CERTAIN INVESTIGATIONS ON DESIGN AND ANALYSIS OF MICROSTRIP RF COIL STRUCTURES FOR 1.5 TESLA MAGNETIC RESONANCE IMAGING SYSTEM

ABSTRACT

In recent years, magnetic resonance imaging (MRI) is widely used to obtain the clear images of the human body, especially those of high water content tissues. The introduction of MRI technique into clinical practice gives a new dimension to the radiological study. Before the invention of MRI; X-ray, ultrasound and computed tomography (CT) were the widely accepted techniques for acquisition of images inside human anatomy. In the case of X-ray or CT medical imaging techniques, the ionizing radiation is used. But in MRI there is no ionization of molecules present in the human body. In addition to the advantage of safety, MRI is better for visualizing the images of soft tissues than CT.

In the MRI system RF coil plays an important role to improve the quality of imaging. The RF coil transmits RF pulses at the Larmor frequency to excite the nuclei in the object to be imaged. When the RF excitation pulse is removed, the nuclei will relax; during relaxation the nuclei will emit the RF energy at the Larmor frequency. This NMR emitted RF signals are again collected by receive RF coil. The signals received by the receive RF coil are suitably processed inside a digital computer for getting the MR image of the anatomy.

The RF coil performs the role of an antenna which radiates a pulse of the electromagnetic (EM) wave into the body to generate a nuclear magnetic resonance (NMR) signal and the same antenna receives the reradiated signal from the body. The quality of the image captured by MR scanners is highly dependent of the performance of RF coil. High field (greater than 3 Tesla) MRI scanners will give better quality images but the cost of imaging devices is very high. Instead of shifting towards high field MRI

systems, it is better to improve the performance of RF coils in a low field environment for producing better quality images. So there is a need for more research participation to design and analysis the performance of RF coils for low field (1.5 Tesla) MRI applications.

The objective of the research is to propose various microstrip based RF coil structures for 1.5 Tesla MRI system. The resonance frequency of the 1.5 Tesla MRI RF coil is 63.87 MHz. Microstrip based structures will radiate effectively for high frequency microwave applications. In other words preferring microstrip based structures for low frequency (63.87 MHz) operation will lead to physically a large sized RF coil. Therefore the challenging part of the RF coil design is, for the resonance frequency of 63.87 MHz the dimension of the microstrip based structure should not be much larger.In this research work a variety of RF coil structures are proposed for the needs of 1.5 Tesla Magnetic Resonance Imaging systems. The surface type RF coils are formed in a FR4 (Flame-Retardant Type 4) substrate with height 1.6 mm and the thickness of the top conducting transmission line is 35μm. The designed RF coil structures are analysed with respect to their return loss and quality factor performance by using Advanced Design system (ADS) scattering parameter simulation. The aim of preferring surface type RF coils is to extend them for phased array coil design.

There are four different types of surface coil geometries are proposed for low field (1.5 Tesla) MRI requirements. The first surface coil design focuses the square shaped RF coil structure with L Type Matching network. The matching network consists of shunt and series configuration of capacitor and inductor. The impedance matching procedure indicated is so simple for matching source impedance with real as well as complex type of load impedances.

In practice, inductors are made up of conducting wires of small diameter which may dissipate energy as heat loss. In order to avoid such limitations a new L type matching network with only capacitive elements is proposed. Such matching network is modified Type1 matching network.

Earlier the concept of stepped impedance transmission line was introduced for microwave filter designs. The ability to produce homogeneous magnetic field along the length of the transmission line makes stepped impedance structure (SIS) as a suitable MRI radiating element. A SIS having 13 transmission line sections (7 low impedance & 6 high impedance) are selected to construct a 300 mm length RF coil. The SIS is analyzed for RF surface coil design. The open and short circuited SIS is considered along with impedance matching network. Short circuited SIS with modified type1 matching is applied for phased array coil implementation. The quality factor of the RF coil is analytically expressed from the input impedance of the RF coil. The performance of the short circuited SIS RF coil is verified by using ADS scattering parameter simulation.

Short circuited stepped impedance structured 8 channel phased array RF coil achieves a quality factor value of 236 and a return loss of greater than 20 dB in all the 8 channels. The total area occupied by the 8 channel SIS RF coil (FOV) is 387 mm x 300 mm. In order to improve the number of channels in the phased array RF coil the octagon shaped geometry is focused.

A single channel octagon shaped RF coil structure is designed with modified Type1 matching. The width value of the RF coil is adjusted from 4 mm to 14 mm and its return loss and quality factor values are observed for each width configuration. A width value which is giving better return loss and quality factor is selected for phased array coil construction.

The 8 mm width octagon shaped 12 channel phased array structure with diagonal spacing of 11.3137 mm is implemented within a field of view of 382 mm x 284 mm. It achieves a quality factor of 169 and a return loss of greater than 19 dB in all the 12 channels. The spacing between the nearby hexagonal channels controls the return loss performance of the phased array coil. To increase the number of channels in phased array RF coil a hexagonal geometry is focused. The speciality of hexagonal geometry is, the given area (FOV) can be covered without any overlap and without any gap. In the non-overlapped phased array RF coil implementation a small amount spatial gap should be provided to reduce the mutual coupling between neighbouring channels.

A single channel hexagon shaped RF coil structure is designed with modified Type1 matching. The width value of the RF coil is adjusted from 4 mm to 14 mm and its return loss and quality factor values are observed for each width configuration. A width value which is giving better return loss and quality factor is selected for phased array coil construction. In addition to return loss and quality factor a mutual coupling between transmission line sections is also considered for phased array coil geometry selection.

The 8 mm width hexagon shaped 24 channel phased array structure with parallel spacing of 12 mm is implemented within a field of view of 427 mm x 281 mm. It achieves a quality factor of 330 and a return loss of greater than 20 dB in all the 24 channels. The spacing between the nearby hexagonal channels controls the return loss performance of the phased array coil. The results clearly shows, the lesser the parallel spacing between neighbouring channels more will be the mutual coupling and lesser the value of return loss.

A 12 element volume type microstrip birdcage coil is proposed for 1.5 Tesla MRI system. The Coil is formed in a Polytetrafluoroethylene (PTFE) substrate with height 10 mm and the thickness of the top conducting transmission line is 35μm. An FDTD simulation in commercial EMPro 2011 software is performed to analyze the behaviour of RF coil at 63.87 MHz. The coil achieves a return loss of more than 25 dB. The SAR value obtained for the proposed design is less than the SAR limitation specified by IEC (IEC 2002) standard.