

Influence of parameters variation on a shielded line submitted at a punctual injection current at any position along its length

Kaoutar Senhaji Rhazi¹, Mohamed Najmouddine²

¹ ENSEM's Lab of electrical engineering Km 8, road El Jadida B.P 8118 Oasis Casablanca, Morocco,

² ENSEM's Lab of electrical engineering Km 8, road El Jadida B.P 8118 Oasis Casablanca, Morocco,

Abstract

Firstly, I note that this draft article is an article continuation already published in your journal in September 2012; n°IJCSI-2012-9-5-3873. This is the reason why you will find repeated diagrams and explanations in order to introduce new work. In reference to articles previously published, one in your journal and two others articles already published in the Annals of telecommunications journal, which we will quote a summary in the following paragraph again, this paper provides a study of the factors influence on a shielded line submitted at a punctual injection current at any position along its length. In the previous article, published in your journal, we have studied the influence of four of them. This study helps to study the influence of four other parameters. Using simulated line for geometric dimensions respecting the line theory assumptions, we try to analyze the sensitivity to changes in various parameters.

Keywords: *transmission line, electromagnetic disturbance, modeling, punctual injection current, parametric sensitivity.*

Summary

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1. Introduction

The design of low-level circuits involved in control systems in the large industrial sites has been for many years, discussions subject of the choice of cable types to use and especially the mode of grounding their shields. Indeed, the cables that connect low electronic components are particularly sensitive to various sources of electromagnetic interference. For more clarification on the this article's finality, we can refer to articles previously published, by the same team in your journal entitled "study of parametric sensitivity of the general model of transmission line" in September 2012; number IJCSI-2012-9-5-3873; and in the annals of telecommunications, respectively entitled "Approached expressions at the low and high frequencies of the induced tensions of common-mode at the end of a shielded line submitted to a punctual injection of current" in March 2005 (n ° 3/4) and "Determination of the disturbance at the ends of a shielded line subject to a punctual excitation current", in November 2002 (n°11/12). Transfer impedance is the quantity which allows the quantitative assessment of the quality of shielding a cable. We also know that the modeling project of a shielded line subject to current disruption in any position of its length, involves several factors. Some of these factors have a major influence on the assessment of parasitic tensions, others are probably less important, so it is necessary to determine the effect on the result for each of them, to conduct a study on parametric sensitivity.

The digital model validated by the previous experiences will allow us to make this study and assess the influence obtained by the variation of each parameter characterizing a line with two strictly coaxial conductors above a perfectly conducting plane of ground. We are still interested in the case of a screen characterized by a poor electromagnetic protection that may form for example a metallic ribbon helically wrapped. This time, we will explore additional parameters in addition to those discussed in the previous article published in your journal.

1.1. Summary of previously published articles

Two articles mentioned above were published in the “telecommunications’ annals” journal. For the article published in November 2002 (n°11/12), we were able to determine the perturbation induced at the ends of each coaxial line on a wide band of frequencies. The source of disruption is a punctual direct current injection on the shielding of the cable in any position. For that, we applied the theory of state variables, on the base of approximation quasi-TEM, to model the coaxial line over a plan of ground with a finite conductivity. This allowed us to provide expressions of tensions and currents at the two ends of the line under their analytic forms for any load conditions. Then, an experimental verification was made to validate the developed code of calculation. Concerning the article published in March 2005 (n°3/4), we were able to determine approached expressions at the low and high frequencies of the induced tensions of common-mode at the end of a shielded line submitted to a punctual current injection, for the case of a helical ribbon. This article also discusses the correction function, the relationship between the exact value and the approximated one of the disturbance and the limit of validity to the high frequencies approached expressions established at low frequencies. For the Article published in your journal in September 2012 (n°IJCSI-2012-9-5-3873°), the transfer impedance is the size that allows quantitative assessment of the quality of a shielded cable. The numerical model validated by various previous studies to perform this study and evaluate the influence obtained by the variation of each parameter characterizing a line with two coaxial conductors strictly above a perfectly conducting ground plane. In this paper (published in September 2012), we studied the influence on the module Z_{ig} (transfer impedance overall), for four parameters:

- The length ℓ_2 of the line portion, located between the point of injection and the left end of the line
- The total coaxial line length \mathcal{L} of the coaxial line
- The Transfer resistance R_T of outside driver of the coaxial line
- The Transfer inductor L_T from outside driver of the coaxial line

In this paper, we will study the influence of other parameters, namely:

- The inner radius “a” of the shield of the coaxial line
- The height h_R of the coaxial line
- Resistance Z_R the inner conductor of the coaxial line
- Relative permittivity ϵ_{r1} of the dielectric within the coaxial line

- Relative permittivity ϵ_{r3} of the dielectric outside the coaxial line

1.2. Geometrical characteristics and configurations of excitation of the model of line of transmission

Always in reference to the articles previously published, the type of shielded transmission line that we consider as the basic circuit includes two coaxial conductors (length \mathcal{L}) above a perfectly conducting plane of ground. This condition on the conductivity of the plane of ground is usually required to not further complicate propagation conditions that can occur at high frequencies. The transverse dimensions and the position of the disturbance are represented on figure 1.

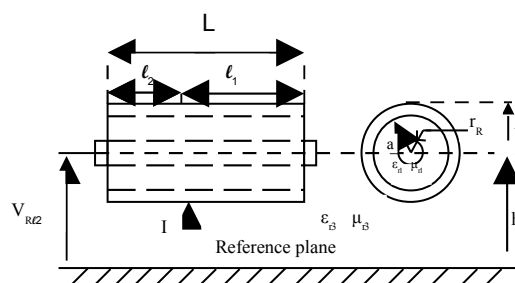


Fig. 1 Geometric configuration of the transmission line studied

Always remember that:

ϵ_{r1} and μ_{r1} are respectively the permittivity and permeability of the inner dielectric environment, and ϵ_{r3} and μ_{r3} are the corresponding values of the outer dielectric. We consider that μ_{r1} and μ_{r3} are those of the vacuum and the dielectric environment outside the cable is the open air. V_{R2} is the induced voltage of common mode on the internal conductor to the left end of the line, and I is the total disruptive current. \mathcal{L} is the total length of the line, h_R is the height at which the line is from the ground; a and b are respectively the inside and outside rays of the external conductor and r_R is the radius of the inner conductor. ℓ_1 and ℓ_2 are the portions of the line between which the disruptive power is.

The values of the parameters presented in the table below (already given in the previous article, March 2005) are chosen arbitrarily but comply with the basic theory of transmission lines assumptions.

Table 1: reference values

Reference values used for lineic parametric calculation	
Values for which we study the sensitivity	Values kept constant
$L = 100 \text{ m}$ $\ell_2 = 5 \text{ m}$ $a = 4 \text{ mm}$ $b-a = e = 0.2 \text{ mm}$ $h_R = 50 \text{ mm}$ $Z_R = 0.01 \Omega/\text{m}$ $\epsilon_{ii} = 2$ $\epsilon_B = 1$	$r_R = 0.7 \text{ mm}$ $\mu_{ii} = 1$ $\mu_B = 1$

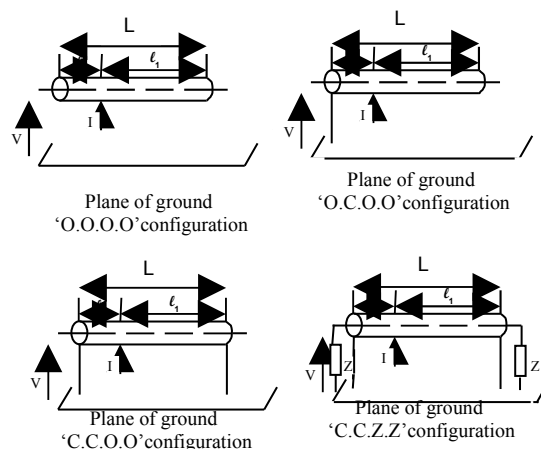


Fig. 2 Configurations of excitation considered in the simulations

In this study, they represent the reference’s values that correspond to a reference’s curve related to a definite load configuration.

To simplify this study, we made the assumption that the resistance of the conductor is a constant. We are interested in the case of a shielding that strongly promotes the penetration of the electromagnetic field (helical ribbon).

As in the previously published article (March 2005), simulations concern the variations according to the frequency of the Z_{ig} module, that is to say the ratio of the induced voltage of common mode on the inner conductor in the left end of the line to total disruptive current. The left end of the line is supposed to be the end where the disturbance-sensitive instrumentation is.

Three configurations of excitation characterized by conditions at the ends often encountered in practice, will allow us to simulate a transmission line shielded connecting an equipment to another. Loads at the ends of the internal conductor simulate input and output impedance of the equipment. Additional configuration for which shielding is open at both line’s ends, is used for comparison and may represent the case of involuntary defect in connections between ground and shielding. Excitation configurations are represented in figure 2 below.

To highlight the effect produced by each parameter on the result of Z_{ig} , we propose to vary successively each parameter while keeping, the others equal to their reference’s values. The results reproduced on all of the plates are calculated between 1 kHz and 10 MHz by setting two additional values around the reference value to each parameter. For more convenience in the analysis of the results, we assembled the effect of a parameter for the four configurations on the same plate. In addition, for a good precision, we increased the number of points calculated by decade of frequency to 150 points, which is not without consequences on the calculation time of each simulation. Furthermore, we retained the four-letter code to designate each configuration. These four letters represent the successive order of load impedances at both line’s ends starting with the shielding and from right to left. The letter 'O' corresponds to an open circuit, 'C' to a short circuit and 'Z' to the characteristic impedance of the line formed by two coaxial conductors.

1.3 Case of a row with a cable whose shielding is likened to a helical ribbon above a plane of ground

Always in reference to previously published articles and in order to quantitatively represent the phenomenon of diffusion through the screen of a cable, we consider a poor quality screen made by a helical ribbon and whose transfer impedance Z_T is characterized by the following approximated expression:

$$Z_T = R_T + j\omega L_T \quad (1)$$

Like the reference value, the resistance value in continuous current R_T is chosen equal to $10\text{m}\Omega/\text{m}$ and the inductor L_T is taken equal to $16\text{nH}/\text{m}$. Such values are arbitrary and should not be interpreted as obtained from the geometric dimensions from the line; in other words, they are independent from the diameter and the thickness of the screen.

1.3.1. Parametric sensitivity

Figures 3 to 7 give below, provide the calculated values of Z_{tg} module by successively varying each parameter for the four load configurations.

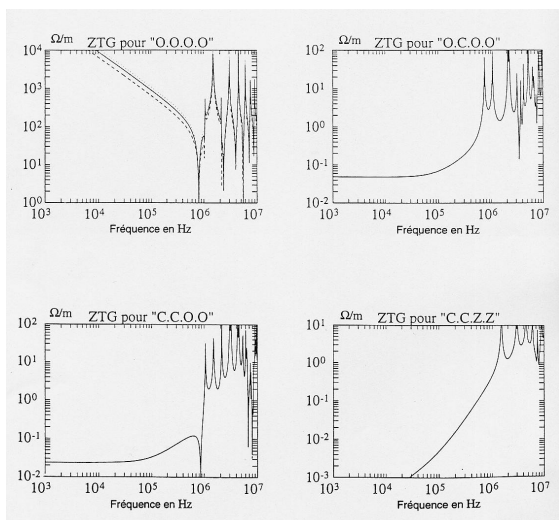


Fig. 3 Influence, on the Z_{tg} modulus, of the radius a of the coaxial line shield (____ : $a=4$ mm), (---- : $a=10$ mm) et (..... $a=2$ mm)

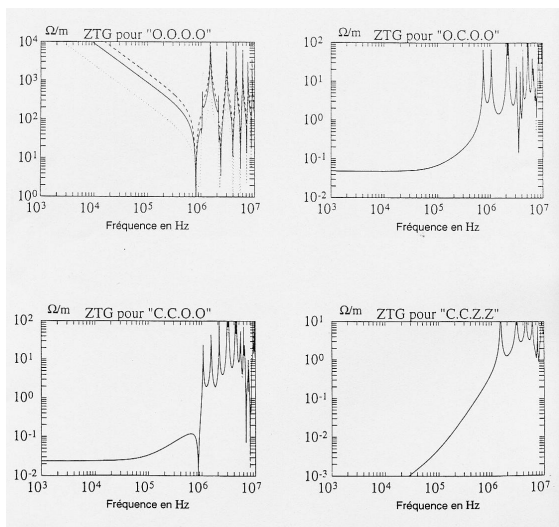


Fig. 4 Influence, on the Z_{tg} modulus of the coaxial line height h_R (____ : $h_R=5\text{cm}$), (---- : $h_R=50$ cm) et (..... $h_R=0,5$ cm)

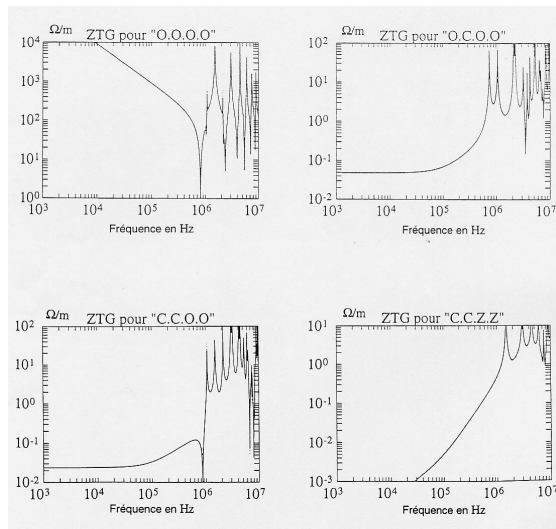


Fig. 5 Influence, on the Z_{tg} modulus, of Z_R resistance of the coaxial line inner conductor (____ : $Z_R=10\text{m}\Omega/\text{m}$), (---- : $Z_R=100\text{m}\Omega/\text{m}$) et (..... : $Z_R=1\text{m}\Omega/\text{m}$)

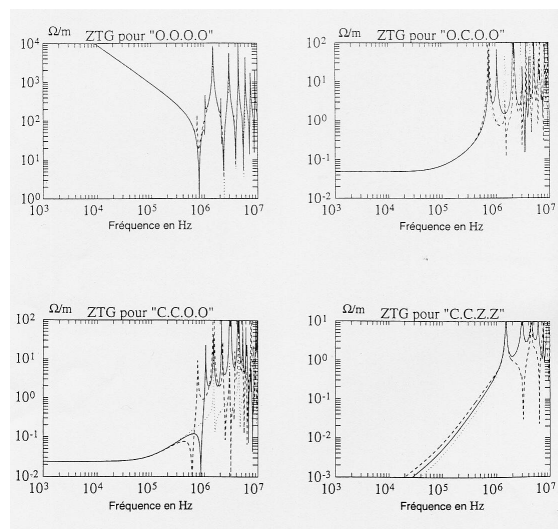


Fig. 6 Influence, on the Z_{tg} modulus, of the dielectric relative permittivity ϵ_{r1} inside the coaxial line (____ : $\epsilon_{r1}=2$), (---- : $\epsilon_{r1}=4$) et (..... : $\epsilon_{r1}=1$)

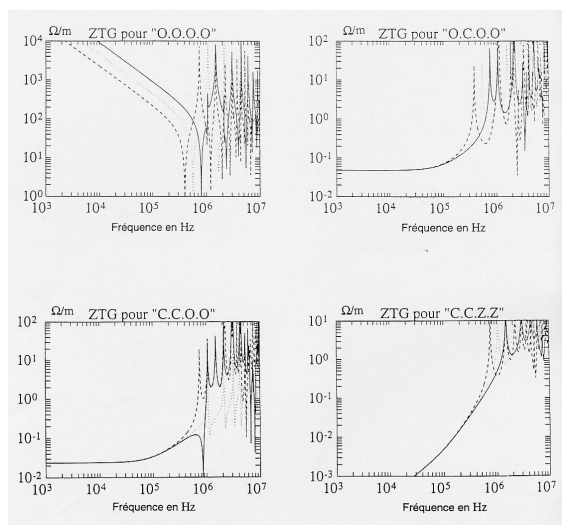


Fig. 7 Influence, on the Z_{tg} modulus, of the dielectric relative permittivity ϵ_{r3} outside the coaxial line
 (____ : $\epsilon_{r3}=1$), (---- : $\epsilon_{r3}=4$) et (... : $\epsilon_{r3}=2$)

1.2.2. Discussion

The results presented in Figure 3 (variation of the space between the inner conductor and the shield) show that in this case where the transfer impedance is defined as an independent function of this space, this parameter only affects the configuration in which the shield is open circuited at both ends. It is obvious that for this configuration where the coupling is essentially capacitive type, the Z_{tg} module is determined by the line admittance formed by the shield and the ground plane and therefore increases when the admittance decreases. The same is true for the line height variation (Fig. 4), but especially when at least one end of the shield is grounded the height parameter does not affect the result.

On the other hand, respecting the realistic values for the resistance of the inner conductor, Figure 5 shows that this resistance has no significant effect on the calculation results because of its negligible value compared to the terminal impedances of common mode considered in this study. However, it gives rise to an attenuation constant that can absorb some resonance peaks at higher frequencies must take place where the skin effect which obviously neglected in this study.

The relative permittivity influence of the inside dielectric medium ϵ_{r1} cable on the simulation results obtained for the four configurations shown clearly in Figure 6.

We note that on low frequencies, the interference voltages amplitudes are independent of the value assigned to this parameter except for the configuration "CCZZ" where impedance characteristic of the line $Z = Z_{CR}$ itself is theoretically defined as a function of the constant, that is to say, the load impedances are different for different values of ϵ_{r1} .

Indeed, one of the features of particular interest of the transmission lines at high frequencies is the characteristic impedance. A coaxial line for using an insulating material which the relative permittivity is ϵ_{r1} and the permeability is that of the vacuum, this expression reduces to the expression:

$$Z_{CR} = \sqrt{\frac{L_R}{C_R}} = L_R \frac{v_0}{\sqrt{\epsilon_{r1}}}$$

(2)
 Where L_R , C_R and v_0 are respectively the inductance per unit length, capacitance per unit length and the speed of light.

The same remarks apply to the curves of Figure 7 for the medium dielectric permittivity that surrounds the line.

We also note that ϵ_{r3} does not affect the low frequencies in the configuration "CCZZ" since in this case ϵ_{r1} being constant, the Z_{CR} is being too.

These results highlight the relative permittivity effect of dielectric media on the evolution versus frequency of Z_{tg} calculated modules.

Thus, the propagation modes can be considered as quasi-TEM and dielectric media can be assimilated in the open air at low frequencies. By cons, for high frequencies, from solving coupling problems, signal waveforms are very attached to velocities and therefore the values assigned to the dielectric media relative permittivity.

These results confirm the interest of using structures better electromagnetic immunity shielded to protect lines against low external disturbances.

These results show once again that when the cable shield is in the air at both ends, its ability to reduce disturbance is almost zero and we find almost the same common mode voltage in the total absence of shielding.

2. Conclusion

The numerical model validity allowed for a study of parametric sensitivity. In this study, we presented and discussed the numerical simulations obtained results. It was made clear that the weak coupling assumption is still effective. It has also emphasized the need to properly ground the two ends of the cable shielding, in particular the right equipment sensitive to disturbance.

It is also clear from this study that, apart from cases where the shield is in the air at both ends and the position of the resonance peaks, only the transfer impedance, line length and frequency decisive.

Was determined separately influence on the level of interference voltages, some parameters involved in the modeling of a shielded line above a perfectly conducting ground plane.

Among the main parameters, the transfer impedance is of particular interest since we see her appear essential that clearly explains the function screen shielded transmission lines.

3. Bibliography

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4. Biography

I am Mrs. Senhaji Rhazi Kaoutar, an assistant professor at the superior school of technology (EST) in Casablanca, Morocco. I wish to inform you that I'm preparing my habilitation (in the field of electromagnetic compatibility). I completed the national thesis in July 2006. I got the research

preparation certificate (CPR) in telecommunications from EMI (Mohammadia School of Engineers Rabat Morocco December 97). I am an engineer of the State owned (EMI) in Rabat, Morocco (in 1991). I have already published two articles in the annals of telecommunications' journal respectively entitled: "Determination of the disturbance at the ends of a shielded line submitted to a punctual current excitation" in the November-December 2002 number and "expressions approached at the low and high frequencies of the voltage induced in the common-mode at a shielded line's ends submitted to a punctual injection of current" in the March / April 2005 number. M. Najmouddine is my supervising professor in the superior normal school of electricity and mechanics (ENSEM Casa Morocco)