Segmentation and GA-based Optimization of Transmission-Line on Printed Circuit Board

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Abstract

The distortion of signal wave form is a major problem in higher frequency of signals on printed circuit board. To overcome this problem, the idea which changes transmission line width and positively using the reflection wave was proposed. However, it is difficult to apply realistic scale circuit because that method needs a lot of parameters. Thus, we propose the idea to reduce parameters and develop the method which decides parameters using GA. Next, we design actual clock line with a memory module and evaluate our new method.

Key Words:
Genetic Algorithm, Optimization problem, Printed Circuit Board, Wave form

1. Introduction

Recently, the clock frequency of CPU is on the order of GHz, however signals propagating on the motherboard is on the order of MHz. This is one of the bottlenecks in high speed processing, thus, higher frequency of signals propagating on the PCB (printed circuit board) has been desired [1].

On a PCB, many ICs connect with transmission lines. Impedances near the connected points are different from other in transmission line[2,3]. Reflection waves are generated from impedance varying boundary and superposed signals and distort signal wave form. As the frequency of the signal is higher, the reflection of the signal is higher[4]. As the result, wave form of the signal is greatly distorted. This "distortion of signal wave form by reflection" is a major problem for making signals on PCB higher.

To overcome this problem, Yasunaga, Yoshihara, et al.[5,6] proposed the segmental-transmission-line in which a transmission line consists of multiple segments of individual impedances. The impedances are designed to make the reflection noises cancel out one another to minimize the signal distortion.

Because this segmental-transmission-line needs a lot of parameters, it is difficult to apply this idea to realistic scale circuit. In this paper, first, we propose the variable segmental-transmission-line to reduce a number of parameters. Next, we develop the method which decides parameters using GA (Genetic Algorithm) for the variable segmental-transmission-line. Finally, we design DIMM clock line and compare with conventional segmental-transmission line.

In the following, we call conventional segmental-tr ansmission-line as "fixed segmental-transmission-line"

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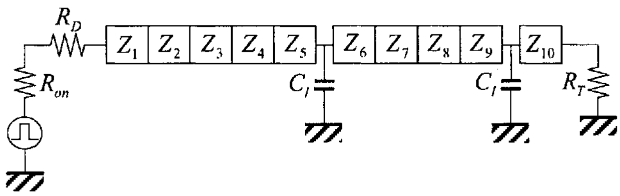

Fig.1 Fixed Segmental-Transmission-Line

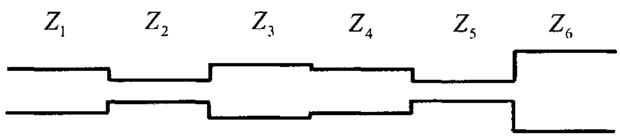

Fig.2 It adjusts impedance by changing the line width

2. Segmental-Transmission-Line

2.1 Fixed segmental-transmission-line concept

Fig.1 shows the framework of fixed segmental-transmission-line. This concept is that

- It divides transmission line into several segments with same length
- It assigns individual impedance to divided segment and generate reflection waves intentionally
- Then, it positively interferes with the reflection wave and the signal.

By adjusting multiple impedances successfully, all of multiple reflections on the transmission line are expected cancel out each other. It adjusts impedance by changing the line width, as shown in Fig.2.

2.2 Difficulties in the fixed segmental-transmission-line concept

Yasunaga et al. designed transmission line with two modules by fixed segmental-transmission-line-concept. However, they prepared 10 – 20 segments and 99 kinds of line widths. That is difficult to design actual scale circuit because of too many parameters. Additionally it is difficult to prepare 99 kinds of line widths by machining technology.

Therefore, we propose the variable segmental-transmission-line concept to reduce a number of parameters.

2.3 Variable segmental-transmission-line concept

Fig.3 shows a part of variable segmental-transmission-line. All segments are the same lengths and only change the line width so far. In this concept, it doesn't adjust only the width of transmission line but also length. This will enable to reduce the number of segments and kinds of line widths.

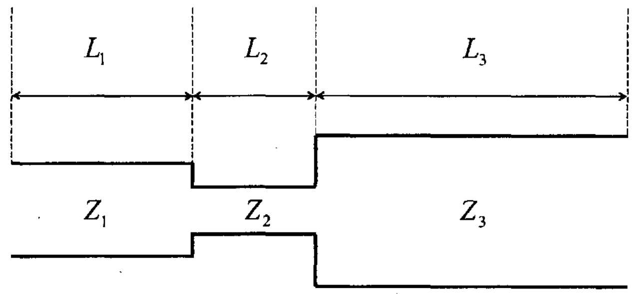

Fig.3 A part of variable segmental-transmission-line

2.4 Task and policy of designing the variable segmental-transmission-line concept

Given the m segments and n kinds of line width, the total of the designing parameter is n^m. Additionally given the length of segment by real number value, it is impossible to search by analytical technique. So we decide parameters using GA for the variable segmental-transmission-line.

We use NG-SPICE[7] for fitness calculation in the GA. NG-SPICE is the analog circuit simulator of SPICE[8] type which is most widely used. NG-SPICE can simulate an analog circuit using the spec file made of the circuit diagram.

3. Optimal segmentation using Genetic Algorithm

3.1 Outline of parameter decision using Genetic Algorithm

Fig.4 shows the flow parameter decision for the variable segmental-transmission-line. First, it generates initial individuals at random. Next, it does genetic operation that includes crossover, fitness evaluation, selection and mutation, repeatedly until matching to the termination condition. The fitness evaluation operation outputs a spec file which written in SPICE format and start up SPICE. SPICE simulates a segment al-transmission-line in

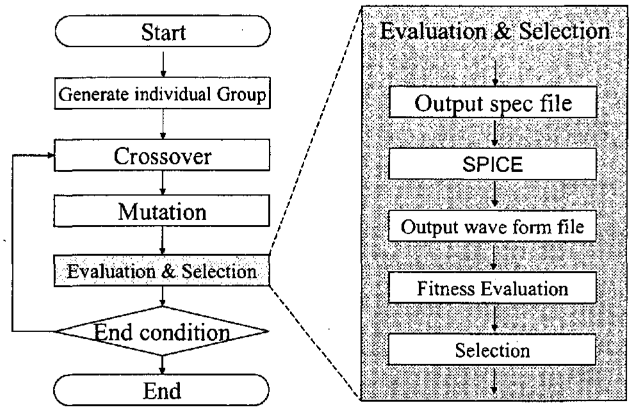

Fig.4 Flow of this method

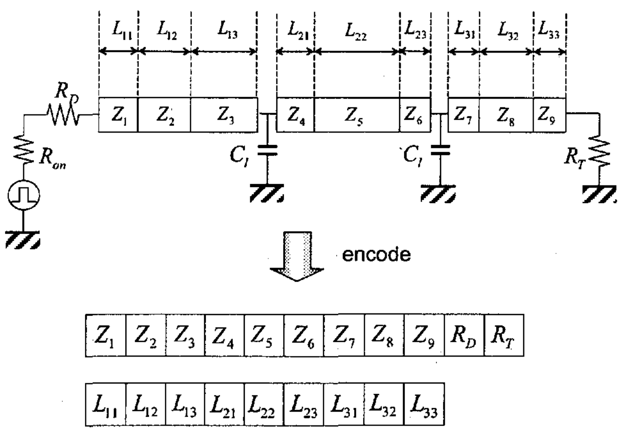

Fig.5 Composition of a Chromosome

the spec file and outputs the signal wave form file. Th e fitness calculates from the signal wave form file. In this research, the parameter decision scheme writes by C and Perl.

3.2 Chromosome Coding

Fig.5 shows a coding from variable segmental-transm ission-line to chromosome. Shape of variable segmental -transmission-line is decided by the kind of impedance and segment length. Thus, we use two kinds of chrom osomes. That is

- Impedance of segment, damper and terminating resistance arrange in one sequence
- Length of segment arrange in one sequence. And $\sum_{j}^{n} L_{ij}$ is constant because the distance bet ween module to module is given.

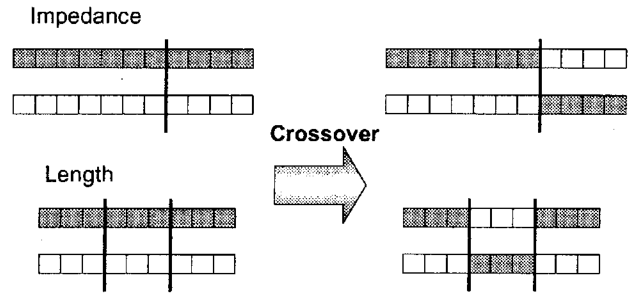

Fig.6 Crossover about each chromosome

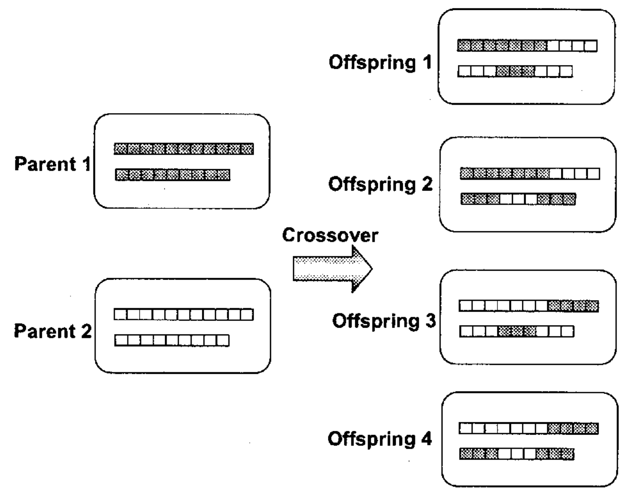

Fig.7 four offspring from a pair of individuals

Shape of variable segmental-transmission-line is expressed by these two kinds of chromosomes. Each individual has two kinds of chromosomes.

3.3 Genetic Operation

(1) Crossover

We operate crossover about each chromosomes, as shown in Fig.6. Crossover about chromosome of impedance uses one point crossover. On the other hand, using one point crossover about chromosome of segment length has the problem that the distance between modules will change. So we swap all segments between modules as crossover.

Thus, operating each crossover generates two offspring. As a result, crossover generates four offspring from a pair of individuals, as shown in Fig.7.

(2) Fitness Evaluation

We define fitness function as follows. *Diff* is the difference in observed wave form on the designed transmission line and the ideal wave form, as shown in Fig.8. If *Diff* becomes small, fitness value will become larger.

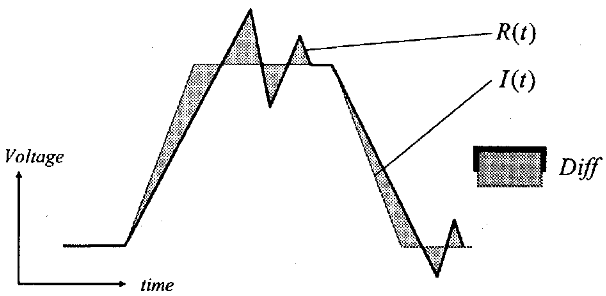

Fig.8 Fitness defined by the difference between observed wave form and ideal wave form

$$Diff = \int |I(t) - R(t)| dt \quad (1)$$

$$fitness = Const - Diff \quad (2)$$

I(t): Ideal wave form

R(t): Observed wave form

Const: Large Constant

(3) Selection

Whether each individual can survive the next generation is determined based on calculated fitness. We choose elitist selection strategies that is only the same population size in individuals can survive to the next generation from what have high fitness in order.

(4) Mutation

We operate mutation excluding the elite individual. Mutation about chromosome of impedance is that changes into another value which is chosen at random. Mutation about chromosome of segment length is that changes into another length which is chosen at random. However, because the distance between modules is given, if mutation happened, the influence reaches other segments between modules. It may be presumed that the number of segment between modules: n and mutation happened L_{im} , the segment length changes as follows.

$$L'_{i,j} = \begin{cases} L_{i,j} - \Delta L_{i,j} & if \quad j = m \\ L_{i,j} + \dfrac{\Delta L_{i,j}}{n-1} & else \quad j \neq m \end{cases} \quad (j = 1 \cdots n) \quad (3)$$

$L_{i,j}$: Segment length before mutation

$L'_{i,j}$: Segment length after mutation

$\Delta L_{i,j}$: Amount of change

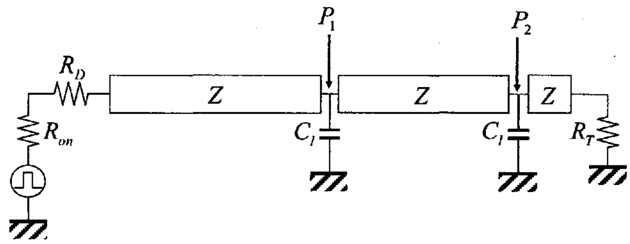

Fig.9 Model of clock line with a memory module

4. Numerical Experiment

4.1 Design Target

We design the transmission line by proposed method. The design target used in this paper is an actual clock line with a memory module (DIMM: Dual In-line Memory Module) on a typical PCB. Fig.9 shows the model of the design target. The model parameter given that impedance of transmission Z_0 is 76Ω, load capacitance assumed to be DIMM C_l is $10pF$. The signal is assumed to be propagation on the transmission line at a constant speed, and it propagates between clock driver to P_1 in $208ps$, between clock driver to P_2 in $504ps$, between clock driver to R_T in $560ps$.

We compare and evaluate variable segmental-trans mission-line with rough transmission line and fixed s egmental-transmission-line. We define r_{imp} as an eval uation standard of transmission line, as follows.

$$r_{imp} = \frac{Diff_{rough}}{Diff_{design}} \quad (4)$$

$Diff_{rough}$: Difference about rough transmission line (see (1))

$Diff_{design}$: Difference about designed transmission line

4.2 Case 1: Situation at shorter switching time

It aims at the higher frequency in the near future, we experiment the waveform distortion if switching time of the signal is short.

(1) Experimental conditions

Experimental conditions are as follows.

- The propagating signals

Signal amplitude	$3.3V$
Switching time	$20ps$

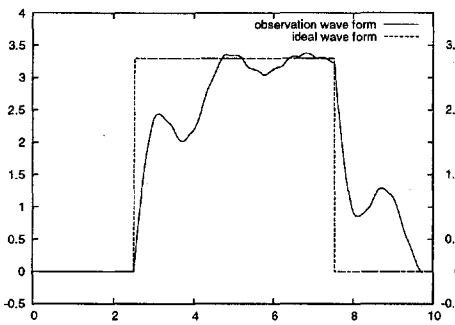

Fig.10 wave form about rough transmission line (Case 1)

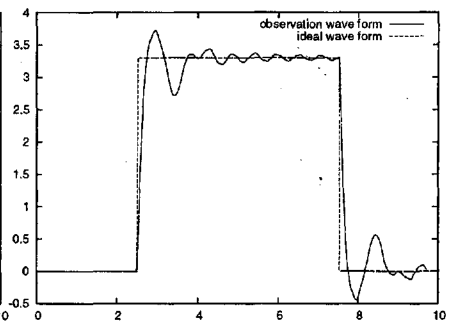

Fig.11 wave form about fixed transmission line (Case 1)

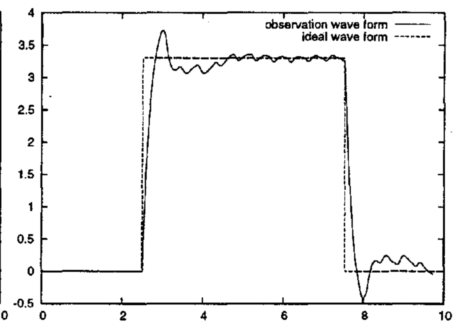

Fig.12 wave form about variable transmission line (Case 1)

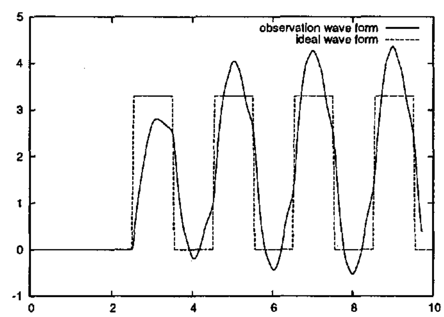

Fig.13 wave form about rough transmission line (Case 2)

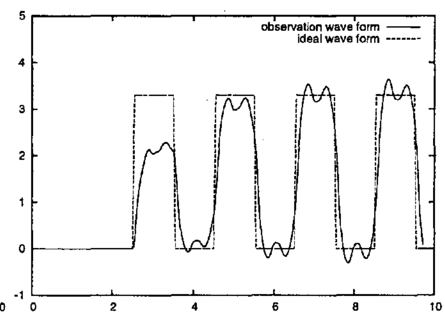

Fig.14 wave form about fixed transmission line (Case 2)

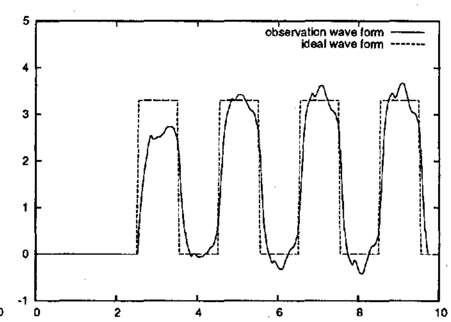

Fig.15 wave form about variable transmission line (Case 2)

Signal cycle 10*ns*

- Parameter about GA

  Population size 16

  Mutation rate

  * Impedance chromosome 5%

  * Segment length chromosome 10%

  Terminal generation 150

- variable segmental-transmission-line concept

  Kind of impedance 5Ω,25Ω,76Ω

  Damper & Terminal resistance 1Ω—99Ω

  The number of segment between modules

  * Damper resistance — P_1 3

  * P_1 — P_2 3

  * P_1 — Terminal resistance 3

(2) Results

Fig.10 shows observed wave form about rough trans mission line, Fig.11 shows about fixed segmental-trans mission-line and Fig.12 shows about variable segmental -transmission-line. Dashed line shows ideal wave form. r_{imp} shows as follows.

- Fixed segmental-transmission line 2.724
- Variable segmental-transmission-line 3.145

Observed wave form shows that it is clear the signal wave form is shaped by segmental-transmission-line. It compares variable segmental-transmission-line with fixed one, the amplitude of bounds noise is promptly attenuate. That leads to the improvement of r_{imp}.

Therefore, we showed that the variable segmental-tra nsmission-line better than fixed and it is able to design by this method.

4.3 Case2: Situation at resonance signal with reflection

We experiment the waveform distortion if signal resonates with reflection noise.

(1) Experimental conditions

Experimental conditions are as follows.

- The propagating signals

  Signal amplitude 3.3*V*

  Switching time 200*ps*

Signal cycle 2ns

- Parameter about GA

  Population size 16

  Mutation rate

  * Impedance chromosome 5%

  * Segment length chromosome 10%

  Terminal generation 150

- variable segmental-transmission-line concept

  Kind of impedance 25Ω,40Ω,65Ω

  Damper & Terminal resistance 1Ω—99Ω

  The number of segment between modules

  * Damper resistance — P_1 3

  * P_1 — P_2 3

  * P_1 — Terminal resistance 3

(2) Results

Fig.13 shows observed wave form about rough transmission line, Fig.14 shows about fixed segmental-transmission-line and Fig.15 shows about variable segmental-transmission-line. Dashed line shows ideal wave form. r_{imp} shows as follows.

- Fixed segmental-transmission line 1.764
- Variable segmental-transmission-line 2.959

Observed wave form shows that the signal wave form on rough transmission line distorts like triangular wave. On the other, the signal wave form on segmental-transmission-line shaped like rectangular wave. A gap of first wave causes a difference of r_{imp}.

Therefore, we showed that it is able to design better segmental transmission line using few segments and kinds of impedance.

5. Conclusion

In this paper, we propose variable segmental-transmission-line concept to reduce parameters. We develop the method which decides parameters using GA for the variable segmental-transmission-line. We design DIMM clock line and compare with fixed segmental-transmission line. As the result, we are success to reduce the number of segments into 40% and the kinds of width into 16%-33% of conventional one. And we showed the variable segmental-transmission-line concept better than fixed.

Future subjects are application of variable segmental-transmission-line concept for large scale circuit and mounting on PCB, and etc.

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