A new methodology on the Pulse Shaping Method for Fast Transient Burst TestGenerator using Bridge Tap. Advances and New Research

Hitoshi Kijima, Koji Ochi
Tokaigakuin University
Yomiuri Rikougakuin, JAPAN
kijima@tokaigakuin-u.ac.jp, spiezswiss@yahoo.co.jp

Abstract: A fast transient phenomenon is observed when a power line circuit is switched on or off. To simulate this phenomenon, we use a fast transient burst test generator. Since the rise time of waveform generated by the fast transient burst test generator is very fast, a waveform distortion affects an immunity test result. Therefore, additional components such as resitor, capacitor and inductor are generally used for adjusting waveform when using a convetinal generator. It takes a long time to obtain an ideal waveform by trial and error. In this paper, a pulse-shaping method using bridge tap is proposed. It means that another coaxial cable having open circuit termination is added to the output terminal of the generator. We call this bridge tap method. The bridge tap is known that the performance is deteriorated. However, distortion can be decreased if it applies to the pulse that there is a distortion. By adjusting the length of the bridge tap depending on the distortion, the waveform can be controlled. This method has already beeing filed as a patent in Japan.

Key-Words: EMC, fast transient burst generator, IEC standard, bridge tap, Spice, rise time

1 Introduction

EMC technologies have been introduced in the articles [1]-[10]. One of EMC items to be considered is a fast transient phenomenon. The fast transient phenomenon is observed when a power line circuit is switched on or off . This transient phenomenon affects apparatus connected to this power line or the signal lines installed nearby [11]-[15]. To simulate this phenomenon, we use a fast transient burst test generator as defined by IEC61000-4-4 [11]. Since the rise time of the fast transient burst test generator is very fast such as 5n sec, waveform distortion affects an immunity test result. Therefore, additional components such as resitor, capacitor and inductor are generally used for adjusting waveform when using conventinal generator. It takes a long time to obtain an ideal waveform by trial and error.

In this paper, a pulse-shaping method using bridge tap is proposed. It means that another coaxial cable having open circuit termination was added to the output of the generator. We call this bride tap method. The bridge tap is known that the performance is deteriorated. However, distortion can be decreased if it applies to the pulse that there is a distortion. At the end of the termination of this bride tap, the reflection wave was generated due to unmatched impedance. As a result of adding bridge tap, both the output wave and the reflection wave are superimposed. By adjusting the length of the bridge tap depending on the distortion, waveform can be controlled. This method has already beeing filed as a patent in Japan [16].

2 A Fast Transient Burst Test Generator as Defined by IEC

Figure 1 shows one example of a fast trasient burst noise obserbed in the field with a 1/1000 voltage divider.

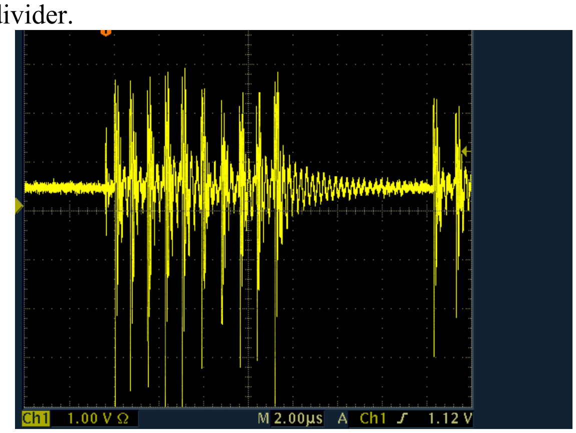

Fig.1: One example of a fast transient burst noise observed in the field

To simulate this phenomenon, we use a fast transient burst test generator as defined by IEC61000-4-4 [11]. Simplified circuit diagram of the fast transient burst test generator as defined by IEC61000-4-4 is shown in Fig. 2. It consists of a high-voltage DC power supply U, a charging resistor Rc, an energy storage capacitor Cc, a switch relay, an impulse duration matching resistor Rs, an impedance matching resistor Rm, a DC blocking capacitor Cd and a coaxial cable having 50Ω characteristic impedance.

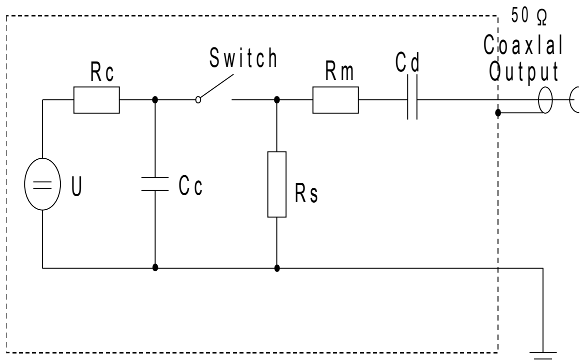

Fig.2: Simplified circuit diagram of a fast transient burst generator

Figure 3 shows the waveform of a single pulse into a 50Ω load as defined by IEC61000-4-4. Output waves are about 75 pulse trains in the frequency of 5 kHz or 100 kHz at intervals of 300 ms. Rise time Tr is an interval time while the instantaneous value of the pulse reaching 10% and 90%. Pulse width Td is width of the time of 50% value of the pulse. The output waveform should meet Tr=5ns and pulse width Td=50 ns.

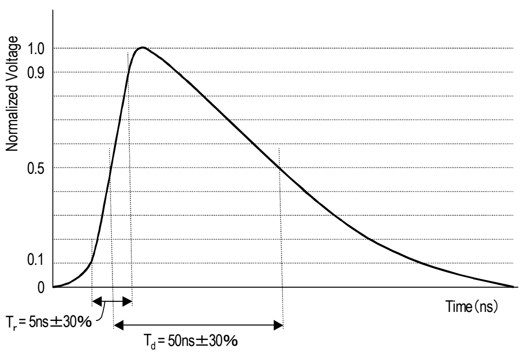

Fig.3: Waveform of a single pulse into a 50Ω load as defined by IEC

3 Problems of An Outputted Waveform when using a Conventional Generator

An outlook of experiment using the conventional fast transient burst generator is shown in Fig. 4. One example of an outputted waveform is shown in Fig. 5. When the charge voltage to a energy storage capacitor Cc is 4 kV, the peak voltage with an oscilloscope (50-ohm termination) is observed as 2 kV.

Even using a circuit as defined by IEC, an ideal waveform as shown in Fig. 3 is not always outputted. It means that the rise time is too fast such as 4ns as shown in Fig. 5. Another problem is a distortion of the waveform. Therefore, additional components such as resitor, capacitor and inductor are generally used for adjusting.

It takes a long time to obtain the ideal waveform by trial and error.

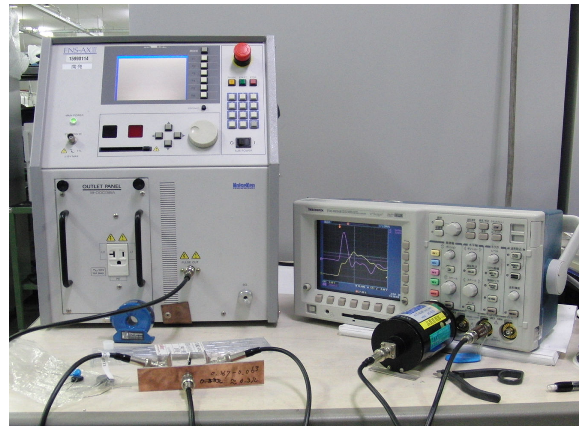

Fig.4: Outlook of expieriment using conventional generator

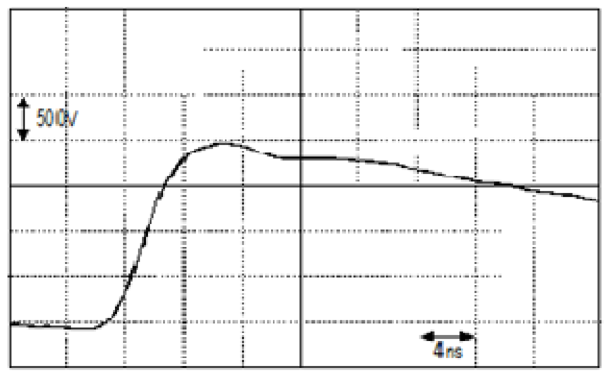

Fig.5: Outputted waveform of a single pulse into a 50Ω load when using conventinal generator

4 Problem Solution using Bridge Tap

4.1 Traveling waves and impedance matching

In the case of charge voltage is E[V] and the termination of the terminating resistor R_2 is carried out at 50Ω in Fig. 6, the output voltage V_{out} across the terminating resistor R_2 becomes V_{out} =E/2.

It means that only half voltage of charged voltage can be obtained. On the other hand, in the case of that the charge voltage is E[V] and the termination of the terminating resitor R_2 is carried out by high resistance value in Fig.6, the output voltage V_{out} across the terminating resistor R_2 becomes V_{out} =E.

It means that the same voltage of charged voltage can be outputted. This phenomenon can be explained using following travelling wave theory.

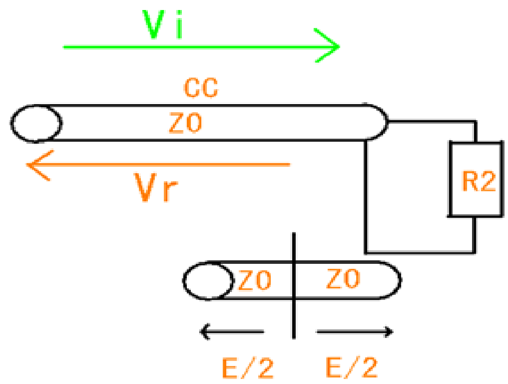

Fig.6: Travelling waves and impedance matching

In the case of charge voltage is E[V] and the termination of the terminating resitor R_2 is carried out at 50Ω in Fig. 6, the incoming voltage V_i becomes E/2. This is because a travelling wave spreads every E/2 in the direction of rightside and leftside. On the other hand, if impedance differs from Z_0 which is a characteristic impedance of a coaxial cable and R_2, the reflective voltage Vr will arise. If the termination of the terminating resistor R_2 is carried out by high resistance value, the reflective voltage Vr will become

Vr=Vi

Then it is set to V_{total}= Vi+Vr. It means that E [V] is outputted.

4.2 Explanation of Principle of the Bridge Tap Method

Bridge tap method is proposed in order to overcome the above-mentioned problem. It means that another coaxial cable having open circuit termination is added to the 50 Ω output terminal of the generator as shown in Fig. 7. We call this bridge tap method. At the end of the termination of this bridge tap, the reflection wave is generated due to unmatched impedance. As a result of adding bridge tap, the output wave and the reflection wave are superimposed. Therefore, by changing the length of this bridge tap, rise time etc. is controlled and waveform shaping becomes possible.

In Fig. 7, the output impedance of generator is 50Ω, and the characteristic impedance of the coaxial cable is 50Ω . Moreover the characteristic impedance of the coaxial cable as the bridge tap is 50Ω. First of all, it thinks about the state of the transition of the pulse shape with the point with which the bridge tap is connected. If the output side is seen with this point, the amplitude of the pulse of which it goes out respectively becomes 1/2 because the coaxial cable for the pulse output and the coaxial cable for the bridge tap are connected in parallel. However, it becomes total reflection and it returns because the other end of the coaxial cable as the bridge tap is opened. Therefore, after delay time of the round trip in the bridge tap, 1/2 of the output wave is synthesized to this delay wave and it is outputed.

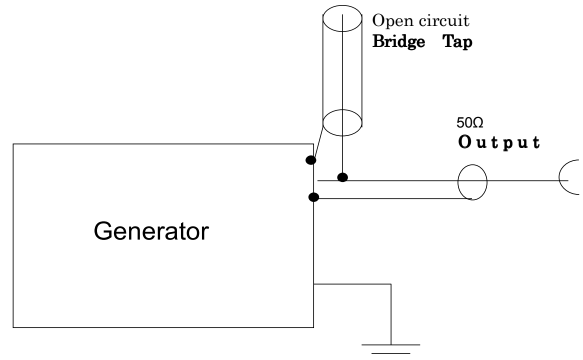

Fig.7: Block diagram of bridge tap method

4.3 When the Waveform is Ideal without Distortion

When the waveform is ideal without distortion, the bridge tap method should not be used. Because bridge tap is known that the performance is deteriorated.

However in order to claryfy the bridge tap method , we would lile to described the principle of the bridge tap method as follows.

The waveform without distortion in the range of 10 to 90 % rise time range is shown in Fig. 8. The alternate long and short dash line 111 is an original pulse from the pulse generation part. An original pulse is divided into the output coaxial cable and the bridge tap coaxial cable.

A wide dotted line 122 is a pulse propagating to the 50 Ω output coaxial cable side. We call this the first division pulse. On the other hand, a narrow dotted line 123 is a pulse propagating to the brigdeg tap coaxial cable side having open circuit termination. We call this the second division pulse.

The second division pulse is reflected at the end of open side of the bridge tap. After the first division pulse's being synthesized to the second division pulse, both pulses are superimposed indicated by the solid line 121.

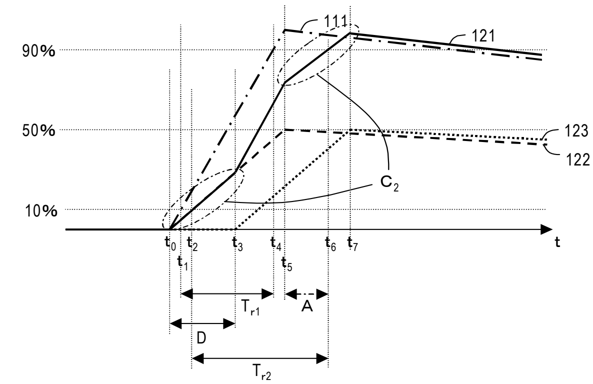

Fig.8: When the waveform is ideal without distortion

Where

D : Delay time when the second division pulse arrived late due to bridge tap

T_{r1} : Rise time of original pulse

T_{r2} : Rise time of total pulse

A : Difference between Tr1 and Tr2

t_0 : Time when original pulse was generated

t_1 : Time of original pulse reaches 10%

t_2 : Time of the first division pulse reaches 10%

t_3 : Time of the second division pulse arrived at the output coaxial cable

t_4 : Time of original pulse reaches 90%

t_5 : Time of original pulse reaches 100%

t_6 : Time of total pulse reaches 90%

t_7 : Time of total pulse reaches 100%

It is understood that the part of C2 of Fig. 8 is distorted. Therefore the bridge tap is known that the performance is deteriorated.

4.4 When the Waveform has a Distortion

It is general that there is a distortion in the rise time range. The waveform having distortion in the rise time range of 10 to 90% is shown in Fig. 9.

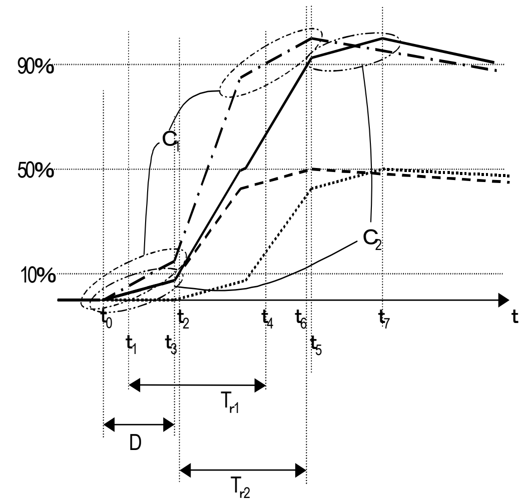

Fig. 9: When the waveform has a distortion

In this figure, an original pulse has a distortion in the range of 0～25% and 75～100%. C1 in Fig. 9 (alternate long and short dash line) is a distortion part of an original pulse. And C2 in Fig. 9 (solid line) is a distortion part after the wave shaping.

Because an original pulse is divided by the bridge tap, part C1 distortion is divided, too. After it undergoes waveform shaping, the instantaneous value of the pulse becomes the range of 0～12.5% and 87.5～100% so that the divided part distortion is not synthesized in a distortion part C2 of the pulse.

In a word, after it undergoes waveform shaping, there is distortion in 10～12.5% and 87.5～90%.

4.5 Discusions on Waveform Shaping

The bridge tap is known that the performance is deteriorated as explained in Fig.8. However, distortion can be decreased if it applies to the pulse that there is distortion like the explanation in Fig. 9. Therefore, it is possible to undergo waveform shaping. In a word, the accuracy of the rise time can be improved.

For instance, the delay time in the coaxial cable of 50Ω is about 5ns/m, the both-way time (length of the coaxial cable×10 ns/m) becomes delay time caused by the bridge tap.

To provide the delay of 1ns, the length of the bridge tap becomes 10cm. Taken into account of this delay time, the delay time is set up so that the portion of the divided distortion may not be superimposed. As a result, waveform shaping can be achieved.

5 The simulation results using Spice

5.1 Original waveform by Spice simulation

The simulations using Spice were carried out. The simulation circuit is shown in Fig. 10. Moreover, the output waveform by Spice simulation is shown in Fig. 11.

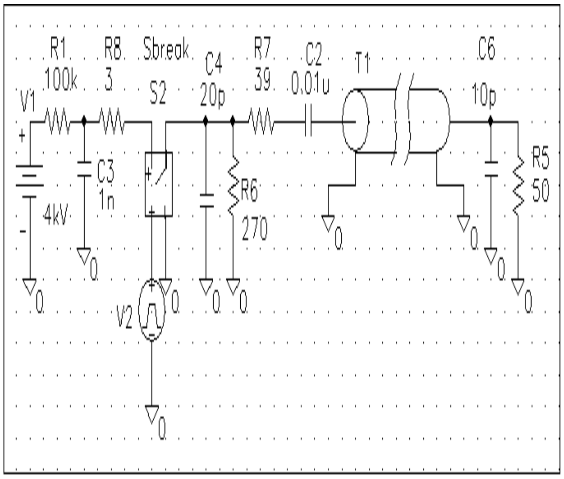

Fig.10: Generating part of fast transient burst generator using Spice

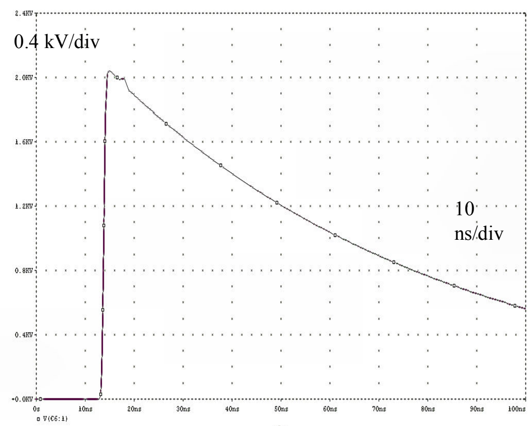

Fig.11: Outputted original waveform by Spice simulation

5.2 Total waveform by Spice simulation when a bridge tap is connected

The bridge tap was connected to the output end of a pulse generating part. And the changes of the waveform with the different bridge tap length were observed. A circuit diagram with a bridge tap is shown in Fig. 12 and outputted waveforms with different bridge tap length are shown in Fig. 13.

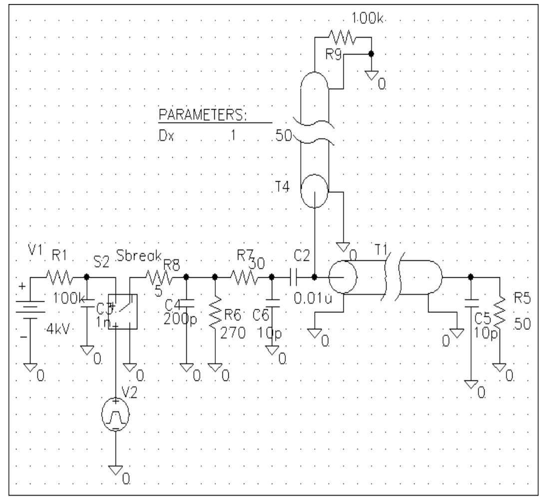

Fig.12: Circuit diagram with a bridge tap

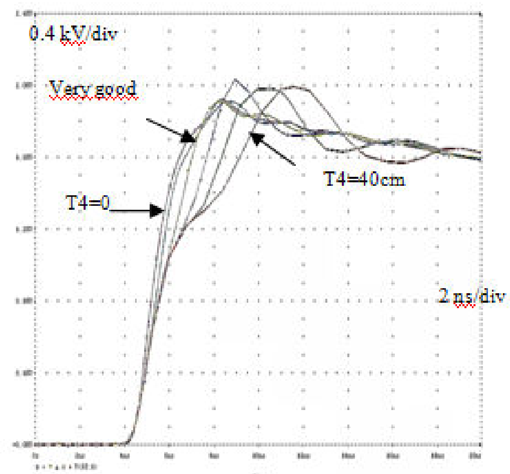

Fig.13: Outputted waveforms with different bridge tap length

The delay time cused by a bridge tap was changed in the pitch for 0.4ns from 0 ns to 2 ns. Since the delay time of a coaxial cable is about 5 ns/m, equivalent length of a coaxial cable becomes 0 cm to 40 cm.

In Fig. 13, from the left side to the right side, delay times were set starting 0 ns (0 cm) and finally 2 ns (40 cm) at every 0.4 ns (8 cm). When a coaxial cable becomes long, it turns out that it generates the step in a rise time area. In addition, the 3rd waveform from the left side was the most beautiful one in this simulation result. In this case, equivalent bridge tap length was 16 cm (0.8 ns).

6 Experimental Test Results using Bridge Tap

The example of an outputted waveform at the time of connecting a 20 cm bridge tap and a 30 cm output line in the expieriment is shown in Fig. 14.

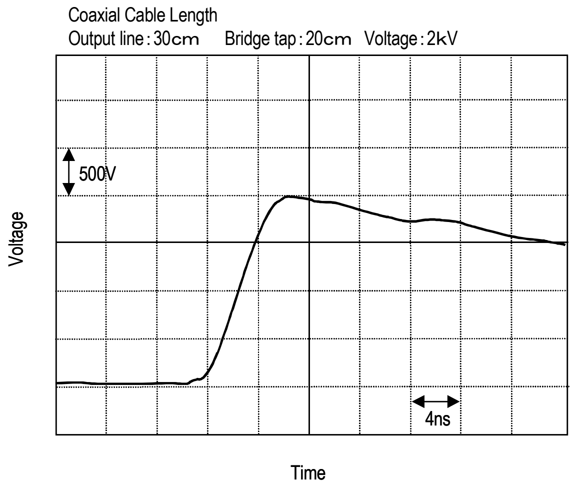

Fig.14: Outputted waveform having bridge tap length of 20 cm by experiment

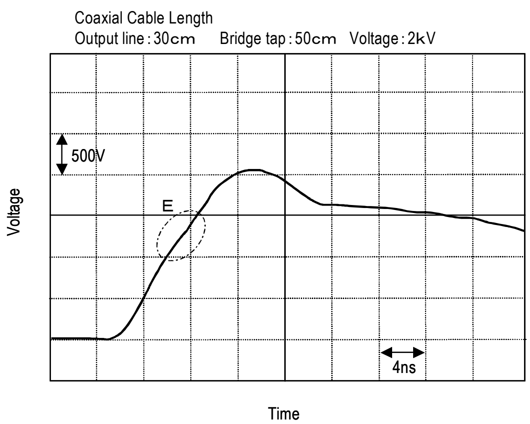

Fig.15: Outputted waveform having bridge tap length of 50 cm by experiment

If a waveform is seen in Fig.14, the rise time Tr is close to 5 ns, and a waveform became nearly the ideal.

Moreover, the waveform in the case of 50 cm bridge tap length and a 30cm output line length is shown in Fig. 15.

Compared with Fig. 14, it is understood that the rise time became slow considerably, and a step was made in the vicinity of the center of the part (E) in Fig. 15.

Bridge tap length is changed and the measured rise time are listed in Table 1. As the bridge tap length became long, the rise time became late. The optimal length of the bridge tap in this experiment was 25 cm.

The simulation results by Spice were almost the same those of experimental results.

Table 1: Relation between bridge tap length and rise time

Bridge tap length	Rise time (ns)
none	4.407
20 cm	4.516
25 cm	4.946
30 cm	5.426
40 cm	6.385
50 cm	7.503

7 Conclusion

A fast transient phenomenon is observed when a power line circuit is switched on or off. To simulate this phenomenon, we use a fast transient burst test generator. Since the rise time of waveform generated by the fast transient burst test generator is very fast such as 5 ns, waveform distortion affects an immunity test result. Therefore, additional components such as resitor, capacitor and inductor are generally used for adjusting waveform when using a convetinal generator. It takes a long time to obtain the ideal waveform by trial and error.

In this paper, a pulse-shaping method using bridge tap is proposed. It means that another coaxial cable having open circuit termination is added to the output terminal of the generator. We call this bridge tap method.

The bridge tap is known that the performance is deteriorated. However, distortion can be decreased if it applies to the pulse that there is a distortion. Therefore, it is possible to undergo waveform shaping. In a word, the accuracy of the rise time can be improved.

The main results are listed as follows.

(1)At the end of the termination of this bridge tap, the reflection wave is generated due to unmatched impedance.

(2)As a result of adding bridge tap, the output wave and the reflection wave are superimposed. By adjusting the length of the bridge tap, the waveform can be controlled.

(3)The optimal length of the bridge tap in the experiment was 25 cm.

(4)The simulation results by Spice were almost the same those of experimental results. The optimal length of the bridge tap in the simulation was 16 cm.

(5) This method has already beeing filed as a patent in Japan.

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