Neuronal Approach for an accurate model of coplanar structures

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Abstract - **A** neuronal approach is proposed to develop accurate and fast CPW models for CAD simulator. The approach is based on the use of the neural network, for which the training phase uses electromagnetic simulation results. The validation tests are performed for junctions and discontinuities that are usually used in flip-chip, packaging technology.

INDEX-TERMS : CPW , discontinuities, and neural networks.

1. INTRODUCTION

The wireless communication and multimedia applications are growing rapidly. They require high flow traffic systems and thus a wide operating band. The rise to the millimeter frequency band allows satisfying this previous need.

However, specific technologies are usually required. Coplanar waveguide technologies offer in fact several advantages due to its configuration, such as low radiation, low dispersion, easy of shunts and series connections. The absence of discontinuity models with high accuracy makes difficult the conception and the optimization of these structures with CAD tools. Time consuming of EM simulators limits theirs use in the conception flow.

The present communication proposes ANN models (Artificial Neuronal Network) for the coplanar structures, where the training set is provided by EM simulation results. The developed models are validated for uniform lines, curved bend, short and open circuit stubs.

2. NEURONAL APPROACH

The used neural network model is the MLP (multi layer perceptron) with one hidden layer **[4]**. This last one was used for modeling and optimizing microwave filters **[2-3]**. The previous neural network is also employed with prior knowledge input **[9]**, where existing model (initial) is used to accelerate the training set of the neural network with a fast convergence. **[7]** used a neuronal approach to generate and optimize the chamfered 90° CPW bend and other discontinuities,[6] optimize the same CPW 90° bend by reducing the width of the line to compensate the unwanted capacitance adde by the air-bridge.

The innovent approach is to generate models considering their standard (constante) parameters as : permittivity of the substrate. In the figure 1, we present the used approach for this work; it permit to us in the next, to create models of some discontinuities referring to their line characteristic (ε_r and impedance characteristic). The existing model for this case is the formula of the permittivity and characteristic impedance.

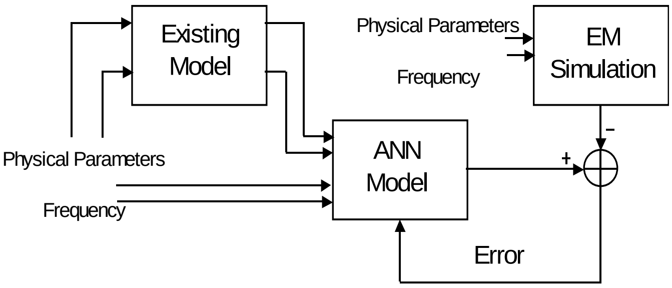

Figure 1:neuronal approach with knowledge input.

The fixed parameters for the training set are: $\varepsilon_r = 12.3$ et $H_{sub} = 0.6mm$ for **GaAs** substrate, the width of the air bridge is 40µm and its height is 5µm. The input data and their corresponding range of the neural network are given below in table 1.

	Min	Max
W (µm)	**20**	**120**
S (µm)	**20**	**60**
Frequency (GHz)	**8**	**80**

Table 1 : Training parameters.

A neuronal model allows to acced to the characteristics of the propagation of the line (Z_c, ε_{eff}), in function of the geometrical parameters and the frequency. The training data are obtained by EM simulation based on the finite elements method (HFSS-Ansoft).

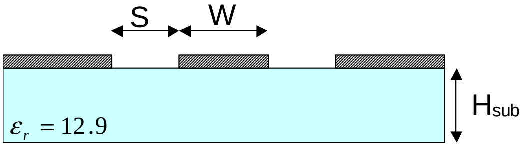

Figure 2:coplanarwave structure.

The training phase is first provided by thirty-five configurations with ten frequency points. The knowledge input is the permittivity and the characteristic impedance given in **[1]**. Three different calculations of the characteristic impedance could be achieved using EM simulator :

Zpi : $Z_{PI} = \frac{P}{I \bullet I}$ adapted for the microstrip lines.
Zpv : $Z_{PV} = \frac{V \bullet V}{P}$, adapted for coplanar and slot lines.
Zvi : $Z_{VI} = \sqrt{Z_{pv} Z_{PI}}$, adapted for TEM lines.

Where: $P = \oint_s E \times H ds$, $I = \oint_l H \bullet dl$, $V = \oint_l E \bullet dl$.

In the second step, the created model is compared to ten new EM results that are different of the training ones. The obtained error results (ANN model compared to EM simulation) are given in table 2.

	Zpv	Zvi	ε_{eff}	losses
Training error	**0.45**	**0.8**	**0.002**	**0.06**
Neurone of the hidden layer	**4**	**4**	**4**	**4**

Table.2 : the obtained error between EM and ANN models.

Figures 3 and 4 present comparisons between the ANN model and EM simulation for Zpv, Zvi, losses and permittivity ε_{eff} . The ANN model is in a good agreement with the EM results. It is to be noticed that the impedance "Zvi" of the line has less frequency dependence behavior. This last one confirms the choice definition of the characteristic impedance "Zpv" used in the EM simulator.

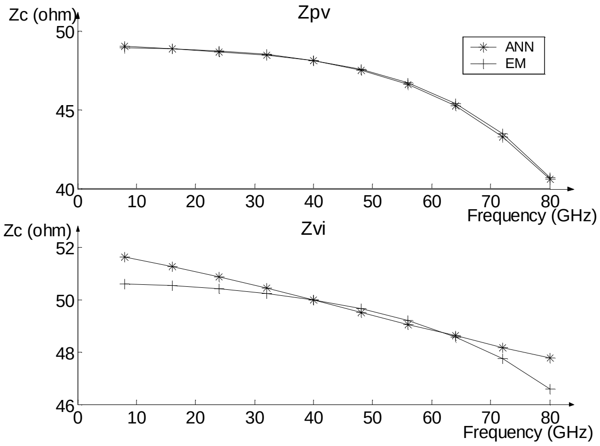

Figure 3: Comparison EM-ANN for the characteristic Impedance w=80 µm s=40 µm.

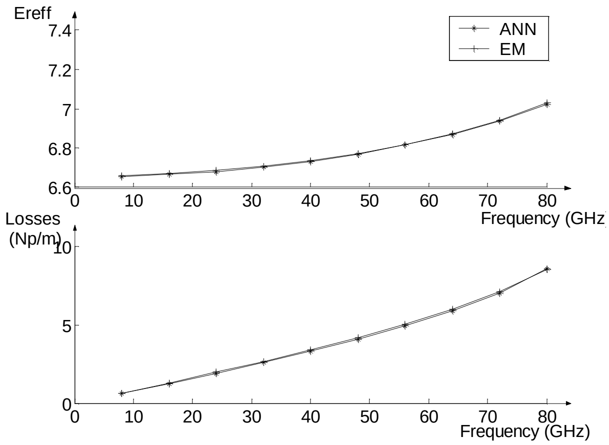

Figure 4: ε_{eff} and losses *EM-ANN w=60µm s=40µm.*

3. OPEN AND SHORT CIRCUIT MODELS

Short and open circuit stubs represent the most used discontinuities in many circuit designs. The geometry of the considered circuits is shown in figure 5. The present development is justified by the no validity of the existing commercial models. Figures 6 and 7 give a comparison between the available commercial model and the EM simulation. One can see that the observed difference become significant in the millimeter wave range. This insufficiency is also observed for the phase behavior.

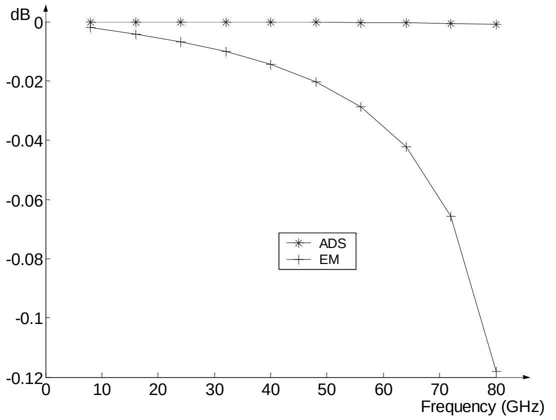

Figure 6: return loss of short circuit (sc)
W=20 µm S=40 µm.

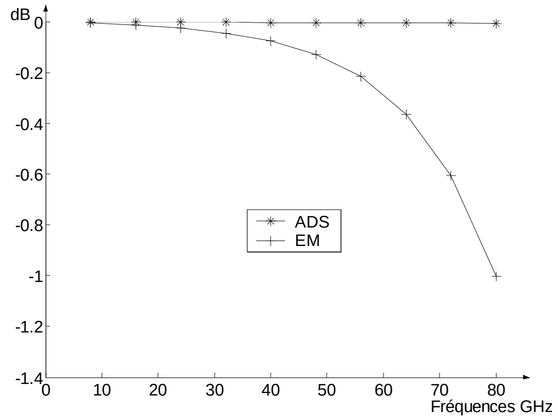

Figure 7: return loss of open circuit (oc2)
W =60 µm S=60 µm.

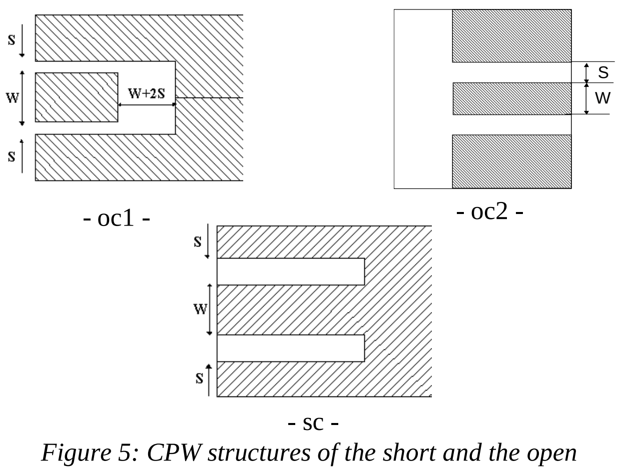

Figure 5: CPW structures of the short and the open circuits.

The generated ANN model has for inputs the geometrical line parameters, the frequency, Z_c and ε_{eff} ; the corresponding range data are given in table 1. The output responses of the ANN are S parameters for which the reference planes are placed at the physical discontinuity ones (Fig. 5). For each circuit, EM simulation has been performed on 18 structures over 8 to 80 GHz frequency range. During the training phase, the number of neurons in the hidden layers is firstly optimized and then fixed in a second step to 4 neurons, which gives to the minimum error.

Finally, 10 structures are used to check the model accuracy. The resulting errors for the training and test procedures are given in tables 3 and 4:

	$\|S_{11}\|$	$\angle S_{11}$ (°)
Training Error	**0.0028**	**1.1**
Neurone of the hidden layer	**4**	**4**

Table.3 : Training Error between simulation and ANN model .for the short circuit.

	OC1		**OC2**	
	$\|S_{11}\|$	$\angle S_{11}$ (°)	$\|S_{11}\|$	$\angle S_{11}$ (°)
Training Error	**0.0008**	**0.45**	**0.0026**	**0.46**
Neurone of the hidden layer	**4**	**4**	**4**	**4**

Table.4 : Error results between simulation and ANN model .for the open circuit.

To validate the capability of the developed models, we present in the next figures 8-10 some comparisons between the EM simulation and the obtained ANN model. A good agreement between the two results could be observed and the obtained accuracy is in the training error range.

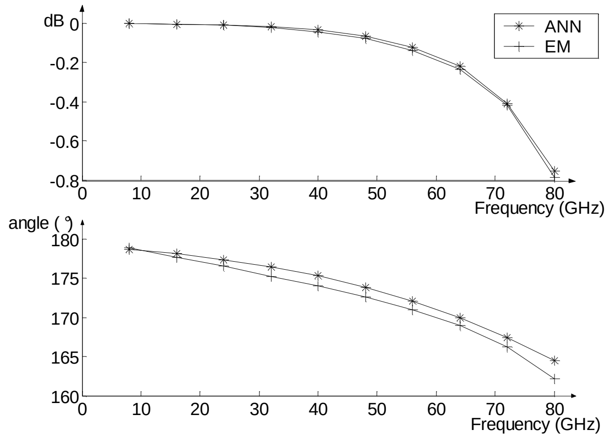

Figure 8: Comparison EM-ANN for a short circuit
W=80µm S=40µm.

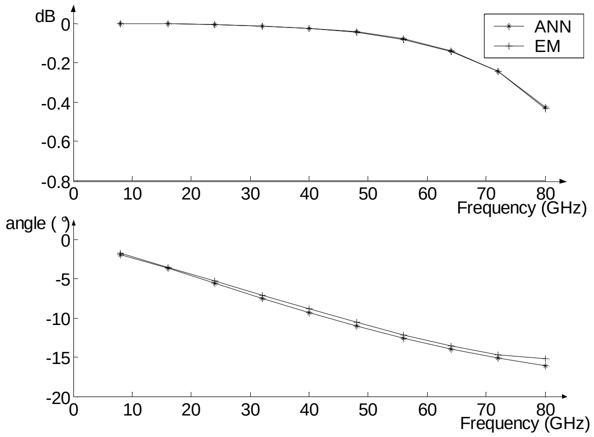

Figure 9: open circuit (oc 1) EM-ANN comparison W=100µm S=60µm.

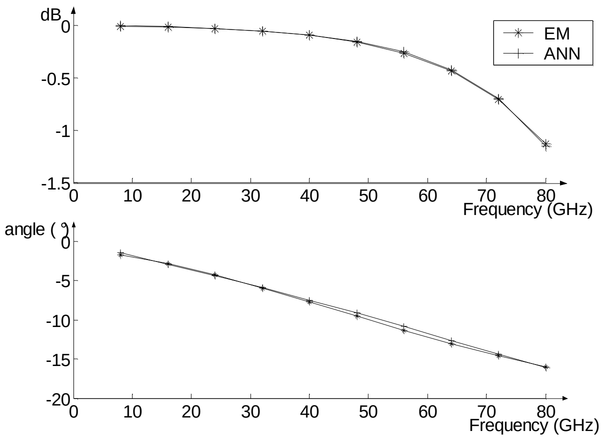

Figure 10: open circuit (oc 2) EM-ANN comparison W=120µm S=20µm.

4. COPLANAR CURVED BEND

The developed ANN model is now proposed to handle a more 3D complex discontinuity as a curved 90° CPW bend with air-bridges (fig. 11).

The neuronal network has for input parameters: the width and slot of the CPW line, the frequency, the permittivity ε_{eff} and the characteristic impedance, the corresponding range of data are given in table 1. The air bridge dimensions are 40µm length and 5µm height.

Using the symmetry of the structure, the output responses of the ANN model are limited to the reflection, S_{11}, and the transmission, S_{21}, parameters. As for the previous case, the training and test phases use respectively twenty-five and ten structures. The resulting errors from the training/test phases are given bellow (Table 5):

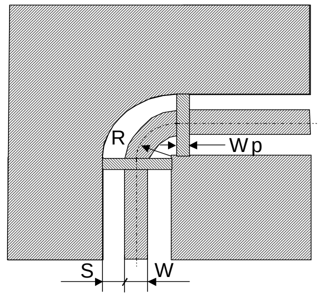

Figure 11: curved bend structure.

	$\lvert S_{11}\rvert$	$\angle S_{11}\,(°)$	$\lvert S_{21}\rvert$	$\angle S_{21}\,(°)$
Training Error	**0.0045**	**1.5**	**0.0038**	**0.45**
Neurone of the hidden layer	**4**	**4**	**4**	**4**

Table 5 : Error results between simulation and the ANN model. of the curved bend.

In figures 12 and 13, we present a comparison of a test example between the ANN models and the EM simulation. Again, a good agreement between this model and the EM simulation can be observed and confirms the validity of the proposed model to describe the discontinuity EM behavior.

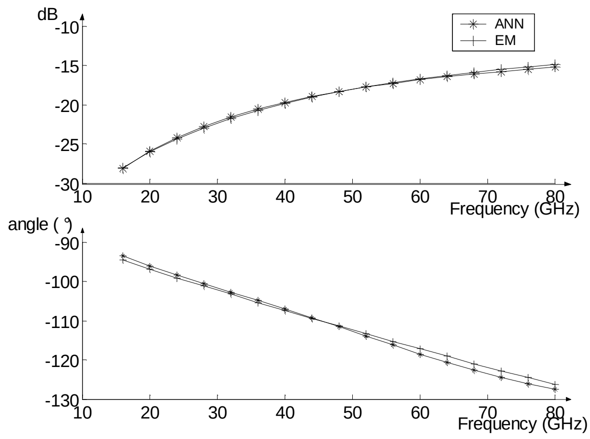

Figure 12: Curved bend EM-ANN *comparison S11 W=40µm S=20µm.*

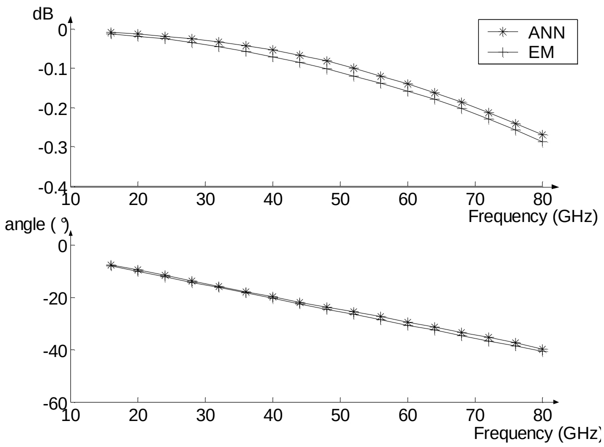

Figure 13: *Curved* bend EM-ANN *comparison S21 W=40µm S=20µm.*

6. CONCLUSION

We develop a procedure to create ANN models for a coplanar technology. The proposed model could be easily extended to other technologies. Validated by electromagnetic simulations, the studied discontinuities confirm the utility of the neuronal approach in reducing simulation time that constitutes a paramount advantage in CAD tools.

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