

# Phantom Fluids for High Field MR Imaging

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## Introduction

Construction of calibration phantoms for MRI systems becomes increasingly difficult as whole body MR imaging systems migrate to higher field strengths. Large, full field-of-view phantoms filled with water-based fluids do not produce uniform intensity images on 3T and higher field systems even when the rf coils are selected to insure the uniformity of the rf field within the imaging space.[1] Standing waves form within phantoms when they are larger than a critical size which is dependent upon the dielectric constant of the phantom fluid and the Larmor frequency of the species of interest. For <sup>1</sup>H imaging at 3T, the critical diameter for spherical water-based phantoms is around 30 cm. Phantoms larger than this dimension will show a pronounced non-uniformity exemplified in figure 1. In this work we describe a phantom filler solution which reduces the standing wave effects in large phantoms while retaining the desirable characteristics of being adjustable in T<sub>1</sub>, non-toxic, thermally and chemically stable, spectrally pure (one peak) and economically viable for mass production.

## Theory

The theory of standing waves in uniform water phantoms has been reported.[1] Water has a relatively high dielectric constant (~80) which leads to the formation of dielectric standing waves when the size of the phantom and MR frequency are large. Dielectric standing waves amplify the rf magnetic field within the phantom resulting in uneven image intensity. The critical phantom diameter scales linearly with inverse of frequency and as the inverse square root of the dielectric constant of the filler fluid. Oils are a common fluid used to avoid standing waves because they possess a lower dielectric constant than water (~3-5). However hydrocarbon oils (vegetable fats and long single-chain molecules) are not spectrally pure, flammable, have intrinsically low T<sub>1</sub>s and T<sub>2</sub>s, and high vapor pressures at low viscosity.

## Methods

A variety of non-aqueous fluids were investigated for the following desirable MR properties: water-like viscosity and T<sub>1</sub> in pure form, T<sub>1</sub> adjustability, low toxicity, high safety, spectral purity, low vapor pressure and low cost. MR properties were measured at 1.5T and 3.0T using GE Signa MRI systems. Chemical compatibility and safety information were taken from data sheets, MSDSs and accelerated stress testing methods. The search also included relaxation agents which were non-toxic, chemically compatible with oils, and low cost.

## Results

The best performance came from the poly(dimethylsiloxane) class of silicone fluids which are manufactured for a wide range of industries. These fluids have a base molecular structure shown in figure 2 where n = 40-100. The fluids exhibit all of the desirable characteristics of a MR phantom fluid and have a low dielectric constant of less than 3. The T<sub>1</sub> of pure SF96-50 (GE Silicones) is ~900 ms at 1.5T and ~1600 ms at 3.0T. A gadolinium beta-diketonate, Tris(2,2,6,6-tetramethyl-3,5-heptanedionato)gadolinium (Gd(TMHD)<sub>3</sub>, STREM Chemical), was found to have good solubility in silicone fluids at concentrations which allowed controlled reduction of the T<sub>1</sub>s of the silicone fluid to 100 ms at 1.5T.

## Conclusion

The critical size dimension of phantoms filled with silicone fluids is increased over 4 times that for water-based phantoms thus greatly increasing the useful size of void-free calibration phantoms for high field MR imaging experiments. Figure 3 compares a silicone fluid filled phantom to the water filled phantom in figure 1 under the same scanning conditions: 3.0T spin echo, spherical phantom 28 cm in diameter. The addition of a gadolinium-based dopant to the fluid allows the T<sub>1</sub> of the solution to be controlled so that the phantom may be tailored for specific calibration purposes.

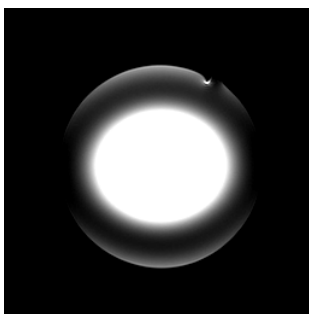
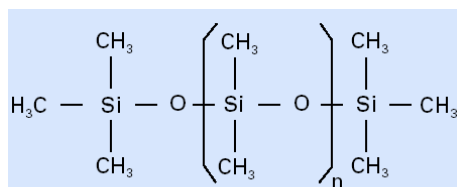


Figure 1. Water filled phantom.



(Polydimethylsiloxane)

Figure 2. Silicone fluid structure.

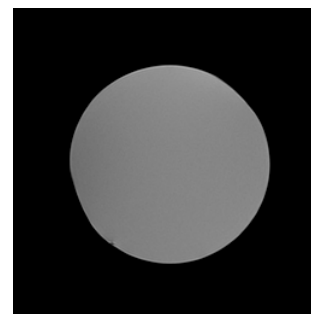


Figure 3. Silicone oil filled phantom.

## References:

1. P.S. Tofts, J. Mag. Res. Ser. B. **104**, 143-147 (1994).