Waveguide Magnetic Resonance Imaging at 3 Tesla

F. Vazquez[1], R. Martin[1], O. Marrufo[1], and A. O. Rodriguez[1]
[1]Departament of Electrical Engineering, Universidad Autonoma Metropolitana Iztapalapa, Mexico, DF, Mexico

Introduction. Waveguides have been successfully used to generate magnetic resonance images at 7 Tesla for whole-body systems [1]. From these results, it has been established that waveguides are only suitable for 7T systems with wide bores of al least 60 cm. This is mainly due to the cut-off frequency of the cylindrical waveguides used. To overcome this limitation a parallel-plate waveguide was employed since its cut-off frequency depends on the separation of the plates [2]. A parallel-plate waveguide was built and used to acquire images of a healthy volunteer's leg at 3 Tesla on a clinical MR imager.

Material and Methods. To investigate the dimensions of the waveguide for the resonant frequency of the 3T system, the cut-off frequency of a parallel-plate waveguide can be computed by [2]:

$$f_{cutoff} = \frac{1}{2d\sqrt{\mu\varepsilon}}$$

where $\mu = 4\pi \times 10^{-7}$ H/m and $\varepsilon = \varepsilon_0 \varepsilon_r$, $\varepsilon_0 = \frac{1}{36\pi} \times 10^{-9}$ F/m, $\varepsilon_r = 80$ at 120MHz, and d (diameter)=30cm, then the f_{cutoff} is 55.90MHz. An acrylic cylinder and four aluminium strips (13cm wide and 50cm long) were used to build a parallel plate waveguide. Strips were equally spaced and mounted on the cylinder (30cm diameter and 60cm long) to form a parallel-plate waveguide. RF transmission was performed with a whole-body birdcage (68 cm long, 66 cm diameter and 16 rungs), and reception was performed with a circular-shape coil array (12 cm diameter). Received-only circular coils were positioned at both end of the cylinder. Fig. 1 shows an illustration of the waveguide and the experimental setup. T1-weighted images of a healthy volunteer's leg were acquired using gradient echo sequences with the following acquisition parameters: flip angle=80^0, TR/TE=500/4.6ms, FOV=484x171mm, matrix size= 840x238, slice thickness=5mm, NEX=10. All imaging experiments were carried out on a 3T clinical imager (Philips Medical Systems, Best, NL).

Figure 1. Experimental setup and an illustration of parallel-plate waveguide.

Results and Discussion. The parallel-plate waveguide is probably the simplest waveguide available. In this work, the cut-off frequency is low enough (approximately 56MHz) to allow to be used on a 3T MR system with a standard bore of 66 cm. However, the cut-off frequency equation above allows us to build waveguides for high magnetic field strength (>3T) systems with smaller bores. T1-weighted images of a healthy volunteer's entire leg were obtained using the whole-body coil only and the parallel-plate waveguide and shown in Fig. 2. Generaly, waveguide-generated images showed a relatively good quality images. The image ends of Fig. 2b) (bottom and top) showed an improvement on the image SNR compared the other images and, extra 5cm can also be gained. Nevertheless, some noise can be observed in the central region, this is probably due to construction imperfections and manipulation of the waveguide. Waveguide images compared reasonable well with those images acquired with the whole-body coil embedded in the imager. We have experimentally demonstrated that the use of parallel-plate waveguides can produce good SNR images for relatively large fields of view. This makes it a good candidate for MRI applications where large fields of view are required. Further investigation is required to explain the physical mechanisms involved in generation of the image. We suspect that operating the coil array in the transceiver model, the image SNR will experience an image improvement. Finally, we have shown that the waveguide approach can also be used with magnetic field intensities lower than 7T and whole-body systems.

Figure 2. Entire leg images acquired with whole-body coil (left) and waveguide approach (right).

Acknowledgments. F. V., O. M. and R. M. would like to thank CONACYT Mexico for Ph. D. scholarships. Email: arog@xanum.uam.mx.

References. 1. Brunner DO, et. al. Nature 457;994:2009. 2. Cheng DK, Fundamentals of Engineering Electromagnetics. Prentice Hall, NJ, 1992.