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Computer Models of Meander Slow-wave System with Additional Shields

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Introduction

In microwave devices various types of slow-wave systems are used. For example helical slow-wave systems offer a wide pass-band and can be applied for retardation of electromagnetic waves in traveling-wave tubes and traveling-wave cathode ray tubes [1, 2]. In this paper meander slow-wave systems are analyzed. They are widely used as delay lines and deflection systems because a pass-band of such systems starts at low frequencies. Moreover meander slow-wave systems are used in antennas for wireless communication devices [3, 4], radio frequency identification (RFID) systems [5, 6], filters [7–9], couplers [10, 11] and phase shifters [12, 13].

A typical meander slow-wave system is shown in Fig. 1. Generally it consists of several parallel conductors connected together to form a shape of meander. Conductors are placed on a dielectric substrate with the permittivity ε_r and a thickness h. Bottom of the substrate is covered by a conductive layer which has a function of a grounded external shield. A single conductor has a length of $2A$ and width w, a gap between neighboring conductors is s.

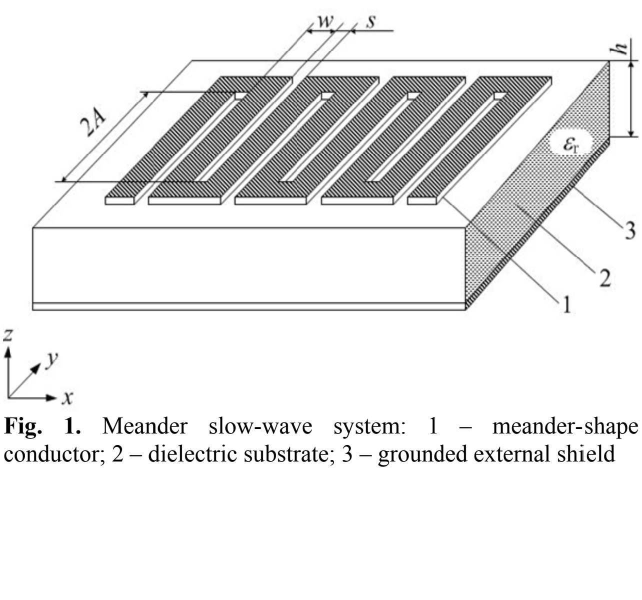

Fig. 1. Meander slow-wave system: 1 – meander-shape conductor; 2 – dielectric substrate; 3 – grounded external shield

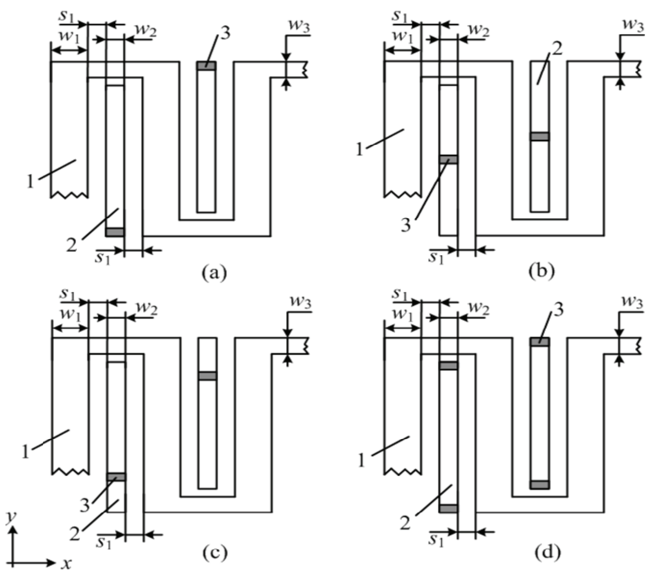

Fig. 2. Top view of proposed models of meander slow-wave system with additional shields grounded at: (a) – one edge; (b) – center; (c) – point between the edge and a center; (d) – both edges; 1 – meander-shape conductor; 2 – additional shield; 3 – grounded via

Wideband signals which propagate through the meander slow-wave system are distorted because of the phase delay time dispersion. In this paper possibilities of reducing a dispersion of phase delay time and widening the pass-band of meander slow wave system are analyzed. During the analysis, new models of meander slow-wave system with additional shields are proposed.

Proposed models of meander slow-wave system with additional shields

In order to reduce the electromagnetic interaction, additional shields are inserted between adjacent meander

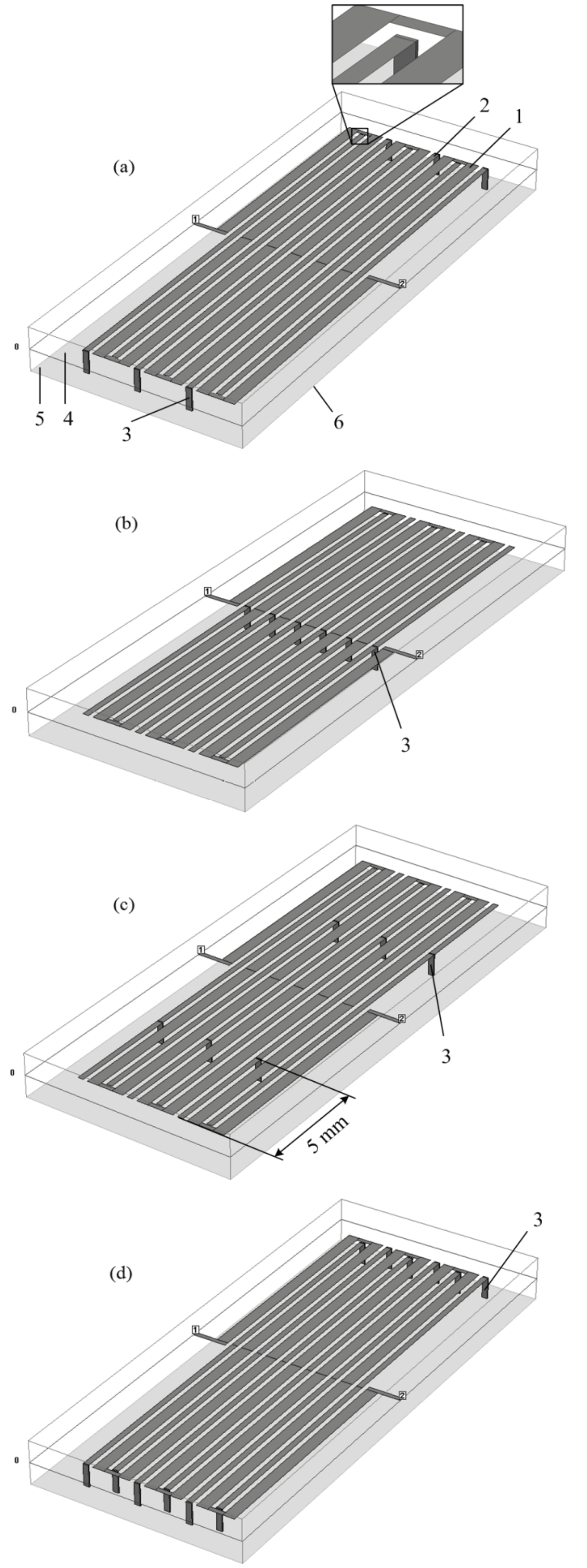

Fig. 3. 3D models of meander slow-wave system with additional shields grounded at: (a) – one edge; (b) – center; (c) – point between the edge and a center; (d) – both edges: 1 – meander-shape conductor; 2 – additional shield; 3 – grounded via; 4 – air; 5 – dielectric substrate; 6 – grounded external shield

conductors and connected to a grounded external shield by via. In a work [14] a model of meander slow-wave system with additional shields grounded at one edge was proposed. Top view of such model [14] is shown in Fig. 2, a.

Characteristics of meander slow-wave system can be changed by grounding additional shields at different points. In this paper three models of meander slow-wave system with additional shields are proposed. The first one is shown in Fig. 2, b. Here additional shields are grounded by via in the center. In the second one grounded via is placed at the point which is situated between the edge and a center of additional shield as shown in Fig. 2, c. In the third model which is shown in Fig. 2, d, additional shields are grounded by vias at both edges.

3D models of meander slow-wave system with additional shields are shown in Fig. 3. Proposed models were simulated using *Sonnet*® software [15]. During simulation a model of meander slow-wave system which consists of 7 parallel conductors, two layers of dielectric, grounded external shield and vias was created. The slow-wave system has a rectangular shape, its top and bottom planes are defined as free space and lossless metal respectively. Bottom dielectric layer has permittivity of $\varepsilon_r = 7.3$, top layer is air. The width of a gap between a main conductor and additional shields s_1 is fixed (Fig. 3, a) and is set to 0.2 mm. Input and output of the system were placed at the center of meander since input impedance at this point has only a real part [16]. Meander line dimensions were set to: $2A = 20$ mm, $w_1 = 0.5$ mm, $w_2 = 0.25$ mm, $w_3 = 0.2$ mm, $h = 0.5$ mm.

Results

The phase delay time dependence on the frequency was calculated from S_{21} parameter, to compare the models, using following formula

$$t_d = \frac{S_{21\_pd}(q)}{360^\circ \times f}, \quad (1)$$

where S_{21_pd} is the phase difference between slow-wave system's input and output, f is the frequency of analysis in Hz.

The phase delay time dependence on the frequency of meander slow-wave system with additional shields grounded at one edge (Fig. 3, a) is shown (curve 2) in Fig. 4. For comparison, the curve representing the phase delay time of meander slow-wave system without additional shields (Fig. 1) which has same dimensions is also shown (curve 1) in Fig. 4. It is seen that when additional shields are inserted, slow-wave system acts like stop-band filter and resonance phenomena can be observed at frequencies of about 1.4 – 1.75 GHz. Moreover it can be noted that an insertion of additional shields reduces the phase delay time dispersion. In a frequency range up to 1 GHz reduction of phase delay time is about 2.3 times.

The phase delay time dependence on frequency of meander slow-wave system with additional shields grounded at the point between the edge and a center is shown in Fig. 5.

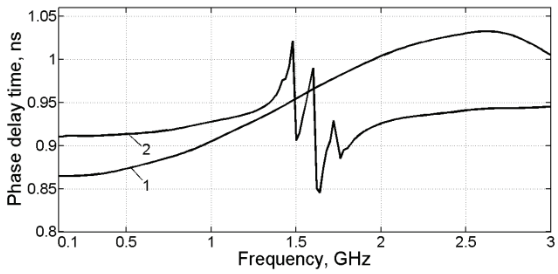

Fig. 4. Delay time dependence on the frequency of meander slow-wave system: 1 – without additional shields; 2 – with additional shields grounded at one edge

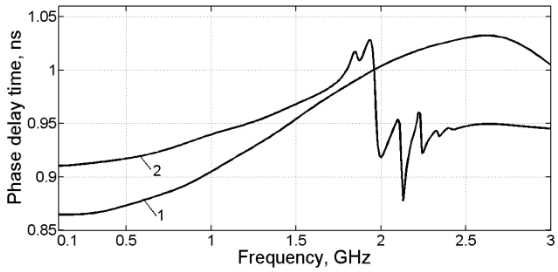

Fig. 5. Delay time dependence on the frequency of meander slow-wave system: 1 – without additional shields; 2 – with additional shields grounded at a point between the edge and a center

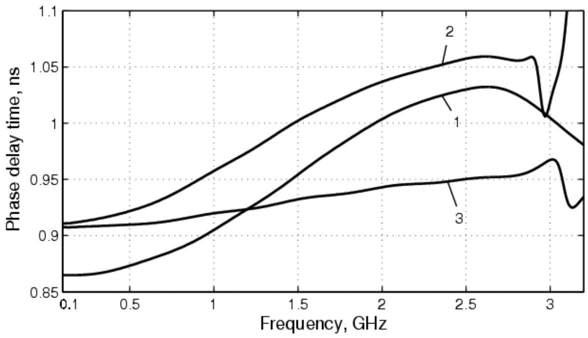

Fig. 6. Delay time dependence on the frequency of meander slow-wave system: 1 – without additional shields; 2 – with additional shields grounded at the center; 3 – with additional shields grounded at both edges

It can be seen that when the grounding point of additional shields is shifted by 5 mm towards the center of a system (Fig. 3, c), the resonant frequency increases. Therefore the frequency range where resonance phenomena can be observed is also shifted to higher frequencies of 1.85 – 2.45 GHz. Also a small dispersion can be seen after the resonance phenomena. Moreover a slight increase of dispersion can be observed in the frequency range up to 1 GHz when compared with meander slow-wave system with additional shields grounded at one edge (Fig. 2, a).

Fig. 6 shows the phase delay time dependence on the frequency of meander slow-wave system with an additional shield grounded at the center (Fig. 3, b) and at both edges (Fig. 3, d).

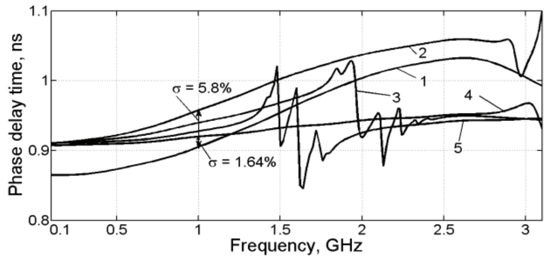

Fig. 7. Comparison of delay time of meander slow-wave systems: 1 – without additional shields; 2 – with additional shields grounded at the center; 3 – with additional shields grounded at a point between the edge and a center; 4 – with additional shields grounded at both edges; 5 – with additional shield grounded at one edge

It can be seen that when additional shields are grounded at the center, resonance phenomena is shifted to even higher frequencies starting at 2. 9 GHz and an increase of the phase delay time is about 10 %. When additional shields grounded at both edges, least phase delay time is obtained. In this case phase delay time in the frequency range up to 2.8 GHz is almost unchanged.

The comparison of phase delay time dependencies on the frequency of proposed models is shown in Fig. 7. It can be seen that in all proposed models of meander slow-wave system a phase delay time is increased in lower frequencies. For example at 1 GHz relative difference of increased phase delay time varies from 1.64 % to 5.8 % when compared to the meander slow-wave system without additional shields. Moreover a meander slow-wave system with additional shields grounded at both edges has the least dispersion. Such slow-wave system can be used in frequency range up to 1.82 GHz.

Conclusions

1. Wideband signals which propagate through a meander slow-wave system are distorted because of the phase delay time dispersion. In this paper possibilities of reducing phase delay time dispersion and widening the pass-band of meander slow wave system are analyzed.

2. In order to reduce electromagnetic interaction additional shields are inserted between adjacent meander conductors and connected to a grounded external shield by via. Characteristics of meander slow-wave system can be changed by grounding additional shields at different points. This paper presents three new models of meander slow-wave system with additional shields. Models were designed and analyzed using *Sonnet*® software.

3. To compare the proposed models a phase delay time dependence on the frequency was calculated from S_{21} parameter. The impact on dispersion properties of meander slow-wave system of grounding point of additional shield was investigated. A largest impact is observed when grounded via is placed in the center of additional shield. In such case an increase in phase delay time is about 10 %. Moreover when additional shields are grounded at both edges, least phase delay time is obtained and phase delay time in the frequency range up to 2.8 GHz is almost unchanged.

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In microwave devices various types of slow-wave systems are used. Meander slow-wave systems are widely used as delay lines and deflection systems because pass-band of such systems starts at low frequencies. Wideband signals which propagate through the meander slow-wave system are distorted because of the phase delay time dispersion. In this paper possibilities of reducing a phase delay time dispersion and widening the pass-band of meander slow wave system are analyzed. Three new models of a meander slow-wave system with additional shields are presented. Models are designed and analyzed using *Sonnet*® software. For comparison of the models phase delay time dependence on frequency is calculated from S_{21} parameters. The impact on dispersion properties of meander slow-wave system of grounding point of additional shield is investigated. Ill. 6, bibl. 16 (in English; abstracts in English and Lithuanian).

E. Metlevskis, R. Martavičius. Kompiuteriniai meandrinės lėtinimo sistemos su papildomais ekranais modeliai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 3(119). – P. 61–64.

Mikrobangų įtaisuose taikomos įvairios lėtinimo sistemos. Meandrinės lėtinimo sistemos plačiai naudojamos kaip vėlinimo linijos bei kreipimo sistemos, nes jų praleidžiamųjų dažnių juosta prasideda žemuosiuose dažniuose. Plačiajuosčiai signalai, sklindantys tokiose sistemose, yra iškraipomi dėl fazinio vėlinimo laiko dispersijos. Straipsnyje aptariamos meandrinės lėtinimo sistemos fazinio vėlinimo laiko dispersijos sumažinimo bei praleidžiamųjų dažnių juostos išplėtimo galimybės. Pateikiami trys, meandrinės lėtinimo sistemos su papildomais ekranais modeliai, kurie yra sudaromi naudojant *Sonnet*® programinę įrangą. Modeliams palyginti iš S_{21} parametrų apskaičiuojama fazinio vėlinimo laiko priklausomybė nuo dažnio. Tiriama papildomų ekranų įžeminimo taško įtaka meandrinės lėtinimo sistemos dispersinėms savybėms. Il. 6, bibl. 16 (anglų kalba; santraukos anglų ir lietuvių k.).