Analysis of the Screening Effect of Small Casings

for

ROLEC Gehäusesysteme Rose + Rose GmbH & Co KG

31725 Rinteln

prepared by the

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Abstract

Small casings manufactured by Messrs. ROLEC were examined with respect to their screening charcteristics. The casings consisted of an aluminium alloy. Especially, certain design types of connections (joints) with the cover were to be examined.

Determining the screening efficiency was the main objective of the analysis. A comparison was made of two design versions with different types of surface treatment of their contacting areas. In addition to this, it was determined as to which extent the screening efficiency depends on various parameters like closing method, gasket type, and overlap of the casing's cover.

The results show the superiority of this novel type of casings (approximately 50 dB) as compared to the conventional type (20 dB) regarding the screening efficiency. However, seals and gaskets play a crucial role. The optimum screening values upto 50 dB can be achieved with several sealing/gasket options so that it is possible to select from various options with different handling properties and cost advantages.

The study of different lengths of overlaps of casing covers showed that these have a rather limited effect on the screening effect value.

Eventually, in the course of the analysis of the screening efficiency, certain differences were observed between screw-type covers and toggle-type fastenings with various springs which were clearly dependant on the type of gaskets.

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1 Theoretical basis

Measuring the screening effect value consists of verifying the efficiency of a means screening or shielding. For this purpose, a pre-defined field is generated. Such field then is registered by means of a field measuring appliance. A second measuring is carried through after the screening device has been installed, all other conditions remaining unaltered. In cases where the existing shielding cannot be removed, a comparison measuring is effected on a second, identical arrangement but without screening. The comparison of the two measuring values allows to calculate the screening effect value.

For electrical fields, the folowing formula applies:

$$a_s = 20 \cdot {}_{10}\log \left| \frac{E_a}{E_i} \right| \text{ (in dB)} \qquad (1)$$

For magnetic fields:

$$a_s = 20 \cdot {}_{10}\log \left| \frac{H_a}{H_i} \right| \text{ (in dB)} \qquad (2)$$

In both cases, the index $_a$ refers to the field without screening, whereas the index $_i$ applies to the field with screening.

The defined field usually consists of the field of an even TEM wave corresponding to the distant field of a transmitter in a great distance. With the field intensities of a normal radio transmitter being too weak, TEM or, respectively, GTEM cells are employed for this. Both are waveguide arrangements of different types. They enable the generation of an even, homogenous TEM field in a confined space. For the purpose of describing the field it is irrelevant whether the magnetic or, respectively, the electric field components are being measured, because an unambiguous relationship can be defined between the two. Within the scope of the examination at hand the E-component was selected because of its lower degree of field distortion. Only few standards or measuring specifications exist for determining the screening effect of shielded rooms. The most common of them is MIL-STD-285 which was issued in 1956 by the American Ministry of Defence. It refers to screening casings or housings of a size starting at about one meter so that the measuring requirements can only be applied by analogy.

The MIL-STD-285 standard stipulates pre-defined points for the arrangement of the measuring points within the screened room and such points are difficult to transfer to smaller objects. The requirement of keeping a minimum distance of 30 cms from the walls of the room cannot be observed in case of the present small casings. Other standards, like for instance NSA No. 65-6, VG 95370, part 15, and IEEE 299 are based on the above mentioned MIL-STD-285, although there are smaller differences regarding the frequency range and measuring method.

2. Description of the experimental set-up

2.1 Measuring method with field sensor

The screening effect value of small casings was determined inside a GTEM cell*). Inside this GTEM cell, a TEM field was generated the field strength of which was measured inside the casing with and without the lid (cover), respectively, with an E-field sensor attached to the centre.
Due to the frequency dependancy of the power amplifiers that were used, a measuring system with a tension regulating circuit was constructed. It serves for the purpose of keeping the test field strength constant. This is the case when the input voltage of the cell is constant.

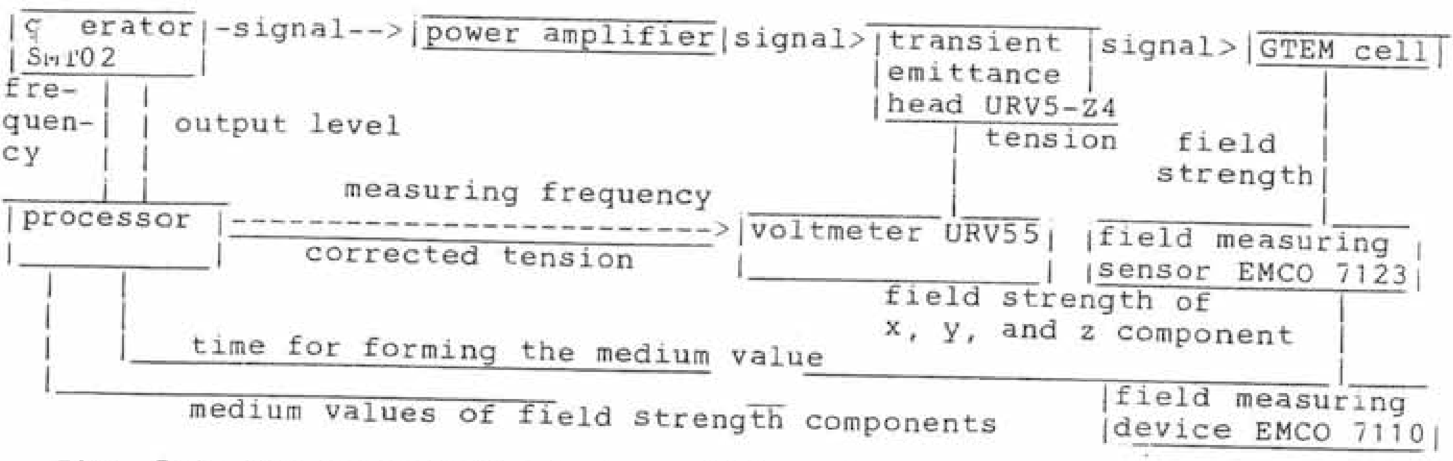

Fig. 2.1: First measuring set-up with E-field sensor (from Kluth (4)).

The measuring system consists of the components listed in appendix A. For stabilizing the voltage amplitude within the frequency range, the automatic control system is used which includes a processor, power amplifier, measuring head, and voltmeter. This is necessary, because the voltage at the entrance of the cell may be influenced by the frequency charcteristic of the power amplifier and possibly by reflections within the cell itself.
The measuring circuit, consisting of processor, signal generator, power amplifier, GTEM cell, and field measuring unit, registers the amplitude characteristic of the electrical field. The signal generator is the source of the signal. The amplitude of the signal is set to the desired value by means of the controllable power amplifier. Within the GTEM cell a transversal, electromagnetic field is produced, the field strength of which is measured with the EMCO field measuring system. The field-strength distribution was detected through a frequency range between 100 kHz and 1000 MHz at increments of 5 MHz.

*) GTEM cell = cell with a transversal electromagnetic wave in the gigahertz range.

2.2 Measuring method with Stripline

After initial examinations were made by means of the E-field sensor, its sensitivity proved to insufficient. The high degree of screening found with the new casings resulted in a residual field in their interior which lay below the sensor's sensitivity limit. This is why the E-sensor then was only used for comparison purposes with older casing types. The problems described here led to the employment of another, novel measuring method.

Here, a stripline with a 50 Ohms ending was built into the casings. To such stripline a tracking signal of a network analyzer was added, the measuring input of which was connected to the 50 ohms output of the GTEM cell. In other words, a frequency characteristic was registered whose transmitter was the stripline, with the GTEM cell as sensor. This procedure was justified by the fact that the sensitivity of this set-up was increased by several orders of magnitude.

A schematic diagram of the structure in accordance eith the second measuring method is shown in the following figure.

Absorber
GTEM cell
50 ohms
septum
stripline
50 ohms
EUT
Network analyzer
50 ohms
50 ohms
field strength measuring device
tracking generator

Fig. 2.2: Second measuring set-up with customized stripline and network analyzer (ill. Kebel)

The measuring set-up consisted of a processor, the network analyzer including the hooked up tracking generator, the GTEM cell and the stripline termination with 50 ohms, which was attached by soldering it onto each casing to be measured.
From the reciprocity theorem follows that the measuring of irradiated interior field strength inside the casing (first measuring method) equals the measuring of the exterior field strength radiated from the outside of the casing (second measuringmethod), with each of the measurings effected with and without cover. The tracking generator fed a constant voltage into the casing with stripline. The processor registerd the amplitude patterns which were measured by the network analyzer in accordance to their respective frequencies.

The structure of the stripline can seen in the following illustration.

Fig. 2.3: Stripline in small casings with 6x300 ohms connection resistors.

3 Representation and evaluation of measuring results

At the outset it is explained how the desired screening effect value was determined on the basis of the measuring results. Here it must be taken into account that in case of screening measurings the frequency pattern of the used GTEM cells is basically irrelevant. Then, the measuring results are represented as frequency pattern graphs of the screening effect value.

3.1 Evaluation method

As it was intended to register frequency pattern graphs covering a wide range of frequencies during the study, a continued processing by means of a processor was indispensable. In case of the first measuring method using the E-field sensor, this was achieved by transferring the values of the HF-mV-meter via an IEC bus interface to a PC where processing took place. This was effected by means of the mathematical software MATLAB, which also served for the graphics output in the HPGL*) format.

When evaluating the results of the second measuring method the data supplied by the spectrum analyzer were also transmitted to the processor via an IEC interface and were then processed as described.

3.2 Representation and comparison of measuring results

3.2.1 E-field sensor versus stripline

First, a comparison between the two measuring methods should give information about the degree of correspondence of the results. The following diagram shows the results for the screening effect value based upon the first (dotted line) and the second (continuous graph) measuring method:

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*) HPGL = Hewlett Packard Graphics Language

s
c
r
e
e
n
i
n
g

(dB)

frequency (Hz)

Fig. 3.1: Comparison of the results of the two measuring methods, illustrated using the example of a casing of the older type

It is obvious that the two measuring methods reflect the frequency pattern similarly. When assessing the results of the E-sensor measuring, however, it should be noted that acute resonances can hardly be detected by the frequency interval of 5 MHz so that the graphs differ significantly in this range. The examination following now was effected on the basis of the second measuring method.

For the screening effect value of the measured, conventional type of casing, values around 20 dB were found which correspond to a lower shielding effect.

3.2.2 Influence of cover position

When examining the conventional type of casing, it was also found that the values for the screening effect value were only at random related to the assembly type using toggle-type covers. This will become clear in the next diagram, where the screening effect value was measured for three positions, the cover being turned by 180° each time for each measuring operation.

.../11

s
c
r
e
e
n
i
n
g

(dB)

frequency (MHz)

Fig. 3.2: Screening effect value of the common type of casing with cover turned two times by 180°

It can be seen clearly that the screening effect value agrees in the identic positions (dotted and broken lines) upto approx. 500 MHz and that thereafter certain differences occur. The comparison to the continuous line which represents an assembly position turned by 180° shows a significant deviation of 20 dB and more in some cases. This signifies that in case of the older type of casings the contact between casing and cover by means of toggle-type connection is relatively unstable.

Influence of gaskets

The next examination was to give information about the values of such shielding effect as could be achieved with various types of gaskets for the new type of casings. Such measurings were executed on a casing called ROLEC Neu 0.0.

screening

frequency (Hz)

Fig. 3.3: Screening effect value of different types of gaskets and covers with a new casing of the type Rolec Neu 0.0

The types of gaskets are denominated in decreasing order of their respective screening effect value (from top to bottom) as follows:

toggle type covers, conductive gasket (----------)
screw-type covers, normal gasket (..........)
toggle-type covers, without gasket (·-·-·-·-·-·)
toggle-type covers, conductive gasket (__________)

The new casing design enables screening effect values between 40 and 50 dB and more, put aside the unfavour able combination of toggle type covers with a conventional gasket. Consequently, a distinct increase of the shielding effect as compared to the old casing can be observed.

The poor effect in case of conventional gaskets can be explained easily, because such gasket exerts a counter force aginst the toggle-type covers so that the contact between casing and cover is bound to deteriorate. If screws are employed instead of toggles, this problem is eliminated. Quite the contrary is true - this type of assembly even enables an additional screening effect of 10 dB as compared to toggle-type covers without gasket.

The best screening effect values of an average of 50 dB are achieved, as was expected, when conductive gaskets are used. Here, also the decline observed at about 750 MHz is the least. With all other types of gaskets, there are minor declines to be observed at 450 MHz and 540 MHz.

3.2.4 Influence of the type of cover

Another measuring series was aimed at finding out if toggle-type covers which provided an increased contact pressure by means of reinforced springs could attain the screening values of the screw-type assembly. The following diagrams demonstrate the success of such operation.

s
c
r
e
e
n
i
n
g

(dB)

frequency (Hz)

Fig. 3.4: Screening effect value in case of normal or, respectively, reinforced toggle-type covers as well as screw-type connections for the casing ROLEC Neu 0.0 without gasket

screw-type covers	(___________)
toggle-type covers, normal spring	(-----------)
screw-type covers, reinforced spring	(·-·-·-·-·-·)

Here, it is obvious that the increase in screening effect in case of an icreased pressure of the springs in the toggle-type covers remains quite low (approx. 3 dB). The screw-type connection is to be taken into account also in this combination. It should be noted that the reinforced toggle-type cover - at least together with slotted screws - is difficult to assemble and requires some strength.

A similar study which, however, was executed using conventional gaskets, demonstrated more significant differences of the values for the screening effect value at different contact pressures of the springs. This can be seen on the next page.

s
c
r
e
e
n
i
n
g

(dB)

frequency (Hz) x10^8

Fig. 3.5: **Screening effect value in case of normal or, respectively, reinforced toggle-type covers as well as screw-type connections for the casing ROLEC Neu 0.0, normal gasket**

screw-type connection (___________)
toggle-type covers, normal spring (-----------)
screw-type covers, reinforced spring (·-·-·-·-·-·)

The increase of the screening effect now amounts to approximately 8 dB. This increase is easily to explain, because the influence of an increased contact pressure will play a major part with normal (insulating) gaskets. Again, the screw-type connection is superior. A final examination of this kind should be enough to explain the differences between the cover types when using conductive gaskets. The results are outlined on the next page.

screening (dB)

frequency (Hz) x10^8

Fig. 3.6: Screening effect value in case of normal or, respectively, reinforced toggle-type covers as well as screw-type connections for the casing ROLEC Neu 0.0, without gasket

screw-type connection	(____________)
toggle-type covers, normal spring	(-----------)
screw-type covers, reinforced spring	(·-·-·-·-·-·)

Here, it becomes clear that the screening effect value for all types of covers lies in the neighbourhood of 50 dB. Differences between the connections amount to approximately 3 dB and are therefore negligeable.

Summarizing this, it can be stated that regarding the cover types only in case of conductive gaskets a screening effect value of 50 dB can be guaranteed. In case of conventional or, respectively, no gasket at all, the screw-type assembly is by far superior to the toggle-type connection. A feasible compromise for moderate demands would consist of a combination of normal gasket and reinforced toggle-type cover. Except for the range around 500 MHz, this would ensure values of more than 40 dB.

3.2.5 Influence of overlapping cover

Finally, the influence of a variation should be examined which consists of an overlap of the cover along the interior of the casing. For this, the frequency pattern of the screening effect values for 5 different overlaps between 0 and 2 mm were registered and displayed. Again, distinct differences became visible when using various types of gaskets. The results without gasket are illustrated in the following graphic.

s
c
r
e
e
n
i
n
g

(dB)

frequency (Hz) $\times 10^8$

Fig. 3.7: Screening effect value in case of various overlaps of casing covers and with normal toggle-type covers without gasket. Casings: ROLEC Neu 0.0 through 2.0.

The types of overlaps were assigned to their respective graphs at 300 MHz from top to bottom as follows:

ROLEC casing Neu 0.5	(- - - - - - -)
ROLEC casing Neu 0.0	(-·-·-·-·-·-·)
ROLEC casing Neu 2.0	(________)
ROLEC casing Neu 1.5	(________)
ROLEC casing Neu 1.0	(________)

The major difference between the three lower and the two upper courses are a consequence of the manufacturing tolerances of the covers in combination with unsufficient contact pressure of the toggle-type covers A varation of the overlap does not significantly influence the screening effect which also becomes clear from the two following diagrams. The results with not-reinforced toggle-type covers and normal gasket can be seen in the following illustration.

screening

(dB)

frequency (Hz) x10^8

Fig. 3.8: Screening effect value in case of various overlaps of casings/covers with not-reinforced toggle-type covers and with normal gasket. Casings: ROLEC Neu 0.0 through 2.0.

The types of overlaps were assigned to their respective graphs at 200 MHz from top to bottom as follows:

ROLEC casing Neu 0.5	(- - - - - -)
ROLEC casing Neu 2.0	(-·-·-·-·-·-·)
ROLEC casing Neu 0.0	(________)
ROLEC casing Neu 1.5	(________)
ROLEC casing Neu 1.0	(________)

Here, no unambiguous statement is possible because the screening effect shows continuously low values due to the toggle-type cover.

The following illustration shows the results with screw-type covers and standard gasket.

screening

(dB)

frequency (Hz)

$\times 10^8$

Fig. 3.9: Screening effect value in case of various overlaps of casings/covers with screw-on covers and with normal gasket. Casings: ROLEC Neu 0.0 through 2.0.

The types of overlaps are assigned to the courses from top to bottom as follows:

three upper graphs: 1.0, 1.5 and 2.0, respectively,
two lower graphs: 0.0 and 0.5.

It is obvious that the screening effect value patterns are above 50 dB, except for the sharp decreases around 500 MHz. Only the versions 0.0 and 0.5 beyond 800 MHz deviate from such pattern.

Thus, the statement with respect to the low significance of the overlap has been confirmed.

Appendix A - Arrangement of devices for the first measuring method

GTEM cell	EMCO Type 5305, frequency range 9 kHz - 5 GHz; impedance 50 ohms; max. effect 50 W, max. VSWR*) 1:1.75; illustration next page
E-field sensor	EMCO Type 7123, frequency range 10 kHz - 1 GHz; dynamic range 4-3000V/m, (38 dB); accuracy ±0.5 dB - 0.05; +1.5 (IEC 801-3); ill. see below.
measuring unit	EMCO Type 7120; scanning rate 3.3 kHz
evaluation unit	EMCO Type 7110, connection to measuring unit via glass fiber; min. processing time 100 ms
signal generator	Rohde & Schwarz, Type SMT02; frequency range 5 kHz - 1.5 GHz; output level -144 to +13 dBm; level error <1dB
power amplifier	RF Power Labs Type R727C; frequency range 6 kHz - 1 GHz; max. effect 10 W; max amplification 43 dB.
HF measuring head	Rohde & Schwarz Type URV5-Z4
HF-mV meter	Rohde & Schwarz Type URV 55

*) Voltage/Standing Wave Ratio)

Fig. A.1: E-field sensor with measuring and evaluation unit

Appendix B - Arrangement of devices for the second measuring method

GTEM cell	EMCO Type 5305, frequency range 9 kHz - 5 GHz; impedance 50 ohms; max. effect 50 W, max. VSWR 1:1.75; see illustration below
network analyzer	Advantest Type TR 4172
integrated stripline	in-house construction, max. VSWR 1:2 upto 800 MHz

Fig. B.1: GTEM cell

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Appendix C - Description of casing

E V

Aluminium Casing for Assembly/Integration

Screening by Design

Assembly version

Integration into control panel

ROLEC (R)

R O S E + R O S E

New ways of casing technology

Aluminium casing and EMC

Metal casings offer a certain degree of protection against radiation interferences without additional measures. The weak link is the joint surface between upper and lower part, because as a rule there exists a non-conductive, insulating gasket. Paint that is present on groove and key even increase such insulating effect. The common solution for this is to keep groove and key free of paint and to use conductive gaskets. This solution is very costly and unsecure, because the unpainted, unprotected aluminium surfaces may easily corrode. The oxydation layer formed by such corrosion further reduces the screening effect.

The new EMC aluminium casings

In the present invention, the contact is made between the upper and lower part by means of contacting abutting surfaces. In order to prevent the damaging effects of corrosion, contact is made in the interior. Upper and lower part will be painted at the outside as one single part whereas they stay free of paint on the inside. In order to meet the provisions of the protection class IP 65, a normal gasket is mounted at the outside.

standard gasket

paint paint

traditional casing principle

standard gasket

inside free of paint paint

new "EV" casing principle

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Dimensioned drawing type EV 122 control panel integration

Additional, costly screening measures are not necessary in most cases. This means **EMC without additional charges**. For highest demands and large frequencyranges, the casings can be subjected to a galvanic treatment and be equipped with conductive gaskets.

Suitable for stand-alone assembly and integration

By means of the assembly rim, the integration options were considerably expanded. Mounting claws which can be supplied as accessories enable an easy integration into control panels, switching cabinet doors, or machine bodies.

Please contact us for further information on planned dimensions, delivery terms etc.

ROLEC Gehäusesysteme - ROSE +ROSE GmbH & Co KG - Kreuzbreite 2 - D31737 Rinteln (Germany) Phone: (0) 5751 - 4003-0; Facsimile: (0) 5751 - 4003-50

Appendix D - List of references

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