OPEN AND SHORT U-SHAPED MICROSTRIP RESONATORS FOR SECOND-ORDER SINGLE- OR DUAL-BANDSTOP FILTER DESIGN

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ABSTRACT: *Single- and dual-band bandstop filters with U-shaped resonators are proposed. First, short and open U-shaped resonators are coupled to a main transmission line to obtain second-order stopband performance with two transmission zeros in the stop band and two reflection zeros in the passband. In contrast to traditional second-order bandstop filters, the two different resonators are coupled to both sides of the microstrip line so that the commonly used quarter wavelength distance between resonators is eliminated. Secondly, open and short U-shaped stepped impedance resonators are employed to obtain dual-band bandstop filters in a compact size. Both filters are prototyped and measured. Good agreement between simulated and measured results demonstrates the reliability of the design method.* © 2017 Wiley Periodicals, Inc. Microwave Opt Technol Lett 59:1362–1365, 2017; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.30544

Key words: *bandstop filters; dual-band filters; U-shaped resonator; microstrip line*

1. INTRODUCTION

Bandstop filters (BSFs) play an important role in receiver front ends of modern wireless communication systems. Therefore, many different configurations in printed-circuit technology have been proposed [1–12]. One method to realize a BSF is to employ defected ground structures [1,2] because of their characteristics to disturb the current distribution in the ground plane. Unfortunately, the structures are a little complex. The second method is to use open stepped impedance stubs [3–5] or coupled-line stubs [6] tapped at a main transmission line. However, the distance between the stubs must be a quarter-wavelength which increases component size.

The third typical way to design dual-mode BSFs is to place resonators in parallel with main transmission lines [7–11]. L-shaped [7–9], T-shaped [9], E-shaped [10], and horizontal U-shaped [11] resonators are employed to achieve stopband performance. At the resonant frequencies, the resonators are in resonance and equivalent to short circuits. At other frequencies, they have very little loading effect on the main transmission line. But in these designs, the distances between resonators are selected as quarter-wavelengths, which is not convenient to reduce the size of filters. Two Hilbert-fork resonators are placed in parallel with the main transmission line to obtain a tri-band BSF [12]. However, the minimum return loss in the lower passband, close to the first stopband, is only 5 dB because the distance between the two Hilbert-fork resonators is less than a quarter-wavelength.

In this article, BSFs with U-shaped resonators are proposed. First, the performances of a transmission line loaded with open or short U-shaped resonators are investigated. The analytic investigation shows that the open U-shaped resonator can provide a reflection zero in the lower passband and the short U-shaped resonator provides a reflection zero in the upper passband. A BSF centered at 3.5 GHz loaded with an open and a shorted resonator is designed. The filter has two transmission zeros in the stopband and one reflection zero in each of the upper or lower passbands. Since the resonators are coupled to both sides of the main microstrip line, compact size is obtained. For dual-band applications, a BSF centered at 3.5 and 5.5 GHz with U-shaped stepped impedance resonators is proposed. For each stopband, there are two transmission zeros in the stopband and two reflection zeros in the upper and lower passbands. To validate the proposed method, both filters are implemented. Good agreement between simulated and measured results confirms the proposed method.

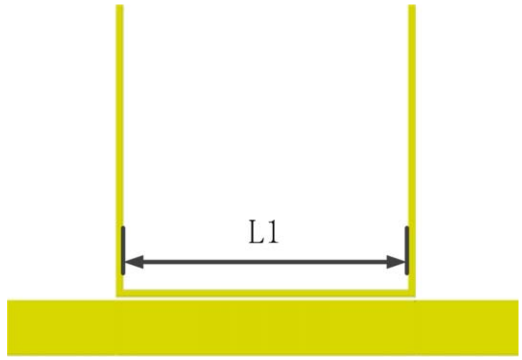

Figure 1 An open U-shaped resonator coupled to a microstrip line. [Color figure can be viewed at wileyonlinelibrary.com]

2. SINGLE BAND BSF

A microstrip line loaded with an open U-shaped resonator is shown in Figure 1. The total length of the resonator is $\lambda g/2$, where λg is the guided wavelength at the center frequency. The length of the coupled line is set as L1, and its effect on *S*-parameters is shown in Figure 2. Because of the magnetic coupling between the main transmission line and the resonator, a reflection zero in the lower passband is created, and with increasing L1, the magnetic coupling becomes stronger and the frequency of the reflection zero decreases.

A transmission line loaded with a shorted U-shaped resonator is shown in Figure 3. The length of the coupled line is set as L2 and its effect on *S*-parameters is shown in Figure 4. Because of the electric coupling between the main transmission line and the

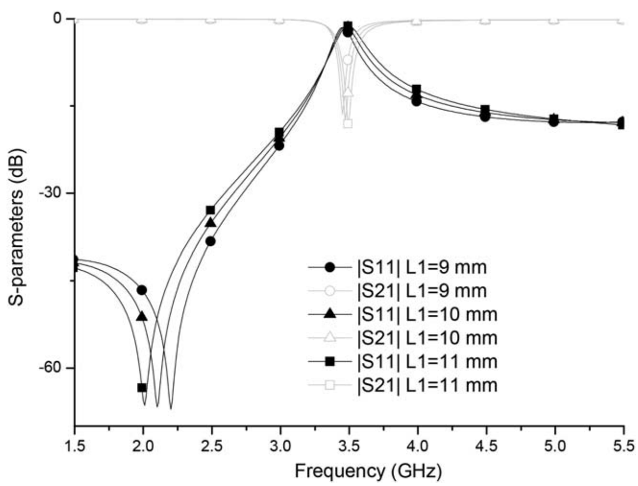

Figure 2 Effect of L_1 on *S*-parameters

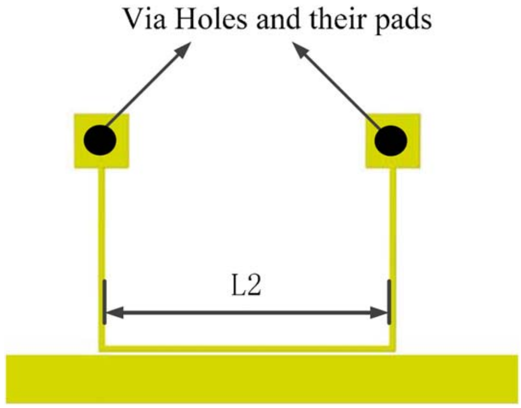

Figure 3 A shorted U-shaped resonator coupled to a microstrip line. [Color figure can be viewed at wileyonlinelibrary.com]

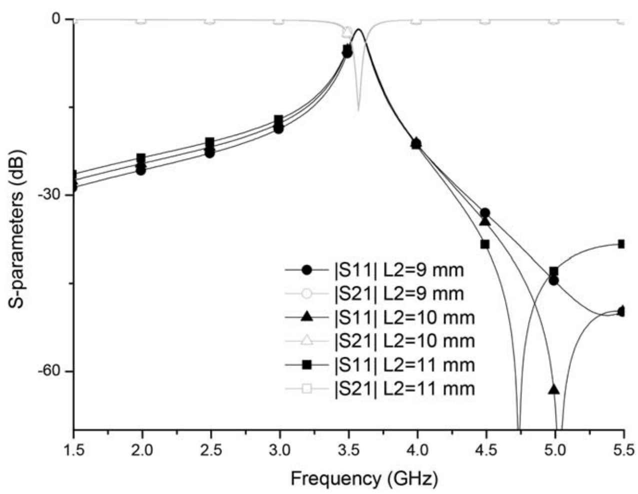

Figure 4 Effect of L_2 on S-parameters

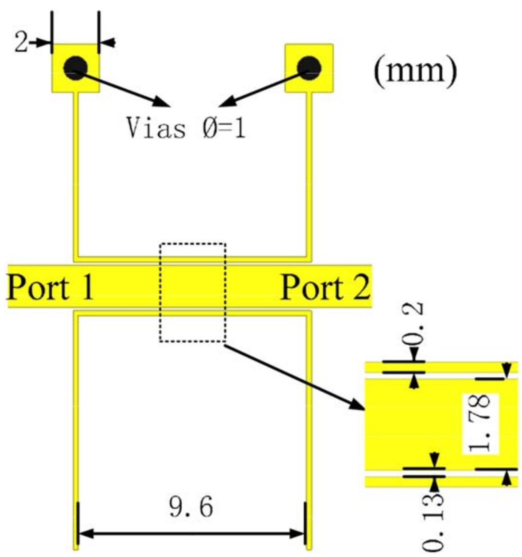

Figure 5 Dimensions of the single-band bandstop filter. [Color figure can be viewed at wileyonlinelibrary.com]

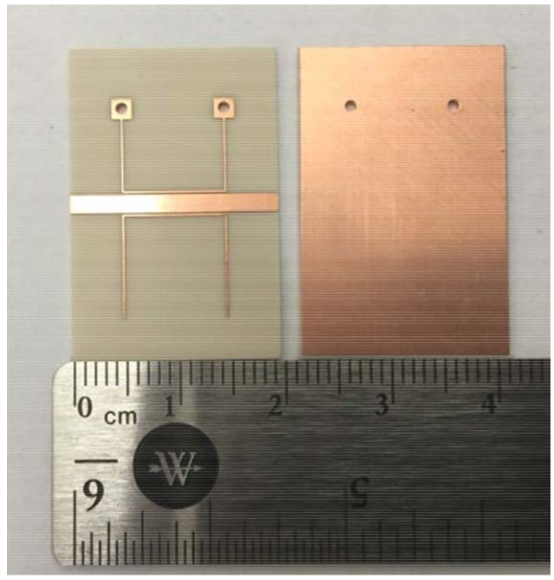

Figure 6 Top- and bottom-view photographs of the fabricated single-band filter. [Color figure can be viewed at wileyonlinelibrary.com]

resonator, a reflection zero in the upper passband is obtained. Similar to the open U-shaped resonator, increasing L2 leads to a stronger electric coupling and a decreasing location of the reflection zero.

Based on the above discussion, a filter with an open and a short U-shaped resonator is proposed and its dimensions are shown in Figure 5. The open resonator provides a reflection zero in the lower passband and a transmission zero in the stopband; the short resonator provides a reflection zero in the upper passband and a transmission zero in the stopband. Top and bottom views of the prototyped filter are depicted in Figure 6. A Thru-Reflect-Line (TRL) calibration kit is used to de-embed the effects of transitions to coaxial ports. Figure 7 shows the comparison between simulated and measured results. Good agreement is observed. The locations of the simulated transmission zeros and reflection zeros are well reproduced in the measurements. The measured stopband attenuation is better than 13 dB, and the return loss in the lower passband is better than 23 dB while that in the upper passband is better than 20 dB.

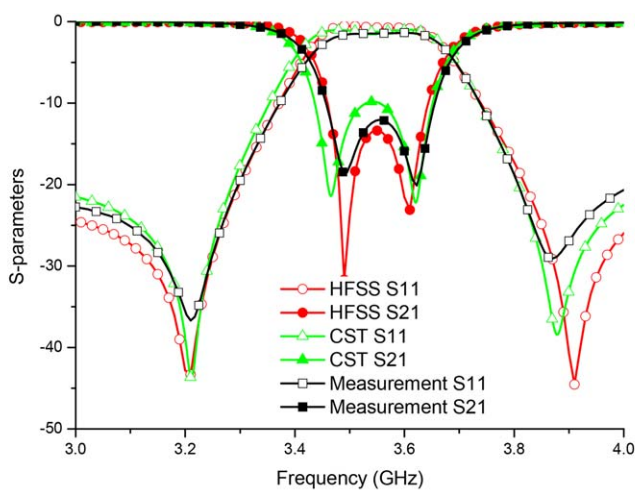

Figure 7 Simulated and measured S-parameters of the filter in Figure 5. [Color figure can be viewed at wileyonlinelibrary.com]

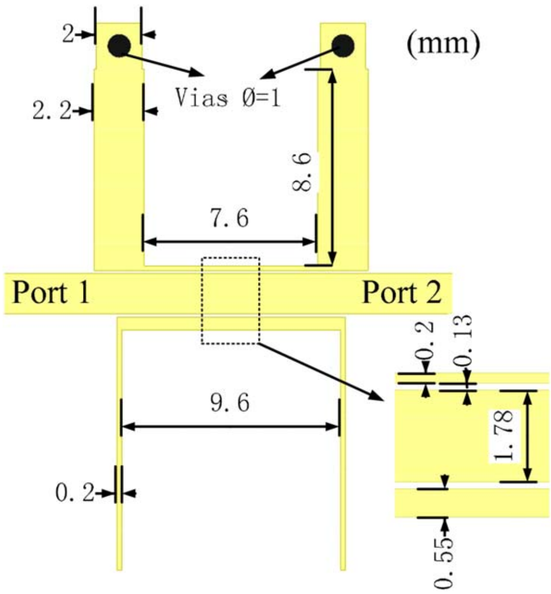

Figure 8 Dimensions of the dual-band bandstop filter. [Color figure can be viewed at wileyonlinelibrary.com]

3. DUAL-BAND BSF

U-shaped stepped impedance resonators are employed to obtain a dual-band BSF with center frequencies at 3.5 and 5.5 GHz. The dimensions of the filter are shown in Figure 8. The frequencies of both stopbands can be controlled by the size of the resonators. There is magnetic coupling between the open resonator at the first stopband and electric coupling at the second stopband. Therefore, the open resonator provides a reflection zero in the lower passband of the first stopband and another reflection zero in the upper passband of the second stopband. Similarly, the short resonator provides a reflection zero in the upper passband of the first stopband because of the electric coupling and a reflection zero in the lower passband of the second stopband because of electric coupling. Top and bottom views of the prototyped dual-BSF are depicted in Figure 9. Simulated and measured *S*-parameters are shown in Figure 10. The locations of the simulated TZs and RZs are well confirmed by measurements. The rejection levels in the stopbands are 20 and 15 dB, and the transmission levels in the passbands are 20, 13, and 10 dB, respectively.

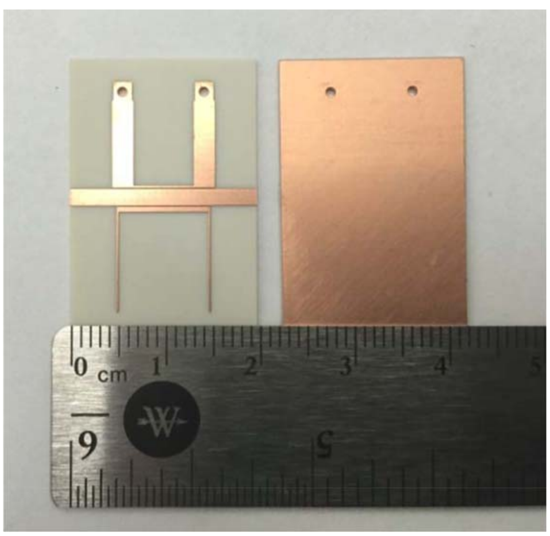

Figure 9 Top- and bottom-view photographs of the fabricated filter dual-band filter. [Color figure can be viewed at wileyonlinelibrary.com]

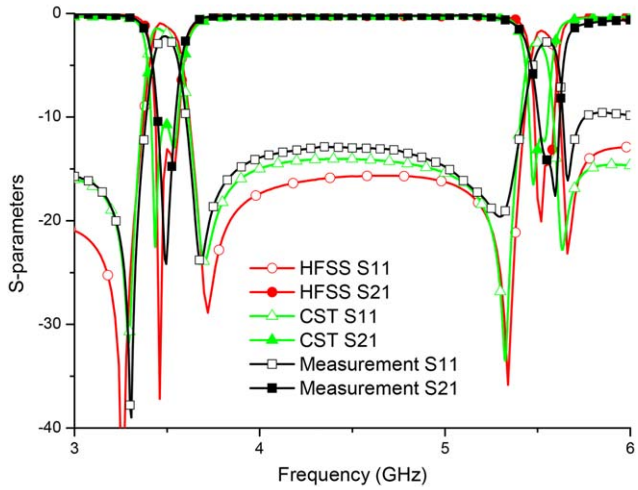

Figure 10 Simulated and measured *S*-parameter of the filter in Figure 8. [Color figure can be viewed at wileyonlinelibrary.com]

4. CONCLUSION

The two novel BSFs using open and short U-shaped resonators are attractive solutions for compact filter designs. The design methodology is described and the proposed BSFs have been implemented. Both filters demonstrate good selectivity and compact size because of the two different couplings on both sides of the microstrip line. The measured results show good agreement with simulations, thus verifying the proposed design approach.

ACKNOWLEDGMENT

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REFERENCES

1. M. Yang, J. Xu, Y. Dong, M. Yu, and G. Lee, "A novel open-loop DGS for compact bandstop filter with improved Q factor," In: Proceedings of The 8th International Symposium on Antennas, Propagation and EM Theory, Kunming, China, November 2008, pp. 649–652.
2. S.U. Rehman, A.F. Sheta, and M. Alkanhal, "Compact bandstop filter using defected structure," In: Proceedings of Saudi International Conference on Electronics, Communications and Photonics, Riyadh, Saudi Arabia, April 2011, pp. 1–4.
3. C.-K. Lung, K-S. Chin, and J.S. Fu, "Tri-section stepped-impedance resonators for design of dual-band bandstop filter," In: Proceedings of 39th European Microwave Conference, Rome, Italy, September/October 2009, pp. 771–774.
4. K.-S. Chin, J.-H. Yeh, and S.-H. Chao, "Compact dual-band bandstop filters using stepped-impedance resonators," IEEE Microwave-Wireless Compon Letts 17 (2007), 849–851.
5. F.C. Chen, J.M. Qiu, and Q.X. Chu, "Dual-band bandstop filter using stub-loaded resonators with sharp rejection characteristic", IET Electron Lett 49 (2013), 351–353.
6. W. Wang, M. Liao, Y. Wu, and Y. Liu, "Small-size high-selectivity bandstop filter with coupled-line stubs for dual-band applications", IET Electron Lett 50 (2014), 286–288.
7. H. Bell, "L-resonator bandstop Filters," IEEE Microwave Theory Tech 44 (1996), 2669–2672.
8. Y. Luo and Q.X. Chu, "A compact high selectivity dual-band bandstop filter using bent L-resonators", In: Proceedings of 43rd

European Microwave Conference, Nuremberg, Germany, October 2013, pp. 25–28.
9. M. Esmaeili and J. Bornemann, “Microstrip stopband filter using L- and T-shaped resonators,” In: Proceedings of Asia-Pacific Microwave Conference Nanjing, China, December 2015, pp. 1–3.
10. S. Saxena, S. Porwal, K. Soni, P. Chhawchharia, and S.K. Koul, “Analysis and design of bandstop filter using E-Shaped dual mode resonator,” In: Proceedings of IEEE International Conference on Microwaves, Communications, Antennas, and Electronics Systems, Tel Aviv, Israel, November 2009, pp. 1–6.
11. A.I. Abunjaileh and I.C. Hunter, “Tunable bandpass and bandstop filters based on dual-band combline structures,” IEEE Trans Microwave Theory Tech 58 (2010), 3710–3719.
12. N. Jankovie, R. Geschke, and V.C. Benign, “Compact tri-band bandpass and bandstop filters based on Hilbert-fork resonators,” IEEE Microwave Wireless Compon Lett 23 (2013), 282–284.

REALIZING FREQUENCY RECONFIGURABLE ANTENNA BY FERRITE-LOADED HALF-MODE SIW

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ABSTRACT: *We propose and experimentally demonstrate a frequency reconfigurable antenna using ferrite loaded half-mode substrate integrated waveguide (SIW). The antenna design is based on a SIW cavity with an embedded ferrite slab, which causes the resonant frequency of the cavity tunable under bias magnetic field. The antenna features omnidirection radiation and small size. A prototype antenna is designed and fabricated. The measurements show the tunable frequency bandwidth is over 11% covering frequencies 5.04–5.62 GHz in low bias magnetic field region, and 5% covering 4.28–4.5 GHz in high bias magnetic field region. The measurement is in good agreement with simulations. The gain of antenna is all over 1.6 dBi, and the frequency reconfiguration does not affect the radiation pattern of the antenna, providing a preferable feature for frequency reconfigurable antenna. This type of antenna may be a good candidate for practical applications such as base stations and satellites.* © 2017 Wiley Periodicals, Inc. Microwave Opt Technol Lett 59:1365–1371, 2017; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.30549

Key words: *SIW antenna; magnetic reconfigurable; ferrite loaded; half mode SIW; cavity backup antenna*

1. INTRODUCTION

Nowadays, reconfigurable antennas (RAs) have gained considerable attention for multimode terminal applications, involving radio communication system, radar system, and smart weapon protection [1]. The key advantage of RAs is its ability to satisfy the need for multifunctional operation, and then reduces the size and the cost of radio system. A great many studies have been contributed to RAs, but most are based on the electric reconfiguration, such as dual band varactor-loaded slot patch antenna [2], compact reconfigurable dielectric resonator antenna [3], and the others [4–8]. The electric reconfiguration needs extra complex circuits to supply electric power, which may connect with reconfigurable elements and then affect the performance of the RA. Compared with electric reconfiguration, field reconfiguration scheme is based on the tunable feature of the materials parameters under bias electric or magnetic fields. This scheme does not need extra circuit as electric tuning and then eases the antenna design. Generally, magnetic materials have stronger responses to the bias magnetic field than the responses of dielectric to the bias electric field at low field strength. Therefore, magnetic field reconfiguration is promising.

Magnetic field RAs (MRAs) can be realized by loading magnetic material into the conventional antennas and work under an external magnetic bias field. In Refs. [9] and [10], ferrite layers are embedded in the substrate of patch or helical antennas, respectively, and both of them achieve 10% of tunable frequency range. Because of the features of light weight, low profile, high Q factor, and easiness to integrate with other circuits, substrate integrated waveguide (SIW) has been used in RA designs, for example, SIW-RA using varactors has a tunable frequency range from 4.13 to 4.50 GHz [11]. Recently, MRAs realized by ferrite-loaded SIW antennas were reported [12–14]. However, there are some shortcomings in practical applications. For example, the SIW-based MRAs have a relatively large size which needs to be miniaturized, and bias magnetic field tuning by mechanical way is neither precise nor convenient in practical applications. Half mode substrate integrated waveguide (HMSIW) reduces half volume of the substrate integrated waveguide, therefore, effectively miniaturize the size of SIW-based RA. Very recently, HMSIW-based RAs were proposed both by electric reconfiguration [15] and magnetic reconfiguration [16].

In this work, based on the half mode substrate integrated waveguide (HMSIW) cavity, we proposed and designed frequency tunable HMSIW antenna. The designed antenna features small size, which is only half volume of associated SIW antenna, and has decent total bandwidth over 16%. When bias

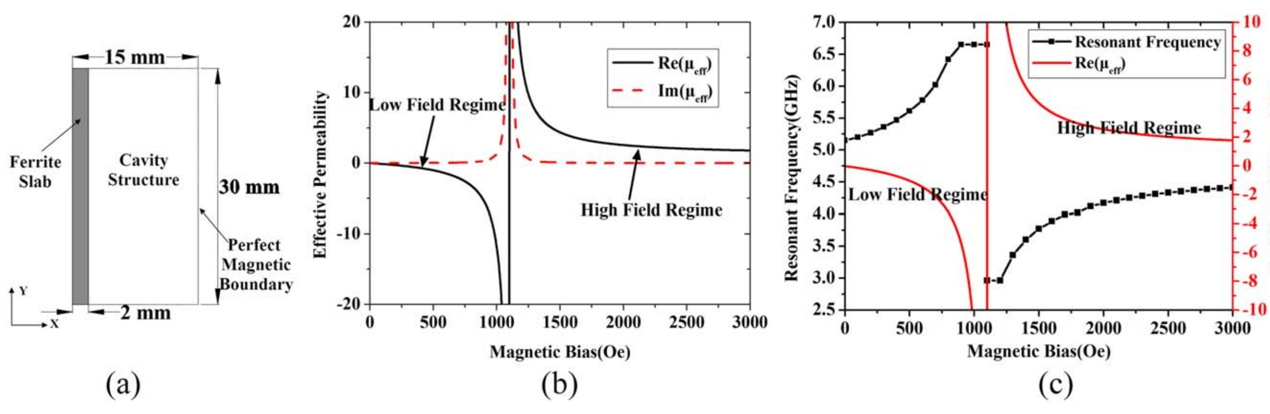

Figure 1 (a) Cavity with ferrite slab, (b) effective relative permeability, and (c) resonant frequency and effective permeability at different magnetic bias. [Color figure can be viewed at wileyonlinelibrary.com]