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ENHANCED C-BAND COAXIAL ORTHOMODE TRANSDUCER

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Introduction

Recently it has become a reality to use higher frequency bands in satellite telecommunication systems and in radioastronomy. Therefore an urgent and challenging problem of development of multiband feeds for large reflector antennas operating at orthogonal polarizations in wide frequency ranges in every band has been arisen. One of the successful ways to solve the problem is to utilize the coaxial feeds of a novel type, viz the ones with the partial dielectric loading [1–3], which provide, as distinguished from conventional coaxial feeds, low level of crosspolar radiation in wide operating frequency bands. In order to select and process radiosignals of orthogonal polarizations in such coaxial feeds it is necessary to design wideband coherent orthomode transducers (OMT) based on coaxial quad-ridged waveguides. The structure and the characteristics of a narrowband coaxial OMT are presented in [4, 5], wherein the high isolation between the ports with orthogonal polarizations has been achieved in the operation frequency range of the lower band. The reflection coefficient of that coaxial OMT is less than −15 dB and its isolation exceeds 39 dB.

The disadvantage of the coaxial OMT developed in [4, 5] is the narrow 9.4% operation frequency range in the lower operation band. Another coaxial OMT has been designed in [6] in order to broaden the operation frequency range of the lower band. It consists of an input circular coaxial waveguide and two output rectangular waveguides. In the operation frequency band 3.4–4.2 GHz (21% bandwidth) input reflection coefficient of the coaxial OMT presented in [6] is less than −20 dB, the isolation exceeds 30 dB. The disadvantage of such coaxial OMT is the impossibility to provide the coherent reception of orthogonally polarized electromagnetic waves in the whole operation frequency range because of space diversity of output rectangular waveguides. This disadvantage has been overcome in the coherent OMT [4, 5], but its operation frequency band is 2 times narrower.

In this paper a novel configuration of a wideband coherent coaxial OMT is presented. Its input part is similar to the one presented in [4, 5], but the structure has been optimized for the operation with minimal reflection in enhanced C-band, namely 3.4–5.4 GHz (45% bandwidth). As a result the wideband coaxial OMT, which provides the coherent reception of orthogonally polarized electromagnetic waves in 3.4–5.4 GHz frequency band, has been developed.

Design of the Orthomode Transducer

The general design of the coherent coaxial OMT proposed is shown in Fig. 1, and its inner structure is presented in Fig. 2. This OMT is coherent, because due to the equality of total geometrical lengths of waveguides for electromagnetic waves of each polarization the differential phase shift between them vanishes. The OMT consists of elements of 3 main types, namely:

1) a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines;

2) 4 right-angle coaxial junctions placed in metal locating blocks for each polarization;

3) an antiphase power combiner/divider for each polarization.

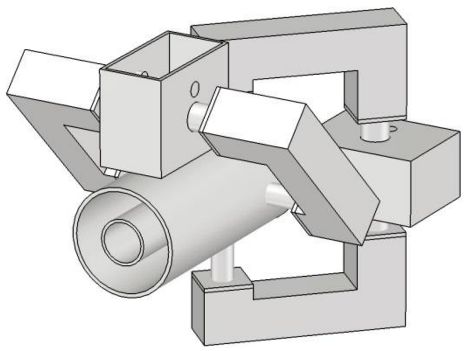

Fig. 1. General design of the coaxial OMT

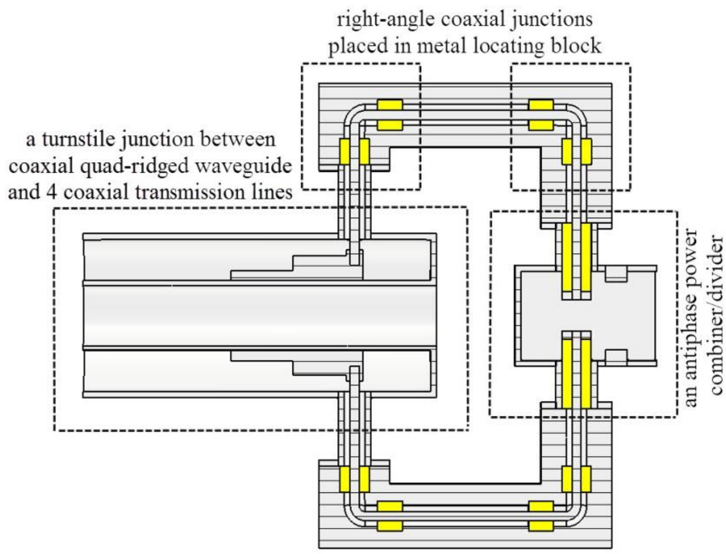

Fig. 2. Inner structure of the coaxial OMT

Electromagnetic waves of two orthogonal linear polarizations from the input coaxial waveguide, which is depicted in Fig. 2 on the left side, pass to a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines. This turnstile junction separates the orthogonally polarized signals to opposite coaxial transmission lines for each polarization. After this the electromagnetic waves pass 2 right-angle coaxial junctions placed in metal locating blocks and join again in an antiphase power combiner/divider.

Each structural element was separately optimized using CST Microwave Studio software to provide low reflection of electromagnetic waves for both polarizations in the coaxial OMT. After this the final optimization has been performed varying the lengths and the heights of locating blocks and matching stubs.

The Turnstile Junction Optimization

The geometrical configuration of the turnstile junction is depicted in Fig. 3. It consists of an input coaxial waveguide, 4 identical ridges and 4 identical output coaxial transmission lines.

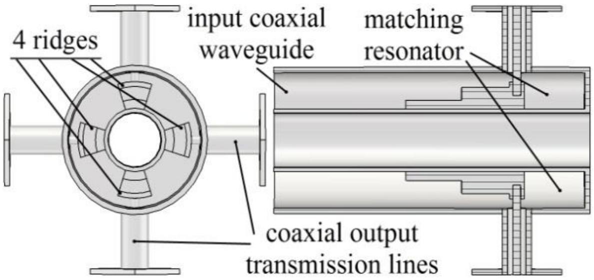

Fig. 3. The geometrical configuration of a turnstile junction

Let us suppose that two TE_{11} electromagnetic waves of orthogonal linear polarizations (one is vertical, the other one is horizontal) propagate from an input coaxial waveguide joined to a coaxial horn antenna. All characteristics of the OMT will be considered at the propagation of one of these waves. The fundamental difference of the turnstile junction designed from the one developed in [4, 5] is the presence of matching resonator in the vicinity of the transition from coaxial quad-ridged waveguide to 4 coaxial transmission lines. The resonators of such kind are used in OMTs based on quad-ridged waveguides [7, 8] in order to obtain wideband matching in coaxial-to-waveguide transitions. Initially the resonator was created by the shift of ridges from the short-circuiting plate on 21.4 mm distance equal to the quarter of wavelength for TE_{11} modes in the coaxial waveguide at the operation frequency band center 4.4 GHz. The results of numerical optimization have shown that the optimal length of matching resonator is slightly larger.

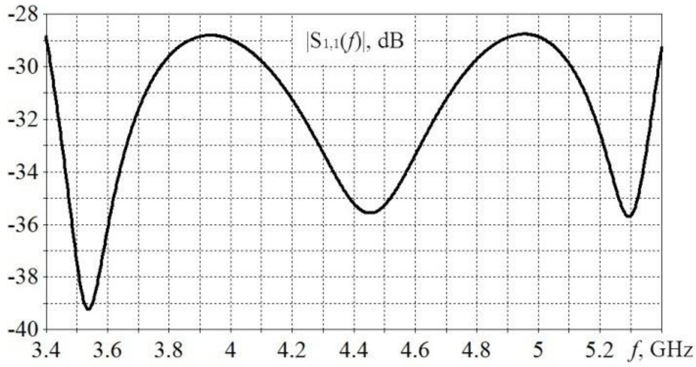

Fig. 4. Frequency dependence of the minimized reflection coefficient of the turnstile junction

The outer diameter of 4 output coaxial transmission lines is 7.0 mm, and inner one equals 3.0 mm. Thus, their wave impedance is 50 Ohms. The angular widths and the linear dimensions of 4 ridges have been varied during the optimization in order to minimize the reflection coefficient for TE_{11} mode of input coaxial waveguide. The frequency dependence of the minimized reflection coefficient (in dB) of the turnstile junction is shown in Fig. 4, where one can see that it is less than −28 dB in the whole operation frequency band 3.4–5.4 GHz.

The Optimized Right-Angle Coaxial Junction

A right-angle coaxial junction has been designed to change the propagation direction in coaxial transmission lines operating at the fundamental TEM mode.

Structure of the right-angle coaxial junction is shown in Fig. 5. It consists of a junction of two air coaxial transmission lines and two Teflon cylinders for matching. These air coaxial transmission lines have outer diameter equal 7.0 mm and the inner wire with diameter 3.0 mm. Their common central conductor is bended at 90°. The inner diameter of Teflon cylinders is chosen to be equal to the inner wire's diameter. The outer diameter of these cylinders is chosen from the equality of the wave impedances:

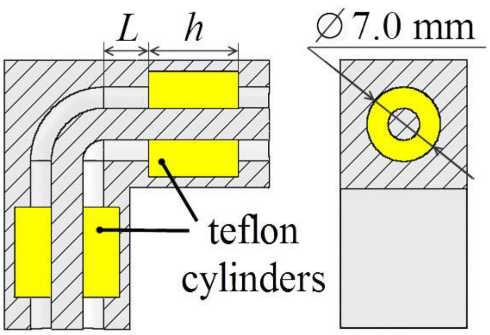

Fig. 5. The structure of a right-angle coaxial junction

$$Z = \frac{60}{\sqrt{\varepsilon_{\text{air}}}} \ln\left(\frac{7\,\text{mm}}{3\,\text{mm}}\right) = \frac{60}{\sqrt{\varepsilon_{\text{Teflon}}}} \ln\left(\frac{D}{3\,\text{mm}}\right),$$

from whence it follows that $D = 3.0\text{ mm} \cdot (7/3)^{\sqrt{\varepsilon_{\text{Teflon}}/\varepsilon_{\text{air}}}} = 10.0\text{ mm}$, where the permittivity of air is 1 and of Teflon is 2.05.

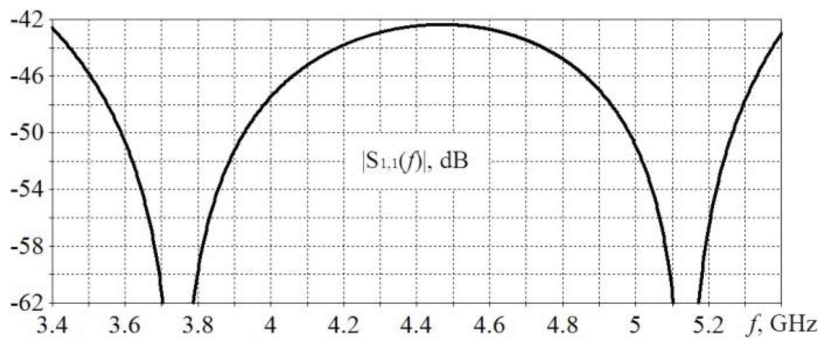

Fig. 6. The frequency dependence of minimized reflection coefficient of a right-angle coaxial junction

The dimensions L and h (see Fig. 5) were varied during the parametric minimization on the reflection coefficient of the right-angle coaxial junction. The optimal values are L = 4.33 mm and h = =8.45 mm. The corresponding frequency dependence of reflection coefficient (in dB) is shown in Fig. 6, where one can see that it is less than −42 dB in the operation frequency band 3.4–5.4 GHz.

The Antiphase Power Combiner/Divider

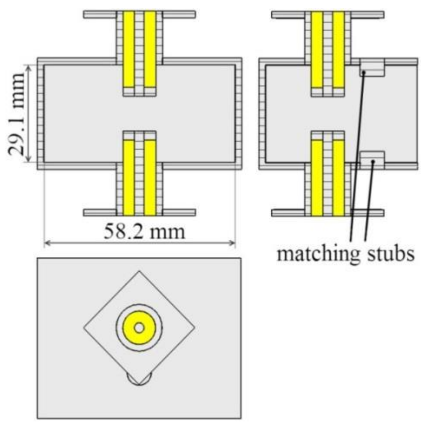

Fig. 7. The structure of an antiphase power combiner/divider

The geometric configuration of the wideband antiphase power combiner/divider developed is shown in Fig. 7. On the whole the construction is similar to the antiphase power combiner/divider presented in [9]. It consists of two coaxial probes with 50 Ohms impedance and a rectangular waveguide short-circuited from one side. The pair of stubs and metal cylinders at the ends of coaxial probes has been added to obtain good matching performance.

The parametric minimization of reflection coefficient has been carried out in the operation frequency band 3.4–5.4

GHz. All simulations have been performed using the CST Microwave Studio software in Transient Solver mode. The inner and outer diameters of coaxial probes are 3.0 mm and 10.0 mm respectively. The dielectric in coaxial probes and transmission lines is Teflon. It was simulated as a lossless isotropic material with relative permittivity ε_r=2.05. All metal surfaces were simulated as perfect conductors. The rectangular waveguide is standard WR 229 with cross section dimensions 58.2 mm × 29.1 mm. All other dimensions were varied in order to provide the minimal reflection coefficient of the structure.

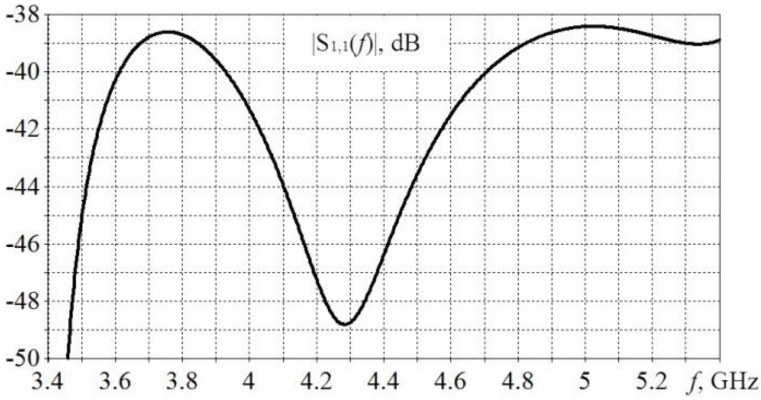

Fig. 8. The frequency dependence of minimized reflection coefficient of an antiphase power combiner/divider

The frequency dependence of minimized reflection coefficient is shown in Fig. 8. As one can see, the reflection coefficient doesn't exceed −38 dB in the whole operation frequency band 3.4–5.4 GHz.

Optimization of the Coaxial Orthomode Transducer

After the optimization of each construction's element of the coaxial OMT the final optimization has been performed varying the lengths and the heights of locating blocks, matching stubs and the location of matching stubs inside antiphase power combiner/divider. The frequency dependence of minimized reflection coefficient is depicted in Fig. 9. It is the same for both linear polarizations. The reflection coefficient of the OMT is less than −27 dB in the whole operation frequency band 3.4–5.4 GHz. The relative operation frequency bandwidth of the coaxial OMT developed, which equals 45%, exceeds the relative operation frequency bandwidth of the OMT presented in [6] more than 2 times and the relative operation frequency bandwidth of OMT from

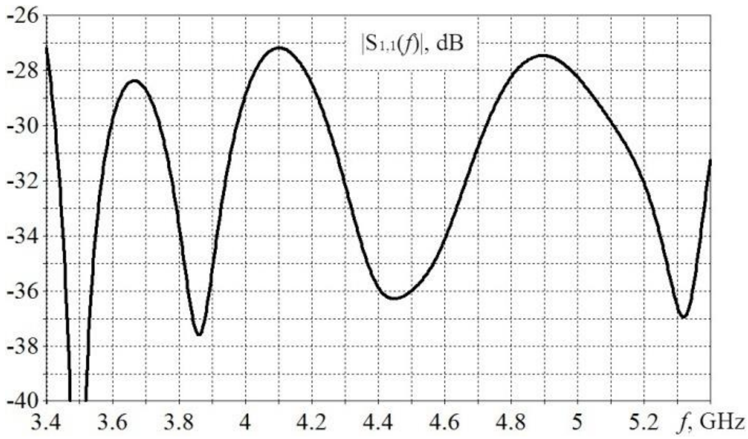

Fig. 9. The frequency dependence of minimized reflection coefficient of coaxial orthomode transducer

[4, 5] — more than 4 times with the lower reflection coefficient.

Conclusions

The wideband coaxial OMT for the frequency band 3.4–5.4 GHz, which provides the coherent reception of orthogonally linearly polarized electromagnetic waves in the whole operation frequency band, has been developed.

The coaxial OMT consists of elements of 3 main types, namely:

1) a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines;

2) 4 right-angle coaxial junctions placed in metal locating blocks for each polarization;

3) an antiphase power combiner/divider for each polarization.

Each structural element was separately optimized using CST Microwave Studio software in order to provide low reflection of electromagnetic waves for both polarizations in the coaxial OMT. After this the final optimization has been performed varying the lengths and the heights of locating blocks, matching stubs and the location of matching stubs.

The reflection coefficient of the coaxial OMT developed is less than −27 dB in the whole operation frequency band 3.4–5.4 GHz. The relative operation frequency bandwidth of the coaxial OMT developed, which equals 45%, exceeds the relative operation frequency bandwidth of the OMT presented in [6] more than 2 times and the relative operation frequency bandwidth of coherent OMT [4, 5] — more than 4 times with the lower reflection coefficient.

The wideband coaxial OMT developed can be used in satellite communication systems, radiotelescopes and other dual-polarized multiband radioengineering systems.

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Пільтяй С. І. ***Коаксіальний ортомодовий перетворювач для розширеного С-діапазону.*** *Розроблено широкосмуговий когерентний ортомодовий перетворювач на основі коаксіального чотириреберного хвилеводу для смуги частот 3,4–5,4 ГГц. Кожен елемент конструкції був окремо оптимізований за допомогою програмного пакету CST Microwave Studio для забезпечення низького відбиття електромагнітних хвиль обох поляризацій. Після цього була проведена фінальна оптимізація при зміні довжин і висот ложементів, узгоджувальних штирів і позиції узгоджувальних штирів. Коефіцієнт відбиття розробленого коаксіального ортомодового перетворювача не перевищує −27 дБ в усій робочій смузі частот 3,4-5,4 ГГц. Розроблений широкосмуговий когерентний коаксіальний ортомодовий перетворювач може бути використаний у різних двополяризаційних багатодіапазонних радіотехнічних системах.*

Ключові слова: *ортомодовий перетворювач, С-діапазон, широкосмугові двополяризаційні антени, коаксіальні ребристі хвилеводи, турнікетне з'єднання, протифазний суматор/подільник потужності, прямокутне коаксіальне з'єднання.*

Пильтяй С. И. ***Коаксиальный ортомодовый преобразователь для расширенного С-диапазона.*** *Разработан широкополосный когерентный ортомодовый преобразователь на основе коаксиального четырехреберного волновода для полосы частот 3,4–5,4 ГГц. Каждый элемент конструкции был отдельно оптимизирован при помощи программного пакета CST Microwave Studio для обеспечения низкого отражения электромагнитных волн обеих поляризаций. После этого была проведена финальная оптимизация при изменении длин и высот ложементов, согласующих штырей и позиции согласующих штырей. Коэффициент отражения разработанного коаксиального ортомодового преобразователя не превышает −27 дБ во всей рабочей полосе частот 3,4–5,4 ГГц. Разработанный широкополосный когерентный коаксиальный ортомодовый преобразователь может быть использован в различных двухполяризационных многодиапазонных радиотехнических системах.*

Ключевые слова: *ортомодовый преобразователь, С-диапазон, широкополосные двухполяризационные антенны, коаксиальные ребристые волноводы, турникетное соединение, противофазный сумматор/делитель мощности, прямоугольное коаксиальное соединение.*

Piltyay S. I. Enhanced C-band Coaxial Orthomode Transducer.

<u>Introduction.</u> In this paper a novel configuration of wideband coherent coaxial OMT is presented.

<u>General Design of an Orthomode Transducer.</u> The OMT consists of elements of 3 main types: a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines; 4 right-angle coaxial junctions for each polarization; 2 antiphase power combiners/dividers.

A Turnstile Junction Optimization. The optimization of a turnstile junction has been performed. Its minimized reflection coefficient is less than −28 dB in the operation frequency band 3.4–5.4 GHz.

An Optimized Right-Angle Coaxial Junction. A right-angle coaxial junction has been optimized to provide reflection coefficient, which is less than −42 dB in the operation frequency band 3.4–5.4 GHz.

An Antiphase Power Combiner/Divider. The optimization of an antiphase power combiner/divider has been performed. Its minimized reflection coefficient is less than −38 dB.

Conclusions. A wideband coaxial orthomode transducer has been developed for the operation frequency band 3.4–5.4 GHz. In this frequency band the reflection coefficient is less than −27 dB.

***Keywords**: orthomode transducer, C-band, wideband dual-polarized antennas, coaxial ridged waveguides, turnstile junction, antiphase power combiner/divider, right-angle coaxial junction.*