International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 1775-1779 www.ijaem.net ISSN: 2395-5252

Electro dynamic properties of five-port wave guide junctions

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Date of Submission: 20-04-2023 Date of Acceptance: 30-04-2023

Annotation

The paper discusses the properties of five-port waveguide junctions when it is excited by several ports simultaneously. In the work, the problems with respect to the unknown coefficients of the scattered fields in the lateral ports and the corresponding systems of triple infinite equations for their solution are given.The graphs of dependence of the coefficients of the fields reflected from and passing through the ports on the frequency parameters of the energies are constructed and analysed. The article presents a picture of the field distribution in the diffraction near zone.

The Main Part

In the fields of radio engineering, radio physics and radio electronics, special attention is paid to the development of new methods for constructing microwave devices based on planar and volume integrated circuits [1].

In Super- high-frequency devices, as volume integrated circuits can be used the multi-stage waveguide systems, the transition between stages of which is carried out by waveguide fragments containing inhomogeneities.

To increase the efficiency of multiport waveguide junction/brunch, it is necessary first of all to increase their bandwidth and reduce energy losses. In addition, when branching, splitting and converting a signal in such systems, it is necessary to ensure an acceptable agreement between the arms, that is, a sufficiently high level of transmission in the necessary arms and a low level in the rest. Finally, for stable operation of the system, it is necessary to achieve stable characteristics in a sufficiently wide frequency range.

To achieve these goals, in different branches of the structure artificial inhomogeneities can be included , which, in turn, can perform the functions of filters, phase inverters, multiplexers, and oth [2].

But an analysis the characteristics of such couplings shows that often it is impossible to achieve the desired level of electromagnetic compatibility in the waveguide only by connecting inhomogeneities [3].

Thus, it is necessary to find another way for improving the matching between the arms of multiport waveguide junctions.

In [4], as a result of the field structure analysis, it was assumed that the matching can be improved if the structure is excited from different ports.

Carrying out the standard procedures necessary for solving such problems ([3]), a triple infinite system of equations is obtained with respect to three sequences of unknown variables:

$$A_s^{(j)} + \sum_{p=1}^{3} \sum_{m=1}^{\infty} Q_{sm}^{(jp)} A_m^{(p)} = a_s^{(j)}; \quad (s = 1, \dots \infty; \ j = 1,2,3) \qquad (1)$$

where:

$$Q_{Sm}^{(11)} = Q_{Sm}^{(22)} = Q_{Sm}^{(33)} = \beta_{Sm}\left(1+(-1)^{m+S}\right)\sum_{n=1}^{\infty} \frac{\alpha_n^{(3)}\left[1-(-1)^S \exp\left(-ih_n^{(3)}a\right)\right]}{h_n^{(3)} b\left(\alpha_m^{(1)2} - h_n^{(3)2}\right)\left(\alpha_S^{(1)2} - h_n^{(3)2}\right)},$$

$$Q_{sv}^{(1`2)} = -(-1)^s \beta_{Sm} \sum_{n=1}^{\infty} (-1)^{p2(2)(n+1)} R_{Sm}^{(n)} \exp\left(-ih_n^{(3)}\ell_1\right)$$

$$Q_{sm}^{(13)} = -(-1)^s \beta_{Sm} \sum_{n=1}^{\infty} (-1)^{p2(3)(n+1)} R_{Sm}^{(n)} \exp\left[-h_n^{(3)}\left(\ell_1 + \ell_2 + \ell_3\right)\right]$$

$$Q_{sv}^{(21)}=-(-1)^m\beta_{Sm}\sum_{n=1}^{\infty}(-1)^{p2(2)(n+1)}R_{Sm}^{(n)}\exp\left(-ih_n^{(3)}\ell_1\right)$$

$$Q_{sm}^{(23)}=-(-1)^s\beta_{Sm}\sum_{n=1}^{\infty}(-1)^{[p2(3)-p2(2)](n+1)}R_{Sm}^{(n)}\exp\left(-ih_n^{(3)}\ell_2\right)$$

$$Q_{sm}^{(31)}=-(-1)^m\beta_{Sm}\sum_{n=1}^{\infty}(-1)^{p2(3)(n+1)}R_{Sm}^{(n)}\exp\left[-h_n^{(3)}(\ell_1+\ell_2+\ell_3)\right]$$

$$Q_{sm}^{(32)}=-(-1)^m\beta_{Sm}\sum_{n=1}^{\infty}(-1)^{[p2(3)-p2(2)](n+1)}R_{Sm}^{(n)}\exp\left(-ih_n^{(3)}\ell_2\right)$$

$$a_S^{(1)}=p1(1)a_S-p1(2)Q_{S\mu1}^{(12)}-p1(3)Q_{S\mu1}^{(13)}+\gamma_S\left[p1(4)-p1(10)(-1)^S\exp\left(-ih_{\mu2}^{(3)}L_2\right)\right]$$

$$a_S^{(2)}=p1(2)a_S-p1(2)Q_{S\mu1}^{(21)}-p1(3)Q_{S\mu1}^{(23)}+$$
$$+\gamma_S\left[p1(4)\exp\left(-ih_{\mu2}^{(3)}(\ell_1+a)\right)-p1(10)(-1)^S\exp\left(-ih_{\mu2}^{(3)}(\ell_2+a)\right)\right]$$

$$a_S^{(3)}=p1(3)a_S-p1(1)Q_{S\mu1}^{(31)}-p1(2)Q_{S\mu1}^{(32)}+\gamma_S\left[p1(4)\exp\left(-ih_{\mu2}^{(3)}L_2\right)-p1(10)(-1)^S\right]$$

$$\beta_{Sm}=\frac{2i\alpha_S^{(1)}\alpha_m^{(1)}}{h_S^{(1)}a\left[i+ctg\left(h_S^{(1)}b\right)\right]}$$

$$R_{Sm}^{(n)}=\frac{\alpha_n^{(3)2}\left[1-(-1)^S\exp\left(-ih_n^{(3)}a\right)\right]\left[1-(-1)^m\exp\left(-ih_n^{(3)}a\right)\right]}{h_n^{(3)}b\left(\alpha_m^{(1)2}-h_n^{(3)2}\right)\left(\alpha_S^{(1)2}-h_n^{(3)2}\right)}$$

$$a_S=\frac{i-ctg\left(h_S^{(1)}b\right)}{i+ctg\left(h_S^{(1)}b\right)}\delta_{Sm}-Q_{Sm}^{(1)}$$

$$\gamma_S=\frac{\alpha_{\mu2}^{(3)}\alpha_S^{(1)}\left[1-(-1)^S\exp\left(-ih_{\mu1}^{(3)}a\right)\right]}{h_S^{(3)}a\left(\alpha_S^{(1)2}-h_{\mu2}^{(3)2}\right)\left(1+ctg\left(h_S^{(1)}b\right)\right)}$$

$\alpha_m^{(1)}=\pi m/a$, $\alpha_m^{(3)}=\pi m/b$, $h_m^{(1)}=\sqrt{k^2-\alpha_m^{(1)2}}$, $h_m^{(3)}=\sqrt{k^2-\alpha_m^{(3)2}}$,

$\mathrm{Im}(h_m^{(1)}),\mathrm{Im}(h_m^{(3)})<0.$

$\{A_m^{(1)}\}_{m=1}^{\infty},\{A_m^{(2)}\}_{m=1}^{\infty},\{A_m^{(3)}\}_{m=1}^{\infty}$ - are the coefficients of scattered fields in the side branches of the junction.

The analysis of matrix elements and free members shows that by index m (which corresponds to the column of the matrix) they behave like 0(1⁄m) at infinity, and by s (row of the matrix) like 0(1/s).

This means that the matrix elements and free members of system (1) satisfy the quadratic summation condition, which means that the system is quasi-regular, so it can be solved on a computer by the reduction (truncation) method.

At each step of the calculations, the fulfillment of the law of conservation of energy and the convergence of the results were checked, which is one of the criteria for verifying the correctness and reliability of the solution of the problem. Another criterion is the images of the field distribution in the near zone of diffraction.

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The results of the numerical calculation showed that the order of reduction N=3 in the single-wavelength range makes it possible to provide an accuracy of about 1%. The results deteriorate as the frequency parameter increases and the distance between the side ports decreases.

On Figure 2 are presented the graphs of dependence the total energy reflected in the side arms (regions 1, 2, 3 in Fig. 1) and transmitted in the main waveguide (4, 10) by the frequency parameter, for the logical multipliers p1(1)= p1(2)= p1(3)=1 , p2(2)=1, p2(3)=0 and parameters $l_1/a=0.5$, $l_2/a=0.4$. To total energy reflected in ports 1,2,3 corresponds green color, passed in port 4 - blue, in port 5 (area 10 in Fig. 1) - red.

On Figure 3 are presened the graphs of dipendence of the coefficients reflected fields in the side branches by frequency parameter for the same structure. Blue color corresponds to reflected in 1 port, red –in 2, green –in 3.

Arom the figures шы seen that for the frequency parameter at which a propagating wave is born in the main waveguide (ν=1.25), the energies coming from the side ports are completely reflected in these ports, therefore, we have no energy spread in the main waveguide ports (4 and 5). This is due to the appearance of non-propagating harmonics (reactive fields) on the surfaces where the side branches merge with the main waveguide, so that they completely block the transition of the side branches to the main waveguide.

On Figure 4 is presented the picture of field distribution in the diffraction near zone for the frequency parameter ν=1.44 and the same other parameters.

From fig. 4, we can assume the following picture: In structure the field mainly is concentrated in the resonator part (0<x<3a+l1+l2, 0<z<b), approximately in the area (l1+3a/2<x<l1+3a/2+l2, 0<z<b) is created a reactive field , which practically blocks the flow of the field from branch 3 to the main waveguide (W(3)≈1), and part of the energy coming from branch 1 is directed to branch 2.

An interesting situation arises when the parameter ν=1.84, in this case the total energy reflected in the side branches is almost equal to 0 and the entire flow goes to the main waveguide - ports 4.5.

Acknowledgement. This work is supported by the ShotaRustaveli National science foundation of Georgia (Project No STEM-22-1210)

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Volume 5, Issue 4 April 2023, pp: 1775-1779 www.ijaem.net ISSN: 2395-5252

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Figures

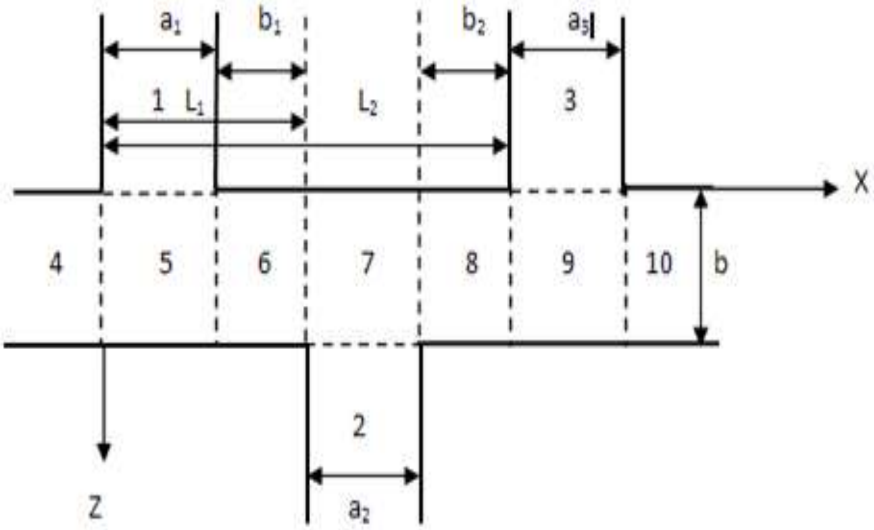

Figure 1

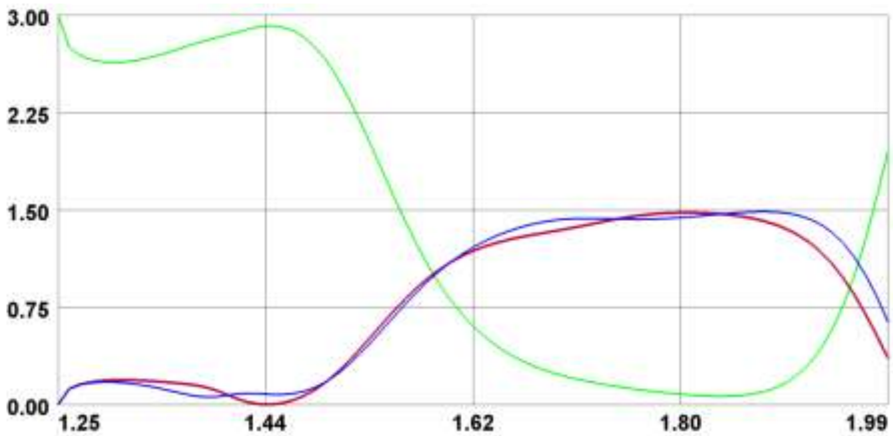

Figure 2

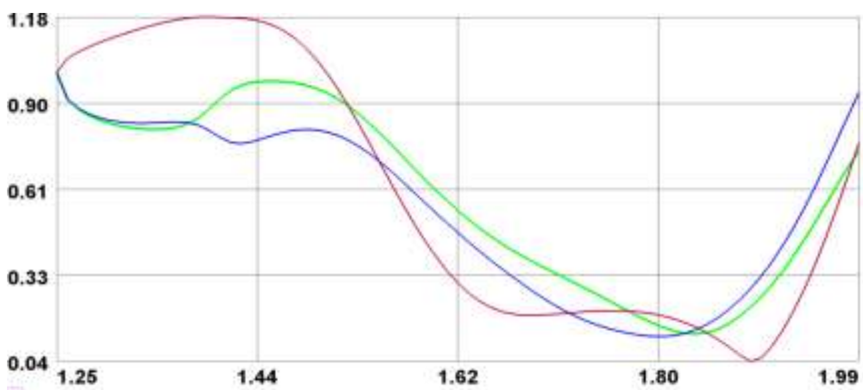

Figure 3

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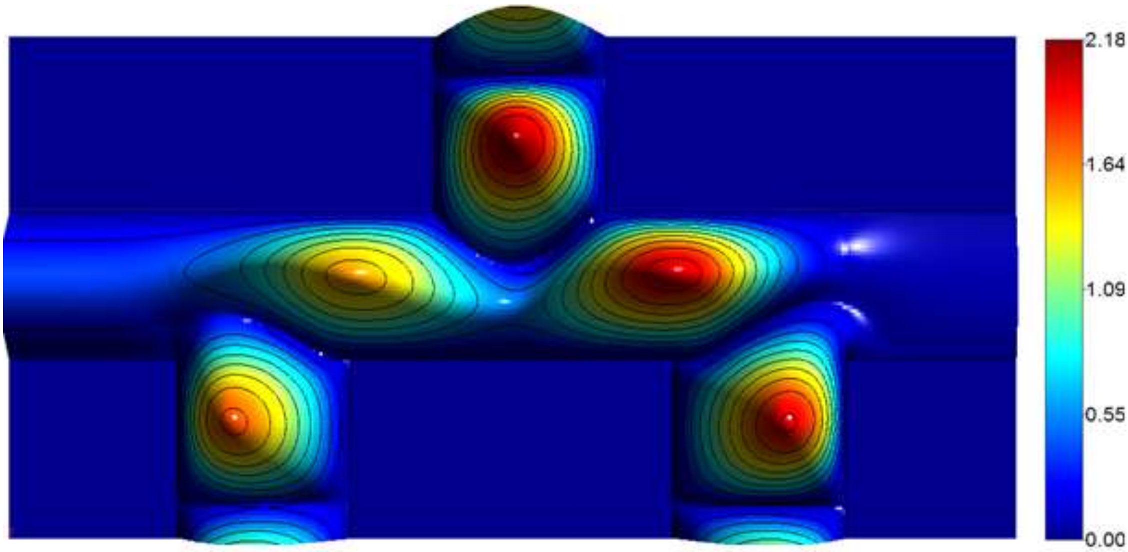

Figure 4

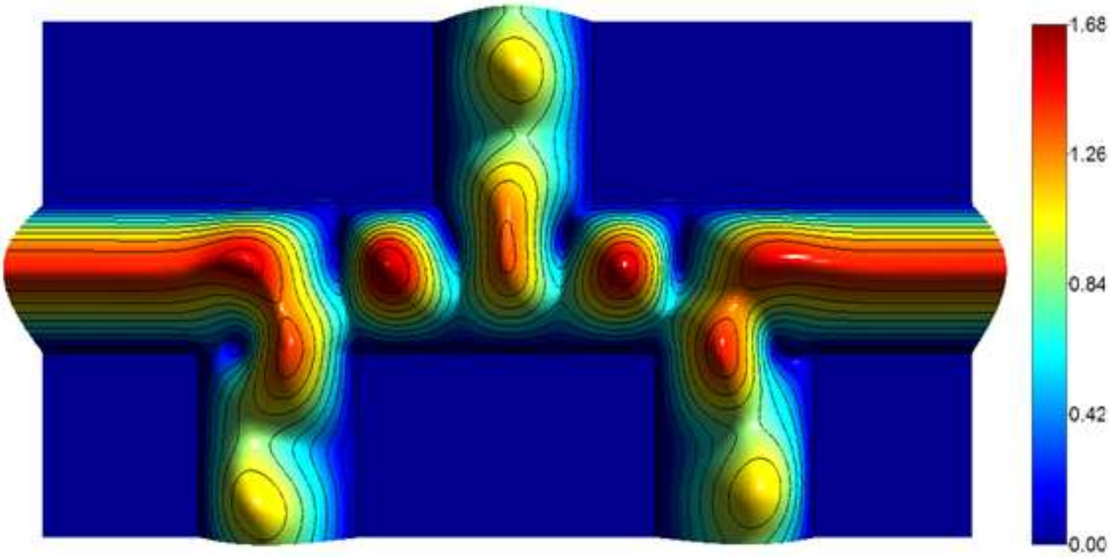

Figure 5

Captions for Figures:

Figure 1 Considered structure

Figure 2Dependence of the total energy of the reflected field on the frequency parameter ащк p1(1)= p1(2)= p1(3)=1, p2(2)=1, p2(3)=0, $l_1/a=0.5$, $l_2/a=0.4$.

Figure 3Dependence of the reflection coefficient in the side ports on the frequency parameter for the same parameters.

Figure 3the picture of field distribution for the same parameters and ν=1.44.

Figure 5the picture of field distribution for the same parameters and ν=1.84.