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SAE[®]

BOSCH

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Integrated analog circuits

- Basic structures:
Stabilized-voltage supply, stabilized-current supply, differential amplifier components, switching elements, potential shift, output stages.
- Application-oriented classes:
Operational amplifiers (OP), voltage regulators, comparators, timers, converters, interface circuits.
- Special analog ICs:
Voltage references, wideband amplifiers, analog multipliers, function generators, phase-lock circuits, analog filters, analog switches.

Integrated digital circuits

The spectrum ranges from LSI (simple logic chips) through to ULSI (memories, microcomponents).

Several conditions must be met before logic chips can be combined within a single system: The power supply, logic level, the circuit speed, and the signal transit time must all be identical. This requirement is met within the respective circuit families. The most important are:

- Various bipolar types (e.g. TTL: Transistor-Transistor-Logic)
- MOS logic, in particular CMOS logic

MOS and CMOS chips make up more than 99% of the production of integrated digital circuits. Bipolar logic circuits are only used in exceptional cases. Here, too, CMOS devices are taking their place more and more.

Semiconductor memories

Data storage includes the following operations: recording (writing, entering), storage (data storage in the narrow sense), retrieval, and readout. The memory operates by exploiting physical properties that facilitate unambiguous production and recognition of two opposed states (binary information). In semiconductor memories, the states produced are "conductive/non-conductive" or "charged/discharged"; the latter state relies on special properties in the silicon/silicon oxide or silicon nitride/metal junction. In future magnetic memory chips (FDRAM) will also be used. They have small ferromagnetic areas integrated on the chip. The direction of the magnetic field is used to store information.

Semiconductor memories are divided into the two main categories of "volatile" and "non-volatile". Virtually all of them are manufactured according to CMOS technology.

- Volatile memories (short-term memories) can be read and over written any number of times, and are therefore referred to as RAMs (Random Access Memories); the information content is lost when the power supply is switched off.
- Non-volatile memory chips (long-term memories) retain their data even when the power supply is switched off; they are also referred to as ROMs (Read-Only Memory).

The chart on the facing page shows the relationships and classification of the most common types of memory chip.

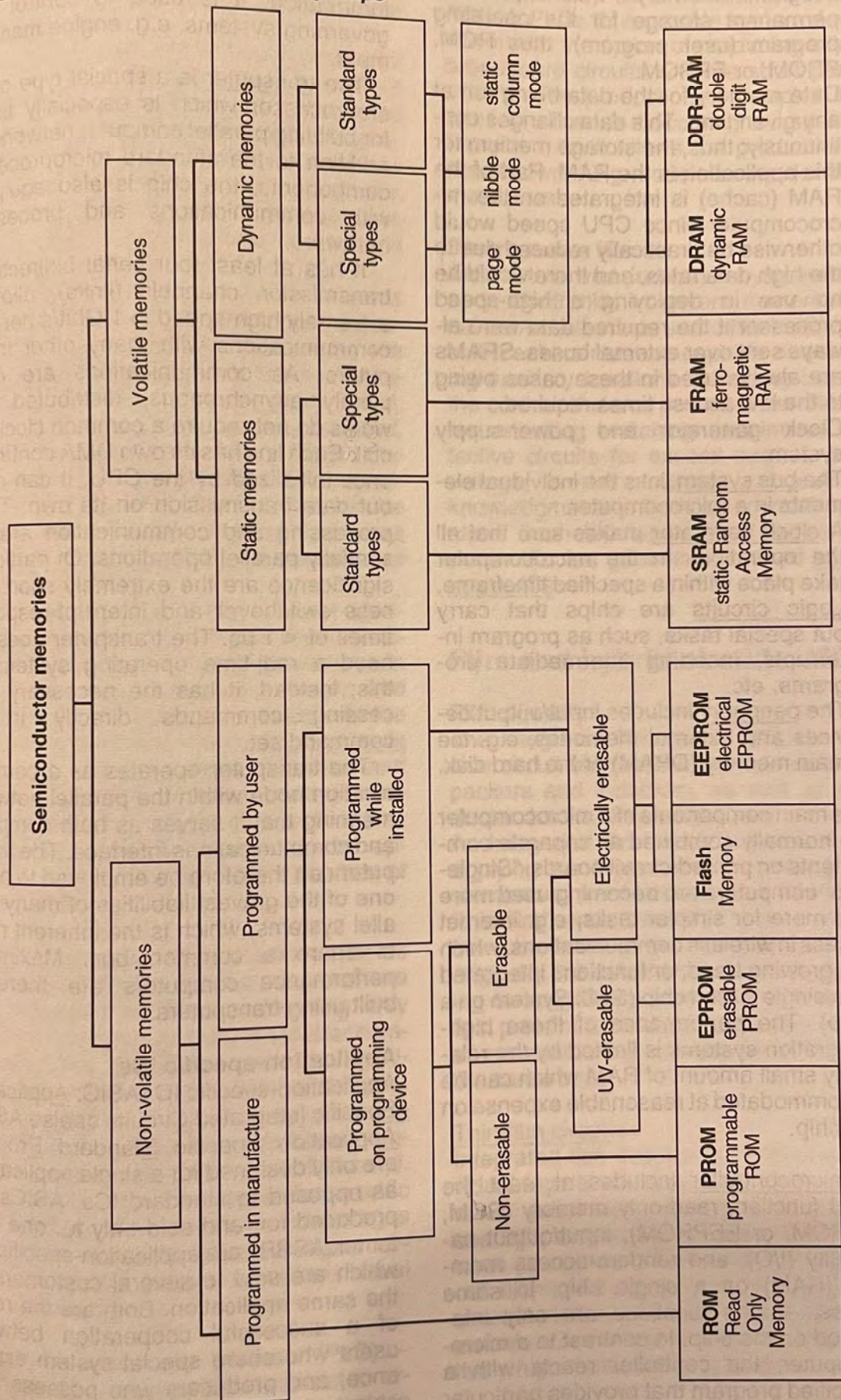
Microprocessors and microcomputers

The microprocessor represents the integration of a computer's central processing unit on a single chip. Microprocessor design seeks to avoid individualization in the face of large-scale integration, and the units can be programmed to meet the varied requirements associated with specific operating conditions. There are two different main groups of processor. A PC (Personal Computer) uses CISC processors (CISC: Complete Instruction Set Computing). These processors are very versatile and user-programmable. A WS (work station) normally uses RISC processors (RISC: Re-duced Instruction Set Computing). These processors are very much faster for the specific tasks frequently associated with WS use, but are significantly slower for all other tasks. A microprocessor cannot operate by itself: it always acts as part of a microcomputer.

A microcomputer consists of:

- Microprocessor serving as CPU (central processing unit). The microprocessor contains the controller and the arithmetic-logic unit. The arithmetic and logic unit performs the operations indicated by its name, while the controller ensures implementation of the commands stored in the program memory.
- Input and output units (I/O), which control data communication with the peripherals.

Overview of semiconductor memory chips



- Program memory which provides permanent storage for the operating program (user program), thus ROM, PROM, or EPROM.
- Data memory for the data being run at any given time. This data changes continuously; thus, the storage medium for this application is the RAM. Part of the RAM (cache) is integrated on the microcomputer since CPU speed would otherwise be drastically reduced due to the high data rates, and there would be no use in deploying a high-speed processor if the required data were always sent over external buses. SRAMs are always used in these cases owing to the low access times required.
- Clock generator and power-supply system.
- The bus system links the individual elements in a microcomputer.
- A clock generator makes sure that all the operations in the microcomputer take place within a specified timeframe.
- Logic circuits are chips that carry out special tasks, such as program interrupts, inserting intermediate programs, etc.
- The periphery includes input/output devices and external memories, e.g. the main memory (DRAM) or the hard disk.

The main components of a microcomputer are normally combined as separate components on printed-circuit boards. "Single-chip" computers are becoming used more and more for simpler tasks, e.g. internet access in wireless communications, which is a growing trend, or functions integrated on a single silicon chip (SoC: System on a Chip). The performance of these high-integration systems is limited by the relatively small amount of RAM which can be accommodated at reasonable expense on the chip.

A microcontroller includes at least the CPU function, read-only memory (ROM, EPROM, or EEPROM), input/output capability (I/O), and random-access memory (RAM) on a single chip. In some cases, analog functions are only integrated on the chip. In contrast to a microcomputer, the controller reacts with a specified program that provides particular

output values depending on the input information. It is used to control self-governing systems, e.g. engine management.

The transputer is a special type of microprocessor which is especially useful for building parallel computer networks. In addition to the standard microprocessor components, the chip is also equipped with communications and processing hardware.

It has at least four serial bidirectional transmission channels (links), allowing extremely high-speed (> 1 Gbit/s per link) communications with many other transputers. As communications are completely asynchronous, distributed networks do not require a common clock circuit. Each link has its own DMA controller; once initialized by the CPU, it can carry out data transmission on its own. Thus, processing and communication are essentially parallel operations. Of particular significance are the extremely short process switchover and interrupt-response times of $\ll 1 \mu\text{s}$. The transputer does not need a real-time operating system for this; instead, it has the necessary processing commands directly in its command set.

The transputer operates as a communication node within the parallel network, meaning that it serves as both computer and communications interface. The transputer can therefore be employed to avoid one of the gravest liabilities of many parallel systems, which is the inherent need to share a common bus. Maximum-performance computers are therefore built using transputers.

Application-specific ICs

Application-specific IC (ASIC: Application Specific Integrated Circuits or also ASSP: Application Specific Standard Product) are only designed for a single application, as opposed to standard ICs. ASICs are produced for, and sold only to, one customer. ASSPs are application-specific ICs which are sold to several customers for the same application. Both are the result of a successful cooperation between users who share special system experience, and producers who possess suitable technologies. The essential advan-

tages of ASICs: fewer components, lower system costs, increased reliability, more difficult to copy.

The ASIC family is generally classified according to the development method which has been selected: chip-mounted circuitry, constructed from individual function elements (full-custom IC), provides the best results with regard to operation and packaging density. It is, however, only suited for large-volume applications (time and expense).

Standardized basic circuit functions (developed and tested in advance) represent one step towards rationalizing the development process. The circuits are incorporated in cells of varying sizes (ROM, RAM, computer core, or individualized, application-specific circuit groups). Depending on the number of available application-specific cells, this method can be employed to reduce development times without sacrificing efficient exploitation of the chip surface.

The next stage is the use of standardized, relatively complex basic functions which are developed in advance in standard cells of the same height and variable width. They are available in the form of cell libraries. These standard cells are automatically placed in series and then automatically connected with polysilicon and aluminum conductors. A dual or triple-layer metallic coating can be applied to achieve even better utilization of the surface area.

Gate arrays are predeveloped as far as the transistor/gate connection, and are manufactured in advance, leaving only the final masking operations for later completion. The connection with the application-specific circuit is then automatic. Rationalization is achieved by providing standard circuits for frequent basic computer functions (similar to a cell library). Special gate arrays designed for specific applications have particular advantages (e.g. pure computer-oriented digital circuits under the general conditions usual for computers).

Programmable logic devices (PLD) – completely preassembled transistor arrays – are programmed by the user in

the same way as a special-application PROM. PLDs thus provide system developers with the option of producing silicon breadboard circuits within a short period of time. The production of complex systems in silicon is becoming increasingly important, as it allows the production of practical working models in the development phase.

Smart-power ICs

Automotive and industrial systems rely upon electronics to govern numerous final-control elements and other loads. Circuit-breakers must be capable of assuming auxiliary functions extending beyond the control of circuit power: driver circuits for activating switching transistors, protective circuits for excess current, overvoltage, overtemperature, and fault acknowledgments in case of incorrect operation. Such bipolar or MOS-technology power ICs are generically termed smart-power ICs.

Film and hybrid circuits, MCM

Film circuits

The integrated film circuit features passive circuit elements – these include capacitors and inductors, as well as conductor tracks, insulators, and resistors. An integrated film circuit is produced by applying the layers which contain these elements to a substrate carrier. The terms “thin-film” and “thick-film” circuit derive from the fact that the film thickness was originally the determining factor for tailoring to specific performance characteristics; present technology employs a variety of manufacturing techniques to achieve the same end.

Thin-film circuits

Integrated film circuits on which the individual layers are applied to glass or ceramic substrates, usually in a vacuum coating process. Advantages: fine structures (to approx. 10 μm) provide high circuit-element density, extremely good HF characteristics, and low-noise resistor elements. On the minus side are the relatively high manufacturing costs.

Mobile and data radio

Telecommunications networks

Telecommunications networks consist of terminals and an infrastructure. Mobile radiocommunications networks can be classified as belonging to telecommunications networks based on the mobility of the terminals and the method these terminals use to access the infrastructure.

		Access method	
		Wired	Wireless
Mobility	Fixed	<ul style="list-style-type: none"> – Traditional phone network – Internet, LAN 	<ul style="list-style-type: none"> – Radio relay
	Mobile	X	<ul style="list-style-type: none"> – Mobile/data radio – Private mobile radio – Radio broadcasting – Marine/aeronautical radio – Cordless phones

Components and structure

Mobile radiocommunications networks can be subdivided in mobile radio telephones and infrastructure.

Mobile radio telephones

Mobile radio telephones include cellular phones and automotive radiocommunication devices. A mobile radio telephone is made up of three functional components:

- an operator unit (microphone, speaker, display, and keypad)
- Radio modem (modem, modulator/demodulator) to convert voice and data signals to electrical signals
- a radio transmitter/receiver unit.

Data terminal devices without radio transmitter/receiver units such as laptop computers or PDAs (Personal Digital Assistants) can communicate with a mobile radio communication system through an internal or external radio modem.

Mobile radiocommunications infrastructure

The mobile radiocommunications infrastructure consists of the fixed radio trans-

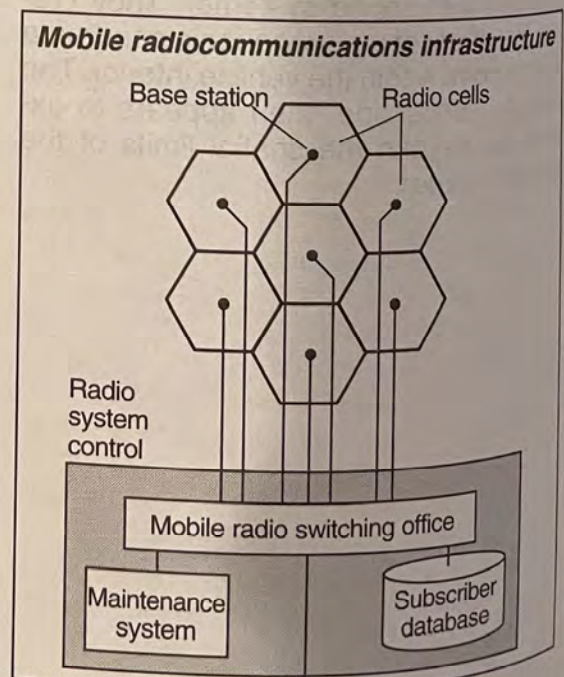
mitter/receiver stations and the radio system control. A radio transmitter/receiver station consists of a base station, which provides radio coverage of an area, and a base-station control system. The positioning of base stations depends on several considerations, including topographical constraints and expected communications traffic levels (maximum subscriber capacity). A cellular network structure allows the few radio frequencies available to be reused in adjacent cells.

Radio system control

The mobile radio switching office controls call connection between mobiles that are in the same or even in different radio cells. It also controls the switching of radio traffic to the wire-line telephone network. In order to control call switching automatically, the mobile radio switching office must know the location of all mobiles within the radio cells at all times. This is made possible by continuously exchanging an identification signal between the mobiles and the base stations. A base station can detect when a mobile moves to an adjacent cell by the drop in field strength or quality of the received signal.

The subscriber database performs the job of authenticating subscribers, and stores each subscriber's location within the radio cells.

A maintenance and control system continuously monitors network operation.



Mobile radiocommunications networks

GSM and DCS 1800 mobile radio networks

The standardized digital mobile communications network for Europe, GSM (Global System for Mobile Communication), has been in operation since 1992. In contrast to analog radio networks, it transmits voice and control data in digital form. GSM radio networks operate in the 900 MHz band, and each has a capacity of around 2 million subscribers. The similar DCS 1800 (Digital Cellular System) network operates using identical technology in the 1800 MHz band, and has been in service since 1994. Each radio cell has several high-frequency channels, each with a bandwidth of 200 kHz. Each high-frequency channel transmits seven voice channels (traffic channels) and one control channel in succession in short time slots within a time frame. When a call is set up, the high-frequency channel is available to each cellular phone every 4.6 ms for the duration of the time slot (time-division multiplexing). The time delay of 4.6 ms between two consecutive identical time slots is short enough to guarantee perfect speech quality.

Each traffic channel can transmit a maximum gross data stream of 22.8 kbit/s. To compensate for errors during radio transmission, digitized speech is only transferred at a data rate of 9.6 kbit/s. The difference between this and 22.8 kbit/s is used for error correction. Instead of speech, a traffic channel can also transfer data (e.g. a fax transmission).

A time slot between the terminals is permanently reserved for the duration of a mobile radio connection (line connection), regardless of whether the connection carries speech or data.

Short Message Service (SMS)

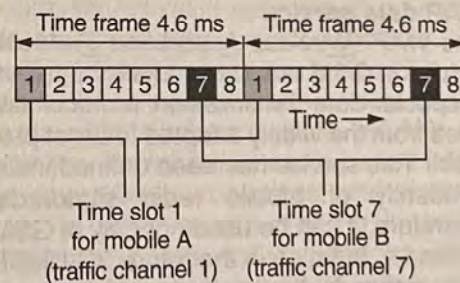
SMS (Short Message Service) offers economical data transmission within GSM mobile radio networks for text messages of up to 160 characters in length. The text in an SMS message is transmitted without occupying a separate voice channel by using unused capacity in the control channels. SMS messages can be sent

from one mobile to another or from a PC to a mobile via the Internet. After an SMS message is sent, it is temporarily stored on the mobile radio network, and automatically sent out as soon as the receiving mobile is switched on ("store and forward" principle).

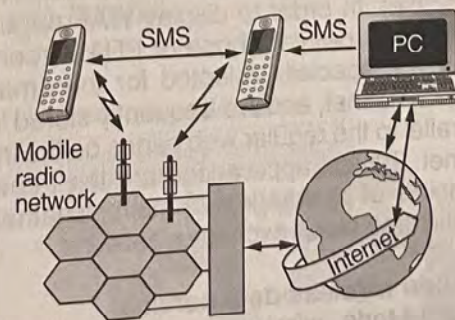
HSCSD data transmission procedure

The HSCSD (High Speed Circuit Switched Data) data transmission procedure involves GSM networks combining up to four adjacent traffic channels for data-transmission purposes (line connection). With a net data transmission rate of 14.4 kbit/s per traffic channel, channel bundling provides an overall data rate of 57.6 kbit/s. The cost of an HSCSD connection is calculated on the basis of the connection time and the number of traffic channels used.

Time-division multiplexing



SMS Short Message Service



GPRS data transmission procedure

In 2001 the packet-based data transmission procedure GPRS (General Packet Radio Service) was introduced to complement the GSM radio network. GPRS data channels and normal voice channels share the time slots in a time frame. GPRS data channels are dynamically allocated according to voice-channel priority. During transmission pauses in GPRS connections, other GPRS connections can use the temporarily "unused" time slots. In contrast with the HSCSD procedure, a data stream is subdivided in individual consecutively numbered data packets for transmission. The data packets are transmitted independently of one another. The receiving mobile rearranges the data packets into the correct order on the basis of their consecutive numbering. Transmission costs are calculated on the basis of the data volume transmitted. A mobile equipped with a GPRS module can connect to data networks (e.g. the Internet).

WAP data service

The WAP (Wireless Application Protocol) service in GSM radio networks is based on a special data-transmission protocol derived from the widely adopted Internet protocol. This service has been defined independently of mobile radio standards. Therefore, it can be used not only in GSM networks, but also in the future 3G/UMTS radio network. A microbrowser integrated in the mobile can access data from the Internet (World Wide Web, e-mail, etc.). In contrast with the SMS and MMS services, access to stored data/messages (WAP pages or e-mails) on the Internet is actively initiated by the user ("store and retrieve" principle). In order to display WAP pages on a small cellular phone or PDA screen, they are specially adapted for the small display format, and are frequently stored in parallel to the regular web pages on the Internet. Typical applications are the transmission of messages (e-mail), weather, traffic, and stock-exchange bulletins.

i-Mode wireless data service

The i-Mode wireless data service ("i" stands for Internet or interactive) in Europe is part of the DC1800 mobile radio

Japan as an alternation to the WAP service. Both services use GPRS data-transmission technology.

MMS data service

MMS (Multimedia Messaging Service) allows the transmission of images, graphics, video clips, audio files, etc. to or from a mobile. The MMS service was defined for the transmission of MMS messages in GSM networks, using GPRS/WAP technology, and in the UMTS radio network. Before transmitting multimedia objects to a mobile, the display format must be adapted. Special computers in the mobile-radio networks therefore configure the multimedia data. Any combination of individual multimedia objects can also be created and reproduced on the mobile based on a specific time plan. In addition to "fun applications" (sending photos live on vacation), there are also possible business uses, such as sending presentations, product data, or directions to field staff on their mobiles.

G3/UMTS mobile radiocommunication network

The future mobile radiocommunications network is G3/UMTS (G3: 3rd generation; Universal Mobile Telecommunication System) is an advance development of the GSM network. The radio communication interface has been optimized for multimedia applications, such as voice, data, music, images, video, games, etc., and packet-based data transmission. The G3/UMTS radio network operates in Europe in the 1.9...2.2 GHz frequency band. The radiocommunications infrastructure is divided into three levels as follows:

1. The macrocellular network, as the highest network level, consists of radio transmitter/receiver stations with a cell size of approx. 2 km. It provides nationwide network coverage. The maximum data transmission rate is 144 kbit/s.
2. The microcellular network, as the middle network level, supplies smaller areas (cell size approx. 1 km, primarily for large conurbations). The maximum data transmission rate is 384 kbit/s.

3. The picocellular network, with a cell size of approx. 60 m, max. data rate 2 Mbit/s) primarily in fixed locations (e.g. airports).

In contrast with GSM time division multiplexing, G3/UMTS transmits within a radio cell simultaneously on the same radio channel.

WCDMA (Wideband Multiple-Access) codes different mobiles in a radio channel. The base station negotiates these codes with the mobile. WCDMA technology allows a higher utilization of radio channels than GSM technology. The transmission capacity can be flexibly adapted to the actual use. Voice transmission requires a lower data rate than the transmission of multimedia data (e.g. images and video clips).

Data radio network

Special data radiocommunication networks, such as Bluetooth, provide a data link between mobile devices or within a data network or the Internet.

Bluetooth

Bluetooth is an alternative to radio links, and is used to provide a connection between PC and mobile devices, such as printers, etc.

The Bluetooth network operates in the unlicensed 2.4 GHz frequency band. Bluetooth appliances such as mobile phones, "Bluetooth" is derived from the name of a Viking king called Harald "Bluetooth" in recognition of his contribution to the development of the technology by Danes. The maximum transmitter output is 1 mW (approx. 10 m). In order to avoid interference, the transmission frequency is changed 1600 times per second (frequency hopping).

3. The picocellular network (cell size approx. 60 m, max. data transmission rate 2 Mbit/s) primarily supplies buildings (e.g. airports).

In contrast with GSM time-division multiplexing, G3/UMTS transmits all data within a radio cell simultaneously on the same radio channel.

WCDMA (Wideband Code-Division Multiple-Access) codes separate data for different mobiles in a high-frequency channel. The base station and the mobile negotiate these codes with each other. WCDMA technology allows more efficient utilization of radio channels compared with GSM technology. Thus, the data-transmission capacity for a connection can be flexibly adapted to suit the service in use. Voice transmission, for example, requires a lower data rate than the transmission of multimedia applications, such as images and video clips.

Data radio networks

Special data radiocommunications networks, such as Bluetooth and WLAN, provide a data link between mobile terminals, or within a data network such as the Internet.

Bluetooth

Bluetooth is an alternative to infrared links, and is used to provide wireless connection between PCs and external devices, such as printers, digital cameras, etc.

The Bluetooth network operates in the unlicensed 2.4 GHz frequency band (like appliances such as microwave ovens). "Bluetooth" is derived from the name of a Viking king called Harald Blåtand (meaning "Bluetooth") in recognition of the leading contribution to the development of the technology by Danish companies. The transmitter output is 1 mW over a range of approx. 10 m. In order to eliminate errors in transmission as far as possible, the frequency is changed 1,600 times a second (frequency hopping). The individual frequency divisions transmit the data se-

division experiences a fault during data transmission, an error correction procedure can completely reconstruct a frequency division on the receiver side.

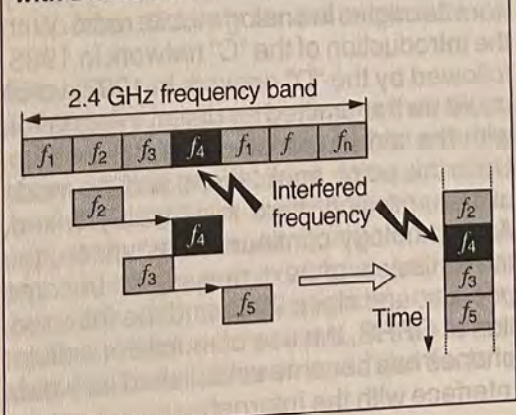
The maximum data rate is 721 kbit/s. In Bluetooth networks, no particular data-encryption method is employed. Data security is limited simply to synchronizing the frequency hopping procedure between devices.

WLAN

WLAN networks (Wireless Local Area Net-work) offer mobile telephones and Bluetooth networks a wireless link to computer networks in the 2.4 GHz frequency band. In contrast with Bluetooth, the frequency is changed only every 2.5 seconds. The transmit output is up to 100 mW, which allows a range of up to 100 m in buildings. Using WLAN, data links to the Internet with a maximum data rate of 11 Mbit/s can be created at a low investment cost. As distinct from Bluetooth, WLAN radio networks also employ an effective data-encryption process.

The terminals used are laptop computers or PDAs equipped with an appropriate radio LAN interface module. WLANs replace or complement cable-based LANs in enterprises, universities, and airports, etc. In order to allow billing in public WLANs (airports, railway stations, etc.), the mobiles must be fitted with a SIM (Security Identify Module) for identification.

Data transmission and error correction with Bluetooth



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