Secondment Report Form

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Host Organization	Id: EPFL
	Name: LEMA, Ecole Polytechnique Fédérale de Lausanne, Switzerland
Research Topic(s)	
	Design of planar wearable antenna for UHF band

ACTIVITIES DURING THE SECONDMENT

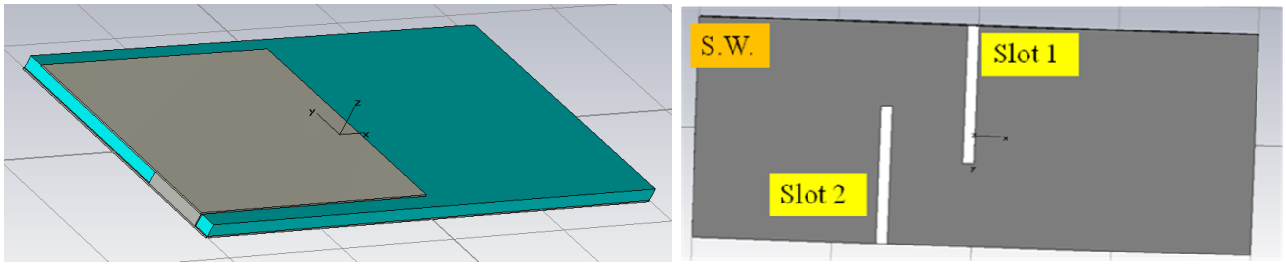
Wearable antennas are integral part of body-centric systems, i.e. systems consisting of body-worn electronic devices which communicate with the environment ("off-body"), mutually ("on-body") and possibly with medical implants ("in-body"). The possible use of body-centric devices has a broad range- they could be used for military, rescue service, medical and entertaining purposes.

The research at the EPFL was focused on the body-centric communications in the UHF range (in particular, around 400 MHz) and the goal was to design proper wearable textile antenna for that range. The demands on such antenna are contradictory – antenna is required to be light-weight, non-obtrusive and conformal to the body, while at the same time maintaining good radiation properties (bandwidth and efficiency). Possible use of such antenna is mainly for medium range off-body communications, which could be useful e.g. for rescue and military teams.

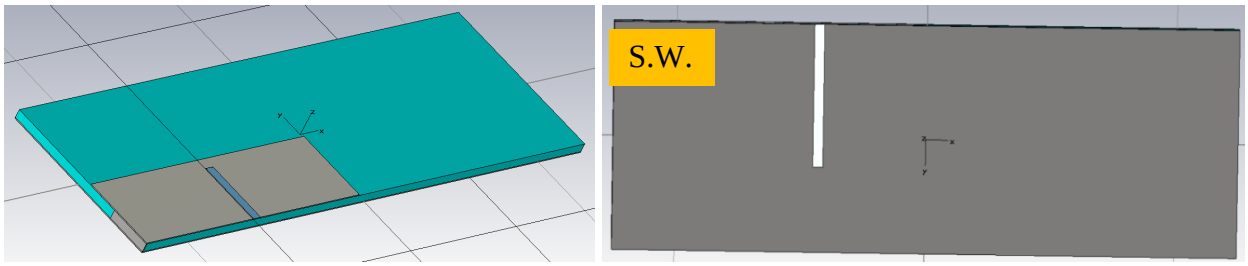
The explored concept was planar antennas – such antennas are low profile, relatively easy to fabricate and their use and miniaturization techniques are well documented in literature. They can thus be considered as a good trade-off between aesthetical and functional point of view. As a substrate, 4 mm thick fleece (permittivity of 1.1) was used, which is quite thin in terms of the wavelength in the UHF frequency range.

Using the commercial software CST Microwave Studio two antennas based on a PIFA concept (which is commonly exploited in GSM communications) have been designed and further simulations were performed in order to analyze and optimize their performances both in free space and with a body model present. The proposed antennas are shown on Fig.1, while their dimensions are summarized in Table 1. Both antennas consist of the ground plane with slot (or slots), patch and shorting wall (S.W.). The only difference is in their dimensions and the number of ground plane slots, meaning the physical mechanism of radiation is the same for both cases.

The first PIFA design has 2 slots in the ground plane and its resonant frequency in free space is around 480 MHz. The patch is slightly narrower than the ground plane and is placed symmetrically above it. The second design corresponds to the modification of antenna 1having a significantly narrower patch (only 3.5 cm width), while its resonant frequency in free space is around 420 MHz. In the second design there is one slot in the ground plane and one slot in the patch (the latter was added to lower the resonant frequency closer to desired range) and patch was placed along one edge of the ground plane, i.e. asymmetrically.



(a)



(b)

Fig. 1. *Proposed PIFA designs – top and bottom view. (a) – antenna 1; (b) – antenna 2*

Table 1. *Technical parameters about proposed PIFA designs*

Parameter – dimensions in [mm]	**Antenna 1**	**Antenna 2**
Ground plane size	200 × 80	250 × 80
Patch length	100	120
Patch width	70	35
Shorting wall length	20	20
Ground plane slot length	50	50
Patch slot length	-	30
Slot width	4	4
Feeding point distance from S.W.	20	49.5
Feeding point distance from centreline	10	30

After designing the antennas in free space, their performance was checked in the vicinity of the human body model. As a simplified body model a rectangular lossy dielectric box of dimensions 45×40×18 cm has been used – it corresponds to the body trunk and antennas are placed in the middle of its largest face. The relative permittivity and conductivity were taken corresponding to the muscle tissue at 400 MHz and amounted 57.129 and 0.8, respectively (loss tangent turns to be 0.626). In Fig. 2 the placement of the antennas on the body model is illustrated.

When placed on the body model, the resonant frequency shifted upwards by 7 and 21 % for antenna 1 and 2, respectively (i.e. to around 500 MHz). Comparison between input reflection coefficient in free space and with body present is given in Fig. 3 for both designs. Such frequency up-shift is confirmed also by looking at the field and current density distribution on the patch. It is in fact unexpected and needs some more theoretical investigation.

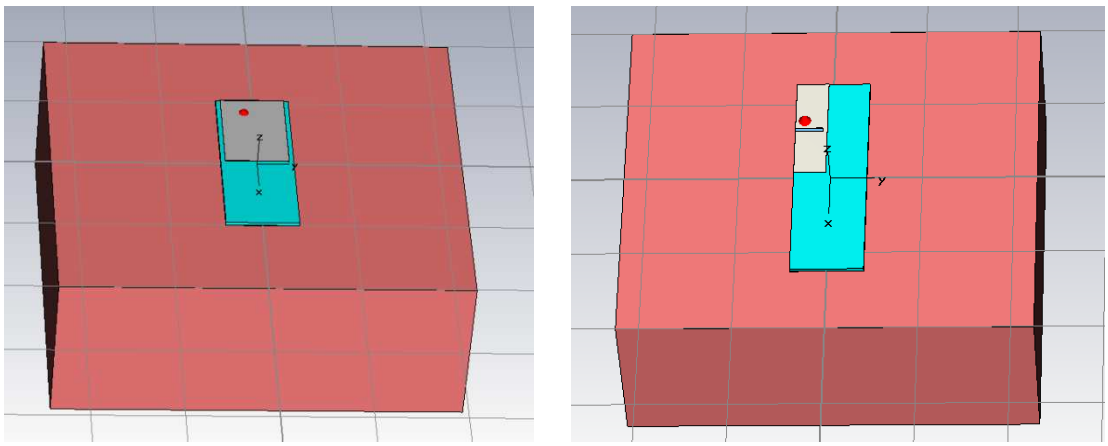


Fig. 2. *Proposed PIFA designs placed on the simplified body model*

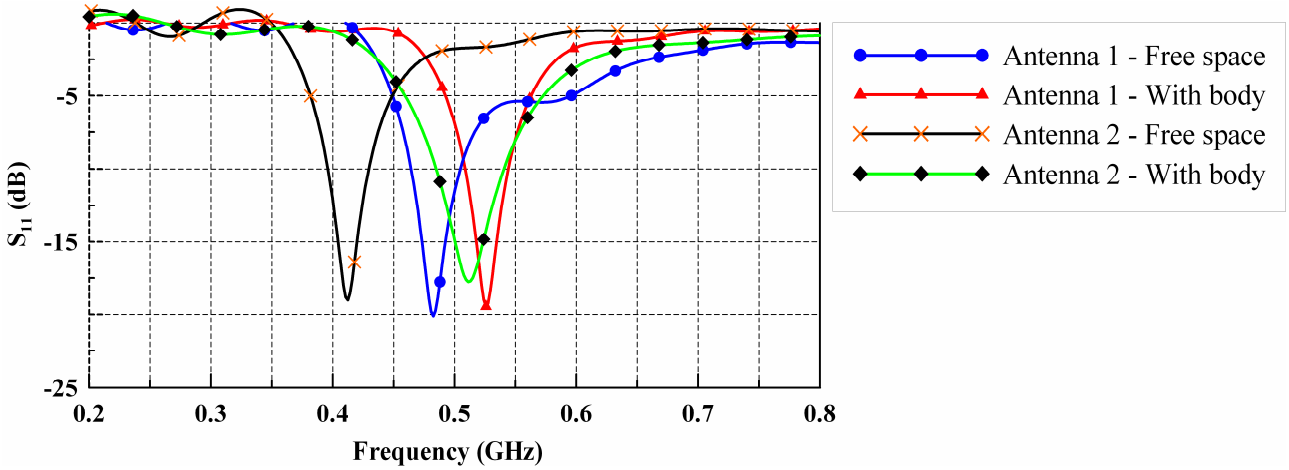


Fig. 3. *Input reflection coefficient vs. frequency for proposed antenna designs*

Furthermore, in presence of the body model, the radiation efficiency plummeted to -12 dB and -17 dB for antenna 1 and 2, respectively, leading to values of gain of -13 dBi. Such low values of the radiation efficiency are common in the relevant literature, meaning there is a major influence of the body to the antenna performance.

In case of the proposed antennas the coupling between the antenna and the body is obtained due to finite ground plane (diffraction from the edges) and via slot in the ground plane. Therefore in further simulations, the size and position of the slot in the ground plane have been systematically changed in order to investigate the slot influence on the antenna performance. It was found that the influence of the slot on the resonant frequency and matching generally diminishes when antenna is placed on the body (compared to free-space case) and is however more pronounced when the slot is placed under the patch and close to the shorting wall.

For antenna 2, the patch position above the ground plane was altered and it was found that it is possible to improve the radiation efficiency by up to 7 dB only by moving the patch away from the edge and leaving the part of the ground plane slot uncovered by the patch. This suggests that the patch and the ground plane form a capacitor in which, when a slot is placed, the near field couples more into the lossy material.

Antenna 1, having a wider patch, in general exhibited better performance in terms of the radiation efficiency and gain. For this concept the width of the shorting wall has also been altered in the

presence of the body. It was found that by narrowing the shorting wall it is possible to reduce resonant frequency in the presence of body up to 20% (i.e. to around 420 MHz) without need to increase the antenna size by scaling antenna dimensions (although at the cost of somewhat reduced radiation efficiency).

MAIN RESULTS OF THE STAY

During the stay the PIFA antennas for UHF band suitable for wearable applications were proposed and their performance was investigated using computer software CST. The proposed PIFA antennas posess one or two slots in the ground plane which contributes to near-field coupling with the body. The influence of the slot(s) was studied and a few modified concepts were proposed which benefit from weaker coupling to the body thus improving radiation efficiency.

Future work will include fabrication and measurements on the prototype and body phantom in order to verify simulations results. Antenna coupling when 2 or more antennas are placed on the body is also to be investigated. Theoretical work will include investigation of the observed up-shift in resonant frequency of the antenna when the body is present. The results are expected to be presented in joint publication.

< List of the publications co-written (or in progress)>

Other(s):

Number of Publications: __1___ (1)_____

Number of Documents/ Reports: __1___ (2)_____

Number of Case Studies & Demonstrators: __2___ (3)_____

* Attach all relevant documentation that specifies your results

FORECAST ACTIVITIES

<Are there any envisaged activities following this secondment project, new collaborations, co directed PhD, etc>

Apart from expected joint publication some more research in methods of controlling the antenna coupling is regarded as a next step in the future work. Depending on the application, coupling could be desired (“on-body”) or undesired (“off-body”). Therefore the use of artificial surfaces to control coupling (AMC, EBG, soft&hard surfaces) is to be considered. There is interest in further collaboration in the area of wearable antennas and body-centric communications. The exact form of collaboration is to be discussed.

In order to improve CARE's secondment program, please fill this short questionnaire. Use the space at the end to expand your answers, if needed. Our aim is to improve the general experience for secondees in future.

Disagree ➢ ➢ Agree

GENERAL				
My objectives were achieved.	**1** ☐	**2** ☐	**3** ☐	**4** ☒
The research topics were relevant to my work.	**1** ☐	**2** ☐	**3** ☐	**4** ☒
I benefited from being part of a wider research culture.	**1** ☐	**2** ☐	**3** ☐	**4** ☒

HOST ORGANIZATION				
I am satisfied with the quality and quantity of supervision I received.	**1** ☐	**2** ☐	**3** ☐	**4** ☒
I had access to adequate resources to support my research.	**1** ☐	**2** ☐	**3** ☐	**4** ☒

SECONDMENT PROGRAM				
I would recommend this secondment programme to others.	**1** ☐	**2** ☐	**3** ☐	**4** ☒
I believe the skills I have learned will help me to improve my job/research.	**1** ☐	**2** ☐	**3** ☐	**4** ☒
I would apply to another programme similar to CARE.	**1** ☐	**2** ☐	**3** ☐	**4** ☒
In general, how would you classify the CARE Secondment Programme?	**1** ☐	**2** ☐	**3** ☐	**4** ☒

Other questions/comments to be potentially considered: _____

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SIGNATURES

Candidate Branimir Ivšić **Date**: (2011/12/07)

Signature _____