A Fuzzy Approach in Designing Microstrip Line

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ABSTRACT: This paper presents a new and flexible approach based on fuzzy logic for design optimisation of geometrical parameters of microstrip lines in high speed integrated circuit technology. For all different input conditions optimum parameters are calculated at the output.

I. INTRODUCTION

Recent advances in integrated circuit technology have reduced the single device switching time to tens of picoseconds or less. Unfortunately, the electrical performance of the interconnect do not scale as well, and this results in many unexpected problems such as delay, reflection, ringing and false switching. In many cases the interconnection delay time is often significantly longer than the devices switching time. In such cases the transmission line property of the lines can not be neglected. Therefore, accurate selection of geometrical and electrical parameters, modelling and simulation of such lines in particular their delay and cross-talk have become very important.

2. CROSSTALK

An obvious solution to the problem of delay and reflection is to decrease the length of the interconnections by increasing the density. This solution, however, leads to increase crosstalk [1]. Since there is not a direct relationship between many parameters trade-offs are to be made between various conflicting parameters or factors which in turn will depend on the line geometrical parameters. When working with a large circuits the relationship between the design criteria and a large number of circuit parameters becomes very complicated. For example, to minimise interline crosstalk and at the same time to decrease the delay time, fuzzy theory can be used as a tool for determining the appropriate geometrical parameters of microstrip lines; width, thickness, spacing and height (see Fig. 1) as well as electrical parameters [2,3].

![Figure 1](image_url)

Figure 1.
3. THE APPROACH

The approach (see Fig. 2) adopted in this work is based on fuzzy theory which best expresses inherent uncertainty, vagueness, and imprecision in a relationship encountered in real world [4], hence in microstrip lines. Fuzzy control is carried out by programming the rules of selection used by skilled individual, $A_i \rightarrow B_i$ ($i = 1, 2, \ldots n$), in which the judgement on manipulated valuable $B$ for a given state $A$ is best made by a computer.

![Figure 2. Flow chart of fuzzy algorithm](image)

4. FUZZY ALGORITHM

All the fuzzy sets $F_{l_i}$ expressing preferences of all input parameters $g_i \in I_i \subset \mathbb{R}^+$ ($i \in N$) are determined, normalised and convex. $I$ is a close interval of positive real numbers. Let $C_g$ be a
The algorithm to determine a fuzzy set induced on \( C_g, \ F_{ind} \), has the following steps:

1. Let \( C_g: I_1 \times I_2 \times \ldots \times I_i \rightarrow R \) is the performance parameter \( (i \in N) \) such that 
   \[
   r = C_g(g_1, g_2, g_3, \ldots, g_n).
   \]

2. Select appropriate values for \( \alpha \)-cut, such that \( \alpha_1, \alpha_2, \alpha_3, \ldots, \alpha_k \in (0,1) \) which are equally spaced.

3. Determine all the \( \alpha_k \)-cuts for all \( F_{I_i} \) \( (i \in N) \).

4. Generate all \( 2^n \) combinations of the endpoints of intervals representing \( \alpha_k \)-cuts for all \( F_{I_i} \) \( (i \in N) \). Each combination is an \( n \)-tuple \( (g_1, g_2, g_3, \ldots, g_n) \).

5. Determine \( r_j = C_g(g_1, g_2, g_3, \ldots, g_n) \) for each \( n \)-tuple \( j \in 1,2,3,\ldots,2^n \).

6. Set \( F_{ind} = (\min_j, \max_j) \) for all \( j \in 1,2,3,\ldots,2^n \).

For defuzzification the following steps are required:

1. Set \( F_{C_g} \cap F_{ind} \).

2. Find the membership value of supremum of step 1, say \( f^* = \sup \{ F_{C_g} \cap F_{ind} \} \).

3. Find the \( C_g \) value of \( f^*, \) say \( C_g^* \).

4. Find \( f^* \)-cut of all \( F_{I_i} \) \( (i \in N) \).

5. Generate all \( 2^n \) combinations of the endpoints of interval representing \( f^* \)-cut of all \( F_{I_i} \) \( (i \in N) \). Each combination is an \( n \)-tuple \( (g_1^*, g_2^*, g_3^*, \ldots, g_n^*) \).

6. Determine \( r_j^* = C_g^*(g_1^*, g_2^*, g_3^*, \ldots, g_n^*) \) for each \( n \)-tuple \( j \in 1,2,3,\ldots,2^n \).

5. NUMERICAL SAMPLES

To illustrate the approach, two types of numerical samples are presented. Table 1 and table 2 show when the algorithm is applied to geometrical [5] and electrical [6] parameters of microstrip lines respectively.

| Parameters        | Initial values (A) | Calculated values (B) | \( |A - B|/A \times 100 \) |
|-------------------|--------------------|-----------------------|------------------------|
| \( \text{Width (mm)} \) | \( 5 \) | \( 4 \) | \( 9 \) | \( 5.402 \) | \( 4.281 \) | \( 7.817 \) | \( 8.04 \) | \( 7.02 \) | \( 13.14 \) |
| \( \text{Height (mm)} \) | \( 9 \) | \( 5 \) | \( 10 \) | \( 8.3 \) | \( 6.614 \) | \( 8.699 \) | \( 7.77 \) | \( 32.28 \) | \( 13.01 \) |
| \( \text{Thickness (mm)} \) | \( 5 \) | \( 4 \) | \( 3 \) | \( 5.3 \) | \( 3.677 \) | \( 3.743 \) | \( 6 \) | \( 8.075 \) | \( 24.76 \) |
| \( \text{Spacing (um)} \) | \( 6 \) | \( 5 \) | \( 4 \) | \( 5.8 \) | \( 6.291 \) | \( 4.299 \) | \( 3.33 \) | \( 25.82 \) | \( 7.47 \) |
| \( \text{Height (um)} \) | \( 9 \) | \( 8 \) | \( 10 \) | \( 8.9 \) | \( 8.645 \) | \( 9.628 \) | \( 1.11 \) | \( 20.35 \) | \( 3.72 \) |
| \( \text{Spacing (um)} \) | \( 3 \) | \( 5 \) | \( 1 \) | \( 3.3 \) | \( 3.708 \) | \( 1.743 \) | \( 10 \) | \( 25.84 \) | \( 74.3 \) |

Table 1. Algorithm applied on geometrical parameters
Table 1. Algorithm applied on electrical parameters

| Parameters | [Min, Prefered (A), Max] | Calculated (B) | |A-B|A (%) |
|------------|--------------------------|---------------|-----------|--------|
| Cij (pF)   | [6.2, 6.6, 7]            | 6.71429       |           | 1.73   |
| Cga (pF)   | [5, 7, 10]               | 6.42857       |           | 8.16   |
| Cgt (pF)   | [8, 15, 15]              | 13            |           | 13.33  |
| Cgd (pF)   | [2, 7, 7]                | 3.42857       |           | 51.02  |
| C't (pF)   | [8, 10, 13]              | 9.42857       |           | 5.71   |

6. CONCLUSION

A novel approach based on fuzzy logic was presented for optimisation of electrical and geometrical parameters of microstrip lines. In this approach we fuzzified all the input parameters to create a fuzzy environment. This is then processed by the extension principle to produce the output data. The output data is then defuzzified to extract the best electrical parameters of the microstrip lines. Algorithm for the processed is presented.

Examples were included to illustrate the application of the proposed technique. It can be incorporated with fuzzified crosstalk [7] information which in turn can produce the best design that can minimize crosstalk.

REFERENCES