Loss Simulation of Ultrashort Pulse Extreme Points in the Microstrip C-section with Changing of Its Length

Rustam R. Gazizov, Ruslan R. Gazizov, Elizaveta E. Gazizova

***Abstract*—The simulation of the ultrashort pulse propagation along the conductors of the microstrip C-section has been carried out when the losses in conductors and dielectric were taken into account and without them. The voltage extreme points have been obtained with using of 7 values of the half-turn length. The highest voltage maximum exceeds the amplitude at the input by 31%. It is shown that the amplitudes of the voltage extreme points increase to 0.618 V when the length of the conductors is 0.15 m, but then begin to decrease to 0.457 V. It is revealed, that with increasing of the conductors' length, the influence of losses on the amplitudes of the voltage maximum and minimum is increased.**

***Index Terms*—simulation, ultrashort pulse, C-section, localization, signal extreme points.**

I. Introduction

WITH increasing of the radioelectronic equipment complexity their reliability and interference immunity decrease. Some of the ways to improve them are detection and localization of signal extreme points because their results may be useful to determine the places in radioelectronic equipment, which are most affected by interference [1, 2]. The detection and localization of signal extreme points have been investigated earlier in lossless two-turn meander line [3] and with losses in the conductors and dielectrics [4]. The C-section has been investigated with a variation of its geometric parameters in [5]. The influence of the ultrashort pulse duration and the separation between the C-section conductors on the detection and the localization of the voltage extreme points with losses has been investigated in [6]. Due to the fact that the investigation in [6] has been carried out without taken losses into account, it is necessary to fill this gap and to compare the results of two simulation types (with taken losses into account and excluding them).

The aim of this work is to investigate the influence of the losses in conductors and the dielectric on the detection and localization of signal extreme points of the signal with the variation of the C-section length and to compare them with lossless results.

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II. Simulation Parameters

The theoretical bases and algorithms of the time response calculation along conductors are given in [7, 8] and are not presented here. The computer simulation of the electromagnetic compatibility TALGAT software and the quasistatic analysis were used in the investigation.

A. Losses calculation in conductors and dielectric

The per-unit-length resistances (**R**) and conductivity (**G**) matrixes which are taking into account the losses in conductors and dielectrics are used in the loss simulation. For lossless simulation, these matrixes are equal to zero. For conductors' losses calculation the skin effect, the proximity effect and the losses in the ground plane are taken into account for the **R** matrix entries calculation by the method proposed in [9]. For dielectrics' losses calculation (**G** matrix) the model of relative permittivity and the tangent of the FR-4 material dielectric loss angel [10] were used.

B. Structure under Investigation

The microstrip C-section (the one-turn meander line) is selected for the investigation. The C-section circuit diagram is shown in Fig. 1 *a* and its cross-section is in Fig. 1 *b*.

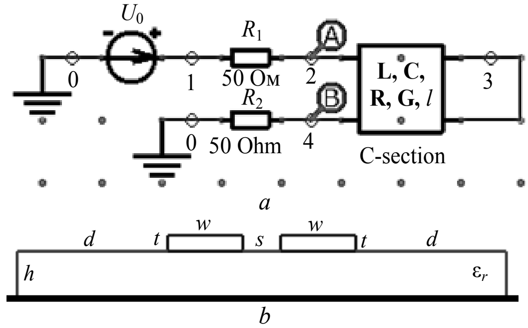

Fig. 1. The circuit diagram (*a*) and the cross-section (*b*) of the C-section

The width of conductor (w) – 0.659 mm, the separation between the conductors s=0.5·w, the conductor thickness (t) – 0.1 mm, the dielectric thickness (h) – 0.3 mm, d=2·w, the relative permittivity (ε_r) – 4.5, the tangent of the dielectric loss angle (tgδ) – 0.017. Resistances of 50 Ohm are connected to the ends of each conductor. The ultrashort pulse in trapezoidal form was used as excitation with the rise, flat top, and fall times by 100 ps and the amplitude of the electromotive force equaled to 1 V. The simulation of the ultrashort pulse propagation along the conductors of the C-section has been carried out with l=0.027, 0.05, 0.15, 0.2, 0.25, 0.3, and 0.5 m.

III. Simulation Results

The signal waveforms calculated with l=0,027 m and with losses were taking into account are shown in Fig. 2, where: U_b is the voltage waveform at the input, U_e – at the end, $U_{maxloss}$ – with the highest peak voltage $U_{minloss}$ – with the lowest peak.

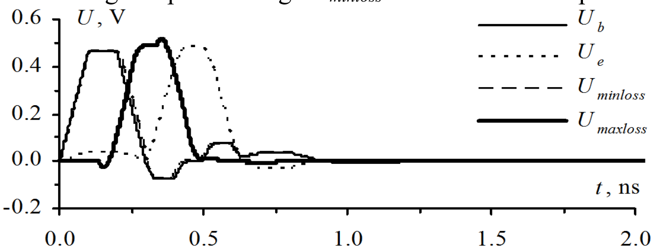

Fig. 2. Voltage waveforms calculated with losses when l=0.027 m

For a more understanding of the results, the scaled-up fragments with voltage extreme points are shown below. The voltage waveforms with the maximum are shown in Fig. 3 *a*, where U_{max} is the voltage waveforms calculated with lossless simulation and $U_{maxloss}$ – the waveforms calculated with loss simulation. The similar results for minimums are shown in Fig. 3 *b*.

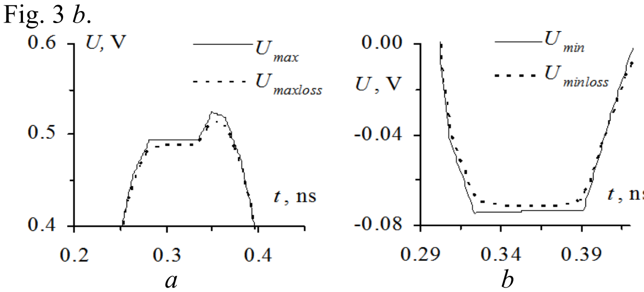

Fig. 3. Voltage waveforms with maximum (*a*) and minimum (*b*) when l=0.027 m

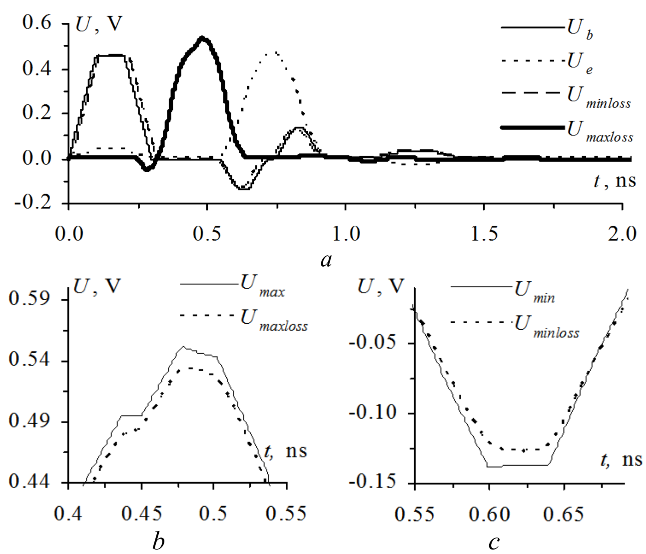

Fig. 4. Voltage waveforms calculated with losses when l=0.05 m (*a*), voltage maximums (*b*) and minimums (*c*)

The results for l=0.05, 0.15, 0.2, 0.25 m are shown in Figs. 4–7 respectively.

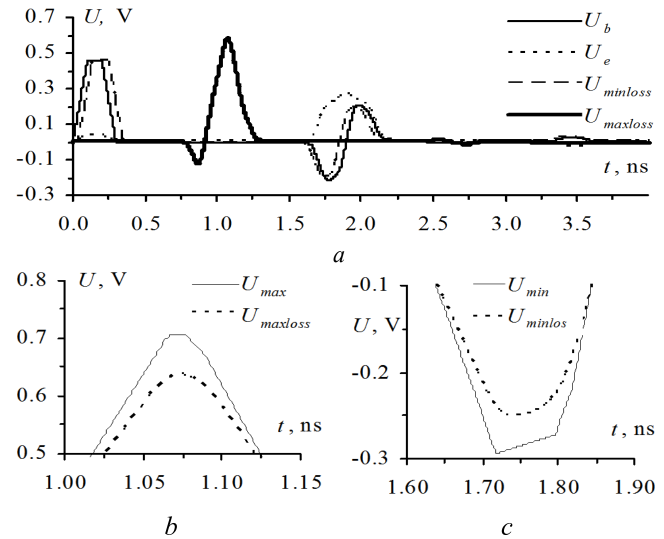

Fig. 5. Voltage waveforms calculated with losses when l=0.15 m (*a*), voltage maximums (*b*) and minimums (*c*)

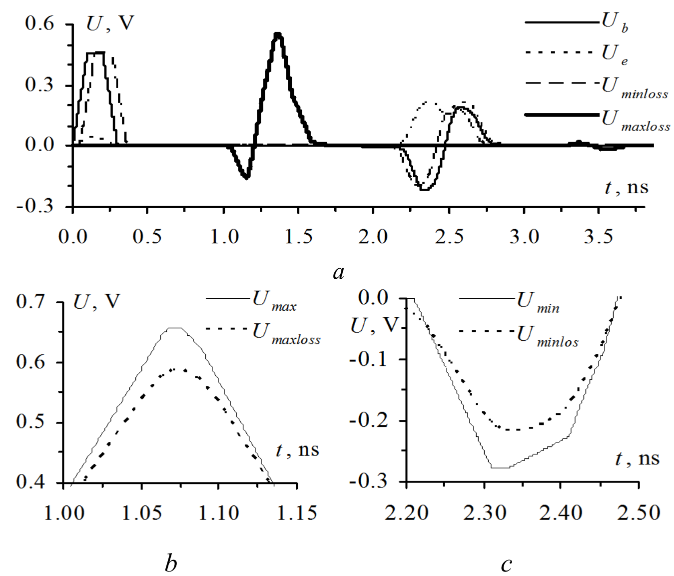

Fig. 6. Voltage waveforms calculated with losses when l=0.2 m (*a*), voltage maximums (*b*) and minimums (*c*)

The voltage waveforms calculated with lossless and loss simulations when l=0.3 and 0.5 m are shown in Fig. 8 and 9 respectively. The simulation results obtained with the l variation for the voltage maximums are shown in Table. I. The voltage minimum values are shown in Table. II. The N – the number of a half-turn, n – the number of a segment, d – the difference between the amplitudes presented by V and % (when the extreme points are located in different segments, the d was not calculated).

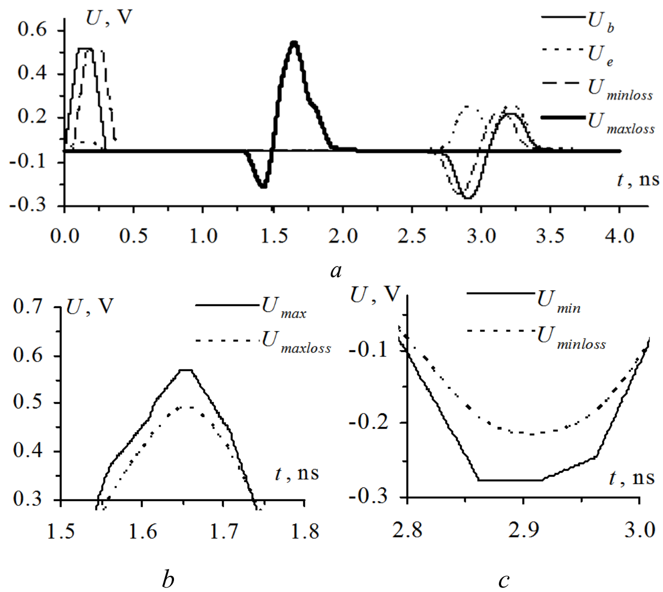

Fig. 7. Voltage waveforms calculated with losses when *l*=0.25 m (*a*), voltage maximums (*b*) and minimums (*c*)

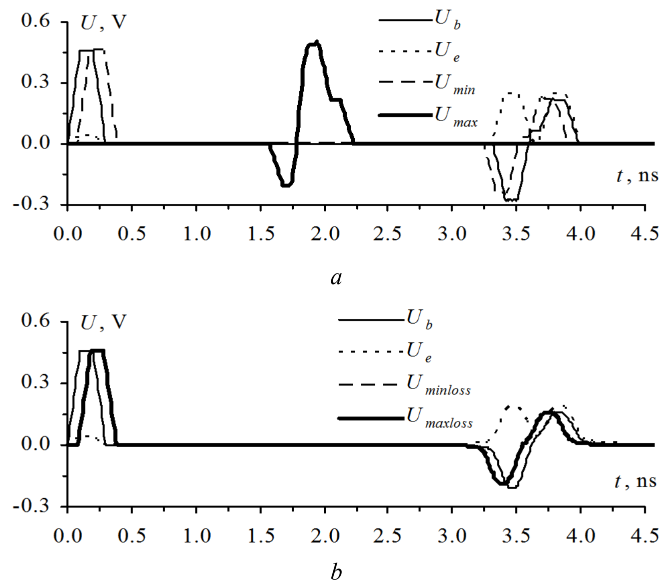

Fig. 8. Voltage waveforms for *l*=0.3 m (*a*) calculated with lossless (*a*) and loss (*b*) simulations

TABLE I. VOLTAGE MAXIMUMS

l, m	Loss simulation			Lossless simulation			*d*, V (%)
	N	*n*	$U_{maxloss}$, V	*N*	*n*	U_{max}, V	
0.027	2	19	0.518	2	19	0.525	0.007 (1.33%)
0.05	2	19	0.539	2	19	0.552	0.013 (2.36%)
0.15	2	20	0.618	2	20	0.657	0.039 (5.94%)
0.20	2	20	0.589	2	20	0.639	0.05 (7.82%)
0.25	2	20	0.516	2	20	0.570	0.054 (9.47%)
0.30	1	1	0.459	2	20	0.501	–
0.50	1	1	0.457	2	20	0.485	–

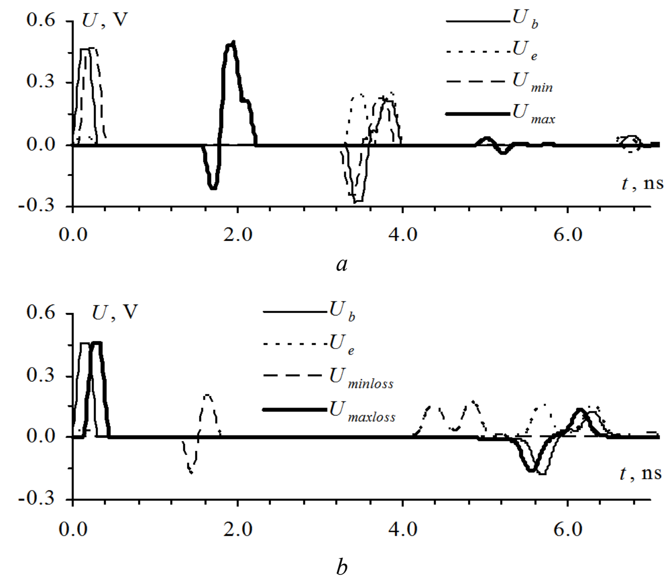

Fig. 9. Voltage waveforms for *l*=0.5 m (*a*) calculated with lossless (*a*) and loss (*b*) simulations

TABLE II. VOLTAGE MINIMUMS

l, m	Loss simulation			Lossless simulation			*d*, V (%)
	N	*n*	$U_{minloss}$, V	*N*	*n*	U_{min}, V	
0.027	1	1	–0.074	1	1	–0.075	0.001 (1.33%)
0.05	1	1	–0.134	1	1	–0.138	0.004 (2.90%)
0.15	1	1	–0.212	1	1	–0.243	0.028 (12.76%)
0.20	1	1	–0.215	1	1	–0.247	0.032 (12.96%)
0.25	1	7	–0.209	1	1	–0.248	0.039 (15.73%)
0.30	1	9	–0.205	1	1	–0.249	–
0.50	2	7	–0.194	1	1	–0.249	–

IV. DISCUSSION OF RESULTS

Let us consider the voltage waveforms changing when *l*=0.027 m. The Fig. 2 shows that the amplitude of the voltage maximum calculated with lossless simulation exceeds the amplitude at the input by 5% and equals to 0.525 V. The voltage maximum obtained with loss simulation exceeds the amplitude at the input by 3.6% and equals to 0.518 V.

Let us consider the voltage waveforms changing when *l*=0.05 m. The Fig. 4 shows that the amplitude of the voltage maximum calculated with lossless simulation exceeds the amplitude at the input by 10% and equals to 0.552 V. The voltage maximum obtained with loss simulation exceeds the amplitude at the input by 7.8% and equals to 0.539 V.

Let us consider the voltage waveforms changing when *l*=0.15 m. The Fig. 5 shows that the amplitude of the voltage maximum calculated with lossless simulation exceeds the amplitude at the input by 31% and equals to 0.657 V. The voltage maximum obtained with loss simulation exceeds the amplitude at the input by 23% and equals to 0.618 V.

Let us consider the voltage waveforms changing when *l*=0.2 m. The Fig. 6 shows that the amplitude of the voltage maximum calculated with lossless simulation exceeds the amplitude at the input by 28% and equals to 0.639 V. The voltage maximum obtained with loss simulation exceeds the amplitude at the input by 18% and equals to 0.589 V.

Let us consider the voltage waveforms changing when *l*=0.25 m. The Fig. 7 shows that the amplitude of the voltage maximum calculated with lossless simulation exceeds the amplitude at the input by 14% and equals to 0.57 V. The voltage maximum obtained with loss simulation exceeds the amplitude at the input by 3% and equals to 0.516 V.

However, in the cases with *l*=0.3 and 0.5 m, the situation changes. In these cases, the losses influence is stronger and maximums along conductors are not detected and are located at the input of the C-section (Fig. 8 and 9).

V. Conclusion

This paper considers the propagation of the ultrashort pulse along the conductors of the C-section with a variation of its length. The voltage extreme points are calculated and their decrease because of the losses is shown. Thus, the highest voltage maximum exceeds the amplitude at the input by 31%. It is also shown that with increasing the length of the half-turns (up to 0.15 m) the voltage extreme points increase up to 0.618 V, but then decrease down to 0.457 V. It is advisable to investigate the influence of the separation between the conductors and length variation of the two-turn meander line on the voltage extreme points.

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