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A Novel Open-Ended Intravascular MRI Loop Probe

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Abstract — Recently, intravascular catheter probes have been developed to increase SNR for MR imaging of coroner arteries. Miniaturization of these catheter probes without degrading their performances is very essential in imaging small arteries. Since both signal and noise received by intravascular loop probes are of low level, the noise generated by the cable connecting the probe to the matching circuit may reduce SNR significantly. Therefore, the tuning and matching circuit must be placed very close to the loop probe, which restricts its miniaturization and flexibility. In this paper, we propose a novel open-ended loop probe for 64 MHz with an input impedance of 20 Ohm and a length of only 4 cm in the bare case. This has two advantages. Firstly, the matching and tuning circuits of the proposed probe can be located outside the vessel. Secondly, its signal level and uniformity is superior to that of the conventional loop antennas.

Keywords — **Magnetic Resonance Imaging (MRI), loop antenna, intravascular probe.**

I. INTRODUCTION

Loop probes have been utilized for magnetic resonance imaging (MRI) to increase the signal-to-noise ratio (SNR) of the resulting images from human internal arteries. Loop probes have two limiting disadvantages. Firstly, their tuning and matching circuits must be placed close to them inside the vessel. Secondly, their SNR is inversely proportional to the square of the distance from the probe [1,2,3]. We have proposed a new open-ended loop probe to alleviate these limitations. In this paper, an analysis is presented for a bare and insulated open-ended loop inside a finite homogeneous medium. In addition, the advantages of the new probe to the conventional loop antennas are discussed from the viewpoint of SNR, size, and input impedance.

II. METHODOLOGY

The SNR of MRI receivers can be compared using their intrinsic SNR [4,5]. Starting from the reciprocity principle [1], one obtains the intrinsic SNR as:

$$\psi_I = \frac{\sqrt{2}\omega\mu M_0 H_+}{\sqrt{4k_B TR}} \qquad (1)$$

where ω is the Larmor frequency, μ is the magnetic permeability of sample, M_0 is the total transverse nuclear magnetic moment in a 1 ml sample, H_+ is the magnitude of the right-hand circularly polarized component of magnetic field generated by the probe with unit input current, k_B is the Boltzmann constant, T is the sample temperature, and R is the real part of the probe's input impedance. In Eq. (1), H_+ and R are the only parameters of the probe that can be manipulated to improve the SNR of the probe. In other words, to evaluate the intrinsic SNR of a new probe, the magnitude of its magnetic field and its input impedance must be determined for a unit current applied to the probe input.

III. PROPOSED PROBE AND ITS ANALYSIS

Fig. 1 depicts the proposed open-ended loop probe. The two wires of the loop are copper wires, each having a radius of 0.1 mm and being 4 mm apart. The wires are assumed to be covered by an insulating layer of $\varepsilon_r = 3.3$. The thickness of this layer is a variable in the following discussions. In the special case of bare wires, this thickness is set to zero. The surrounding medium of the loop is considered to be infinite with a relative permittivity of $\varepsilon_r = 80$ and a conductance of $\sigma = 0.8$ S/m. The working frequency of the probe is assumed to be 64 MHz which is the operating frequency of 1.5-Tesla MRI systems.

To evaluate H_+ and R for the proposed loop, use has been made of a finite element method. As a result of this analysis the current on the antenna conductors was determined. This was used to calculate the magnetic field and the input impedance of the loop. To this end, commercially available finite–element software was linked with MATLAB to allow parameter sweep.

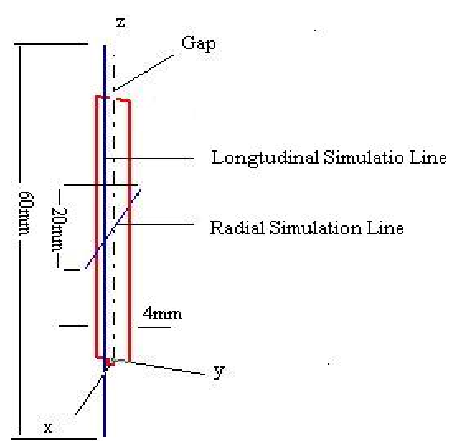

Fig. 1. Proposed Open-Ended Loop Probe.