

UWB ANTENNA WITH DUAL BAND REJECTION FOR WLAN/WIMAX BANDS USING CSRRs

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Abstract—A compact microstrip-fed ultra-wideband (UWB) planar monopole antenna with dual band rejected characteristic is presented in this paper. By etching two identical square complementary split ring resonators (CSRRs) in the radiation patch, dual band rejections in the WiMAX and WLAN bands are achieved. The proposed antenna, with the size of $30 \times 34 \text{ mm}^2$, has been constructed and tested. And the measured results show that the antenna can operate over the frequency band between 3 and 11 GHz for $\text{VSWR} < 2$ with dual band notches of 3.4–3.6 GHz and 5.1–5.9 GHz. Besides, in the working bands, the antenna shows good omnidirectional radiation patterns in the H -plane and monopole-like radiation patterns in the E -plane and has good time-domain characteristic as well.

1. INTRODUCTION

Since the Federal Communications Commission (FCC) authorized the unlicensed use of ultra-wideband (UWB, range of 3.1–10.6 GHz) for commercial purposes [1], UWB technology has attracted much more attention for communication applications [2–5]. However, the frequency range for UWB systems will cause interference to the existing communication systems such as the worldwide interoperability for microwave access (WiMAX 3.5 GHz) and the wireless local area network (WLAN 5.2/5.8 GHz) bands. Therefore, the UWB antenna with rejected characteristic is required. In the present literatures, the most popular methods to generate the frequency band-notch function are embedding slots [6–8], using defected ground structure (DGS) [9–11], or employing the above two methods simultaneously [12–14]. Unfortunately, these designs can only obtain one rejected band with

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the complicated structures. Recently, researches in split ring resonator (SRR) and its complementary structure (CSRR) have risen drastically because of their novel properties, both of which have been increasingly used in the designs of antennas and filters [15–18].

In this paper, a simple and compact planar monopole antenna with dual band notches for WiMAX 3.5 GHz and WLAN 5.2/5.8 GHz is proposed. The antenna consists of a microstrip feedline, a ground plane and a mushroom-shaped radiation patch with two identical square complementary split ring resonators (CSRRs) which realize the dual band stop-band function etched in it. Since both the lower and higher resonant modes of the CSRRs has been fully used to generate the notched bands, the designed antenna can realize the dual band rejection conveniently by etching the CSRRs in the radiation patch only, while most of the antennas reported in the references had to employ the DGS structure as well to realize the same function. Details of the proposed antenna are described and studied.

2. ANTENNA DESIGN

The geometry of the designed antenna is shown in Fig. 1(a). The antenna is printed on a substrate with size of $30 \times 34 \text{ mm}^2$, thickness of 1 mm, and relative permittivity of 2.65. It has a semicircular patch with two steps on the front side and a ground plane of $30 \times 12 \text{ mm}^2$ on the back side. A $50\text{-}\Omega$ microstrip feed line is designed with a width of 2.84 mm. To realize the filtering property, two identical square complementary split ring resonators (CSRRs) are etched in the radiation patch. A CSRR is constructed by etching two concentric square split rings with small cuts which are placed on opposite sides of each ring in the metal plate. The geometry of the UWB antenna without rejection is depicted in Fig. 1(b) for comparison. The reference antenna has the same dimensions as the proposed antenna, except that it doesn't have the structure of CSRRs. The detailed dimensions of the radiation patch can be found in Fig. 1 and the analyses of the CSRRs are given below.

CSRR is inspired on Babinet principle [19], and as occurs with the SRR, it also exhibits a quasi-static resonance. Usually, the total dimension of the CSRR is approximately equal to half of the guided wavelength at the notched frequency, which is

$$L_{total} \approx \frac{\lambda}{2} = \frac{c}{2 \cdot f_{notch} \cdot \sqrt{\varepsilon_{eff}}} \quad (1)$$

where c is the velocity of the light; L_{total} is the total length of the CSRR; ε_{eff} is the effective dielectric constant. In our study, for

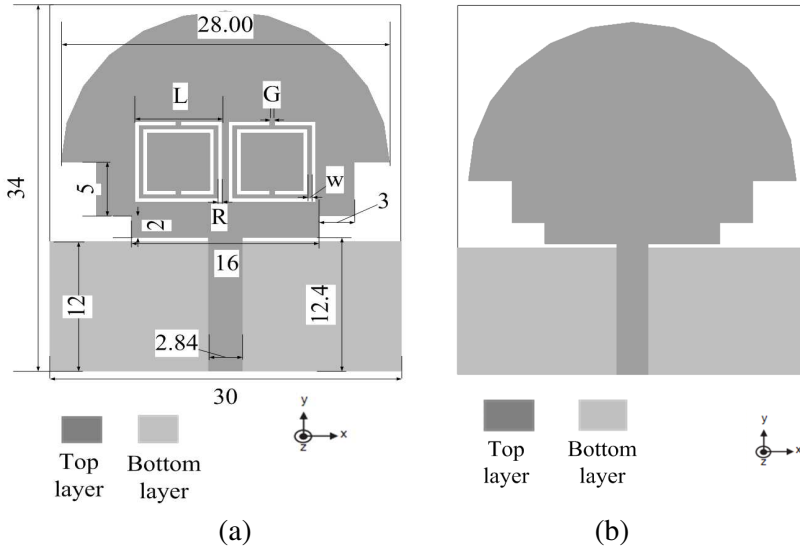


Figure 1. (a) Geometry of the proposed antenna. (b) Geometry of the reference antenna.

$f_{notch} = 3.5$ GHz, the total length of the CSRR can be calculated to be $L_{total} \approx 31.75$ mm, so that the initial length of the outer ring of the square CSRR is $L = \frac{L_{total}}{4} \approx 7.9$ mm. The final dimensions and the distances between two CSRRs can be optimized through full-wave EM simulation. The optimal results are given as: $L = 7.5$ mm, $R = G = 0.4$ mm, $W = 0.3$ mm. Fig. 2 depicts the model and the characteristics of a CSRR entity embedded in the substrate's ground plane with the dimensions above. It can be observed that two resonant frequencies were generated at 3.4 GHz and 5.5 GHz by a single CSRR. When the single CSRR was etched in the radiation patch of the reference antenna, two narrow stopbands at 3.4 GHz and 5.5 GHz can be realized, which can be observed in Fig. 3. However, the stopbands are too narrow to cover the WiMAX/WLAN bands, so that two CSRRs has to be embedded in the radiation patch to widen the bandwidth of the notched bands.

The equivalent circuit model of the proposed antenna is shown in Fig. 4. Approximately, the radiating element of UWB antenna can be seen as several parallel RLC cells in series [20]. The CSRRs behave as a parallel and a series LC resonator, respectively, and the resonant frequency is given by $f = 1/\sqrt{2\pi\sqrt{LC}}$ [21], which is related to the dimensions of the CSRRs.

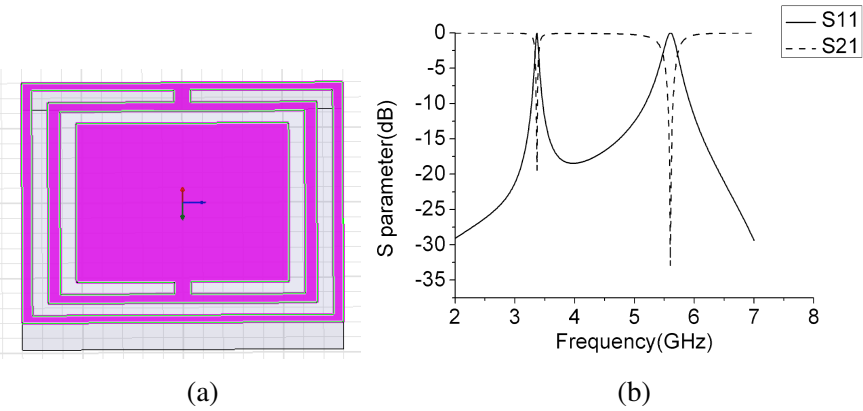


Figure 2. (a) Model of CSRR entity. (b) Characteristics of CSRR entity.

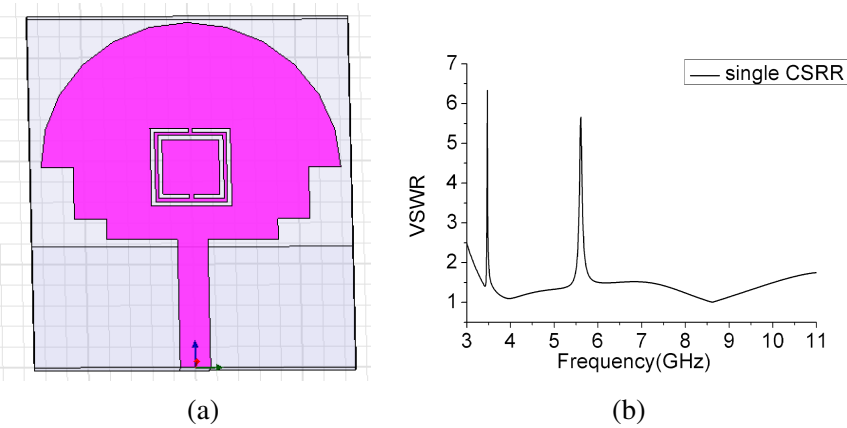


Figure 3. (a) Model of antenna with single CSRR. (b) Simulated VSWR of antenna with single CSRR.

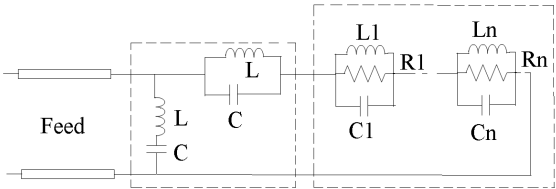


Figure 4. Equivalent circuit model of the proposed antenna.

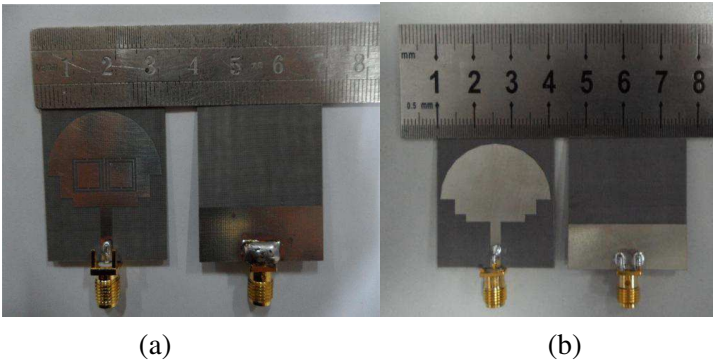


Figure 5. (a) Prototype of the proposed antenna. (b) Prototype of the reference antenna.

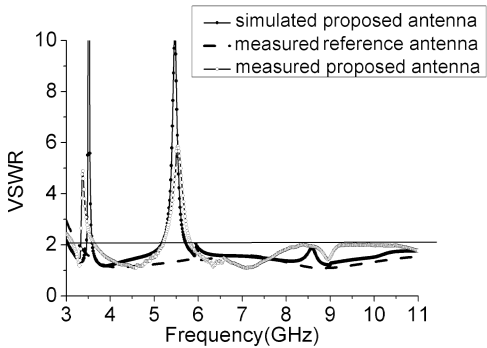


Figure 6. Simulated and measured VSWR of the proposed antenna.

3. RESULTS AND DISCUSSIONS

The proposed antenna and the reference antenna are simulated by Ansoft HFSS v12, fabricated and then measured by the Agilent N5230A network analyzer. The prototype of the antennas are shown in Fig. 5. The simulated and measured VSWR performances are plotted in Fig. 6. It is clear that the results show a good agreement, and the difference between the measured and simulated VSWR as well as the frequency shifts are caused by the slight fabrication and measurement error. Fig. 6 depicts that the designed antenna operates over the frequency band between 3–11 GHz, which covers the UWB frequency range, with two steep stopbands of 3.4–3.6 GHz and 5.1–5.9 GHz.

Figure 7 illustrates the current distribution of the proposed

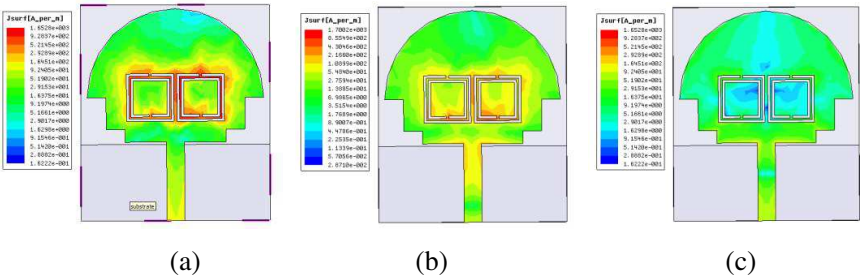


Figure 7. current distribution of the proposed antenna at (a) 3.5 GHz; (b) 5.5 GHz; (c) 6.5 GHz.

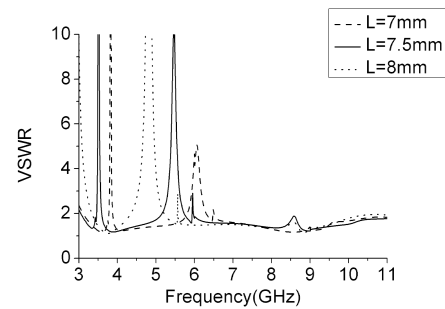


Figure 8. Simulated VSWR of the proposed antenna with various L .

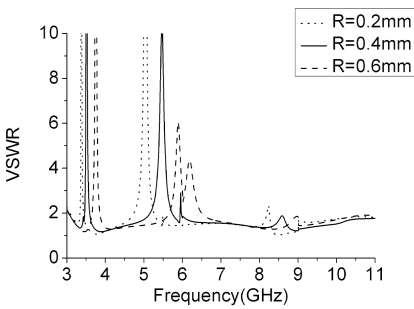


Figure 9. Simulated VSWR of the proposed antenna with various R .

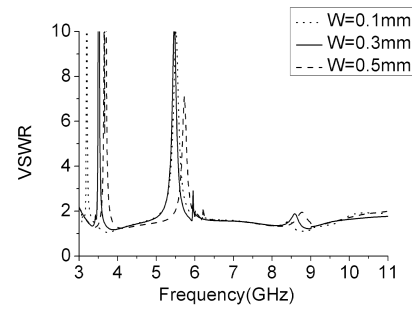


Figure 10. Simulated VSWR of the proposed antenna with various W .

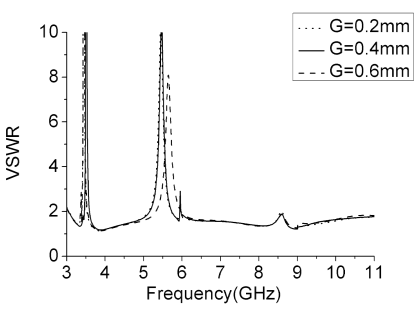


Figure 11. Simulated VSWR of the proposed antenna with various G .

antenna at 3.5 GHz, 5.5 GHz and 6.5 GHz, respectively. It can be found that the current flows mainly along the edge between the inner and outer ring of the CSRRs at 3.5 GHz and 5.5 GHz where the CSRRs resonate. While at 6.5 GHz, the current mainly distributes in the radiation patch. It justifies that the CSRRs operate as a resonator and disturb the current distribution on the patch at 3.5 and 5.5 GHz destructively, which make the input impedance singular and prevent the antenna from radiating normally.

Parameter analysis is made for further studies. The simulated VSWR of the proposed antenna with various L is depicted in Fig. 8. It can be observed that an increase in L shifts down both the lower and upper notched frequencies. However, as shown in Fig. 9, both the lower and upper rejected frequencies are raised with the increase of R . Fig. 10 plots the variation of the VSWR with the width between the inner and outer ring (W). It can be seen that the growth of W shifts down the lower notched band but doesn't cause great changes in the upper notched band. This allows for the tuning of the lower resonant frequency after the upper frequency is tuned by varying W . As depicted in Fig. 11, the changes of the size of the split of the CSRR (G) do not affect the rejected frequencies significantly.

Figure 12 shows the measured far-field radiation patterns of E -plane and H -plane at 4.2, 6.5 and 9.8 GHz, respectively. It can be seen that a monopole-like radiation pattern in the E -plane (y - z -plane) and a nearly omni-directional radiation plane (x - z -plane) are realized by the proposed antenna. Fig. 13 shows the measured peak gain of the antenna with and without the rejected band. Two sharp decreases of the realized gain at 3.5 GHz and 5.5 GHz can be observed, which shows

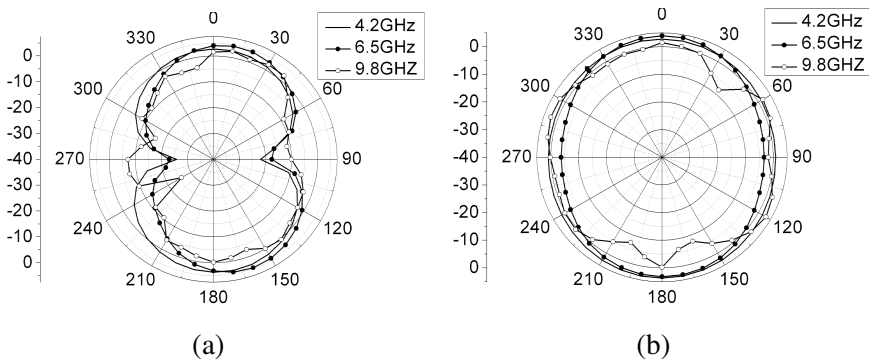


Figure 12. Measured radiation pattern of the proposed antenna. (a) E -plane (y - z plane). (b) H -plane (x - z plane).

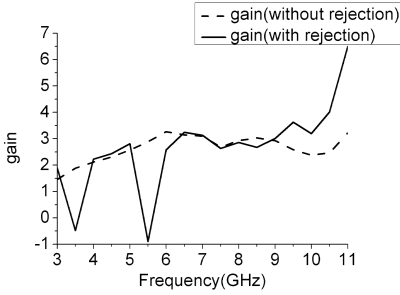


Figure 13. Measured gain of the proposed antenna and the reference antenna.

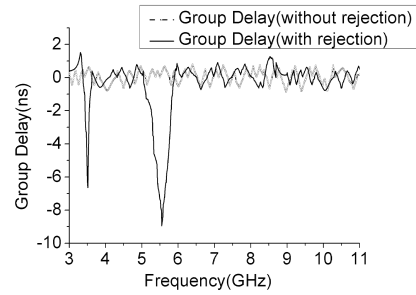


Figure 14. Measured group delay of the proposed antenna and the reference antenna.

the rejected characteristic clearly.

A pair of the proposed antennas served as the transmitting and receiving antennas, which were positioned face to face with a distance of 30 cm. A pair of the reference antennas was also measured for comparison. Fig. 14 depicts the measured group delay of the proposed antenna and the UWB antenna without rejection. It can be seen that the variation of the group delay is within 1 ns across the working band, except that in the rejected bands, the maximum group delay is more than 8 ns. It confirms that the proposed antenna has a good time-domain characteristic.

4. CONCLUSION

In this article, a novel UWB planar monopole antenna with dual band rejected characteristic is proposed. The two stopbands are generated by etching two identical square CSRRs in the radiation patch. The proposed antenna covers the entire UWB frequency band and has good radiation performance and time-domain characteristic in the working bands. It achieves dual band rejection for WiMAX 3.5 GHz and WLAN 5.2/5.8 GHz, which can eliminate the interference among UWB systems and WiMAX/WLAN systems. In addition, the designed antenna has simple structure and can be fabricated easily, which makes it a good candidate for UWB systems.

REFERENCES

1. FCC First Report and Order on the Ultra-wideband Technology, 2002.

2. Marchais, C., G. Le Ray, and A. Sharaiha, "Stripline slot antenna for UWB communications," *IEEE Antennas and Wireless Propagation Lett.*, Vol. 5, 319–322, 2006.
3. Liu, H.-W. and C.-F. Yang, "Miniature hook-shaped monopole antenna for UWB applications," *Electron. Lett.*, Vol. 46, No. 4, 2010.
4. Chen, M.-E. and J.-H. Wang, "CPW-fed crescent patch antenna for UWB applications," *Electron. Lett.*, Vol. 44, No. 10, 2008.
5. Chen, D. and C. H. Cheng, "A novel compact ultra-wideband (UWB) wide slot antenna with via holes," *Progress In Electromagnetics Research*, Vol. 94, 343–349, 2009.
6. Hu, Y.-S., M. Li, G.-P. Gao, J.-S. Zhang, and M.-K. Yang, "A double-printed trapezoidal patch dipole antenna for UWB applications with band notched characteristic," *Progress In Electromagnetics Research*, Vol. 103, 259–269, 2010.
7. Jiang, J.-B., Z.-H. Yan, and C. Wang, "A novel compact UWB notch-filter antenna with a dual-Y-shaped slot," *Progress In Electromagnetics Research Letters*, Vol. 14, 165–170, 2010.
8. Barbarino, S. and F. Consoli, "UWB circular slot antenna provided with an inverted-L notch filter for the 5 GHz WLAN band," *Progress In Electromagnetics Research*, Vol. 104, 1–13, 2010.
9. Zaker, R., C. Ghobadi, and J. Nourinia, "Novel modified UWB planar monopole antenna with variable frequency band-notch function," *IEEE Antennas and Wireless Propagation Lett.*, Vol. 7, 112–114, 2008.
10. Yang, Y.-B., F.-S. Zhang, F. Zhang, L. Zhang, and Y.-C. Jiao, "Design of novel wideband monopole antenna with a tunable notched-band for 2.4 GHz WLAN and UWB applications," *Progress In Electromagnetics Research Letters*, Vol. 13, 93–102, 2010.
11. Li, X., L. Yang, S.-X. Gong, and Y.-J. Yang, "Ultra-wideband monopole antenna with four-band-notched characteristics," *Progress In Electromagnetics Research Letters*, Vol. 6, 27–34, 2009.
12. Liao, X.-J., H.-C. Yang, N. Han, and Y. Li, "UWB antenna with dual narrow band notches for lower and upper WLAN bands," *Electron. Lett.*, Vol. 46, No. 24, 2010.
13. Tu, S., Y. C. Jiao, Y. Song, B. Yang, and X. Z. Wang, "A novel monopole dual band-notched antenna with tapered slot for UWB applications," *Progress In Electromagnetics Research*

- Letters*, Vol. 10, 49–57, 2009.
14. Zhang, X., T.-L. Zhang, Y.-Y. Xia, Z.-H. Yan, and X.-M. Wang, “Planar monopole antenna with band-notch characterization for UWB applications,” *Progress In Electromagnetics Research Letters*, Vol. 6, 149–156, 2009.
 15. Tang, M.-C., S. Xiao, T. Deng, D. Wang, J. Guan, B. Wang, and G.-D. Ge, “Compact UWB antenna with multiple band-notches for WiMAX and WLAN,” *IEEE Transactions on Antennas and Propagation*, Vol. 59, No. 4, 1372–1396, 2011.
 16. Deng, J. Y., Y. Z. Yin, X. S. Ren, and Q. Z. Liu, “Study on a dual-band notched aperture UWB antenna using resonant Strip and CSRR,” *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 5–6, 627–634, 2009.
 17. Kim, D.-O., N.-I. Jo, D.-M. Choi, and C.-Y. Kim, “Design of the ultra-wideband antenna with 5.2 GHz/5.8 GHz band rejection using rectangular Split-Ring Resonators (SRRs) loading,” *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 17–18, 2503–2512, 2009.
 18. Montero-de-Paz, J., E. Ugarte-Munoz, F. J. Herraiz-Martínez, V. Gonzalez-Posadas, L. E. Garcia-Munoz, and D. Segovia-Vargas, “Multifrequency self-diplexed single patch antennas loaded with split ring resonators,” *Progress In Electromagnetics Research*, Vol. 113, 47–66, 2011.
 19. Falcone, F., T. Lopetegi, J. D. Baena, R. Marques, F. Martin, and M. Sorolla, “Effective negative- ϵ stop-band microstrip lines based on complementary split ring resonators,” *IEEE Microwave and Wireless Compoment Lett.*, Vol. 14, No. 6, 280–282, 2004.
 20. Chu, Q.-X. and Y.-Y. Yang, “A compact ultrawideband antenna with 3.4/5.5 GHz dual band-notched characteristics,” *IEEE Transactions on Antennas and Propagation*, Vol. 56, No. 12, 2008.
 21. Marqués, R., F. Martín, and M. Sorolla, *Metamaterials with Negative Parameters: Theory, Design and Microwave Applications*, Wiley Series in Microwave and Optical Engineering, New York, 2008.