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Investigation of Meander Delay System Properties using the „MicroWave Studio“ Software Package

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Introduction

Symmetrical and non-symmetrical meander delay-deflecting systems have been widely investigated by analytical methods. In the works on meanders systems, frequency dependences of the phase delay time and wave resistance have been most frequently investigated in the low and medium frequency range until the phase angle θ between currents and voltages of adjacent conductors does not exceed $\pi/2$. As the multi-line method is suitable for modeling the planar electrode structure of meander systems [1], numerical methods up to now have been scarcely applied to the investigation of these systems. The investigation of properties of helical delay systems has shown that numerical methods (application of MicroWave Office and MicroWave Studio packages) allow revealing many new and unknown properties of the systems. Numerical methods evaluate the finite electrode length and reflections which have influence on frequency dependences of the transfer factor and input impedance, enables observing the electromagnetic field distribution in the system cross-section and scattering at the ends of the system.

The original patented meander delay-deflecting system is known [2], but its characteristics and possibilities have not been investigated yet.

The aim of this work is to investigate and compare characteristics of known symmetric and non-symmetric systems as well as systems with meander electrodes shifted by half the period as well as to evaluate the influence of the finite electrode length on the amplitude-frequency response and phase-frequency response (AFR and PFR).

Model and investigation methods

The meander system patented by the authors of the work [2] was chosen for the investigation. The construction of non-symmetric version of this system created using the internal MicroWave Studio graphical editor is presented in Fig. 1. The system comprises the meander *1*, single side through dielectric plating *2* with holders *3*, around which plating windows are left, and the external shield *5*. The meander width h = 8,5 mm, step $L = 1$ mm and the turn width $l = 0{,}5$ mm determine the structural retardation factor value $k \cong 10$. The required wave resistance of 50Ω of the system in the low frequency range was ensured by selecting the meander distances to the single side through dielectric plating w_1=0,2 L and the external shield w_2 = 0,1 L.

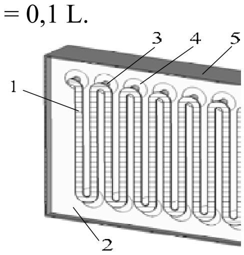


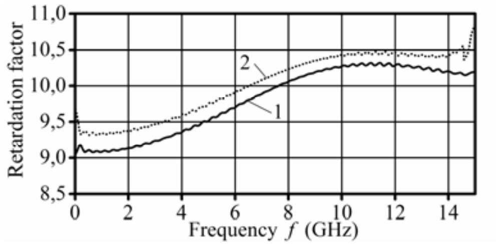
Fig. 1. Non-symmetrical meander delay system: 1 – meander; 2 – single side through dielectric plating; 3 – holder; 4 – plating window around the holder; 5 – external shield

The investigation scheme of the meander delay system is very simple: the scheme of the system construction is drawn using the system internal graphical editor on a scale 1:1 as well as the signal source and load switching-on ports are indicated. The methods of measuring the frequency characteristics of the phase delay time and wave resistance by the CST MWS program are analogous to the scheme and methods presented in [3, 4].

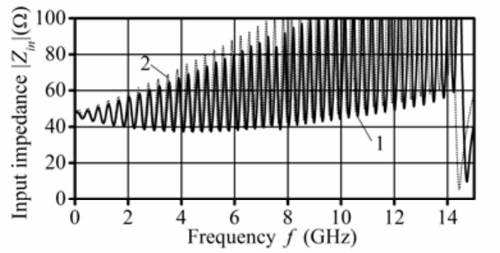
Frequency characteristics of the retardation factor and the input impedance of the non-symmetric meander delay system are presented in Fig. 2, a and b.

First of all the statement of the authors, that in the patented construction the dielectric practically does not influence the system properties, was tested. The performed investigations have shown that the phase delay time dispersion and AFR of the systems with the ideal dielectric (ε = 1) and real dielectric (ε = 4) coincide. The increase in the phase delay time due to the dielectric in the whole frequency range is less than 1%. When ε = 8, the pass-band becomes narrower by ≈ 1 GHz, and the retardation factor increases by ≈ 2,5 % (curves *2* in Fig. 2 and 3).
Further investigations have shown that a large phase delay time dispersion (compared with the helical systems) is characteristic of the meander delay system. The retardation

factor in the low frequency range is smaller than the structural one (Fig. 2, a). It reaches the structural retardation factor value of 10.4 at about 10 GHz. In the frequency range from 0 to the stop-band boundaries when the phase difference between currents and voltages of adjacent turns reaches π (in this case it happens at ≈15 GHz), the retardation factor changes by more than 10 %. Frequency dependence of the input impedance is presented in Fig. 2, b.



a



b

Fig. 2. Frequency dependences of retardation factor (a) and input impedance (b) calculated for the meander delay system (Fig. 1) with different dielectrics of meander holders: 1 – $\varepsilon = 1$; 2 – $\varepsilon = 8$

The obtained results show that the input impedance in the low frequency range makes up about 45Ω. With the frequency increase the input impedance of the meander delay system increases. Non-uniformities of input impedance are caused by reflections from the system input and output. The distance between two input impedance minimums or maximums Δf is inversely proportional to the meander system twofold delay time $t_V = 1/2 \cdot \Delta f$.

The obtained results agree well with the theoretical research results of known authors, specialists in this field [5, 6]. AFR of the meander delay system are presented in Fig. 3. The results show that reflections appear in the higher frequency range (over 2 GHz). The cause of reflections is the capacitance non-uniformities at the ends of the system and the increased wave resistance of the meander delay system at high frequencies. When the phase angle θ between currents and voltages of adjacent turns approaches $\pi/2$ and the integer number of half-waves of the non-retarded wave fits along the meander conductor, reflections in the system are minimal.

Investigation of the symmetric meander system

The scheme of the symmetric meander system investigation is shown in Fig. 4. Two signal sources with internal impedances Z_g are switched-on at the system input. Synchronic anti-phase signals are applied to the arms *1* and *2* of the system. Outputs 1ʿ and 2ʿ of the system are loaded with impedances Z_L. These impedances are selected to be equal to the system wave resistance ≈50 Ω in the low frequency range.

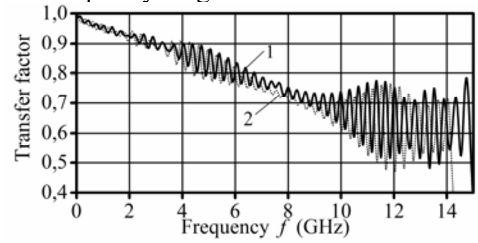


Fig. 3. AFR of non-symmetric meander delay system with different dielectrics of meander holders: 1 – $\varepsilon = 1$; 2 – $\varepsilon = 8$

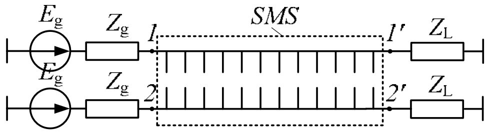


Fig. 4. Scheme of switching-on of the symmetric meander system (SMS) into the signal channel

The symmetric meander system chosen for the investigation (Fig. 5) consists of two non-symmetric systems (Fig. 1) by placing them symmetrically to the external shield plane (at the w_2 distance from the meander). The distance between meander electrodes in the symmetric system is equal to 2 w_2.

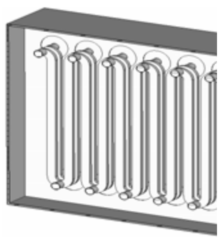


Fig. 5. Symmetric meander system

In the known works [1] for the simplification of theoretical research the symmetric delay-deflecting systems are changed by non-symmetric ones by dividing them into two parts by the ideal conductor plane crossing the system symmetry axis. During this investigation it was intended to ascertain if such a change is correct. For this purpose, characteristics of the non-symmetric meander system (Fig. 1) and of the symmetric system formed from it were compared.

The performed investigations of non-symmetric systems and symmetric meander systems formed from them as well as comparison of their characteristics have shown that in case the distance between the symmetric system meander electrodes is of the same order or larger than the distance between the meander conductors, characteristics of non-symmetric and symmetric systems practically coincide. When the distance between the symmetric system electrodes decreases, its change by a non-symmetric system can induce errors. AFR of the non-symmetric system (solid curve *1*) and of the symmetric system formed from it (dotted curve *2*), when 2 w_2=0,2 L, are shown in Fig. 6.

In this case the symmetric system retardation factor by about 5% lower and a larger wave resistance are obtained. This can be explained by the MicroWave Studio automated decomposition into finite elements.

Investigation of the meander system with electrodes shifted by half the period

The meander system, in which meander electrodes shifted by half the period are used, is known. It is shown in the work [1] that the system is distinguished for the larger wave resistance and the retardation factor when distances between meander electrodes are small, while with larger distances between meander electrodes the system advantages disappear.

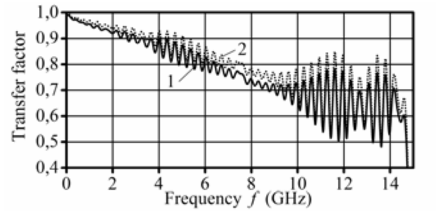


Fig. 6. AFR of non-symmetric (1) and symmetric (2) meander systems

A sketch of the system with shifted meander electrodes is presented in Fig. 7.

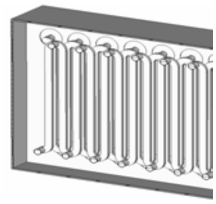


Fig. 7. System with meander electrodes shifted by half the period

The investigation results are presented in Figs. 8 and 9 together with the results of the symmetric meander system (Fig. 5).

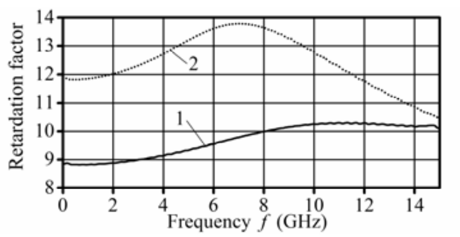


Fig. 8. Frequency dependences of retardation factors: 1 – of the symmetric meander system; 2 – of the system with shifted meander electrodes

Analysis of the obtained results and comparison with the results of the symmetric system with a small distance between meander electrodes have shown that the wave resistance of the system with shifted meander electrodes in the low frequency range increased from 47Ω to 61Ω, and the retardation factor – from *9* to *12* (Fig. 8). AFR of the systems are presented in Fig. 9.

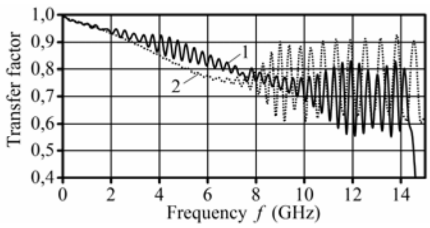


Fig. 9. Amplitude-frequency responses: 1 – of the symmetric meander system; 2 – of the system with shifted meander electrodes

Their comparison shows that in the low frequency range until the phase angle between adjacent conductor currents and voltages $\theta \le \pi/2$ in the system with shifted meander electrodes the suppression is much larger and there are no reflections. The reason for this can be not uniform distribution of surface currents in meander conductors. The relation between central parts of meander conductors is strong because they are very close, currents in them flow in one direction and magnetic fields induced by them are summed. This cannot be said about peripheral parts of meanders where conductor loops are shifted. In spite of that, the pass-band of systems with shifted meander electrodes at the 3 dB level is not narrower, and an odd wave also propagates when $\theta = \pi$. This can be explained by the fact that interaction between meander conductors being over each other is much stronger than the interaction between adjacent conductors of the same electrode when the distance between shifted meander electrodes is small (smaller than the gap between meander conductors). Therefore, the field is concentrated between meanders and a significant part of energy is transferred in this region.

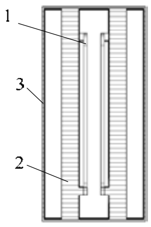


Fig. 10. Cross-section of meander systems (Fig. 5 and 7) obtained after increasing the distance between meander electrodes to 0.7 mm: 1 – meanders, 2 – single side through wafers with meander holders, 3 – external shield

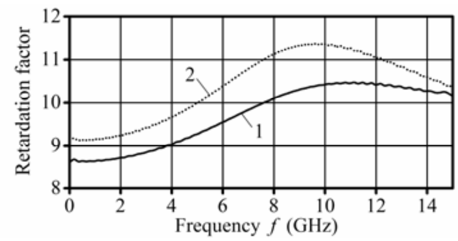


Fig. 11. Frequency dependences of retardation factors of meander systems (Fig. 5 and 7) obtained after increasing the distance between meander electrodes: 1 – of the symmetric system, 2 – of the system with shifted meander electrodes

In order to know how the system properties change by increasing the distance between meander electrodes by 2 w_2, two systems (analogous to those presented in Fig. 5 and 7) were investigated. The cross-section of these systems is shown in Fig. 10, and the investigation results in Fig. 11 and 12.

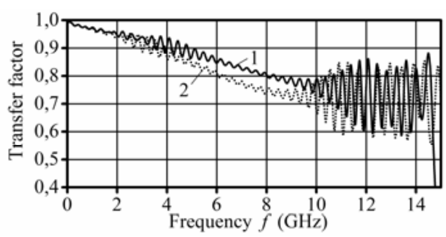


Fig. 12. AFR of meander systems (Fig. 5 and 7) obtained after increasing the distance between meander electrodes: 1 – of the symmetric system, 2 – of the system with shifted meander electrodes

The analysis of the obtained results and their comparison with the results presented in Fig. 8 and 9 show that properties of the system with shifted meander electrodes (curves *2* in Fig. 11 and 12) approach the properties of the symmetric meander system (curves *1* in Fig. 11 and 12) when the distance between the system meander electrodes becomes larger than the gap between meander conductors. When $\theta = \pi$, a narrow pass-band also appears in the system with shifted meander electrodes.

Conclusions

1. Non-symmetric and symmetric systems as well as systems with meander electrodes shifted by half the period of earlier unknown construction have been investigated. The investigation results confirmed the advantage of this system indicated in the patent – little influence of dielectric on the system properties

2. The obtained results of investigations agree well with the theoretical research results of known authors, specialists in this field [1]. Moreover, it should be mentioned that the application of the MicroWave Studio package to the investigation of meander systems revealed some new properties of investigated systems.

3. Properties of the delay system with meander electrodes shifted by half the period strongly depend on the distance between electrodes. If this distance is small (smaller than the gap between meander conductors), the system acquires properties which are not characteristic of symmetric meander systems:

- the influence of reflections on AFR of the meander delay system is not revealed when the phase angle between adjacent conductor currents or voltages is $\theta = \pi/2$ and when the integer number of half-waves of the non-retarded wave fits along the meander conductor;
- the delay system with meander electrodes shifted by half the period has no AFR break at $\theta = \pi$, and in the frequency range where the phase angle θ changes from 0 to $\pi/2$ the suppression is increased and reflections are smaller.

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J. Skudutis, V. Daškevičius. Investigation of Meander Delay System Properties using the „MicroWave Studio“ Software Package // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 8(72). – P. 11–14.

Possibilities of applying the MicroWave Studio package to the investigation of properties of meander delay systems were analyzed. It is shown that properties of the delay system with meander electrodes shifted by half the period strongly depend on the distance between electrodes. If this distance is smaller than the gap between meander conductors, the system acquires properties which are not characteristic of symmetric meander systems. When the phase angle between adjacent conductor currents or voltages is $\theta = \pi/2$ and when an integer number of half-waves of the non-retarded wave fits along the meander conductor, the influence of reflections on the meander delay system AFR is not revealed. The delay system with meander electrodes shifted by half the period has no pass-band (AFR break) at $\theta = \pi$, and in the frequency range where the phase angle θ changes from 0 to $\pi/2$ the suppression is increased and the reflections are smaller. Ill. 12, bibl. 6 (in English, summaries in English, Russian and Lithuanian).

Ю. Скудутис, В. Дашкевичюс. Исследование меандровых систем с применением пакета MicroWave Studio // Электроника и электротехника. – Каунас: Технология, 2006. – № 8(72). – С. 11–14.

Анализируются возможности применения пакета MicroWave Studio для исследования свойств меандровых замедляющих систем. Показано, что свойства системы со смещенными на половину периода меанровыми электродами сильно зависят от расстояния между электродами. Если это расстояние меньше промежутка между проводниками меандра, система отличается свойствами, не характерными симметричным меандровым системам. Когда фазовый угол между токами или напряжениями в соседних проводниках $\theta = \pi/2$ и когда вдоль меандрового проводника помещается целое число половин длин не замедленной волны, влияние отражений на АЧХ меандровой замедляющей системы не проявляется. Замедляющая система со смещенными на половину периода меанровыми электродами не имеет полосы заграждения (разрыва АЧХ) на $\theta = \pi$, а в диапазоне частот, в котором фазовый угол меняется от 0 до $\pi/2$, увеличено затухание и меньше отражения. Ил. 12, библ. 6 (на английском языке; рефераты на английском, русском и литовском яз.).

J. Skudutis, V. Daškevičius. Meandrinės lėtinimo sistemos savybių tyrimas MicroWave Studio programų paketu // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 8(72). – P. 11–14.

Analizuojamos galimybės tikyti MicroWave Studio paketą taikymo meandrinių lėtinimo sistemų savybėms tirti. Parodyta, kad lėtinimo sistemos su perstumtais per pusę periodo meandriniais elektrodais savybės labai priklauso nuo atstumo tarp elektrodų. Jeigu šis atstumas yra mažesnis už tarpą tarp meandro laidininkų, sistema įgyja nebūdingų simetrinėms meandrinėms sistemoms savybių. Kai fazės kampas tarp gretimų laidininkų srovių arba įtampų $\theta = \pi/2$ ir kai išilgai meandro laidininko telpa sveikas nesulėtintos bangos pusių skaičius, atspindžiai neturi įtakos meandrinės lėtinimo sistemos DACH. Lėtinimo sistema su perstumtais per pusę periodo

meandriniais elektrodais neturi užtvarinės juostos (DACH trūkio) ties $\theta = \pi$, o dažnių ruože, kuriame fazės kampas θ kinta nuo 0 iki $\pi/2$, yra didesnis slopinimas ir mažesni atspindžiai. Il. 12, bibl.6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).