Розроблена еквівалентна схема дванадцятиполюсного вимірювального перетворювача, у якому застосована чотирьохплеча неоднорідність хвилеводного хрестоподібного дільника потужності. Для Е-площинного дільника потужності еквівалентна схема перетворювача має вигляд чотирьохзондової секції. Проведено математичне моделювання та експериментальні дослідження фазових зсувів між зондами

Ключові слова: векторний аналізатор кіл, чотирьохплеча неоднорідність, коефіцієнт відбиття

Разработана эквивалентная схема двенадцатиполюсного измерительного преобразователя, в котором используется четырехплечая неоднородность волноводного крестообразного делителя мощности. Для Е-плоскостного делителя мощности эквивалентная схема преобразователя представлена в виде четырехзондовой секции. Проведены математическое моделирование и экспериментальные исследования фазовых сдвигов между зондами

Ключевые слова: векторный анализатор цепей, четырехплечая неоднородность, коэффициент отражения

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EQUIVALENT CIRCUIT OF X-SHAPED CONVERTER OF COMPLEX REFLECTION COEFFICIENT ANALYZER

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1. Introduction

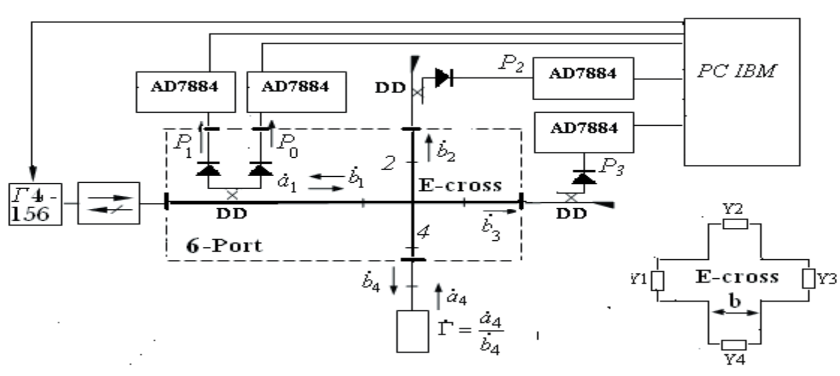
The complex reflection coefficient (RC) is one of the principle operation characteristics of antenna-feeder devices. One of the perspective techniques for developing automated meters of complex reflection and transmission coefficients is the method of 12-pole reflectometer (TPR) [1]. The main feature of 12-pole measuring converters (MC) of millimeter wavelength range is that the vector conversion of input waves is carried out by means of the passive multiport connection construction, and the power indicators are set into its output consistent ports. The mathematical and geometrical models of the consistent constructions of 12-pole joints are made on the complex plane RC (G-plane). The mathematical model of a reflectometer is limited to solving a system of three quadratic equations, while the geometric model of the system solution is the cross point of three circles involved. The centers of three circles, their modulus and phase are the main parameters of consistent 12-pole measuring converters. Their mutual arrangement and their modulus influence a decision of the applicability of this construction for the unique determination of the complex RC and of its difference from the optimal construction of the 12-pole joint. The TPR with consistent constructions of 12-pole joints employs the method of gauged converters: a measuring converter is regarded as a "black box", and its constant characteristics are found by the result of the preliminary gauge of a reflectometer using at least four standard measures of the complex RC [2].

The paper considers an alternative development of vector analyzers of the complex RC using a simple multiport construction of discontinuity in their measuring converters [3], instead of a complex construction of the consistent multiport joint.

2. Literature data analysis and problem statement

The possibility of making 12-pole joints based on a four-port discontinuity of the wave E-planar X-shaped power divider was explicated in the paper. Both mathematical and geometrical models of such converter are formed not on the complex RC plane, but on the intermediate plane of its input wave correlation $\dot{A}_4 = \dot{a}_4/\dot{a}_1$.

The Fig. 1, a shows a structural circuit of the complex RC analyzer (Fig. 1, a) and an equivalent circuit of the E-planar X-shaped power divider (Fig. 1, b).



a b

Fig. 1. Circuit: a — structural of the X-shaped analyzer; b — equivalent of the E-cross

As the structural circuit of the analyzer (Fig. 1, b) shows, its 12-pole measuring converter (6-Port) consists of the E-planar X-shaped power divider (E-cross) and four directional detectors (DD) from the scalar reflectometer P2-65. The directional detectors are used for their designated purpose: measuring the RC as well as attenuation in the output ports of the charged power divider, i.e. introducing minimum errors into the scatter matrix of the whole construction of the converter.

Further it is assumed that the scatter matrix of the X-shaped power divider coincides with the scatter matrix of the measuring converter.

If by analogy with consistent MC the mathematical model of the relevant converter on the complex plane of some RC $\dot{\Gamma} = \dot{a}_4/\dot{b}_4$, is made, then the model will be represented as a system of three quadratic equations as follows:

$$\left|\Gamma - \frac{S_{i1}D_i^* - S_{44}^*\bar{P}_i}{|D_i|^2 - |S_{44}|^2\bar{P}_i}\right|^2 = \frac{|S_{i4}S_{41}|^2}{\left(|D_i|^2 - |S_{44}|^2\bar{P}_i\right)^2}\cdot\bar{P}_i,$$

$$\bar{P}_i = P_i/P_0,\ i=1,2,3. \qquad (1)$$

where $D_i = S_{i1}S_{44} - S_{i4}S_{41}$, S_{ij} - the known number values of coefficients of the X-shaped power divider scatter matrix [5].

As the equations (1) show, the location of circle centers on the plane $\dot{\Gamma} = \dot{a}_4/\dot{b}_4$ depends on the readings of the power indicator (PI) P_i, i.e. on the RC phase when $|\Gamma| = \text{const}$. Hence, the geometrical model on the plane $\dot{\Gamma}$ is impractical for the qualitative analysis of the MC properties.

For making a geometrical model of inconsistent X-shaped MC the paper (6) suggests using a complex plane of an offset (virtual) reflection coefficient $\dot{G}$. The forward and backward transformations between the measured $\dot{\Gamma}$ and virtual $\dot{G}$ reflection coefficients are written as:

$$\dot{G} = \dot{\Gamma}\frac{1 - S_{44}^*\Gamma^*}{1 - S_{44}\Gamma},\quad \dot{\Gamma} = \dot{G}\frac{1 + S_{44}^*G^*}{1 + S_{44}G}. \qquad (2)$$

The reflection coefficients G and Γ appear from the same load, but they are bound to different reference planes.

The mathematical model for finding the virtual RC G is written as follows:

$$\left|G + \frac{S_{i1} - D_iS_{44}^*|G|^2}{S_{i4}S_{41}}\right|^2 = \frac{\left(1 - |S_{44}G|^2\right)^2}{|S_{i4}S_{41}|^2}\cdot\frac{P_i}{P_0}. \qquad (3)$$

The equations (3) refer to the equations of the circles (four in general) with points Q_i as centers and R_i as radii:

$$Q_i = -\frac{S_{i1} - D_iS_{44}^*|G|^2}{S_{i4}S_{41}},\qquad R_i^2 = \frac{\left(1 - |S_{44}G|^2\right)^2}{|S_{i4}S_{41}|^2}\cdot\frac{P_i}{P_0}. \qquad (4)$$

The Fig. 2 shows mutual arrangement of the centers Q_1, Q_2, Q_3 and Q_4 with reference to the circles $|G|=1$ and $|G|=0{,}2$ on a frequency of 38 GHz.

As the Fig. 2, b shows, when RCs are small, measuring the RC phase becomes "stable" at any value of it.

Using the complex plane of the virtual RC G the properties of the X-shaped converter at any normalization of the PI [7] can be qualitatively estimated.

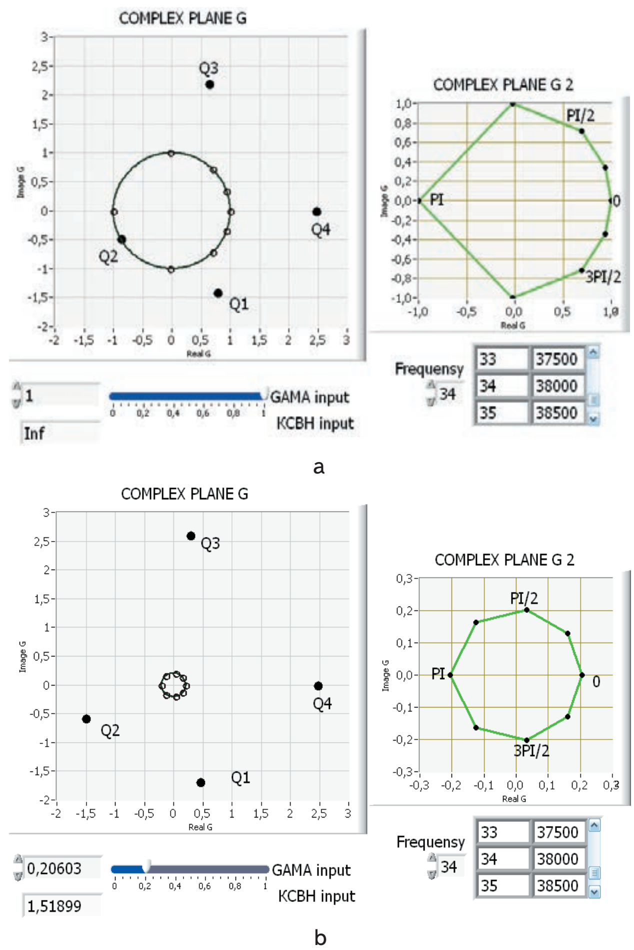


Fig. 2. The geometrical models of X-shaped MC: a — when $|\Gamma|=1$; b — when $|\Gamma|=0{,}206$

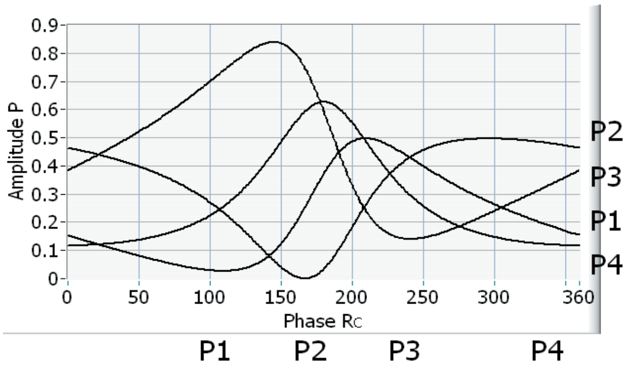
These geometrical models estimate properties of the MC, where multiport discontinuities are used, in a qualitative manner exclusively as they do to the consistent MC. It follows from the expressions (4) that the centers Q_i are not constants of the converter any more, as their number values depend on the modulus of the measured RC and the generator frequency. For the numerical estimate of operation characteristics of the X-shaped converter an equivalent circuit of its measuring channel has been developed.

3. Mathematical modeling and experimental research of the equivalent circuit of the X-shaped converter

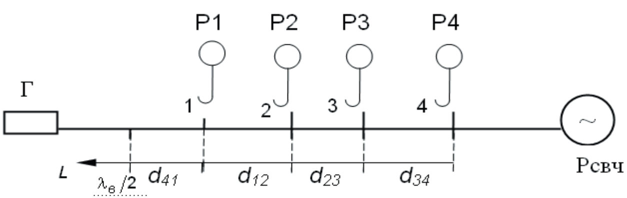
The equivalent circuit of the E-plane X-shaped divider, as the E-plane T-junction, can be represented in the form of a series type connection of its four side ports (Fig. 1, b). The strict sequence of ports coincides with the strict sequence of centers Q_1, Q_2, Q_3 and Q_4 on the geometrical models, Fig. 2, a, b.

For the conventional four-probe section with capacitance probes the corresponding centers lie in the vertexes of the square, formed on the circle $|\dot{\Gamma}|=1$ [8]. By analogy, the measuring channel of the X-shaped converter can be represented in the form of a four-probe section with four magnetic probes-ports, as the E-cross scatter matrix is calculated with the help of the dominant mode $\dot{H}_x$ of the corresponding dilatational waves [9]. The location of probes-indicators coincide with minimum readings of the indicators P_1, P_2, P_3, P_4, that is, with phases of the centers Q_1, Q_2, Q_3 and Q_4 on the complex plane of the examined load $\dot{\Gamma}$.

The Fig. 3 shows the gradation of minimum (nodal) readings of the PI on the phase plane of the RC (Fig. 3, a) and along the transmitting channel (Fig. 3, b) for the X-shaped converter with the discontinuity area cross dimensions 7,2 mm×3,4 mm for the frequency of 38 GHz.



a



b

Fig. 3. Gradation of nodal cross sections in output ports of: a — converter; b — its equivalent four-probe model

The Fig. 4 shows the graphic interface for the mathematical modeling and experimental research of the main equivalent circuit operation characteristics of the X-shaped converter.

The Fig. 4, a, b show the results of the mathematical modeling of the X-shaped converter equivalent circuit. The original data are the following: generator frequency (Frequency) F=33 GHz and the value of RC load modulus RC=0,5355, with "vibration" amplitude $\lambda_w/2$ (RC phase $0 \le \theta \le 2\pi$).

The Fig. 4, a shows the curves of the phase location of four equivalent probes depending on the frequency (in the operational frequency range of a rectangular waveguide) at the original RC modulus $|\Gamma|$= RC=0,5355. With the given frequency (according to the hair-line) F=33 GHz the phase shifts between the adjacent probes-indicators are equal to: $\phi_{41} = 76{,}71^0$, $\phi_{12} = 90{,}67^0$, $\phi_{23} = 65{,}05^0$, $\phi_{34} = 127{,}57^0$.

The Fig. 4, b shows the influence curves of locations of the probes-indicators depending on the RC modulus of the load under examination, for the fixed frequency of F=33 GHz; the hail-line is set at the value of $|\Gamma|$= RC=0,5355.

The Fig. 4, c and Fig. 4, d show the research results of the analyzer operating in the "Vector oscillogragh" mode [10].

The RC of a sliding wedge, vibrating at the frequency of 10 Hz and with approximate amplitude of 3/4 has been gauged. In accordance with the Ox axis (Fig. 4, d), 7500 values of indicators P1, P2, P3 of a 6-port MC (Fig. 1, a) have been sampled. The number value analysis of PI readings (Fig. 3, a) shows that the phase shifts between adjacent probes-indicators are equal to (Fig. 4, a): $\phi_{12} = 91{,}823^0$ (error in relation to the estimated value is 1,2 degree), $\phi_{23} = 65{,}7046^0$ (error is 0,7 degree).

According to the Fig. 4, d, the average measured RC value is $|\Gamma| = 0{,}54$, $\delta|\Gamma| \le 1{,}833\%$. The Fig. 4, c shows the circle on the complex plane of the RC, based on the results of processing 7500 samples of PI readings.

As the Fig. 4, d shows, the minimum error of RC measurements appears at the frequency of 33031 MHz, with the generator frequency 33000 MHz. This frequency error $\delta F \approx 0{,}1\%$ is caused either while setting the Г4-156 generator frequency (according to the test certificate, it is $\delta F \le 0{,}2\%$), or as a result of practical errors when producing a discontinuity area of the X-shaped joint.

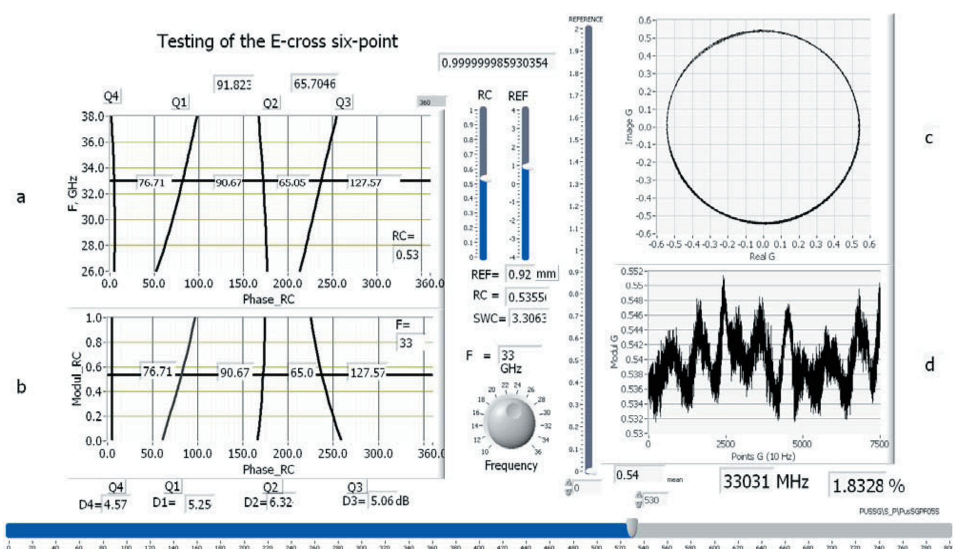


Fig. 4. Graphic interface for testing main operation characteristics of the equivalent circuit of the X-shaped converter: a — dependence of phase shifts on the frequency; b — dependence of phase shifts on the RC modulus; c — display of measurements over the G-plane; d — oscilloghaph chart of the RC modulus from the oscillating load

5. Conclusions

The equivalent circuit of the measuring channel of the X-shaped converter of the complex reflection coefficient analyzer in the form of a four-probe section has been developed. The location of the probes corresponds to nodal cross sections of a standing wave in each output port of the E-planar X-shaped power divider. The main operation characteristics of the X-shaped converter are phase shifts between adjacent ports-probes. The developed graphic interface allows setting the X-shaped power divider for the real phase shifts and using it as an installed monoparameter reference standard for gauging external loads in future.

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ТЕХНИЧЕСКИЕ АСПЕКТЫ РИНОМАНОМЕТРИИ

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Розглянуто методи діагностики порушень носового дихання. Запропоновано нову схему вимірювання диференційного тиску. Вимірювання диференційного тиску проводиться між носоглоткою і підмасковим простором, а саме у точці, де швидкість повітряного потоку дорівнює нулю. Розроблено технічне рішення риноманометра, використання якого в клінічній практиці дозволяє підвищити діагностичну значимість методу активної передньої риноманометрії

Ключові слова: риноманометрія, диференційний тиск, витрата повітряного потоку, коефіцієнт носового опору

Рассмотрены методы диагностики нарушений носового дыхания. Предложена новая схема измерения дифференциального давления, в которой измерение дифференциального давления производится между носоглоткой и подмасочным пространством, а именно в точке, где скорость воздушного потока равна нулю. Разработано техническое решение риноманометра, использование которого в клинической практике позволяет повысить диагностическую значимость метода активной передней риноманометрии

Ключевые слова: риноманометрия, дифференциальное давление, расход воздушного потока, коэффициент носового сопротивления

1. Введение

Исследование функции носового дыхания – актуальная проблема современной ринологии. Затруднение носового дыхания испытывают пациенты с заболеваниями носа и околоносовых пазух в 85% случаев. Затруднение носового дыхания – это самый мучительный из всех симптомов, испытываемых такими больными. К таким заболеваниям относят острые и хронические воспалительные заболевания носа и околоносовых пазух, вазомоторный, аллергический и полипозный ринит, различные опухолевые процессы в полости носа, посттравматические искривления носовой перегородки. По анализу литературных источни-