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ENHANCED C-BAND COAXIAL ORTHOMODE TRANSDUCER

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КОАКСІАЛЬНИЙ ОРТОМОДОВИЙ ПЕРЕТВОРЮВАЧ ДЛЯ РОЗШИРЕНОГО С-ДІАПАЗОНУ

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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, videlicet 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 this coaxial OMT is less than −15 dB and its isolation exceeds 39 dB.

The disadvantage of the coaxial OMT developed in [4, 5] is relatively narrow operation frequency range (i.e. 9.4 % relative bandwidth) in the lower operation band. A different 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 (i.e. 21% relative 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 is absent in the OMT presented in [4, 5], but its relative operation frequency band is more than in 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 (i.e. 45% relative bandwidth). As a result the wideband coaxial OMT, which provides the coherent reception of orthogonally linearly polarized electromagnetic waves in 3.4–5.4 GHz frequency band, has been developed.

General Design of an Orthomode Transducer

The general view of the coherent coaxial OMT 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 and coaxial transmission lines for electromagnetic waves of each polarization the differential phase shift between them is absent. 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) 2 coaxial transmission lines of LMR400 type [7] for each polarization;
3) a wideband antiphase power combiner/divider for each polarization.

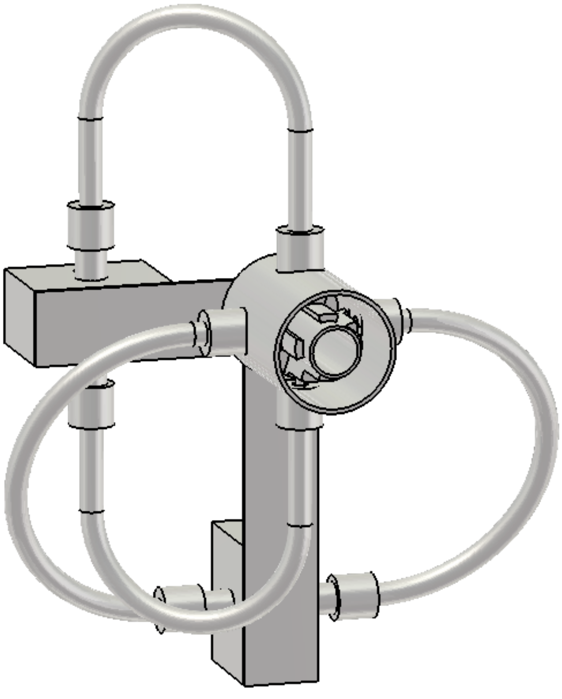

Fig. 1. General view of coaxial OMT.

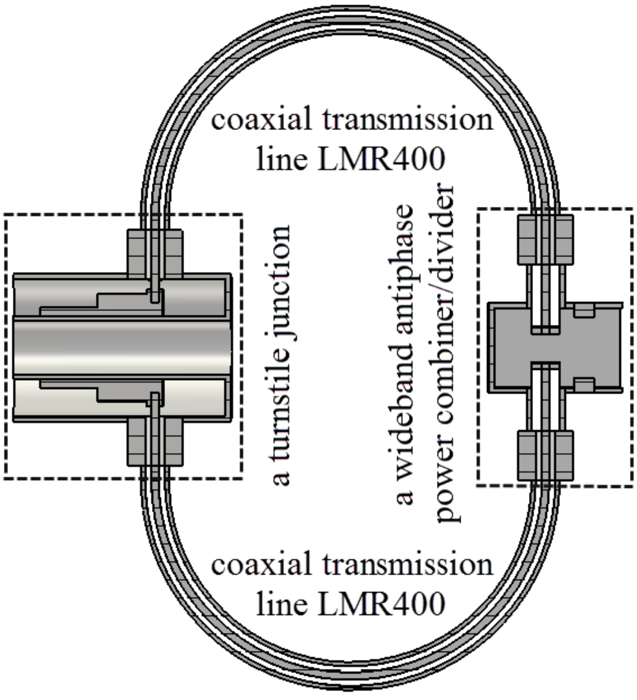

Fig. 2. The inner structure of coaxial OMT.

Electromagnetic waves TE_{11} of two orthogonal linear polarizations from the input coaxial waveguide, which is depicted in Fig. 2 from the left side, pass to a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines. It separates orthogonally polarized electromagnetic waves TE_{11} to opposite coaxial cables LMR400, that are joined with it by N-type connectors.

Then electromagnetic waves pass through these 2 bended coaxial cables and join again in a wideband antiphase power combiner/divider. The coaxial transmission lines are connected with it also by N-type connectors. In the 3.4–5.4 GHz frequency band the attenuation of LMR400 coaxial cable is less than 0.35 dB/m [7]. Thus, the attenuation of this cable with 230 mm length, which is used in the OMT configuration, is less than 0.08 dB.

A turnstile junction and a wideband antiphase power combiner/divider were separately optimized using CST Microwave Studio software in order to provide the minimal reflection of electromagnetic waves for both polarizations in the operation frequency band 3.4–5.4 GHz. After this the final simulation of the whole coaxial OMT has been performed in CST Design Studio software.

A Turnstile Junction Optimization

The geometrical configuration of a turnstile junction is depicted in Fig. 3. It consists of an input coaxial waveguide, 4 identical ridges and 4 identical N-type connectors for output coaxial transmission lines. The outer diameter of an input coaxial waveguide is 50.0 mm, and the inner one equals 23.0 mm.

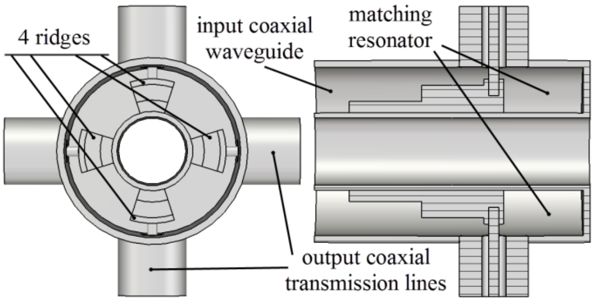

Fig. 3. The geometrical configuration of a turnstile junction

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 [8, 9] in order to obtain wideband matching in coaxial-to-waveguide transitions. Initially the resonator was created by the shift of ridges from the back conducting plate on 21.4 mm distance equal to the quarter of wavelength for TE_{11} modes in 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 23.0 mm, i.e. the quarter of wavelength for TE_{11} modes in coaxial waveguide at the frequency 4.2 GHz.

It has been shown in [10] that the maximal single-mode operation frequency range at antiphase excitation of coaxial quad-ridged waveguide with ridges on inner conducting cylinder is obtained at the ridges' angle 32°. This value of angle was used as the initial one for the optimization of a turnstile junction. After the optimization it has been determined that the minimal reflection of TE_{11} electromagnetic waves in frequency band 3.4–5.4 GHz is obtained at the angle 35°.

The outer diameter of 4 output coaxial transmission lines is 7.0 mm, and inner one equals 3.0 mm. Thus, their characteristic 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

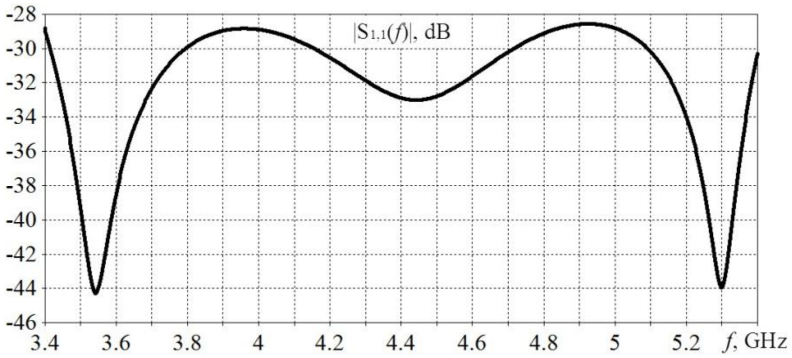

Fig. 4. The frequency dependence of minimized reflection coefficient of a turnstile junction

input coaxial waveguide. The frequency dependence of 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 operation frequency band 3.4–5.4 GHz.

A Wideband Antiphase Power Combiner/Divider

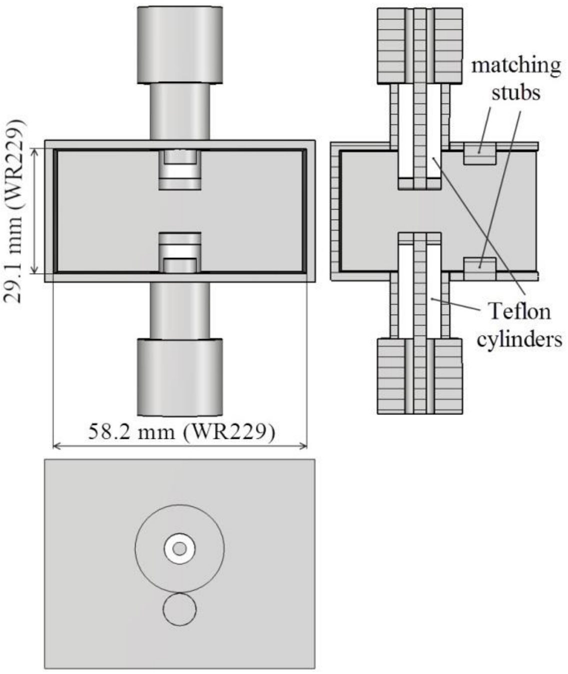

Fig. 5. The structure of a wideband ntiphase power combiner/divider

The geometric configuration of the wideband antiphase power combiner/divider developed is shown in Fig. 5. On the whole the construction is similar to the antiphase power combiner/divider presented in [11]. 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 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 characteristic impedances:

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

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.

All metal surfaces were simulated as perfect electric conductors. The rectangular waveguide is standard WR 229 with cross section dimensions 58.2mm × 29.1mm.

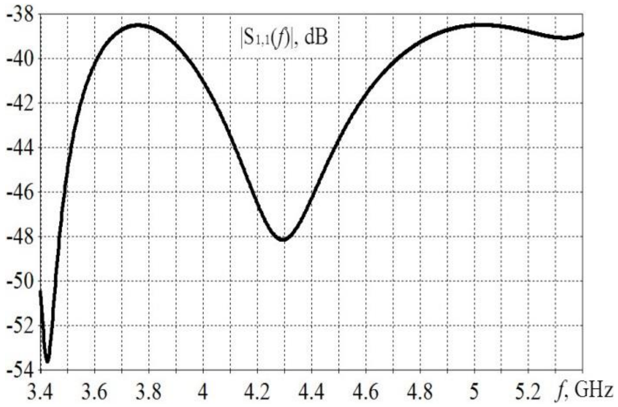

Fig. 6. The frequency dependence of minimized reflection coefficient of an antiphase power combiner/divider

All other dimensions were varied in order to provide the minimal reflection coefficient of the structure.

The frequency dependence of minimized reflection coefficient is shown in Fig. 6. As one can see, the reflection coefficient of an optimized antiphase power combiner/divider doesn't exceed −38 dB in the whole operation frequency band 3.4–5.4 GHz.

Characteristics of Coaxial Orthomode Transducer Developed

After the optimization of a turnstile junction and of an antiphase power combiner/divider the final simulation of OMT characteristics has been performed using CST Design Studio software. The frequency dependence of minimized reflection coefficient is depicted in Fig. 7, and the one of crosspolar isolation is presented in Fig. 8. It is the same for both linear polarizations.

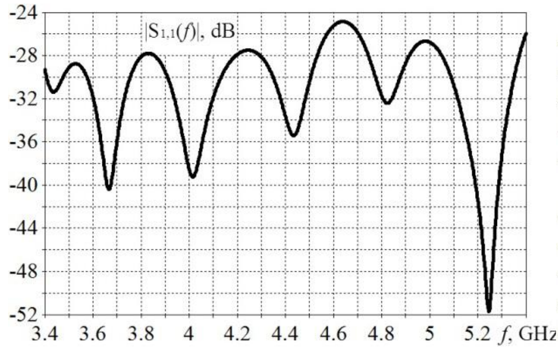

Fig. 7. The frequency dependence of minimized reflection coefficient of coaxial orthomode transducer.

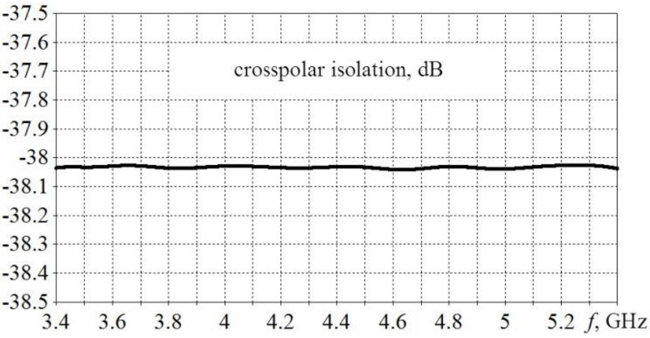

Fig. 8. The frequency dependence of crosspolar isolation of coaxial orthomode transducer.

As one can see in Figs. 7 and 8 the reflection coefficient of the OMT is less than −24 dB and its crosspolar isolation exceeds 38 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 in 2 times and the relative operation frequency bandwidth of OMT from [4, 5] — more than in 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 developed consists of elements of 3 main types, namely:

1) a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines;
2) 2 coaxial transmission lines of LMR400 type [7] for each polarization;
3) a wideband antiphase power combiner/divider for each polarization.

A turnstile junction and an antiphase power combiner/divider were separately optimized using CST Microwave Studio software in order to provide the minimal reflection of electromagnetic waves for both polarizations in the coaxial OMT. After this the final simulation of OMT characteristics has been performed using CST Design Studio software.

The reflection coefficient of the OMT is less than −24 dB and its crosspolar isolation exceeds 38 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 in 2 times and the relative operation frequency bandwidth of OMT from [4, 5] — more than in 4 times with the lower reflection coefficient.

The wideband coaxial OMT developed can be used in dual-polarized multiband antennas for satellite telecommunication systems and for radioastronomy.

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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 мінімального відбиття електромагнітних хвиль обох поляризацій. Після цього було проведено фінальне моделювання характеристик ортомодового перетворювача в програмі CST Design Studio. Коефіцієнт відбиття розробленого коаксіального ортомодового перетворювача не перевищує −24 дБ, а його крос-поляризаційна розв’язка перевищує 38 дБ у всій робочій смузі частот 3,4-5,4 ГГц. Розроблений широкосмуговий когерентний коаксіальний ортомодовий перетворювач може бути використаний у двополяризаційних багато діапазонних антенах для супутникових телекомунікаційних систем і для радіоастрономії.*

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

Пильтяй С. И. ***Коаксиальный ортомодовый преобразователь для расширенного С-диапазона.*** *Разработано 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 минимального отражения электромагнитных волн обеих поляризаций. После этого было проведено финальное моделирование характеристик ортомодового преобразователя в программе CST Design Studio. Коэффициент отражения разработанного коаксиального ортомодового преобразователя не превышает −24 дБ, а его кросс-поляризационная развязка превышает 38 дБ во всей рабочей полосе частот 3,4–5,4 ГГц. Разработанный широкополосный когерентный коаксиальный ортомодовый преобразователь может быть использован в двухполяризационных многодиапазонных антеннах для спутниковых телекоммуникационных систем и для радиоастрономии.*

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

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

Introduction. In this paper a novel configuration of wideband coherent coaxial OMT is presented.

General Design of an Orthomode Transducer. The OMT consists of elements of 3 main types: a turnstile junction between coaxial quad-ridged waveguide and 4 coaxial transmission lines; 4 coaxial transmission lines of LMR400 type; 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.

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

Characteristics of Coaxial Orthomode Transducer Developed. The simulation of OMT characteristics has been performed using CST Design Studio software.

Conclusions. A wideband coherent coaxial orthomode transducer has been developed for the operation frequency band 3.4–5.4 GHz. In this frequency band the reflection coefficient of OMT is less than −24 dB and its crosspolar isolation exceeds 38 dB. The wideband coaxial OMT developed can be used in dual-polarized multiband antennas for satellite telecommunications and for radioastronomy.

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