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Advanced Technologies in Material Science,
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# «MIP: Engineering-2020: Modernization, Innovations, Progress: Advanced Technologies in Material Science, Mechanical and Automation Engineering»

## «Complete ultrashort pulse decomposition in modal filters with circular symmetry»

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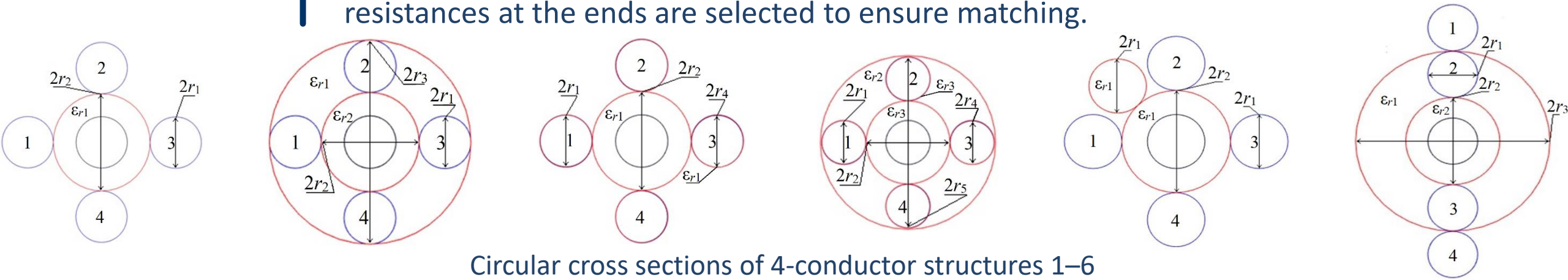
# Problem statement

- There are problems: a narrow group of multiconductor modal filters (MF), limited to strip structures and incomplete decomposition of the exciting ultrashort pulse (USP) at the end of MF with circular symmetry.
- Task 1: to identify the possibility of complete USP splitting in MF with a circular cross section.
- Task 2: to improve their characteristics through optimization.

# Solution methods

- The parameters and waveforms of the structures were calculated in the TALGAT software.
- We did not take into account losses at this stage of the study.
- It is assumed that $\varepsilon_{r1}=5$, $\varepsilon_{r2}=10$, $\varepsilon_{r3}=20$ and $\varepsilon_{r4}=3$, and $r_1=0.9$ mm, $r_2=1.7$ mm, $r_3=6.1$ mm, $r_4=0.91$ mm and $r_5=6.2$ mm. The length of the structures is 1 m and the values of the resistances at the ends are selected to ensure matching.



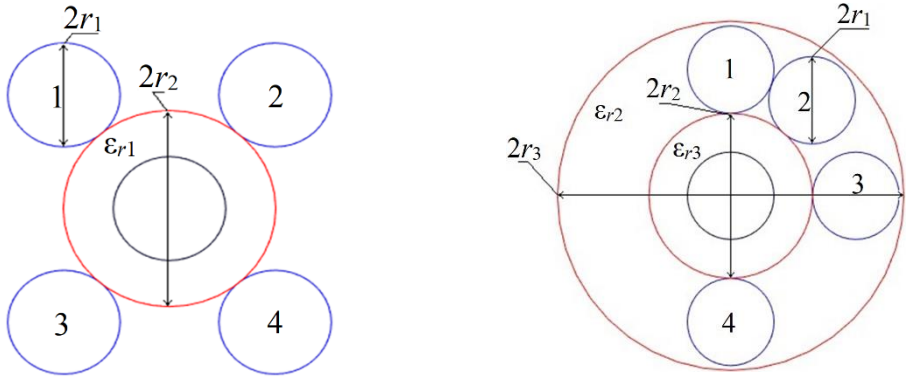

Circular cross sections of 4-conductor structures 1–6

The calculated pulse voltages (V) and per-unit-length modal delays (ns/m) for structures 1–6

| № | $U_{in}$ | $U_1$ | $U_2$ | $U_3$ | $U_4$ | $\tau_1$ | $\tau_2$ | $\tau_3$ | $\tau_4$ | min (Δτ) | max (Δτ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 2.49 | 0.6 | 1.26 | | 0.59 | 4.37 | 4.73 | 4.73 | 6.21 | 0 | 1.48 |
| **2** | 2.49 | 0.6 | 1.25 | | 0.59 | 7.58 | 7.87 | 7.87 | 9.87 | 0 | 2 |
| **3** | 2.5 | 0.6 | 1.25 | | 0.59 | 3.49 | 3.78 | 3.78 | 4.82 | 0 | 1.04 |
| **4** | 2.49 | 0.6 | 1.25 | | 0.59 | 10.55 | 10.93 | 10.93 | 13.86 | 0 | 2.93 |
| **5** | 2.5 | 0.23 | 0.42 | 1.13 | 0.63 | 4.44 | 4.74 | 4.95 | 6.26 | 0.208 | 1.35 |
| **6** | 2.51 | 0.9 | 0.59 | 0.02 | 0.24 | 3.63 | 4.44 | 7.88 | 9.22 | 0.81 | 3.43 |

# Solution methods

- As can be seen, the min (Δτ) values for structures 1–4 are 0 ns/m, which means that some values of $\tau_i$ coincide, as a consequence, the resulting attenuation coefficient decreases.
- This is associated with the equal coupling between the active and passive conductors.




Circular cross sections of 4-conductor structures 1–2 (after optimization)

The calculated pulse voltages (V) and per-unit-length modal delays (ns/m) for structures 1, 2 with optimal parameters.

| № | $U_{in}$ | $U_1$ | $U_2$ | $U_3$ | $U_4$ | $\tau_1$ | $\tau_2$ | $\tau_3$ | $\tau_4$ | min (Δτ) | max (Δτ) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 2.49 | 0.61 | 0.62 | 0.62 | 0.59 | 4.49 | 4.79 | 4.97 | 6.29 | 0.18 | 1.317 |
| **2** | 2.5 | 0.75 | 0.35 | 0.22 | 0.31 | 4.8 | 5.24 | 5.74 | 7.22 | 0.44 | 1.476 |

# Conclusions

The work considers the simulation and optimization of multiconductor transmission lines with circular symmetry to ensure protection against ultrashort pulses. Six cross section configurations of such structures are considered. Parametric optimization was performed by heuristic search to ensure complete decomposition of the exciting pulse into a pulse sequence in the 50 Ω path.

- The reason for the coincidence of some values of $\tau_i$ was revealed.
- As a result of the performed optimization, we obtained the structures, in which complete splitting of the USP is achieved with minimized amplitude of the output signal.
- Future research would be noteworthy to study the in-depth optimization of such structures according to various criteria (including global optimization methods), their cascading, and their performance when they are shielded.

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