Journal of Engineering and Technology Research Vol. 4(3), pp. 57-64, 22 February, 2012
Available online at http:// www.academicjournals.org/JETR
DOI: 10.5897/JETR11.080
ISSN 2006-9790 ©2012 Academic Journals

Full Length Research Paper

Liquid crystal-reconfigurable conformal monopole antennas structures for microwave applications

S. Missaoui* and M. Kaddour

Electronics Laboratory, Department of Physics, Faculty of Science, Tunis El Manar, Tunisia.

Accepted 14 February, 2012

In this article, the design of conformal monopole antennas on a very thin layer of flexible liquid crystals (LCs) is introduced. The flexible LC substrate can be bent and folded over the module case, resulting in a tight integration of the antenna with the frontend module. Firstly, a meander monopole antenna, designed for single band operation, is presented with details of the structure, simulation and measurement results. Secondly, a method to increase the peak gain and decrease the return loss of the antenna is proposed. The simulated results are compared with measured data, and good agreement is obtained.

Key words: Liquid crystals, monopole antennas, agile structure, microwave.

INTRODUCTION

The planar-monopole antenna has been shown to be a useful candidate for wideband communications systems. The increasing demand for low cost, low profile wireless devices has resulted in a need for highly efficient, compact antennas that can integrate well into future portable wireless communication devices. Owing to their advantages in terms of weight, cost, manufacturability and compatibility with microwave circuits, electrically small planar antennas are seen as the favorable candidates to be used in such systems. In particular, printed monopole antennas are gaining in popularity due to their nearly omnidirectional far-field radiation pattern. Up to now, several approaches have been proposed to study the meander monopole antenna (Altunyurt et al., 2007; Shackelfford et al., 2003; Liang et al., 2005; Zhang et al., 2009). One of the sought properties for this device is the possibility to folded and rolled resulting in a compact design and integration of the antenna with the RF module package. For decades, enormous efforts have been deployed for using new materials which have a better functionality. Among these materials, liquid crystals (Swaminathan et al., 2005; Altunyurt et al., 2007; Zakharov and Mirantsev, 2003) are potentially useful.

This material consists on a state of matter which has properties between those of a conventional liquid and those of solid crystals. LC is a low-cost dielectric with a combination of good electrical and mechanical properties. LC has a low dielectric constant of $\varepsilon_r = 2.95$, and a low loss tangent of 0.002 up to microwave frequencies. LC also has favorable mechanical properties such as flexible for conformal and flex circuit applications, a low coefficient of thermal expansion and low moisture absorption (Swaminathan et al., 2005; Tentzeris et al., 2004). All of these advantages make it appealing for high frequency applications (DeJean et al., 2005; Symeon et al., 2006; Negar et al., 2007; Serkan et al., 2006). Nevertheless, recent studies (Missaoui et al., 2010; 2011; Gaebler et al., 2009; Spinglart et al., 2001) have shown their dielectric anisotropy property.

In this paper, a method to enhance the performance of printed monopole antennas is presented. The proposed approach consists of placing a metal patch next to the patch in order to direct the fields in one direction by using the reflexion from the metal patch and a method to decrease the return loss will be introduced.

CONCEPTION AND SIMULATION OF A MEANDER MONOPOLE ANTENNA BASED ON LCs

Conception of a meander monopole antenna

The structure of the meander monopole antenna based on LCs as shown in Figures 1 and 2. The substrate of the

*Corresponding author. E-mail: Asayed.elmissaoui@gmail.com.

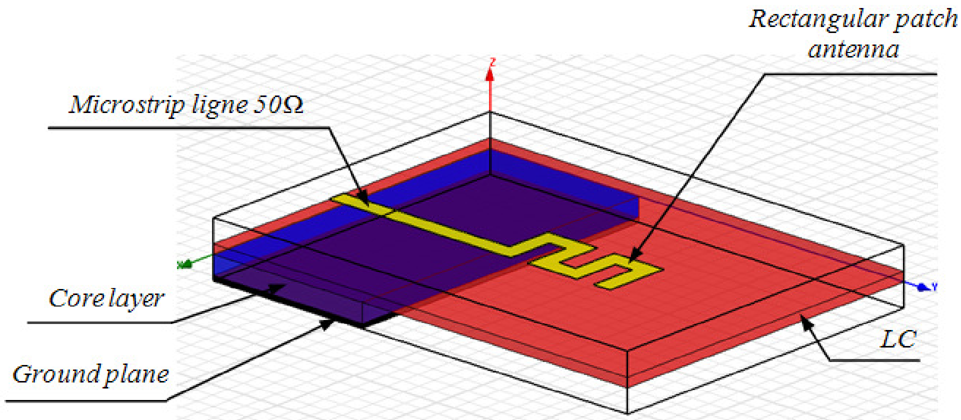

Figure 1. Structure of a meander monopole antenna based on *LCs*

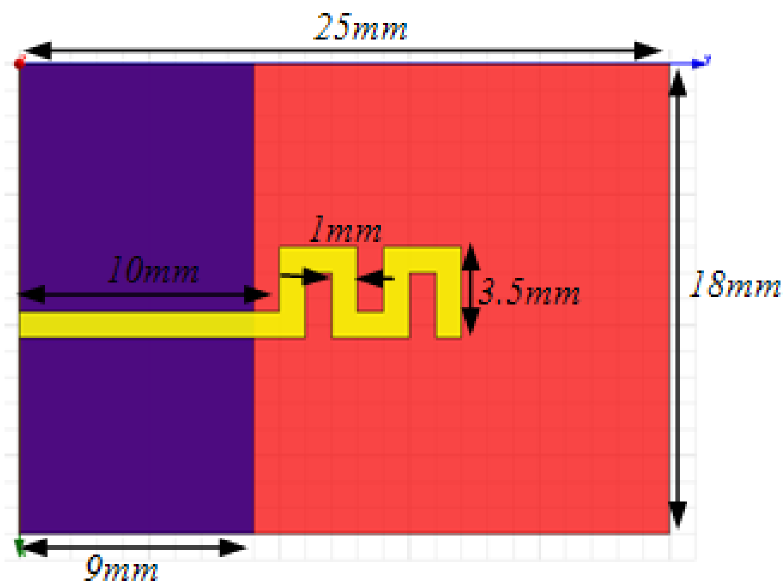

Figure 2. size of a meander monopole antenna

antenna is composed of two layers of dielectric. This meander antenna is printed on LC substrate with thickness of 25 µm and size of 18 × 25 mm, the LC is inserted by capillarity with a dielectric constant permittivity of $\varepsilon_r = 2.9$ and a loss tangent of 0.002, the bottom layer is a 508 µm rigid, glass-reinforced organic prepreg layer (core layer) with a size of 18 × 9 mm. The core layer has a loss tangent of 0.0037 with a dielectric constant of 3.48.16 mm long portion of the LC layer is not supported by the core layer and can be easily conformed due to the flexibility of LC. The antenna is printed on the flexible portion of LC.

The antenna is excited with a 50 Ω microstrip line which is printed on the rigid part of the substrate, supported by the core layer. The ground plane of the signal line covers the back side of the core layer with a size of 18 × 9 mm.

Figure 3 shows the design for the proposed meander monopole antenna with a three rectangular slots.

Simulation of a meander monopole antenna

The high frequency structure simulator (HFSS) was used to optimize the dimensions of the antenna to obtain a resonant frequency of 6 GHz.

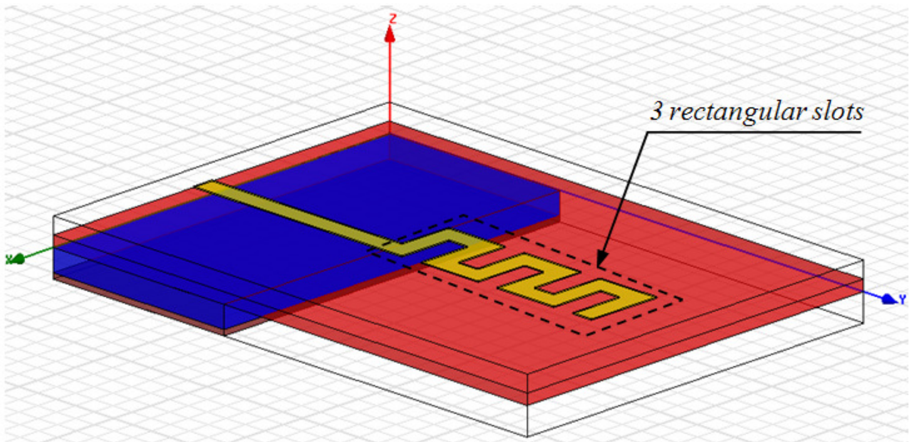

Figure 3. Structure of a meander monopole antenna based on LCs with three rectangular slots

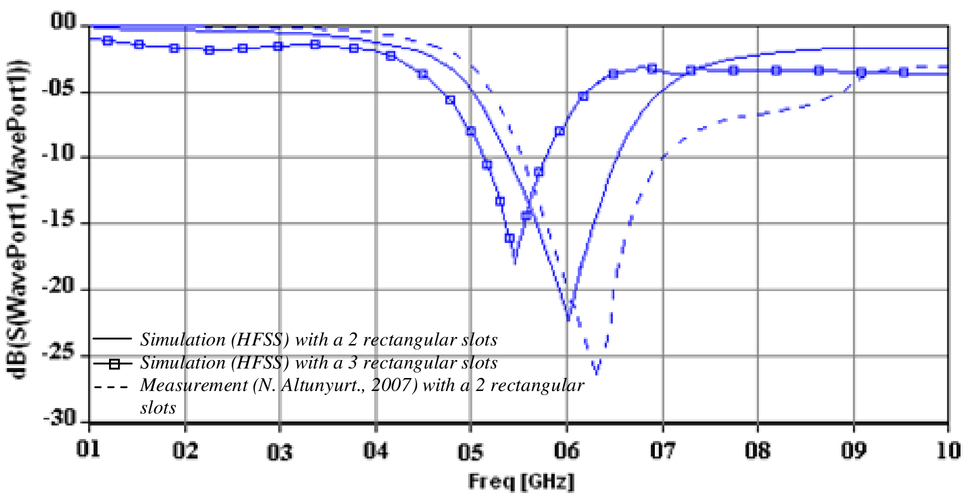

Figure 4. Simulated (HFSS) and measured (Altunyurt., 2007) return losses.

Figure 4 depict the results of simulated and measured return losses, we can see that return loss achieved -20 dB from 5.5 to 6.5 GHz for the results of simulated and measured with a patch to *2* rectangular slots. The resonance frequency variation (ΔF_r) between simulated and measured results is 300 MHz. The bandwidths simulated and measured of the monopole antenna with a two rectangular slots at -10 dB are respectively 1.19 GHz(19.8%) and 1.46 GHz (24.3%). The simulation resonant frequency for the meander monopole antenna with a 3 rectangular slots is 5.46 GHz. one notices that, if one adds a third rectangular slots, one obtained a variation of the simulation resonant frequency ($\Delta F'_r$ = 530 MHz), the return loss achieved -15 dB from 5 to 6 GHz.

Figures 5 and 6 depicts the simulated radiation patterns of the meander monopole antenna with a two slots for the plane (φ = 0°), (φ = 90°) and (θ = 90°) at a resonant frequency of 6 GHz. The antenna has a nearly omnidirectional pattern like that of dipole and the simulated peak gain of the antenna was found as 2.9 dB.

CONCEPTION AND SIMULATION OF A NEW STRUCTURE TO INCREASE THE PEAK GAIN OF THE MEANDER MONOPOLE ANTENNA BASED ON LCs

Conception of a new structure antenna

In this section, a method to increase the peak gain of the monopole antenna is introduced. The new structure and size of the meander monopole antenna based on LCs as shown in Figures 7 and 8. This directly affects the

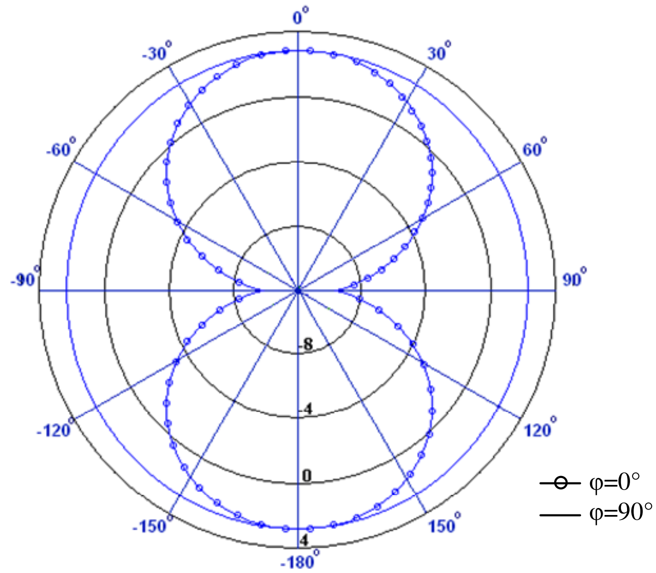

Figure 5. The simulated radiation patterns of the meander monopole antenna with a two slots for φ = 0° and φ = 90° at 6 GHz.

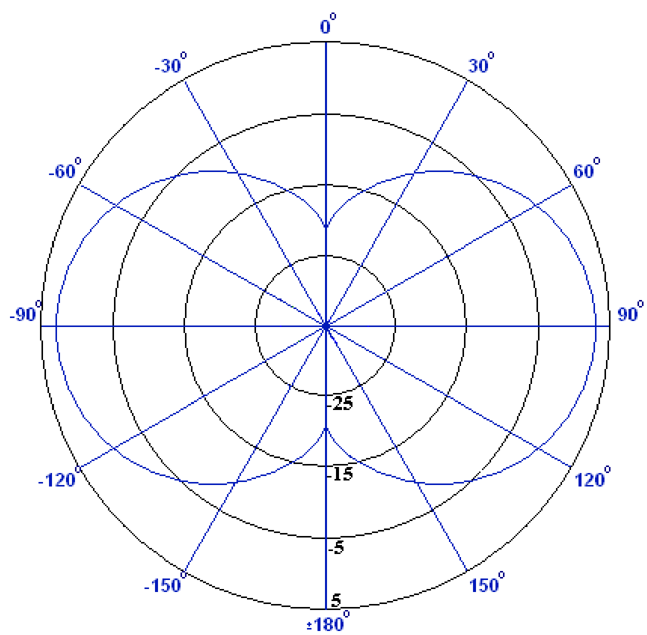

Figure 6. The simulated radiation patterns of the meander monopole antenna with a two slots for *θ=90°* at *6 GHz*

antenna gain which has to be maximized to lower the power consumption of the wireless terminal. The proposed approach consists of placing a metal patch (Altunyurt et. al., 2007) next to the antenna in order to direct the fields in one direction by using the reflection from the metal patch. This topology provides compact antenna solutions with broader bandwidth and higher peak gain suitable for use in portable electronics. The parameters affecting the matching and the peak gain of the antenna are:

- The horizontal length of the metal patch (7 mm) and the distance between the metal patch and the antenna (4 mm).
- The width and length of the ground plane (7.3 × 7 mm).

Figure 9 shows the new design for the proposed to

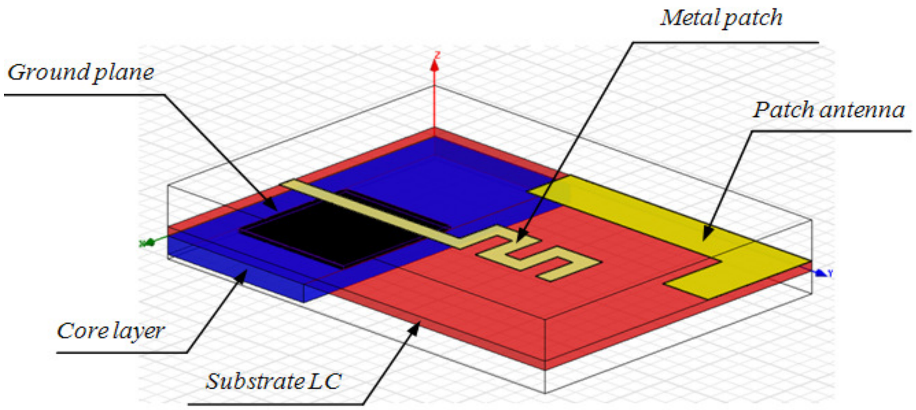

Figure 7. New structure to increase the peak gain of the meander monopole antenna based on *LCs*

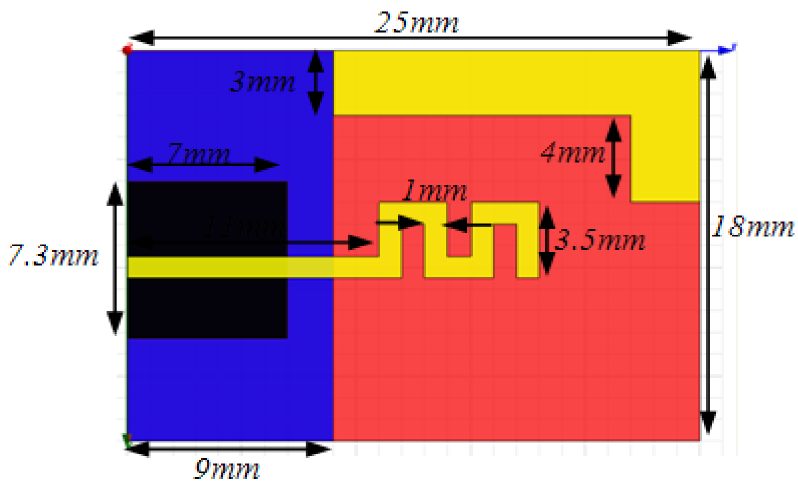

Figure 8. size of a new structure to increase the peak gain of the meander monopole antenna

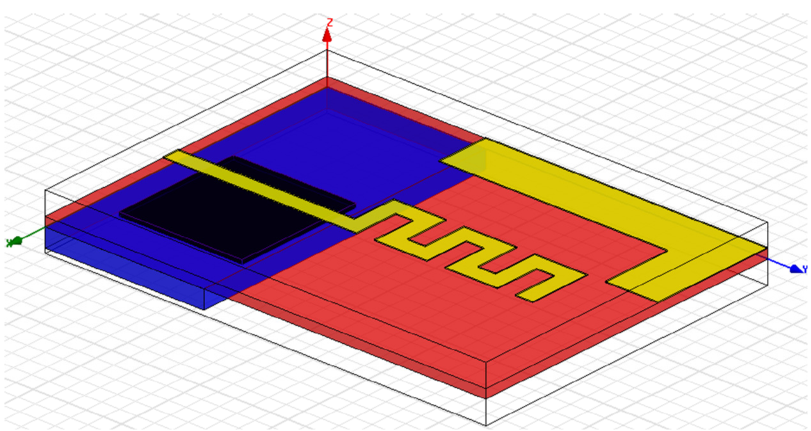

Figure 9. New structure to increase the peak gain of the meander monopole antenna based on LCs with a 3 rectangular slots.

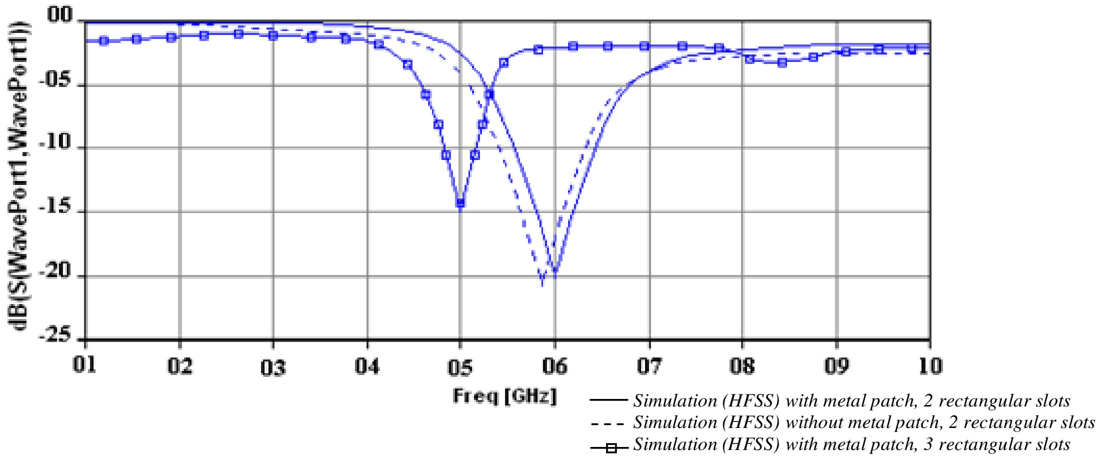

Figure 10. The comparison of the simulated return loss for with and without metal patch cases, to 2 and 3 rectangular slots.

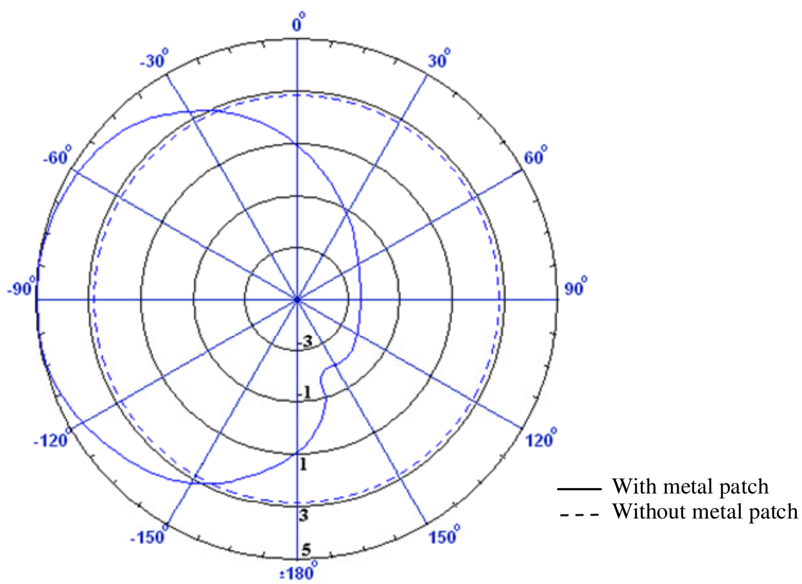

Figure 11. The simulated radiation patterns with and without metal patch of 2 slots for φ = 90° at 6 GHz.

increase the peak gain and decrease the return loss of the meander monopole antenna based on *LCs* with a *3* rectangular slots.

Simulation of a new structure antenna

Figure 10 depict the comparison of the simulated return loss for with and without metal patch cases, to 2 and 3 rectangular slots.

We can see that return loss achieved -15 dB from 5.5 to 6.5 GHz for the results of simulated with and without metal patch to *2* rectangular slots. The resonance frequency variation (ΔF_r) is 140 MHz and the bandwidths simulated with and without metal patch at -10 dB are respectively 846.15 MHz (14.1%) and 941.17 MHz (15.68%). The simulation resonant frequency for the meander monopole antenna with metal patch to 3 rectangular slots is 5 GHz. one notices that, if one adds a third rectangular slots, one obtained a variation of the simulation resonant frequency ($\Delta F'_r$ = 1 GHz), the bandwidths result at -10 dB is 346.15 MHz and the return loss achieved -10 dB from 4.5 to 5.5 GHz.

Figures 11 and 12 depicts the simulated radiation patterns of the meander monopole antenna with and without metal patch of 2 slots for the plane (φ = 90°) and

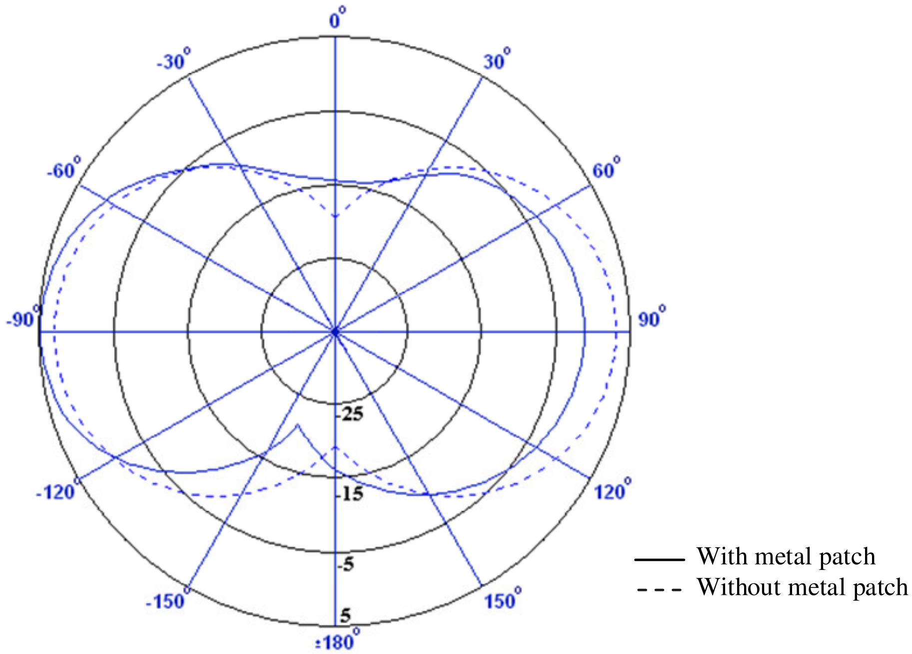

Figure 12. The simulated radiation patterns with and without metal patch of 2 slots for θ = 90° at 6 GHz.

(θ = 90°) at a resonant frequency of 6 GHz.

It is clearly seen from the radiation pattern comparison that, the fields are directed in one direction, the peak gain with and without metal patch is respectively *5 dB* and *2.9 dB*, therefore the found gain with metal patch is improved.

CONCLUSION

This paper presents the fundamentals of LC material and its applications for reconfigurable monopole antenna. To verify the performance of the proposed conformal configuration, a prototype was designed and simulated with a very thin layer of flexible LC. We have shown that the return loss of the meander monopole antenna with metal patch to *3* rectangular slots can be achieved -10 dB from 4.5 to 5.5 GHz. The meander monopole antenna based on LCs with a 2 rectangular slots gives a better performance for the bandwidth and the resonance frequency.

Therefore, for an increase of number of rectangular slots, we noticed a serious mistake of the resonance frequency and a reduction of the bandwidth. The only advantage o the antenna structure with a 3 rectangular slots is the reduction of the return loss. The results of simulated radiation patterns with and without metal patch to 2 rectangular slots have greatly improved about 2.1 dB and the fields are directed in one direction. A good agreement is obtained between measurements and numerical model results and it confirms the validity of our approach.

REFERENCES

Altunyurt N (2007). "Printed Monopole Antennas with Increased Bandwidth and Gain for Wi-Fi Applications," IEEE AP-S, June.

Altunyurt N, Swaminathan M, Sundaram V, White G (2007). "Conformal antennas on Liquid Crystalline Polymer substrates for consumer applications," 2007 APMC Asia-Pacific Microwave Conference, Dec.

DeJean G, Bairavasubramanian R, Thompson D, Ponchak GE, Tentzeris MM, Papapolymerou J (2005). "Liquid Crystal polymer (LCP): a new organic material for the development of multilayer dual-frequency/dual-polarization flexible antenna arrays." Antennas and Wireless Propagation Lett., 4: 22 - 26.

Gaebler AM, Goelden F, Manabe A, Goebel M, Follmann R, Koether D, Modes C, Kipka, M. Deckelmann, T. Rabe, B. Schulz, P. Kuchenbecker, A. Lapanik, S.Mueller, Haase WA, Jakoby R (2009). "Liquid Crystal-Reconfigurable Antenna Concepts for Space Applications at Microwave and Millimeter Waves." Int. J. Antennas Propagat., Article ID 876989, p. 7.

Liang J, Chiau CC, Chen X, Parini CG (2005). "Printed circular ring monopole antennas." Microwave optical Technol. Lett., 45(n° 6): 372-375.

Missaoui S, Kaddour M, Gharbi A (2010). "Development and design of multilayer antennas based on liquid crystals," IOP Conference Series. Materials Sci. Eng., 13: 1.

Missaoui S, Kaddour M, Gharbi A (2011). "Design and Simulation of Tunable Phase Shifters Based on Liquid Crystals." Electromagnetics, 31(4): 285 - 293, May.

Missaoui S, Kaddour M, Gharbi A (2011). "Design and simulation reconfigurable liquid crystal patch antennas on foam substrate." J. Chem. Eng. Mater. Sci., 2(7): 96-102.

Negar T, Nikolaou S, Tentzeris MM (2007). "Microwave tumor detection using a flexible UWB elliptical slot antenna with a tuning uneven U-shape stub on LCP," IEEE Antennas and Propagation Soc. Sym., pp. 257-260.

Serkan B, Bhattacharya S, S, Li Y, Rida A, Tentzeris MM, Laskar J (2006). "Design of a novel high-efficiency UHF RFID antenna on flexible LCP substrate with high read-range capability," IEEE Antennas and Propagation Soc. Sym. pp. 1031-1034.
Shackelfford AK, Lee KF, Luk KM (2003). "Design of small-size wide-bandwidth microstrip-patch antennas." IEEE Antennas Propagation, Mag, 45(n° 2): 75-83.
Spinglart B, Tentillier N, Huret F, Legrand C (2001). "Liquid crystals applications to RF and microwave tunable components." Molecular Crystals and Liquid Crystals, 368: 183-190.
Swaminathan M, Bavisi A, Yun W, Sundaram V, Govind V, Monajemi P (2005). "Design and fabrication of integrated RF modules in LCP Substrates." 2005 IECON 32nd Annual Conference of IEEE Industrial Electronics Society, pp. 2346-2351.
Symeon N, Ponchak GE, Papapolymerou J, Tentzeris MM (2006). "Conformal double exponentially tapered slot antenna (DETSA) on LCP for UWB applications." IEEE Trans. Antennas and Propag., 54(6): 1663-1669.
Tentzeris MM, Laskar J, Papapolymerou J, Stéphane P, Palazzari V, Li R, DeJean G, Papageorgiou N, Thompson D, Bairavasubramanian R, Sarkar S, Lee JH (2004). "3-D-Integrated RF and millimeter wave functions and modules using liquid crystal polymer (LCP) systemon-package technology." IEEE Trans. on Advanced Packaging, 27(2): 332-340.
Zakharov AV, Mirantsev LV (2003). "Dynamic and dielectric properties of liquid crystals." Phys. Solid State, 45: 183-188.
Zhang X, Zhang T-L, Xia Y-Y, Yan Z-H, Wang X-M (2009). "Planar monopole antenna with band notch characterization for UWB applications". Progress Electromagnetics Res. Lett., 6: 149-156.