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Enhanced Wide Band Microstrip Hairpin Filter

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Abstract: A new practical design for hairpin resonator filters is presented in this study. The typical hairpin filter has been optimized by changing the resonators and the gap between resonators. The preferences in bandwidth return loss and insertion loss has been improved. The proposed filter simulated using the commercially available simulation software Ansoft HFSS and fabricated that is verified by good agreement between simulated and measured results. Measurement results show <1 dB insertion loss and return loss better than 8 dB.

Key words: Hairpin filter, microstrip filter, wide bandwidth, resonator, mobile communication

INTRODUCTION

Numerous applications use microstrip circuits which should be as small as possible to ensure ease of use in mobile communications. Since, these filters have open-circuit ends, they do not require grounding; therefore their mass production becomes easy (Hong and Lancaster, 2001; Matthaei, 2000).

In this study, the goal is to obtain a wide bandwidth while maintaining the size relatively small. The characteristics and configuration of conventional hairpin resonator filter, which is the base of our optimization procedure has been discussed by Hong and Lancaster (2001) and Matthaei (2000). The angle of the arms were also accounted because the effects of discontinuities such as tap point Tee-junction and the angle bends become quite significant when the angle changes from 90-0. Numerous methods were proposed by others to reduce the size of filter, return loss and insertion loss, or change the bandwidth of hairpin filter.

A new design of multilayer hairpin wideband filter in two-layer configurations has been presented by Adam *et al*. (2009). Since, the strong coupling needed for wideband filter can be easily obtained by overlapping two hairpin resonators, the filter can produce wider bandwidth. Another advantage that this filter is the independence to choose high dielectric constant substrate without tight concern on resulting very small gap that therefore is complex and costly to be fabricated.

Various forms of miniaturizing of hairpin resonators filters have been shown in Sgawa *et al*. (1989). In Srisathit *et al*. (2005) a stepped impedance coupled-line structure for suppressing the second-harmonic spurious response in the passband of a microstrip hairpin diplexer has been explained. A small variation in coupled line's width not only reduces the spurious response but also reduces the design size.

In Jen-Tsai and Hung-Sen (2004) compact miniaturized hairpin, the resonators are used to design cross-coupled filters with a dual-passband response of elliptic function type.

In Di *et al*. (2003) the design of the six-resonator multiple-coupled microstrip hairpin filter has been explained. The multiple-coupled microstrip hairpin filter designed due to smaller size and high selectivity is attractive for the communication applications.

In Lung-Hwa and Kai (2003) a compact elliptic function of a low-pass filter using microstrip stepped-impedance hairpin resonators and their equivalent- circuit models has been developed.

To increase the width of pass-band, improve the performance and reduce the size, several types of elliptic-function low pass filters have been designed and proposed using modified hairpin resonators in recent years (Nosrati and Najafi, 2008).

To enhance the bandwidth and further size reduction of the conventional microstrip stepped-impedance hairpin elliptic-function low-pass filter, two models of compact microstrip open-loop and semi-hairpin resonators may be used (Hayati *et al*., 2009).

In Hasan and Nadeem (2008) the novel improved hairpin line microstrip narrowband bandpass filter with via ground holes is presented and the new filter design methodology is derived from conventional hairpin line filter design.

In this study, at first step, we studied the characteristics of bandwidth, return loss and insertion loss of conventional hairpin and parallel coupled resonators. Later, we will discuss the effect of changing angles of the resonators and spacing between resonators and arms on bandwidth, return loss and insertion loss. Too many configurations will be discussed for the proposed structure which will satisfy our goal of 1 GHz bandwidth, high return loss, low insertion loss and central frequency of 3.9 GHz.

However, the bandwidth size is 3.7-4.5 GHz and the board size is 1.2-0.5".

MATERIALS AND METHODS

Hairpin-line bandpass filters are compact structures. They may conceptually be obtained by folding the resonators of parallel-coupled, half-wavelength resonator filters, which were discussed in the previous section, into a U shape. This type of U shape resonator is the so-called hairpin resonator. Consequently, the same design equations for the parallel-coupled, half-wavelength resonator filters may be used (Hong and Lancaster, 2001).

However, for folding the resonators, it is necessary to accentuate reduction of the coupled line lengths to reduce the coupling between resonators. So if two arms, if each hairpin resonators are closely spaced they will act as a pair of coupled line, which could affect coupling as well. An experimental hairpin filter with this type has been demonstrated by Hong and Lancaster (2001) where, the design equation proposed for estimating the tapping point T is:

$$T = \frac{2L}{\pi} \times \arcsin\left(\frac{\pi}{2} \times \left(\frac{Z_o}{Q_e Z_r}\right)\right)^{0.5} \quad (1)$$

Where:

T = The tap point height
L = $\lambda/8$ long
Zr = The characteristic impedance of the hairpin line
Z_o = The terminating impedance
Q_e = The external quality factor

So, if we can find the best size for the filter and T, we can find the best return loss bandwidth and insertion loss.

RESULTS AND DISCUSSION

An optimized microstrip hairpin filter which uses changes between the angle of the arms as shown in Fig. 1 has been designed, fabricated and tested over the RO4003 substrate with 0.813 mm thickness and dielectric constant of 3.38. Detailed dimensions are shown in Fig. 1a and a series of typical dimensions are shown in Table 1.

Table 2 shows the specification of hairpin filter with different angle and Fig. 2 shows the measured and computed transmission response and return loss of the optimized compact size hairpin filter (75°).

Table 1: Enhanced hairpin filter dimensions

Parameters	Value (mm)	Parameters	Value (mm)
W	1.65	L1	0.94
W1	1.02	L2	7.43
W2	1.27	L3	2.03
W3	1.40	L4	2.54
S1	0.27	L5	2.54
S2	0.35	L	2.54

Table 2: Changes Effect of the angle of arms on hairpin filter

Angle (°)	Frequency band (GHz)	BW (GHz)	Max return loss (dB)	Min insertion loss (dB)	Max insertion loss (dB)
90	3.37-4.07	0.70	35.8	0.01730	0.712
80	3.38-4.1	0.72	36.7	0.01110	0.639
70	3.41-4.14	0.73	43.4	0.01320	0.583
60	3.43-4.18	0.75	44.6	0.00957	0.511
50	3.47-4.23	0.76	44.0	0.02180	0.459
40	3.5-4.28	0.78	53.8	0.02300	0.396
30	3.54-4.33	0.79	40.1	0.02400	0.341
20	3.57-4.38	0.81	41.3	0.02100	0.292
10	3.6-4.43	0.83	45.7	0.02200	0.243
0	3.64-4.49	0.85	47.3	0.00720	0.191

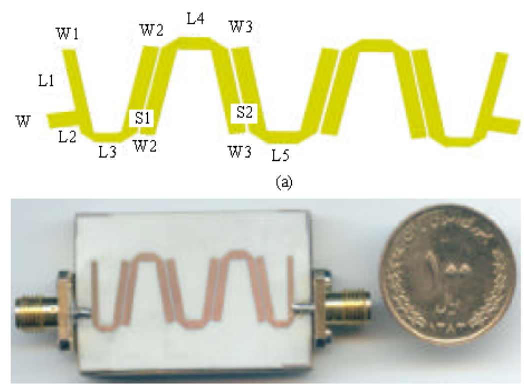

Fig. 1: Photo of the optimized compact size hairpin filter (75°) (a) Schematic and (b) Fabricated

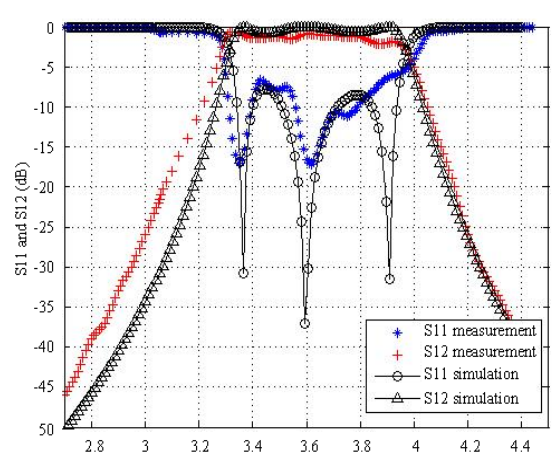

Fig. 2: Simulated and measured responses of the optimized filter

CONCLUSION

In this study, a miniaturized hairpin-shaped resonator with parallel coupled lines, which uses changes between the angles of the resonator arms was developed. The experimental bandpass filter has excellent performance, as seen in its compact size and low insertion losses. The frequency responses indicate close correlation with design results.

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