DESIGN AND REALIZATION OF PRINTED ON PAPER ANTENNAS

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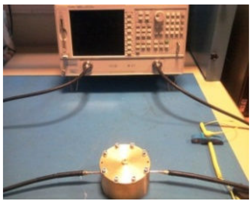
Introduction

Printed electronics are still growing at the level of research labs and start to generate industrial applications where traditional electronics is not suitable (transparency, flexibility, low cost). Substrates used so far on printed electronics were mainly PET, but in the context of eco-design, it is interesting to print the circuits directly on substrates made from cellulose [1-3]. Design of planar antennas on paper substrate differs from antennas on epoxy substrate since paper and inks are not usual materials in terms of losses and mechanical properties. Therefore a preliminary step of dielectric and conductive material characterization is necessary for the simulation of circuit performances.

Paper and ink characterization

Dielectric parameters

Both resonant cavity and transmission line methods are used to characterize dielectric parameters of paper substrate (ε_r and tanδ)



The complex permittivity is determined by resonant cavity method at 2.45GHz ➡ This method can be only performed on a given frequency.
The transmission line method complete the study by checking that the permittivity remains constant on the whole frequency band (0.5 GHz to 4 GHz).

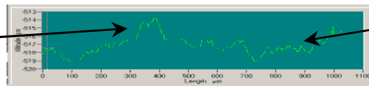
Cavity Method	SP1	SP2	SP3	SP4
εr	2.478	2.946	2.47	2.478
tanδ	0.111	0.0831	0.0806	0.111

Conductor parameters

✓ Thickness "T", roughness "r", conductivity "σ" and corresponding skin depth "δ"

An optical profilometer was used to measure the ink thickness and roughness.

Halo phenomenon



inhomogeneous

The recorded thickness of the ink is between 3µm and 10µm.
The conductivity was measured with the Van Der Pauw method [5]
$\sigma = 829814\ S.m^{-1}$

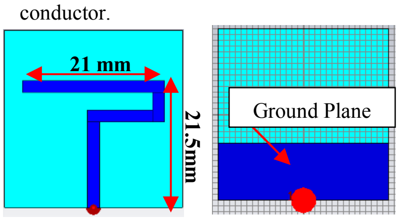
r (roughness) = 8 mm
Roughness value is important ➡ It increases the current density at some points of the line and so the conductive losses.

Losses are important in a paper substrate, T is not constant

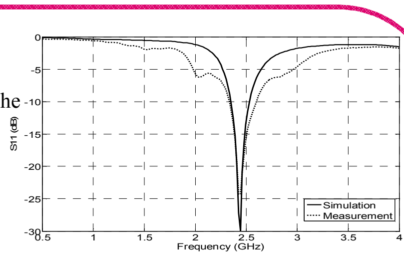
Antenna Design

A monopole antenna radiating at Wi-Fi frequency band is designed.
The antenna was folded for the purpose of miniaturization.
The microstrip technology was not used anymore in order to increase bandwidth [6]; the ground plane is chosen so that it does not cover the entire surface of the antenna

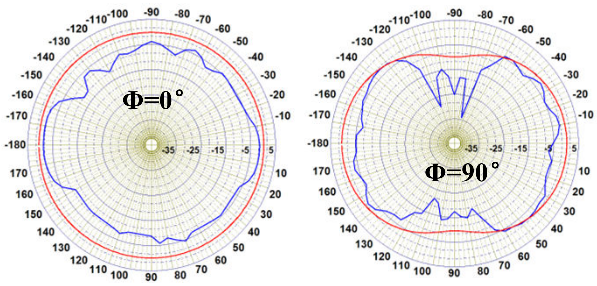
➢ Electric and magnetic fields are no longer confined between the ground plane and the conductor.



✓ S_{11} = -30 dB at 2.45 GHz, the bandwidth of the antenna covers the entire frequency range of the Wi-Fi (2.4 GHz to 2.48 GHz)



✓ The radiation pattern plotted shows that the antenna is omnidirectional. It exhibits an efficiency of -1.4 dB corresponding to 72%. The gain of the antenna is about 0.4 dB



Conclusion and Prospects

The design an antenna on a paper substrate has been demonstrated. The achieved example antenna presents a simulated efficiency of 72% despite the important dielectric and conductive losses in paper substrate and ink.
The conductor thickness is not sufficiently controlled with the flexography printing method. New antenna design will be made with a more accurate printing method called "serigraphy".

[1] F. Eder, H. Klauk, M. Halik, U. Zschieschang, G. Schmid, and C. Dehm," Organic electronics on paper", Appl. Phys. Lett., Vol. 84, No. 14, pp.2673-2675, 5 April 2004.
[2] G. Nystro¨m, A. Razaq, M. Strømme, L. Nyholm, and A. Mihranyan, "Ultrafast All-Polymer Paper-Based Batteries", Nano Letters 2009, Vol.9, No. 10, pp. 3635-3639, 14 August 2009.
[3] R. Martins, A.Nathan, R.Barros, L.Pereira, P.Barquinha, N.Correia, R.Costa, A. Ahnood, I.Ferreira and E.Fortunato, "Complementary metal Oxide Semiconductor Technology With and on Paper", Advanced Materials On Line Journal, Vol.23, No.36, 5 September 2011
[4] L.Yang, A. Rida and M. Tentzeris, "Design and development of Radio Frequency Identification (RFID) and RFID-Enabled Sensors on Flexible Low Cost Substrates", Copyright 2009 by Morgan & Claypool.
[5] Quantum Design "Performing Van Der Pauw Resistivity Measurements", Application Note 1076-304 Rev.A0, March 2007.
[6] C.A.Balanis, "Antenna Theory Analysis and Design" Second edition Arizona state university, copyright1989, John Wiley & Sons.