

Compact design of diplexer for base stations operating within frequency bands 2.3–2.4/ 2.49–2.69 GHz

Konstantin Kobrin¹, Vyacheslav Rudakov², and Mikhail Manuilov^{1,*}

¹Southern Federal University, Physics Department, 344090 Rostov-on-Don, Russia

²Guandong Sigtenna Communication Technology Co., Ltd., Shipai Town, Dongguan, China

Abstract. A new compact design of diplexer with high electrical performances is proposed for base station antennas operating within frequency bands 2.3-2.4/2.49-2.69 GHz. The diplexer consists of two interdigital band-pass filters and coaxial power divider. Proposed design has high potential from view poin of implementation of wide-band as well as medium and narrow bands filters. The fabricated diplexer shows the following measured characteristics: reflection coefficient is -18 dB within passbands, insertion loss is -0.28 dB, isolation of ports is -30 dB. Diplexer has the relatively simple easy to manufacture design and compact dimensions, so it may be directly integrated into the base station antennas.

1 Introduction

Currently, the revolutionary fast progress of mobile communications systems is accompanied with the use of more high frequency bands, essential extension of operational bands, utilizing the multi-band and multi-beam operational mode. This is due to very high technical requirements to the base stations and their antennas which should satisfy the increasing wireless systems capacity needs.

One of the most widely utilizing solutions is the combined aperture of base station antenna. In this case only one wide-band linear antenna array is used which operates simultaneously in two frequency bands, instead of two linear antenna arrays placed in parallel and operating in two narrow frequency bands. This technology is known as "dipole reuse" and it is based on the use of various radio frequency diplexers [1-6]. The base station antennas designed with the dipole reuse technology have the reduced geometrical dimensions. In this case the independent beam tilt may be obtained for each operational frequency band of multi-band base station antenna. Thus, the radio frequency diplexers are key components for modern base stations and the development of diplexers is a problem of current importance.

2 Design of diplexer

The following main requirements are imposed on characteristics of RF diplexers for base station applications: high impedance matching (reflection loss should be about -20dB), low

* Corresponding author: m_manuilov@sfedu.ru

insertion loss (about -0.2dB), high power operation capability, relatively high isolation between diplexer channels, the opportunity to implement narrow frequency band (some percents) as well as wide operational frequency bands (20% and more), the compact easy to manufacture design, which is appropriate for mass production.

In accordance with these requirements a novel design of radio frequency diplexer was developed, successfully fabricated and tested (Fig.1,2). The proposed design of diplexer is implemented on the base of inter-digital filters. This choice is founded on the high potential of inter-digital filters for implementation of pass band filter characteristics for various specifications including wide or narrow operational band (from several percents to 30% and more) and various slope of frequency response. The diplexer design includes the coaxial power divider which provides the wide band operation of diplexer.

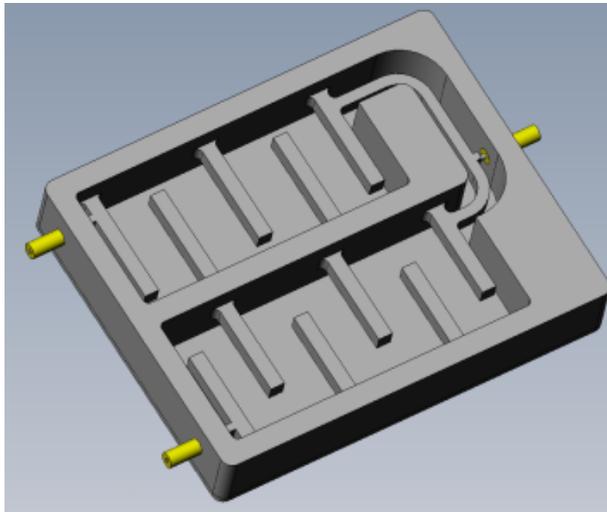


Fig. 1. Design of proposed diplexer without upper metal cover.

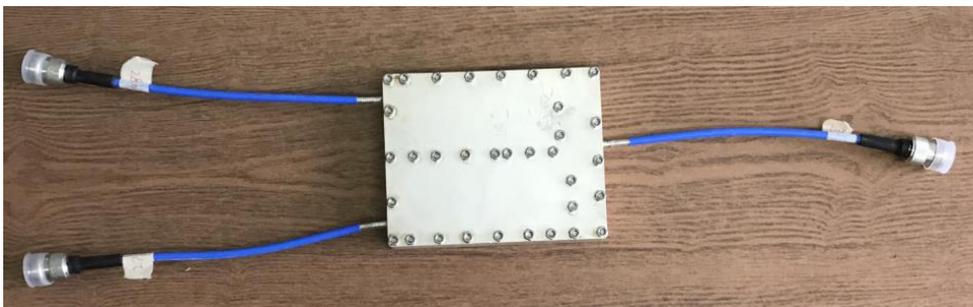


Fig. 2. Photograph of fabricated diplexer.

Diplexer consists of all-metal housing and two thin metallic plates which play the role of upper and lower covers (Fig. 1,2). The covers are attached by screws to the housing. The all-metal housing includes two pass band filters and coaxial power divider. Thus, all resonant elements are manufactured from the one metal part blank. This provides precise fabrication of resonators and power divider and the high repetition of frequency characteristics.

The diplexer is excited by 50-Ohm coaxial cables or coaxial connectors. In accordance with specified frequency bands 2.3-2.4/2.49-2.69 the inter-digital filters are implemented on 5 and 6 resonators, respectively. The input and output resonators play the role of the matching elements.

3 CAD of diplexer

Full wave electrodynamic simulation of diplexer has been carried out by means of finite element method on Ansys HFSS [7]. In the first step two inter-digital pass band filters were synthesized utilizing finite element method and hybrid full wave method developed in [8-9].

Hybrid full wave technique is based on Galerkin method, mode matching method, generalized scattering matrix method and this technique includes the following steps: (i) decomposition of diplexer into the basic discontinuities; (ii) solving the eigenvalue problems for ridged waveguide and calculation of cut-off frequencies of ridged waveguide; (iii) solving the scattering problems for each discontinuity and evaluation of its multi-mode scattering matrix; (iv) recombination of multi-mode scattering matrices of discontinuities and calculation of generalized scattering matrices of filters.

The eigen value problem solution for ridged waveguide is based on Galerkin method with taking into account the edge condition. The weighted Gegenbauer polynomials are used as basis functions each of which takes into account the field asymptotic near the rectangular edge of ridge. The problem is reduced to the uniform system of linear algebraic equations (SLAE). Solving the transcendental equation obtained from condition that determinant of SLAE is equal to zero we calculate the spectrum of cut-off frequencies. This modification of Galerkin technique has the dramatically fast convergence and high accuracy due to appropriate choice of basis functions.

Mode matching technique is used to solve the scattering problems for junction between the rectangular waveguide and ridge waveguide. Direct combination of generalized scattering matrices of discontinuities yields the generalized scattering matrix of filter. Suggested hybrid technique is an efficient tool for fast and accurate CAD of this class of filters.

4 Results

The inter-digital filter may be considered as a system of coupled strip-line resonators operating on TEM mode and each strip-line resonator has an open end and short circuit on the other end [10]. The length of each resonator is about one quarter of wave length on the central frequency of operational frequency band. An initial evaluation of geometrical dimensions of filters structure were obtained utilizing the circuit theory [10]. Next the full wave CAD of each filter was based on Ansys HFSS [7] and hybrid method above. The final full wave CAD of diplexer was carried out on Ansys HFSS.

The simulated frequency responses of diplexer S-parameters after numerical optimization are presented in Fig. 3. The reflection coefficient S11 within frequency bands 2.3-2.4/2.49-2.69 is less than -30 dB, the isolation of channels is about -30 dB. The tolerances analysis of proposed design of diplexer is shown in Fig. 4. The family of characteristics in Fig. 4 was calculated for random variation of the all dimensions with tolerance 0.05 mm. In this case the reflection coefficient S11 may increase up to -18 dB and some deviations of S21 and S31 are observed.

The suggested diplexer was successfully fabricated, experimentally tested and its measured frequency characteristics are shown in Fig. 5. The measured and theoretical results are in good agreement. Measured reflection coefficient within pass bands of diplexer is less than -18 dB and isolation of channels is about -30 dB. Diplexer has a compact easy-to-manufacture design with dimensions (15×77×100 mm) and it can be directly placed into the base station antennas.

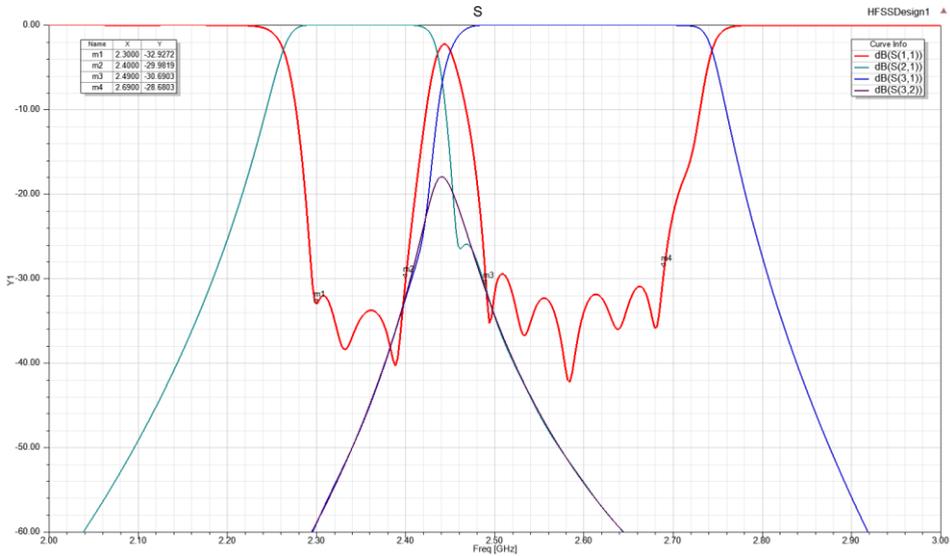


Fig. 3. Calculated frequency responses of diplexer.

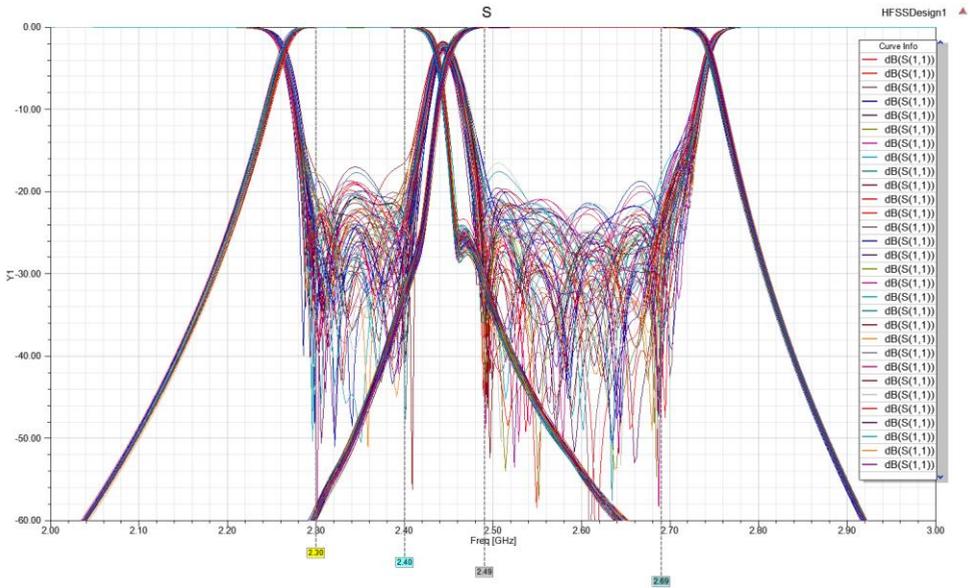


Fig. 4. Tolerances analysis of diplexer.

5 Conclusion

A novel design of diplexer for base stations of mobile communication systems is proposed. The manufactured diplexer shows within operational frequency bands 2.3-2.4/2.49-2.69 the reflection loss -18 dB, insertion loss 0.28 dB, isolation of ports -30 dB. Diplexer has compact dimensions (15×77×100 mm) and it can be set up directly into the base station antennas. The suggested diplexer design possess high potential for implementation for various radio frequency mobile communication diplexers with narrow and wide pass bands (up to 25% and more). The achieved diplexer characteristics are not ultimate and they can be improved by means of the use of tuning elements.

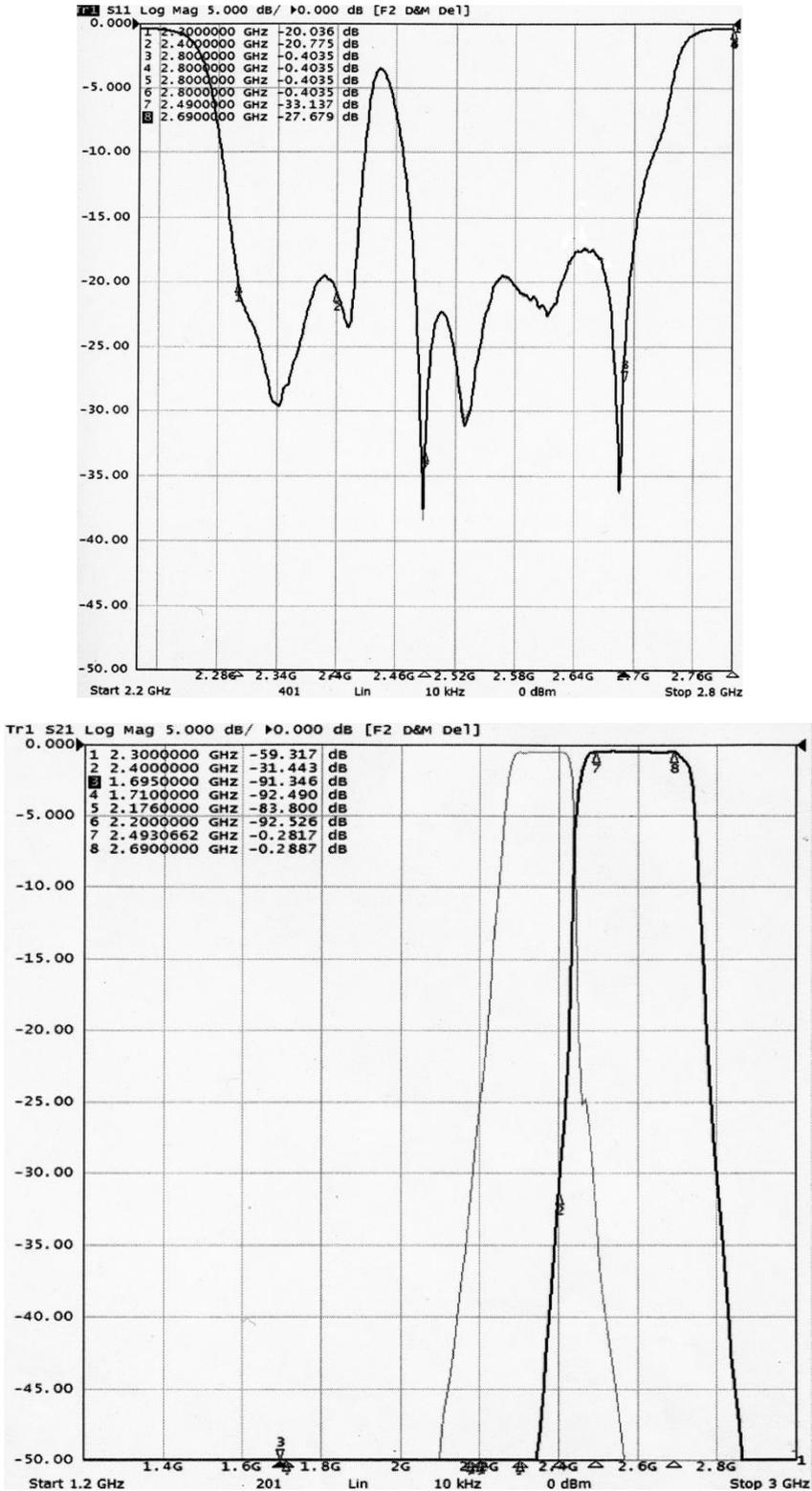


Fig. 5. Measured frequency responses of diplexer.

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