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MEASUREMENTS OF COUPLING THROUGH BRAIDED SHIELD VIA NEW CONDUCTED IMMUNITY TECHNIQUE

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Abstract—A new method for evaluating the performance of the shield and coupling through holes on braided shields is introduced. The method is based on conducted immunity test. A comparison is made between two kinds of shields, based on introduced technique. One is braided shields and the other is adhesive foil that does not contain any holes. The value of coupling through holes in braided shields is determined via a new technique.

1. INTRODUCTION

Designing the shields of the cables is one of the most important fields in an EMC design. The strong electromagnetic pollution produces EMI voltages on the electronic equipment that are comparable to the used signals. Electromagnetic shielding of the cable is the key technique in protection against the leakage of information from electronic equipment. If a current produced by interference field flows over a cable braid, this generates a voltage drop on the inner surface of the braid, which acts an EMI voltage on the central conductors. This voltage can be evaluated by surface transfer impedance (STI) parameter: little transfer impedance means a good Shielding Effectiveness (SE).

So calculation and measurement of these parameters are one of the most important factors for choosing EMC measures. Different formulas are given in [1, 2] for calculation of STI. Along with calculation, measurements of these parameters shall be done before use. A triaxial structure is introduced in [3] for measurement of cable shielding properties.

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In this paper, STI is introduced briefly and the equation for calculation of STI for braided shields are presented. Coupling from holes in braided shields will be introduced as inductive term in expression of STI. Then a new method for measuring the properties of shield is introduced that is based on conducted immunity. In the last section of this paper induced power on inner conductor of coaxial cable is measured in two cases, first with braided shield and second when the braided shield is replaced by adhesive foil. Neglecting other influencing factors, comparison between these two measurements will lead to the effects of coupling through holes.

2. COUPLING THROUGH BRAIDED SHIELDS AND TRANSFER IMPEDANCE

Coaxial cables consist of a concentric shield enclosing an interior wire that is located on the axis of the shield. The function of the shield is to avoid external fields penetrating to the inner wire. It would be possible if we had a solid perfectly conducting shield. Impinging of external field to the shield will cause occurrence of current on external surface of the shield. Transfer impedance is a fundamental value of a shield's performance, and it relates a current on one surface of the shield to the voltage drop generated by this current on the opposite surface of the shield. This value depends solely on the shield construction.

The shield current diffuses through the shield wall to give a voltage drop on the interior surface of the shield of:

$$dV = Z_T I_{SH} dx \tag{1}$$

where Z_T is surface transfer impedance and is given in [2, 4–6] as:

$$\hat{Z}_T = \frac{1}{\sigma 2\pi r_{sh} t_{sh}} \frac{\gamma t_{sh}}{\sinh \gamma t_{sh}} \,\Omega/\mathrm{m} \tag{2}$$

And the propagation constant γ is:

$$\gamma = \frac{1 + j1}{\delta} \tag{3}$$

where $\delta = 1/\sqrt{\pi f \mu_0 \sigma}$ is the skin depth in the shield material. The shield inner radius is denoted by r_{sh} and the shield thickness is by t_{sh}.

The characteristics of a cable braid is defined in [7].

The complete transfer impedance for the braided-wire shield can then be written as:

$$Z_T \approx R_{cc} \frac{d\gamma}{\sinh(d\gamma)} + j\omega M_{12} \tag{4}$$

R_{cc} will be determined by the parameters of braid [7].

At very low frequency, the STI is equal to the direct current resistance of the braid. The low-frequency shielding properties are determined by number of wires, weave angle and shield material conductivity. The high-frequency behaviour of the STI function are thus determined by the coverage, weave angle and the number of carriers in the weave. With increasing frequency, two effects will occur:

- due to the skin effect the STI will drop
- due to the H field coupling through the braid structure there will be a rise of the STI proportional to the frequency

Calculation of transfer impedance is presented in [7]. Based on the theory mentioned here different methods for measurement of transfer impedance have been proposed. A triaxial structure is proposed in [3]. Two well-known methods based on triaxial fixture are mentioned in IEC 61196-1 and EN 50289-1-6.

3. CONDUCTED IMMUNITY

As the base of measurement technique it is necessary to introduce the conducted immunity technique briefly. In this measurement, that is one of the compulsory tests in EMC immunity tests the disturbing signal will be injected to the desired point via a coupling device. In [8] three different injection methods are introduced for this purpose. Injection via coupling decoupling networks (CDN), bulk current injection (BCI) and injection via EM-clamp. According to structural performance of CDNs they can not be used for our purpose. Between two other techniques, injection with EM-clamp is used in this investigation.

EM-clamp is a ferrite structure which couples the input power directly to the cable in it. Of course in order to inject the desired level of disturbance to the cable, a calibration setup shall be defined. A typical calibration setup is shown in Figure 1. More details on setups and calibration are available in [8]. This setup is the base of measurement in this investigation and proposed method.

Using current clamp for evaluating the performance of shielded cable has been done in [9]. Two improvements can be mentioned while using EM-clamp. The first is that according to the structure of EM-clamp and its 1 meter length, the problems of placement of current clamp will be solved. While in using current clamp, the results will differ dramatically when changing the place of current clamp along the cable under test.

The second is that EM-clamp is a kind of injection method that uses both inductive and capacitive coupling, while current clamp uses just inductive coupling. So using of EM-clamp resembles to interaction of electromagnetic wave, more.

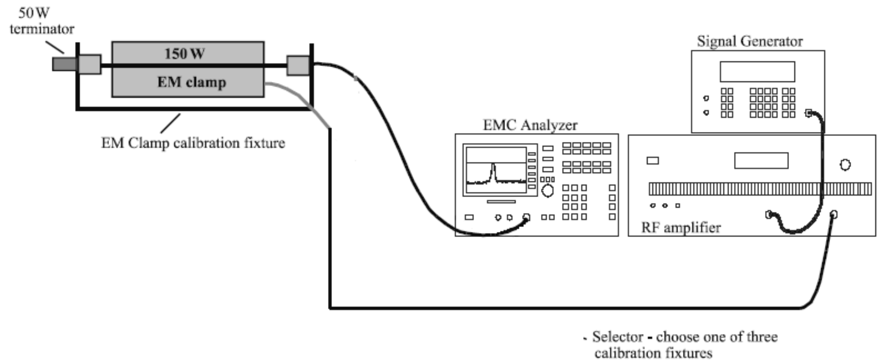

Figure 1. Calibration setup for EM-clamp.

The basis of applied method for evaluating the performance of the shield is to inject the interference via EM-clamp and measuring the induced power on the core. Details about setup are presented in Section 4 of present document. Main advantage of this method is simplicity of implementation; however application of methods mentioned in IEC 61196-1 and EN 50289-1-6 needs the construction of certain structure. Another point that should be considered is that in this method performance of the shield is measured (i.e., shielding effectiveness) and measurement of surface transfer impedance is not done (IEC 61196-1 and EN 50289-1-6 measure surface transfer impedance directly). Although surface transfer impedance is a key feature of a shield but usually the practical parameter that is important for designers is shielding effectiveness. However surface transfer impedance can be related to shielding effectiveness [10], in this method shielding effectiveness is measured directly. After methods based on radiated immunity this methods most resembles to the real electromagnetic condition and environment that will happen in practical situations. From this point of view application of EM-clamp is preferred. In comparison with method based in radiated immunity the key advantage of EM-clamp method is that it does not need any special electromagnetic environment while methods based on radiated immunity should be performed in anechoic chambers. A parameter that restricts application of EM-clamp and can be considered as it's disadvantageous is frequency limit. Upper and lower frequencies of interest are limited by upper and lower frequencies of EM-clamp. Today EM-clamps working in the range of 150 kHz to 1GHz are available.

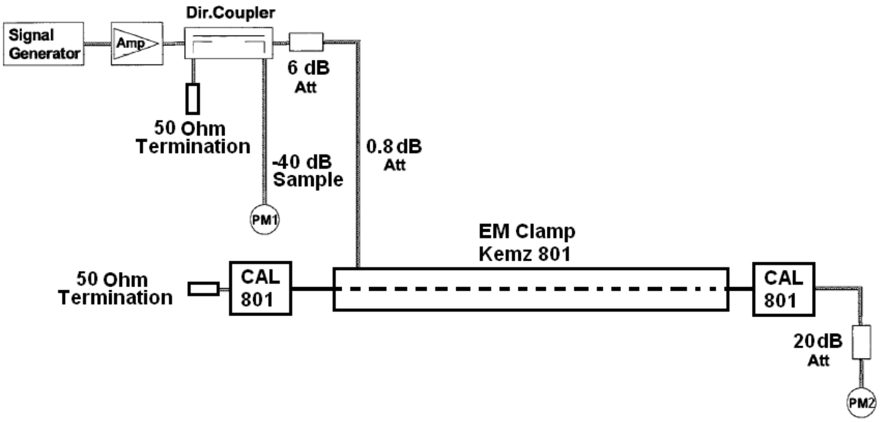

Figure 2. Block diagram of the measurement setup.

4. MEASUREMENT SETUP AND RESULTS

The induced power on the core of RG213 cable was under consideration in two cases:

1. The cable had its own braided shield.
2. The braided shield of the cable was replaced by cooper adhesive foil with no holes or penetration points.

A cable with the length of 104 cm was used. Effective length of cable that was placed in the EM-clamp was 100 cm. Block diagram of the measurement setup is shown in Figure 2.

Output of signal generator is amplified in order to provide the required power for input of EM-clamp. Forward power is monitored via a directional coupler getting a sample, 40 dB less than the forward power. This sample is used to set the forward power to a certain value in each frequency. 6 dB attenuator is for improvement of matching. CAL 801 units are standard impedance transformer units for preparing the required input impedance for measuring instrument. As the purpose of measurement is to measure the induced power on the core only the core will be inserted in the impedance transformer. The impedance transformer provides female banana connector on cable side and female N connector on measuring side. This unit is a standard unit and is constructed in accordance to IEC 61000-4-6. As the EM clamp is a 150 Ω system, this adaptor is a 150 Ω to 50 Ω adaptor. Measuring instrument is a dual channel RF power meter. Measurement has been done on a ground plane of 80 × 160 cm. forward power was set on +30 dBm (1 W) in each frequency by monitoring the sample

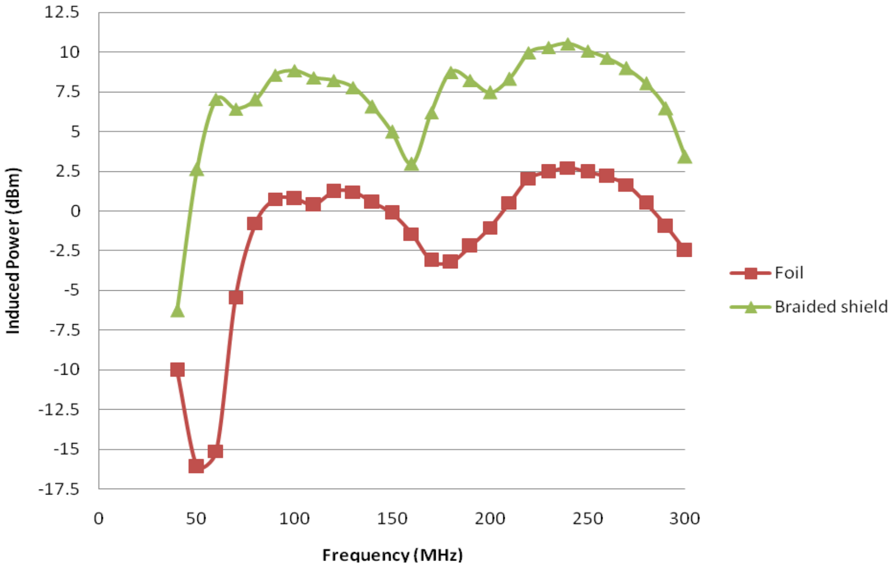

Figure 3. Induced power against frequency in two cases of braided shield and adhesive foil.

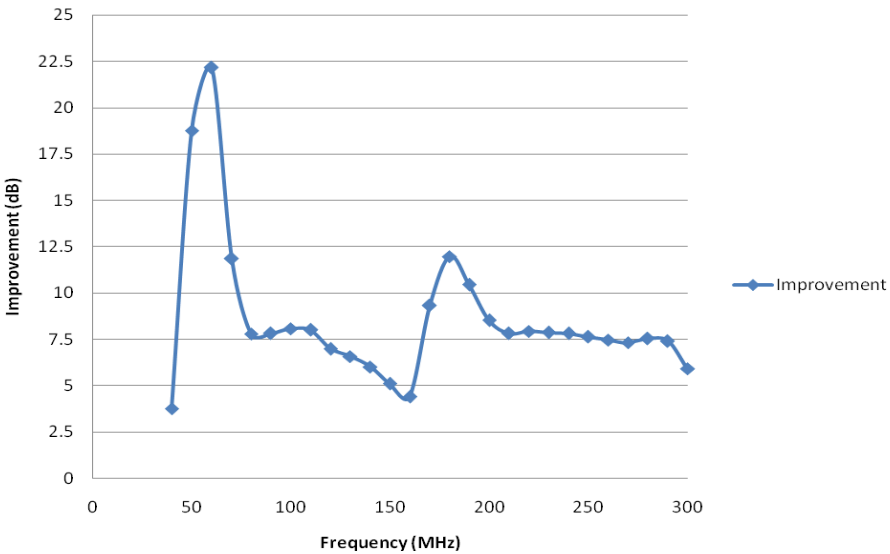

Figure 4. Value of improvement while replacing braided shield with adhesive foil.

and adjusting the generator level to set the sample to the certain level. Evaluation has been done in VHF band from 40 MHz to 300 MHz with 10 MHz steps.

As mentioned earlier two measurements has been performed: Measurement with braided shield and measurement when the braided shield was replaced by cooper adhesive foil. The key difference between these two cases was that in the second case there were no holes in the shield, so the coupling through holes would be eliminated. Induced power in two cases and value of improvement (defined as Induced power in the case of braided shield minus Induced power in the case of adhesive foil) while replacing braided shield with adhesive foil is shown in Figures 3 and 4 respectively.

As was expected there is a considerable decrease in induced power when the braided shield is replaced by the adhesive foil. This decrease in 60 MHz is 22.15 dB. Another fact that can be deduced from Figure 3 is that the variation trend of two curves is same, however a slight shift in frequency can be observed. Average improvement of 8.7 dB is seen from Figure 4. Two peak can be detected in Figure 4. The first is occurred in 60 MHz ($1/\lambda = 0.2$) and the other at 180 MHz ($1/\lambda = 0.62$). It is clear that the performance of any shields is length dependant and in some frequencies that are determined by the structure and grounding method of the shield, the performance of the shield will be the best. It seems that in these frequencies some resonance phenomena are happening. Although in high frequencies the curve is smooth but in low frequencies it has much more variation. Because of frequency restrictions of power amplifier investigation of lower frequencies could not be performed. Two minimum of the improvements are happening at 40 MHz ($1/\lambda = 0.14$) and 160 MHz ($1/\lambda = 0.55$). Occurrence of minimums and maximums can be related to the resonance phenomena that are determined by the structure of the shield.

5. CONCLUSIONS

A new method for evaluating the performance of shields was introduced. The method was based on conducted immunity. The specification of proposed method in comparison with other methods was mentioned. The key feature of proposed method is the simplicity and direct measurement of shielding effectiveness. Using this method a comparison was made between braided shield and adhesive foil. Considerable reduction in induced power is seen using adhesive foil. However the value of improvement is frequency dependant, but an average improvement of 8.7 dB can be considered for adhesive foil.

The important point is that using adhesive foil will not restrict the mechanical movement of cables. So in cases which this values of improvement is considerable using adhesive foil is preferred.

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