American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-08, pp-267-272
www.ajer.org

Research Paper Open Access

Design and Analysis of Compact UWB Bandpass Filter with Wide Passband Using Defected Ground Structure

Yashika Saini[1], Mithilesh Kumar[2]
[1,2]*Electronics Department, University College of Engineering, Rajasthan Technical University, Kota, India*

ABSTRACT : *A compact ultra-wideband (UWB) bandpass filter (BPF) with wide passband using defected ground structure (DGS) is proposed. The proposed UWB filter is constructed by cascading a high pass filter (HPF) and a lowpass filter (LPF). HPF with short-circuited stubs is used to realize the lower stopband and a LPF is used to attenuate the upper stopband. In order to make the filter size compact, DGS technology is incorporated in the filter design, with this technique the size of filter becomes extremely compact compared with the other UWB bandpass filters in different published papers. In designing the filter integrated with DGS, four rectangular shaped DGS were etched on the ground plane. Furthermore, the bandwidth is enhanced from the original UWB filter, by varying the widths of the rectangular shaped DGS in the ground plane. The BPF is designed with the desired frequency band of 3.1GHz-10.6GHz and a flat group delay across the pass-band. The occupied area of the proposed filter is 22.4mm × 12mm, both simulated and experimental results are provided with good agreement.*

Keywords *- Band pass filter (BPF); Defected ground structure (DGS); High pass filter (HPF); Low pass filter (LPF); Ultra Wide band (UWB).*

I. INTRODUCTION

In 2002, the Federal Communication Commission (FCC) has authorized the unlicensed band 3.1 GHz to 10.6 GHz for commercial communication purposes [1]. UWB BPFs, as one of the essential components of the UWB systems, have gained much attention in recent years. In concerning to the development of UWB filter especially bandpass filter, some problem which often arises is that parameters of filter are unsatisfied for some UWB application. Hence, the physical dimension is becoming crucial issues particularly for communication devices which have small size. Defected ground structure (DGS) is one of the new design techniques used to improve the quality of the system [2, 3]. DGS adds an extra degree of freedom in microwave circuit design and opens the door to a wide range of applications. A large number of reports on UWB BPF's have been published [4]-[10] to achieve UWB characteristics. In [4,5] UWB BPF's are designed using DGS, whereas, in [6]-[9] the cascaded low-pass/high-pass Filters are proposed. In [10] a compact microstrip UWB bandpass filter with triple-notched bands and wide upper stopband is proposed.

DGS is now widely used to enhance the performance of the filter. The various technologies of size reductions are used by the researchers such as photonic band gap structure (PBG), frequency selective surface (FSS) etc. Furthermore, DGS has extensively applied to the design of microwave circuits such as filters, couplers, circlers, amplifiers, power dividers, and so on [11]-[16]. The defected ground structures demonstrate advantages that include compactness, wide-band operation and competent and flexible usage of the ground plane structure for changing characteristics of microwave devices [17].

In this paper, we present a new compact UWB bandpass filter. The initial UWB BPF without DGS with overall size of 26.4mm × 16mm is stated. To make the size of the filter more compact, an attempt is carried out by applying DGS on the ground plane of the initial filter**.** The BPF is designed to have working bandwidth of 3.1GHz-10.6 GHz. In the design process, the performances of filter and its physical dimension are investigated to obtain the optimum design for realization. Hence, the filter parameters such as insertion loss, return loss, and working bandwidth will be used as indicators for the performance evaluation, after hardware realization and experimental characterization, the measured results are then compared to the design results for verification and analysis. The organization of this paper is as follows. In section II, the design is briefly described. While fabricated and measured results are discussed in section III. Finally the work is concluded in section IV.

II. DESIGN DESCRIPTION OF UWB BPF

2.1. UWB bandpass filter without DGS

The structure of initial UWB bandpass filter is depicted in Figure 1. In this the optimum distributed HPF is embedded in the step impedance LPF with 9 reactive elements as reported in [8,9]. Here, the length of the filter is 13.8mm. This filter has overall size of 26.4mm × 16mm with thickness of 0.8mm and relative dielectric constant 2.2. The simulated insertion loss and return loss are depicted in Figure 2.

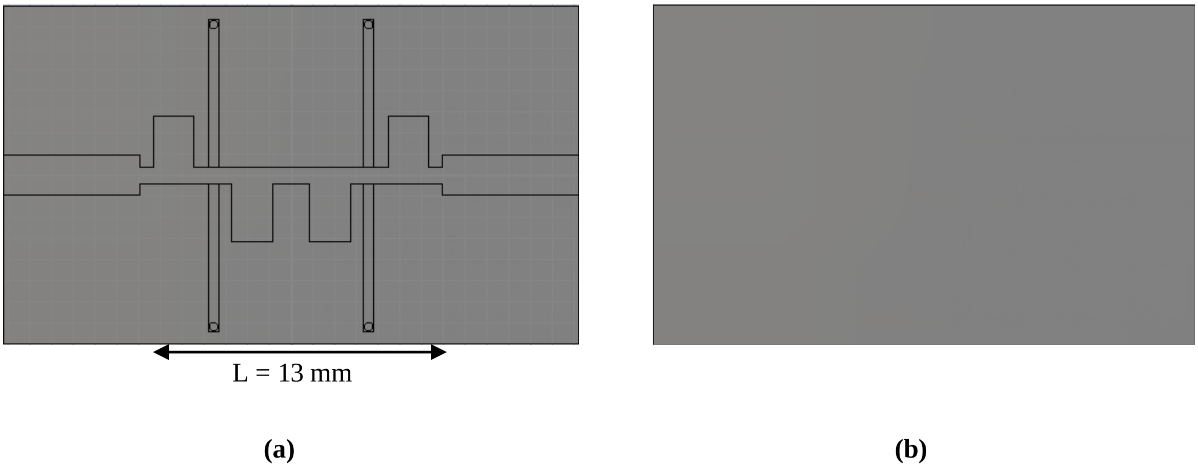


Figure 1. Schematic of initial UWB BPF (a) Top view, (b) Bottom view.

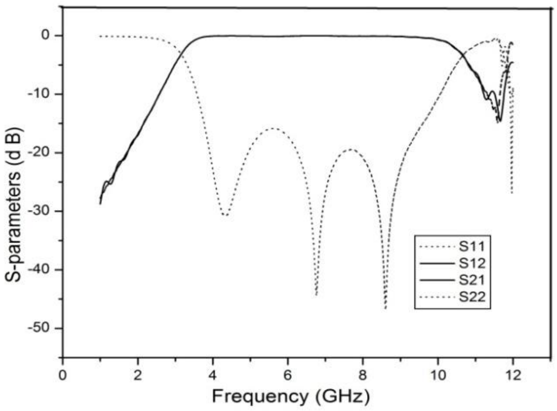
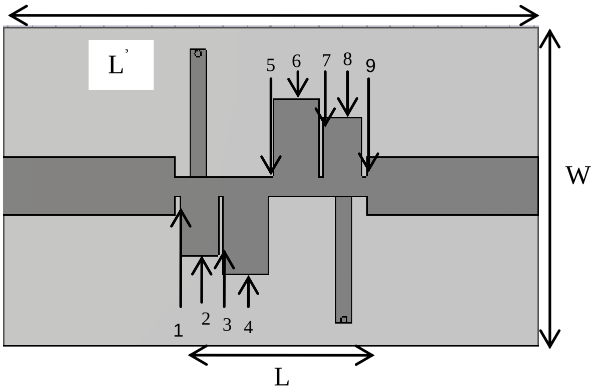


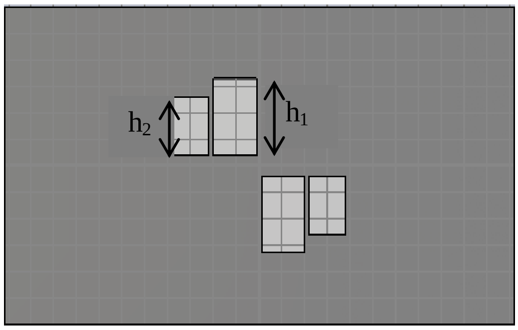
Figure 2. Simulated S-parameters of initial UWB BPF.

In the further section we will be designing UWB BPF using DGS technique. We will be observing that the size of the structure will become more compact.

2.2 DGS based UWB bandpass filter

Using the similar technique as applied for initial UWB microstrip BPF, a new compact UWB BPF is proposed, to make the size of the filter more compact DGS is incorporated in the filter design. Figure 3 shows the layout of the proposed UWB BPF with DGS. The length of the filter here is 8mm, which is extremely small than the initial filter and the overall size of the filter is 22.4mm × 12mm. Figure 3(a) shows the top view of the proposed UWB filter. The designed structure consists of two short circuited stubs of equal length acting as optimum distributed HPF embedded in step impedance LPF. Here for HPF the cutoff frequency is 3.1GHz and for LPF the cutoff frequency is 10.6 GHz. The dimensions of the filter elements are as given in Table 1. The width of lines section for series inductor is 0.75mm and for shunt capacitor elements are 3.306mm and 2.6mm respectively. These widths correspond with the high impedance value (Z_{high}) of 82Ω for series inductor elements and with the low impedance value (Z_{low}) of 36Ω and 42Ω for shunt capacitor elements. The end of each stub is short-circuited to the ground plane through a wire. It is a vertical symmetry structure and the two stubs have the same length 5.15mm and width of 0.7mm. Figure 3(b) shows the bottom view of the proposed UWB filter. It shows that the proposed DGS is constructed of 4 rectangular slots etched on the ground plane symmetrically. The slots are cut beneath the step impedance LPF in the ground plane. The rectangular slots dimensions are h_1 = 3.306mm and h_2 = 2.6mm. These 2 slots are symmetrical to the other 2 slots. Figure 4(a) depicts the simulated return loss and insertion loss of the filter. In the passband area, the minimum insertion loss is 0.104dB which occurs at 6.8GHz. The simulated group delay is depicted in Figure 4(b). The variation of group delay is below 0.3ns within the band. CST microwave studio software is used for the simulation of the designed structures.



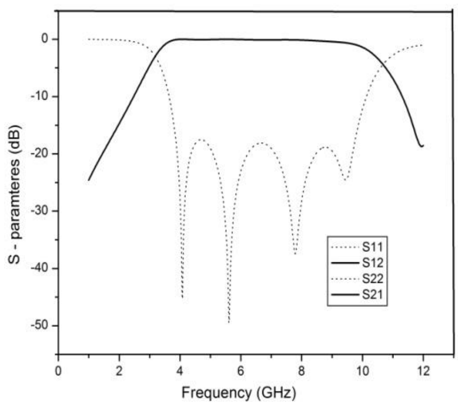


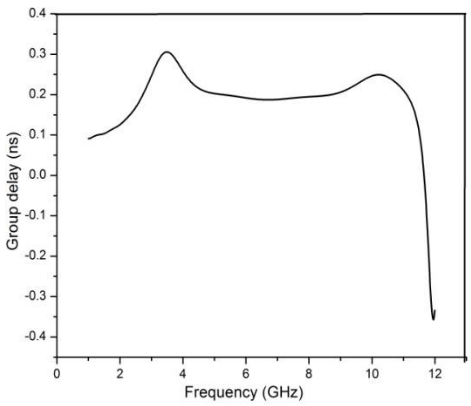
(a) (b)

Figure 3. (a) Layout of Compact UWB filter (Top view), (b) Ground plane with DGS (Bottom view).

Table 1 Key dimensions of filter design

Elements	1	2	3	4	5	6	7	8	9	L	L'	W
Length of element Values(mm)	0.2	1.6	0.2	1.9	0.2	1.9	0.2	1.6	0.2	8	22.4	12



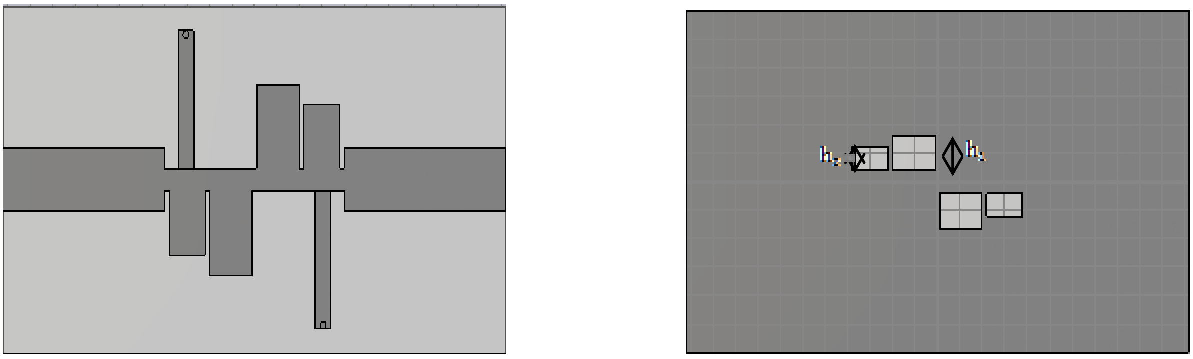


(a) (b)

Figure 4. Simulated responses of the UWB filter (a) S-parameters, (b) Group delay.

2.3 Bandwidth enhancement by varying the height of the rectangular slots in ground plane

To demonstrate the bandwidth enhancement of the DGS-based UWB BPF is designed by locating 4 rectangular slots etched on the ground plane symmetrically. Figure 5 illustrates the utilization of DGS over the ground plane. The top view dimensions are same as stated in section 2.2 of this paper. The variations of the rectangular slots in the ground plane are as shown in Table 2.



(a) (b)

Figure 5. (a) Layout of Compact UWB filter (Top view), (b) Ground plane with DGS (Bottom view).

Table 2. Variation of bandwidth with height variation

S.No	Height variation h_1	Height variation h_2	Frequency range (GHz)	Bandwidth (GHz)
a	1.62mm	1.22mm	3.1~10.6	7.5
b	2.2mm	1.8mm	3.17~10.71	7.54
c	2.5mm	2.09mm	3.19~10.91	7.72
d	3.09mm	2.6mm	3.23~11.18	7.95

From Table 2, it should be noted that as the height of the rectangular DGS increases, the frequency shifts. Hence, the bandwidth is enhanced. The comparative S-parameters graphs at different height variation are depicted in Figure 6.

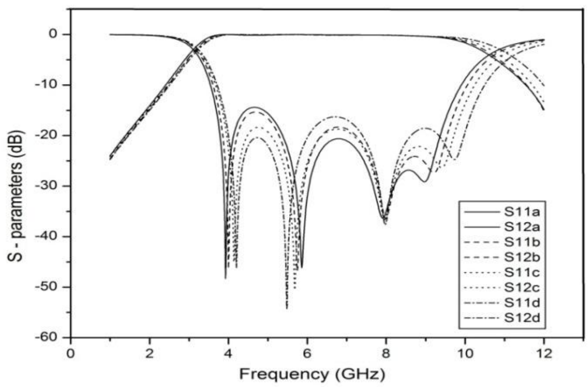
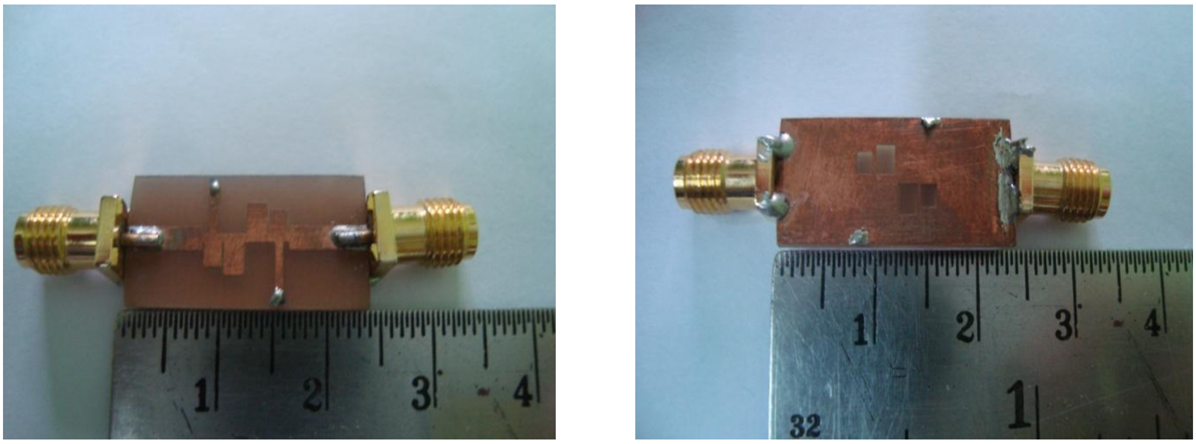


Figure 6. Comparative S-parameters graph at different height variation of h_1 and h_2.

III. FABRICATION AND MEASURED RESULTS

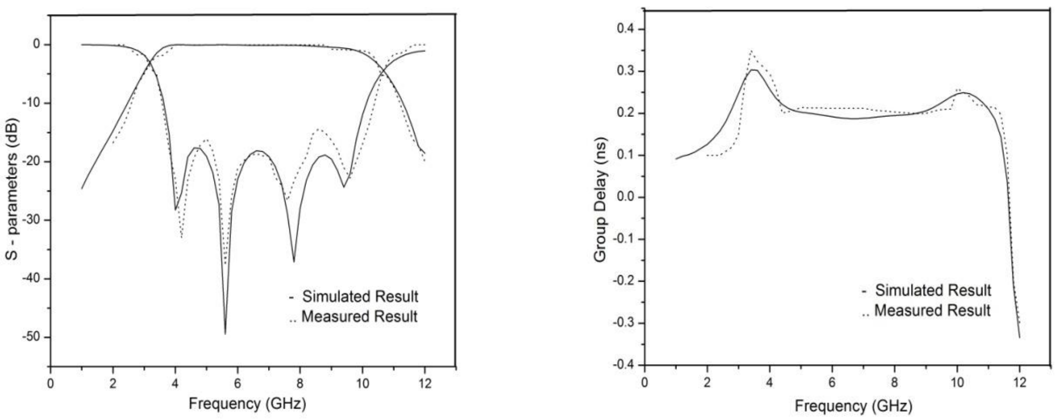
Figure 7 shows the picture of fabricated filter. A compact ultra-wideband BPF using DGS is fabricated on FR-4 substrate with a relative dielectric constant of 4.05 with thickness of 1mm and loss tangent of the filter is 0.02. The overall size of the filter is 22.4mm × 12mm. The filter use microstrip line feed impedance of 50Ω with the width of each port 2.18mm. The results of the filter are measured on the vector network analyzer Rohde & Schwartz ZVB20 calibrated using SOLT method.

Figure 8 depicts the measured result of proposed UWB BPF with the simulated result is plotted together for comparison. Although there is slight difference in the return loss along passband area, in general the measured results have agreed very well with the simulated ones. The compact UWB bandpass filter has a bandwidth of 7.5 GHz with the desired frequency band of 3.1GHz-10.6GHz.



(a) (b)

Figure 7. Fabricated picture of the compact UWB filter (a) Top view, (b) Bottom view.



(a) (b)

Figure 8. Simulated and Measured responses of the compact UWB filter (a) S-parameters, (b) Group delay.

It is evident from figure 8(a) that 3dB start and stop frequencies of the filter are 3.1GHz and 10.6GHz, which implies that 3dB fractional bandwidth as given by following

$$B.W\% = \frac{F_H - F_L}{F_{centre}} = \frac{(10.6-3.1)}{6.85}$$

is 109%.

The measured group delay response is below 0.35 ns over the whole passband. This work is compared with the already reported UWB BPF [4][8][9] in Table 3. The size of the filter is extremely small in the current work than the reported filter.

Table 3. Comparison with other proposed UWB BPF's.

Parameters	[4]	[8]	[9]	This work
Passband (GHz)	3.1~10.6	3.1~10.6	2~12	3.1~10.6
Bandwidth (GHz)	7.5	7.5	10	7.5
length of filter (mm)	-	13.8	13.9	8
Return Loss (dB)	<11	<16	<9	<18
Insertion Loss (dB)	-	0.15	-	0.104
Group delay (ns)	-	Below 0.5	-	Below 0.35
Overall size	30mm×15mm	26.4mm×16mm	25mm×25mm	22.4mm×12mm

IV. CONCLUSION

A compact UWB BPF with wide passband using defected ground structure has been designed. A filter without DGS is first designed acting as reference, by comparing reference filter with DGS filter, it shows that DGS do gives beneficial results and the size becomes compact. Furthermore, the bandwidth enhancement of UWB BPF has been investigated by varying the defected rectangular slots on the ground plane surface. Good agreement between simulation and measurement results validates the introduced design method. With the advantages of excellent performance and compact size, the proposed filter is useful in UWB systems.

REFERENCES

[1] "Revision of part 15 of the Commission's rules regarding ultra-wideband transmission systems," FCC, Washington, DC, Tech. Rep, ET-Docket 98-153, FCC02-48, adopted in Feb. 2002.

[2] Oraizi, H. and M. S. Esfahlan, "Miniaturization of Wilkinson power dividers by using defected ground structures," *Progress In Electromagnetics Research Letters*, Vol. 4, 113- 120, 2008.

[3] Wu, B., B. Li, T. Su, and C. H. Liang, "Study on transmission characteristic of split ring resonator defected ground structure," *Progress In Electromagnetics Research*, Vol. 50, 710-714, 2006.

[4] Shobeyri, M. and M.-H. Vadjed-Samiei, "Compact ultra-wideband bandpass Filter with defected ground structure," *Progress In Electromagnetics Research Letters*, Vol. 4, 25-31, 2008.

[5] Naghshvarian-Jahromi, M. and M. Tayarani, "Miniature planar UWB bandpass Filters with circular slots in ground," *Progress In Electromagnetics Research Letters*, Vol. 3, 87-93, 2008.

[6] Comez-Garcia, R. and J.-I. Alonso, "Systematic method for the exact synthesis of ultrawideband Filtering responses using high-pass and low-pass sections," *IEEE Trans. On Microw. Theory and Tech.*, Vol. 54, No. 10, 3751-3764, 2006.

[7] Hao, Z.-C. and J.-S. Hong, "UWB bandpass Filter using cascaded miniature high-pass and low-pass Filters with multilayer liquid crystal polymer technology," *IEEE Trans. on Microw. Theory and Tech.*, Vol. 58, No. 4, 941-948, 2010.

[8] Yashika Saini, Mithilesh Kumar, "Ultra-wideband Bandpass filter using short circuited stubs," *International Journal of Engineering Research and Technology*, Vol. 3 (01), ISSN 2278 -0181, January 2014.

[9] Achmad Munir, Ivan Pradibta, Mohammad Ridwan Effendi, "Microstrip based ultrawideband composite BPF with short circuited stubs," *in IEEE Electrical Engineering/Electronics Computer, Telecommunications And Information Technology* (ECTI-CON), 2013.

[10] Huaxia Peng, Junding Zhao and Bing Wang, "Compact Microstrip UWB Bandpass Filter with Triple-Notched Bands and Wide Upper Stopband," *Progress In Electromagnetics Research Letters*, Vol. 144, 185-191, 2014.

[11] D. Ahn, J. S. Park, C. S. Kim, J. Kim, Y. Qian, and T. Itoh, "A design of the low-pass filter using the novel microstrip defected ground structure," *IEEE Trans. Microw. Theory Tech.*, vol. 49, no. 1, pp. 86–93, Jan. 2001.

[12] J. S. Lim, S.W. Lee, C. S. Kim, J. S. Park, D. Ahn, and S. Nam, "A 4:1 unequal Wilkinson power divider," *IEEE Microw. Wireless Compon.* Lett., vol. 11, no. 3, pp. 124–126, Mar. 2001.

[13] J. S. Lim, J. S. Park, Y. T. Lee, D. Ahn, and S. Nam, "Application of defected ground structure in reducing the size of amplifiers," *IEEE Microw. Wireless Compon.* Lett., vol. 12, no. 7, pp. 261–263, Jul. 2002.

[14] J. S. Lim, C. S. Kim,Y. T. Lee, D. Ahn, and S. Nam, "A spiral-shaped defected ground structure for coplanar waveguide," *IEEE Microw. Guided Wave Lett.*, vol. 12, no. 9, pp. 330–332, Sep. 2002.

[15] Y. T. Lee, J. S. Lim, S. Kim, J. Lee, S. Nam, K. S. Seo, and D. Ahn, "Application of CPW based spiral-shaped defected ground structure to the reduction of phase noise in V - band MMIC oscillator," *IEEE MTTS Int. Microwave Symp*. Dig., vol. 3, pp. 2253–2256, Jun. 2003.

[16] Han-Jan, C., H. Tsung-Hui, C. Chin-Sheng, " A novel cross-shape DGS applied to design ultra-wide stopband low-pass filters", *IEEE Microwave and Wireless Components Letters*, vol. 16, no. 5, pp. 252–254, 2006.

[17] X.-H. W. a. B.-Z. Wang, "Compact Broadband Dual-Band Bandpass Filters using Slotted Ground Structures," *Progress In Electromagnetics Research*, vol. 82, pp. 151-166, 2008.