Available online at www.sciencedirect.com
ScienceDirect
Measurement 40 (2007) 816–822
Measurement
www.elsevier.com/locate/measurement

3-D Silicon Hall sensor for use in magnetic-based navigation systems for endovascular interventions

Konstantin Dimitrov

Institute of Control and System Research with the Bulgarian Academy of Sciences, Bl. 2, Acad. G. Bonchev Street, P.O. Box 79, 1113 Sofia, Bulgaria

Received 20 December 2006; received in revised form 11 June 2007; accepted 25 June 2007
Available online 4 July 2007

Abstract

This paper presents the design of a new 3-D Hall sensor compatible with standard silicon IC technology and optimization of its characteristics through originally realized amperometric scheme. This magnetic Hall effect sensor is intended to be fitted at the tip of a catheter for use in a magnetic-based navigation system for endovascular interventions. Unfortunately, at present the general feeling is that vector Hall sensors cannot be used for clinical trials, mainly because of their large size and low sensitivity. Proposed 3-D silicon Hall sensor has denied suspicions with its advantages: simultaneous on line 3-D measurement of the magnetic field components; high spatial resolution 150 μm × 150 μm × 100 μm; the lowest detected magnetic induction of the three output channels is about 15/20 μT; magnetosensitivities of the three channels at a supply current 10 mA reach 360 μA/T for $\boldsymbol{B}_x$ and $\boldsymbol{B}_y$, 250 μA/T for $\boldsymbol{B}_z$, respectively.

Keywords: Endovascular intervention; 3-D Hall sensor; Magnetic-based navigation system

1. Introduction

In minimally invasive surgery endovascular interventions special medical tools are navigated to the site of intervention to diagnose and treat different vascular diseases. At the start of a vascular intervention, a guide wire is inserted into a blood vessel and navigated to the point of interest. Once the guide wire is in place, a catheter is inserted over it and pushed along the guide wire to the intervention site. While a guide wire is used to find a pathway to the place of intervention, a catheter aids the radiologist in the treatment of a vascular disease. Guide wires and catheters are thin, flexible instruments, which are introduced into the cardiovascular system through small openings in the groin, the arm or the neck, depending on the place of the vascular disease. Once they are placed into the blood stream, their location needs to be monitored. Generally, this is done by means of diagnostic X-ray devices. Produced in the röntgen tube X-rays are sent through the patient to the image intensifier. The generated image is visualized on the monitors showing the internal structure of the patient and the medical tools being used. Throughout the guidance process, a rather high radiation dose is needed to continuously monitor the medical tools. Unfortunately,

E-mail address: kdimitrov@icsr.bas.bg

0263-2241/$ - see front matter
doi:10.1016/j.measurement.2007.06.005

the extensive use of X-rays during the procedures creates an important health risk to which not only the patient but also the medical staff is exposed. Generally, intervention radiologists wear special protection clothes against harmful radiation and most of the fluoroscopes have protection screens. Despite these protection measures, intervention radiologists continue to be exposed to a significant amount of radiation. To reduce this risk the total radiation dose should be considerably reduced. In this sense, one possible solution could be the use of a system to guide the medical tools without X-rays, to the intervention site. Carried out investigations show that a reduction of 38% up to 52% of the dose to which clinicians are effectively exposed during the procedures could be achieved, when the instrument would be navigated without the use of radiation [1–3]. To find a solution of this problem, a number of navigation systems have been developed over the years. Most of them were developed for interventional cardiology or neurology, while systems for interventional radiology are rather scarce. To overcome the drawbacks of the existing systems, such as poor image quality, high cost and low spatial and temporal resolution, magnetic-based navigation system could be used to meet the needs of interventional radiologists.

2. Magnetic-based navigation system

The complete navigation system consists of a magnetic source located on the image intensifier of the fluoroscope and a 3-D magnetic sensor at the tip of the catheter. The magnetic source consists of three electromagnets, which are mounted on the image intensifier of the fluoroscope, Fig. 1.

The functioning of the system is based on the sequential excitation of the three electromagnets, similar to the well-known tracking system [3,4]. The dc pulsed magnetic fields generated by the magnetic source are detected by means of the magnetic sensor. A mathematical algorithm is used to convert the three components of the magnetic field into the position and orientation of the sensor, with respect to the reference system *x–y–z* coupled to the magnetic source [3,5].

Once the location of the catheter tip is known, image-processing techniques will be used to continuously superimpose the detected location on a reference image. The reference image is a medical image taken once during the intervention, to serve as background, on which the location and orientation of the catheter tip can be indicated. This way, the need to take continuous X-ray images is reduced and thus the total radiation dose is significantly reduced.

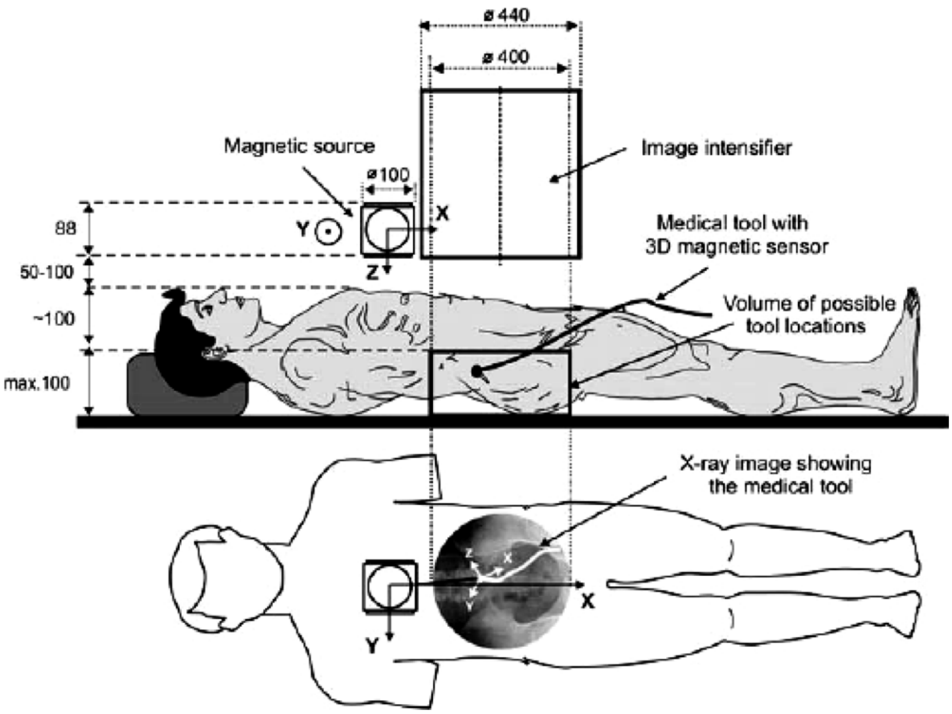

Fig. 1. Schematic of magnetic-based navigation system [3].