

HIGH EMC - COMPLIANCE LVDS BUS

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Abstract: The article deals with the results which were obtained during the process of designing the LVDS (low voltage differential signal) bus. This bus is very resistant to interference from the environment and to spurious emissions of electromagnetic waves. According to the concrete requirements we prepared a design of the LVDS by means of numerical methods. The design was realized and its parameters verified experimentally. The basic parameter of bus is its impedance $Z = 100 \Omega$, up to frequency $f_1 = 100 \text{ MHz}$ of the first harmonic of rectangular signal

Key words: LVDS bus, EMC, finite element method, ANSYS

INTRODUCTION

The LVDS bus is used in many applications, especially in those requiring fast and reliable data transmission. The advantages of this bus are commonly known. In special cases, we need to use the LVDS transmission technology with great immunity to electromagnetic interference (EMI). The main problem of the design of this type of bus is how to find the optimal impedance matching with respect to production technology. Fig.1 shows the obvious LVDS bus configuration which interconnects a set of functional blocks, for example plug-in cards.

The high electromagnetic susceptibility (EMS) of the LVDS bus is required by relevant rules, valid for the system application in nuclear power plants. With respect to electromagnetic compatibility (EMS) regulations the specific design of the high-EMS LVDS bus was implemented with the help of numerical analysis, as shown in Fig.2. The total length of the bus is $l = 265 \text{ mm}$. The design exploits a multi-layer configuration, including the ground layer ensuring the shielding.

The bus design exploits the multi-layer PCB technology. Due to the used multi-layer technology, some restrictions have to be considered, for example the thickness of microstrip lines or dielectric layers. Fig.2 shows basic dimensions of the bus design - the microstrip line spacing (A , B , X), the layer spacing (H_1 , H_2), the thickness of the microstrip and the ground layer (T), the width of the microstrip line (W) and the width of the

reference microstrip line (W_s). The thickness of the microstrip and the ground layer is $H = 35 \mu\text{m}$.

The electrode S in Fig.2 is the reference electrode placed on both sides of the PCB. The symbols $+$ and $-$ stand for the pair of the differential transmission line. The basic scheme of the setup of the LVDS system is in Fig.3. The setup includes duplex data transmission. The right part of Fig.3 shows the interconnection of the transmitter-receiver pairs via the bus. Each pair of the microstrip lines is terminated with the impedance $Z = 100 + j0 \Omega$. Fig.4 shows the example of the signal spectrum of the transmitter produced by TES.

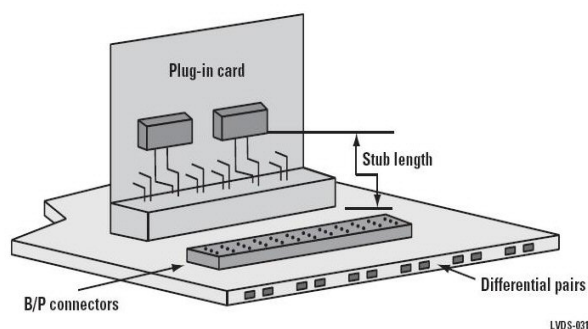


Fig.1. An example of the classical LVDS bus configuration.

Measurement of the LVDS transmitter was performed. The model of the transmitter was made on the basis of obtained results. The amplitudes of all the

following significant spectrum frequencies $f_1 = 100$ MHz, $f_2 = 130$ MHz, $f_3 = 270$ MHz, $f_4 = 500$ MHz, $f_5 = 680$ MHz are $U_1 = 1,300$ V, $U_2 = 0,310$ V, $U_3 = 0,031$ V, $U_4 = 0,002$ V, $U_5 = 0,001$ V. The finite element method

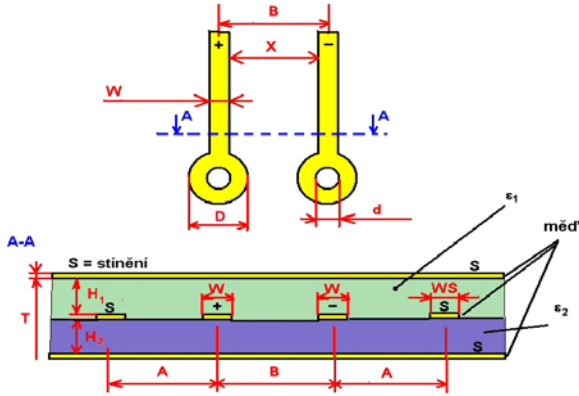


Fig.2. Details of the designed LVDS bus.

(FEM) model of the LVDS bus was supplied by the transmitter model. The input impedance of the differential pair of transmission lines was calculated with the help of the superposition principle. The bus differential pair was terminated with the pre-defined

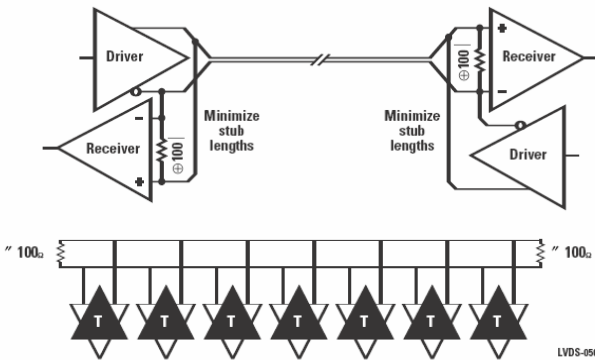


Fig.3. The interconnection of the LVDS transmitter-receiver system.

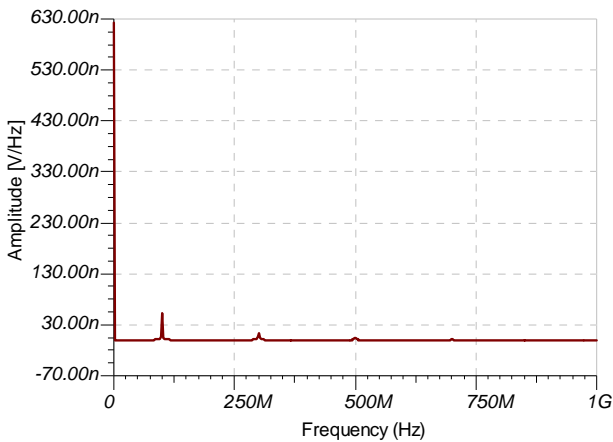


Fig.4. Amplitude spectrum of the TES LVDS transmitter.

impedance. However, it's rather problematic to talk about the impedance in the case of non-harmonic signal. The optimal design with constrained conditions was solved with target function with penalties

$$\Phi_{V,G,X}^o = f_W^o + f_G^o + f_X^o \left[1 + \sum_{i=1}^{N_d} P_X^o(\chi_i) + \sum_{j=1}^{N_s} P_G^o(G_j) \right], \quad (1)$$

$$o=1, \dots, N_o$$

where f_W, f_G, f_X are the Kreisselmeier-Steinhauser object, state and shape approximation functions respectively

$$f_W = \frac{1}{\zeta} \ln \left(\sum_{j=1}^7 e^{\langle \zeta_j V_j \rangle} \right) \forall \zeta, \zeta_j \in \langle 1, 20 \rangle, \quad (2)$$

$$f_G = \frac{1}{\eta} \ln \left(\sum_{\ell=1}^{N_s} e^{\langle \eta_\ell G_\ell \rangle} \right) \forall \eta, \eta_\ell \in \langle 1, 20 \rangle, \quad (3)$$

$$f_X = \frac{1}{\xi} \ln \left(\sum_{k=1}^{N_d} e^{\langle \xi_k X_k \rangle} \right) \forall \xi, \xi_k \in \langle 1, 20 \rangle, \quad (4)$$

where V, G, X are the object function, the state approximated function, the design approximated function respectively. This normed approximation function has very good properties and may be used in a high frequency FEM model and for global optimization. The design process has fast convergence to optimal solution. This method converges faster than the standard gradient optimization method.

1 MATHEMATICAL MODEL OF THE LVDS BUS

It is possible to carry out an analysis of an MG model as a numerical solution with the help of the finite element method (FEM). The electromagnetic part of the model is based on the solution of full Maxwell's equations.

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}, \nabla \times \mathbf{H} = \sigma \mathbf{E} + \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}, \nabla \cdot \mathbf{D} = \rho, \nabla \cdot \mathbf{B} = 0, \text{ in } \Omega, \quad (5)$$

where \mathbf{E} and \mathbf{H} are the electrical field intensity vector and the magnetic field intensity vector, \mathbf{D} and \mathbf{B} are the electrical field density vector and the magnetic flux density vector, \mathbf{J}_s is the current density vector of the sources, ρ is the density of free electrical charge and γ is the conductivity of material, Ω is the definition area of the model. The relationships between the electric and the magnetic field intensities and densities are given by material relationships

$$\mathbf{D} = \varepsilon \mathbf{E}, \quad \mathbf{B} = \mu \mathbf{H}. \quad (6)$$

The permittivity ε , the permeability μ and the conductivity γ in HFM are generally tensors with main axes in the direction of the Cartesian coordinates x, y, z . When all the field vectors perform rotation with the same angular frequency ω , it is possible to rewrite the first Maxwell equations as

$$\nabla \times \underline{E} = -j\omega\mu\underline{H}, \nabla \times \underline{H} = (\sigma + j\omega\varepsilon)\underline{E} + \underline{J}_s, \text{ in } \Omega, \quad (7)$$

where \underline{E} , \underline{H} , \underline{J}_s are field complex vectors. Taking into account the boundary conditions given in (1) and after rearranging (7) we get

$$(j\omega)^2 \varepsilon \underline{E} + \sigma \underline{E} + \nabla \times \mu^{-1} \nabla \times \underline{E} = -j\omega \underline{J}_s. \quad (8)$$

We apply Galerkin's method with vector approximation functions \underline{W}_i . We use the vector form of the Green theorem on the double rotation element [3]. After discretisation we get the expression

$$-k_0 [M] \{E\} + jk_0 [C] \{E\} + [K] \{E\} = \{F\}, \quad (9)$$

where $\{E\}$ is the column matrix of the electric intensity complex vectors. The matrixes $[K]$, $[C]$ and $[M]$ are in the form that is given in manual [1] and vector $\{F\}$ is evaluated from expression

$$\{F\} = -jk_0 Z_0 \int_{\Omega} [\underline{W}_i] \{J_s\} d\Omega + jk_0 Z_0 \int_{\Gamma_0 + \Gamma_1} [\underline{W}_i] \{n \times H\} d\Gamma. \quad (10)$$

The vector approximation functions \underline{W} are given in manual [1], k_0 is wave number for vacuum, Z_0 is the impedance of the free space. The set of equations (9) is independent of time and it gives \underline{E} . For transient vector \underline{E} we can write

$$\underline{E} = \text{Re} \left\{ \underline{E} e^{j\omega t} \right\}. \quad (11)$$

The input impedance of the microstrip line was evaluated with the help of the IMPD program. Mutual impedances and impedances of wires referring to the common reference potential were investigated as shown in Fig.5. In accordance with traces marked as E and H in Fig.6, the distribution of the electric and the magnetic field intensities were analyzed. Next, the module of corresponding impedance was calculated (8).

$$U = \int_{E_i} \underline{E} \cdot d\ell, I = \int_{H_i} \underline{H} \cdot d\ell, Z = \frac{U}{I}. \quad (12)$$

For an optimal bus design, the relation (13) should be kept.

$$Z_1 = Z_2 = Z_3 = Z_4 = Z. \quad (13)$$

A geometric model utilizing the HF 120 element was built according to the mathematical model [1].

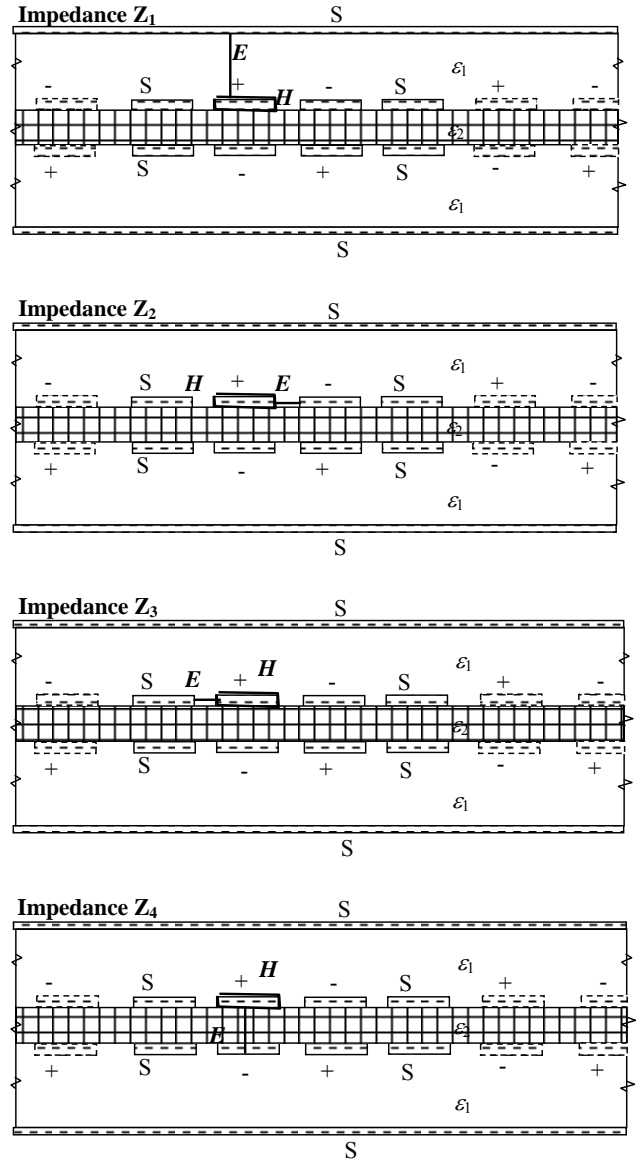


Fig.5. The analysis of LVDS bus impedance.

2 CONCLUSION

The analysis was performed for the required frequencies and signal levels. A short APDL program was used to find the geometrical optimum of the LVDS bus dimension. Fig.6 shows the distribution of modules of the electric field intensity vector \underline{E} and the magnetic field intensity vector \underline{H} of the selected bus pair. This evaluation serves to verify the designed characteristic impedance Z . A wrong bus design causes the presence of standing waves on the transmission lines. The characteristic impedance values were experimentally verified for some frequencies (Table 1). The spectrum analyzer Agilent N1996A was used in the experiment.

	LVDS1		LVDS2		LVDS3		LVDS4		LVDS5	
f [MHz]	Z [Ω]	φ [$^\circ$]	Z [Ω]	φ [$^\circ$]	Z [Ω]	φ [$^\circ$]	Z [Ω]	φ [$^\circ$]	Z [Ω]	φ [$^\circ$]
1	100	0	100	0	100	0	100	0	100	0
10	98	-1	98	-1	98	-1	98	-1	98	-2
50	86	2	86	2	86	3	87	2	86	1
100	76	-6	88	2	86	5	74	23	78	4

Tab. 1: Differential pair mutual impedances

4 REFERENCES

- [1] ANSYS manual, v.8.1, USA.
[2] Fiala P.: Coupled electromagnetic model of smoothing choke. In Proceedings of the 5th AMTEE International Conference, Pilsen, Czech Republic, p.C05, 2001.

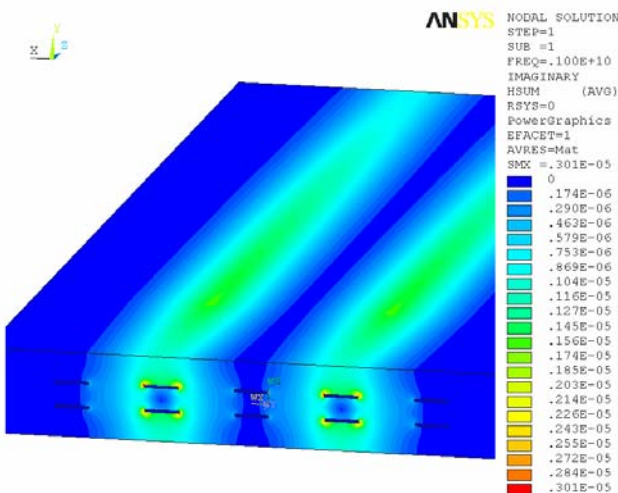
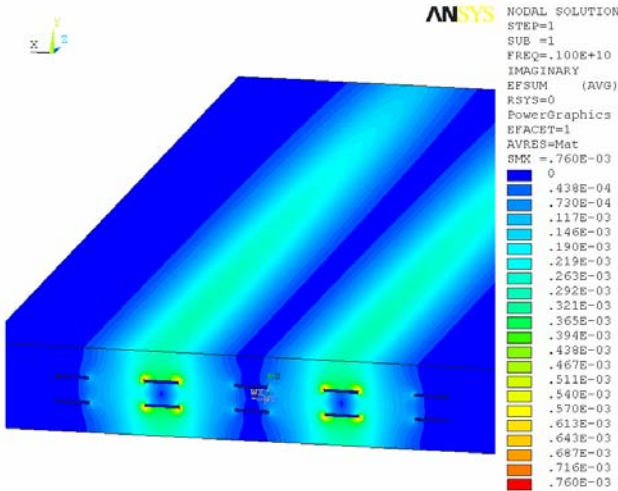


Fig.6. Distribution of the electric field intensity vector module E (upper) and the magnetic field intensity vector module H (lower).

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