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KWS ELECTRONIC
HIGH FREQUENCY TEST EQUIPMENT

APPLICATION NOTE AN002

Electro Magnetic Interference Measurement (EMI)

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Chapter 1

About this document

This document contains information about the EMI measurement option of the antenna measuring receivers of type AMA310.

1.1 Revisions

V00.01 January 2011
First release

V00.02 June 2011
Update concerning signal level reduction of the identification frequency with analog allocation of S21.

V00.03 September 2011
Update concerning the variable user-definable frequency range and the antenna correction factor in the AMA 310 measuring instrument for firmware version Vxx.07a and higher.

1.2 Reference documents

This application note refers to the following documents:

- AMA 310 Antenna Measuring Receiver operating manual
- The German regulation on the protection of public telecommunication networks and transmission and receiving radio plants that are operated in the defined frequency ranges for security purposes ("SchuTSEV") ["Sicherheitsfunk-Schutzverordnung"].

1.3 Contact with the manufacturer

For current information about products from KWS-Electronic, visit our website at **www.kws-electronic.de**. All contact details can also be found there.

Chapter 2

Basics

2.1 **Background information**

The German regulation on the protection of public telecommunication networks and transmission and receiving radio plants that are operated in the defined frequency ranges for security purposes (SchuTSEV) ["Verordnung zum Schutz von oeffentlichen Telekommunikationsnetzen und Sende- und Empfangsfunkanalgen, die in definierten Frequenzbereichen zu Sicherheitszwecken betrieben werden"] has been in effect since May 2009. This regulation controls, for example, the switching off of analogue TV content in the special channels S2 to S5 for the protection of aircraft radio frequencies (108-137 MHz). In addition, the regulation sets high requirements on the cable networks regarding their maximum permitted transmitted interference field strengths. In addition to some aircraft radio bands, radio services for security authorities and organisations (local and federal police, fire departments, etc.) can also be disturbed by interference from cable networks.

From a theoretical point of view, coaxial structures (such as those found in broadband cable networks) do not emit electromagnetic waves. In practice, cable networks deviate from the ideal situation, and some of the energy from the signal that passes through the cable does get emitted into the environment. The intensity of these undesired radio waves can be minimised by high-quality materials, proper installation, and conducting appropriate maintenance on the systems.

The German Federal Network Agency ["Bundesnetzagentur"] is responsible for making sure that the limits are adhered to.

For analogue signals, the SchuTSEV defines a limit of 27 dB μ V/m for the electrical interference field strength at a distance of 3 meters from the device to be tested (for the frequency range of 30 to 1000 MHz). The limit is 18 dB μ V/m for broadband digital signals. This means that after you commission a new broadband cable house distributor, you must ensure that the maximum interference field strength does not exceed 27 dB μ V/m anywhere within 3 metres of the building's outer wall. You do not have to make the measurement at precisely 3 metres from the building. You can also measure at a different distance and then use a formula to normalise the measured value to the standard distance.

You must comply with the limits required by the SchuTSEV, so it is essential to perform a check. In the final analysis, the German Federal Network Agency can partially or completely forbid operation of the telecommunications system when limits have not been complied with or when the operator is unwilling to make corrections to the line-bound system and reduce interference. The regulation also requires that you document the measurement of the emitted interference. This documentation must be provided at the request of the German Federal Network Agency. You must also keep in mind that documentation must be kept for more than just newly constructed systems or when changes are made to the design of the system. Whenever you reassign a channel, activate new channels, or digitise analogue channels, you must prove and document that the limits for interference are still being complied with after you have finished your work.

A measuring method that allows you to appraise the problem of emitted electromagnetic energy in both qualitative and quantitative terms is an indispensable tool for the network operator.

The principle of the procedure implemented in this measuring instrument for measuring electromagnetic interference is implemented by many major cable network operators and is fully compatible with their measuring procedures.

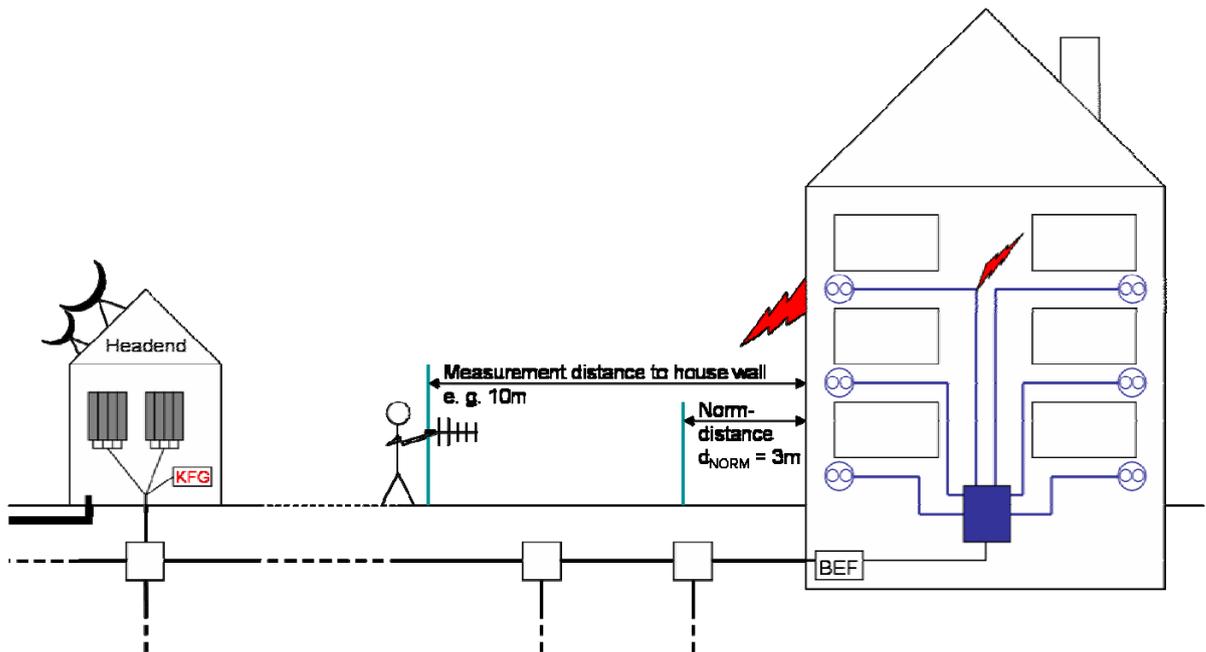
2.2 **Principle of measurement**

The principle of measurement is shown in the figure below. A frequency identification generator must be integrated in the head end for the measurement. This output signal is fed into the cable network, along with all analogue and digital television programmes and other services. The frequency identification generator transmits a continuous narrowband signal at a frequency of

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approximately 301 MHz. The reason for selecting a frequency of 301 MHz is because almost every cable network with standard channel spacing has a frequency gap there.

This means that no television, Internet or other services can be fed into the network in the range of this frequency. The frequency identification generator's signal is transmitted through the cable network with all of the television programmes and value-added services. If there are leaks along the cable route between the head end and the consumer's end device (where electromagnetic energy can escape the coaxial structure of the cable network), the frequency identification generator's signal can be measured in the vicinity of the leakage area. Reasons for leaks may include cables with insufficient insulation, cable breakage, corroded plugs and connections, damage to the cable jacket, loose F plug connectors, and more. An identification is modulated onto the frequency identification generator's signal to allow for clear identification of the source of a measured interference level. This identification consists of up to 13 letters, digits, and special characters, and can be configured as required.



Take measurements around the building to document escaping electromagnetic interference. A receiving antenna that is optimised to the frequency of 301 MHz is used to receive the escaping electrical field strength at this frequency. The output signal amplitude of the antenna is measured with the measuring receiver and converted to an electrical field strength at the measurement location using the antenna's specifications. If the measurement is not taken at the standard distance of 3 metres, the measuring instrument can convert the field strength to this distance. Since the frequency identification generator's signal is a narrowband analogue signal, the limit for the electrical field strength is 27 dB μ V/m at a distance of 3 metres. You can now decide whether or not the permissible maximum value has been complied with. The identification that is received can be used for identification and documentation.

Chapter 3

Hardware components

3.1 Required hardware and additional options

3.1.1 Hardware in the AMA 310 measuring receiver

The "EMI" option must be activated in the measuring receiver.

3.1.2 Frequency identification generator KFG 242



The KFG 242 frequency identification generator must be integrated in the head end. A frequency identification generator in the head end is a requirement for measuring electromagnetic interference in accordance with the principle of measurement shown in the above figure and for the measuring equipment that is presented in this document. More information on the technical data and operation of the KFG 242 is provided later on in this document.

3.1.3 Peilset EMI 240



The EMI 240 direction finder set ["Peilset"] consists of a Yagi antenna (EMI 240/Y), a selective pre-amplifier (EMI 240/V) and a measuring cable (EMI 240/K), which is used to connect the two elements. The antenna and the pre-amplifier are optimised to the identification frequency of 301 MHz. The EMI 240 direction finder set or the EMI 241 leak detector (see 3.1.4) is the minimum requirement for detecting the identification from the KFG 242 and determining an exact measured value (with the AMA 310) for the interference field strength at the measurement location.

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3.1.4 EMI 241 leak detector



The EMI 241 active leak detector already has an integrated selective pre-amplifier. An adapter (F to IEC) may be needed for the measuring cable connection. An antenna of type EMI 241 or the EMI 240 direction finder set (see 3.1.3) is the minimum requirement for detecting the identification from the KFG 242 and determining an exact measured value (with the AMA 310) for the interference field strength at the measurement location.

3.1.5 BOSCH DLE70 Professional laser rangefinder



The battery-powered DLE70 Professional rangefinder from BOSCH is an optional accessory that is extremely useful. As mentioned above, you can use the EMI measuring option to normalise an interference signal strength measured at any distance to the standard distance of 3 metres. The optional laser rangefinder is a powerful tool for determining the distance from the device to be tested. The DLE70 Professional features an extensive range and a high degree of reliability, especially when determining the distance under difficult conditions (e.g. when the device to be tested is exposed to extreme sunlight, is very light in colour, or has a reflective surface). The DLE70 can be permanently attached to the EMI 240/Y Yagi antenna to keep it ready for use at all times.



3.1.6 Scope of delivery

The EMI 240 direction finder set is delivered in a spacious carrying case. The original operating instructions from Bosch are included with the DLE70 Professional laser rangefinder.

3.2 Technical Data and Operating

3.2.1 Frequency identification generator KFG 242

The KFG 242 is used to feed a radio frequency carrier (with identification) into a broadband cable network to measure levels and electromagnetic interference.

Technical Data:

- Frequency: 301.00 ... 301.70 MHz (programmed in 0.1 MHz steps)
- Output level : 90 ... 108 dB μ V, adjustable
- RF Output: F socket, 75 Ohm
- Input: External control input for special applications
- Identification: 13 alphanumeric characters
- Programming: with 2 keys
- Modulation: FM
- Frequency deviation: 100 kHz
- Dimensions: 196 mm x 96 mm x 55 mm
- Weight: Approx. 1 kg

Installation:

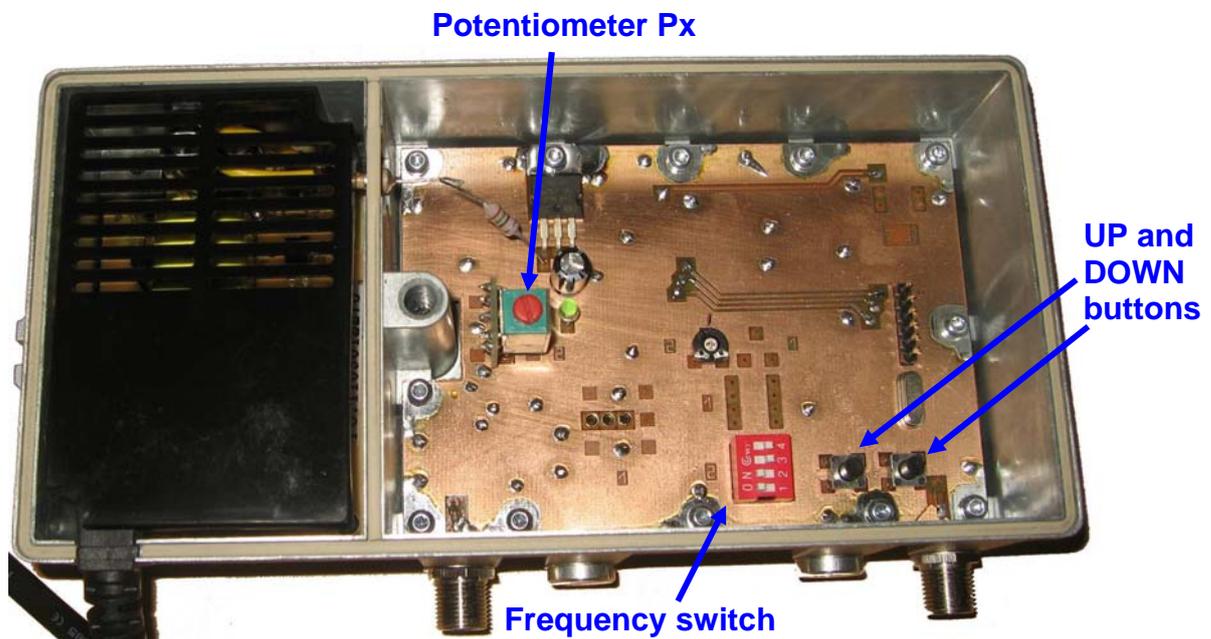
The KFG 242 is usually installed in the head end of a television cable network. Install the device using two screws (not included in the scope of delivery) on a level surface – an appropriate connection is provided for earthing.

The input (Mod) is NOT a radio frequency input. Instead, it is a control input for special applications. NEVER terminate this with a 75-ohm resistor!

Operating elements:

Open the KFG 242 to access the operating controls. To open it, unscrew the screw on the top of the device and then remove the cover. You can now access the relevant adjustment elements. You will normally only need to open the frequency identification generator once to set an individual identification, a different frequency, and the output level. This should always be done by qualified personnel. You can use the displayed operating controls to set and change the transmitting frequency, the transmission level, and the identification (as described below).

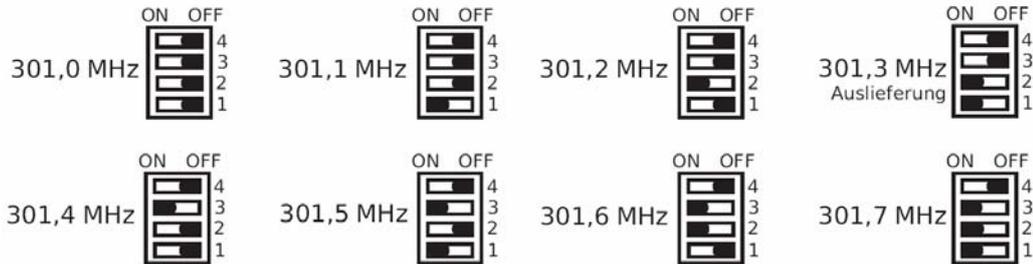
After you have finished making settings, make sure that the frequency identification generator is completely closed. To prevent interference radiation, continuous operation of the frequency identification generator is ONLY allowed when the housing is closed.



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Setting the identification frequency:

The factory setting for the identification frequency is 301.30 MHz. You can use the frequency switch to set other frequencies.



Programming the identification:

The identification is set to "MUSTERSTRASSE" at the factory. You can use the two buttons inside the KFG 242 to configure an identification of your choosing, which consists of a combination of the following characters:

A	K	U	.	8
B	L	V	/	9
C	M	W	0	:
D	N	X	1	;
E	O	Y	2	<
F	P	Z	3	=
G	Q	SPACE	4	>
H	R	+	5	?
I	S	,	6	@
J	T	-	7	

To change the display text, the AMA 310 must be connected to the radio frequency output of the frequency identification generator, the EMI measuring range must be activated, and the current transmitting frequency of the frequency identification generator must be configured (see the "Electro Magnetic Interference Measurement (Option)" chapter in the operating instructions). Now press the frequency identification generator's UP and DOWN buttons **at the same time** (for 1 second). When you see an inverted character in the display for the AMA 310, the frequency identification generator is in programming mode. Now you can **briefly** press (for one-half of a second) **one** of the two buttons (UP or DOWN) on the KFG 242 to change the characters. You change the character position by pressing **one** button and **holding** it (for about 1 second). To save your settings and exit programming mode, press and **hold** both buttons **simultaneously** (for 1 second).

Setting the transmission level:

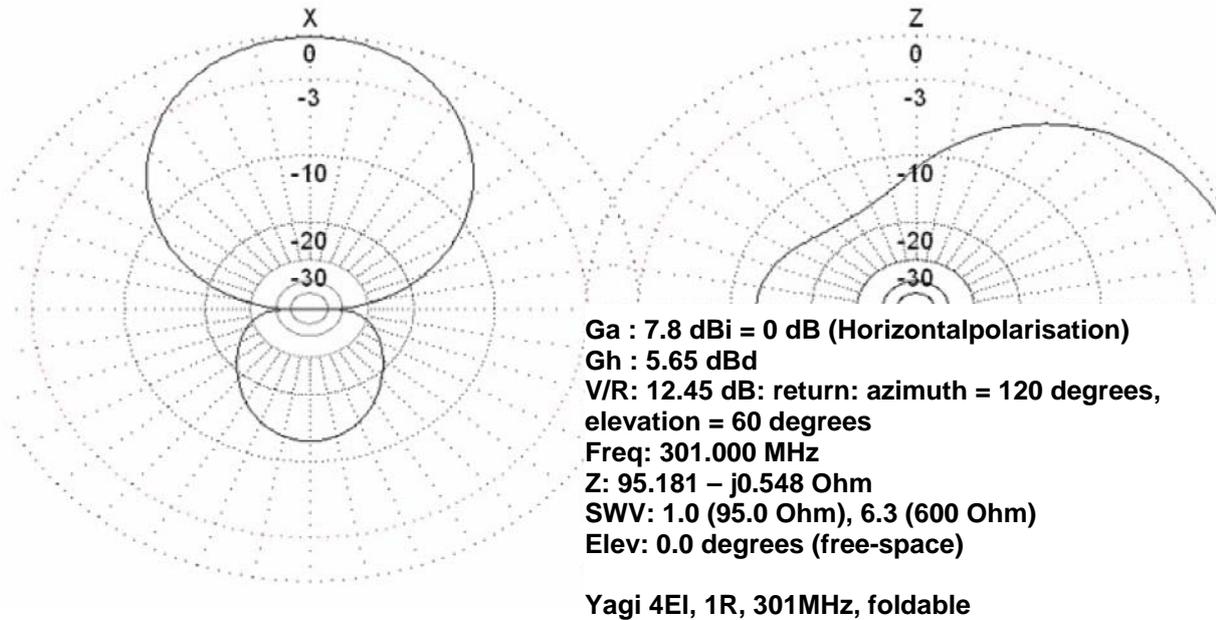
Use the potentiometer Px to set the transmission level within the aforementioned limits.

Cleaning and care:

You can use a dry, soft and lint-free cloth to clean the housing surfaces. No other maintenance measures are required.

3.2.2 Yagi antenna EMI 240/Y

- Yagi antenna 300-302 MHz
- Foldable, with directly
- Length: 65 cm
- Connection: BNC socket



3.2.3 EMI 240/V pre-amplifier

- Selektive pre-amplifier
- Connections: F plug and F socket
- Supply voltage: 5 V
- Gain: 25 dB

3.2.4 EMI 241 leak detector

- Active and selective for 301 MHz
- Pre-amplifier is already integrated
- Length: Approx. 29.2 cm
- Connection: F socket
- Supply voltage: 5 V

3.2.5 BOSCH DLE70 Professional laser rangefinder

The most important technical details are:

- Measuring range: 0.05 to 70 m
- Measuring accuracy (typical): ± 1.5 mm
- Smallest display unit: 1 mm
- Laser class: 2
- Laser type: 635 nm

For further technical details and notes on operation, consult the original operating instructions that are included.

3.2.6 AMA 310

Consult the operating instructions for technical details and information on the measuring instruments operating steps.

Chapter 4

Measurement Procedure

4.1 *Fitting the head end with the frequency identification generator and level adjustment*

As previously mentioned, the KFG 242 must be integrated in the head end so that an output signal can be transmitted in the cable network together with all of the television and added-value services. The signal is fed continuously to allow for EMI measurements at any time. The identification should be configured (see 3.2.1) so that the head end can be clearly identified. The transmitting frequency can be adapted to the conditions in the system (within certain limits). The transmission level should be set so that it matches the level of the PAL picture carrier (reference level in cable TV systems). This is absolutely necessary to be able to check whether the requirements for the system's radio frequency density (as formulated in the SchuTSEV) have been complied with.

However this rule can only be applied, if TV channel S21 (centre frequency: 306 MHz) is allocated with a digital TV signal. When allocated with an analogue signals (picture carrier frequency: 303.25 MHz) things are different. The reason is that the identification frequency of the KFG 242 is in the range of a sound carrier frequency, if there was no frequency gap in the channel allocation between channels S20 and S21, which is used for the identification frequency. With analogue allocation of S21 an feed-in of the identification frequency with full PAL signal level leads to a drastic reduction of the picture quality of the above lying channel. In this case the level of the KFG 242 has to be reduced by 13 dB just as the first sound carrier of an analogue TV signal. This reduces influence to S21 to a minimum. **Of course the value of 13 dB has to be added after an EMI measurement to the shown measurement value!**

Measurements have shown that an identification frequency of 301.3 MHz has the highest influence on S21. If the output signal of the KFG 242 is configured to be on a frequency of 301.7 MHz a level reduction compared to PAL of 6 dB to 10 dB is sufficient. It is of course up to the network operator to which frequency and to which output level the KFG 242 is tuned and which influence on the picture quality is tolerated. In any case the level difference to PAL picture carrier level has to be added to any EMI measurement result.

4.2 *Measurement process*

Determining the **maximum** field strength of the interference around a building represents the most important criterion for verifying whether the terms of the SchuTSEV have been complied with. This means that you must always conduct measurements at several places around a building, and not just in one location. Of course, the primary focus of the testing performed by German Federal Network Agency ("BNetzA") ["Bundesnetzagentur"] is directed towards the side of the building that faces the street, but you should keep two things in mind. For one thing, the German Federal Network Agency can demand to see documentation (as we mentioned earlier), which should not be limited to the street in front of the house. For another, detailed measurements may also be taken away from the street when there are conspicuously high interference levels along the measuring route of the German Federal Network Agency.

To measure electromagnetic interference at a measuring point, proceed as follows (see the "Electro Magnetic Interference Measurement (Option)" chapter in the operating instructions):

- Activate the EMI measuring range on the AMA 310
- Tune the AMA 310 to the transmitting frequency of the KFG 242
- Select the correct measuring set in the "Antenna" submenu or enter the data for a different antenna set (see Chapter 4.3)
- In the "Distance" submenu, enter the distance from the device to be tested (this can be determined easily and reliably with the optional Bosch DLE70 laser rangefinder)
- Select the supply for the measuring set from the LNB selection menu (both the EMI 241 rod antenna and the (absolutely essential) pre-amplifier for the EMI 240 direction finder set must be supplied with 5 V DC)

You can now read the result on the measured value display of the AMA 310.

KWS TEST 1234		EMI240	D= 5.0m
EMI 301.30MHz		33.3dBμV/m	
Limit exceeded!		E(3.0m)= 37.7dB μ V/m	
ANTENNA	DISTANCE	LIMIT	

You can see the identification that is received on the left side of the upper display row (in this case, KWS TEST 1234). The measuring set that is configured is displayed next to it (in this case, EMI240). The distance that is set can be read from the right side of the upper row. The identification is written to the measured value display once, but not just during the first correct decoding.

When the identification is received with a sufficient signal-to-noise ratio, it is quickly assembled (received letter by letter in a frame, with error protection to correct errors caused by poor reception conditions), deleted each second, and then re-assembled. This ensures that when you walk around with the antenna and aim at various building parts, you always know whether or not the identification can (still) be received. When the signal-to-noise ratio of the signal that is received from the frequency identification generator reaches critical values, you can see that the identification is assembled very slowly. In such a case, the 13 characters are not deleted every second. Instead, they are deleted only after each character of the identification has been received once without errors.

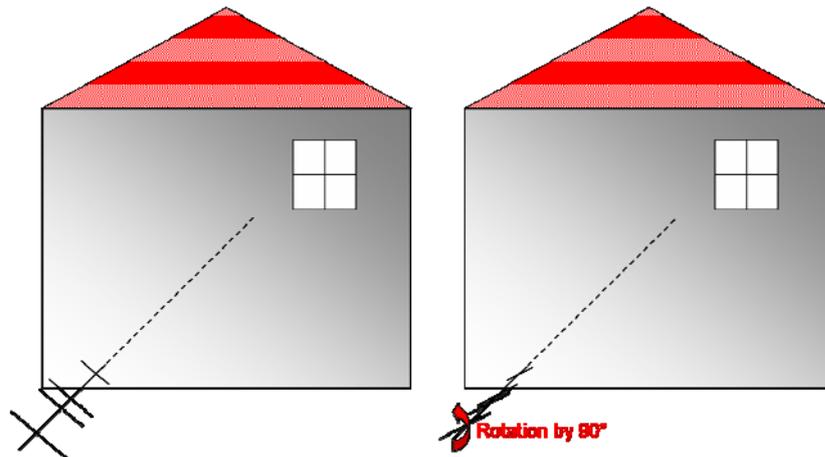
In this sense, the update speed of the identification is a reference point for determining the reception quality (see the following chapter for more information).

The receiving frequency that is set and the interference field strength that was **actually received at the measurement location** (in this case, 33.6 dB μ V/m) are displayed in large letters in the middle row of the LCD. Below this measured value, the value for the interference field strength which is normalised to the standard distance of 3 metres is displayed. **This value is crucial for documentation and for assessing whether the standard has been complied with.** If this normalised measured value exceeds the maximum permissible interference field strength (as shown in the above screenshot), a warning message will appear on the LCD. An acoustic signal can also be heard through the loudspeaker on the measuring instrument (CAUTION: this warning signal cannot be heard when the volume control below the graphic display has been turned down all the way).

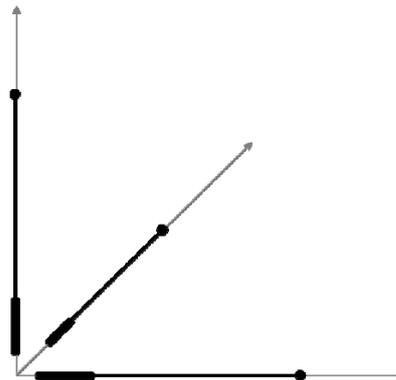
You can change the limit for the maximum permissible interference field strength in the "Limit" submenu. The limit of 27 dB μ V/m (as prescribed in the SchuTSEV) is preset at the factory. Therefore, this value should usually not be changed. You can adjust the measuring instrument to meet new requirements when they come into effect. You can also enter a limit which deviates from the standard, if the network operator requires other internal limits for maintenance and service. The warning message on the LCD and the acoustic warning signal are triggered **if the measured value** which is **normalised to 3 metres** in the lower-right part of the display exceeds the limit that is entered in this submenu. The limit is saved in non-volatile memory and is retained after a change has been made, even after you switch the device off and back on again.

The following points must be mentioned with regard to selecting the measuring set. Generally speaking, the EMI 240 direction finder set is better suited for taking measurements in front of a building (outdoors). The antenna has a pronounced directivity. This means that when you point the antenna at an object or spot on a house facade (i.e. aim at a spot), you are mostly measuring the interference field strength that comes from the direction or object that the antenna is "pointing at". The EMI 241 rod antenna is better suited for locating leaks, which also requires measurements to be taken at closer distances and within buildings. For example, if you measure in front of a building and find an excessively high interference field strength at a specific spot on the facade using the EMI 240 direction finder set, you can then use the EMI 241 detector in the affected room (behind the building's outer wall) to re-measure and try to locate the source of the high emissions. In an ideal situation, you can find a spot on a cable with a damaged jacket, a defective connection socket, a defective amplifier, a loose F connector nut, or similar defect, which is causing the limit to be exceeded. After you have repaired or replaced the presumed source of the interference, use the direction finder set in front of the house to verify that the limit is no longer exceeded.

Another important criterion in determining the **maximum** level of the emitted electromagnetic interference is that you measure more than just different spots around the building. You have to almost "travel" along the facade with the direction finder set, in order to determine the spot with the greatest emissions. The measured field strength is also polarisation dependent. This means that you need to orient both the Yagi antenna on the direction finder set and the rod antenna at the measurement location along all three axes in space. For every change in orientation, the measured field strength value will usually change, too. The figure below shows how you can hold the EMI 240/Y Yagi antenna in two different orientations when aiming at a spot.



In order to locate maximum levels at the measurement location, the rod antenna must be aligned in all three spatial directions, as shown in the figure below.



4.3 Increased flexibility of EMI measuring option for firmware version Vxx.07a and higher

With firmware version Vxx.07a and higher, the EMI measuring option in the AMA 310 can be used with much more flexibility. Previously, the instrument could only be tuned within the frequency range of the KFG 242 generator (301.00 to 301.70 MHz) with EMI measurement activated. Now you can specify frequencies within the entire broadband cable range (44.75 to 867.25 MHz).

In addition, a user-defined antenna may also be defined. Enter the name and correction factor of any EMI antenna using the menu item **ANTENNA** -> **EMIAANT** (see AMA 310 operating manual).

User defined EMI antenna			
Name: EMIAANT			
Factor: -13.0 dB			
APPLY			
			BACK

If a new name is entered for the user-defined antenna, the name of the menu item will also change under the **ANTENNA** menu. The correction factor that is entered governs the conversion of the level measured by the receiver (in dB μ V) to the displayed field strength (in dB μ V/m). The following relationship applies: $E[\text{dB}\mu\text{V}/\text{m}] = L[\text{dB}\mu\text{V}] + \text{Factor}[\text{dB}]$.

This function can also be used to compensate for a reduction in the level of the identification frequency when channel S21 carries an analogue TV signal (see Chapter 4.1).

4.4 Correction factors for the antenna sets EMI 240 and EMI 241

The conversion factors listed below enable you to adjust the correction factors for the measuring sets featured in this application note:

Antenna set EMI 240: -13 dB

Leak detector EMI 241: -15 dB

4.5 Possible sources of errors and effects on the measurement

- The EMI 240/Y Yagi antenna MUST always be operated with the EMI 240/V pre-amplifier. Since the pre-amplifier is included in the conversion of the antenna voltage to a value for the electrical interference field strength, connecting the Yagi antenna directly to the AMA 310 will lead to incorrect measurement results.
- Both the EMI 240 direction finder set and the EMI 241 rod antenna must be supplied with 5 V (see operating instructions). Using antennas that are not supplied with voltage causes the interference field strength to be assessed as being lower than it actually is, or the identification and the interference field strength cannot be detected at all.
- **Using a voltage supply that is greater than 5 V can cause permanent damage to the measuring equipment.**
- Always select the correct measuring set in the "Antenna" submenu or set a valid user defined correction factor respectively
- The receiving frequency that is set in the AMA 310 must be exactly the same as the transmitting frequency on the KFG 242. For example, if the frequency identification generator is set to 301.30 MHz and the AMA 310 is tuned to 301.40 MHz, the identification will still be decoded when the signal-to-noise ratio is good, because the modulation that is used is extremely robust. However, in this case there may be measurement errors in the interference field strength.
- To correctly assess whether a measured interference field strength meets the aforementioned guideline, the measuring distance must always be included (you set this in the "Distance" EMI submenu in the AMA 310; see operating instructions).
- In order for the measuring instrument to decode the identification, the signal that is received from the KFG 242 must extend at least 6 dB beyond the general noise and interference field strength floors. Under ideal reception conditions, the identification will generally be correctly decoded at field strengths as low as 5 dB μ V/m. However, you may experience situations in which the identification cannot be decoded, despite a high reception field strength. The reason for this is that the signal from the KFG 242 is overlapped by other interference products. Laptops are one example of a source of interference that can overlap the identification, but a number of other influences can also be named.

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