Using Simulation Method to Optimize CompoNet Physical Layer

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Abstract:
Since CompoNet joined the ODVA network family in recent years, various demands have been given to it by manufacturers and users. CompoNet is in the process of specification enhancement and usability improvement. The specification enhancement, however, involves many verification tests to check if the aimed specifications are satisfied. This is due to CompoNet features, which allow uses of different cables, different communication speeds, and different topologies. Concurrent enhancement also requires many man-hours. This paper focuses on the simulation technology that was used to improve efficiency in enhancement. It also can be referenced for other network physical evaluations.

Keywords:
CompoNet. Physical Layer. Simulation. Cable. Media. Circuit.

Definition of terms:
HSPICE™: Circuit simulator produced by Synopsys™.
SPICE: Simulation Program with Integrated Circuit Emphasis, a simulator analyzing the circuit developed in University of California.
real units : Products. Trial products.

1. Introduction

CompoNet is a field network in ODVA CIP network family, which is designed for applications dominated by sensors and actuators. Its feature ranges in high speed communications (1000 points per 1ms), availability of non-shielded communications media, extendable installation area with repeaters, and a large number of connectable slaves.

Technology developments and expended applications require physical layer enhancements. CompoNet can be used in material handling systems such as conveyors and automatic warehouses, for electronic parts manufacturing and for switch control device such as building illuminations. The application is expanding. At the beginning when CompoNet specification was first released, there were only three supported cables: round cable I, Flat Cable I and Flat Cable II. In a response to customer demand, round cable II was later added in a group. Round cables, in general, are superior in flexibility, environmental resistance and cost to Flat Cables. Besides, round cable II satisfies the demand to convey power line and signal line in a single cable, and to reduce required space and cost. Variation of connectable media will expand in future, too.

Also vendors need to customize their own device implementations. According to the expansion of applications to various devices, there are also demands for CompoNet masters to be compatible with multi-vender CPUs, and for reinforcement of connectable slaves. Device venders of CompoNet want CompoNet devices to be much simpler and easier to fabricate. They want device components to cost lower, need less mounting space and fabrication know-how, and have wide variations and easy availability.

All these requirements and related specification enhancements need verification by tests. As CompoNet uses four data rates and allow a topology with T-branching, the verification needs a large number of test cases and takes many man-hours.

Conventionally, actual CompoNet master and slave units have been used for all verifications in deciding and enhancing specifications. This time, in contrast, computer simulation was introduced to improve the efficiency of evaluations. This paper elaborates the technical matters to realize the improvements.

2. Background and issues to be solved

Conventionally, the communications cables were wired to real CompoNet master and slave units. Then the waveforms of communications signals were monitored. The real units were then run to confirm the communications error occurrence.

One difficulty is defining configurations for network evaluation. In CompoNet network which allows T-branching, vast reflection can generate at T-branching sections on communications path due to inconsistent impedance. As the specification allows T-branching at any locations of the communications path, it is virtually impossible to evaluate all configurations in advance. The test cases must be narrowed down, by discussion and analysis first, to some representative configurations which cause major quality declines. However, the representative cases at this stage contain all factors, and the number is still yet great many. It was difficult to have detailed running tests for all representative cases of configurations.

Another method was taken additionally to reduce the number of representative cases further. Measuring waveforms roughly on real units can complete the preliminary verification in a shorter period. The configurations which need to be tested can be further narrowed down. This way the number of detailed tests was reduced. Only the focused number of cases had the prolonged running test.

Even the number of test cases was reduced, it still required a large amount of man-hours in wiring, preparing the running tests with real units, writing the test reports, and measuring the waveforms.

3. Technical works done

3.1. Test flow

The test with real units takes a major part of a confirmation test process of deciding the specification. Man-hours were greatly reduced by replacing it by simulation.

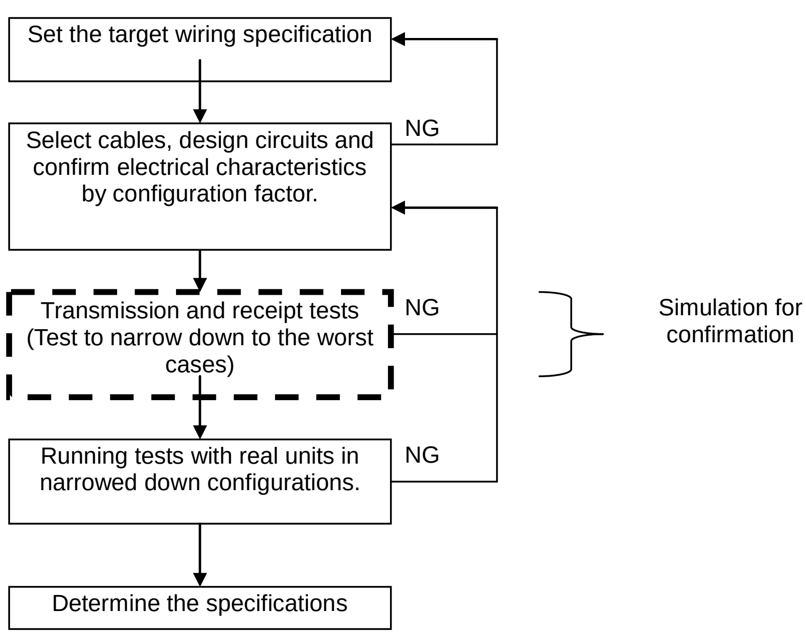

Figure 3-1 Flow of an entire test process

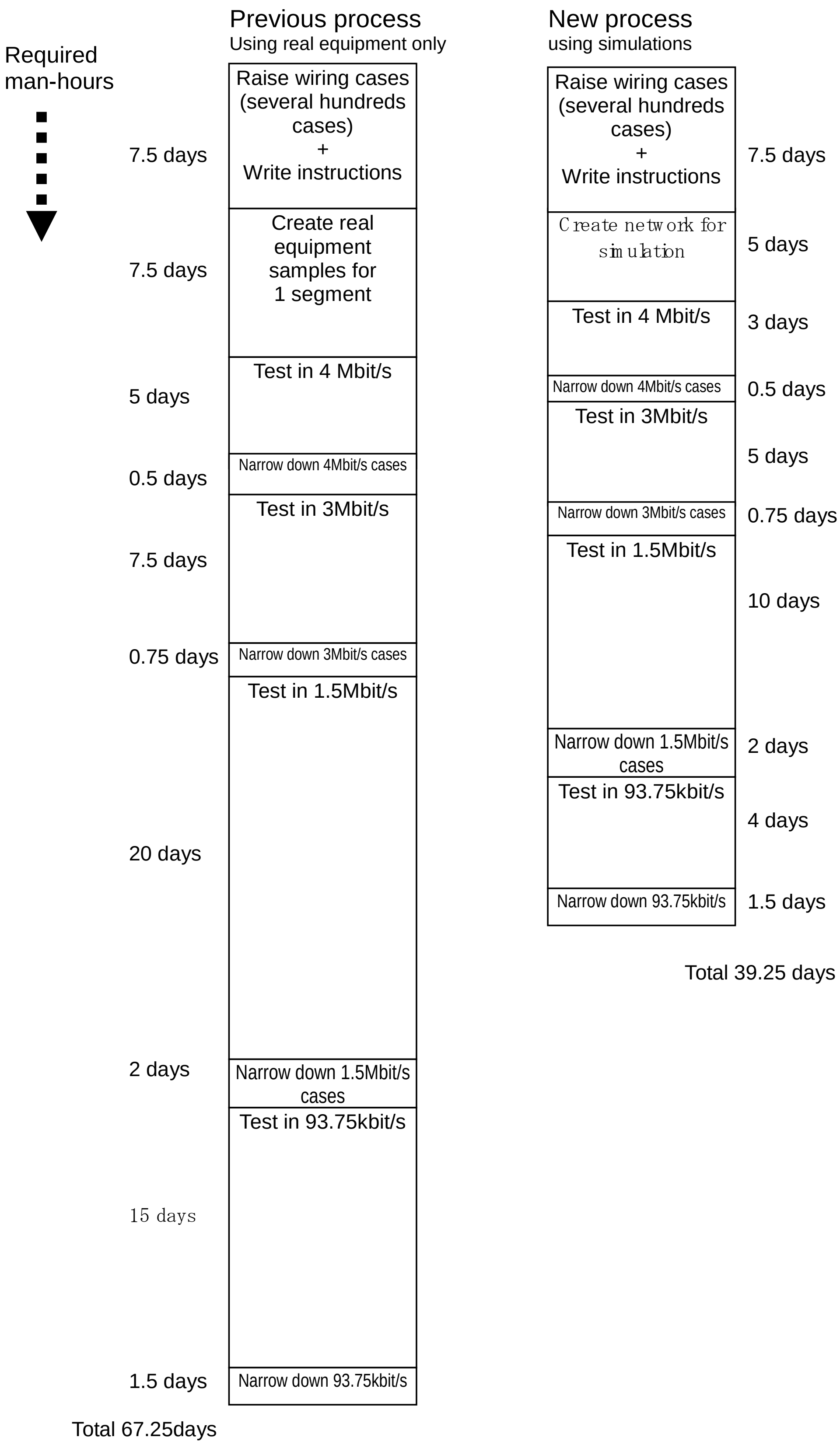

Figure 3-2 Selection flow of worst configurations for transmission and receipt test

The Figure 3-2 compares the previous and the new test processes.

The effect of simulation may be seen most clearly in transmission and receipt tests of the worst configuration cases.

Simulation can reduce the man-hours in preparation stage before the transmission and receipt test. CompoNet has several hundreds cases which assume deterioration of communications waveforms. In previous test process, the confirmation with real units was performed for these several hundred cases and repetitive work of wiring and measuring. A test with real units needs a sample of 1 segment. The test requires getting, processing and converting all samples for the test length and the number of test units. In contrast, a simulation requires one sample. Copying it and pasting can create samples of 1 segment for the required length and amount.

Also, simulation can save time during in test stage and after test. The test itself can be completed much easily with a single computer. That is, tests with real units required rewiring, getting waveforms in oscilloscope, and writing test reports. In simulation, a series of these tasks, i.e., modifying the Net List, saving the result, and writing the report, can all be completed on a computer. Thus the simulation considerably reduces man-hours.

There are a few things that a simulator can not replace at present. One is to narrow down the worst wiring cases. This must be performed by an expert engineer. Because there are unlimited combinations of wiring specifications, selecting the cases in which communications waveforms deteriorate is a mastery job. The other is the evaluation by measuring the bit error rate obtained by running tests of real units with narrowed-down configurations. Improvement in these areas is future assignments.

3.2. Communication system simulation and modeling

This section describes technical realization of the simulation. The simulator used is HSPICE, and the communication system model is composed of circuitry components and cable.

Condition for modeling includes verifying variations in component parameters, and verifying future component change and remodeling for cost reduction. That is, all PWB circuits are not using a single model. Instead, mounted parts were modeled individually. Equivalent circuits were used to the possible extent to reduce time for analysis even though part models can be S parameter. Basic models composed with equivalent circuits were used and examined for circuitry components, PWB and communications cables. The parameters for the basic models are adjustable.

In order to achieve higher agreement with the real units, comparison is made for each component parameter between the measurement results on the real units and those from equivalent circuits and models provided by manufacturers. The results were used for individual parameter adjustment. Finally, the measurement results from real units with CompoNet circuits and the simulation result are compared for agreement.

It was proved that the agreement with real units was accurate enough for narrowing down the configuration. It means we could use simulation at the intermediate process of verification test.

3.2.1. Components

The section describes the modeling procedures for composing elements of CompoNet Physical Layer: each component, PWB and communications cable.

（1） Chip Beads

Either the models provided by component manufacturers or the equivalent circuits as shown in Figure 3-3 were used. The constant was adjusted to conform to the characteristic measurement result of actual parts.

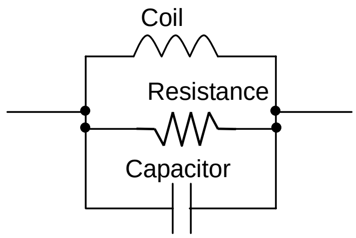

Figure 3-3 Simplified equivalent circuit to Chip Beads

(2) Pulse transformer
Coil inductor, DC resistance, combination coefficient between coils and capacity component were adjusted to be consistent with the measuring results from the real units.

(3) Common mode filter
As the characteristic matched with the real units, the spice model provided by the manufacture was used.

(4) Communications transceiver
Equivalent circuit was not available for the output characteristic of the transceiver. The output characteristic was measured with the waveform meter and the curve tracer. The IBIS was prepared.

(5) Capacitor and Resistance
Based on the ideal model of individual capacitor and coil, the measuring results of real units were used to adjust the constant.

(6) Zener Diode
The voltage is the one when the zener diode does not operate during normal communications. The equivalent circuit was prepared for a capacitor. And the measuring results of real units were used to adjust the constant.

(7) PWB
The capacitor was used for an equivalent circuit.

The simulator can provide much detailed simulation by having layer constitution, pattern and material type and dimensions written in it. The analysis takes, however, a long time. It was examined to simplify the circuit, and to shorten the required time. Finally, there was not big difference in the result between the real units and the simulation. To prioritize the shorter analysis time, the simulator used the capacitor.

(8) Communications cable
The RLGC circuit was used as an equivalent circuit.

The simulator has a function to output parameters by having profile and material type entered. The parameter is then adjusted based on the measuring result form the real units.

There is another method to create a model by measuring the real units with S parameter for the cable. The RLGC circuit, however, can have a shorter analysis time than the S parameter. When setting the parameters for communications cables, some items are not described correctly on the data sheet. They are the dielectric tangent (tanδ) and the specific inductive capacity (εr) for the cable material. These values are adjusted by confirming the waveforms on the time domain reflectometer (TDR, See Figure 3-4), and by aligning the measuring results of real units and the cable model. The adjustment continues until the waveform measured by the real units and the waveform simulated by HSPICE become fairly consistent as shown in Figure 3-5.

The following is a comparison example between the communications cable measurement by the real units and by the simulator. The Figure 3-4 shows the configuration used, while the Figure 3-5 does the measured results.

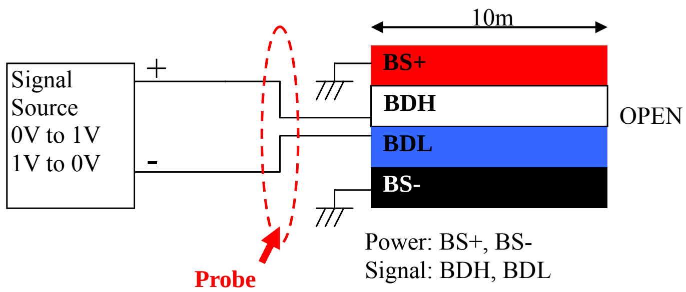

Figure 3-4 Configuration to measure the cable characteristics

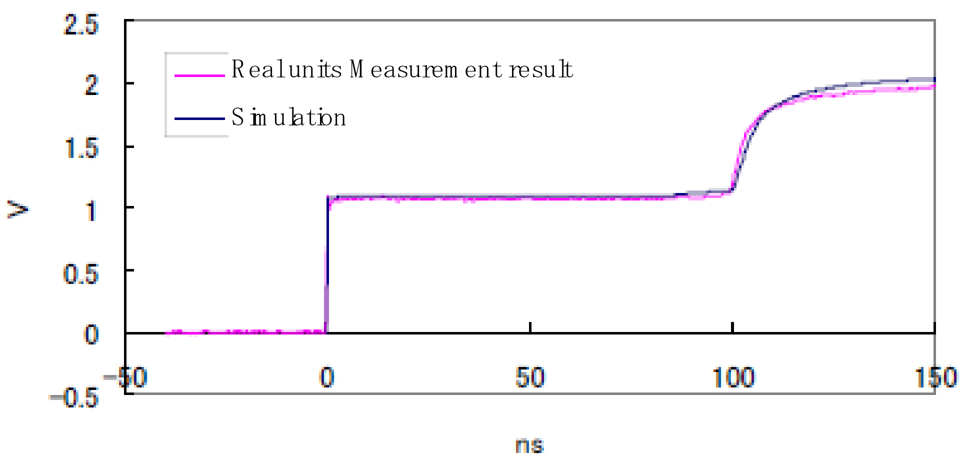

Figure 3-5 Waveforms measured by the configuration Figure 3-4

3.2.2. Simulation examples

The section describes the adjustment results by using above mentioned modeling.

This first case uses round cable I, multi-drop connection, 4 Mbit/s, and 9 Slave Units. The Figure 3-6 shows the connection configuration, while the Figure 3-7 does the waveform comparison.

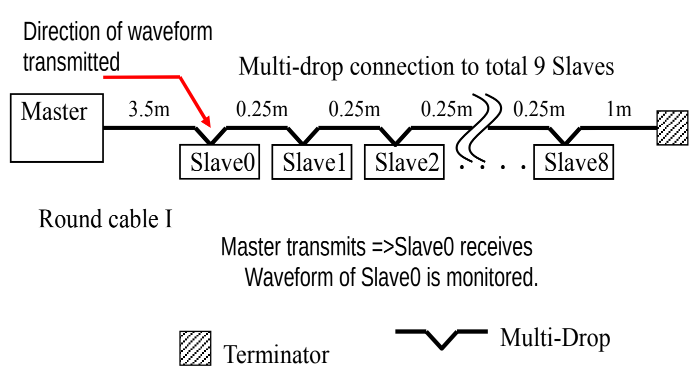

Figure 3-6 Configuration of connecting 9 Slave Units with round cable I in 4 Mbit/s

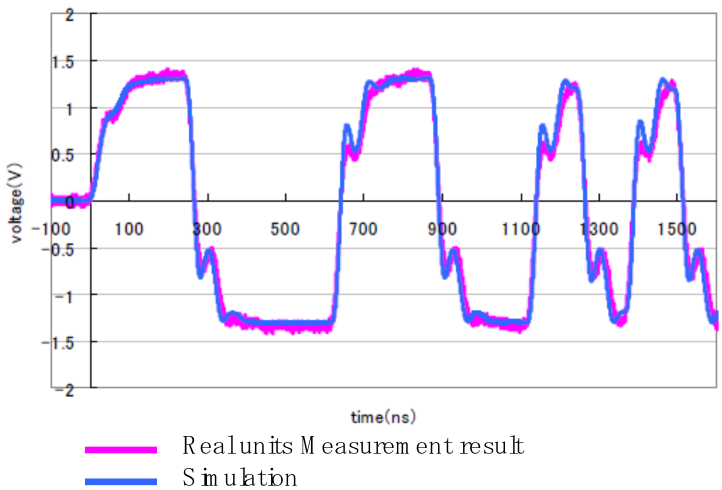

Figure 3-7 Waveforms measured by the configuration Figure 3-6

The next case uses Flat Cable I, multi-drop connection and T-branching, 1.5 Mbit/s, and 4 Slave Units. The Figure 3-8 shows the configuration, while the Figure 3-9 does the waveform comparison.

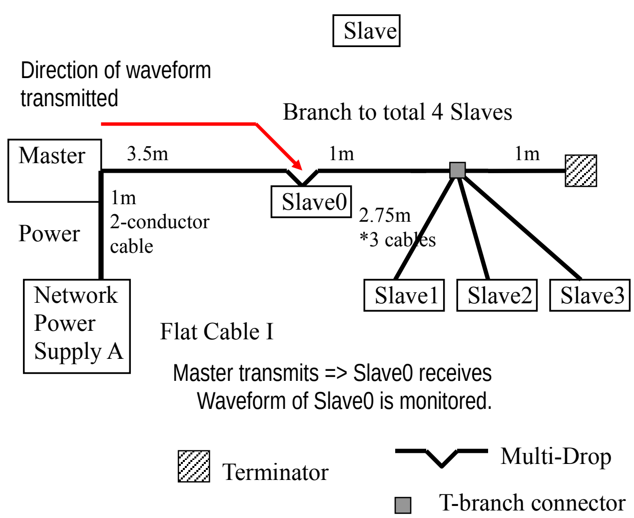

Figure 3-8 Configuration of connoting 4 Slave Units with Flat Cable I in 1.5 Mbit/s

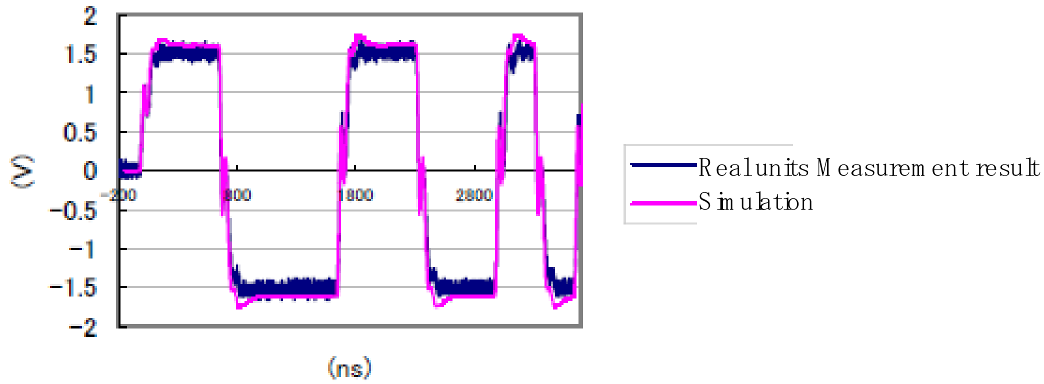

Figure 3-9 Waveforms measured by the configuration Figure 3-8

In this way, using the simulation method of high reproducibility minimized the man-hours required for tests to narrow down the configurations by 40%.

The simulation using the equivalent circuits with set parameters can get the high level of consistency with the measurement result from real units. This enables identification of specification requirements for circuitry components, and thus component manufacture. This achievement can be expanded to other circuitry components and mounting cases. It also satisfies CompoNet device vendors' demand to have circuits of easier fabrication.

4. Conclusion

The examination as described in this paper realized use of the simulation method, and enables prompt response to the demands for further physical layer enhancements. The technical exploration will continue for CompoNet to be further user friendly field network of sensor and actuator level.