Star-Junction X-Band Coupled Resonator Multiplexer

Talal Skaik*

*Electrical Engineering Department, Islamic University of Gaza, P.O. Box 108, Gaza, Palestine

talalskaik@gmail.com

***Abstract*— A novel design of coupled resonator star-junction multiplexer is presented. The multiplexer has been designed at the X-band with four non-contiguous channels. The multiplexer topology is based on coupled resonator structure, and it consists of thirteen waveguide cavities, one of which serves as a resonating junction. The multiplexer is miniaturized in comparison to other conventional multiplexers, as it does not contain manifolds, circulators ...etc. It also has reduced number of connections to the resonating junction.**

Keywords- multiplexer; resonator; star-junction.

I. INTRODUCTION

Multiplexers are widely used in communication systems. There are many methods to design and implement multiplexers. The most common multiplexers' structures are circulator-coupled, manifold-coupled, and hybrid-coupled multiplexers [1]. In [2-6], configurations of Diplexers/multiplexers formed of coupled resonators without energy distribution junctions have been proposed. Those configurations consist of many coupled resonators similar to filters but with many output ports.

Star-junctions multiplexers have also been proposed in literature. In [7], a general technique to the design of star-junction multiplexers with a resonating junction with the configuration shown in Fig. 1 has been presented. The grey circle in Fig. 1 represents a resonant junction, an extra resonator in addition to the resonators forming the filters. In [8-9], Diplexers and triplexers implemented with resonant junction configurations like that in Fig. 1 have been reported. It is noticed that in the general topology in Fig. 1 it is required to have $N+1$ connections to the resonant junction, where N is the number of channels. Consequently, it is not practical to implement multiplexers with relatively large number of channels with this configuration, since more connections to the resonating junction will be required.

In [10], novel configurations for star-junction multiplexers employing a resonating junction are proposed by the author of this paper. In those configurations, the number of connections to the resonating junction is reduced from $N+1$ to $\lceil N/2 \rceil+1$, and hence multiplexers with more channels can be implemented.

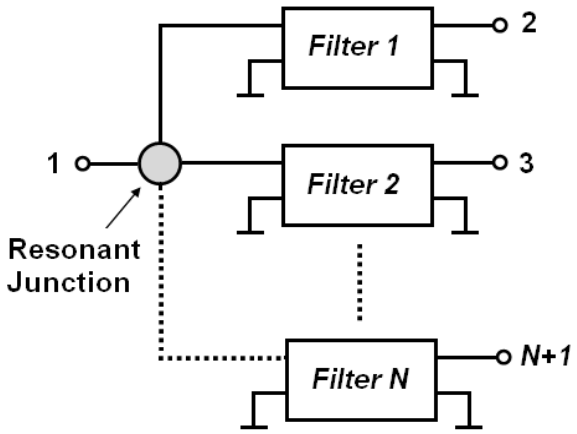

Fig.1. General topology of resonant star-junction multiplexer.

Fig.2 shows a topology for a four-channel multiplexer, with three connections to the resonating junction (including the input port) [10]. In [10], the synthesis method for the proposed multiplexers based on coupling matrix optimization is presented, and numerical examples of the proposed novel star-junction multiplexers are illustrated.

In this paper, a non-contiguous four-channel multiplexer based on the topology proposed in [10] is presented here. It is designed at the X-band using waveguide cavity resonators to verify the design technique proposed by the author in [10]. The advantage of the proposed multiplexer is that it does not include external junctions like the conventional multiplexers, which makes miniaturization possible. Moreover, it has fewer connections to the resonating junction than the star-junction multiplexers in Fig. 1. For example, the proposed four-channel multiplexer here has only three connections to the resonating junction, whereas five connections are needed if it is to be implemented with the structure in Fig. 1 proposed in [7].

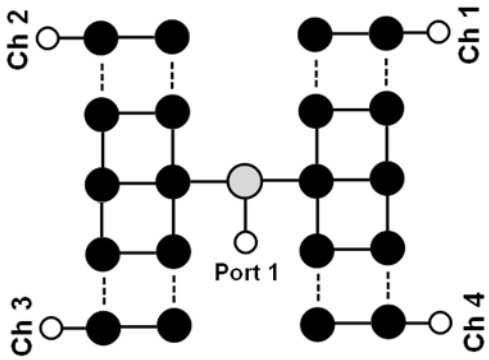

Fig. 2: General Four-channel star-junction multiplexer topology

II. MULTIPLEXER DESIGN

The multiplexer synthesis is based on optimization of the coupling matrix for a multi-port multiple coupled resonator circuit. The design method is detailed in [5, 10]. The topology of the designed multiplexer is shown in Fig. 3, where resonator 1 is the resonant junction. The scattering parameters of the multiport coupled-resonator circuit are related to a general matrix [*A*] by [5]:

$$S_{11} = 1 - \frac{2}{q_{e1}}[A]^{-1}_{11}, \qquad S_{ij} = \frac{2}{\sqrt{q_{ea}q_{eb}}}[A]^{-1}_{ba}$$

where port 1 is assumed at resonator 1, port *i* is at resonator *b* and port *j* is at resonator *a.* The matrix [*A*] is a general matrix given by [5],

$$[A] = \begin{bmatrix} 1/q_{e1} & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 1/q_{e(n-1)} & 0 \\ 0 & \cdots & 0 & 1/q_{en} \end{bmatrix} + P\begin{bmatrix} 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & 1 & 0 \\ 0 & \cdots & 0 & 1 \end{bmatrix} - j\begin{bmatrix} m_{11} & \cdots & m_{1(n-1)} & m_{1n} \\ \vdots & \vdots & \vdots & \vdots \\ m_{(n-1)1} & \cdots & m_{(n-1)(n-1)} & m_{(n-1)n} \\ m_{n1} & \cdots & m_{n(n-1)} & m_{nn} \end{bmatrix}$$

where q_{ei} is the normalized external quality factor of resonator *i*, *P* is the complex lowpass frequency, and m_{ij} is the normalized coupling coefficient.

The target specifications of the designed star-junction multiplexer shown in Fig. 3 are as follows:

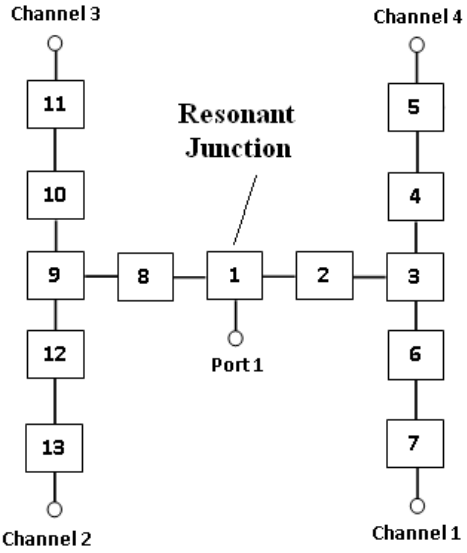

Fig. 3: Multiplexer topology

- 4-channel non-contiguous multiplexer at X-band.
- each channel has 3rd order Chebyshev filtering function.
- each channel has a return loss of 20 dB.
- centre frequencies of: 9.5, 9.833, 10.167 and 10.5 GHz.

A local optimization technique has been utilised to synthesise the coupling matrix [m] using a cost function similar to that given in [5]. The optimized normalized coupling coefficients are as follows: m_{12}=1.3531, m_{18}=1.1571, m_{23}=2.0381, m_{34}=m_{36}=0.3978, m_{45}=m_{67}=0.2881, m_{44}=-m_{66}=2.1294, m_{55}=-m_{77}=2.1684, m_{89}=0.6819, $m_{9,10}$=$m_{9,12}$=0.3557, $m_{10,11}$=$m_{12,13}$= 0.2963, $m_{10,10}$=-$m_{12,12}$=0.6171, $m_{11,11}$=-$m_{13,13}$=0.6769, and the normalized external quality factors are q_{e1}= 0.4 and q_{e5}=q_{e7}=q_{e11}=q_{e13}=3.1536. The prototype response of the synthesised multiplexer is shown in Fig. 4.

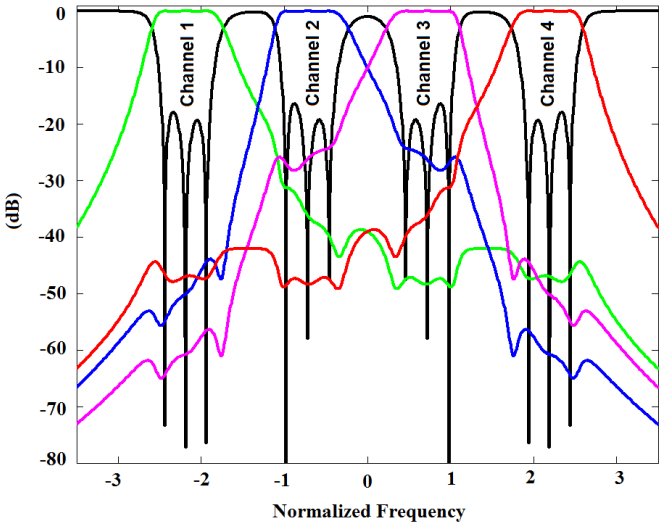

Fig.4. Prototype response of the multiplexer

The multiplexer is designed using waveguide cavity resonators at the X-band to verify the proposed design technique of the novel star-junction multiplexers in [10]. The structure of the multiplexer is shown in Fig. 5 (a), and the top view is shown in Fig. 5 (b). The whole structure is formed of cavity resonators coupled together using inductive irises. The widths of the irises have been initially set according to the synthesised coupling coefficients. The fundamental resonant frequency of each cavity resonator ***i*** is set according the optimised coefficient m_{ii} as listed in Table 1.

CST simulation software has been used to optimize the multiplexer, and the simulated response of the multiplexer is shown in Fig. 6. The simulated response verifies the proposed method but further optimization may be needed to improve the return loss.

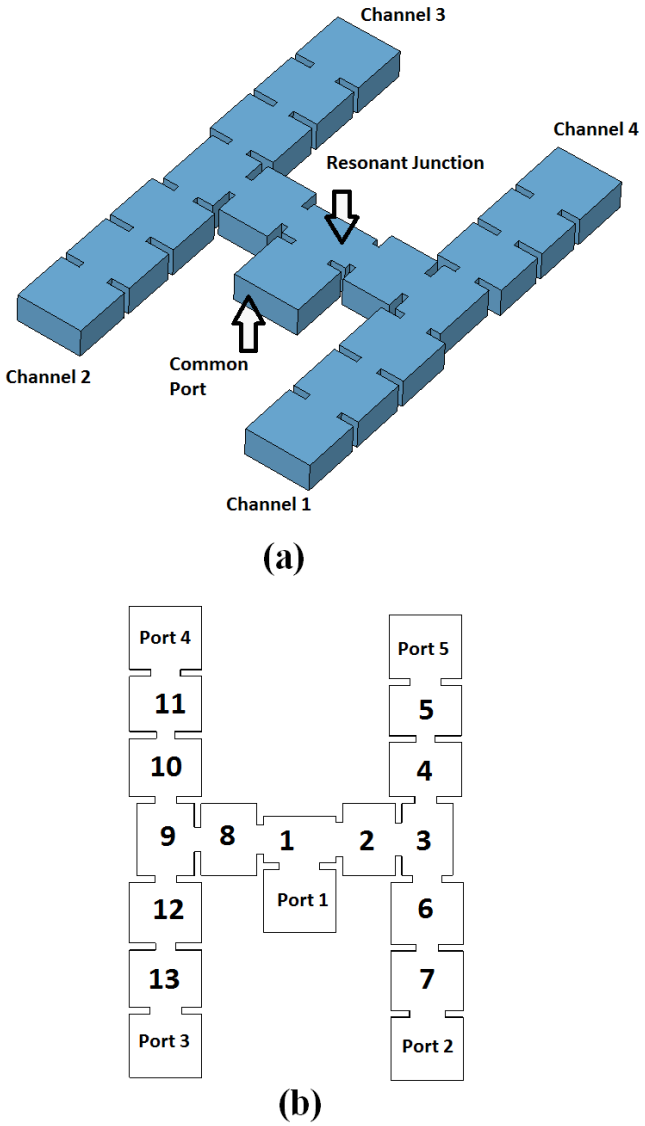

Fig.5. Multiplexer structure (a) 3D view (b) Top view

Table 1. Resonant frequencies of cavities.

Resonator	m_{ii} (normalised)	Frequency (GHz)
1	0	9.985
2	0	9.985
3	0	9.985
4	2.1294	10.473
5	2.1684	10.482
6	-2.1294	9.519
7	-2.1684	9.511
8	0	9.985
9	0	9.985
10	0.6171	10.123
11	0.6769	10.137
12	-0.6171	9.848
13	-0.6769	9.834

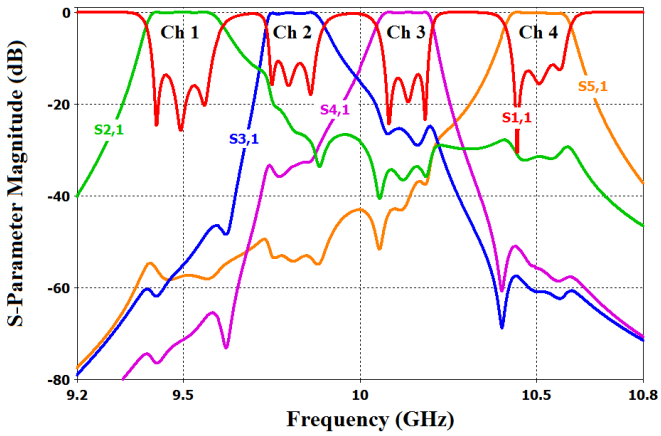

Fig.6. Simulated response of the multiplexer

III. Conclusions

A novel star-junction coupled resonator multiplexer is presented. The multiplexer structure consists of inductively coupled waveguide cavities, and it does not involve manifolds, circulators …etc, and hence it is miniaturized in comparison to conventional multiplexers. The synthesis is based on coupling matrix optimization for the coupled resonators. The multiplexer has four non-contiguous channels at the X-band, and it consists of thirteen waveguides cavities, one of which acts as a resonating junction. The resonant junction is connected only to two cavities and the common port, and thus

the difficulty in design has been reduced. The simulated response has been presented, and it agrees with the synthesized response resulting from coupling matrix optimization.

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