Study of parametric sensitivity of the general model of transmission line

Kaoutar Senhaji Rhazi[1], Mohamed Najmouddine[2]

[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

In reference to two articles previously published in the annals of telecommunications journal from; which we will quote a summary in the following paragraph, this paper provides a study of the parametric sensitivity of the transmission line's general model. Indeed, we 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 have lesser importance. So, it is necessary to identify the effect produced on the result by each of them to perform a parametric study. This latter helps clarify some of the instructions on the previous articles about the differences that occur between calculations and measurements at high frequencies.

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

Summary

1. Introduction

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. For more clarification on the this article's finality, we can refer to articles previously published, by the same team, 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). 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 interested in the case of a screen characterized by a poor electromagnetic protection that may form for example a metallic ribbon helically wrapped.

1.1. Summary of two previously published articles

The 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.

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 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.

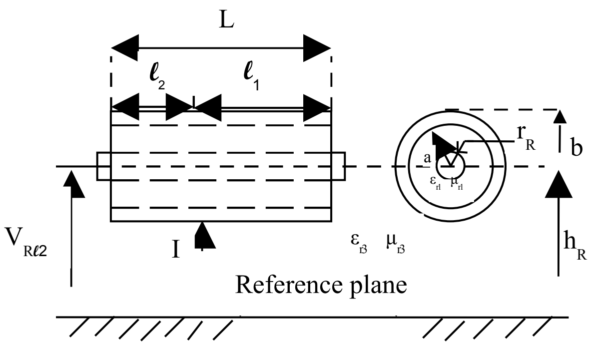

Fig. 1 Geometric configuration of the transmission line studied

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. $V_{R\ell 2}$ 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. 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 m ℓ_2 = 5 m a = 4 mm b-a = e= 0.2 mm h_R =50 mm Z_R = 0.01 Ω/m ε_{r1} = 2 ε_{r3} = 1	r_R = 0.7 mm μ_{r1} = 1 μ_{r3} = 1

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_{tg} 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.

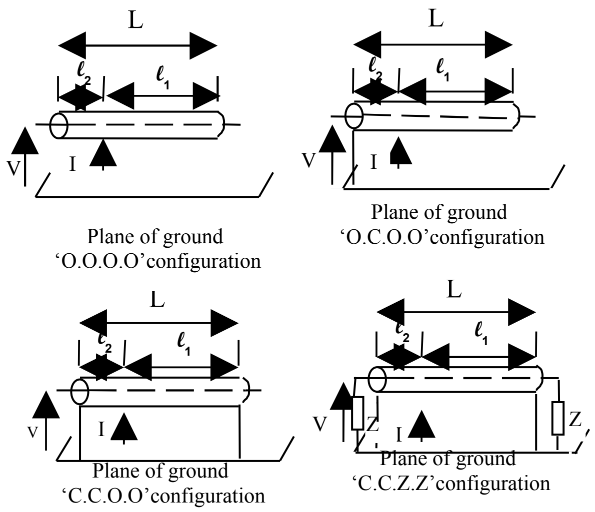

Fig. 2 Configurations of excitation considered in the simulations

To highlight the effect produced by each parameter on the result of Z_{tg}, 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:

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

Like the reference value, the resistance value in continuous current R_T is chosen equal to 10 mΩ/m and the inductor L_T is taken equal to 16nH/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 6 give below, provide the calculated values of Z_{tg} module by successively varying each parameter for the four load configurations.

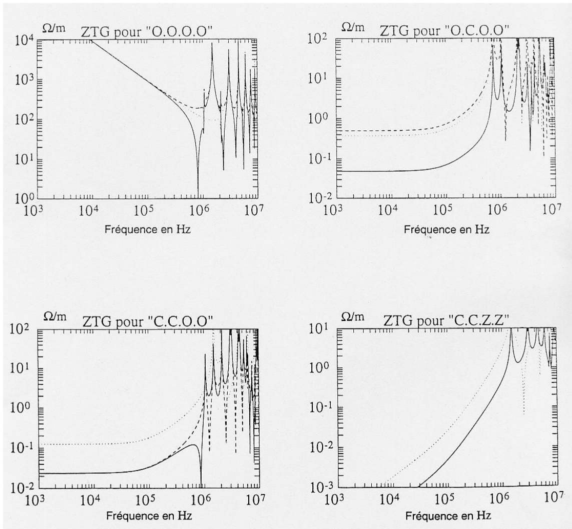

Fig. 3 Influence, on the Z_{tg} modulus, of the length ℓ_2 of the line portion, located between the point of injection and the left end of the line (___:ℓ_2= 5 m), (---:ℓ_2= 95 m) and (...: ℓ_2= 50 m)

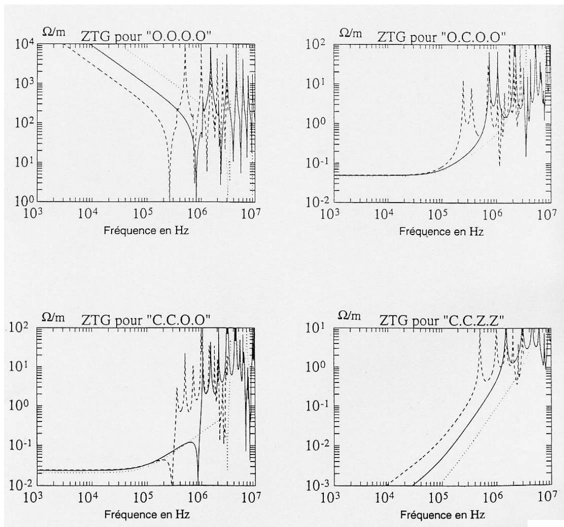

Fig. 4 Influence, on the Z_{tg} modulus, of total coa line length "L"(___: L= 100 m), (--:L = 300 m) and (...: L = 30 m)

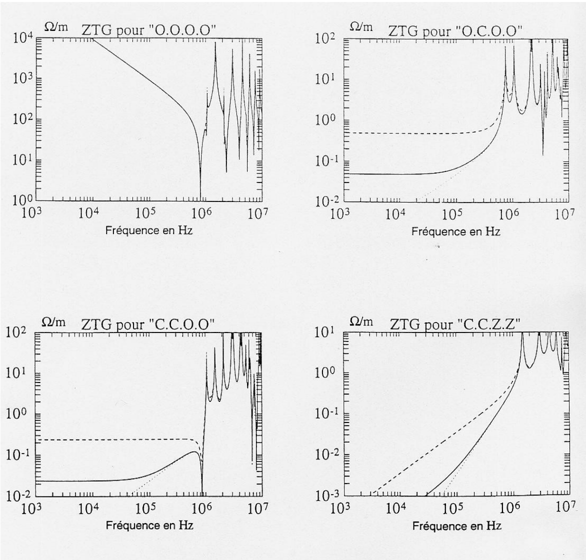

Fig. 5 Influence, on the Z_{tg} modulus, of transfer resistance R_T of outside driver of the coaxial line (___: R_T = 10 mΩ/m), (---: R_T= 100 mΩ/m) and (... : R_T= 1 mΩ/m)

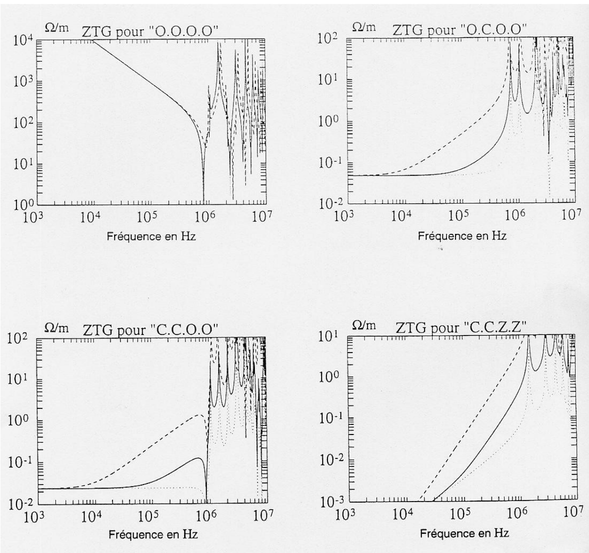

Fig. 6 Influence, on the Z_{tg} modulus, of the transfer inductor L_T from outside driver of the coaxial line (___: L_T = 16 nH/m), (-----: L_T= 160 nH/m) and (....: L_T= 1, 6nH/m)

1.3.2 Discussion

Figure 3 illustrates the evolution of Z_{tg} based on the position of the disruptive current injection.
As we can notice, the results are the same at both line's ends when the end's conditions are the same.

The calculations also indicate that the position of the point impact of the disruptive current implies a modification in the fluctuations that accompany the propagation phenomenon.

At high frequencies, the examination of the curves for the three positions of the injection shows significant fluctuations according to frequency. This effect is produced in a large part by the reflections of waves resulting from setting two portions of line end to end and therefore complicates the propagation. For configuration where the line is charged on its characteristic impedance, signals always stay the same at both line's ends regardless of frequency.

Examination of figure 4 clearly shows the (classical) phenomenon associated to a variation in length of the portion of line located between the point of injection and the opposite end from the calculation point. We note that resonances occurring at high frequencies, appear when the wavelength of the disruptive signal becomes comparable to the line's length without changing propagated waves' form. In addition, outside the "O.O.O.O" case, the obtained characteristics are overall similar to the characteristic of transfer impedance.

To highlight the importance of transfer impedance, the parametric sensitivity relative to transfer resistance R_T and the transfer inductor L_T are represented on figures 5 and 6 respectively. As expected, Z_{tg} module variation law is strongly influenced by the values L_T and R_T can take. We immediately notice, on simulations corresponding to the variation of R_T, that the amplitudes of disruptive tensions are so attenuated at lower frequencies that the shielding presents a better electrical conductivity.

Therefore, it is necessary to take into account the resistance of the shielding in theoretical modeling. Thus, the typical curves of the diffusion phenomenon through the shielding show that Z_{tg}'s evolution is characterized by an even more pronounced increase than the L_T, which is big with a high frequency, as shown on figure 6. In other words, the level of parasites increases rapidly with frequency when shielding promotes the penetration of external disturbances.

These results confirm the interest of using shielded structures for better electromagnetic immunity to protect low level lines against external disturbances.
These results show once again, that when the shielding of the cable is in the open air at its both ends, its ability to reduce disturbance is almost zero and we find practically the same voltage of

common mode than in the total absence of shielding.

2. Conclusion

We have separately determined the influence on the level of disruptive tensions, of some parameters which intervene in the modeling of a shielded line above a plane of perfectly conductor ground.

Among the main parameters, transfer impedance presents a particular interest, since we see its essential role which clearly explains the function of screen in shielded transmission lines.

In addition, this study made in the case of an infinite conductivity ground confirms the necessity of correctly putting the shielding in the ground at the ends. It also shows that parasites can be reduced by using suitable lines.

Furthermore, this study clearly establishes that the assumption of the weak combination is always acceptable.

For the complex transmission line model considered in this study, we have shown that it is possible to obtain with very remarkable accuracy the level of disruptive tensions of common-mode, in the field of low frequencies, using very simple relations that are directly dependent on the value of transfer impedance's parameter.

3. Bibliography

[1] K. Senhaji Rhazi , M.Najmouddine, J. Hoeffelmann, , A. Lamine , "Approximate expressions at low and high frequencies of induced voltages of common mode at the ends of an armored submissive line at a punctual injection of current". Ann. Telecommun.60, n ° 3-4, pp454-471, March April 2005

[2] M.Najmouddine, K. Senhaji Rhazi J. Hoeffelmann, "Determination of disturbances induced at the ends of a line reinforced subjected to point excitation current ", Ann. Telecommun. , 57, n ° 11-12, pp.1091 - 1123, November-December 2002"

[3] SHELKUNOFFE.F (SA) "The electromagnetic theory of coaxial transmission lines and cylindrical shields," Bell System Tech. Day., Pp. 533-579, October 1934.

[4] BLECH (P.), DIJAMATOVIC (Y) and Ianoz (Mr.) "Measurement of the impedance transfer in pulsed mode," Tech. MES, Bulletin ASE / UCS 78, no.. 9, pp. 488-492, May 1987.

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 owened (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)