



**HAL**  
open science

## Microstrip Diplexers with Double-Stub Bandpass Filters

M. Khalaj-Amirhosseini, M. Moghavvemi, Hossein Ameri Mahabadi, A.  
Attaran

► **To cite this version:**

M. Khalaj-Amirhosseini, M. Moghavvemi, Hossein Ameri Mahabadi, A. Attaran. Microstrip Diplexers with Double-Stub Bandpass Filters. *International Journal on Communications Antenna and Propagation*, 2011, 1 (1), pp.64-67. hal-00722715

**HAL Id: hal-00722715**

**<https://hal.science/hal-00722715>**

Submitted on 3 Aug 2012

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## Microstrip Diplexers with Double-Stub Bandpass Filters

M. Khalaj-Amirhosseini<sup>1</sup>, M. Moghavvemi<sup>2</sup>, H. Ameri<sup>2</sup>, A. Attaran<sup>2</sup>

**Abstract** – This paper presents a microstrip diplexer using two Double-Stub Band-Pass Filters (DS-BPFs), composed of several double-stubs connected to a main microstrip line. Each DS-BPF has a null at the center frequency of the other. Therefore, these types of filters are suitable for diplexers with two near frequencies. A diplexer at frequencies 5.875 and 6.225 GHz is designed, fabricated and measured. Measured results of the fabricated diplexer have a good agreement with the calculated results. **Copyright © 2011 Praise Worthy Prize S.r.l. - All rights reserved.**

**Keywords:** Diplexers, Double-Stubs, Microstrip Transmission Lines

### I. Introduction

Diplexers are one of the important components in microwave circuits for channel separation in communication systems. They are commonly using two Band-Pass Filters (BPFs) with a common input [1]. Some of microstrip BPFs reported in the literature are based on using parallel-coupled transmission lines [2]-[4], symmetric EBG structure [5], dual behavior resonators [6], periodic stubs [7], and coupled open-loop resonators [8]-[11].

In some applications, two frequencies of diplexer are very near to each other, necessitating the use of two high-order BPFs. A novel idea in these applications may be the use of two low order BPFs that have a null at center frequency of one another. In this article, a new structure is proposed for these types of BPFs. The proposed structure contains some microstrip double-stubs composed of two parallel non-equal length open-ended stubs. A diplexer can be created by simply connecting two Double-Stub BPFs (DS-BPFs) at their inputs through two quarter-wavelength transmission lines.

Despite the simplicity of the proposed diplexer, good transmission performances and high isolation between the output ports are achieved. A microstrip diplexer at two near frequencies of 5.875 and 6.225 GHz has been designed, fabricated and measured to verify the usefulness of the proposed diplexer.

### II. Diplexer with DS-BPFs

Fig. 1 depicts the proposed microstrip diplexer consisting of two DS-BPFs with center frequencies  $f_1$  and  $f_2$ , whose corresponding null frequencies are  $f_2$  and  $f_1$ , respectively.

As explained in the next section, the output of the DS-BPFs is zero and their input impedance becomes short circuit at null frequency.

Therefore, according to presence of two quarter-wavelength transmission lines in a crossed way in diplexer shown in Fig. 1, neither of two filters have effect around the centerfrequency of the other one.

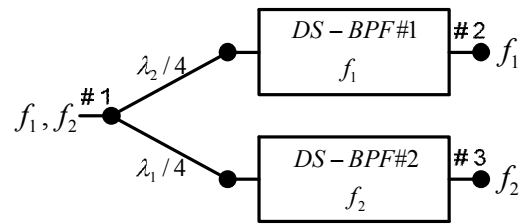


Fig. 1. The proposed diplexer consisting of two DS-BPFs

Assuming the diplexer is lossless and is connected to real load  $Z_0$  at its three ports, the scattering parameters can be determined as follows:

$$S_{11} = \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \quad (1)$$

$$\begin{aligned}
 |S_{21}| &= \sqrt{\frac{P_{L2}}{P_A}} = \sqrt{\frac{P_{in,2}}{P_A}} = \\
 &= 2\sqrt{Z_0 \operatorname{Re}(Z_{in,2}^{-1})} \left| \frac{Z_{in}}{Z_{in} + Z_0} \right|
 \end{aligned} \quad (2)$$

$$\begin{aligned}
 |S_{31}| &= \sqrt{\frac{P_{L3}}{P_A}} = \sqrt{\frac{P_{in,3}}{P_A}} = \\
 &= 2\sqrt{Z_0 \operatorname{Re}(Z_{in,3}^{-1})} \left| \frac{Z_{in}}{Z_{in} + Z_0} \right|
 \end{aligned} \quad (3)$$

where,  $Z_{in,2}$ ,  $Z_{in,3}$  and  $Z_{in}$  are impedances at the input (after two quarter-wavelength lines) of the upper filter, lower filter and both filters, respectively.

### III. Double-Stub BPFs

In this section, an  $n$ -th order BPF is introduced at center frequency  $f_p$ , which has a zero at frequency  $f_s$ . Figure 2 shows the structure of a BPF consisting of  $n$  double-stubs connected to the main transmission line. Each double-stub is composed of two parallel open-ended stubs of lengths  $(2N+1)\lambda_s/4$  and  $[2K-(2N+1)f_p/f_s]\lambda_p/4$ , where  $N$  is an arbitrary positive integer for over-sizing,  $K$  is a positive integer number to avoid negative length and  $\lambda_p$  and  $\lambda_s$  are the wavelength at frequencies  $f_s$  and  $f_p$ , respectively. The distance between two adjacent double-stub is  $\lambda_p/4$  on the main line whose characteristic impedance is  $Z_0 = 1/Y_0$ . The characteristic impedance of the  $i$ -th double-stub ( $i = 1, 2, \dots, n$ ) is  $Z_i = 1/Y_i$ , so the input impedance of the  $i$ -th double-stub is as follows:

$$Y_{in}^{(i)} = Y_s + Y_p = jB_i \quad (4)$$

in which:

$$Y_s = jY_i \tan\left((2N+1)\frac{\pi f}{2f_s}\right) \quad (5)$$

$$Y_p = jY_i \tan\left(\frac{\pi f}{2f_p}\left(2K - (2N+1)\frac{f_p}{f_s}\right)\right) \quad (6)$$

Therefore, it can be seen that the input impedance of each double-stub is zero and infinite at frequencies  $f_s$  and  $f_p$ , respectively. Also, the known slope of susceptance parameter of the  $i$ -th double-stub can be obtained as follows:

$$\begin{aligned} b_i &= \left. \frac{f_p}{2} \frac{dB_i}{df} \right|_{f=f_p} = \\ &= \frac{K\pi}{2} Y_i \left( 1 + \tan^2\left(\frac{\pi}{2}(2N+1)\frac{f_p}{f_s}\right) \right) \end{aligned} \quad (7)$$

From (7), it is seen that over-sizing, i.e.  $N > 0$ , help to move away the argument of tangent function from  $\pi/2$  and so to avoid high values for characteristic impedances. From theory of microwave filters [1], each double-stub acts as a resonator at center frequency  $f_p$  and each segment of the main line between two adjacent double-stub acts as an admittance inverter with constant  $Y_0 = 1/Z_0$ .

Figure 3, shows the equivalent model of a BPF utilizing resonators and admittance inverters. The relationships between the slope of susceptance parameter of resonators and the characteristic admittance of the inverters are given as follows [1]:

$$J_{0,1} = \sqrt{\frac{Bb_1}{g_0g_1}} Y_0 \quad (8)$$

$$J_{i,i+1} = B \sqrt{\frac{b_i b_{i+1}}{g_i g_{i+1}}} \quad \text{for } i = 1, 2, \dots, n-1 \quad (9)$$

$$J_{n,n+1} = \sqrt{\frac{Bb_n}{g_n g_{n+1}}} Y_0 \quad (10)$$

in which  $B$  is the fractional bandwidth and  $g_i$  ( $i = 0, 1, 2, \dots, n+1$ ) are the element values of the prototype lowpass filter. Equating the parameter of all inverters to  $Y_0$ , yields the following required parameters for double-stub resonators:

$$b_1 = \frac{g_0 g_1}{B} Y_0 \quad (11)$$

$$b_{i+1} = \frac{g_i g_{i+1}}{b_i B^2} Y_0^2 \quad \text{for } i = 1, 2, \dots, n-1 \quad (12)$$

$$b_n = \frac{g_n g_{n+1}}{B} Y_0 \quad (13)$$

Finally, the characteristic impedance of all double-stubs can be determined using (7) and (11)-(13).

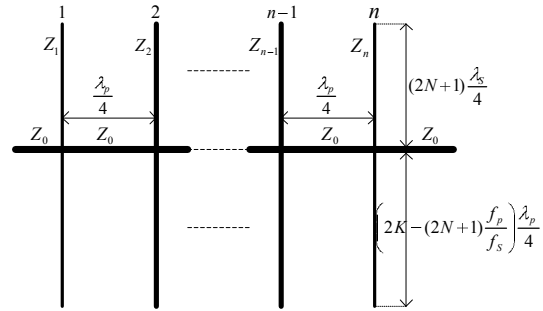


Fig. 2. The structure of a DS-BPF consisting of  $n$  double-stubs

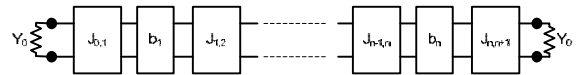


Fig. 3. The equivalent model of a BPF utilizing resonators and admittance inverters

### IV. Example and Results

In this section a diplexer is designed and fabricated in frequencies  $f_1 = 5.875$  GHz and  $f_2 = 6.225$  GHz with 270 MHz bandwidth in each frequency, considering  $Z_0 = 50$   $\Omega$ . Therefore, the specifications of two required filters have to be as the following:

1. BPF-1:  $f_p = 5.875$  GHz,  $f_s = 6.225$  GHz,  $B = 270$  MHz.
2. BPF-2:  $f_p = 6.225$  GHz,  $f_s = 5.875$  GHz,  $B = 270$  MHz.

For both filters, we use DS-BPF structure with a third order chebychev response of passband ripple 0.1 dB, considering  $N = 1$  and  $K = 2$ .

Table I shows the required characteristic impedance of stubs of two filters. If we don't use over-sizing, i.e.  $N = 0$ , the characteristic impedance of stubs become too high for fabrication.

TABLE I  
THE REQUIRED CHARACTERISTIC IMPEDANCE  
OF STUBS OF TWO DS-BPFs

BPF	$Z_1 [\Omega]$	$Z_2 [\Omega]$	$Z_3 [\Omega]$
No. 1	102.05	91.75	102.05
No. 2	96.31	86.59	96.31

Fig. 4 shows the amplitude of the scattering parameters of designed diplexer. It is seen that although the order of two BPFs is low, the results can be acceptable.

The designed diplexer is fabricated on a substrate with  $\epsilon_r = 2.2$  and  $h = 20 \text{ mil} = 508 \mu\text{m}$  (RT/Duroid 5880 from Rogers) as shown in Fig. 5.

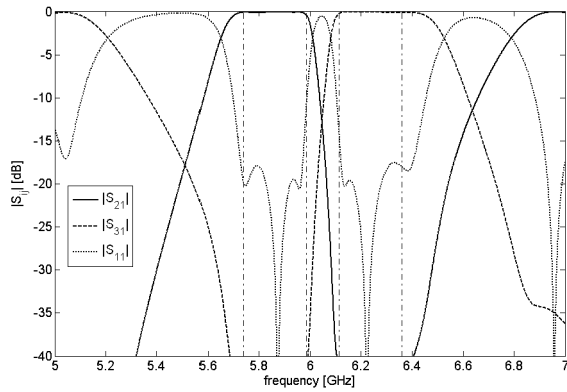


Fig. 4. The theoretical scattering parameters of designed diplexer

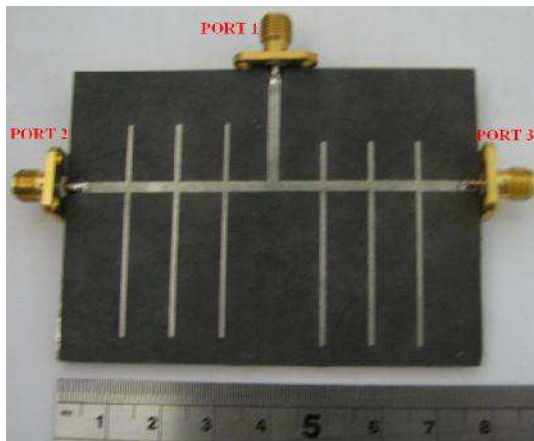


Fig. 5. The photo of the fabricated diplexer

Fig. 6 shows the measured amplitude of the scattering parameters of the fabricated diplexer. It is seen from Figs. 4 and 6 that the agreement between theoretical and measurement results is good except a minus shift

frequency less than 300 MHz which may be related to the effect of microstrip discontinuities at the cross points.

The insertion loss of the fabricated diplexer is 2.3 dB and 2.2 dB at frequencies 5.875 and 6.225 GHz, respectively, which is due to the losses of substrate, conducting strips and connectors. Finally, Fig. 7 shows the measured reflection parameters of the output ports along with the isolation between them. It is seen that the return loss of all ports is more than 10 dB at passband frequencies. In addition, the isolation between two output ports is more than 40 dB at two center frequencies.

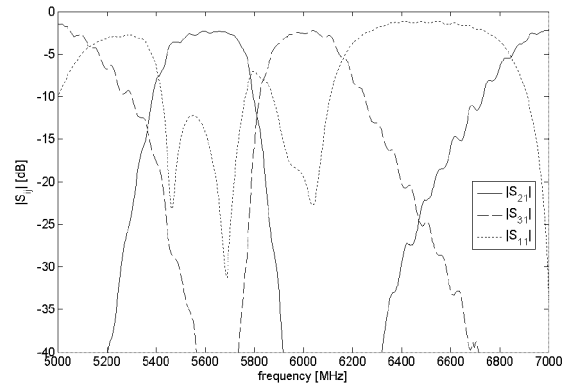


Fig. 6. The measured scattering parameters of the fabricated diplexer

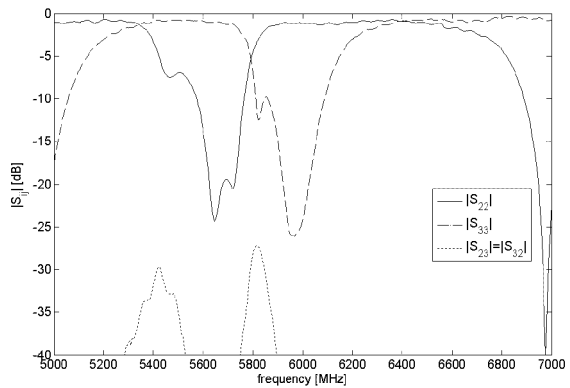


Fig. 7. The measured reflection parameters of fabricated diplexer

## V. Conclusion

A new microstrip diplexer using two Double-Stub Band-Pass Filters (DS-BPFs), composed of several double-stubs connected to a main microstrip line was proposed. A diplexer at frequencies 5.875 and 6.225 GHz is designed, fabricated and measured. An excellent agreement between the theoretical and practical results is observed. The insertion loss of the fabricated diplexer is about 2.25 dB and the isolation between two output ports is more than 40 dB. Also, the return loss of all ports is more than 10 dB at passband frequencies. So, the

proposed diplexer can be used as de-diplexer (two frequency combiner) too.

## References

- [1] G. Matthaei, L. Young, and E. M. T. Jones, "Microwave Filters, Impedance-Matching Networks and Coupling Structures", New York: McGraw-Hill, 1964.
- [2] G. Matthaei and E. G. Cristal, "Multiplexer channel-separating units using interdigital and parallel-coupled filters," *IEEE Trans. Microwave Theory Tech.*, vol. 13, pp. 328-334, May 1965.
- [3] D. Rubin and D. Saul, "Millimetre wave MIC bandpass filters and multiplexers", *IEEE MTT-S Int. Dig.*, vol. 78, pp. 208-210, Jun. 1978.
- [4] S. Hong and K. Chang, "Stub-Tuned microstrip bandpass filters for millimeter-wave diplexer design", *IEEE Microwave and Wireless Components Letters*, vol. 15, no. 9, pp. 582-584, Sep. 2005.
- [5] X. Chen, W. Zhang and C. Yao, "Design of microstrip diplexer with wide band-stop", *Int. Conf. Microwave and Milimeter Wave Tech.*, ICMMT'07, 2007.
- [6] A. Manchec, E. Rius, C. Quendo, C. Person, J. F. Favennec, P. Moroni, J. C. Cayrou and J. L. Cazaux, "Ku-Band Microstrip Diplexer Based on Dual Behavior Resonator Filter", *IEEE MTT-S Int. Microwave Symp.*, 2005.
- [7] B. Strassner and K. Chang, "Wide-Band Low-Loss High-Isolation Microstrip Periodic-Stub Diplexer for Multiple-Frequency Applications", *IEEE Trans. Microwave Theory and Tech.*, vol. 49, no. 10, pp. 1818-1820, Oct. 2001.
- [8] S. S. Oh and Y.-S. Kim, "A Compact Duplexer for IMT-2000 Handsets using Microstrip SlowWave Open-Loop Resonators with High-Impedance Meander Lines", *Radio and Wireless Conf.*, RAWCON'01, pp. 177-180, 2001.
- [9] C.-F. Chen, T.-Yi Huang, C.-P. Chou and R.-B. Wu, "Microstrip Diplexers Design With Common Resonator Sections for Compact Size, But High Isolation", *IEEE Trans. Microwave Theory and Tech.*, vol. 54, no. 5, pp. 1945-1952, May 2006.
- [10] M. H. Weng, H. W. Wu and K. Shu, "Design of compact microstrip diplexer with simple coupled resonators", *Microwave and Optical Technology Letters*, Vol. 49, No. 5, pp. 1222-1225, May 2007.
- [11] D. Budimir and L. Athukorala, "Miniaturized Microstrip Diplexers for WiMAX Applications", *IEEE Int. Symp. Antennas and Prop. Soc.*, AP-S, 2008.

## Authors' information

<sup>1</sup>Iran University of Science and Technology,  
Tehran, Iran.  
E-mail: [khalaja@iust.ac.ir](mailto:khalaja@iust.ac.ir)

<sup>2</sup>Department of Electrical Engineering,  
University of Malaya (UM), Kuala Lumpur, Malaysia.  
E-mails: [mahmoud@um.edu.my](mailto:mahmoud@um.edu.my)  
[itmmwave@streamyx.com](mailto:itmmwave@streamyx.com)  
[aliyar.attaran@gmail.com](mailto:aliyar.attaran@gmail.com)



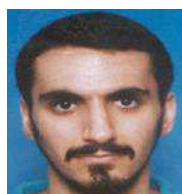
**Mohammad Khalaj Amirhosseini** was born in Tehran, Iran in 1969. He received his B.Sc, M.Sc and Ph.D. degrees from Iran University of Science and Technology (IUST) in 1992, 1994 and 1998 respectively, all in Electrical Engineering. He is currently an Associate Professor at College of Electrical Engineering of IUST. His scientific fields of interest are electromagnetic direct and inverse problems including microwaves, antennas and electromagnetic compatibility.



**Prof. Dr. M. Moghavvemi** was born in Tehran, Islamic republic of Iran in 1969. He obtained his BSc in Electrical Engineering from the State University of New York, MSc from University of Bridgeport and PhD from the University of Malaya. Prof. Moghavvemi is the Director of Centre for Research in Applied Electronics (CRAE). He is an invited member of New York Academy of sciences and member of who is who in the world since 2007. His current research interests are; Electronic circuit design; application toward sensory interface electronics in industrial, commercial, scientific, transportation, and biomedical systems.



**Hossein Ameri** was born in Ardestan, Iran. He received the B.S.E.E. and M.S.E.E degree from the University of Tehran, and is currently working toward the Ph.D. in electrical engineering at the University of Malaya (UM) at Malaysia. His research interests include microwave, millimeter-wave, passive and active components, sub-systems and systems. Such as Synthesizer, power amplifier, high power combiner, antennas, digital microwave, mm-wave Links, Terahertz synthesizer and antennas.



**Aliyar Attaran** was obtained his BSc in Electrical Engineering from the Multimedia University in Malaysia in 2009, and currently pursuing MSc degree under center of research and applied electronics (CARE) center in University of Malaya.