Electronics for Gastroenterology

430 MHz antenna dedicated to colonic transit investigation solution

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Abstract — **Biomedical and health applications are representing nowadays a very attractive area for electronics devices. The state of the art shows a multitude of solutions based on in body sensors devices to measure and survey human physiological parameters enabling a distance medical monitoring systems and higher out-of-hospital care services for patients. These emergent systems have a lot of challenges related to their power consumption, size and complexity. In this article, we focus on one of the technological locks of the electronic gastric pill, which is the antenna. A miniaturized patch antenna a key element of the receiving system is presented. The antenna size and performances are very important to consider as it have to be integrated on a jacket in order to collect the transmitted information from an electronic gastric pill to trace cartography of the collected data. The designed antenna resonates in the desired ISM frequency band (430 MHz) and was simulated and optimized with the presence of a model of the human body for a more realistic use case.**

Keywords* — *biomedical systems, gastrointestinal exploration, swallowed pill, in-body, power optimization, RFID tags CCT (Colonic Transit Time, antenna design, miniaturization

I. INTRODUCTION

Nowadays, digestive diseases represent the second major medical problem after cardiovascular diseases. The use of Information and communication technologies (ICT) for their cure is thus very relevant, both from the social and the economic perspectives. Motility is one of the principal functions of the digestive system. One of the most common digestive problems is the Irritable Bowel Syndrome (IBS), defined as a combination of abdominal pain and recurrent bowel dysfunction (the duration of this dysfunction may vary). This syndrome is observed all over the world, and several recent epidemiological studies have focused on it [2]. One of the most reliable ways of determining IBS is to measure the transit time using radio-opaque markers or scintigraphy [1],[3]. Alternative techniques have consisted of swallow able pill whose travel time through the digestive tract is equal to the transit time.

II. PILL LOCALIZATION PRINCIPLE

This project is a proof-of-concept project for accurate positioning of the ingested pill inside the human body. This positioning method, combined with pill measurements (the pill contains several sensors), provides, so far , a complete view of the digestive mechanism [4].

The overall system - Fig. 2 - consists of the ingested pill P0 and four receivers housed in a belt around the body (these receivers R1 to R4 are synchronized and similar to the satellite constellation in the GPS system). A reference beacon B0 is required for calibration and improves the localization accuracy.

The set-up is as follows:

- Once every second, the pill P0 will emit a signal.
- This signal will be received by the different receivers R1 – R4 with different phase shifts.
- The phase shift due to the different distances between the pill and each receiver will be measured and analyzed in order to find the pill location by triangulation.
- The reference beacon B0 will then emit a signal in order to check and correct the position of each receiver (the belt will move around the body).

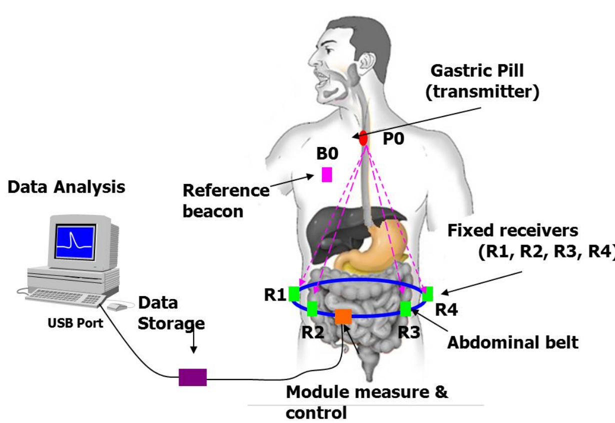

Fig 1: system description

III. 430 MHz Band Patch Antenna

Patch antenna are widely used in mobile communication system because of their low design complex, easy to integrate with other system , good performance and low manufacturing cost. However the issue arises when used in low frequency as size of the patch is directly proportional to the half of wavelength.

In our case in order to realize a patch antenna for 430 MHz we need a patch of length 348.837 mm . Antenna with such big dimensions cant be used for on body sensor applications, so miniature of antenna has to be done to for its desired application in human body. Different methods through which miniaturization can be achieved:

- Folding technique:
  This technique can be achieved by folding the patch of the antenna to covert the antenna from single layer to double layer . The size of the patch is considerably reduced from the original size.

- Quarter Wavelength antenna :
  Instead of using the patch length of wavelength /2 , we can use wavelength/ 4 which decrease the patch size of antenna and the over all size of antenna .

- Substrate with high permittivity :
  High dielectric constant substrate reduces wavelength propagation under the patch. Increase in dielectric constant of the substrate decrease the bandwidth and resonant frequency.

- Multiple feed:
  Multiple layers of feeds stacked over each other with a dielectric material between the feeds are used to increase the gain of antenna.

IV. Antenna Design And Characterization

A simple patch antenna is designed with resonating frequency of 430 MHz . The substrate used is silicon with 2.8 mm (εr =11.9) , high dielectric constant to minimize the size. A 50 Ω feed line with slots is used for the excitation. The substrate length is 100 mm and the width is 80 mm. Simulated results of return loss and input gain obtained for the original antenna (Fig. 2) are shown in Fig.3 and Fig.4 respectively (S_{11}= -24.3 dB at 430 MHz and max gain=-6 dBi).

A. Human body model

The human body is a complex structure composed by several layers (skin, fat, muscle) with different dielectric characteristics and different thickness depending on different person. The antenna must be simulated in such environment to get real model results.

We have considered human body based of most general model. Muscle (εr =57.87, σ=0,805s/m), fat (εr =5.58, σ=0,04s/m) and skin (εr =46.08, σ=0,702s/m). The muscle is has a the thickest layer of (20mm) while the fat and skin layers have similar thickness (5mm). For long time issues in simulation, the size of the of human body simulated model is compared to antenna size is: (80x80x30mm).

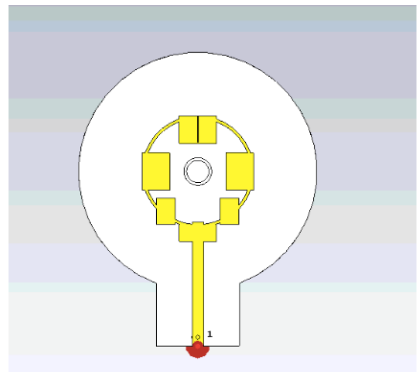

Fig. 2 Original Patch antenna

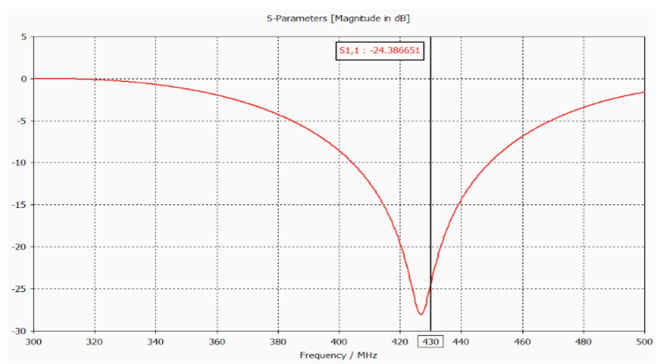

Fig. 3 Return loss Vs frequency of original antenna on human body.

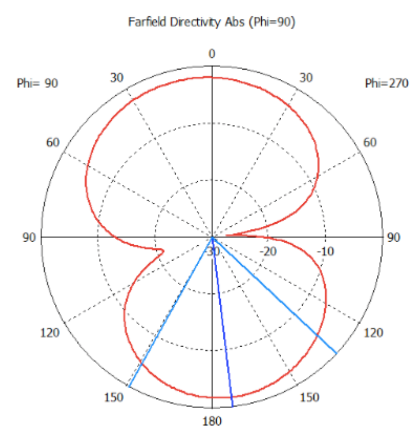

Fig. 4 Input gain of original antenna on human body

B. Antenna optimization

The previously obtained results are still large in size. when used in medical application smaller size is desired maximum of 50 x 50 mm . In order to get the desired size of antenna we had to reduce the dimension to match quarter wavelength antenna (174.41mm of patch length). The length and width of antenna foot print where reduced almost by 40 % .

We have also include another layer of feed to increase the gain of the antenna . The new secondary feed added is similar to the primary feed in terms of dimensions .The dielectric material used between the primary feed and the secondary feed is Rogers RT5880 (epsilon=2.2, dimension 61x50x.39mm) .

Antenna performances are estimated using E.M simulations software (CST microwave studio) . It presents a -28.03 dB return loss with a desired bandwidth and maximum gain of -4.45 dBi at 430MHz and a Half-power angle of 66.8° on human body .Results obtained for miniaturized antenna on human body, are shown in Fig. 5, Fig. 6.

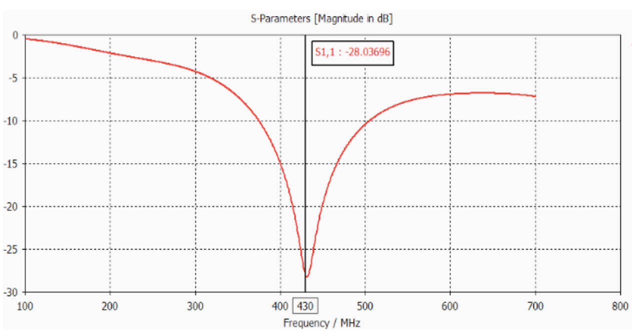

Fig. 5 Return loss Vs frequency of miniaturized antenna on human body

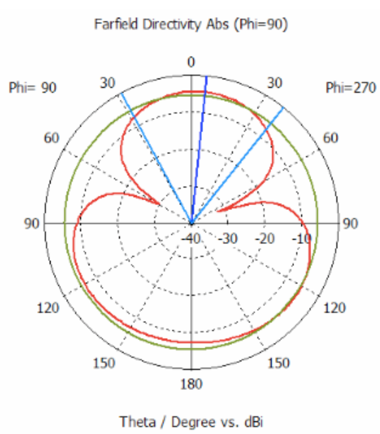

Fig. 6 Input gain of miniaturized antenna on human body

C. Simulated results

Using a high dielectric substrate and quarter wavelength reduce the antenna size effectively while keeping reasonable performances compared to the state of the art in terms of return loss values, gain, VSWR, and bandwidth and angular width which is important for the pills localization.

Properties	Original Antenna on human body	Miniaturized Antenna on human body
Resonant frequency (MHz)	430	430
Return loss (dB)	- 24.3	-28.03
Gain (dBi)	-6	-4.4
Angular width (deg)	83	66.8
Miniaturization (%)	0	40

V. CONCLUSION:

Two systems based on in-body devise localization solutions are presented in this paper with the aim of understanding the transit and digestive mechanism. Preliminary results are obtained by simulations and measurements and demonstrate the potentiality of the two approaches. First demonstrators were developed and works are ongoing in order to optimize them for a maximum accuracy and low costs solutions.

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