Design of a Microstrip Quadplexer for the RoFnet Project

Wafa Isam.A.Elboushi and Izzat Darwazeh
University College London

Abstract: This paper presents the design of a micro-strip quadplexer developed for the downlink communication between the central office (CO) and base stations (BS) of the multi wavelength Radio over Fibre project RoFnet. The quadplexer is to be used as channel separator for remote antenna sites. Parallel coupled resonators are used for the realisation of the quadplexer and filters. The designs are assessed through simulations.

1 Introduction

The reconfigurable Radio over Fibre network (RoFnet) project is a collaborative project involving UCL and the Universities of Faro, Aveiro and Coimbra in Portugal. The project aims to provide a solution for the increasing demand for high channel capacity and mobility by combining optical and wireless network technologies [1]. This is realised by using wavelength division multiplexing (WDM) as a method of sharing the capacity of existing fibre between multiple base stations (BSs). These BSs will be designed to provide broadband wireless coverage for mobile users through millimetre–wave radio links. Such systems employ microwave quadplexers at base stations transceivers as channel separators. Design steps of microwave and mm-wave quadplexers starts by designing microwave filters [2], then combining the filters using matching networks[3]. In this paper a quadplexer based on parallel coupled structures is presented. The quadplexer will be employed to separate the four data channels communicated between the central office and base stations of the RoFnet project. The channels are at 11 GHz,13 GHz,15 GHz and 17 GHz with data rates of 2Gb/s.

2. Design Concept and Procedure

The quadplexer was developed by firstly designing four band pass filters and then joining the filters by a transmission line that has varying widths .Each section of the line (of a different width) has a length that equals a quarter of the guided wavelength λ_0 of one of the control channels. Signals propagating through the line will effectively see an open circuit at points where the length of the line is at $\lambda_0/4$. Therefore, they could be coupled to an output port at which the corresponding band pass filter will be attached.

Microstrip transmission lines are chosen for the design since the operating frequencies are in the mm-wave regime and parallel coupled resonators are used because when compared to other types of coupling structures , such as end coupled resonators, they provide the maximum coupling for a given spacing between resonators.

We follow standard filter design procedures, as described in [4, 5]. The design of the microstrip parallel coupled bandpass filters starts by determining the order of the filter depending on the required stop band attenuation and the filter central frequency. Then, a low pass prototype of a Butterworth response is selected as it has the maximally flat passband response. Element de-normalization is done to transfer the low pass prototype into band pass prototype. Microstrip width and separations for the parallel coupled resonators lines could be determined form Quasi-Static synthesis graphs, or equations described in [5]. They could also be obtained by means of CAD programs. In these designs, ADS-LineCalc™ [6] is used to obtain the physical parameters of the resonators. Then transmission lines of varying width and length are designed so as to connect the filters.

3. Parallel Coupled Microstrip Bandpass Filters Design and Simulation results

The employed substrate has a relative dielectric constant of 10.2, a height of 250 µm and metal thickness of 35 µm. For narrow band filtering thin substrates are required to achieve the maximum coupling. Filters A, B, C and D are designed to be centred at 11, 13, 15, 17 GHz, respectively, with a fractional bandwidth of 0.1.

Fig.1 shows the layout diagram of one of the designed four filters (Filter D). Basic ADS simulation of the S21 parameters are shown in Figure 2 and full lay out (electromagnetic) simulation, obtained using Momentum™ is shown in the set depicted in Figure 3.

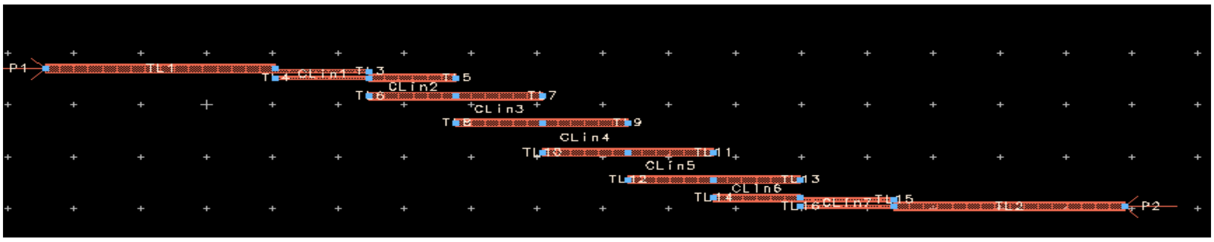

Fig. 1 Layout of filter D

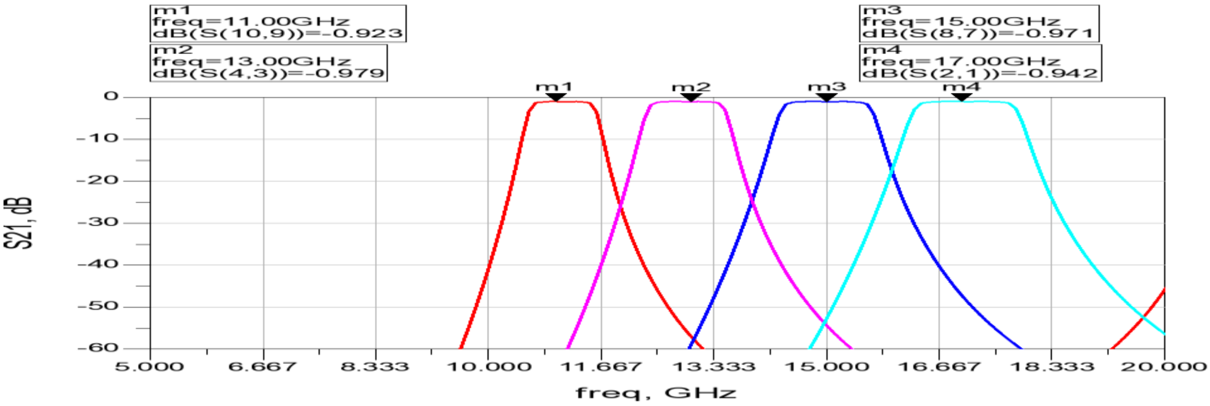

Fig.2 Simulated S21 of the four parallel coupled microstrip Filters (using ADS)

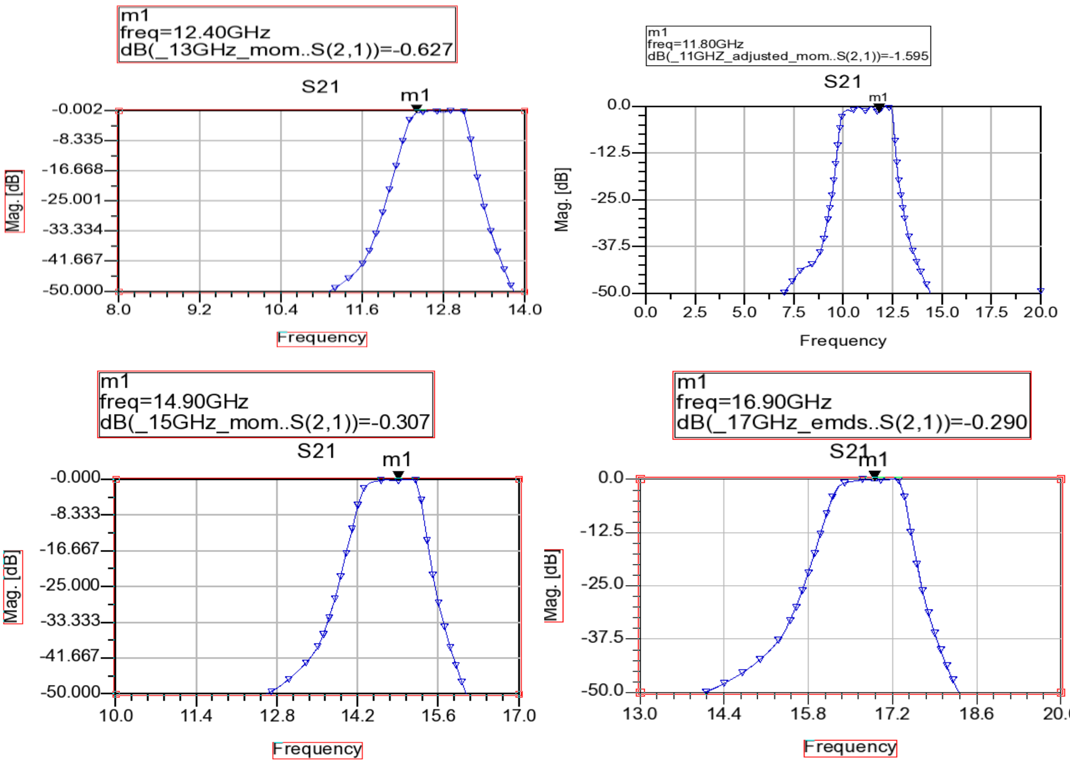

Fig. 3 Simulated S21 of the four parallel couple microstrip filters (using ADS-Momentum)

4. Quadplexer Design and Simulation Results

The quadplexer is designed by coupling a transmission line at four different resonance frequencies with four parallel coupled microstrip filters. The transmission line is designed to resonate at 17, 15, 13 and 11 GHz.. This is done by designing four sections. Each of these sections is coupled to the transmission line via a quarter wave coupler. Each of the couplers feeds a parallel coupled line filter tuned to one of the operating frequencies of the channels. Fig 4 shows the schematic of the quadplexer and indicates its layout structure. Fig. 5 shows the simulated S -parameters of the five outputs of the quadplexer.

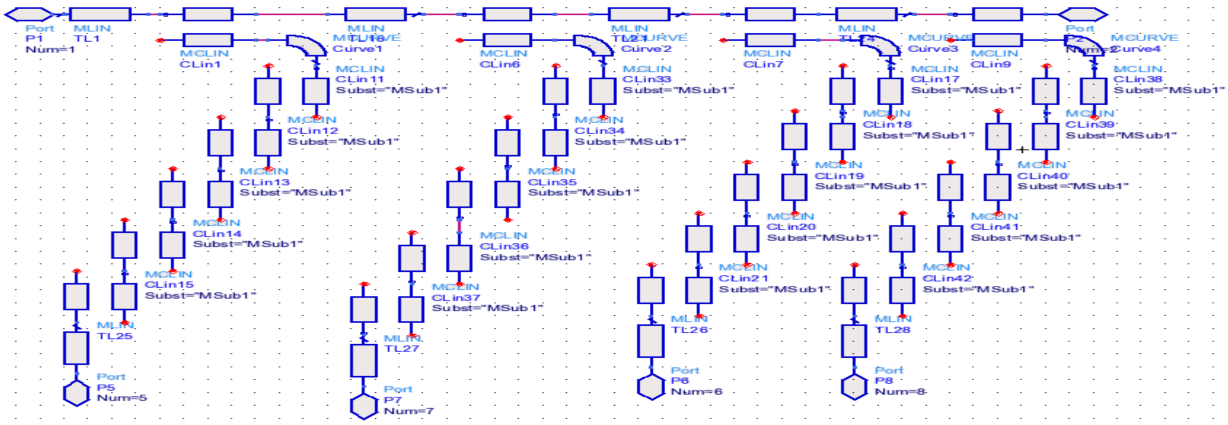

Fig. 4 Schematic Diagram of the quadplexer proposed design (from ADS)

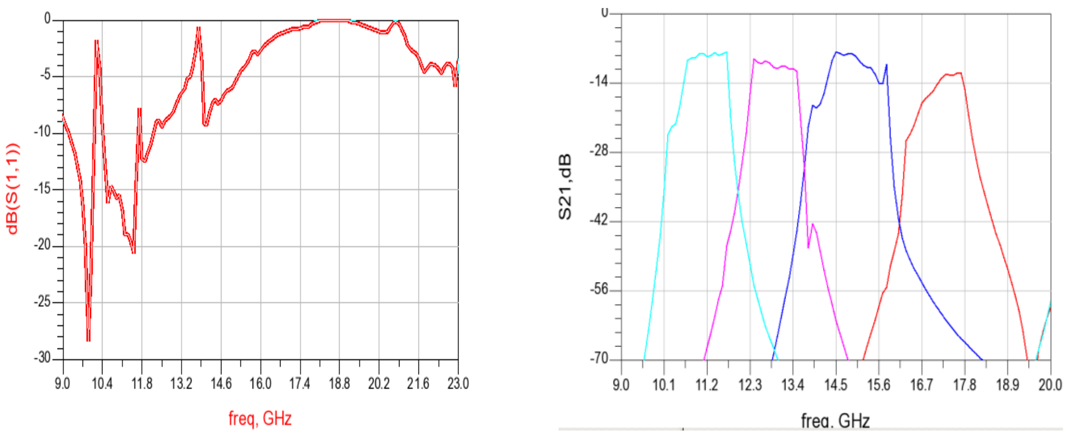

Fig. 5 Simulated s-parameters of the quadplexer. Input match (left) and four S21 parameters.

As the spacing between the resonators decreases coupling increases; this leads to coupling among output ports which decrease the isolation between the quadplexer ports. The design in Fig 6 is expected to give better isolation. Preliminary results indicate good gain and match characteristics; however, further studies of this structure are required.

The parallel coupled lines presented here have the advantages of simple design and synthesis procedures, planar character, tolerance to fabrication non-idalities and the possibility of achieving a wide range of filter fractional bandwidths. However, they have two drawbacks. The first, of importance when broadband filtering is required, is that the rejection of the upper stop band is less than that of the lower one. This is due to the difference between the even and odd modes phase velocities resulting in a specific filter section having two different effective electrical lengths. The second problem is particularly important for narrow band filtering for which strong coupling is required which leads to very small dimensions of strip width and strip spacing that may not be accurately fabricated. In our designs, both issues may be dealt with through careful signal characterisation and filter optimisation, before the filters and quadplexer are used in the network.

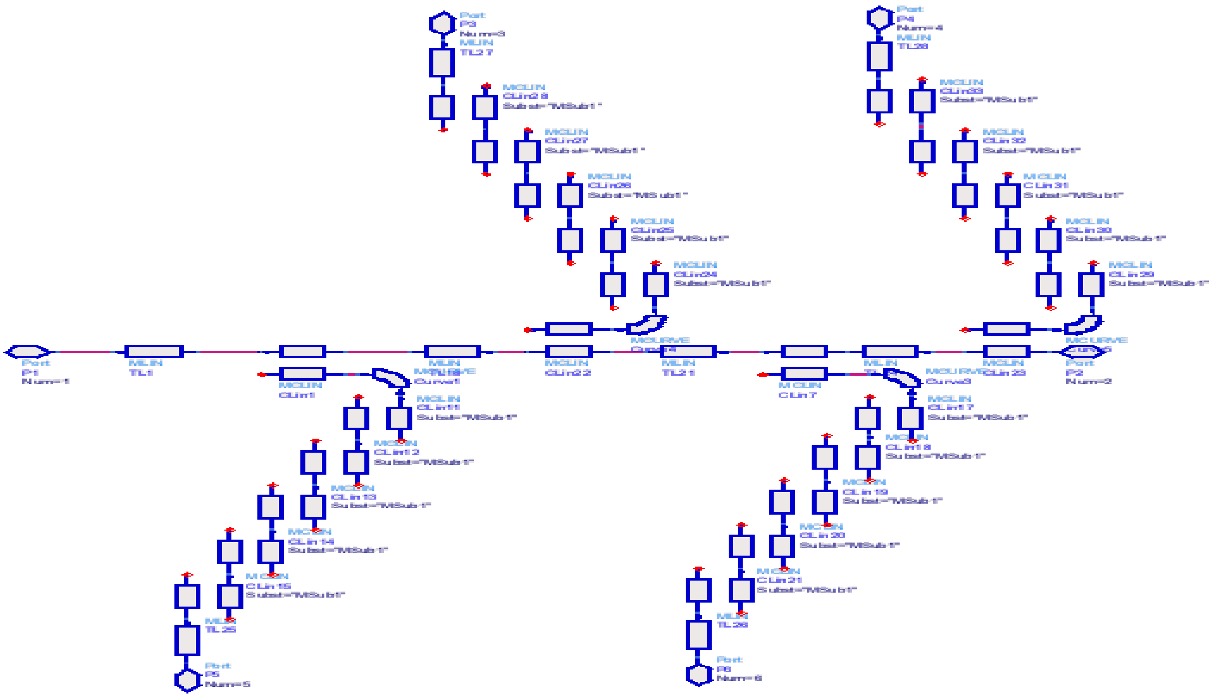

Fig. 6 Quadplexer; alternative layout (from ADS)

5. Conclusions

In this work designs and preliminary results of filters and quadplexer responses were reported. The circuits were designed as microstrip structures and aimed to operate at frequencies from 11 to 17 GHz. The filters are for use in a Radio over Fiber network and the results indicate the suitability of the design techniques of both filters and quadplexer for the required operation.

References

[1] M.C.R. Medeiros, R. Avo, P. Laurencio, N.S. Correia, A. Barradas, H.J.A da Silva, I. Darwazeh, J. E. Mitchell and P.M.N. Monteiro, “RoFnet reconfigurable radio over fiber network architecutre overview”, Journal of Telecommunications and Information Technology, no. 1, pp. 38-43, 2009.

[2]G.L, Matthaei and E.G Cristal “Multiplexer channel-separating units using interdigital and parallel coupled filters,” IEEE Trans, Microwave Theory Tech,vol.MTT-13, pp.328-334,May 1965

[3] G.L, Matthaei, L.Young and E.M.Jones, Microwave Filters, Impedance-Matching Networks and Coupling Structures, Artech House, 1980.

[4]D.M.Pozar,Microwave Engineering.New York:Wiley, 1997.

[5]Jia Sheng Hong and M.J.Lancaster, Microstrip Filters for RF /Microwave Applications, New York:Wiley,2001.

[6]Agilent EESof, http://eesof.tm.agilent.com.