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A Wideband Monopole for Reconfigurable Multiband Radio Terminals

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Wideband Reconfigurable Rolled Planar Monopole Antenna

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***Abstract*—A novel technique to reconfigure the frequency range of a planar monopole antenna is presented. By adjusting the degree of spiral tightness, a shift of the well-matched operating frequency range is achieved. The proposed antenna is capable of covering the frequencies in the range from 2.9 to 15 GHz, depending on the degree of spiral tightness. The antenna yields a high-efficiency across the full operating bandwidth. Radiation patterns show good omnidirectional features in all primary cuts and remain relatively stable with the change of antenna configuration, so that it is a remarkable candidate for indoor or mobile applications where a large frequency range and omnidirectional radiation are required.**

***Index Terms*—Antennas, band-notching, monopolar antennas, reconfigurable antennas.**

I. Introduction

IN the last decade, the research community has dedicated a great deal of effort to reconfigurable antennas for efficient use of the electromagnetic spectrum [1]. One the more successful techniques of reconfigurability is based on RF microelectromechanical systems (MEMS). These have been shown to be a useful component in the design of reconfigurable multiband antennas where the feed network of a patch array is reconfigured [2]. However, this technology presents numerous problems which limit its applications. For instance, the dc biasing circuit requires very high voltage and the switching speed is also very low. Moreover, MEMS comprise costly sealed packaging, which is not easily integrated with a planar antenna. Applications where continuous electronic tuning is required are also incompatible with this solution as MEMS are only bistatic switches. In 1991, a novel idea of electronic tuning was introduced using integrated FET components in a microstrip slot antenna as 1-port reactive devices [3]. By changing the bias voltages, the reactance of the FET varied and the length of the slot was tuned electronically. A 10% tuning of the center frequency was achieved with negligible changes in the radiation pattern but many problems arose from the effects of the reactive circuits for feed line matching. Since then many different semiconductor-based solutions such as varactors and PIN diodes have been proposed and some difficulties overcome [4]. In 2006, a new technique to reconfigure a dual-band slot antenna achieving a frequency ratio, ranging from 1.3 to 2.67 was proposed [5], [6]. The use of varactors enabled tuning of the effective slot length while the radiation pattern and polarization purity for both bands remained consistent across the entire tunable frequency range. A novel reconfigurable patch antenna which employs switchable slots to provide circular-polarization diversity has been reported [7]. Two orthogonal slots were incorporated into the patch and two PIN diodes were utilized to switch the slots on or off. Right-hand and left-hand circular polarizations were generated by diode switching.

One of the major drawbacks of PIN diodes is that the bias current can influence the reconfigurable antenna efficiency [8]. A drop in radiation efficiency was observed for some values of the PIN diode bias current. A tradeoff between the dc consumption of the diodes and the antenna gain was demonstrated. Moreover, even though PIN diodes and varactors present faster switching speeds, high tunability, reduced cost, and better integrability with monolithic millimeter-wave integrated circuits (MMIC) compared to MEMS, they have limited power handling and can introduce intermodulation interference due to nonlinear behavior. Recently, an innovative reconfigurable antenna concept with significant practical relevance was reported [9]. It is based on dynamic definition of metal-like conductive plasma channels in high-resolution silicon fabrication technology that are activated by the injection of dc current. These dynamically defined plasma reconfigurable antennas enable frequency hopping, beam shaping and steering without the complexity of RF-feed structures. However, they present a complex PIN diode biasing circuit that introduces nonlinearities into the system. Also the antenna efficiency is strongly influenced by several factors (i.e., wafer size, solid-state plasma density, thermal considerations and packaging), which considerably limit its performance.

The technique presented in this paper to modify the structure of the antenna and reconfigure band-notches and working bandwidths is simple and innovative. The antenna comprises a planar monopole-fed rolled horizontal element, whose spirals can be mechanically adjusted in order to tune the capacitive coupling between them. Multiple bandwidths are obtained within the UWB frequency range and above. Rolled monopole antennas have been investigated and demonstrated to enhance the impedance bandwidth performance [10], [11]. Moreover, beveling and using an offset feed point reshapes the base of the antenna and these have been demonstrated to be a successful bandwidth enhancement technique [12], [13]. A very high efficiency and good omnidirectional radiation patterns are achieved

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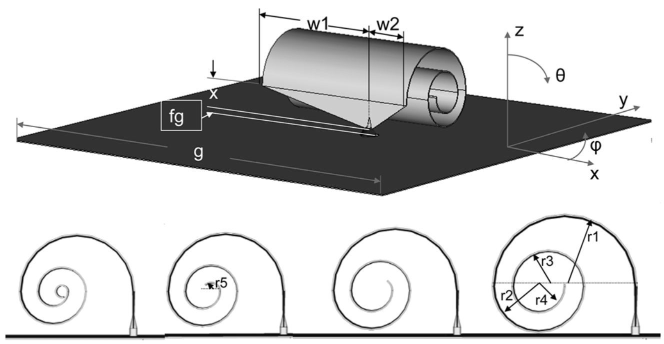


Fig. 1. Geometry of the antenna and the four configurations investigated. $g = 100$ mm, $fg = 1.3$ mm, $x = 6.3$ mm, $w1 = 30$ mm, $w2 = 9$ mm.

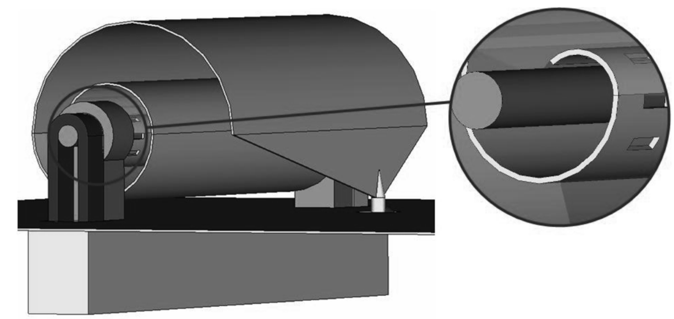


Fig. 2. Mechanical layout proposed.

throughout the operating spectrum. Compared to other existing solutions to realize reconfigurable antennas, the antenna presented in this paper offers several advantages. First of all, the efficiency of the antenna is very high throughout the working spectrum and is not affected by dielectric loading of the mechanical parts that tune its structure. Moreover, due to its simple design and the absence of semiconductor circuit elements, higher power handling is possible compared to other reconfigurable antennas [14]. In the same way, because nonlinear elements are not present, intermodulation is not as critical an issue, as it is for most of the reconfigurable antennas in the literature. Continuous tuning is also feasible with this technology. The use of IEEE 802.11a WLAN in the frequency-band 5.15–5.825 GHz has increased. Therefore, antennas providing a reject notch-function are becoming necessary to reduce WLAN interference effects. This antenna is able to notch out this band when $r1$ is tuned to 11 mm, whereas all the other configurations investigated cover this part of the spectrum. This feature is applicable over different bandwidths. Not only can the proposed antenna reconfigure its operating bands but also parts of the spectrum can be notched out in the same manner.

II. Antenna Structure and Working Principles

The antenna presented in this paper comprises an adjustable rolled horizontal element attached to a vertical planar section, which is connected to the feed point as shown in Fig. 1. The base of the radiating element is appropriately shaped to enhance the match by the insertion of a double asymmetrical bevel and an offset feed point. The optimum geometry for the double asymmetrical bevel at the base of the radiator was obtained by finite integration time domain method, so that W is given by the sum of $w1 = 30$ mm and $w2 = 9$ mm. The asymmetrical feed introduces extra modes and broadens the bandwidth, while the bevels improve the match at the higher frequencies. The input signal is launched into the antenna through a 50-Ω coaxial cable located below the horizontal square ground plane of dimension 100×100 mm. The optimum feedgap f_g between the ground plane and plate tip, was found to be 1.3 mm. The distance x from the tip of the beveled plate to the first planar half-cylinder of radius $r1$ is 6.3 mm. All parts of the radiating element are made of 0.2-mm-thick brass sheet. The different configurations of the cylinder investigated have radii equal to $r1 = 11, 10.5, 10,$ and 9.5 mm as shown in Fig. 1. The radii of the other half-cylinders are related to $r1$ according to the rule

$$r2 = r1\text{–}4 \text{ mm } r3 = r1\text{–}5.5 \text{ mm}$$
$$r4 = r1\text{–}7 \text{ mm } r5 = r1\text{–}8.5 \text{ mm}.$$

The total length of the rolled section remains the same in all the configurations and is equal to 29.5π mm. The total height of the antenna above the groundplane is given by $h = f_g + x + r1$. In Fig. 2, a mechanical layout for the proposed antenna is proposed. In particular, a motorized design for the control of the rolling/unrolling mechanism has been proposed. Special care has been taken to keep the mechanical elements (such as spacers, spindle, spindle mounts, toothed-belts, and motor) as RF-transparent as possible. For this reason the motor is located below the groundplane in a shielded box measuring $60 \times 6 \times 8$ mm. This configuration has a minimal effect on simulations. Moreover, motors that present very low electromagnetic interference are available [15]. Also linearity between load and speed and load and current are important features that commercial motors offer. Foam spacers have been introduced to keep a constant distance between spires when the monopole rolls in or out. RF transparent extruded polystyrene thermal insulation material is available in different shapes and sizes under the trademark name of Styrofoam [16]. At frequencies up to 400 MHz, the relative permittivity is 1.02 with a typical loss tangent of 0.0002. The spindle that enables the rolling/unrolling action and the two spindle-mounts are made of Polystyrene (PS). This material offers in its pure solid form is a hard plastic material with limited flexibility. It can be cast into molds with fine detail. It is economical and is used for producing economical plastic model assembly kits where certain rigidity is desired . Also its electrical properties suit the application presented in this paper. Polystyrene presents a dielectric constant ε_r equal to 2.5 and a dissipation factor of 0.00005 in the frequency range where the antenna presented operates. The mechanical rolling action is very simple. The spindle is driven by the stepper motor below the groundplane, by a combination of geared PS cogwheels and nylon toothed-belts, symmetrically placed beside the antenna. Four slots are cut out from each side of the monopole corresponding to teeth located on the spindle. This way the spindle is locked to the monopole and governs the spiral tightness. In order to reconfigure the antenna in all the configurations investigated, a rotation of the spindle corresponding to an angle of 288° is required.

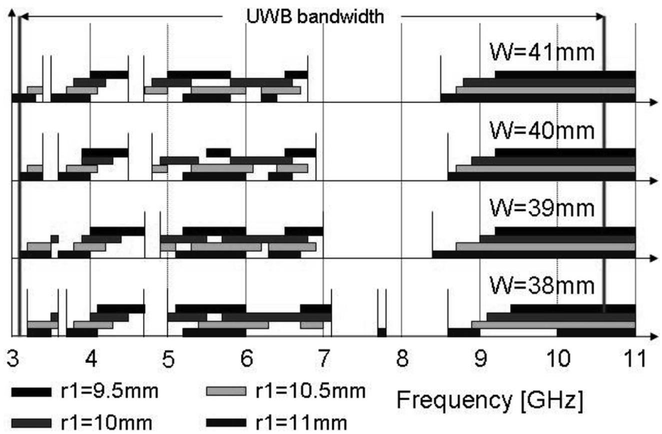


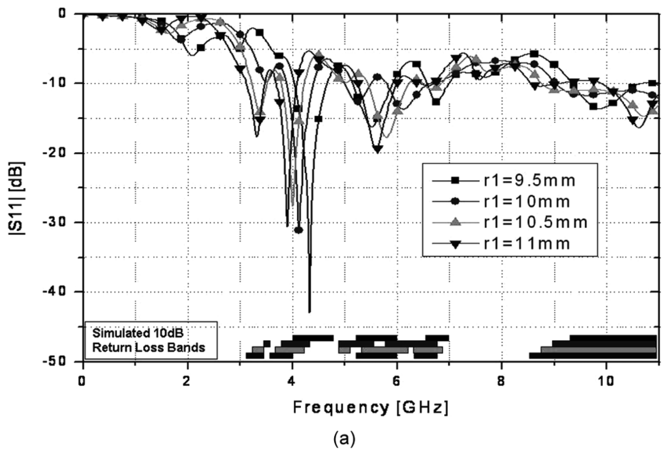
Fig. 3. 10-dB bandwidths for the four configurations investigated when W is tuned.

All simulations have taken the effects of the motor shield and plastic parts into account. No significant differences were seen either in terms of radiation patterns, total efficiency, or impedance bandwidth with respect to the model without mechanical parts. Four prototypes were built (one per configuration investigated) to observe the effects of the mechanical parts in the design. In particular, a PS spindle with the diameter of 2 mm has been inserted, around which the monopole rolls. The four small horizontal rectangular slots on each side of the planar element have a dimension of 2×1 mm. Additionally, two PS spindle-mounts and the motor-shielding brass box have been prototyped. The insertion of these mechanical parts has not introduced significant changes in the performance of the antenna itself.

III. Results and Discussions

A. Tuning the Structure

Numerical analysis for the structure was made using the finite integration time domain method, CST Microwave Studio. Unfortunately, the structure is highly resonant and presents difficulties for the mesh grid composition as the thickness of the rolled metal sheet is about $\lambda/500$ at the lower edge frequency. These reasons justify some discrepancy between numerical and experimental results. However, simulations were able to predict the general trend of the parameters investigated. The antenna has been simulated for different values of the total width W of the radiating element ($W = w1 + w2$, see Fig. 1). The parameter W is varied but the proportion between $w1$ and $w\,2$ is kept constant in order to maintain the offset feed point in its optimized position. This parameter is crucial as it shifts up or downward the resonances of the structure as shown in Fig. 3. From simulation, it was found that the resonances of the antenna and the 10-dB bandwidths can be controlled by adjusting the parameter W. In particular, the results for $w1 = 30$ mm and $w2 = 9$ mm is convenient as the uncovered 10-dB return loss areas are drastically reduced, therefore, $W = 39$ mm was used for the experimental work.



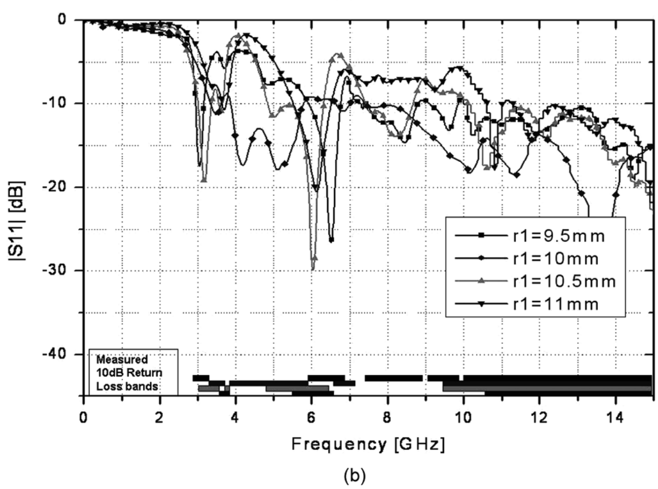


Fig. 4. (a) Simulated return loss and 10-dB bandwidths. (b) Measured return loss and 10-dB bandwidths.

B. Impedance Bandwidth Characteristics

The four different configurations of the antenna presented are investigated in terms of impedance bandwidth and radiation patterns both numerically and experimentally. The 10-dB return loss bands are displayed in Fig. 4(a)–(b). An effective frequency reconfigurable antenna is realized by adjusting the degree of tightness of the rolled element, where, by rolling in and out the radiation element, different 10-dB return loss bandwidths can be covered. In fact, the rearrangement of the spiral has a significant effect on the capacitive coupling between close segments of the rolled antenna as it regulates whether sections of the roll overlaps or not. This mechanical tuning directly affects the impedance of the antenna and its resonances. It can be seen from Fig. 4(b) that a very large band (3–15 GHz) can be covered simply by changing from one configuration to another.

C. Radiation Characteristics

The radiation pattern is illustrated in Figs. 5–7, which are normalized to maximum gain. Three plane cuts of the radiation pattern at 6 GHz are shown for the four configurations investigated: $\phi, \theta = 90$, (xy-plane), $\theta, \phi = 0$, (xz-plane) and $\theta, \phi = 90$ (yz-plane) cuts for $r1 = 9.5, 10, 10.5$, and 11 mm, respectively. All the measured radiation patterns are reported against the simulated component in 10-dB/division scaled plots.

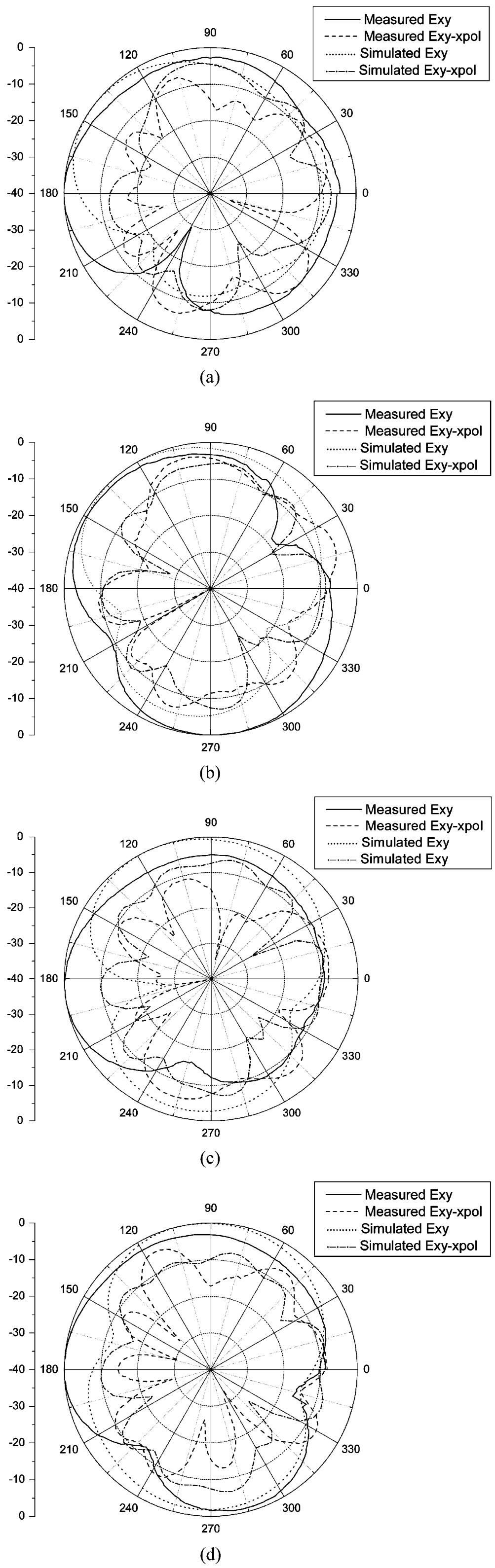


Fig. 5. (a) Radiation patterns at 6 GHz. xy-cut, $\mathrm{r1} = 9.5$ mm. (b) Radiation patterns at 6 GHz. xy-cut, $\mathrm{r1} = 10$ mm. (c) Radiation patterns at 6 GHz. xy-cut, $\mathrm{r1} = 10.5$ mm. (d) Radiation patterns at 6 GHz. xy-cut, $\mathrm{r1} = 11$ mm.

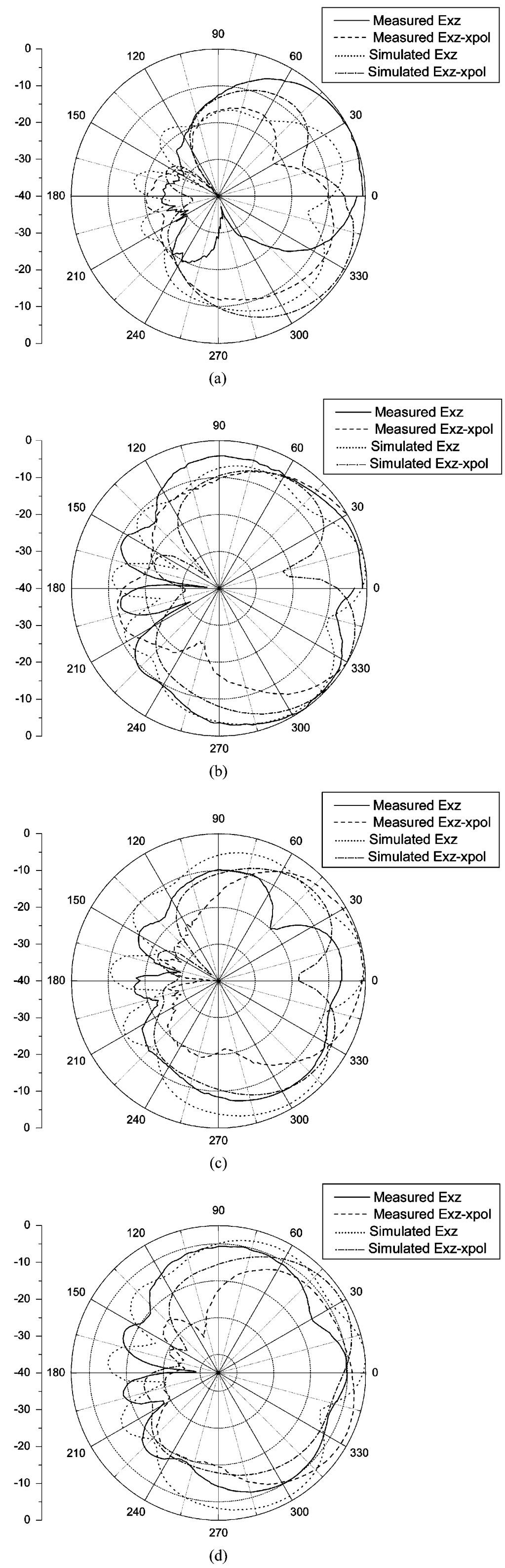


Fig. 6. (a) Radiation patterns at 6 GHz. xz-cut, $\mathrm{r1} = 9.5$ mm. (b) Radiation patterns at 6 GHz. xz-cut, $\mathrm{r1} = 10$ mm. (c) Radiation patterns at 6 GHz. xz-cut, $\mathrm{r1} = 10.5$ mm. (d) Radiation patterns at 6 GHz. xz-cut, $\mathrm{r1} = 11$ mm.

Moreover, each radiation pattern cut is presented together with the simulated co- and cross-polar component. The cross-polarization purity performance is poor but remains stable as the monopole rolls in or out, however for mobile applications this is not a relevant issue. An overall good agreement is obtained for all the cuts and configurations investigated except for the

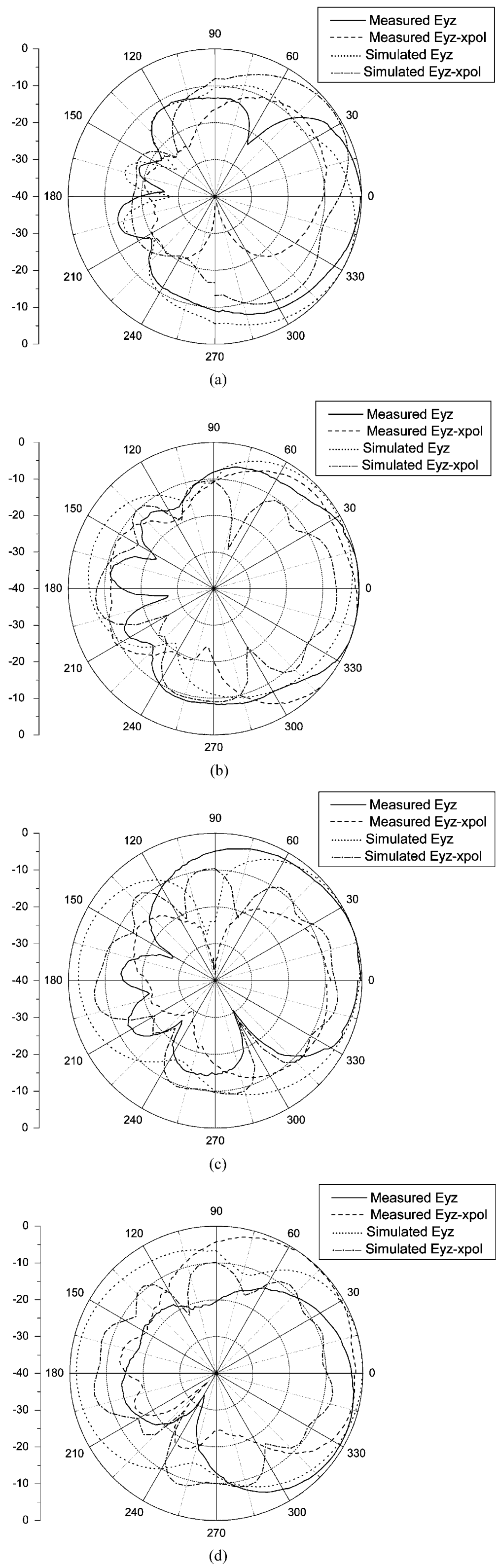


Fig. 7. (a) Radiation patterns at 6 GHz. yz-cut, r1 $= 9.5$ mm. (b) Radiation patterns at 6 GHz. yz-cut, r1 $= 10$ mm. (c) Radiation patterns at 6 GHz. yz-cut, r1 $= 10.5$ mm. (d) Radiation patterns at 6 GHz. yz-cut, r1 $= 11$ mm.

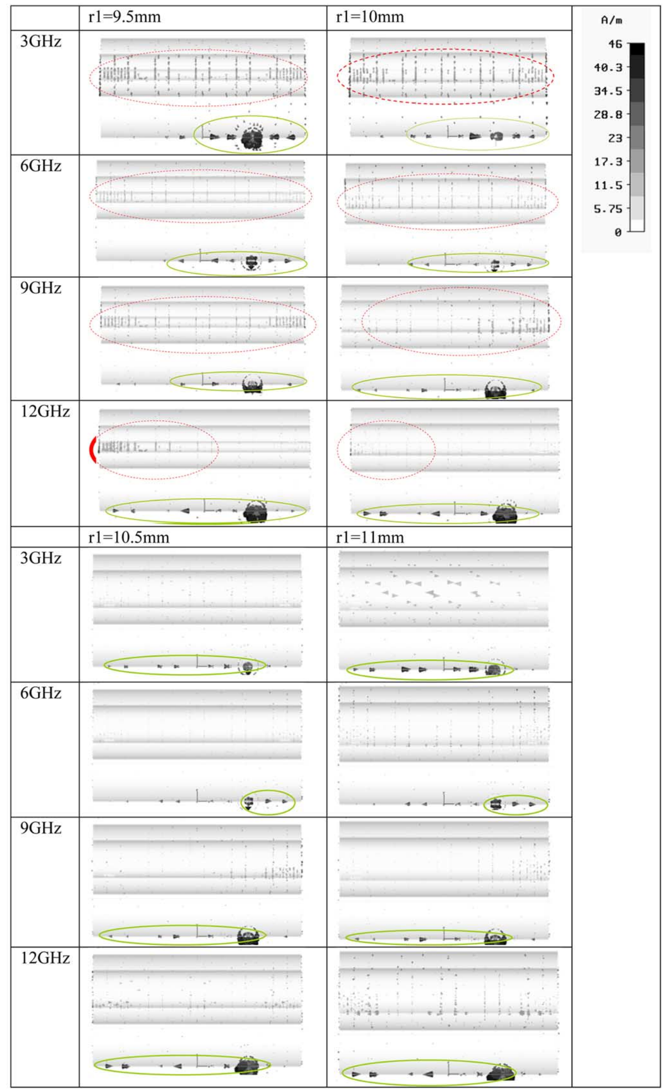


Fig. 8. Current distribution on the radiator (seen from above) for the four configurations investigated at 3, 6, 9, and 12 GHz.

copolar xy-cut for $r1 = 9.5$ mm. The antenna maintains good omnidirectionality as the structure is rearranged apart from the case for $r1 = 9.5$ mm. Fig. 5(a) shows a 25-dB deep null in the radiation pattern, for this particular value of $r1$, at around $\phi = 240°$. This behavior vanishes as the monopole is rolled less tightly as shown in Fig. 5(b)–(d). Very little differences occur in terms of omnidirectionality of the radiation pattern as the antenna rolls in and out as it can be observed in Fig. 5(b)–(d). The largest cylinder of the antenna acts as a cavity, in which the most significant mechanical change takes place. The rolled planar antenna introduces a parasitic capacitance due to the strong mutual coupling between the adjacent layers and inductance due to the spiral cross section. Changing the configuration the antenna changes the parasitic capacitance and inductance so that the resonance frequencies vary. This avoids significant alterations of the pattern as the configuration of the spiral changes. The xz cuts for $r1 = 9.5$ mm also display some distortion, which is reduced when the radius increases. These xz cuts show a very different behavior compared to a planar monopole. Deep nulls typical of monopoles at zenith are not present for the proposed structure. This gives an indication about the operating mode of the antenna. Indeed, it is believed that the radiating element works in a hybrid mode; a combination of the monopolar and transmission-line or patch mode [17]. The latter is due to the parts of the radiator, which are horizontal with respect to the ground plane. However, the dominant fundamental mode is a transmission-line (patch) one. In fact, through simulations of the far field at low frequencies, a strong distribution of the electric field points in the z axis; this is typical of a patch radiation. Also the current distribution in Fig. 8 supports this thesis. It shows the current distribution on the rolled monopole seen from above (z axis) at 3, 6, 9, and 12 GHz for the four configurations investigated. The strongest current concentrations have been marked. For the configuration with $r1 = 9.5$ mm and partially when $r1 = 10$ mm, the current distribution presents a maximum in the most internal spire of the roll across the entire bandwidth considered. However, as the contribution to the far field of the strong current distribution in the inner spirals is limited because shielded by more external spirals, the dominant role is played by the horizontal currents on the upper part of the radiator. Moreover, from the configuration with $r1 = 9.5$ mm and $r1 = 10$ mm at 12-GHz currents result asymmetrically distributed on the most internal spiral as marked in Fig. 8. When the roll opens up the current distribution gets more equally distributed throughout the radiator until a new strong concentration is obtained in the gap between the roll and groundplane when $r1 = 11$ mm. In fact, for this last configuration a strong capacitive coupling takes place in the gap before mentioned. Those currents influence the far field heavily. As the distance between the most external cylinder and the ground plane is reduced, nulls in the xy-cut are largely reduced.

The off-center feeding generates an unbalanced current on the antenna structure. As it is marked in Fig. 8 current distribution at the lower edge of the antenna appears asymmetrical. This phenomenon is more evident at higher frequency (9 and 12 GHz) and when the structure is more loose ($r1 = 10.5$–11 mm). However, its effects do not affect heavily the pattern in the xy-plane, where the antenna presents omnidirectional features. On the other hand, the xz-cut appears strongly asymmetric as a strong x-component of the far field is supported by an unbalanced current in that direction on the radiator and reflected on the ground plane. Indeed, from Fig. 7(a)–(d) a maximum in the pattern is traceable between $\theta = 0°$ and $\theta = 30°$. Fig. 9 shows the electric field intensity in the yz-cross section for the four configurations investigated at 3, 6, 9, and 12 GHz, respectively. From this, it is evident that the four configuration investigated represent different steps between two conditions of equilibrium. In the first the monopole is tightly rolled and most of the energy is retained within the most internal spirals with minor effects on the far field. Then the monopole gradually opens up and most of the energy is transferred to the gap between the most external cylinder and the ground plane with strong consequences in the far field.

The behavior of the gain and the total efficiency is plotted on Fig. 10 for the four configurations investigated and at three frequencies: 3, 5, and 7 GHz. The maximum gain was found to be between 7.5 and 8.5 dBi in the broadside direction for $r1$ between 10.0 and 11.0 mm. The patterns are broad beamwidth

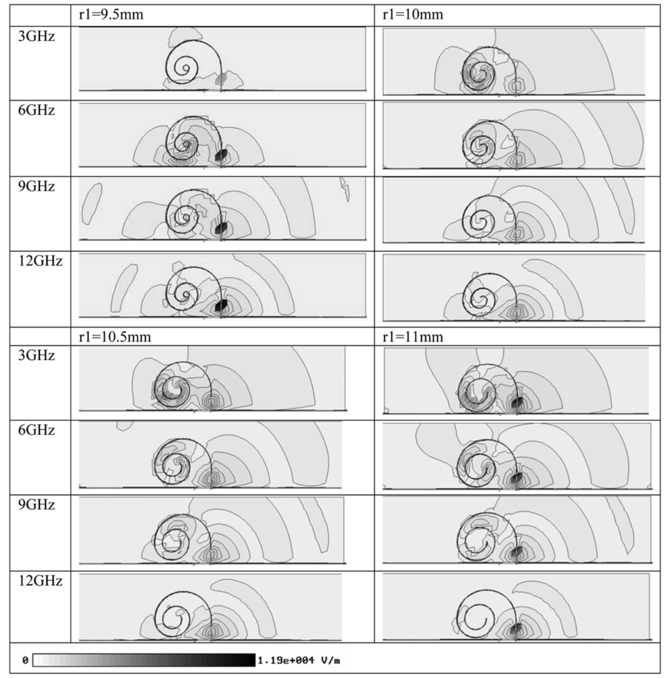


Fig. 9. Field intensity on the yz cross section for the four configurations investigated at 3, 6, 9, and 12 GHz.

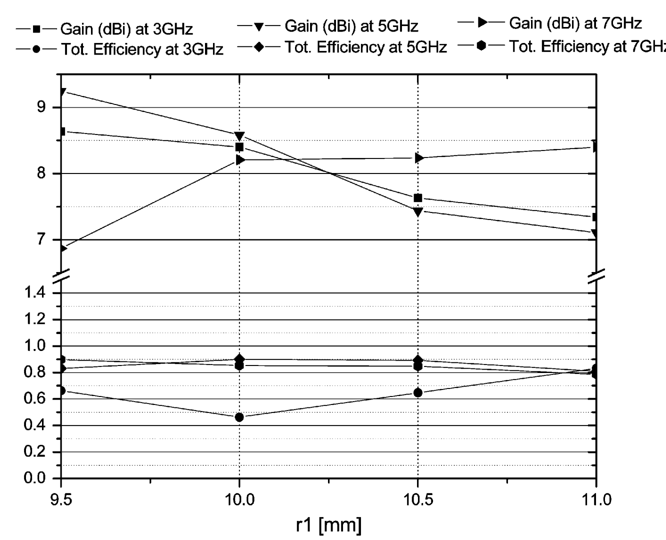


Fig. 10. Gain (dBi) and total efficiency for the four configurations at 3, 5, and 7 GHz, respectively.

and have high radiation efficiency. The efficiency results were obtained by simulation but they are important to understand the radiation properties of the proposed antenna. It is evident that significant changes occur in terms of gain and efficiency, for the configuration represented by $r1 = 9.5$ mm. In fact, for this case, the antenna is tightly rolled, so that the effective dimensions are reduced and the Q-factor increased as the structure becomes more resonant.

IV. Conclusion

A novel reconfigurable antenna has been introduced. By adjusting the degree of spiral tightness in the rolled planar monopole type antenna, a shift in the resonant frequencies has been obtained by revolving in and out the planar adjustable section of the proposed antenna. Four different typical configurations have been analyzed in terms of impedance bandwidth and radiation properties. The study has shown that the proposed antenna is capable of covering a range from 2.2 to 15 GHz. Radiation patterns have shown good omnidirectionality in the H-cut and acceptable gain across the operating bands.

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REFERENCES

[1] J. T. Aberle, S.-H. Oh, D. T. Auckland, and S. D. Rogers, "Reconfigurable antennas for wireless devices," in *IEEE Antennas Propag. Mag.*, Dec. 2003, vol. 45, no. 6, pp. 148–154.

[2] W. H. Weedon, W. J. Payne, and G. M. Rebeiz, "MEMS-switched reconfigurable antennas," in *IEEE Antennas Propag. Symp. Dig.*, 2001, vol. 3, pp. 654–657.

[3] S. Kawasaki and T. Itoh, "A slot antenna with electronically tunable length," in *IEEE Antennas Propag. Symp. Dig.*, 1991, vol. 1, pp. 130–133.

[4] S. V. Shynu, G. Augustin, C. K. Aanandan, P. Mohanan, and K. Vasudevan, "C-shaped slot loaded reconfigurable microstrip antenna," *Electron. Lett.*, vol. 42, no. 6, pp. 216–318, 2006.

[5] N. Behdad and K. Sarabandi, "A varactor-tuned dual-band slot antenna," *IEEE Trans. Antennas Propag.*, vol. 54, no. 2, pp. 401–409, Feb. 2006.

[6] N. Behdad and K. Sarabandi, "Dual-band reconfigurable antenna with a very wide tunability range," *IEEE Trans. Antennas Propag.*, vol. 54, no. 2, pp. 409–416, Feb. 2006.

[7] F. Yang and Y. Rahmat-Samii, "Patch antennas with switchable slots (PASS) in wireless communications: Concepts, designs, and applications," *IEEE Antennas Propag. Mag.*, vol. 47, no. 2, pp. 13–29, Apr. 2005.

[8] J. M. Laheurte, H. Tosi, and J. L. Dubard, "Microstrip antenna controlled by PIN diodes: Influence of the bias current on the antenna efficiency," *Microw. Opt. Technol. Lett.*, vol. 33, no. 1, pp. 44–47, Apr. 2002.

[9] A. E. Fathy, A. Rosen, H. S. Owen, F. McGinty, D. J. McGee, G. C. Taylor, R. Amantea, P. K. Swain, S. M. Perlow, and M. ElSherbini, "Silicon-based reconfigurable antennas-concepts, analysis, implementation, and feasibility," *IEEE Trans. Microw. Theory Techn.*, vol. 51, no. 6, pp. 1650–1661, Jun. 2003.

[10] Z. N. Chen, M. Y. W. Chia, and M. J. Ammann, "Optimization and comparison of broadband monopoles," in *Inst. Elect. Eng. Proc.-Microw. Antennas Propag.*, Dec. 2003, vol. 150, no. 6, pp. 429–435.

[11] Z. N. Chen, "Novel Biarm rolled monopole for UWB applications," *IEEE Trans. Antennas Propag.*, vol. 53, no. 2, pp. 672–677, Feb. 2005.

[12] M. J. Ammann, "Control of the impedance bandwidth of wideband planar monopole antennas using a beveling technique," *Microw. Opt. Technol. Lett.*, vol. 30, no. 4, pp. 229–232, Jul. 2001.

[13] M. J. Ammann and Z. N. Chen, "An asymmetrical feed arrangement for improved impedance bandwidth of planar monopole antennas," *Microw. Opt. Technol. Lett.*, vol. 40, no. 2, pp. 156–158, 2004.

[14] D. Girbau, A. Lazaro, and L. Prandell, "Characterization of dynamics and power handling of RF MEMS using vector measurement techniques," *IEEE Trans. Microw. Theory Technol.*, vol. 52, no. 11, pp. 2627–2633, Nov. 2004.

[15] [Online]. Available: www.maxonmotor.com

[16] [Online]. Available: www.dow.com

[17] M. J. Ammann and Z. N. Chen, "Investigation on L-shaped planar antennas," *Radio Science*, vol. 39, no. 2, Apr. 2004, RS2009.

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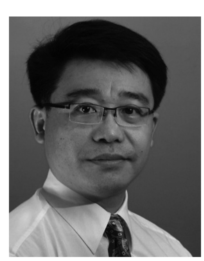

Zhi Ning Chen (M'99–SM'05) received the B.Eng., M.Eng., and Ph.D. degrees from the Institute of Communications Engineering, China, and the Do.E. degree from the University of Tsukuba, Japan, in 1985, 1988, 1993, and 2003, all in electrical engineering.

Since 1988, he has been with the Institute for Communications Engineering, Southeast University, City University of Hong Kong, China, with teaching and research appointments such as Teaching Assistant, Lecturer, Associate Professor, Research Fellow, Postdoctoral Fellow, and so on. During 1997–1999, he was with the University of Tsukuba, Japan, as a Research Fellow awarded by the Japan Society for Promotion of Science (JSPS). In 2001 and 2004, he visited the University of Tsukuba, again sponsored by the Invitation Fellowship Program (senior level) of JSPS. In 2004, he conducted research with the Thomas J. Watson Research Center, International Business Machines Corporation (IBM), Yorktown, NY, as an Academic Visitor. In 1999, he joined the Institute for Infocomm Research as a Member of Technical Staff (MTS) and then was promoted to Principal MTS. He is now working as Principal Scientist and Department Manager for Radio Systems. He is concurrently appointed as an Adjunct Associate Professor with the National University of Singapore and Nanyang Technologies University, Singapore, and Concurrent Professor with the Nanjing University, Adjunct Professor with the EM Academy of Zhejiang University, and Southeast University, China. He submitted the first proposal on UWB technology to the *Thematic Strategic Research Program of Agency of Science, Technology and Research (A*Star)*, Singapore in 2002, and now is leading one of projects of the program *Ultra-Wide Band (UWB) Technologies and Pervasive Computing*. He is coordinating the joint projects of A*Star and DSTA in the fields of microwave and electromagnetics. His main research interests include applied electromagnetics and antenna theory and design. Particularly, he focuses on small and broadband antennas and arrays for wireless communications systems, such as WLAN/WiFi/WiMAX, multi-input multioutput (MIMO) systems, and UWB systems, and RF imaging systems. Since 1990, he has authored and coauthored more than 190 technical papers published in international journals and presented at international conferences. He hold three patents and has eleven patent applications filed. His books, entitled *Broadband Planar Antennas* (New York: Wiley, (2005), *UWB Communications* (coedited, New York: Wiley, 2006), and *Antennas for Portable Devices* (edited, New York: Wiley, 2007).

Dr. Chen founded the IEEE International Workshop on Antenna Technology (IEEE iWAT) and, as General Chair, organized the IEEE iWAT: *Small Antennas and Novel Metamaterials*, 2005, Singapore. He is chairing the iWAT Steering Committee for future iWAT events. He was invited to give keynote speeches about UWB and Antennas at Loughborough Antennas and Propagation, U.K., in 2005 and 2007, as well as China-Ireland International Conference on Information, Communication and Electronics in 2007. He is the Chair for Subcommittee of Emerging Technology at the 2006 IEEE Radio and Wireless Symposium, USA. He was invited to give talks at UWB technology workshops of the 2003/2004 IEEE Radio and Wireless Conference, USA. He also organized and chaired many special sessions at many international events, and served many international conferences as the member of Technical Program Committee or International Committee. He is the Editor for the *Field of Microwaves, Antennas and Propagation: International Journal on Wireless and Optical Communications (IJWOC)*. He has edited special issues for *IJWOC*, *International Journal of Antennas and Propagation*, and the *IEICE Transactions on Communications*, and also reviewed many papers for prestigious journals and conferences.