Conditions for ultrashort pulse decomposition in multi-cascade protection devices based on meander microstrip lines

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Problem statement

- A powerful ultrashort pulse (USP), which can penetrate into the radio electronic equipment and disable it due to its wide spectrum and high power, is particularly dangerous.
- Traditional protection means (for example, voltage suppressors, varistors, passive RC and LC filters) often cannot provide adequate protection due to their disadvantages.
- Therefore, it is necessary to search for and explore the new ways of effective protection.

The aim of this paper is to formulate universal conditions for the USP decomposition in the meander MSL for an arbitrary number of cascades.

Dependencies of the real operating voltage relative to the declared:

- a – 3-Electrode Gas Discharge Tube;
- b – for metal oxide varistors;
- c – TVS diodes (With actuating signals with a front / width ratio: 5 ns/50 ns for EFT, 1,2 μs/50 μs for CWG, 10 μs/1000 μs for Telecom**)

**Note:** The values mentioned for Telecom are approximate and may vary depending on specific conditions and equipment.
Results of the work

The conditions for the USP decomposition in the meander MSL of an arbitrary number of cascades:

\[
2l_n \tau_{on} \geq \sum_{i=n+1}^{N} 2l_i \tau_{ei} + t_{\Sigma}, \quad n = 1...N
\]

\[
2l_n \tau_{en} \geq 2l_n \tau_{on} + \sum_{i=n+1}^{N} 2l_i \tau_{ei} + t_{\Sigma}, \quad n = 1...N
\]

where \(N\) is the number of the line turns. Thus, when sequentially substituting \(n\) with the number of cascades from 1 to \(N\), we obtain the conditions for the USP decomposition in a meander MSL consisting of \(N\) cascades.

Cross-section of one turn of the line (\(a\)) and circuit diagram of three turns (\(b\))

Voltage waveforms at the end of the meander MSL of 3 (\(a\)), 4 (\(b\)) and 5 (\(c\)) turns while ensuring the formulated conditions.

Attenuation 8.1 times

Attenuation 19.9 times

Attenuation 33.16 times
The optimal values of parameters for the meander microstrip line of three cascades: \( w_1=100 \, \mu m, \\
t_1=160 \, \mu m, \, s_1=20 \, \mu m, \, h_1=200 \, \mu m, \, \varepsilon_{r_1}=480, \\
l_1=100 \, mm; \, w_2=400 \, \mu m, \, t_2=600 \, \mu m, \, s_2=20.3 \, \mu m, \\
h_2=200 \, \mu m, \, \varepsilon_{r_2}=120, \, l_2=60 \, mm; \, w_3=w_2, \, t_3=t_2, \, s_3=s_2, \\
h_3=h_2, \, \varepsilon_{r_3} = \varepsilon_{r_2}, \, l_3=15 \, mm \\

The optimal values of parameters for the meander microstrip line of four cascades: \( w_1=100 \, \mu m, \\
w_2=w_3=w_4=400 \, \mu m, \, t_1=160 \, \mu m, \, t_2=t_3=t_4=600 \, \mu m, \\
s_1=s_2=s_3=s_4=20 \, \mu m, \, h_1=h_2=h_3=h_4=200 \, \mu m, \, \varepsilon_{r_1}=800, \\
\varepsilon_{r_2}=440, \, \varepsilon_{r_3}=110, \, \varepsilon_{r_4}=50. \\

The optimal values of parameters for the meander microstrip line of five cascades: \( w_1=100 \, \mu m, \\
w_2=w_3=w_4=w_5=400 \, \mu m, \, t_1=160 \, \mu m, \\
t_2=t_3=t_4=t_5=600 \, \mu m, \, s_1=s_2=s_3=s_4=s_5=20 \, \mu m, \\
h_1=h_2=h_3=h_4=h_5=200 \, \mu m, \, \varepsilon_{r_1}=800, \, \varepsilon_{r_2}=440, \, \varepsilon_{r_3}=110, \\
\varepsilon_{r_4}=\varepsilon_{r_5}=50. \\

Quasi-static simulation was performed in the TALGAT software

Conclusion

• The paper presents universal conditions, the providing of which allows the complete USP decomposition in a meander MSL of an arbitrary number of turns.

• The verification of these conditions was carried out on the example of meander MSLs of 2–5 turns.

• The fulfillment of these conditions makes it possible to attenuate a USP at the end of the meander MSL of 3 turns by 8.1 times, of 4 turns – 19.9 times and of 5 turns – 33.16 times.

Note that the values of the parameters of the meander MSL cross-sections were obtained by a heuristic search according to the criterion for fulfilling the formulated conditions without taking into account the real geometric parameters. Therefore, in practical implementation of such devices, it is necessary to take into account real parameters. Since the structures under investigation are linear this can be achieved through scaling and optimization with genetic algorithms.
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