

# UHF Propagation in a Partially Filled Short Cylindrical Waveguide

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## Introduction

An experiment is conducted to determine expected signal attenuation when the bore is empty (air-filled) or dielectrically loaded (patient-filled). This information is especially important to the wireless network designer, implementing an in-bore physiological monitoring network. Experimental results show that the MR bore shows impressive path loss performance at UHF, specifically 433 MHz, with greatest signal strength arriving at the receiver when the bore is dielectrically loaded.

## Methods

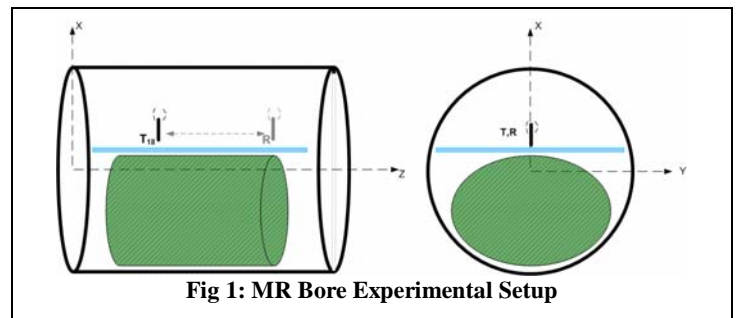
Path loss is a measure of the effective attenuation of an electromagnetic wave as it travels through space. Relative path loss for all experimentation in this work is calculated as the difference between the average received signal and the source power while taking cable losses and attenuation into account. The representative equation is

$$\text{Path Loss}_{\text{Relative}} (\text{dB}) = [\text{avg}(\text{Power}_{\text{rcvd}}(\text{dBm})) - \text{Power}_{\text{Source}}(\text{dBm})] - \text{Losses}(\text{dB}). \quad \text{Eqn 1}$$

This study is supported by the concepts that the MR bore behaves like a waveguide [1] and that by design the signal attenuation across the bore should behave similarly to a cylindrical tunnel [2]. Additionally, Leung [3] found that there is significant signal degradation when integrating a 2.4 GHz Bluetooth communication system in the bore environment without an in-bore repeater. Therefore, a lower operating frequency of 433 MHz is chosen for this experimentation.

## Results

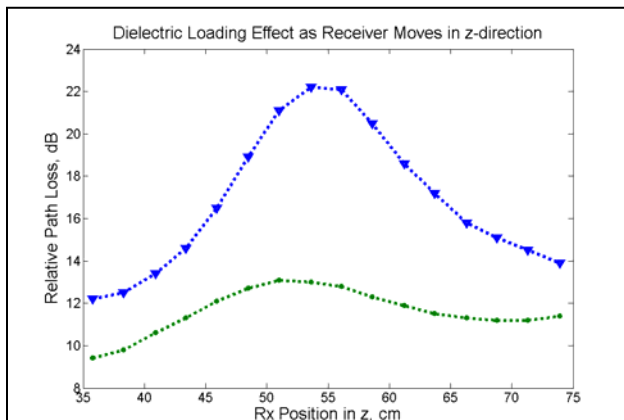
Several experimental trials are performed to determine relative path loss behavior for a 433 MHz wireless system. This experimentation takes place within a 60-cm diameter, 105-cm long MR bore manufactured by GE Healthcare. The setup information for each trial is shown in Fig 1. The phantom-filled trial is conducted with matched helical antennas perched on top of a large body phantom (platform shown in picture is removed). The phantom represents a human torso and fills approximately 87% of the available bore space. The phantom's dimensions are 42 cm x 23 cm x 85 cm, and the body of the phantom is filled with 14 mmol NiCl solution. The air-filled trial is conducted with matched antennas perched on non-conductive foam (phantom removed), at the same distance from the bore bottom as in the first trial.



Relative path loss measurements start at a transmit-receive (T-R)

separation of 18 cm ((T (10,0,18), R (10,0,36)). The T-R separation increases in 2.5cm increments up to 55 cm of separation, where T is held at a fixed location from the edge of the body coil (10, 0, 18). Three trials per experimental configuration were executed and subsequently averaged. The experimental results for the phantom-filled (green dots) and air-filled (blue triangle) trials are shown in Fig 2. The maximum standard deviation for each data point is 0.25 dB and 0.7 dB, respectively. When compared to the phantom-filled data, the air-filled data shows 7 dB greater path loss

across the center of the MR bore. Peak relative path loss occurs close to the median of the z-axis, around 54 cm. The phantom-filled scenario boasts a much more stable received signal, where variations in relative path loss across the bore are within a 3 dB window. The peak path loss occurs around 51 cm and is less than 13 dB.



**Fig 2: Relative Path Loss Measurements Across the Bore Space with (green) and without (blue) phantom loading**

## Conclusion

At 433 MHz, there should be sufficient signal strength to receive data at any location within the bore, given an appropriately designed communications network. Results shown here indicate that when a human body is in the bore, there is an improvement in relative path loss and received signal stability, regardless of signal transducer position within the bore.

## References

- [1] G.O. Brunner, et al. "Traveling Wave MR on a Whole Body System". *Proc Intl Soc Magn Reson Med 2008*. Toronto, Canada.
- [2] D. Dudley, et al. "Wireless Propagation in Tunnels". *IEEE Antennas Propag. Mag.* April 2007: p. 11-26.
- [3] G. Leung, et al. "On the Operation of Bluetooth Devices inside the MR Faraday Cage". *Proc Intl Soc Magn Reson Med 2008*. Toronto, Canada.