The miniWatt pro

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Since the 1990's, individual mobile communication has had a major impact on our communication behaviour. Alongside the sources to which the population as a whole is subjected from regional and national networks, immissions in the private sphere are also increasing continuously due to personal communication technologies like DECT, WLAN, Bluetooth and so on. However, while a large section of the population is intensively using the new communication media, there is also a degree of insecurity about the health effects of high frequency applications. The German Federal Ministry of Education and Research (BMBF) is not only promoting the development of new technologies, but is also making a contribution to assessing the effects of these technologies by funding specific projects in the field of electromagnetic compatibility with regard to the environment (EMCE). The following report outlines the miniWatt project.

Overview

From January 2002 to March 2003, the BMBF funded the project "Alternative Radio Systems with Minimal Radiation Density for Digital Broadcasting, Mobile Communications, and Wireless LANs" (known as **miniWatt**). The project, backed to the tune of approx. 1.1 m was subdivided into seven fields of work with a total of 38 sub-projects. Eleven university institutes, three industrial concerns, four medium-sized companies and an independent research institute were involved. The aim of the project was to conduct a comprehensive investigation aimed at reducing exposure by technical, structural and organisational measures in digital radio, mobile communications and WLANs.

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The state of the art

Today's commercially available mobile phone systems use digital modulation modes. Analogue systems are still used only by authorities and organizations with security responsibilities (BOS). In the case of terrestrial radio, both analogue and digital broadcasting strategies currently coexist. Digital technologies, thanks to their better data security features, allow the use of lower transmitting power levels. As a result, a reduction in the amount of exposure in comparison to analogue transmission technologies is possible in principle. On the other hand, the use of the electromagnetic spectrum, particularly in the mobile telephony and home networks is increasing, so that the number of exposure sources is also growing. The technologies now in existence have been designed in such a way that the signals can be decoded, as long as the necessary signal quality criteria have been achieved in relation to parasitic induction (SINR). In addition, to minimize interference, no unnecessarily high transmitting powers are used, i.e. the sensitivities of the devices are fully exhausted. Systems with reverse channel capabilities (such as mobile telephony) also possess mechanisms for controlling transmitting power, reducing emissions to the level necessary for a reliable connection or as demanded by specifications.

Increasing efficiency

The starting point for an all-round reduction in emissions is increased efficiency through using resources that have not yet been developed (e.g. space diversity). This means designing an ideal system where the energy needed to securely transmit a useful bit (data bit) in a required time (data rate) is minimized. The minimum has to be found while taking particular limiting parameters (allowed spectrum, costs, etc.) into account. Thus for instance, it might well be that higher efficiencies, and thus lower emissions, are possible if another working frequency were employed, though not one approved for use. More complicated techniques are, as a rule, tied up with higher costs, which may hinder the economical introduction of new technologies.

In order to increase the efficiency of a radio system, a variety of individual system parameters or the whole system may be changed. Related technologies thus have been appropriately linked in the context of the miniWatt project (see table 1).

Reference models

In order to be able to assess the various measures with regard to their potential for reducing transmitting power, each subproject has been based on a suitable reference model. For the WLAN, PAN, mobile telephony (GSM and UMTS) and digital television systems, parameter sets were defined for comparison purposes, and the investigated technologies were to be compared with regard to these.

Findings

Selected results from the project are shown below. The complete concluding report can be found at [1].

Intelligent antenna systems

Through the superimposition of the individual signals emitted by the individual antennas, systems comprising a number of antennas form an overall directional pattern deviating from that of the individual elements. As a result of this, electromagnetic energy may be

WP 1	Spread spectrum technique
WP 2	Space-time signal processing
WP 3	Alternative frequency ranges
WP 4	Self-organising networks, algorithms and protocols
WP 5	Alternative networks
WP 6	Developments in mobile telephony (standards-compliant)
WP 7	Developments in digital broadcasting (standards-compliant)

Table 1: Work packages of the miniWatt project.

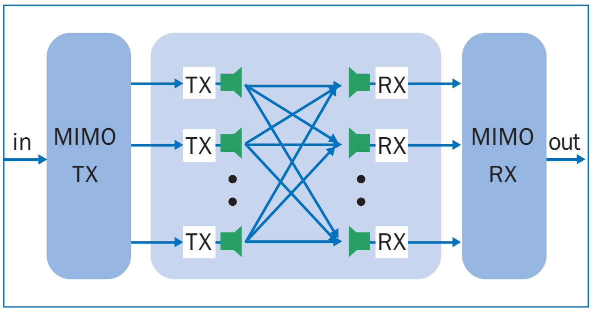

Figure 1: Schematic depiction of a MIMO multi-antenna system.

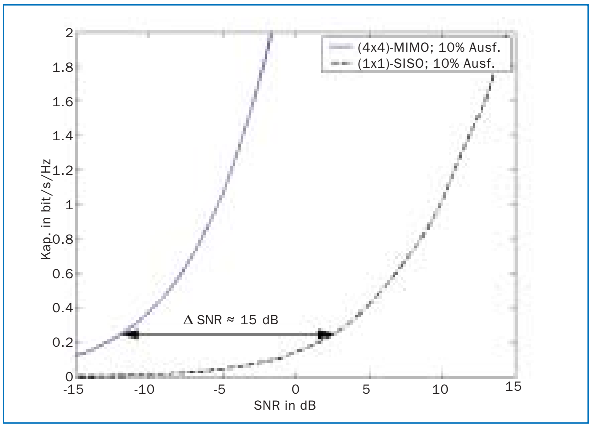

Figure 2: 10% outage capacities for a classical antenna configuration of one transmitter and receiver antenna (SISO system (single input – single output)) and a MIMO system consisting of four transmitter and receiver antennas in a Rayleigh channel [2]. The case shown represents a possible reduction in transmitting power of approx. 15 dB (a factor of 32).

concentrated at the desired space for the receiver, while at the same time, it may be reduced at other sites. As this can occur in an adaptive way, it is easy to organise an orientation towards different subscriber locations. This is called beam forming (adaptive beam forming). Beam forming can be exploited to reduce transmitting power. MIMO (multiple input – multiple output) systems, which possess a number of antennas on the transmitter and receiver sides, go one step further. By exploiting diversity, for instance that of space, the signals at the individual receiver antennas are uncorrelated. The power available in the environment of the receiver is used more effectively, in particular any brief breaks in the signal can be greatly reduced. Besides this, it is possible to transmit different information via different antennas, information which could then be combined by the receiver in a suitable way. A MIMO system is displayed schematically in Figure 1.

The capacity of a MIMO system is a random variable and depends on the implementation of the radio channel. Thus, the transmission capacity details stated refer to capacities that are not achieved in a certain percentage of cases. This capacity is usually referred to as the outage capacity. Figure 2 shows that in a multi-antenna system (unbroken blue line) a specific outage capacity can be achieved with a far lower signal-to-noise ratio than with the conventional configuration that uses one receiver antenna (dotted black line).

Savings in transmitting power are mainly dependent on the transmission capacity necessary (in bit/s/Hz) the number of antennas on the transmitter and receiver sides as well as the radio channel. However, savings of around one order of magnitude are certainly realistic though suitable signal processing mechanisms are needed (at least on the receiver side, and also the transmitter side, in the case of certain MIMO transmission procedures) in order to achieve an appropriate gain in capacity or a reduction in transmitting power. Meanwhile, this technology is soon about to be introduced in mobile telephony. Nevertheless, it is also usable for other forms of transmission, e.g. radio broadcasts.

New kinds of network structure

A change in the network structure of the transmitter devices as a result of making the necessary parameter adjustments to the transmitter units has an immediate effect on emission. In the context of the miniWatt project, multi-hop systems have been looked at in which the radio signal from one terminal device reaches a base station via a number of other different user terminals (in some cases of inactive users) (Figure 3). Due to the short distance to the next terminal, the user wanting to make a connection can do so employing a significantly smaller transmitting power. However, closer investigation has shown that the administrative effort is very large with a large number of hops, leading simultaneously to reductions in efficiency. So it may be that no reliable connection can be provided. In addition, the presence of other available terminals in the environment is needed, which in turn become sources.

Emissions can be reduced greatly by reducing the coverage area. In the case of cellular networks (mobile telephony) the term used is „cell division" (image 4). Limiting supply to smaller areas also allows a reduction of transmitting power in radio networks. As the maximum number of users per cellular base station is limited, the advantages are greater in mobile telephony than in broadcast due to the simultaneous increase in capacity as a result of the cell division.
In the case of digital terrestrial television (DVB-T), it could be possible to greatly reduce emissions by replacing the "portable indoor" supply target, which envisages supplying broadcasting services in the core area within basements of buildings, by demanding that the necessary field strength is only achieved at roof height outside the buildings. Using a roof-mounted antenna with a gain of approx. 10 dB, it would then be possible to cut the overall transmitting power needed by a factor of 1000 (30 dB) to 10000 (40 dB).

Figure 3: Reduction in transmitting power through the use of multi-hop-capable terminal devices. Only a small transmitting power is needed due to the short distances to neighbouring terminal devices.

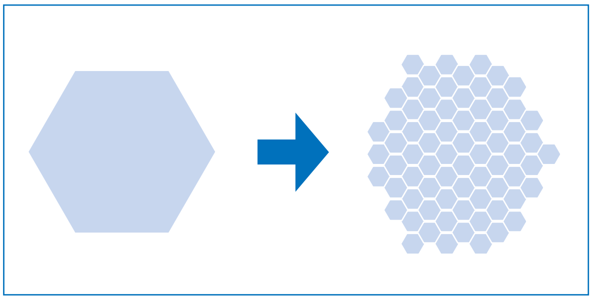

Figure 4: Cell division decreases the area to be supplied. Thus transmitting power can be reduced and capacity increased.

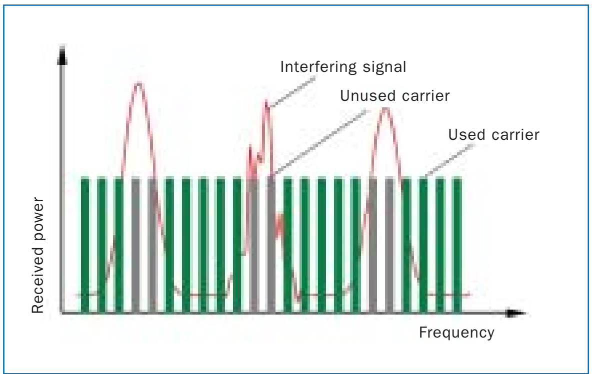

Figure 5: Transmitting power can be saved by abandoning the transmission of carriers that cannot be correctly decoded at the receiver.

In addition, a denser network structure would lead to a further reduction in emissions.

High-flying platforms or satellites are characterised by a very homogenous power density distribution on the ground. In particular for broadcasting systems without reverse channels, where in addition, large areas have to be supplied with a finite number of channels, this type of supply is also attractive from a cost perspective. Exposure due to satellites used for broadcasting is significantly smaller than that from terrestrial television, despite their providing a number of channels that is larger by several orders of magnitude.

Innovative signal processing techniques

Multi-carrier procedures use different carrier frequencies from a given frequency range to transmit information. Techniques of this type have the advantage that when transmitting signals, it is possible to use only those carrier frequencies with which lower transmission loss occurs and/or which can be picked up by the receiver in a sufficiently high quality. OFDM (orthogonal frequency division multiplex) is an example of a suitable procedure. By means of adaptive “bit-loading“, information is only transmitted on those frequencies that can be decoded by the receiver (figure 5). Simulations conducted during the miniWatt project have shown that by employing adaptive bit-loading, the necessary transmitting power can typically be cut by approx. 1.5 dB (a factor of 1.4).

Another way of reducing emissions is by using a suitable interference cancellation method. Here the information available to the receiver on the interfering signals is used to reduce these disturbing influences. This way the transmitting power needed can be cut.

In addition, the use of higher data compression can also reduce the emission. The transmitting power can be reduced because a lower data transfer rate (in bit/s) and thus a lower transmission capacity are needed.

Alternative frequency ranges

The miniWatt project has analysed potential reductions in transmitting power by using alternative frequency ranges.

The lower propagation loss existing with lower transmission frequencies allows transmitting power to be reduced. For example, if frequencies in the range of approx. 450 MHz (former C-band) were used for UMTS services, instead of the normal frequencies around 2 GHz, it would be possible to cut the transmitting power by approx. 14 dB (a factor of 25).

Infrared transmitters could be used as alternatives to using frequencies in the GHz range for some applications within the building (e.g. WLAN, Bluetooth, or radio headphones). The biological effects of infrared radiation are known and are accepted in the general population through the common use of infrared remote controls or IrDA interfaces. Besides, the components are available extremely cheaply. Use is limited by the fact that IR transmission virtually calls for a clear line of sight.

Both transmission by sound waves and the possibility of inductive transmission have proven themselves to be inefficient.

Additional information

The coordinator of the miniWatt project, the German Aerospace Centre (DLR) has published a brochure which can be downloaded from [3]. The entire report is available from the catalogue (OPAC) of the TIB/UB Hanover [1].

The current miniWatt II research project

Since April 2005, carrying on from the results of the miniWatt project, power densities, specific absorption rates and pulsations of the most diverse services have systematically been analysed and compared. The current project is entitled „Minimising the immission of future radio services“ (a.k.a. miniWatt II) and is being supported jointly by the BMBF (Federal Ministry of Education and Research) and the BMU (Federal Environment Ministry).

In contrast to the recently completed miniWatt project, in which special emphasis was placed on emission, main attention is now being given to the question of immission. In addition, immissions are to be comprehensively assessed by scientists with a broad specialist knowledge in the field of biomedicine.

The findings could make an important contribution to the planning of radio communications networks with optimised immission characteristics. It is also intended to place the equipment industry in the position where it can provide all-embracingly optimised solutions for reducing exposure.

Expression of thanks

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