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Influence of loading ferrites films on the duality of patch antenna with slots

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Abstract: *by dint of the lightweight patch antenna, a new incentive is given to research on innovative solutions that overcome the limitations of their bandwidth. The evolution of modern communications systems requires operating at two separate sub-bands, which in turn goes hand in hand with increased bandwidth. In principle the dual-frequency patch antennas must operate at two distinct frequencies with similar characteristics in terms of radiation and impedance matching. Obtaining these characteristics becomes more difficult when preserving the structural simplicity and technology. Several studies have been made in the field of dual frequency planar antennas.*
Keywords: *Dual band, Patch antenna, permeability greater than 1, ferrites films, thin layer, dual frequency*

I. Introduction

Dual-frequency antennas have a double resonance behavior with a single radiating element which allows weight reduction, surface optimization, and cost efficiency. The article by S. Maci and Gentili G. BifJi [1], provides a brief overview of the techniques used for dual frequency patch antennas, where the first category of bi-frequency antennas is the result of using orthogonal modes on an asymmetric patch; this technique allows for two separate accesses for each band but locks operation of polarization (there is only one frequency polarization). The second category results from dual multi-frequency patch antennas (which involves having different patches operating as resonators at different frequencies and that can be stacked vertically or distributed on the surface, however this technique is very cumbersome). The third category is due to the dual-frequency antenna where the radiating element is loaded reactively (the load can be represented by line stubs, loaded micros-trip or coaxial, by "playing pieces" vertical short circuits or by incorporation of slots, apertures or notches on the patches themselves).

Techniques used to increase the bandwidth are also valid to reach functioning in dual-band. Thus, for multilayer configurations, the electromagnetic coupling or the coupling by crack, with adjustment of the air gap, can be used to operate the antenna in double band. Hybrid configuration by connecting a circular antenna to a waveguide was conceived for functioning in double band [2].

The slotted dual-band patch antennas were studied in the works of S. Maci. This provides dual-frequency operation by means of two narrow slots close to the patch's radiating edges. The two modes of operation show similar radiating properties [3]. The slot loading allows to strongly modify the resonant mode of a rectangular patch, particularly when the slots cut the current lines of the unperturbed mode.

After validating the results summarized in the article [4], we changed the substrate of the patch antenna and resumed calculating dimensions of the radiating element; the results to determine the performance of designed prototypes are summarized in [13].

Work has been done to optimize the performance of the antenna patch design, where we studied the influence of the integration of a slot in the radiating element on the antenna performance, and the effect of the slotted patch antenna loaded with ferrite, hence came the idea to invent a dual patch antenna loaded with ferrite.

In this paper, we present the simulations results of a series of patch antennas in dual-band. The design of these patch antennas are realized by the software CST Microwave Studio. The simulation technique used to calculate the tri dimensional electromagnetic field inside a structure is based on the Finite Integration technique (FIT) introduced in 1977 by Weiland [5]. The principle of the method is to do the space-time discretization of Maxwell's equations in integral formulation. The computational domain is decomposed into cubic unit cells [6]. They are essentially based on the variation of the shape of the antenna by the slots and loading the films of ferrite in the substrate to have a structure which resonates in the frequencies used for precise applications.

II. Design of patch antenna with slots

Slot patch antenna shown in Fig. 1 has double resonance behavior in a single radiating structure. The antenna is adapted with two notches, and fed with microstrip line to 50Ω. The substrate used is glass epoxy (which is a dielectric of permittivity $\varepsilon r=4.32$ and relative permeability $\mu_r=1$) with a thickness of 2mm, and the two slot dimensions are optimized to Lx=5mm (length along x-axis) and Ly=5mm (Length along y-axis).

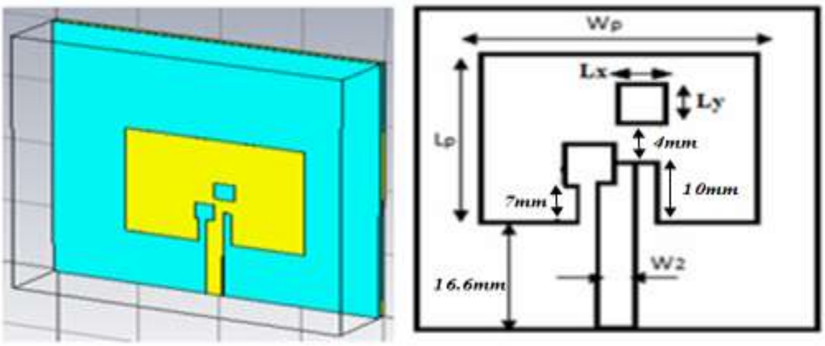

Fig. 1 Slotted patch antenna: (Wp=43.79mm, Lp=32.6mm, L1=10mm, L2=16.6mm, W1=2mm, W2=4mm, Lx=6mm, Ly=5mm

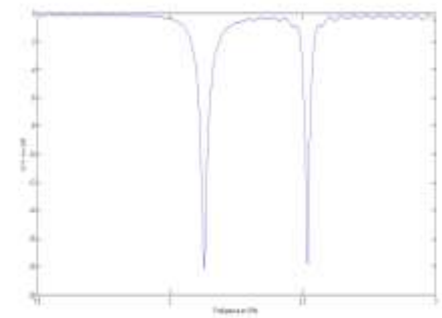

Fig. 2 Variation of return loss as a function of frequency of slotted patch antenna

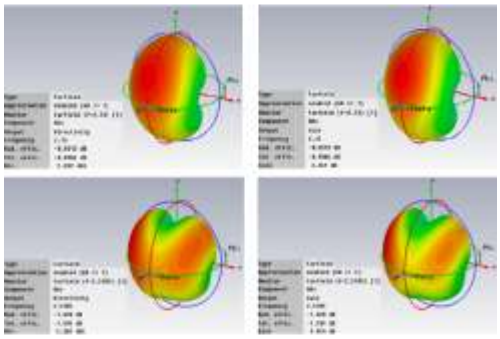

Fig.3 3D radiation pattern directivity and gain

Slot patch antenna shown in Fig.1 has double resonance behavior in a single radiating structure, the first frequency of resonance is 2.13GHz with return loss S11=-18.126162dB, Gain G_1=4.461dBi, and directivity D_1=5.392dBi. And the second frequency of resonance is 2.5185GHz with S11=-17.790764dB, Gain G_2=3.954dBi, and directivity D_2=5.382dBi shown in Fig.2 and Fig.3,
In the next part we did a parametric study, where we studied the influence of the variation of Lx and Ly, respectively. The different results obtained are presented.

1. variation effect of Lx:

To ensure the effect of the variation of the slit width (Lx) on the frequencies of the dual band antenna with two slots we set Ly 5mm and we vary Lx. As shown in Fig.4, it is noted that the more one increases the width of the slots; the frequencies F_{100} and F_{300} are reduced.

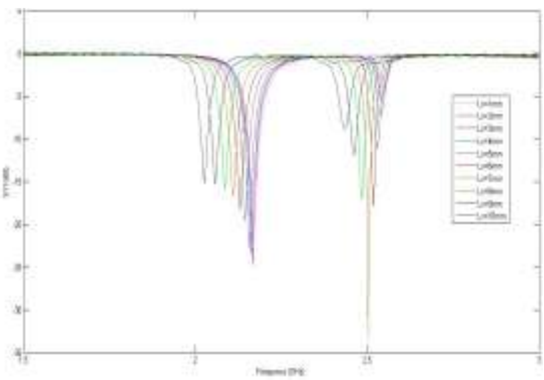

Fig. 4 S11 depending on the slit width Lx (Ly = 5mm)

Ly=cte	Lx (mm)	f_{r_1} (GHz)	S11 (dB)	f_{r_2} (GHz)	S11 (dB)
5mm	1	2.167	-19.861	–	–
	2	2.167	-24.750	2.547	-4.457
	3	2.163	-23.387	2.544	-5.666
	4	2.157	-22.632	2.540	-7.346
	5	2.145	-19.606	2.531	-11.117
	6	2.13	-18.126162	2.5185	-17.791
	7	2.109	-16.642328	2.5035	-33.220
	8	2.0865	-15.848893	2.484	-17.001
	9	2.058	-15.248117	2.4615	-11.90
	10	2.0265	-15.089877	2.4345	-8.955

Table 1 variation effect of Lx with Ly = 5 mm on the duality of the patch antenna with slots

The results summarized in TABLE 1 and Fig.4 show that during the variation of Lx, the patch antenna loses its duality. When we lower the width of Lx, the first frequency increases from 2.13GHz (S11=-17.791dB), the second frequency disappears for Lx = 1 mm. when increasing (Lx) the first frequency is moved to 2.0265GHz (S11=-15.09dB), and the second frequency is moved to 2.0265GHz (S11=-8.955dB) for Lx=10mm.

2. variation effect of Ly:

To ensure the effect of the variation of the slit length (Ly) on the frequencies of the dual band antenna with two slots we set Lx=6mm and we vary Ly. The results obtained summarized at TABLE 2 and Fig.5.

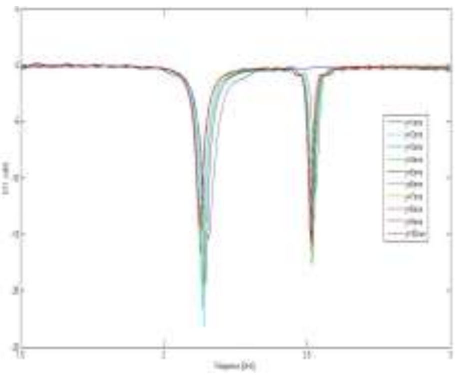

Fig.5 S11 depending on the slit width Ly (Lx = 6mm)

Lx=cte	Ly (mm)	f_{r_1} (GHz)	S11 (dB)	f_{r_2} (GHz)	S11 (dB)
6mm	1	2.1555	-15.431	–	–
	2	2.141	-23.190	2.523	-13.563
	3	2.136	-21.550	2.52	-15.985
	4	2.133	-19.589	2.518	-17.325
	5	2.13	-18.126	2.518	-17.791
	6	2.127	-16.677	2.517	-17.734
	7	2.124	-15.412	2.515	-17.134
	8	2.124	-14.752	2.515	-16.605
	9	2.125	-14.223	2.514	-15.969
	10	2.127	-14.752	2.511	-15.530

Table 2 variation effect of Ly with Lx = 6 mm on the duality of the patch antenna with slots

Fig.5 and TABLE 2 show that variation of Ly does not much affect the dual resonant patch antenna.

III. loading effects of ferrites films on bi-band patch antenna

1. Ferrites and their effects on patch antenna performance:

operation of non-reciprocal passive devices is based on ferrimagnetic material properties around the gyromagnetic resonance [12]. In the discipline of microwaves ferrites are widely used, and this thanks to their non-conductive, non-reciprocal character, and the dependence of their dynamic response relative to their polarization state. Ferrites are also characterized by high permittivities (which allows reducing the bandwidth and the excitation of surface waves, which leads to a decrease in the radiation efficiency), and high permeability (which leads to miniaturization of the size of the antenna, bandwidth increases, tunable radiation frequency, and polarization diversity) and low loss at microwave frequencies [7].

Achieving relative permeability greater than 1 in antenna substrates can lead to antenna miniaturization [4], frequency shifting, and scattering reduction. This is achieved by external magnetic field biasing coupled with the inherent magnetization of the substrate [8]. Composites of ferrite particles in polymer matrix [9], meta-materials with embedded metallic circuits [10] and so on, have been used as antenna substrates for achieving $\mu_r > 1$. However, all these magnetic antennas are based on magnetic materials or composites which are too lossy to be used at frequencies > 600MHz, and large biasing magnetic fields are needed.

Loading ferrite films with a relative permeability greater than 1 ($\mu_r > 1$) allows the introduction of an inductive effect which counterbalances the capacitive behavior of the relative dielectric permittivity. Consequently, there is an increase of antenna matching, and miniaturization of its dimension.

We used the self-biased spinel NiCo-ferrite films manufactured by a low-cost spin-spray deposition process, where the thickness of the product ferrite film is 2 μm. The relative permittivity equal to 13 and the magnetic permeability is about 10 [11].

2. Loading effects of ferrites films on bi-band patch antenna

The antenna shown in Fig.1 resonates at f_{r1} = 2,13GHz, belongs to the (2.110-2.170)GHz band (downlink frequency of 60 MHz of FDD Duplex) assigned to the UMTS, and the second resonance frequency does not belong to the band wifi (2.4-2.4835)GHz. For solving this problem we loaded spinel NiCo-ferrite films between the ground and the substrate of the patch antenna (Fig. 6). The different results obtained are presented below.

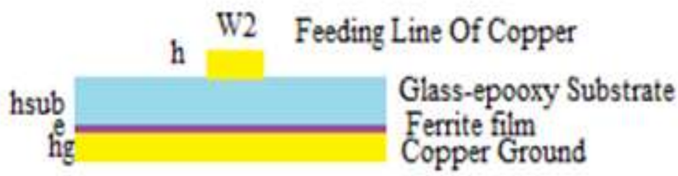

Fig.6 Ferrites films inserted between ground and substrate

(Lx,Ly)=(6,5) mm^2		f_{r_1} (GHz)	S11 (dB)	f_{r_2} (GHz)	S11 (dB)
	Without Ferrite	2.13	-18.126	2.518	-17.791
	With 2µm of ferrite	2.121	-18.531	2.509	-18.245
	With 4µm of ferrite	2.111	-33.643	2.482	-30.825
	With 6µm of ferrite	2.106	-19.424	2.49	-18.76
	With 8µm of ferrite	2.097	-19.936	2.481	-18.979

TABLE 3 Loading effects of ferrite films on bi-band patch antenna

Self-polarized ferrite films inserted into the structure of the patch antenna leads to a correction of the resonance frequency therefore the fr_1 = 2.13GHz shifts to fr_1 = 2.111GHz which belongs to the band assigned to UMTS (downlink frequency of 60 MHz of FDD Duplex), and fr_2 = 2.518GHz which shifted from fr_2 = 2.482GHz belongs to the band wifi (2.4-2.4835)GHz where we use 4µm of ferrite between the ground and substrate, and also the performance of the patch antenna is evaluated.

IV. Conclusion

The insertion and good location of two slots in the radiator brought the antenna back to resonating at two different frequencies.

The integration of a thin ferrite layer solves the problem of the integration of self-polarized magnetic materials in the antenna patches of more than 600MHz frequency range (f> 600 MHz) because of the limit of Snoek.

The loading self-polarized ferrite films in patches antennas affects the performance of these antennas. The integration of these films between the ground and substrate of patch antenna has a favorable effect on the resonance frequency of dual patch antenna.

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References

Journal Papers:

[1] S. Maci and G. BifJi Gentili, “Dual-frequency patch antennas”, IEEE Antennas and Propagation Magazine, Vol. 39, No. 6, December 1997

[2] S. ZAAKRI, L. ZENKOUAR and S. BRI, “ Conception of Bi-band Rectangular Microstrip Array Antenna”, in Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol. 12, No. 1, June 2013

[3] S. Maci G. Biffi Gentili P. Piazzesi and C. Salvador, “Dual-band slot-loaded patch antenna”, IEE Proc.-Microw. Antennas Propag., Vol. 142, No. 3, June 1995

[4] G.M. Yang1, X. Xing1, O. Obi1, A. Daigle1, M. Liu1, S. Stoute1, K. Naishadham2, N.X. Sun1 “loading effects of self-biased magnétic films on patch antennas with substrat/superstarte sandwich structure”; the journal of IET Microwaves, Antennas & Prpapagation, 2009

[5] T. Weiland, “A discretization method for the solution of maxwell’s equations for sixcomponent fields,” Electronics and Communications AEUE, vol. 31, no. 3, pp. 116–120, 1977

[6] M. Clemens and T. Weiland, “ Discrete electromagnetism with the finite integration technique”, Progress In Electromagnetics Research, PIER 32, 65–87, 2001.

[7] Jorge Lezaca[1], Patrick Queffelec[1], Alexis Chevalier[1]“ Method of characterization of the dynamic response of magnetic materials in a random magnetic state : direct problem ”; JCMM 2010

[8] A.D. Brown, J.L. Volakis, Fellow, IEEE, Leo C. Kempel, Member, IEEE, and Youssry Y. Botros, “Patch Antennas on Ferromagnetic Substrates”, IEEE Transactions on Anetennas and Propagation, Vol. 47, N°. 1, January 1999

[9] DO T.B., HALLORAN J.W. ‘Fabrication of polymer magnetics’, Proc. IEEE Int. Symp. Antennas and Propag., June 2006, pp. 1709–1712

[10] J.L.Valakis, C.C. Chen, “Miniaturization and materials in antenna design”, IDG’S Military Antennas 2007 Conf. Washington DC, September 2007

[11] K. Kondo, S. Yoshida, H. Ono, and M. Abe, “Spin sprayed Ni(-Zn)-Co ferrite films with natural resonance frequency exceeding 3GHz,” Journal of Applied Physics, 101, 09M502, 2007

Theses:

[12] Fatima Jjerfaf,«wide band dielectric and magnetic characterization of thin layers and of substratescaractérisation large bande diélectrique et magnétique de couches minces et de substrats ». University of Ferhat Abbas-Setif-UFAS (Algerie), 27-06-2012

Proceedings Papers:

[13] F.Z. Hanin, L. Setti, “Performance of patch antenna loaded of ferrites films”, DOI: 10.1109/MMS.2014.7088958, ISBN: 978-1-4799-7390-3, IEEE Microwave Symposium (MMS), 2014 14th Mediterranean (8)