Electro-textiles as Potential Candidate of Flexible MRI RF Coil for Stroke Prevention

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***Abstract*—RF coils are essential part of Magnetic Resonance Imaging (MRI), which is a widely used imaging modality nowadays. Flexible surface RF coils are desired for potential higher signal to noise ratio (SNR) and ergonomic advantages. Electro-textiles are explored as potential candidate for MRI RF surface coils. A Flexible MRI RF coil for transmission or reception using electro-textiles is designed, fabricated and measured for 1.5Tesla MRI. The design of the prototype is targeted towards the carotid artery imaging to prevent strokes, which is one of the leading cause of death world wide. The S11 is -19.8dB at resonant frequency of 122MHz. H1+ field with different conformal radius is shown to demonstrate its potential advantage to increase MRI image quality.**

Keywords—MRI; RF coil; flexible; electro-textile

I. Introduction

Magnetic Resonance Imaging (MRI) has been an imaging modality widely used today. RF coils are integral part of the MRI scanners for transmission and reception of RF magnetic signals. When the imaging area is not the entire human body, surface RF coils are preferrably used due to its advantageous signal to noise ratio (SNR). They spatially reject noise from parts of the human body that is not imaged and as a result inherantly have higher SNR than whole body coils. Current RF coils however have disadvantage of not comfortable to wear. Due to the comparatively long imaging time needed for MRI than other imaging modalities, this disadvantage may consequently lead to other problems such repetitive imaging trials, MRI image motion artefact etc. As a result, flexible MRI RF coils are desired.

Flexible RF coils not only are more ergonomic but also bring another chance to increase SNR, which is a fundamental limiting factor of MRI image quality. The SNR of surface RF coils is very sensitive to the placement of the coil relatively to the imaging tissue. When the coil is placed near the imaging tissue, markable increase in signal sensitivity is expected [1]. The noises in MRI come from two different sources: human tissue and coils along with its relevant circuitry. For most clinical applications of RF surface coils, noises from human tissue is much larger or at least comparable to those from coils and circuitry. This observation brings an opportunity to the various materials to be used in flexible MRI RF coils. A slight increase in losses by coils and circuitry is offset by the advantage of ergonomic consideration and potential higher SNR of flexible RF surface coils. Flexible MRI RF coils are studied using screen printing in [1], ink-jet printing in [2] and copper braid in [3]. The substrate of the first two methods is flexible in limited angles and directions. Additionally the second method is limited by the thickness of the conductor it can print. As a result its conductivity is limited at interested frequencies. The third method uses meandered copper braid and as a result may be worn out over the time. In this paper electro-textiles are explored and used to buid flexible MRI RF coils. Electro-textiles have the advantages of being highly conductive, as flexible as normal cloth and also enduring over the time.

In our work, systematic steps are proposed to explore the potential of electro-textiles for MRI RF coils. Flexible RF coils conformal to human neck are desired in the carotid artery imaging using MRI method. A flexible MRI RF coil for transmission or reception using elecro-textiles is designed, fabricated and measured for this application. The S11 of the coil is -19.8dB at resonant frequency of 122MHz. In section II, design of MRI RF coils using electro-textiles will be discussed. In section III, simulated and measured results will be discussed. In section IV, conclusions will be drawn.

II. Design of RF Coils Using Electro-textiles

A systematic approach to explore the potential of electro-textiles utilized in RF coils is proposed and shown in Fig. 1 and [4]. In step 1, single coil near human neck using normal fabrication method is studied and designed. In step 2, electro-textiles are used to design coils based on the experience from step 1. In step 3, RF receiving coil array with electro-textiles will be designed to complete the design cycle.

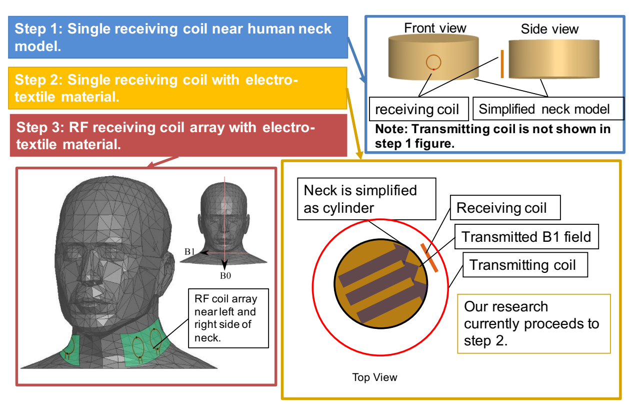

Fig. 1. Road map to explore the potential of electro-textiles to construct MRI RF coils

Our work currently proceeds to step 2, where single coil using electro-textiles is designed, fabricated and measured. Liberator 40 from Syscom Advanced Materials is used as the electro-textile due to its high conductivity (linear conductivity of around 3Ω/meter) and superior strength. Silver epoxy is used to connect capacitors, SMA port and the coil. The coil is simulated in HFSS near the 4mm accuracy human neck model before being sewed on cotton cloth. The design and detailed parameters is seen in Fig. 2 and Table I.

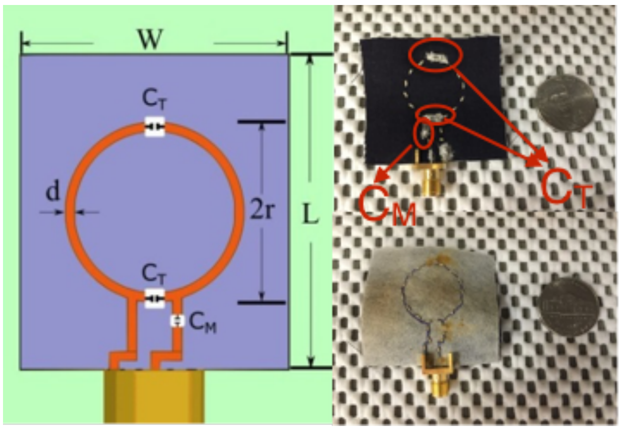

Fig. 2. Design and prototype of the fabricated RF coil using electro-textiles

TABLE I. DESIGN PARAMETERS

Design parameters	Substrate width, W	Substrate length, L	coil radius, r
Values	30 mm	35 mm	10 mm
Design parameters	**Loop width, d**	C_T	C_M
Values	1.26 mm	60 pF	10 pF

III. Measured and Simulated Results

The simulated and measured S11 is shown in Fig. 3. The S11 of the simulated coil near human neck model is -27.5dB at 128.1MHz. The S11 of the fabricated coil using electro-textiles is -19.8dB at 122MHz. The small shift in resonant frequency can be tuned back with varable capacitors or tuning kit. There is no significant shift in resonant frequency comparing S11 measured in open air, near human neck and on human neck. The effect of deformation when the coil is conformal to human neck is studied by simulation in HFSS. It is shown in Fig. 4 that the larger deformation angle leads to deeper signal penetration depth (larger H1+ field) when the input is 1W. Simulation also shows that the resonant frequency is shifted only by 1.1 MHz when the coil is conformal to cylinder with radius of 30mm.

IV. Conclusion

Electro-textile is explored as potential candidate of flexible MRI RF coil for transmission or reception. The design is target towards stroke prevention by imaging carotid artery. The work in this paper presents a systematic road map to explore the potential of electro-textiles for RF coil array. It is shown that RF coil using electro-textile has low S11 at the required resonant frequency for 1.5 Tesla MRI. The performance is comparable to copper coils of similar coil radius.

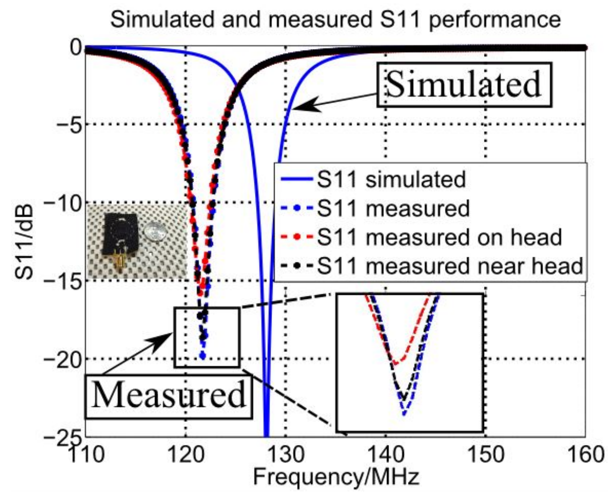

Fig. 3. Simulated (together with cylindrical human neck model) and measured S11 in open air, near human neck and on human neck

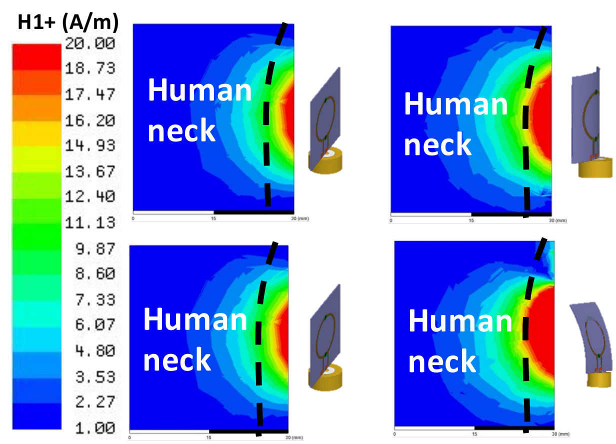

Fig. 4. H1+ distribution of 30mm×35mm cut 10mm away from coil center

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