11.1

Dual-band circular polarization radiating element on coupled resonators for operation in the millimeter wavelength range

© A.D. Poligina [1,2], A.V. Taganov [2]

[1] Siberian State University, Krasnoyarsk, Russia
[2] JSC „Scientific and Production Enterprise„ Radiosvyaz“, Krasnoyarsk, Russia
E-mail: anastasia0711@mail.ru

Received October 11, 2023
Revised November 2, 2023
Accepted November 9, 2023

The paper is devoted to the study of the possibility of realizing a technological dual-band radiating element with circular polarization for application in low-profile antenna arrays, including the millimeter wavelength range. The results of modeling of the obtained structure are presented. The proposed radiator is a system of coupled resonators, the ellipticity coefficient of which exceeds 0.8 in both ranges of operating frequencies. The coupled resonator systems are excited through a strip transmission line via a slot transition. The element gain is 6 dB and 8 dB in the receiving and transmitting bands, respectively.

Keywords: microstrip antenna array, coupled resonators, slot transition, circular polarization.

DOI: 10.61011/TPL.2024.02.57984.19765

Parabolic reflectors and antenna arrays (AAs) are most commonly used in antenna systems for satellite and tropospheric communications. Two separated frequency bands are used to realize duplex satellite communication. Several approaches are used to address the issue of combining receiving and transmitting antennas:

- — using two single-band parabolic antennas;
- — using a dual-band combined irradiator [1];
- — the use of two single-band AAs;
- — using a combined transceiver AA [2].

In those applications that have strict requirements for mass-dimensional parameters, such as in wearable and mobile communication stations, the use of low-profile antenna arrays is most appropriate. AAs with combined bands makes it possible to minimize the size of the communication station by 2 times, since in this case only one receiving and transmitting antenna will be needed. An important task in the design of a dual-band AA is the selection of an effective radiating element, the parameters of which determine the final energy characteristics of the antenna.

To design low-profile AAs, microstrip printed radiators are traditionally used [3], the main disadvantage of which is their narrow operating frequency bandwidth (less than 5%) due to the resonant nature of operation. To extend the operating frequency bandwidth, multilayer structures are used [4], which are two or more coupled resonators, one of which serves as the primary energy source for excitation of the others.

One of the frequent requirements for communication systems is operation on circular polarization, where the ellipticity coefficient must be sufficiently high (more than 0.8) to allow the antenna to be used in systems with polarization densification.

To realize a printed microstrip resonator with circular polarization, longitudinal and transverse current asymmetry must be introduced. This is most often achieved by implementing a power supply method where there are two power supply points exciting two orthogonal polarizations with a phase shift of 90° [5]. To realize this, a power divider is required to provide the necessary phase shift, which complicates the antenna array design when it comes to multilayer printed circuit boards.

Another way to obtain a circularly polarized element is to perforate it with holes of different shapes, which shifts the direction of the currents [6].

The ellipticity factor can be increased by using different shapes of radiating elements (e.g., square resonators have their corners on the same diagonal cut off [7]).

In the present work, excitation of circular polarization is achieved by using a rectangular patch. Each such transmitter will have two resonant frequencies: along the long and short sides. In this configuration, the transmitter is excited by a single power point located closer to the edge relative to both sides.

To improve the processability of the fabrication, a possible embodiment case has been considered where the excitation of the resonators is realized through a slot junction powered by a strip transmission line. The length of the slot is chosen to be about half the wavelength. A U--shaped slot is implemented to ensure compact wiring.

Fig. 1 shows the structure of the obtained transmitter, which is a system of coupled resonators operating each in its own frequency range.

The transmitter system is a multilayer board made on F4BM grade PTFE. The material between the two resonators has a dielectric constant equal to 2.2. The substrate material of the active resonator has a dielectric

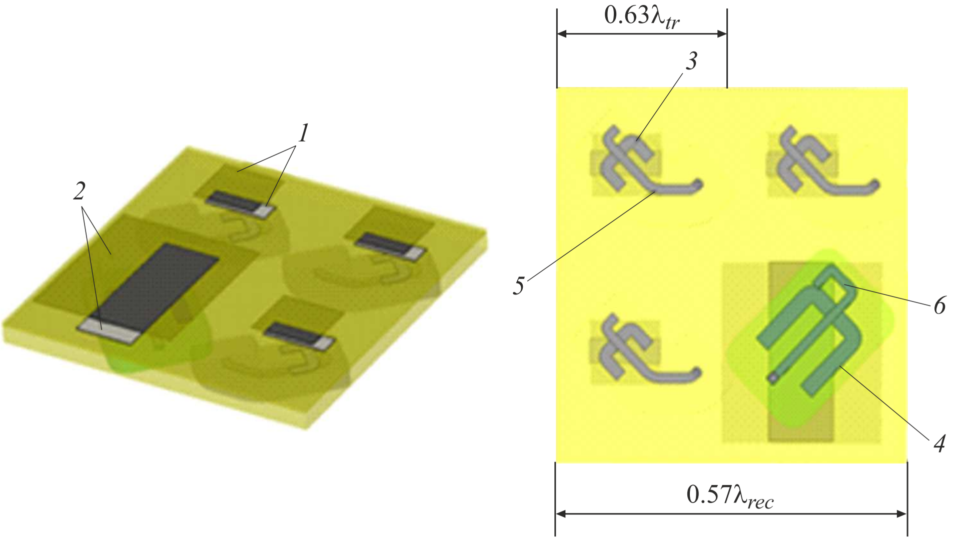

Figure 1. The structure of a dual-band radiating element on coupled resonators. *1* — transmitting band emitter, *2* — receiving band emitter, *3* — transmitting band powering slot, *4* — receiving band powering slot, *5* — transmitting band excitation strip, *6* — receiving band excitation strip.

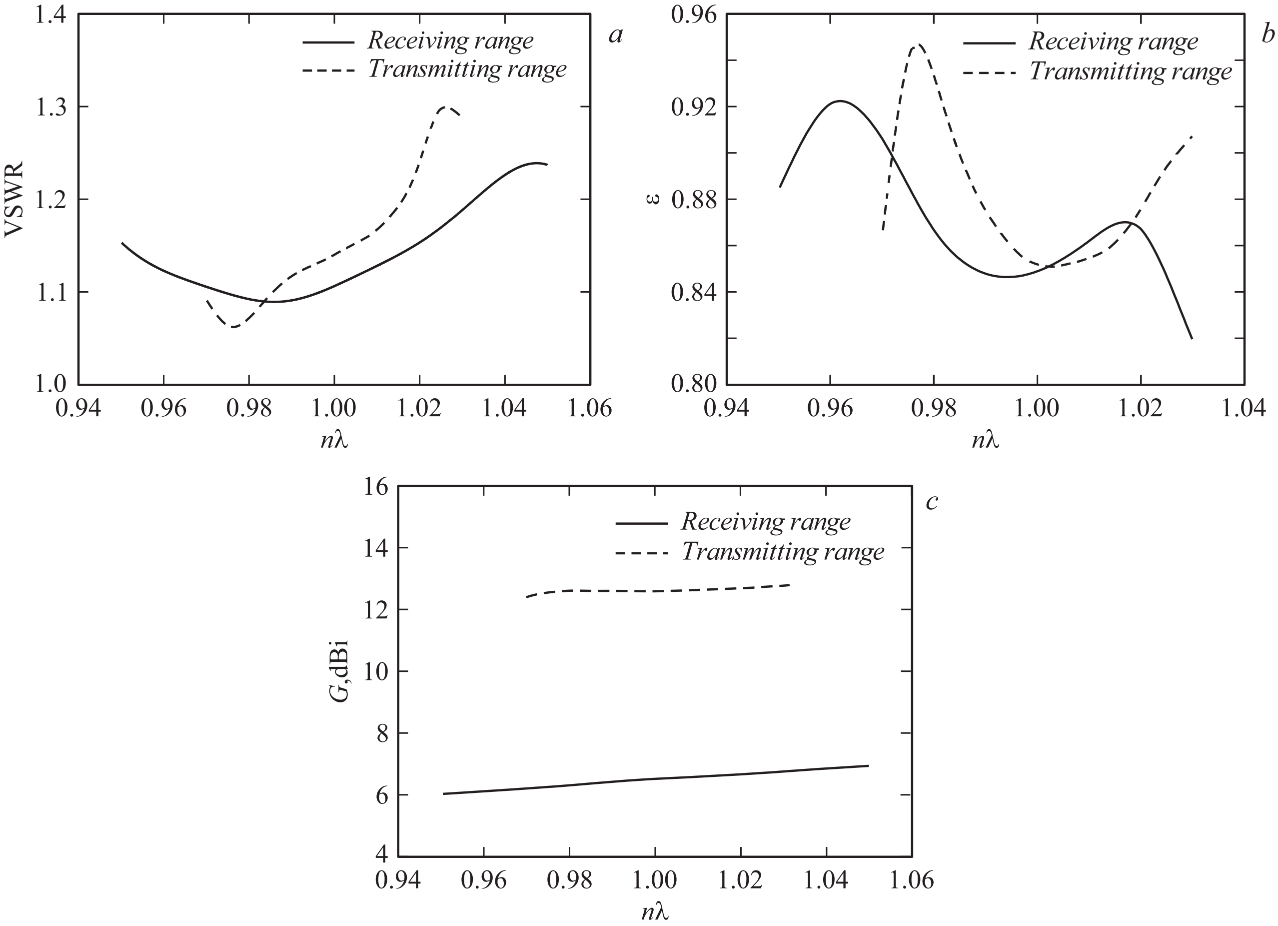

Figure 2. Frequency dependences of voltage standing wave ratio (VSWR) (*a*), ellipticity factor ε (*b*), and gain factor G (*c*).

constant equal to 3.0. The strip element excitation system on the symmetrical line is made of the same material. The array pitch for this radiating element in the receiving range is $0.57\lambda_{rec}$, in the transmitting range — $0.63\lambda_{tr}$, where λ_{rec} and λ_{tr} — the center frequencies of the receiving and transmitting ranges, respectively. The obtained configuration can be used to construct an efficient combined AA without diffraction maxima of the directivity pattern, since the array pitch corresponds to this.

Fig. 2 shows the main characteristics obtained from the modelling. The frequency ranges of the proposed transmitter are spreaded by 2 times. The voltage standing wave ratio (VSWR) (Fig. 2, a) in both bands does not exceed 1.3. The ellipticity coefficient ε in the two frequency bands (Fig. 2, b) is above 0.8, which is currently sufficient to ensure efficient radiation in the enhanced polarization compaction mode. The gain G for the receiving element is 6 dBi, for the transmitting element system — about 12 dBi.

Thus, the research shows that there is a possibility to create an effective technological radiating dual-band element for application in low-profile AAs of millimeter wavelength range. With the help of this structure, it is possible to create a multilayer printed AA in fewer pressing steps due to the use of a slot transition instead of the classical coaxial transition, which increases the processability of fabrication. The high ellipticity factor of the element allows simplifying the excitation system by using in-phase and equal-amplitude board wiring. This in turn also increases processability in terms of AA development and design.

Funding

The study was carried out within the framework of the state assignment of the FSAEI HE „Siberian Federal University“ (number FSRZ-2023-0008).

Conflict of interest

The authors declare that they have no conflict of interest.

References

[1] S.V. Polenga, A.M. Aleksandrin, Y.P. Salomatov, K.V. Lemberg, A.A. Popovich, Uspekhi sovremennoi radioelectroniki (in Russian), № 11, 43 (2016).

[2] D.I. Voskresensky, E.V. Ovchinnikova, V.V. Fam, S.G. Kondratieva, P.A. Shmachilin, Antenny (in Russian), № 3, 8 (2018).

[3] R. Rajitha, K. Nishitha, R.M. Mandeep, G.L. Priya, in *2019 IEEE Int. Conf. on innovations in communication, computing and instrumentation (ICCI)* (Chennai, India, 2019), p. 8–11. DOI: 10.1109/ICCI46240.2019.9404482

[4] A.D. Poligina, A.V. Taganov, Y.P. Salomatov, in the collection *Proceedings of the XXIIIth All-Russian Sc.-Tech. Conf. with international participation, devoted to the 127-th Anniversary of the Day of Radio* (Krasnoyarsk, 2022), pp. 237–242.

[5] M.A. Rahman, Q. Delwar Hossain, M.A. Hossain, in *2014 Int. Conf. on electronic engineering and information & communication technology* (Dhaka, Bangladesh, 2014), p. 1–4. DOI: 10.1109/ICEEICT.2014.6919074

[6] L.C. Paul, R.K. Pramanik, M.M. ur Rashid, M.N. Hossain, M.Z. Mahmud, M.T. Islam, in *2019 Joint 8th Int. Conf. on informatics, electronics & vision (ICIEV) and 2019 3rd Int. Conf. on imaging, vision & pattern recognition* (*icIVPR*) (Spokane, WA, USA, 2019), p. 79–84. DOI: 10.1109/ICIEV.2019.8858553

[7] H.J. Kim, S.M. Kim, J.M. Son, W.G. Yang, in *2005 Asia-Pacific Microwave Conf. Proc.* (Suzhou, 2005), p. 4–7. DOI: 10.1109/APMC.2005.1606902

Translated by D.Kondaurov