Optimization of Shielding Effectiveness of Coaxial Double Braided Screens in Contact

Bektas COLAK
Karabuk University
Karabuk,Turkey
bektascolak@karabuk.edu.tr

Osman CEREZCI
Sakarya University
Sakarya, Turkey

Niyazi ARI
ETH
Zurich, Switzerland

Selcuk HELHEL
Akdeniz University
Antalya, Turkey

***Abstract*— In this paper, the optimization of the shielding effectiveness of double braided coaxial screens in contact is obtained using semi-empirical single braid optimization formulas. Also the effect of the mutual inductance term between the double braided screens in contact is investigated. A sample optimization has been obtained practically, on one of the standard double braided RF coaxial cable namely, RG-142.**

Keywords—screening efficiency; transfer impedance; coaxial cable; double braid; optimization

I. INTRODUCTION

The braid form is in general use, for the screen of the coaxial cables. The shield of braided coaxial cables is formed by woven wires. These woven wires are lying parallel to each other in spindles. Spindles are woven in right and left handed helix geometry. There is diamond shaped holes at each passing point between right and left handed spindles. (Fig.1). Insufficient shielding at braided screens is one of the interference sources for the RF communication and /or the measurement systems. Therefore, the holes are the main reason of leakage at braided form of the cable screens. Since the leakage term is not a precise technical term, a more unique and measurable term is introduced and widely used. This is the transfer impedance *(Z_T)* of the screen of the coaxial cables and it is the main parameter of the coupling mechanism from/to cable especially for the frequency range after 10MHz. For single braided screens, many authors worked on the calculation of this parameter. The earlier works were done by Kaden [1]. The leakage can be reduced from braided screens. Every cable manufactures should consider the special designing of the braid structure such a way that to obtain the maximum shielding effectiveness with minimum cost. One of the most effective tools is optimization of the braid parameters for the shielding efficiency. The optimization could supply a meaningful degradation at the production cost. Detailed works focused on the braid optimization were done by Homann[2], Tyni[3], Fowler [4] and Madle [5]. Kley [6] tried to remove the differences between the theory and the measurements by a semi-empirical model. He modified the formulations taken from [1] and [3] by meaningful constants via experimental results. The optimization at triaxial cables was investigated by Sali [7]. Since there is a dielectric layer between each shield layer, modeling of this type of the cables based on the triaxial transmission line. If the both braided shield is in contact, there is no detailed optimization work in the literature. Only Fowler [4] mentioned that the braid optimization for double braid was too difficult to assess owing to cross-coupling between individual spindles of each braid. He has also advised an empirical technique to obtain the optimized double braid structure by removing one wire from each single layer spindles. We have experienced this technique but found that it is not valid generally. A comparative measurement performed on a sample double braided cable is given in third part of this paper. At this point, one can ask following questions. When both layers of double braided screen are optimized themselves, the resultant transfer impedance is optimized or not? What is the effect of the intermediate mutual inductance, M_{12}, to the total optimization process? In this paper the applicability of single layer optimization formulations is investigated for the double braid optimization. Also we investigated the effect of the mutual inductance to the optimization process.

II. OPTIMIZATION

Kley has summarized the high frequency optimization in five different factors for single braided cable shields [6]. We assumed that, since the double braided screens in short circuit at both ends of the cable, the only effective optimization parameter is the transfer impedance of the total shielding. The transfer impedance of multilayer homogeneous screens is modeled by Kaden [1] as

$$Z_{T12} = \frac{Z_{T1}\, Z_{T2}}{Z_1 + Z_2 + j\omega M_{12}} \tag{1}$$

where,

Z_{Ti} , Z_i : i. layer transfer impedance and characteristic impedance of line and,

M_{12}, : mutual inductance between braided screen layers and is given at [9] as,

$$M_{12} = \mu_0 \frac{t_{eq}}{\pi D_2} \cos(2[\alpha_2 - \alpha_1]) \tag{2}$$

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where the α_2 and α_1 is the braid angle at second and first layers respectively. If the difference between these angles is equal to $\pi/4$, there will be no magnetic coupling between the layers. The relation of the equivalent distance, t_{eq}, to the braid parameters are given as,

$$t_{eq} \approx \frac{D_2 - D_1}{2} - (d_2 + d_1) \quad (3)$$

Where, D_i is the average diameter of i. braid layer.
Transfer impedances of each braid layer, Z_{T1} and Z_{T2} simulated by Tyni's model [3]

$$Z_T = Z_R + i\omega L_K + (1+i)\omega L_S \quad (5)$$

where Z_R, L_K and L_S, represent *DC*, magnetic coupling and eddy current loss terms respectively. DC component can be neglected at higher frequencies. Also the eddy current loss term is proportional with $\sqrt{\omega}$, therefore can be neglected with relative to magnetic coupling term which is proportional with ω. Magnetic coupling term L_K , includes M_D and L_A as hole and braid inductance parts respectively

$$L_K = M_D + L_A \quad (6)$$

The braid and hole inductances are investigated by The phases of these two terms are 180° shifted from each other [6]. Therefore, the optimization phenomena based on balancing these terms. If the optical coverage is increased, then the braid inductance is increased. Therefore, imaginer component of the transfer impedance will tend to increase in negative direction. If the optical coverage is decreased, than hole inductance will be dominant and the imaginer part of the transfer impedance tend to increase in positive direction. On the other hand, the magnitude of the transfer impedance will be same for the loose and tight braids while only optimized braided shields will be successful for the higher frequency region. These facts are well known for the single braided shielded cables. The main optimization factor for the double braided shields in contact is simplified as,

$$Z_{T12} \approx j\omega\left(\frac{L_{K2}L_{K1}}{M_{12}}\right) \quad (7)$$

If we look more deeply to the high frequency transfer impedance equation (7), we see that the intermediate mutual inductance, M_{12}, changes only the level of each braid layer's inductive terms and not change the total balance of the braid layer from the optimization point of view. Therefore, the balancing of the hole and braid inductance as a optimization factor obtained for each braided shield layers will be kept at same ratio. If one of the braided shield layers is not optimized, in order to obtain the total optimization, it is necessary to destroy the single layer optimization for the other layer in an inverse phase of the first layer. As if, if one layer is loose braided, then the second layer should be tight braided. For the most economical solution, the outer layer can be chosen as loose braided layer since its diameter is more than the inner one. Once the optimized braid parameters obtained it is necessary to check the applicability in the production process. Because the real production parameters related with the wire and spindle numbers are some fixed integers. For example the spindle numbers should be integer multiples of eight such as (8,16, ..). On the other hand, angle of the spindles can be attained to fixed number of values since the mechanical structure of the braid machines includes diameters of different mechanical gears. Therefore, it is not possible to obtain some intermediate values. Also some difficulties arise when one tries to apply the same optimized braid parameters of one company brand named cable to another company brand named cable. Therefore, it is necessary to support theoretical evaluations by measurements. And then with curve fitting techniques the theoretical expressions should be fine tuned. We have applied same strategy on defining the mutual coupling value between braided layers [8],[9],[10],[11]. Also in order to protect ourselves from the tolerances on the braid parameters originated from the different cable manufacturers we have performed the measurements from a single company which also Kley [6] used as if Huber Suhner company cables. Also a Time Domain Reflectometer (TDR) is used in order to detect phase information.

TABLE I

Braid Parameters of RG-142						
Layer	**M**	**N**	**D**	**d**	**α**	**ε_r**
1	16	7	0.00295	0.00012	27.88	2.111
2	16	7	0.00360	0.00012	37	2.111

III. MEASUREMENT

The transfer impedance of the samples is measured at IEC triaxial test setup. The shielding braid of the cable outer plastic layer peeled and braid parameters were obtained. Diameter and spiral step length was measured by precise calipers. The outer diameter of the second layer region between the outer diameter of the first layer and the second layer, refers to the thickness. This mid-point of the thickness, calculating the average diameter is referred to as mesh screens. Kley [6] has attained this value as,

$$D_m = D_0 + 2.5\,d \quad (8)$$

Wire diameter, d, has been multiplied with 2, and 2.25 at Kaden's works [1]. In our measurements we have found this value between 2.2 and 2.7. Since it is important at transfer impedance calculations we did not fixed this value and calculate it for each layer separately. And then we have obtained the braid angle for each layer by applying below equation.

$$\alpha = \arctan(\pi D_m / s) \quad (9)$$

where s is the one spiral step length. We have tried to get these values from the company but because they have evaluated as company confidential information we could not verify them. So we have used the measured braid values for our

calculations. As mentioned before there are five primary independent braid parameters. Unfortunately for the manufactured cable we can change only the number of the wires in each spindles. So the optimization is limited only with this parameter. Thanks to its value in optimization process that when the number of the wires is decreased the phase of the total inductive term is tending to increase in positive side because of the increasing of the hole inductance. For simulations the other four parameters are fixed and the number of the wires is changed for a feasible range and for each frequency the transfer impedance is calculated. And then the related wire number for the minimum transfer impedance value for each frequency is recorded. And then the same calculations are repeated for the real double braid structure under measurement by adding the intermediate inductive terms and compared at Fig.1 for RG142. The optimized wire numbers are not same for each frequency. But in can say that after 10 MHz the optimized values are fixed. From Fig.1 it can be taken as 5.35 averagely. The nearest integer is 5 as the optimum wire number. For a coaxial double braided cable namely RG 142, the simulation is done in order to see the effect of the intermediate mutual inductance, M_{12}, at double braid optimization process. The braid layer parameters of RG142 are given at Table. I. Since the outer braid layer parameters are optimized, it is shown that in calculations, the optimized inner braid wire number is not changed with the effect of the intermediate mutual inductance, M_{12}, at double braid optimization process. Wire numbers of inner braid layer is decreased from each carrier one by one. The results shown at Fig.2. It is shown that for n1=5 the optimized single braid layer and the total optimized transfer impedance is obtained. This results is contrary to the idea of removing one wire more from each single optimized braid layer carriers [4]. Measured results show that the intermediate mutual inductance does not play a role for total braid optimization of double or multilayered screens. The measurements proved that with optimized wire number the transfer impedance is decreased nearly 10-15dB at high frequency region. The variation comes from the noise level of the measuring system. Since the coupling length of the measured cable is low as 13cm in order to shorten the time of removing the wires from each carrier practically, the measured coupled signal level is very low as –120dBm. The obtained results are 32 times averaged and %3 smoothing is applied in order to remove the high variations from noise level.

IV. Conclusion

In this paper, the optimization of the screening effectiveness of double braided coaxial screens are investigated from the point of view both theory and measurement. The effect of this mutual inductance to the optimization of double braided screens is investigated and it is shown that the mutual inductance term is not effective on the optimization process, contrary to the early investigations [4]. A sample optimization has been obtained practically, on one of the standard double braided RF coaxial cable namely, RG-142.

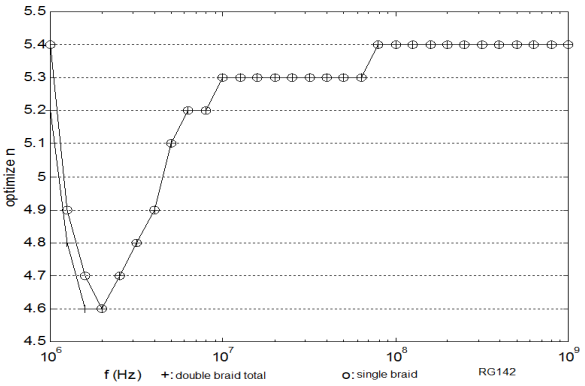


Fig.1. Optimized wire numbers for each frequency.

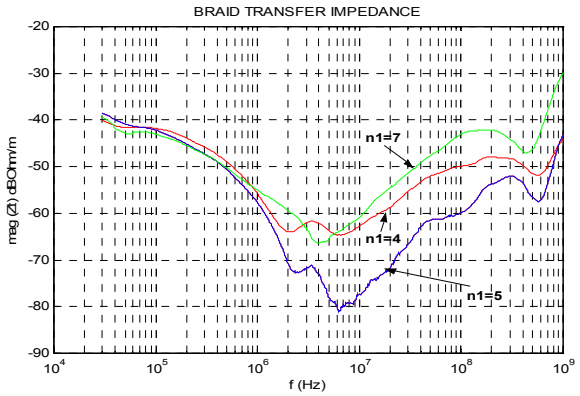


Fig. 2. Total transfer impedance with first layer wire number changing for optimization.

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