System Documentation

KNX RF Multi



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Legal Information

KNX RF Multi System Documentation
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ise Individuelle Software und Elektronik GmbH
Osterstraße 15
26122 Oldenburg, Germany

Feedback and information about products

If you have any questions regarding our products, please contact us via email at sales@ise.de. We would be pleased to receive your ideas, suggestions for improvements and criticism via e-mail at support@ise.de.

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1 The KNX RF Multi system

The KNX RF Multi System (RF = Radio Frequency) is based on the manufacturer-independent KNX standard and operates in the 868 MHz frequency range. KNX RF enables existing KNX systems to be retrofitted or new installations to be upgraded with RF components. Built-in devices with KNX RF allow a conventional electrical installation to be converted into a modern smart home with, for example, switching and dimming functions, heating control and remote access. KNX RF devices can be connected to wired KNX installations via a KNX RF Multi/TP media coupler. Suitable RF actuators can be controlled directly by RF transmitters.

Like KNX TP, KNX RF Multi offers bidirectional, encrypted and reliable communication. The bidirectionality of the KNX RF components is ensured by a transmitter and receiver module. This allows for:

- Status displays on the RF operating points
- Status feedback for actuators
- Commissioning by the ETS

Some KNX RF Multi products are battery-operated. To save battery power, the devices have an energy-saving mode. There are two different variants here, so-called semi-bidirectional devices (which support Ready and Fast) and SLE (Slow Low Energy) devices. After the last operation or after an ETS download operation, the semi-bidirectional devices automatically switch to the energy-saving mode after an adjustable time. The devices are then temporarily inoperable. If an RF device is in energy-saving mode, this must be actively terminated before a download operation by the ETS is possible. This can usually be done by pressing an operating button or the programming button. The same applies to unloading the application programme or reading out the device information by the ETS.

When the energy-saving mode is active, the receiver of a semi-bidirectional RF device is switched off. As a consequence, the device cannot receive any telegrams, meaning that status changes of group addresses cannot be tracked. With hand-held transmitters or pushbutton sensors which are configured to the button function “Switching - TOGGLE”, it may be necessary to press the button up to two times for the switching command (ON ➔ OFF / OFF ➔ ON) to be switched correctly.

The ETS requires the user to press the programming button if no direct access to the devices is possible due to an active energy-saving mode.

SLE devices, however, also switch to an energy-saving mode but they continue to be availabe via so-called SLE telegrams. SLE telegrams are slower and their transmission can last several seconds. This means that these devices can be permanently accessed by other participants and the ETS.

KNX RF devices comply with the KNX standard “KNX RF Ready (KNX RF1.R)” or “KNX RF Multi (KNX RF1.M)”. KNX RF Multi is the further development of KNX RF Ready. All devices from all manufacturers complying with this standard are compatible with each other; an intermediary may be required between KNX RF Ready and SLE devices.

1.1 KNX RF Multi channels

While KNX RF 1.1 and Ready only use one channel (a channel corresponds to a transmission or receive frequency), several channels are available for KNX RF Multi. The use of multiple channels allows you to switch to another channel if the current channel is blocked by an external transmission. This increases availability.

These channels are referred to as Fast channels (F1, F2) and SLE channels (SLE1, SLE2).
Accordingly, the KNX RF Multi modes are called Fast and SLE. Physically, they differ in terms of the reception bandwidth and the frequencies used.

1.2 Fast Ack to confirm receipt

With KNX RF Ready, telegram losses are possible because the transmitter does not receive a confirmation from the receiver. The reliability of KNX RF Multi has been significantly improved by the introduction of confirmed transmissions. This mechanism, known as “Fast Acknowledgement”, enables up to 64 receivers of a telegram to acknowledge it after reception by sending a short response to the transmitter. If there is no confirmation from at least one device, the transmission of the telegram is repeated. For this, several channels are used: For Fast e.g. F1, F1, F1, F2, F2, F1 and for SLE e.g. SLE1, SLE1, SLE2. The transmission is only deemed to have failed if it has been repeated on all these channels and not all expected acknowledgements have been received.

1.3 Battery-operated devices

KNX RF Multi and especially KNX RF Multi SLE have been optimised for battery-operated devices.
The decisive factor here is the type of preamble. A preamble is a sequence of zeros and ones, e.g. “01010101010”, it is sent before the actual radio telegram and is used to synchronise the transmitter and receiver.

KNX RF 1.1 and KNX RF Ready, for example, use very short preambles of approx. 1 ms and 5 ms in length.
KNX RF SLE telegrams use a comparatively long preamble of 501 ms. This allows SLE receivers to remain in sleep mode for 489 ms, for example, thus saving energy.
The Fast channel was developed for mains-powered devices and has a shorter preamble of 15 ms.

KNX RF Multi devices can either receive in SLE RF mode or in Fast RF mode, but not in both. In contrast, all RF modes can be used for transmitting.
To further increase the sleep time of battery-operated receivers during reception, a special preamble is used for KNX RF Multi SLE. This preamble is divided into a sequence of several short blocks of “010101...” preambles, each followed by additional information such as part of the domain address (DoA), the destination address and information for calculating the time until the telegram starts.

This allows the receiver to find out whether it is addressed at all while receiving the preamble. If it is not addressed, it can cancel the reception and switch to sleep mode; it can calculate from the information contained in the preamble about the telegram start when it must wake up again in order to skip the current telegram and be ready to receive the next telegram. If it is addressed, it can cancel the reception for the time being and switch to sleep mode, then it uses the same preamble information to calculate the wake-up time for receiving the current telegram.

The two lower bytes of the domain address are used in the SLE preamble to filter telegrams at an early stage and thus save energy. For this mechanism to work, it must be ensured that the domain addresses differ in the lower 2 bytes if several RF segments exist.
Example:
Segment 1: DoA 0011:2233**4455**
Segment 2: DoA 0011:2233**6677**

1.4 Prioritisation of telegrams

To extend an existing TP installation with a radio component, an RF/TP media coupler must be used. The media coupler has the task of translating from the physical medium TP to the medium RF and vice versa. As the media coupler is mains-powered, it receives Fast on the RF side in RF mode. Nevertheless, it must be able to send Fast/Ready and SLE telegrams in order to integrate all possible KNX RF device types into the installation.

If the media coupler transmits an SLE telegram, it is not available for Fast reception during SLE transmission. This is problematic because the SLE preamble of 501 ms is very long compared to the Fast preamble of 15 ms and can last for several Fast telegrams.

SLE Gap solves this problem by inserting a gap in the SLE preamble at regular intervals. The transmitter scans the Fast channels within this gap. If an ongoing Fast transmission is detected, the Fast telegram is received and the SLE transmission is restarted later.

This reduces the latency of Fast telegrams for devices with high latency requirements, such as devices with user interaction or media couplers, at the expense of SLE devices with predominantly low latency requirements.

If the transmission of a telegram with SLE gap preamble is interrupted by the reception of a Fast telegram, the transmission is repeated. The repetition starts after the Fast telegram has been received and an additional delay time has elapsed. To prevent excessive delays of SLE transmissions, a maximum number of “five” interrupted SLE Gap preamble transmissions due to a Fast telegram has been defined (default value). If the fifth repetition of the SLE GAP transmission is interrupted, the telegram is repeated with the normal SLE preamble (without gaps), this telegram is called the “Last Chance Telegram”. By sending an SLE telegram (without gaps), further interruption by fast telegrams is prevented.

1.5 Blacklist

In certain cases, for example in the event of a defect or interrupted power supply, a receiving device may not be able to send a Fast Acknowledgement for a specific telegram.
Transmitters have a blacklist so that telegrams that have not been confirmed do not contribute to a high bus load due to constant repetition. If a telegram is not confirmed by the receiver with a Fast Ack, the sender of the telegram writes the destination address, the information as to whether it is Fast or SLE and the Fast Ack slot number to its blacklist.

If a Fast Ack is not received after three consecutive telegrams, this entry in the blacklist becomes active. This means that no more repeat attempts will be made for this Fast Ack. If a Fast Ack stored in the blacklist is received, the entry becomes inactive again. All ise devices support the blacklist procedure.

1.6 Approval and frequency use

KNX RF Ready (KNX RF1.R) and KNX RF Multi (KNX RF1.M) use frequencies from the Europe-wide SRD band (SRD = Short Range Device). This licence-free frequency range covers low-power radio applications. In addition to KNX RF, these include radio remote controls, wireless microphones and headphones or other simple data transfer systems. KNX RF devices are generally approved and can therefore be used in all countries that recognise the standards and directives of the European Union. These generally include the EU and EFTA states.

The frequency band around 868 MHz used by KNX RF has good properties in buildings in terms of signal propagation, as the attenuation caused by walls, concrete reinforcements and metal parts is kept within acceptable limits.

Frequency	Transmission capacity	Application (example)
26.9 … 27.2 MHz	≤ 10 mW	PC devices, babyphones, model radio
40.6 … 40.7 MHz	≤ 10 mW	Model radio
433.05 … 434.79 MHz	≤ 10 mW	Motor vehicle remote controls, headphones, weather stations
446.0 … 446.2 MHz	≤ 500 mW	PMR radio equipment
868.0 … 868.6 MHz	**0.5 … 25 mW**	**KNX RF Ready / KNX RF Multi Channel F1**
868.7 … 869.2 MHz	**0.5 … 25 mW**	**KNX RF Multi Channel F2**
869.7 … 870.0 MHz	**0.5 … 25 mW**	**KNX RF Multi Channel SLE1**
869.4 … 869.65 MHz	**0.5 … 25 mW**	**KNX RF Multi Channel SLE2**

Table 1: Overview of standard SRD frequency bands

In addition to the SRD frequency bands, there are other frequency ranges that are intended for other radio services from different areas of application (e.g. analogue and digital audio and video transmission systems, WLAN, Bluetooth). The division into frequency ranges according to the approved application is required for the range of different radio services to coexist and not interfere with one another.

The frequency range used by KNX RF is not exclusively available to the KNX radio service. In this frequency range, too, there may be parallel radio systems in a building, which have an influence on signal transmission. The shared use of a frequency range can lead to interference between the different radio services, which can result in the loss of transmitted information.
Using appropriate procedures, KNX RF Multi reduces its own influence on other systems and is itself less sensitive to interference (see Control of media access, p. 11).

Frequency	Transmission capacity	Application (example)
868.0 … 868.6 MHz	≤ 25 mW	Including radio alarm systems, garage door openers, eNet
868.7 … 869.2 MHz	≤ 25 mW	Including radio alarm systems, garage door openers
869.7 … 870.0 MHz	≤ 25 mW	Including radio alarm systems, garage door openers
869.4 … 869.65 MHz	≤ 25 mW	Including radio alarm systems, garage door openers
2.40 … 2.48 GHz	≤ 100 mW	WLAN , Bluetooth
5.725 … 6.875 GHz	≤ 1.000 mW	WLAN

Table 2: Overview of standard radio services in the same and neighbouring frequency ranges to KNX RF (also not SRD)

With KNX RF1.R, the mean frequency is specified as 868.3 MHz. A transmission power in the range 0.5 ... 25 mW is possible. The system provides a communication channel for all devices.

With KNX RF1.M, there are several communication channels for the devices.
Their mean frequencies are:

- F1: 868.3 MHz
- F2: 868.95 MHz
- SLE1: 869.85 MHz
- SLE2: 869.525 MHz

A transmission power in the range 0.5 ... 25 mW is possible.

1.7 Duty Cycle

The Duty Cycle (also "limitation of the transmission load") describes a legally regulated limitation of the transmission time of devices in the 868 MHz range. It specifies how many seconds per hour can be used for transmission on the individual Fast and SLE channels. The following values apply for the individual Fast and SLE channels:

Channel	Duty Cycle in %	Transmission time in seconds per hour	Number of telegrams per hour (Secure telegram with 4 byte payload)
Ready/F1	1 %	36	811
F2	0.1 %	3.6	81
SLE1	2.7 %	97.2	105 - 183
SLE2	10 %	360	391 - 678

If a device reaches the Duty Cycle for channel F1, for example, it would automatically switch to channel F2. The following scenarios are possible for the Duty Cycle:

- If the Duty Cycle is also reached on channel F2, the device may no longer send telegrams on Fast until transmission time is available again on one of the channels.
- If the Duty Cycle is not reached on channel F2 and channel F1 is enabled again during this time, the device automatically switches back to channel F1.

The Duty Cycle only applies to multicast communication and not to service tasks such as firmware updates, loading an application or writing a individual address.

1.8 KNX Secure und Security Proxy

Use KNX Secure to protect the KNX installation from attacks by third parties.
KNX RF is not encrypted without the commissioning of Secure, which is why the use of KNX Secure is strongly recommended.

All KNX RF Multi devices from ise Individuelle Software und Elektronik GmbH support KNX Secure. Secure commissioning is performed via the ETS.

In order to be able to work with secure communication on the RF side, even though connected devices in the TP area do not yet support KNX Secure, there is the Security Proxy extension. This system component translates secure and non-secure group addresses between two lines or segments.
It does not matter whether the secure communication is on the primary or secondary side, the Security Proxy can be used for both directions.

The ise KNX RF Multi/TP media coupler supports the Security Proxy extension, which is automatically configured by the ETS6.

2 Practical tips

2.1 Consideration of the installation situation

Structural conditions

- Pay attention to structural circumstances, such as load-bearing metal parts, metal reinforcements, wall and ceiling panelling made of metal, metal-coated glass panes/thermal insulation glazing, etc. These cause shadowing, reflections and cancellation of radio signals.
- Keep your distance from larger metal surfaces, e.g. doors, frames, aluminium roller shutters, ceiling panelling, distribution cabinets, insulating foils, ventilation grilles.
- In large buildings or extensive building sections, set up several RF lines, each with its own media coupler, so that they do not negatively influence each other (see figure 22).
- In smaller buildings (e.g. detached houses), set up several RF lines, each with its own media coupler, if the building structure and the consistency of the ceilings and walls strongly shield the individual RF areas from each other. Solid, load-bearing walls can also cause strong attenuation of the radio signals.

Device placement

- Install RF devices so that they are still accessible after installation.
- Position the antennas of media couplers or repeaters as straight as possible (stretched, unbent) or in a circle in a flush-mounted box.
- Install RF devices such as pushbutton sensors or media couplers at a mounting height of 1 to 1.50 metres. Installation close to the ground or floor should be avoided.
- A media coupler can also be used outdoors (as a repeater, for example) in a suitable installation box (plastic, surface-mounted, wall-mounted) to provide or amplify the KNX RF signals across buildings. This means that KNX RF devices can also be used outdoors - provided the nature of the devices allows it - or in remote buildings (e.g. garden shed).

Interference from materials

- Avoid installation in or behind shielding materials, e.g. a metal switch cabinet.
- Avoid installing media couplers/repeaters behind flush-mounted dimming actuators in the same flush-mounted box. Use a separate flush-mounted box for the media coupler/repeater.
- Position RF devices so that radio waves can penetrate neighbouring walls and ceilings by the shortest possible route.

Interference due to external devices

- Avoid sources of interference in the immediate vicinity of KNX RF devices. These include devices that emit electromagnetic waves, e.g. electrical machines, electronic ballasts and light sources, microwave ovens.
- Keep your distance from other radio sources, e.g. cordless telephones, wireless headphones, WLAN routers.

2.2 Expansion of existing installations

Mixed operation of KNX RF Ready and KNX RF Multi devices

A device with Ready to Slow Proxy is required for the Ready to Multi or Multi to Ready translation. The ise KNX RF Multi/TP media coupler or RF repeater is suitable for this purpose.

Retrofitting KNX RF Multi

First set up the media coupler and programme it before continuing with the KNX RF Multi devices.

2.3 Topology

Use of media couplers

- Position media couplers centrally in the centre of an RF installation (domain) to enable low-loss and interference-free communication with all associated RF devices.
- If several media couplers are used, make sure that they receive each other's signals (see figure 2, case 1) or are completely separated from each other (see figure 2, case 2). The same must be observed when there is a mixed operation of media couplers and repeaters.

Use of repeaters

- Recommended for large buildings with few RF devices.
- Recommended for buildings without clearly separated reception areas, e.g. with insufficient attenuation due to wooden ceilings or thin walls.
- Position the repeater at the edge of the building, but within the range of the media coupler and also within the range of other repeaters.
- If several media couplers are used in the same communication mode (Fast or SLE), make sure that they receive each other's signals (see figure 2, case 1) or are completely separated from each other (see figure 2, case 2). The same must be observed when there is a mixed operation of media couplers and repeaters.
- Use a Fast repeater for Fast telegrams and an SLE repeater for SLE telegrams.
- When using an SLE repeater, a Fast repeater is usually also required (see figure 8).

2.4 Parametrisation

Compliance with the Duty Cycle

- Avoid cyclical transmission if possible.
- If possible, select long transmission intervals.
- In KNX RF Ready projects (ETS5), ensure that the filter tables of the media coupler are activated.

Using a USB interface

- Use a KNX RF Ready USB interface for an RF Ready domain.
  The ise KNX RF Multi USB interface can be used for KNX RF Ready. To do this, however, the RF mode must be set to “Ready” in the local settings of the ETS6.
- Use the ise KNX RF Ready USB interface for an RF Ready domain.
- Parameterise the domain address of the USB interface in the ETS so that it matches the domain address of the RF line or RF segment.

Insufficient APDU length

- Do not use a bus choke. In the project details of the ETS under “Compatibility”, the parameter “Use low bus communication rate” must be disabled.

2.5 Diagnosis

Use group or bus monitor

- Use a KNX RF Multi USB interface to record RF telegrams of the corresponding RF domain in the group or bus monitor of the ETS. KNX RF Multi is also supported in the ETS6.
  A monitor can then receive or send either Fast/Ready or SLE telegrams.
- A KNX RF Multi USB interface only shows group-addressed telegrams of the same RF domain in the group monitor. The interface also shows individual addressed telegrams if it is also used as a programming interface for the ETS. In the bus monitor, a KNX RF Multi USB interface shows all telegrams of the RF line or RF segment.
- Move your KNX RF Multi USB interface close to the RF devices to be monitored in order to be within radio range. If you are out of range, it may not be possible to show all telegrams in the group monitor.

Further information

3 Control of media access

Radio is a medium that all KNX RF devices share and via which they can communicate with each other. If two or more KNX RF devices transmit simultaneously into the medium, at least one of the transmitted telegrams is lost. To prevent this, each KNX RF transmitter checks whether the radio channel is already used by another RF transmitter (LBT) when it wants to send a KNX telegram (LBT: Listen Before Talk).

KNX RF Multi always tries to transmit on the channel called “Call Channel” first. Before sending, a check is made to detect whether there is a KNX communication in the RF mode of the transmitting channel and whether the transmitting channel is occupied. For this purpose, the interframe random phase is used for a fixed time (interframe time) depending on the RF mode, and a random time also depending on the RF mode, on all channels of the RF mode (scanning). If another KNX transmitter starts transmitting withing this time range, its telegram is received and the test is started again. If no KNX transmitter has been detected during this time, a final check is carried out exclusively on the transmitting channel (analysis phase). A check is made whether the channel is blocked by other transmitters, whether parts of a KNX telegram are using the channel or whether a KNX transmission is taking place and then received.
If the channel is blocked, the system switches to the next channel of the RF mode and the analysis phase starts again. If parts of a KNX telegram have been detected, the end of the partial KNX transmission is waited for and the interframe random phase starts again. If the end of the partial transmission is not recognised, the system switches to the next channel of the RF mode, in the same way as if the transmission is blocked, and the analysis phase starts again. Only if no blocking, partial or complete KNX transmission was detected in the analysis phase is transmission carried out on the currently set channel.
With KNX RF Ready, media access works in a similar way, with the following exceptions: During the interframe random phase, reception takes place exclusively on the Ready channel, as well as in the analysis phase. If a transmitter blocks the Ready channel during the analysis phase, the interframe random phase is restarted on this channel.
As the random time in the interframe random phase is different for each transmission process, radio collisions between devices that actually want to transmit at the same time (e.g. media couplers that have received a group telegram via the TP side that they should forward) are largely suppressed in combination with LBT.
With KNX RF Multi, blockages caused by external KNX transmitters are also bypassed by sending on the alternative channel of the RF mode.

The described transmission methods for controlling media access usually prevent radio collisions in a KNX RF environment, but do not completely avoid them. For example, during a transmission from an RF transmitter (A) to an RF receiver (B), there may be an additional RF transmitter (C) that is within the range of the RF receiver but cannot reach the other RF transmitter due to the spatial distance (see figure 1). In such a case, it is impossible for the two RF transmitters to recognise when one of them is transmitting radio signals (hidden station problem). As a result, radio collisions can occur at the receiver, which is within range of both RF transmitters.

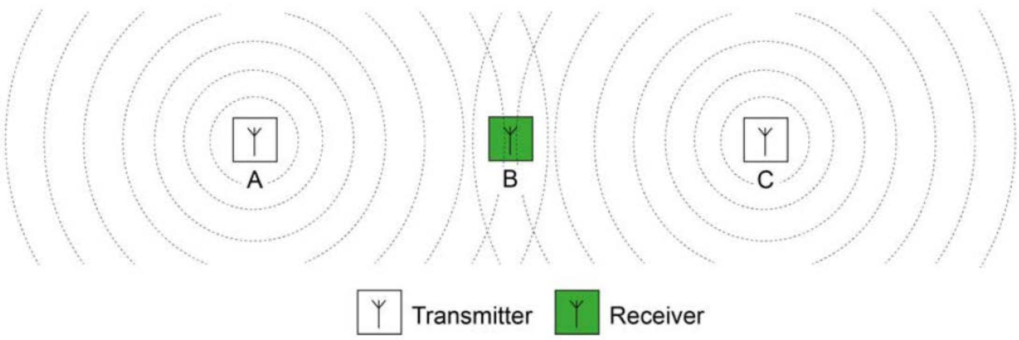


Figure 1: Radio collisions at the receiver because transmitters are located far away from each other

The described effect is system-dependent and can be a particular problem when there are two or more media couplers in a KNX system. If the media couplers are out of the other's range, then they cannot detect whether another media coupler is already transmitting a group telegram. However, the KNX devices in the various RF lines can be located in such a way that they are in the overlap areas of the couplers' RF domains. Consequently, the subscribers receive the colliding telegrams of several media couplers (see figure 2). This fact must already be taken into account when planning a KNX RF system.

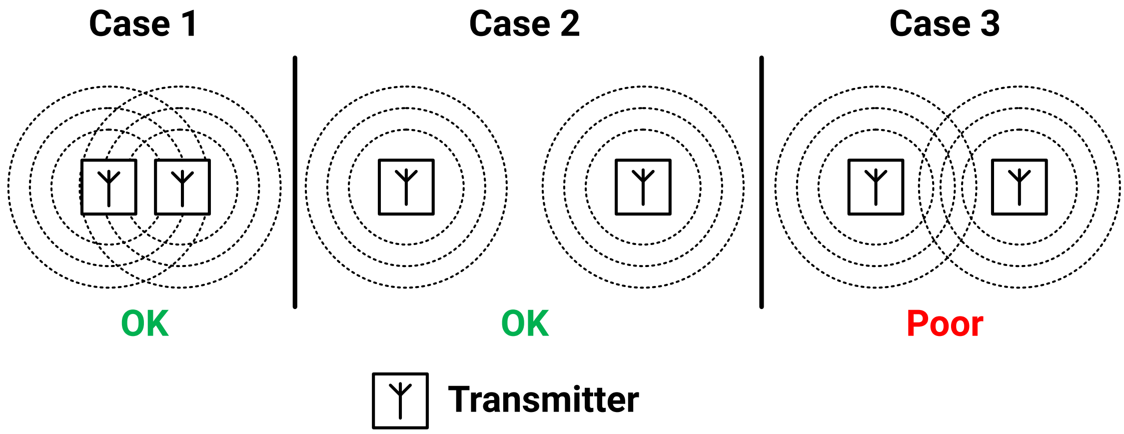


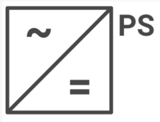
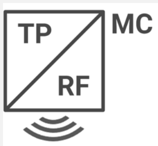
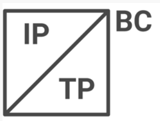
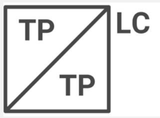
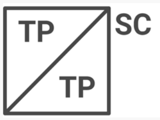
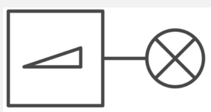
Figure 2: Correct arrangement of repeaters and/or media couplers

- If some areas in a system are largely isolated from each other on the RF side (see figure 2, case 2), for example individual storeys in a house with reinforced concrete ceilings or underfloor heating, and there are many devices in each of these areas, a connection via additional media couplers and RF lines makes sense.
- If two or more media couplers are used, the spatial arrangement must ensure that either all media couplers can receive each other's signals (see figure 2, case 1) or that the reception areas of the two media couplers are completely separated from each other (see figure 2, case 2).
- If two repeaters are used for one communication mode, the spatial arrangement must ensure that either both repeaters can receive each other's signals (see figure 2, case 1) or that the reception areas of the two repeaters are completely separated from each other (see figure 2, case 2).

With KNX TP (TP = Twisted Pair), the bus access of a subscriber is controlled by the CSMA/CA method (Carrier Sense Multiple Access/Collision Avoidance).
This bus access procedure avoids telegram collisions. In addition, received telegrams are confirmed by each addressed TP bus participant (telegram confirmation by LinkLayer-Confirm: Ack, Busy, Nack). This allows transmitters of KNX messages to detect whether potential recipients have understood the message or whether telegram repetitions are necessary due to transmission or processing errors.

4 RF topology

4.1 Graphic symbols

Symbol / label	Meaning
	Power supply
	RF/TP media coupler
	Backbone coupler
	Line coupler
	Segment coupler
	RF-USB interface
	TP-USB interface
	RF repeater
	RF button
	Dimmer

4.2 Domain address for KNX RF

The radio range of KNX RF devices cannot be determined exactly in spatial terms. KNX RF telegrams cannot be limited to one specific KNX installation. Radio telegrams pass through the borders of buildings and plots of land and can be received by devices installed in neighbouring KNX systems. For this reason, it is important that different KNX RF installations are delimited topologically and thus logically from one another. The domain address helps here.

In accordance with the topology defined in the ETS project, devices assigned to the RF lines also always receive a domain address, in addition to the individual addresses. Only devices with the same domain address can communicate with each other within an RF environment. As a result, a media coupler must always have the same domain address as all the devices in its subordinate RF line.

The domain address is defined in the ETS for each RF line or for each RF area. The ETS automatically programmes the domain address in the RF devices when the individual address is programmed.

A domain address is 6 bytes long and is entered in the ETS in hexadecimals or generated automatically. After the first 2 bytes, the input notation requires a colon (when read from the left). A domain address can look like this, for example: "0011:22334455" or "00FA:4F5B3122".

The two lower bytes of the domain address are used in the SLE preamble to filter telegrams at an early stage and thus save energy. For this mechanism to work, it must be ensured that the domain addresses differ in the lower 2 bytes if several RF segments exist.
Example:
Segment 1: DoA 0011:2233**4455**
Segment 2: DoA 0011:2233**6677**

KNX RF systems always influence each other physically when they are spatially located in each other's radio range and two or more transmitters transmit more or less simultaneously, which is perfectly possible. Radio telegrams can be superimposed. In this case, the radio telegrams concerned can no longer be analysed by the receivers.

4.2.1 Devices in different RF domains

Devices in different RF domains must be topologically divided into two different lines or segments, each with their own domain addresses. These different lines or segments must then also contain their own media couplers so that the devices can communicate with each other. The logical connection of two or more KNX RF environments therefore always takes place via media couplers and higher-level TP/IP lines (see figure 3).

KNX RF USB data interfaces, as used in the ETS, are also assigned to a domain address. Consequently, only RF devices of the same domain can be put into operation directly via radio telegram. Only group telegrams and individual addressed telegrams of the appropriate RF domain are recorded in the group monitor of the ETS. Exception: System broadcast telegrams, see RF addressing types, p. 21.

If other RF devices of another domain are to be contacted with an RF data interface, a communication via media couplers is necessary. If the KNX topology is set up correctly, then such communication takes place automatically via the KNX routing. Requirement: media and backbone/line couplers forward the telegrams according to their filter properties.

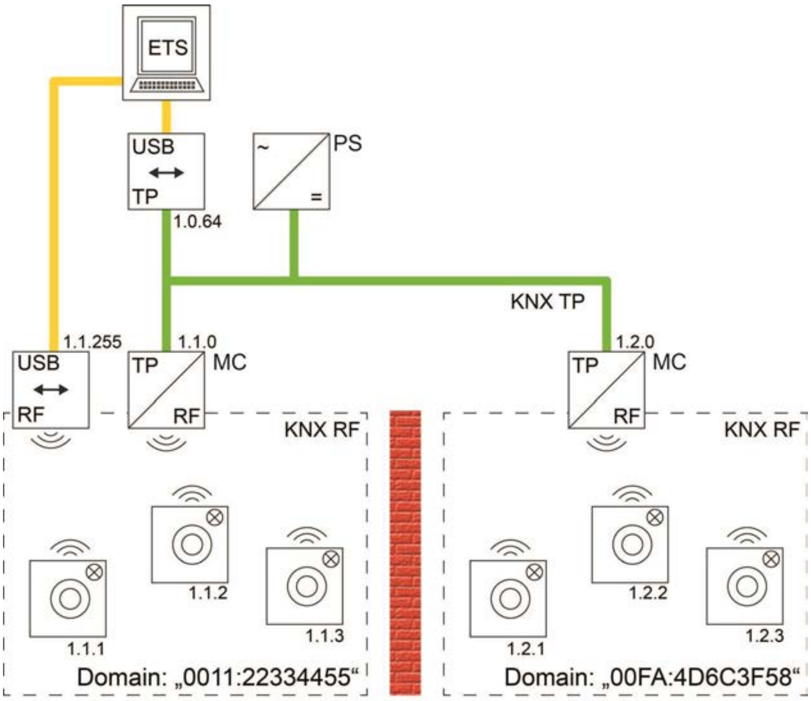


Figure 3: Possible KNX topology with two RF lines and coupling via a TP main line

In general, several media couplers can be used in different lines and segments in a KNX topology. The ETS allows such a configuration.

Media couplers cannot be used to connect two or more KNX installations via RF (no proxy function).

RF lines or segments of a joint KNX installation or of directly adjacent KNX installations within radio range may never have an identical domain address! The ETS offers a function for random assignment of a domain address for RF lines in order to avoid this improper situation. Domain addresses generated automatically by the ETS are characterised by the hexadecimal digits “00FA...” (e.g. “00FA:4D6C3F58”).

4.2.2 Use of a KNX RF USB interface

All devices in an RF line or RF segment can be programmed and diagnosed directly via the ise KNX RF Multi USB interface. It is important that the USB interface has a valid individual address of the RF segment, the RF line or the RF area and is configured with the same domain address. In addition, all the other devices of the KNX installation can be programmed using a media coupler with an identical domain address. A wired data interface is not absolutely necessary for this. If necessary, the KNX RF USB data interface can also be used in the group or bus monitor of the ETS, in order to record RF telegrams of the corresponding RF domain. KNX RF Multi is also supported in the ETS6. A monitor can then receive or send either Fast/Ready or SLE telegrams.

A KNX RF Multi USB interface only shows group-addressed telegrams of the same RF domain in the group monitor. The interface also shows individual addressed telegrams if it is also used as a programming interface for the ETS. In the bus monitor, a KNX RF Multi USB interface shows all telegrams of the RF line or RF segment.

One advantage of using a KNX RF USB interface to diagnose the RF system is the display of Fast-Ack information and its visualisation in the group monitor.

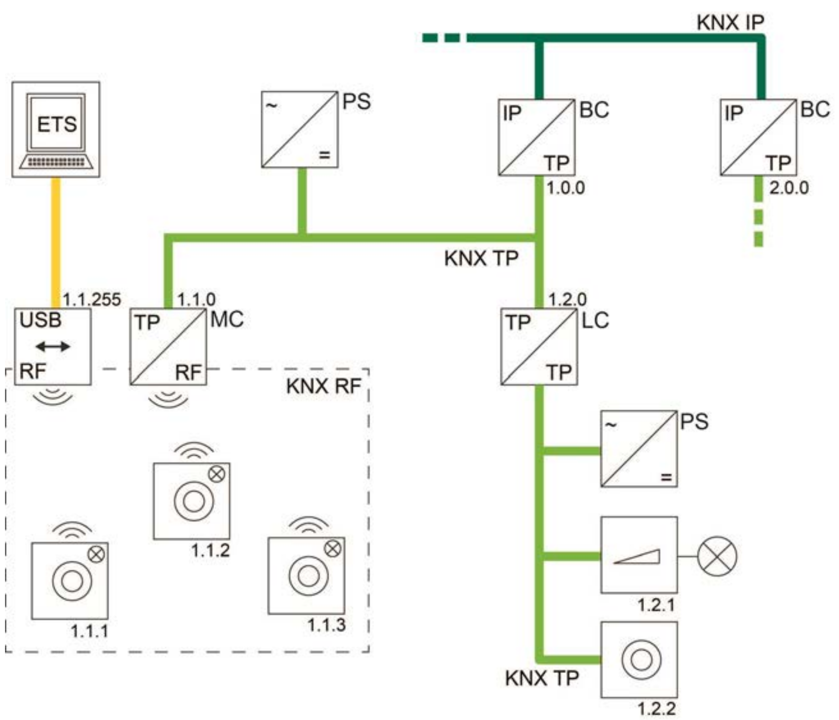


Figure 4: Possible KNX topology with a KNX RF USB interface

4.2.3 Use of a KNX RF IP interface

An ETS IP connection can be used to commission or diagnose devices in a KNX RF environment. This connection can be made remotely via an ise SMART CONNECT KNX Remote Access.
For this application, the ETS and the Remote Access Windows Client must be installed on the same PC. An IP connection to the router of the home network and to the ise SMART CONNECT KNX Remote Access is established via the my.ise server. A KNX IP router or a KNX IP interface acts as a backbone coupler to enable access from the IP environment (IP backbone) to the main line of the TP area. A KNX RF/TP media coupler connects the TP line with the RF domain.

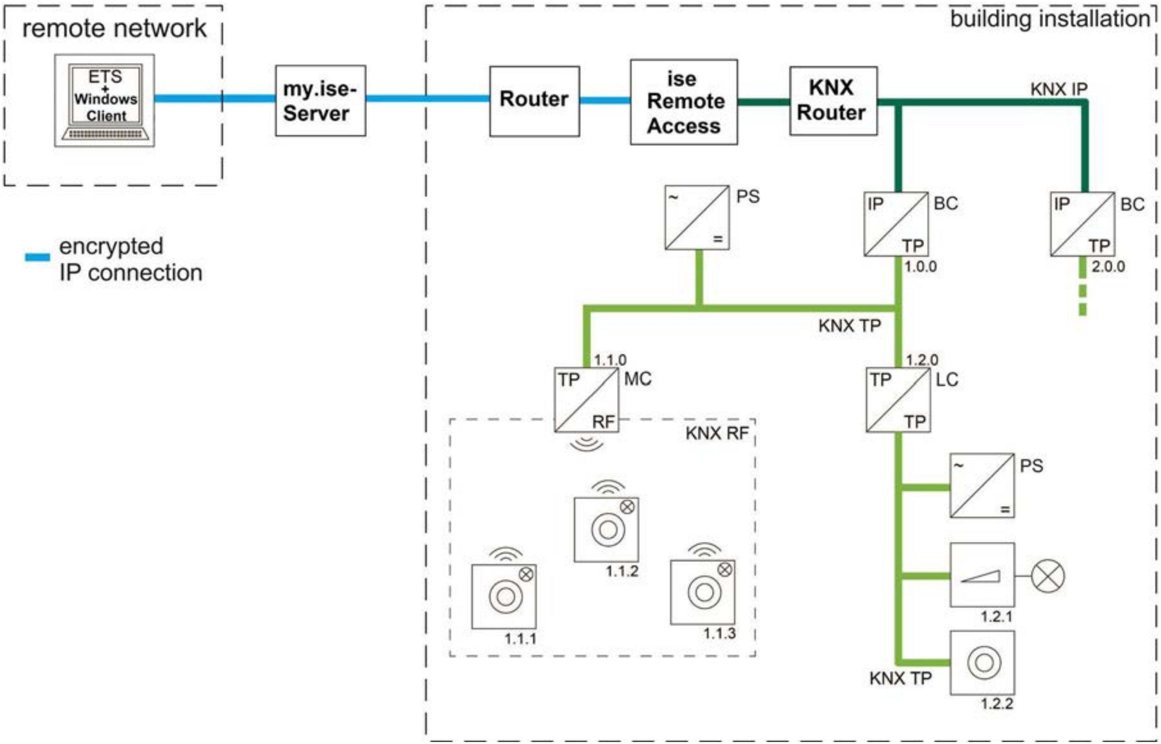


Figure 5: Possible KNX topology with a KNX IP connection of the ETS (KNX/net IP)

4.3 Media coupler

Media couplers are the link between a specific KNX RF environment (line or segment) and a wired KNX twisted pair installation. With regard to the routing property of telegrams, media couplers work like standard KNX TP backbone/line couplers or segment couplers. This means that RF devices can communicate with TP or IP devices and vice versa.

Media couplers have filter settings and filter tables that are automatically programmed by the ETS. ETS5 still supports manual filter tables, but these are not compatible with KNX RF Multi.

A media coupler cannot be an backbone coupler (this is still possible in ETS5), as it does not make sense to operate many KNX RF devices with a single media coupler.

The ise KNX RF Multi/TP media coupler is a device that allows the “RF” media type on the subordinate line and the “TP” media type on the superordinate line.

KNX RF devices, like all other KNX components with S-mode commissioning, are configured and commissioned using the ETS. Consequently, RF devices also have an individual address, parameters and group objects. In addition, a unique domain address is assigned for each RF line or RF segment in the ETS. Only devices with the same domain address can communicate with each other.

A media coupler can be integrated in the KNX topology either as a line coupler or alternatively as a segment coupler. The operating mode is defined by the individual address. With KNX RF, the number of devices is limited by the individual addresses assigned in the ETS.

4.3.1 Media coupler as line coupler

A KNX RF line can contain up to 256 RF devices (including media coupler) (see figure 6). The media coupler is connected to the main TP line of an area. Additional TP lines can be set up using additional TP line couplers.

There may only ever be one media coupler in an RF line or RF segment.

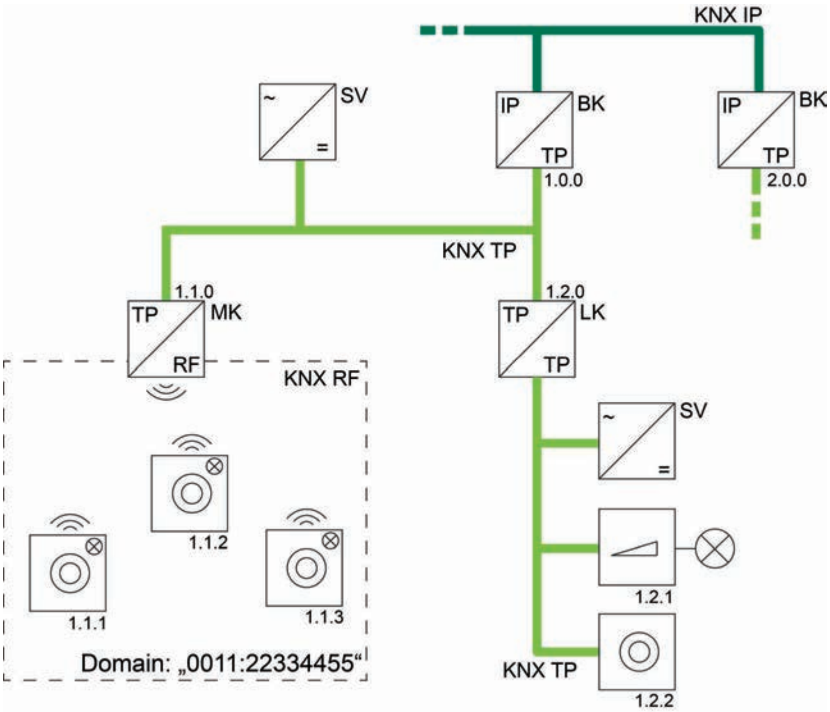


Figure 6: Possible KNX topology with RF, TP and IP lines with media coupler as line coupler

4.3.2 Media coupler as segment coupler

The segment coupler has an individual address in the form x.y.1...255 (x = TP backbone address, y = TP line address/e.g. “1.1.47”). A KNX RF segment can contain up to 256 RF devices (including segment couplers) (see figure 7).

> There may only ever be one segment coupler in an RF segment.
> It is not possible to create manual filter table entries for RF segments in the ETS. This means that no additional group addresses can be added to the automatically calculated filter tables for lower-level segments. If devices for which group addresses cannot be assigned with the ETS are used in the KNX installation, the group addresses must be linked in higher-level areas or lines. This link can be realised through dummy applications or the use of tunnelling interfaces. The SMART CONNECT KNX Remote Access has three tunnelling servers.

The ise KNX RF Multi/TP media coupler can be used as a segment coupler. Segment couplers are routers for connecting two segments of the same subnetwork with different physical layer types. The segment coupler extends either a line or an area. There can be up to 254 devices in a segment. The device address 0 is reserved and the own address is not available. Each RF segment has its own domain address.

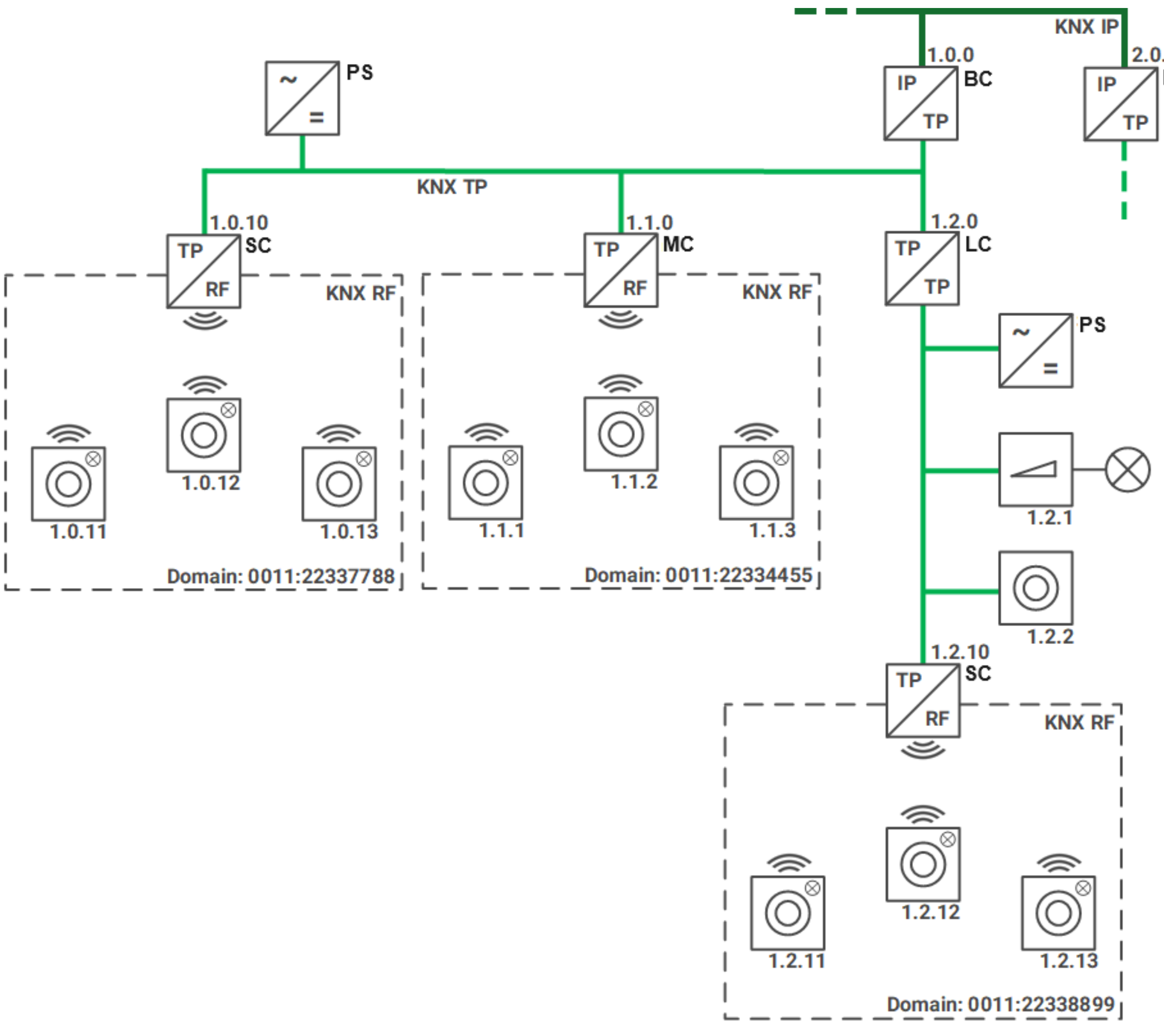


Figure 7: Possible KNX topology with RF, TP and IP lines with media coupler as line coupler

4.4 RF addressing types

As with all KNX media, the user data is also transmitted on the KNX RF using group telegrams (Multicast). A group telegram (e.g. for switching on the light) can be received by several bus participants at the same time, provided the group objects of the devices are linked with identical group addresses.
In an RF group telegram according to KNX RF1.R S-Mode or KNX RF Multi Standard, the domain address (6 bytes long) is transmitted in addition to the actual group address (2 bytes long).
This means that the receivers of the group telegrams can immediately detect whether they are addressed by the group address, are located in the same RF domain and must therefore react to the group telegram. A media coupler inserts the required domain address into the group telegrams automatically, provided that they were received on the TP side and were transmitted to the RF environment in accordance with the filter setting. In the same way, a media coupler removes the domain supplement when a group telegram is received on the RF side and transmitted to the TP side.

Broadcast telegrams (address 0/0/0) are a special form of group telegrams.
Broadcast telegrams always address all bus participants in an RF environment or in the entire KNX system simultaneously. Such telegrams are used by the ETS, for example, to programme individual addresses or domain addresses or to read out which bus devices are in programming mode. Only in RF environments is a distinction made between simple broadcast telegrams and system broadcast telegrams. Only the latter are domain-independent and generated by media couplers as required, for example if the ETS has to programme or diagnose RF devices across media couplers (TP → RF).
The ETS controls the existing media couplers as required so that the conversion of TP broadcast telegrams to RF system broadcast telegrams takes place in a targeted manner and these system telegrams are forwarded.

In the same way, a media coupler converts system broadcast telegrams to normal broadcast telegrams on the TP side. Here too, the ETS automatically controls the function of the routing of such system telegrams in media couplers as required.

The ETS can generate system broadcast telegrams directly if it communicates via an RF-USB interface.

In addition to broadcast telegrams, the ETS also uses individual addressed telegrams in the RF system for programming RF devices (unicast).

> Group telegrams, broadcast telegrams and individual addressed telegrams can be filtered independently of each other in the media coupler as required or can even be disabled completely. This allows RF lines to be logically decoupled from the rest of the KNX system, according to the requirements.

4.5 KNX RF Multi Repeater

Alternatively, the ise KNX RF Multi/TP media coupler can operate as an RF repeater. A repeater repeats the radio telegrams received in its RF line by retransmitting them immediately. This allows the radio range of a KNX RF installation to be extended, making it possible to position RF devices as required even in difficult transmission and reception conditions in a building. In principle, an additional RF segment should be created before a repeater is used.

Like all other KNX RF Multi devices, a repeater can only receive Fast and Ready telegrams **or** SLE telegrams and process them further.
A repeater is therefore always a dedicated Fast/Ready **or** SLE repeater.
If an SLE device is to be connected to the system via a repeater, this means that both a Fast and an SLE repeater must be used, as SLE devices generally send Fast telegrams themselves, which would not be received in the system without a Fast repeater.

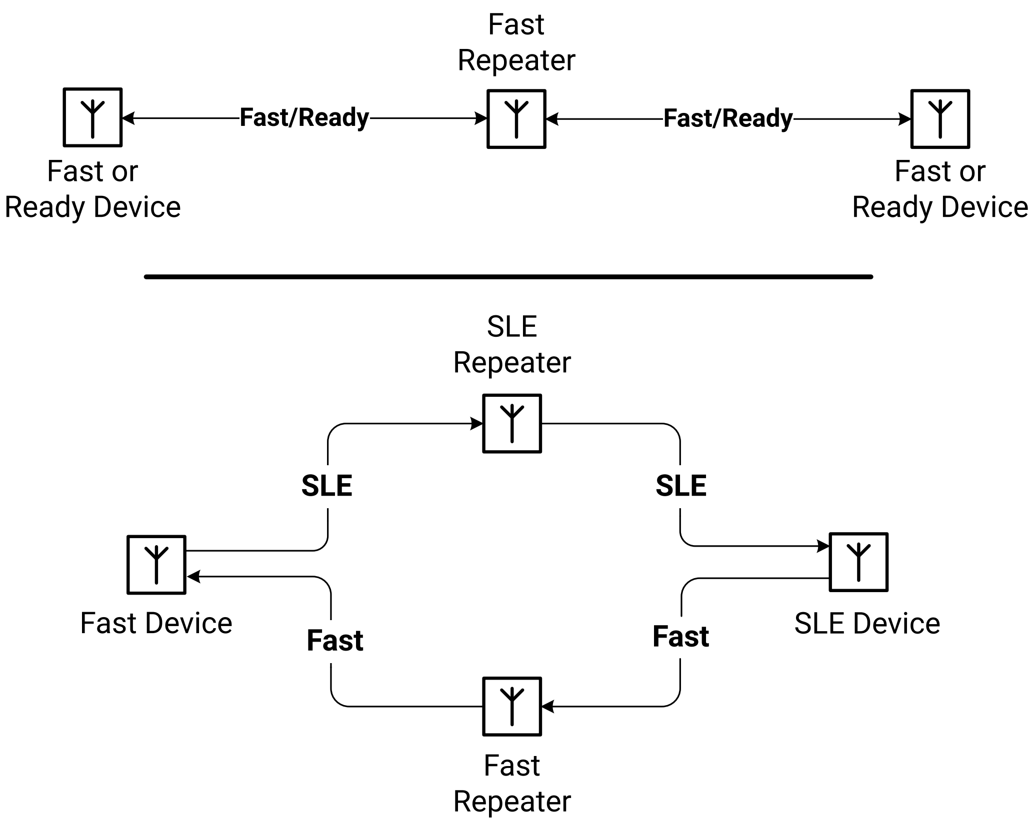


Figure 8: Difference between Fast/SLE repeater

Repeaters slow down RF communication because they have to repeat telegrams and block the radio medium during this time. This applies in particular to KNX RF Multi, as a repeater not only repeats the actual user data, but also sends back the received Fast ACK information. The repetition of the user data is referred to as an ECHO telegram, while the Fast ACK information is transported in the so-called ACKREP telegram. The following figure shows the time sequence for a telegram T1 with two receivers and one repeater. Receiver 1 can receive the telegram directly and confirms this with Fast-ACK #1, but the Fast-ACK from receiver 2 is missing. The repeater notices that not all Fast-ACKs have been sent and repeats the telegram with the ECHO for telegram T1. This is confirmed by receiver 2 with Fast-ACK #2, which the transmitter itself has not necessarily received. The repeater therefore sends the ACKREP telegram at the end, which is received by the transmitter and in which all Fast-ACKs observed by the repeater are coded for telegram T1. The transmitter analyses this information and decides whether all the Fast-ACKs expected for telegram T1 are present.

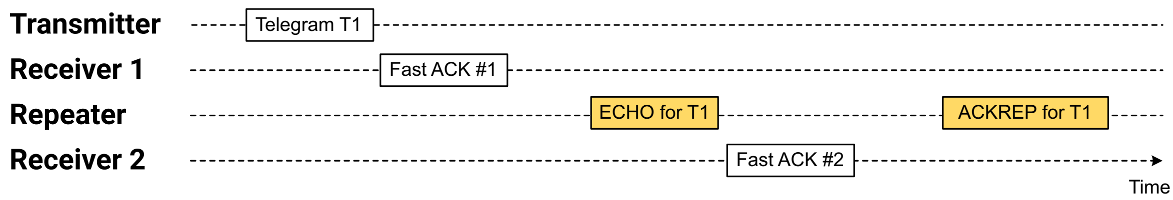


Figure 9: RF communication with repeater

One telegram T1 therefore becomes three telegrams with repeater, with a corresponding loss of time. In order not to delay communication unnecessarily, a repeater is only activated if a Fast-ACK is missing or if no Fast-ACK is required. Ready or Multi telegrams without a Fast ACK request are always repeated, but no ACKREP telegram needs to be generated for them. For multi-telegrams with a Fast-ACK request, the repeater analyses the number of expected Fast ACKs encoded in the telegram and compares it with the number of Fast ACKs received. The repeater only repeats the telegram if fewer ACKs are received than expected.

KNX RF Multi supports up to two repeaters per RF mode per domain, i.e. a maximum of two Fast and two SLE repeaters. If two repeaters are used for one RF mode, it must be ensured, as with the media couplers, that either both repeaters can receive each other's signals or that the reception areas of the two repeaters are completely separated from each other. It must be avoided that the reception areas of the two repeaters overlap without the repeaters being able to receive each other's signals (see figure 10, case 3).
In such a case, devices that receive the signals of both repeaters cannot communicate correctly via the repeaters, since the repeated telegrams overlap.

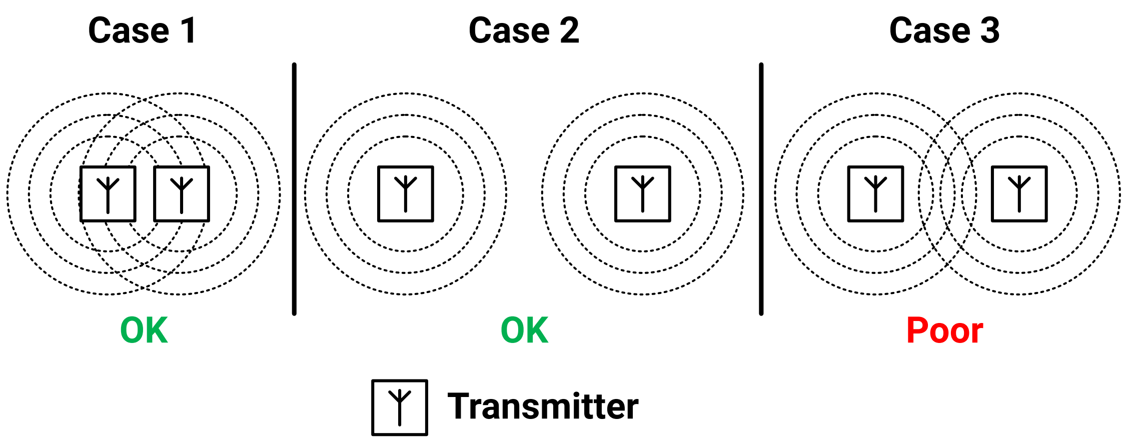


Figure 10: Correct arrangement of repeaters

5 Basic physical principles

5.1 Electromagnetic wave

Radio waves are waves of coupled electrical and magnetical fields (see figure 11). Electromagnetic waves are emitted by antennas into the surrounding area as free progressive waves. They do not require a special medium for propagation. In a vacuum, radio waves propagate at the speed of light. In other media, the propagation is always slower. Like light, electromagnetic waves are subject to diffraction, refraction, reflection, polarisation and interference.

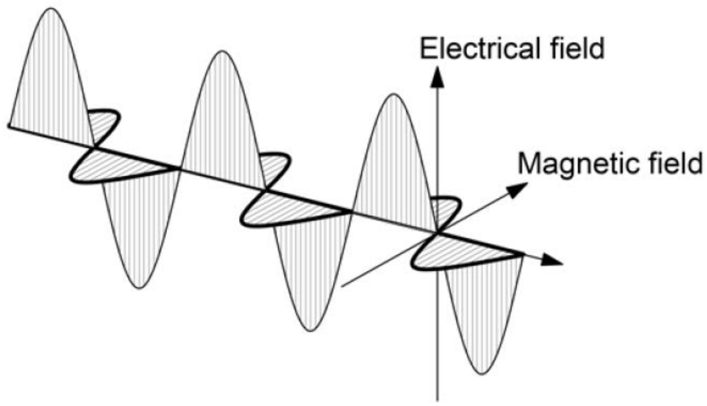


Figure 11: Model of an electromagnetic wave in free space

Electromagnetic waves propagate in a straight line in all directions in space. If multiple electromagnetic waves meet, then they will be superimposed. With KNX RF, the radio signals (due to positioning of the transmitters and reflections) come from almost any direction. If RF radio waves are superimposed, noise (signal with an unspecific frequency spectrum) is generated in the communication channel that cannot be interpreted by any RF receiver. This can result in transmitted information being lost. Therefore, when planning a KNX RF environment, various specifications must be taken into account (see RF topology, p. 13).

5.2 Information transmission with radio signals

An electromagnetic wave with constant amplitude and frequency does not yet carry any information. To make this possible, the transmitter must change the amplitude or the frequency of the wave continuously according to an agreed method and the carrier signal must modulate the information in this manner. With KNX RF, the modulation type “frequency shift keying” (FSK = frequency shift keying) is used (see figure 12). Frequency shift keying is a variant of frequency modulation (FM) and is suitable for the transmission of digital information. Two time-coded signals of a different frequency are transmitted, in order to inform the receiver of the logical states “0” and “1”. Frequency shift keying is impervious to interference. Even high transmission losses in the signal amplitude do not have a negative effect on the demodulation of the transmitted information.

The data rate for KNX RF is 16.384 kBit/s. Manchester encoding is used to apply the “0” and “1” information to the radio signal. This makes it very easy to synchronise the transmitter and receiver.

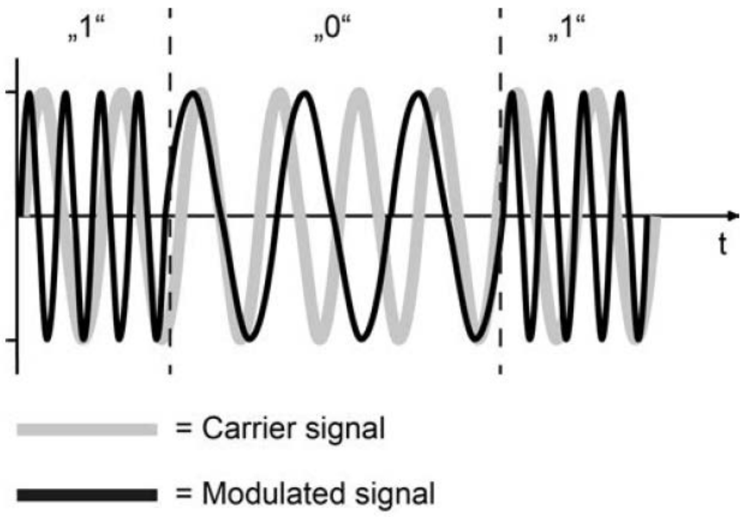


Figure 12: Frequency shift keying as a modulation method (FSK=Frequency Shift Keying)

5.3 Propagation and attenuation of radio signals in buildings

Radio waves with a frequency such as that used by KNX RF can penetrate ceilings or walls in a building. Depending on the thickness and conductivity (metal content, moisture), this is associated with a greater or lesser loss of energy. This loss of transmission energy is also known as attenuation (ratio between transmitted and received radio radiation power).
Radio signals are attenuated by various influences on their journey between the transmitter to the receiver. The prerequisite for communication between transmitter and receiver is, of course, that the transmitter's radio signals still have enough energy at the receiver for the receiver to be able to evaluate the signals.
Almost ideal propagation conditions for electromagnetic radio signals prevail in the free field. The term “free field” refers to an open area in which radio waves can propagate largely unhindered and interference caused by structural conditions or obstacles has no influence.

If walls and ceilings have to be penetrated on the transmission path, the attenuation – and thus the radio range – depends largely on the number, type and nature of the building materials to be penetrated and on the effective wall and ceiling thicknesses. Part of the incident radio radiation is reflected at the boundary areas, while another part is absorbed. Moist material, as is found in new buildings or recently renovated rooms (newly wallpapered or plastered), attenuates electromagnetic radio waves to a greater extent.

Material (dry)	Material thickness	Transmission
Wood, plaster, plasterboard *, glass **	< 30 cm	90…100 %
Brick, chipboard panels	< 30 cm	65…95 %
Reinforced concrete	< 30 cm	10…70 %
Metal grid	< 1 mm	0…10 %
Metal, aluminium cladding	< 1 mm	0 %

Table 3: Attenuation in buildings

*without conductive coated thermal insulation

**without metallisation or wire inlay, no lead glass

Attenuation factors of a building must be taken into account when selecting the installation sites of RF devices (hand-held transmitters, pushbutton sensors, media couplers)! It should be taken into account that, in principle, every RF device is both a transmitter and a receiver due to bidirectionality (e.g. hand-held transmitters with or without LED status display and media couplers are transmitters and receivers in the same way).

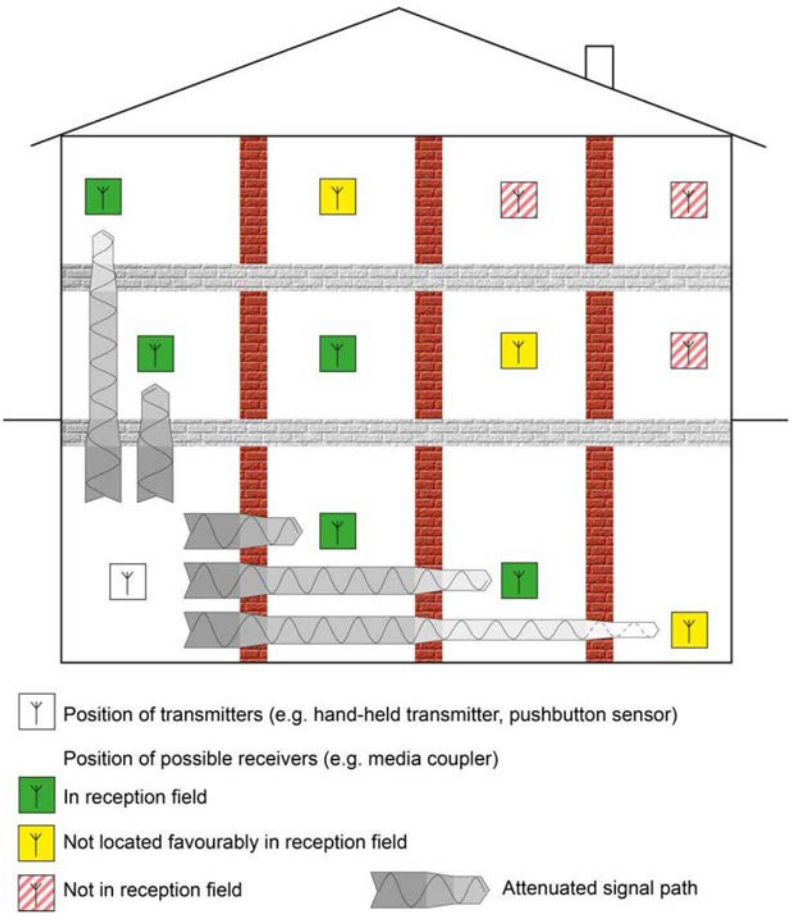


Figure 13: Attenuation of the radio signal by walls and ceilings (here: edge position of the transmitter)

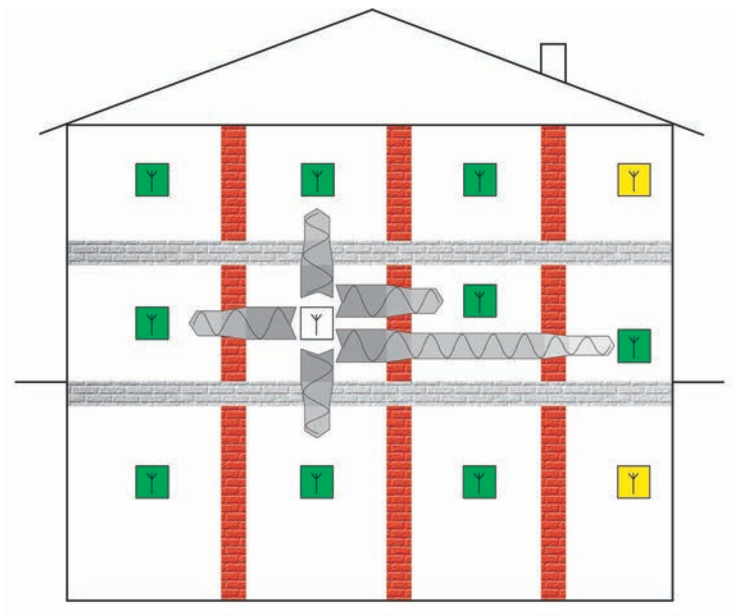


Figure 14: Attenuation of the radio signal by walls and ceilings (here: central position of the transmitter)

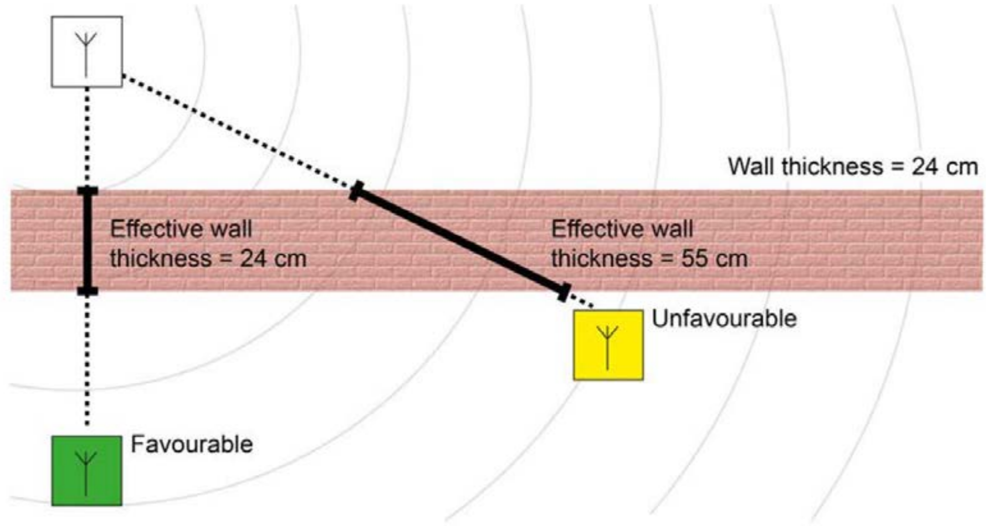


Figure 15: Attenuation through effective wall or ceiling thickness

Care is required if a building is equipped with shielding materials to reduce electromagnetic waves. Flush-mounted appliance boxes with a conductive coating are not usually suitable for wireless products. Special shielding plasters and plasterboard protective panels, in which conductive fibres are incorporated, reduce the permeability of radio waves by up to 95%. The same applies to stands, into which high level of metallic components (e.g. supporting parts, metallised insulation material) are integrated.

Due to the wide range of influences, it is difficult to evaluate radio sections in buildings. Ultimately, a manufacturer of wireless products – including other systems such as WLAN - cannot make a binding statement on the range of wireless transmission in buildings. For this reason, the free-field range is always stated, which refers to undisturbed propagation of the radio waves and optimally aligned antennas. If there are no special structural measures for shielding in buildings, targeted radio transmission should be possible.

Electrically conductive materials of sufficient strength cannot be penetrated by electromagnetic waves. Metal components in buildings, e.g. furnishings or steel reinforcements in concrete (see figure 16), but also design frames made of metal or design parts with metal-containing paintwork therefore have a shielding effect. Metal shielding can also be used deliberately to keep an area free of radio waves.

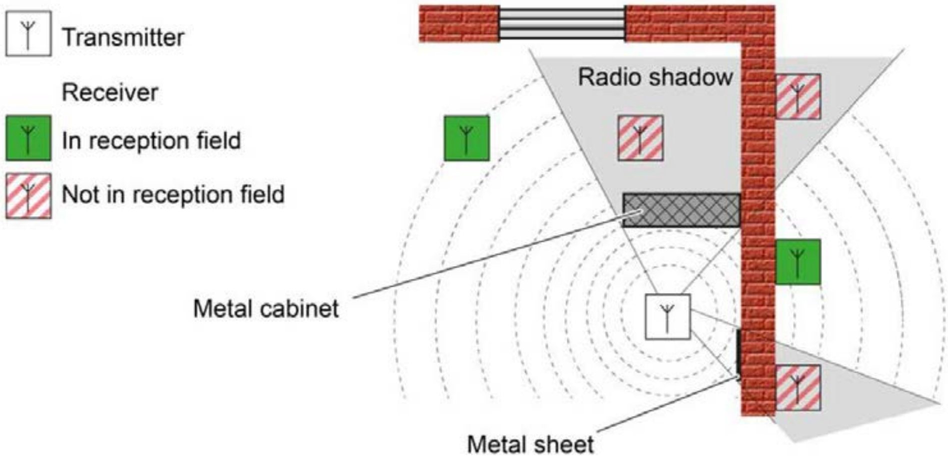


Figure 16: Radio shadows in a building due to metal parts

Radio waves reach a receiver both directly (linear distance) and via diversions (multiple route propagation). Such diversions are caused by reflection of the radio waves at boundary layers to other materials, e.g. on the surfaces of walls or ceilings. The receiver then receives radio waves from an identical source with a different phase angle. In many cases, the reflected radio power is too low to significantly influence the direct path of the radio wave.
A receiver can then receive the transmitter's signal without interference (see figure 17).

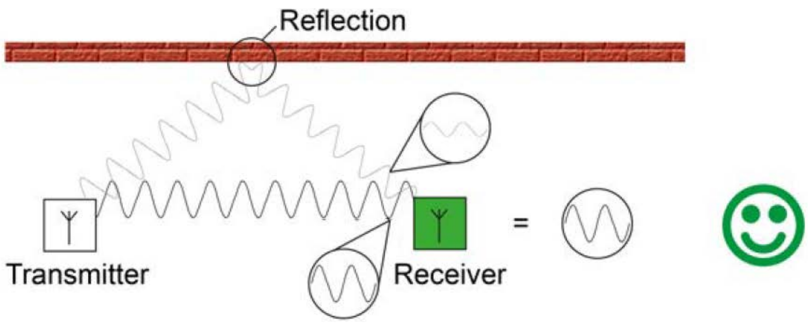


Figure 17: Interference has no effect at the receiver

However, in the worst case, the waves received directly and via reflection are superimposed unfavourably at the target location, creating a signal which receivers can no longer evaluate reliably (see figure 18). Positive and negative superposition of radio waves of the same direction is also known as interference.

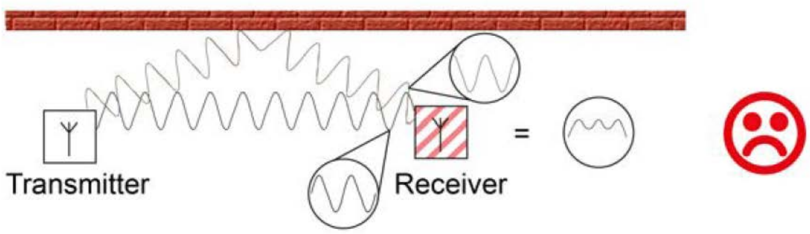


Figure 18: Interference at the receiver prevents reception

In practice, reflection and interference effects can often be eliminated by simply changing the installation location or the installation environment.

6 Building structure

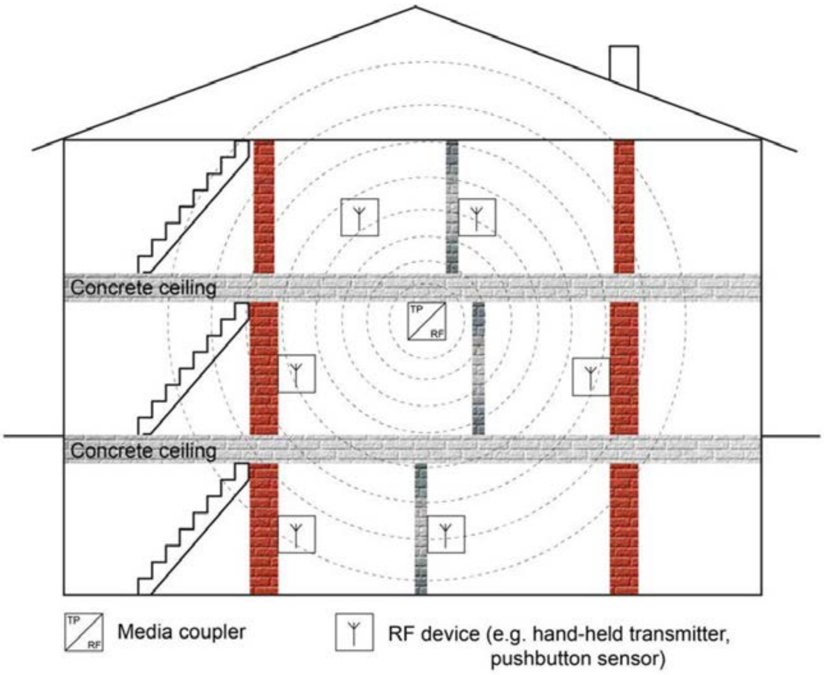


Figure 19: Building structure with a KNX RF line

The frequency band around 868 MHz used by KNX RF has good properties in buildings in terms of signal propagation, as the attenuation caused by walls, concrete reinforcements and metal parts is kept within acceptable limits. This is positive when - for example in a detached house - one storey or even multiple storeys are to be covered with one and the same RF line. The media coupler should then be positioned as centrally as possible in the building (see figure 19).

The good signal propagation may be a disadvantage in properties if the RF lines influence each other physically, are only partially within their radio ranges due to a small spatial distance or through insufficiently large attenuation due to wooden ceilings or thin walls (see figure 20). Here it is advisable not to set up two or more RF lines (each with its own media coupler), but to use RF repeaters that extend the radio range of an RF line (see figure 21). Here too, the media coupler should then be positioned as centrally as possible in the building. Repeaters should preferably be located on the edges of the building but within the range of the media coupler and also within the ranges of other repeaters.

Media couplers from ise can only be used as media couplers **or** as repeaters. The operating mode is defined by the parameter setting and by the individual address of the media coupler.
The functional description of the media coupler provides more details.

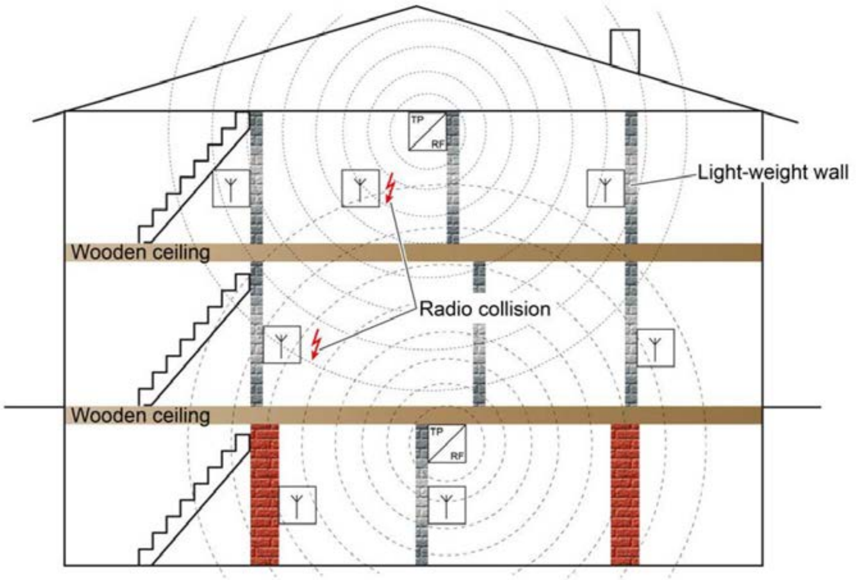


Figure 20: Building structure with two KNX RF lines, unfavourable interference

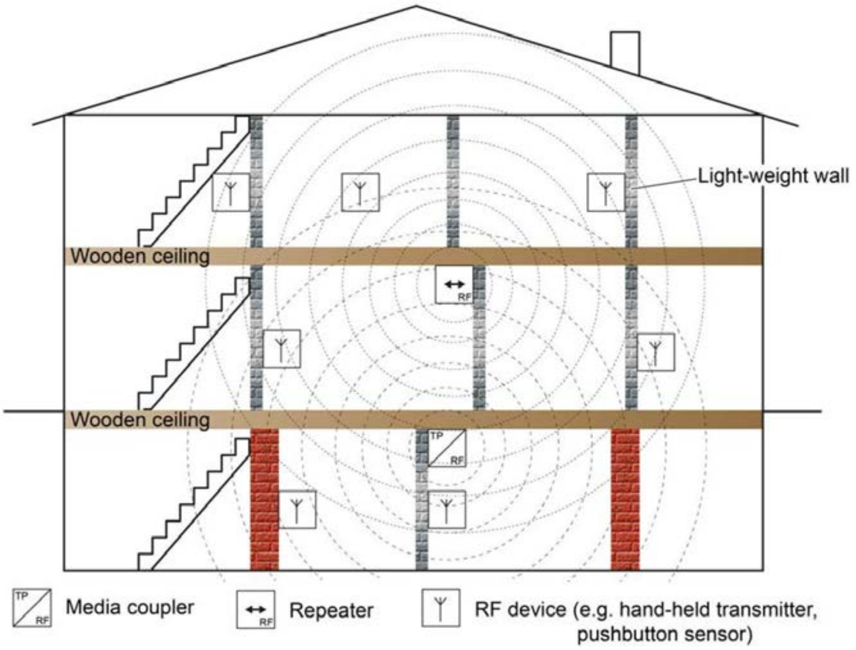


Figure 21: Building structure with a KNX RF line and repeater

The use of more than one RF line is advisable in large buildings or extensive building sections, as the RF lines can then be spaced far enough apart so that they no longer have a negative influence on each other. Different RF lines, each with their own media couplers, can also be used in smaller buildings (e.g. detached houses) or in apartment buildings, if the building structure and the consistency of the ceilings and walls shields the individual RF areas sufficiently (see figure 22). In the long-distance range, solid, supporting walls can make a positive contribution to achieving sufficiently large attenuation of the radio signals.

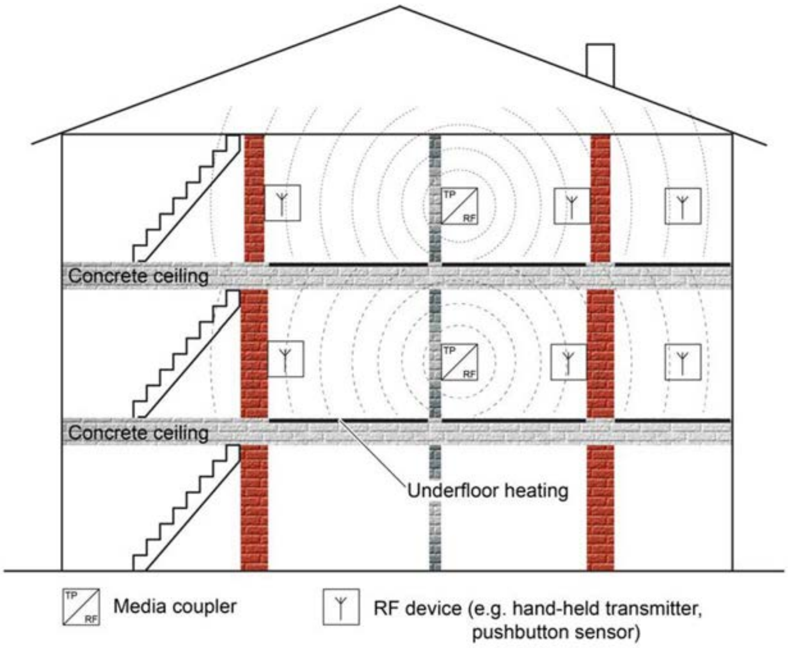


Figure 22: Building structure with two KNX RF lines, which do not influence each other negatively due to the building consistency

A media coupler can also be used outdoors (if necessary as a repeater) in a suitable installation box (ideally plastic, surface mounted, water protected), in order to make the KNX RF signals available directly between buildings or to amplify them. This means that KNX RF devices can also be used outdoors – provided the nature of the devices allows it – or in remote buildings (e.g. garden shed) (see figure 23).

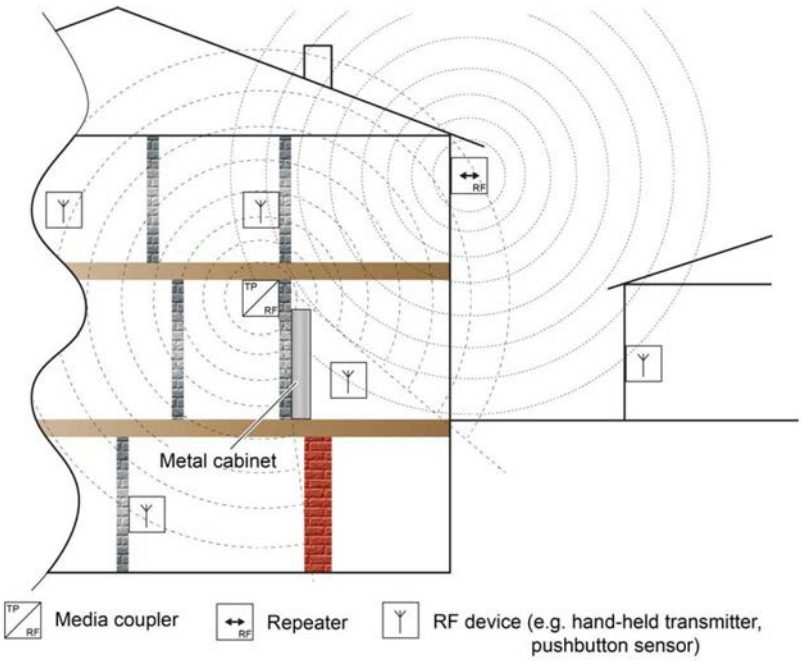
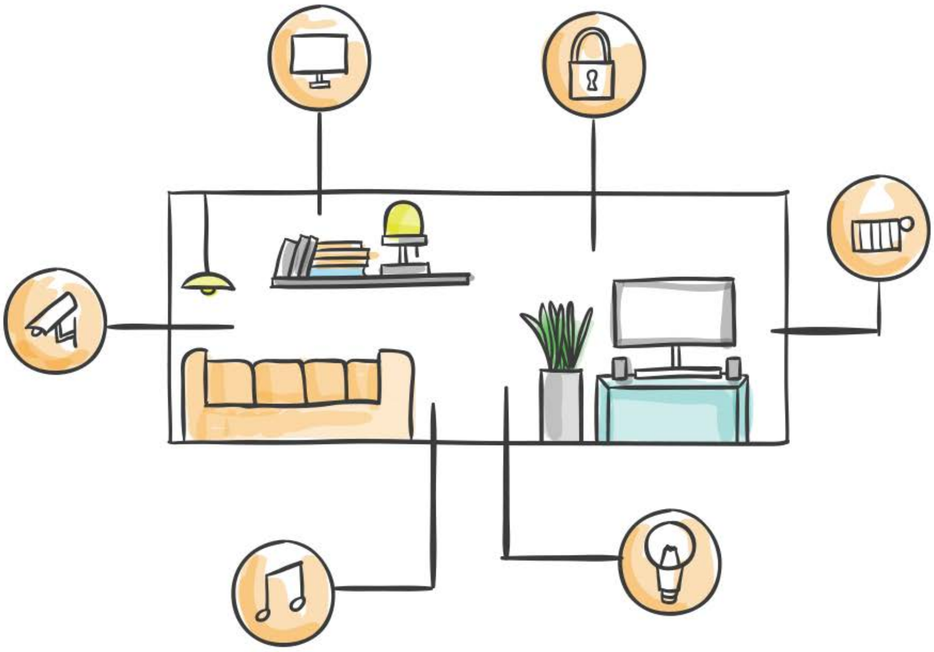


Figure 23: Use of a media coupler as a repeater for signal amplification and elimination of radio shadows for indoor and outdoor applications



ise Individuelle Software und Elektronik GmbH
Osterstraße 15
26122 Oldenburg, Germany

Phone: +49 441 680 06 11
Fax: +49 441 680 06 15
E-mail: sales@ise.de