ЗБОРНИК РАДОВА

65. годишња конференција за електронику, телекомуникације, рачунарство, аутоматику и нуклеарну технику

ЕТРАН 2021

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8. интернационална конференција за електротехнику, електронику и рачунарство

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8th International Conference on Electrical, Electronic and Computing Engineering

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Радови укључени у Зборник прихваћени су од стране рецензената и приказани на 65. годишњој конференцији Друштва за ЕТРАН (ЕТРАН 2021) и 8. Интернационалној конференцији (ИцЕТРАН 2021) које су одржане од 08. до 10. септембра 2021. године у Етно селу Станишићи, Република Српска.

Број пријављених радова за конференције ЕТРАН и ИцЕТРАН је 162. Рецензије радова обавило је укупно 266 рецензената. Просечан број рецензената по раду био је 2. Прихваћен је и на конференцији приказан 141 рад који су публиковани у овом зборнику.

Заједничка тематска сесија "Дигитална Србија и Република Српска" окупила је научнике, стручњаке, истраживаче, представнике високошколских установа и представнике државе који су изнели своје погледе на значај и развој информационих технологија и вештачке интелигенције, на њихову улогу у развоју привреде и на одговарајуће промене у образовном систему. Координатори сесије били су проф. др Бранко Докић и проф. др Мило Томашевић, док су активни учесници сесије били Мр Срђан Рајчевић, Министар за научнотехнолошки развој, високо образовање и информационо друштво у Влади Републике Српске, др Саша Стојановић, помоћник Министра за просвету, науку и технолошки развој Владе Србије, проф. др Мило Томашевић декан Електротехничког факултета Универзитета у Београду, проф. др Зоран Ђурић, декан Електротехничког факултета Универзитета у Бањој Луци и проф. др Божидар Поповић, декан Електротехничког факултета Универзитета у Источном Сарајеву.

Координатор специјалне седнице на секцији Метрологија, под насловом "Стохастичке методе у мерењима био је Владимир Вујичић. Координатор специјалне седнице на секцији Рачунарство и вештачка интелигенција, под насловом "Шта рачунари данас не могу" био је Бошко Николић. У оквиру секције за електроенергетику одржана је специјална седница "Електроенергетика у 21. веку" у организацији Одбора за енергетику САНУ.

Члан Председништва Предраг М. Петровић био је координатор заједничке тематске седнице организоване као омаж Милољубу Смиљанићу, Почасном члану Друштва за ЕТРАН и Генералном секретару Академије инжењерских наука. Уз поруку "Драги Мићо, дивљење и поштовање са захвалношћу" говорили су Предраг М. Петровић, Дејан Б. Поповић, Председник ЕТРАН-а.

Председник ЕТРАН-а, академик Дејан Б. Поповић био је координатор заједничке тематске седнице организоване као омаж академику Нинославу Стојадиновићу, бившем Председнику ЕТРАН-а, члану Председништва и Заслужном члану Друштва за ЕТРАН. Уз поруку "Остајемо да негујемо његове идеје" говорили су проф. др Данијел Данковић, Дејан Б. Поповић, Председник ЕТРАН-а и Братислав Миловановић, академик АИНС.

Посебно се захваљујемо организаторима из Републике Српске и домаћинима из Бијељине, који су допринели стварању услова за рад и плодну размену мишљења и критички осврт на резултате у оквиру свих секција.

Београд, 12.10.2021.
Академик Слободан Вукосавић
заменик председника ЕТРАН

The papers included in the Proceedings were selected in a peer review process and presented at the 65th annual conference of the ETRAN Society (ETRAN 2021) and at the 8th international Conference IcETRAN 2021, both held September 8 – 10, 2021 in Stanišići ethno-village, Republic of Srpska, Bosnia and Herzegovina.

The number of the submitted papers for the ETRAN and IcETRAN conferences was 162 in total. Peer reviewing was done by 266 reviewers. The average number of reviewers per paper was 2. A total of 141 papers was accepted, presented at the two conferences and published in full in these Proceedings.

The joint thematic session "Digital Serbia and Republic of Srpska" gathered scientists, experts, researchers, representatives of universities and governmental representatives who presented their opinions about the significance and development of information technologies and artificial intelligence, their role in the economic development and the corresponding changes in the educational system. Session coordinators were prof. dr. Branko Dokić and prof. dr. Milo Tomašević, while the active participants of the session were Mag. Sci Srdjan Rajčević, Minister of Scientific and Technological Development, Higher Education and Information Society in the government of the Republic of Srpska, dr. Saša Stojanović, Assistant Minister of Education, Science and Technological Development in the government of Republic of Serbia, prof. dr. Milo Tomašević, Dean of the School of Electrical Engineering, University of Belgrade, prof. dr. Zoran Djurić, Dean of the Faculty of Electrical Engineering, University of Banja Luka and prof. dr. Božidar Popović, Dean of the Faculty of Electrical Engineering, University of East Sarajevo.

The coordinator of the special session within the Metrology Section titled "Stochastic Methods in measurements" was Vladimir Vujičić. The coordinator of the special session within the Computers and Artificial Intelligence Section titled "What computers cannot do today" was Boško Nikolić. Within the Power Engineering Section a special session "Electric Power in 21st Century", organized by the Power Engineering Board of Serbian Academy of Sciences and Arts (SASA).

The member of the ETRAN Society Board Predrag M. Petrović was the coordinator of the plenary thematic session organized as a homage to late dr. Miloljub Smiljanić, Fellow of the ETRAN Society and Secretary General of the Serbian Academy of Engineering Sciences. With the message "Dear Mićo, admiration and respect with gratitude" the speakers were Predrag M. Petrović and academician Dejan B. Popović, ETRAN Society Chairman.

The ETRAN Society Chairman, academician Dejan B. Popović was the coordinator of the plenary thematic session organized as a homage to late academician Ninoslav Stojadinović, Member of ETRAN Society Board and a Fellow of ETRAN Society. With the message "We continue to forward his ideas" the speakers were prof. dr. Danijel Danković, academician Dejan B. Popović, ETRAN Society Chairman and Bratislav Milovanović, academician of Serbian Academy of Engineering Sciences.

We express our special gratitude to the organizers from the Republic of Srpska and our hosts from Bijeljina who contributed to creating working conditions and a fruitful interchange of opinions, as well as a critical review of the results within all sections.

Belgrade, October 12, 2021.
Academician Slobodan Vukosavić
Vice-Chairman of the ETRAN Society

Reduced Dimensions Planar Rat Race Coupler Design

Denis A. Letavin and Dusan A. Nesic, *Member, IEEE*

***Abstract*—The design of a rat race directional coupler was investigated in the Cadence AWR Design Environment program. By using low-pass filters instead of quarter-wave sections, it was possible to reduce the size of the device by 82.3%. In this case, the following deterioration of frequency characteristics occurred: narrowing of the operating frequency band by 19.3%, an increase in imbalance, and a decrease in matching. Also, the area of the compact double ring coupler was reduced by 84.5% while the bandwidth was narrowed by 29.2%.**

***Index Terms*—Filter, miniaturization, stub, coupler.**

I. Introduction

THE rat race directional coupler functions as a signal power divider with two phase differences, 0 and 180 degrees, depending on which port is considered to be the input port. The topology of such a device consists of four segments, three of which have an electrical length of 90 degrees, and the remaining 270 degrees. After combining such segments, a ring with a length of 1.5 wavelengths per line is obtained. Due to the fact that the wavelength and frequency are related, the lower the operating frequency of the device, the more area on the printed circuit board it will have. Therefore, at low frequencies, where the couplers turn out to be cumbersome, its miniaturization is actual, with the minimum possible deterioration of frequency characteristics. There are a lot of options for miniaturizing the spokesmen. Let's take a look at just a few. The following approaches are used to miniaturize tap-off devices: microstrip cells [1], T-shaped structures [2], dual-transmission lines [3], using C-SCMRC resonators with distributive equivalent circuit [4], artificial transmission lines [5, 10, 14, 15], resonators [6, 7, 13], circular defected ground structure [8], shunt-stub-based artificial transmission lines [9], multilayer LTCC [11, 12]. In the proposed work, a method is considered for obtaining a compact ring coupler by replacing all quarter-wave sections with low-pass filters. Also considered is a compact double ring coupler, which, due to the addition of one more circuit, increases the operating frequency band and dimensions.

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II. Design Coupler

A circular directional coupler is a type of power divider used in microwave technology. Using the Cadence AWR DE program and the built-in TXLine calculator, the topology of a standard coupler was calculated (Fig. 1). The well-known FR4 material acts as a substrate material, with ε = 4.4 and h = 1 mm, and as a central frequency of 1 GHz. The obtained frequency characteristics of the coupler in the AWR program are illustrated in Figures 2 and 3. The area of the device is 43 x 91.5 = 3934.5 mm^2.

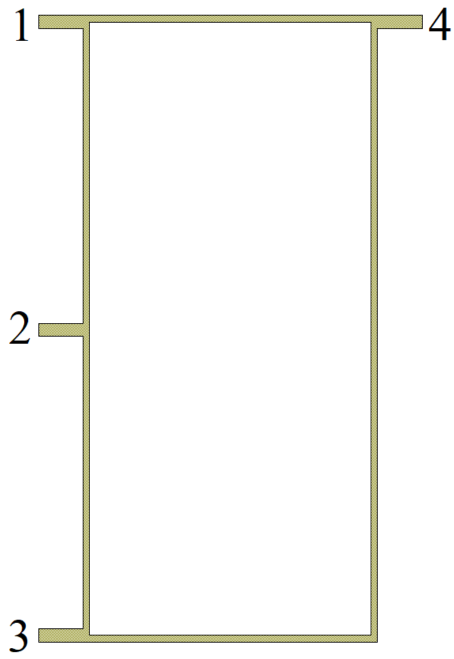

Fig. 1. Standard rat race coupler layout

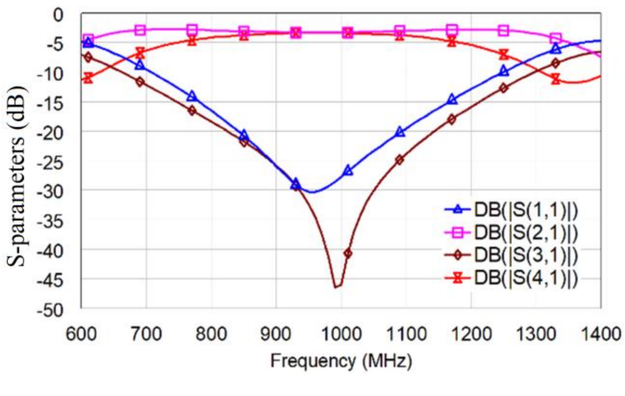

Fig. 2. S-parameter versus frequency plot for a standard rat race coupler

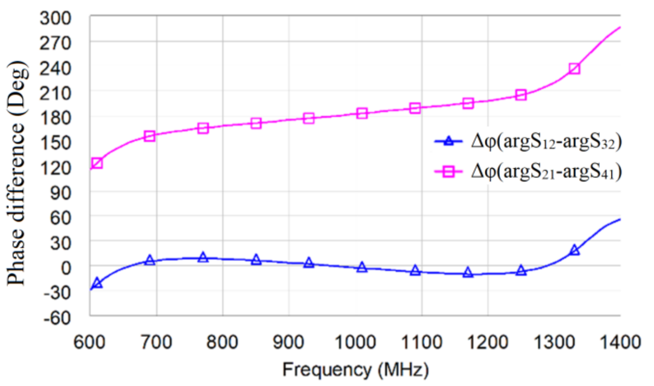

Fig. 3. The graph of the phase difference of the output signals depending on the choice of the input port (blue line - 1 input port, pink line - 4 input port)

According to the graphs obtained, it can be seen that the operating frequency band of the coupler at the isolation level "minus" 20 dB is 320 MHz (824-1144 MHz). The imbalance between the output signals of the structure in the frequency band does not exceed 1.3 dB. The area inside the coupler is not used in any way, which is an additional disadvantage of such a device. To reduce the size of the ring coupler, the required low-pass filters are initially calculated, which are used instead of the quarter-wave sections. For this purpose, a filter is calculated for the required wave impedance of 70.7 Ohm, which has a phase incursion of 90 degrees at a central frequency of 1 GHz. Filters can be implemented in a T-shaped or U-shaped circuit (Figure 4). They are completely equivalent to each other and can be used with equal efficiency. However, in our case, a U-shaped circuit was chosen, due to the fact that the extreme capacitive elements can be combined with the extreme elements from other filters, which can make it possible to more successfully fill the space inside the coupler. Low-pass filters can be calculated using the built-in iFilter tool in the Cadence AWR software.

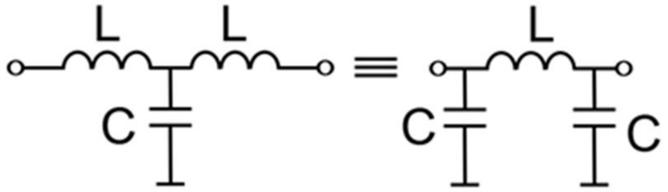

Fig. 4. T-shaped and U-shaped low-pass filter circuit

To calculate the ratings of CLC (capacitance - inductance - capacitance) elements, it is necessary to know the characteristic impedance of the transmission line, the parameters of the substrate material, the central frequency at which it is necessary to provide a phase shift of 90 degrees. After all filters are calculated, they are gradually installed instead of the quarter-wave sections of the coupler. The arrangement of the filter elements is carried out in such a way that there is no electrical contact between the elements of adjacent filters. After this procedure, an electrodynamic design calculation is performed, and if the frequency characteristics are unsatisfactory, then a forced optimization of the coupler design is performed in order to obtain the required characteristics. The topology of the compact ring coupler is shown in Figure 5. The obtained frequency characteristics of the compact coupler in the AWR program are illustrated in Figures 6 and 7.

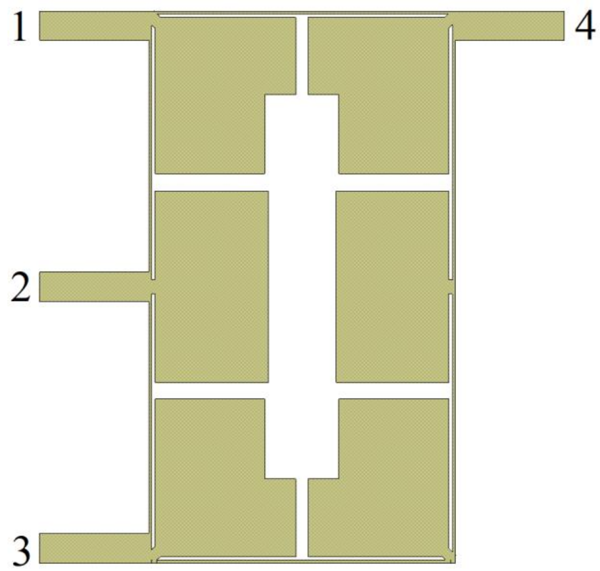

Fig. 5. Compact rat race coupler

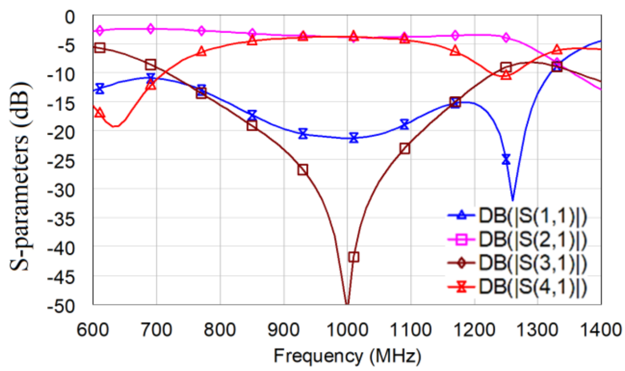

Fig. 6. S-parameter versus frequency plot for a compact rat race coupler

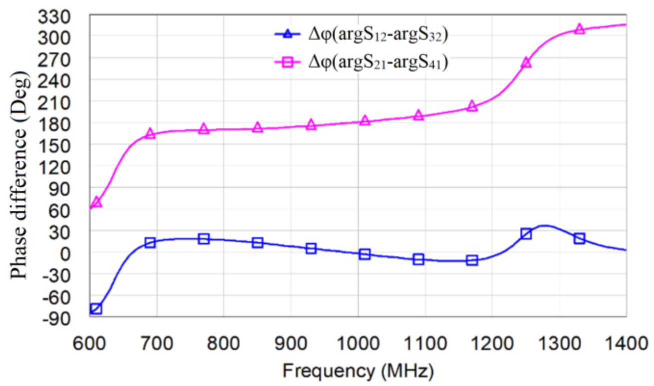

Fig. 7. The graph of the phase difference of the output signals depending on the choice of the input port (blue line - 1 input port, pink line - 4 input port)

By replacing the quarter-wave sections with low-pass filters and using the area inside the device, it was possible to reduce the area of the device by 82.3%. In a miniature version, the coupler has an area equal to 19.65 x 35.5 = 697.6 mm^2. According to the graphs obtained, it can be seen that the operating frequency band of the coupler at the isolation level "minus" 20 dB is 258 MHz (860-1118 MHz). The imbalance between the output signals of the structure does not exceed 1.1 dB. As a result of the miniaturization of the coupler, the operating frequency band was narrowed by 19.3%. The differences are primarily due to the incomplete coincidence of the characteristics of the quarter-wave sections and the elements installed instead of them. From the data in Table 1, you can compare the characteristics of the standard and miniature coupler.

TABLE I
COMPARATIVE DATA OF COUPLER

Parameters	Standard	Compact
bandwidth, MHz	320	258
Area, mm^2	3934,5	697,6
Relative area, %	100	17.7
Central frequency, MHz	1000	1000
The phase outputs on the central frequency, °	0 180	1.8 180.3

To increase the bandwidth of operating frequencies, an additional circuit is added to the design of the coupler, the length of which is equal to the wavelength in the line. To increase the bandwidth of the quadrature directional couplers, the addition of additional stub lines (cascading) is used. In the case of ring (common-phase-antiphase) taps, cascading is also used to increase the bandwidth. The dual ring coupler topology is shown in Figure 8. A single wavelength loop is added to the coupler design, with a characteristic impedance of 100 ohms. To further increase the strip, a third and subsequent circuit can be added, but this will lead to an increase in dimensions and complicate the design of the device. Low-pass filters are also asymmetrically designed to occupy the internal area of the coupler and further reduce the size of the device. The obtained frequency characteristics of the compact coupler in the AWR program are illustrated in Figures 9 and 10.

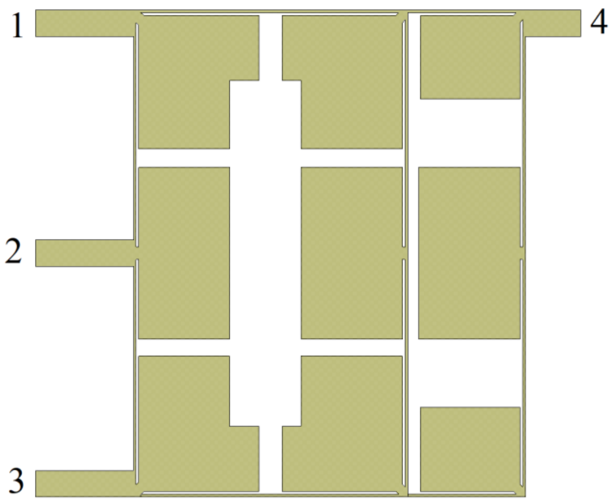

Fig. 8. Compact double rat race coupler

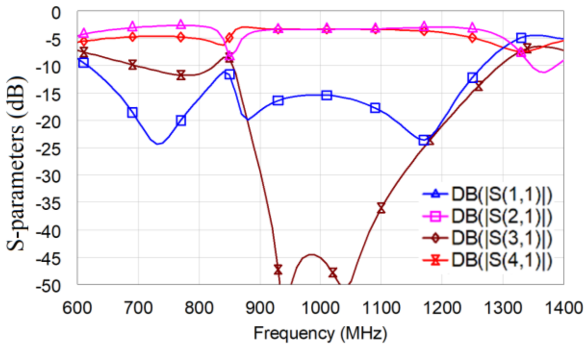

Fig. 9. S-parameter versus frequency plot for a compact double rat race coupler

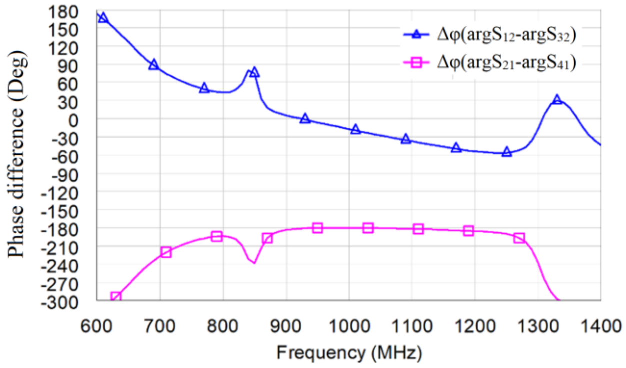

Fig. 10. The graph of the phase difference of the output signals depending on the choice of the input port (blue line - 1 input port, pink line - 4 input port)

By adding a loop, it was possible to increase the operating frequency band of the coupler to 329 MHz. At the same time, the area of the device increased to 977.2 mm^2. From the data in Table 2, you can compare the characteristics of the standard and miniature coupler.

TABLE II
COMPARATIVE DATA OF COUPLER

Parameters	Standard	Compact
bandwidth, MHz	465	329
Area, mm^2	6302	977.2
Relative area, %	100	15.5
Central frequency, MHz	1000	1000
The phase outputs on the central frequency, °	0 180	12 180

III. CONCLUSION

A miniature ring coupler obtained by replacing quarter-wave sections with low-pass filters is investigated in this work. Filter elements are located in the internal space of the device. All this made it possible to reduce the area of the coupler by 82.3% with a relative bandwidth of 25.8%, which is 19.3% less than that of a standard device. A double ring coupler was also obtained, the area of which is 84.5% less than the area of its standard implementation, with a relative bandwidth of 32.9%, which is 29.2% less than that of a standard device.

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