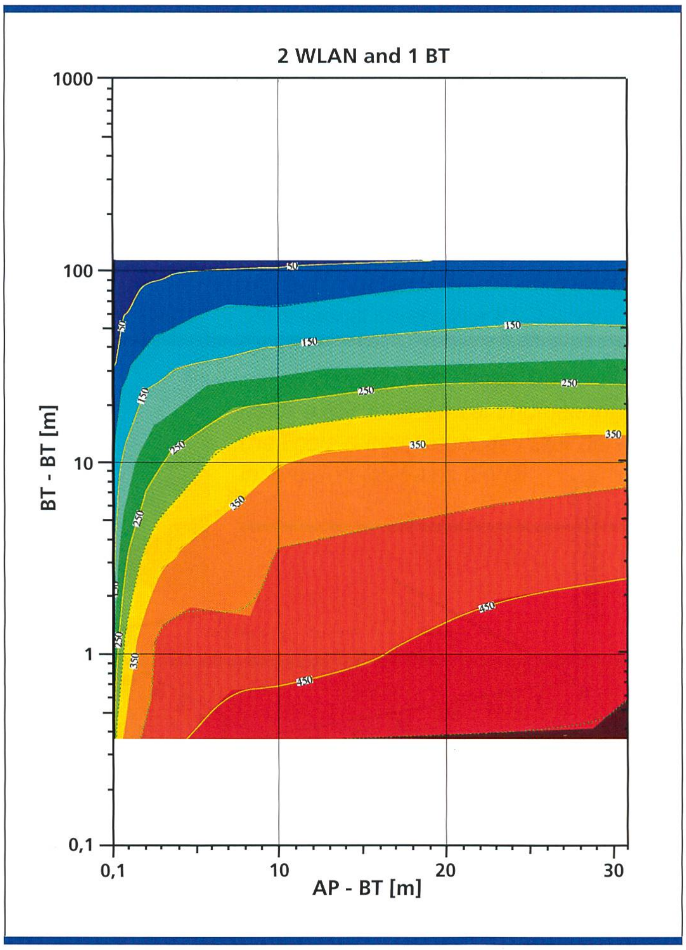

Fig. 3. Two WLAN channels disturb Bluetooth. Throughput is colour-marked from 10% (blue) to 100% (dark red).

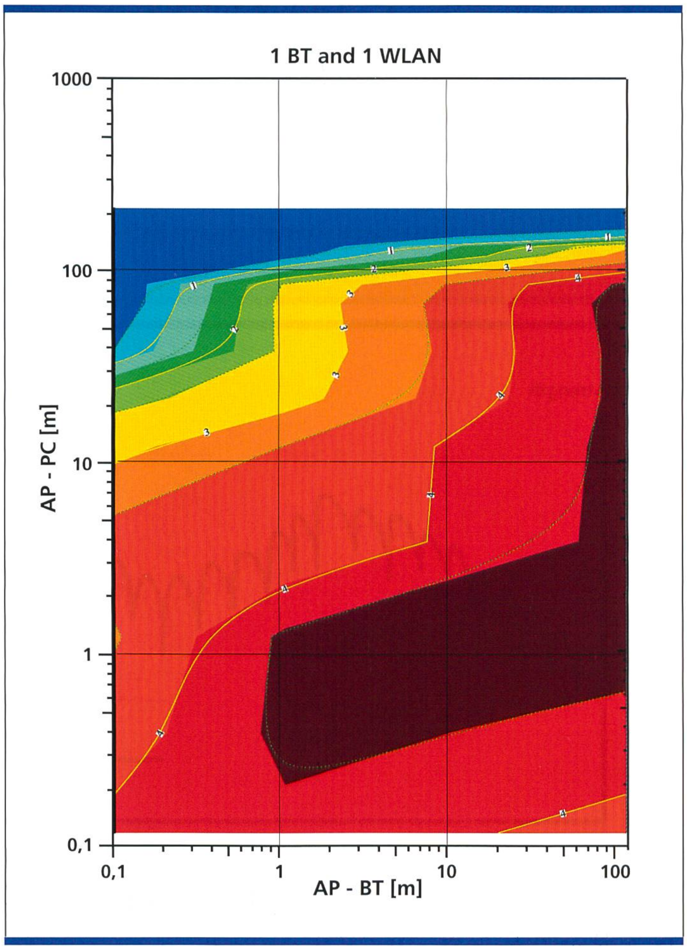

Fig. 4. One Bluetooth disturbs one WLAN channel. Throughput is colour-marked from 10% (blue) to 100% (dark red).

3. Proceed with the measurements.
Comparing our measurement results with published data validates the developed reference measurement approach.

Coexistence of WLAN and Bluetooth Services in the ISM Band

In public locations like airports, conference rooms, and exhibition halls, 2 or 3 WLANs or even more need to be co-located for capacity reasons. The co-located WLANs use different carrier frequencies with a minimum separation of 30 MHz or a shift of 6 channels. The number of available adjacent channels is 13.
The measurements were made with the following setups:

- One WLAN channel disturbs Bluetooth (fig. 2). Here, the degradation of the throughput begins when the distance between WLAN and BT is under 5 m (80% value of throughput).
- Two WLAN channels disturb Bluetooth (fig. 3). Here, the degradation of the throughput begins when the distance between WLAN and BT is under 11 m (80% value of throughput).
- One Bluetooth disturbs one WLAN channel (fig. 4). Here, the degradation of the throughput begins when the

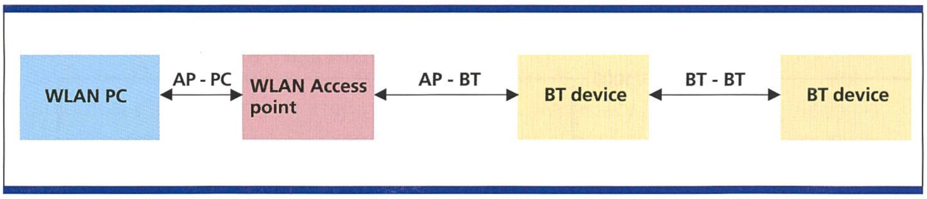

Fig. 5. Distance terminology used in figures 2, 3 and 4.

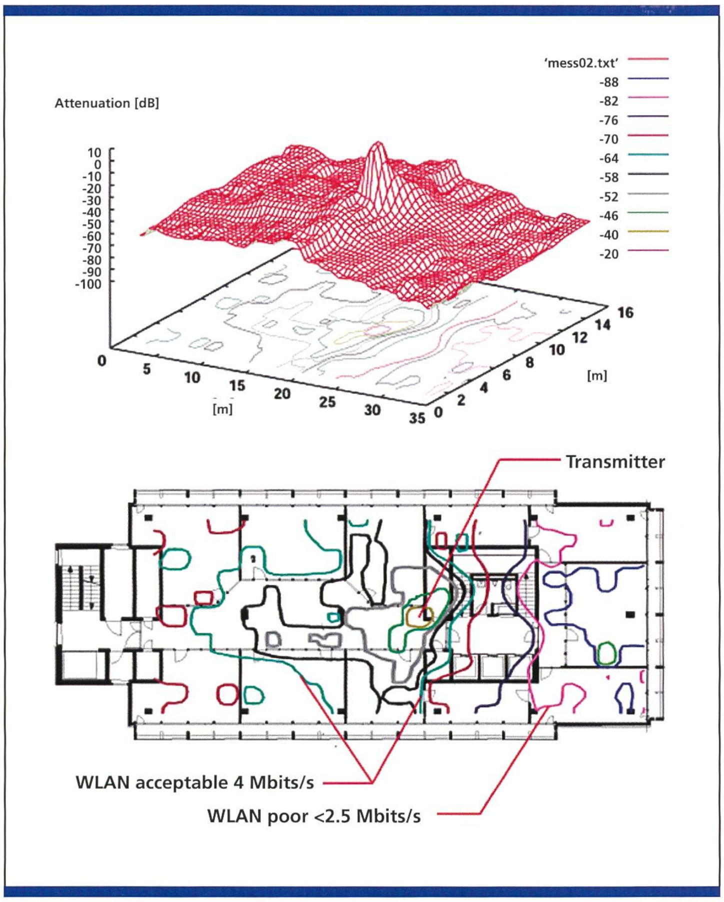

Fig. 6. Indoor propagation measurements.

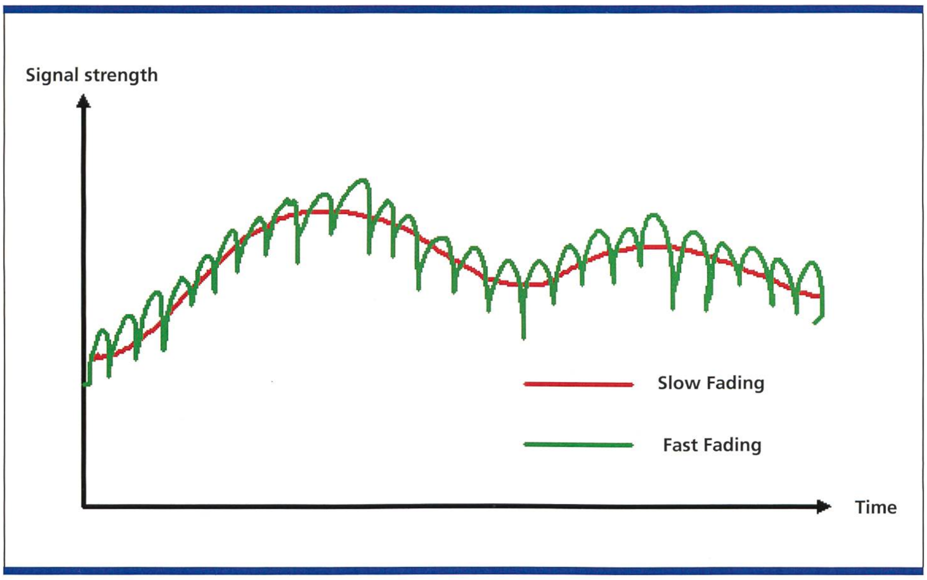

Fig. 7. Signal fading.

distance between BT and WLAN is under 0.2 m (80% value of throughput).
The schematic drawing of figure 5 explains the meaning of the distance terminology used in figs. 2 to 4.

Indoor Propagation and Fading

The indoor propagation environment is a complex one considering

- room dimension, wall material, door and window arrangement, room-to-room arrangement, room-to-corridor arrangement,
- furniture size, shape, material, arrangement,
- influence of people moving around.

An example of an indoor propagation measurement is given in figure 6. The propagation path through the doors and in the rooms can be observed. In an indoor environment, LOS (Line Of Sight) is the dominant propagation path. The LOS condition is defined as direct sight between the transmitter and receiver, i.e. no obstacle inside the Fresnel zone.
Figure 7 shows a typical fading effect, where the fluctuation of the received signal with distance or with time is caused by two kinds of fading, i.e. slow fading (marked red) and fast fading (marked green). Fading measurements and propagation measurements show level variations of up to 22 dB in a closed room and level deviations of up to 28 dB by closing the door of the room.
A propagation environment composed of fixed objects, for example walls, doors, furniture, plants and other indoor obstacles, causes slow fading, while multipath propagation and moving objects like humans and machines cause fast fading. Multipath propagation is the effect of reflection, diffraction or scattering by obstacles near or between transmitter and receiver.
In an office environment, slow and fast fading are the main cause for wireless communication problems. Because of the big level variation, the reach of a disturbance-free WLAN is even smaller than the reach measured with free tools delivered with the WLAN equipment.

Conclusions

The reference measurements were performed to verify the proposed setup of figure 1. The results are in agreement with the predictions and satisfy the specifications of the manufacturer.
The laboratory measurements show

some relevant positive aspects: they represent a worst case measurement (without reflections), provide stable results and good quality, are reproducible, and are not influenced by ambient perturbations.
The propagation behaviour measurements, which were carried out in an office environment, provide basic data to plan a WLAN network. The results show that the optimisation of a WLAN network will be easier in big open spaces compared to floors with a large number of rooms, walls and objects. In addition, mechanical vibrations and indoor / outdoor acoustical noise influence the propagation mode and the signal level in a significant mode.
In conclusion, our results show that in order to ensure a reasonable QoS it is necessary to allow for a sufficient margin when planning WLAN networks.

Outlook

The reference measurement method developed will help Swisscom to plan WLAN coverage in coexistence with Bluetooth and other WLAN devices and offer even better quality of service to its customers. 3

Abbreviations

AP	Access Point
BT	Bluetooth
DECT	Digital Enhanced Cordless Telecommunications
EMC	Electro-Magnetic Compatibility
GSM	Global System for Mobile Communications
ISM	Industrial Scientific and Medical
LOS	Line Of Sight
PC	Personal Computer
QoS	Quality of Service
RF	Radio Frequency
WLAN	Wireless Local Area Network

Enrico Blondel *is currently deputy Programme Manager of the Exploration Programme "Electromagnetic Effects" at Swisscom, Corporate Technology. Since 1991 he has been member of the EMC team at Corporate Technology and works as a specialist for power supply and environmental testing. He began his professional career in a R&D laboratory for Telecom power supplies, and specialised later in EMC tests. Enrico Blondel holds a BSc in Electrical Engineering from the Ecole d'ingenieurs de l'Etat de Vaud in Yverdon-les-Bains (EIVD).*

Zusammenfassung

Die Koexistenz von WLAN und Bluetooth

In der heutigen Unterhaltungselektronik wird bereits recht häufig die drahtlose Kommunikation wie Bluetooth, Wireless LAN, HomeRF benutzt. Alle diese Geräte funktionieren auf der gleichen so genannten ISM-Frequenz (2.4 GHz). Dieses Frequenzband ist frei von Konzessionen und Bewilligungen. Die Verwendung mehrerer Funkdienste im selben Frequenzband erzeugt aber gegenseitige Störungen. Für Swisscom bedeutet dies eine mögliche Verminderung der Dienstqualität. Diese kann vom Kunden fälschlicherweise als Qualitätsproblem der Swisscom-Netze interpretiert werden. Die Resultate zeigen, dass die Planungskomplexität der WLAN-Netze nicht zu unterschätzen ist, da räumliche Veränderungen die Ausbreitung massiv beeinflussen können, positiv wie vor allem auch negativ.