# Optimal Permittivity of Dielectric Liners and their Effects on Transmit Array Performance

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**Purpose** The insertion of high dielectric constant (HDC) pads between the coil and the patient/phantom has been shown to increase the local signal intensity in the region adjacent to the dielectric [1, 2]. This results from displacement currents which increase with permittivity, and behave as secondary sources to enhance the magnetic field [2]. The use of HDC liners surrounding the imaging volume has also been proposed in [3, 4] but the high permittivity of such materials can make them resonant at frequencies near the Larmor frequency thus raising potential safety concerns. Furthermore, wave impedance mismatch is known to cause reflections between different dielectric layers, potentially reflecting power back towards the source thus lowering sensitivity. Finally, the permittivity of materials near array elements strongly affects mutual impedance [5] which can also degrade performance. In this abstract, we investigate the effects of a dielectric liner on the transmit performance of a 4.7 T head coil array and find an optimal permittivity.

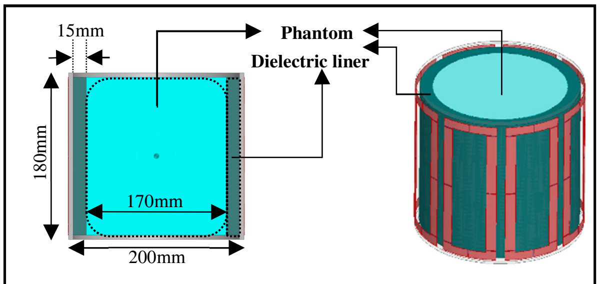


Figure 1. Head coil array, dielectric liner and phantom.

**Methods** The array shown in Fig. 1 was simulated using High Frequency Structure Simulator (HFSS, Ansys Corp.) including the dielectric liner between the phantom and coil. The coils are made of 10-mm-wide copper strips attached to a 6-mm-thick PMMA former with relative permittivity $\varepsilon_r = 4$. Resonance at 200 MHz is achieved using discrete capacitors distributed across eight gaps. Each coil port is excited using progressive phase shifts (birdcage mode) using a 1A current source to generate fields and 1W wave ports to generate the S-parameters. Different liner permittivities ranging from air ($\varepsilon_r = 1$) to high values ($\varepsilon_r = 150$) achieved in HDC pads described in the literature [2] are used to evaluate the liner's effect on array performance. A value of $\varepsilon_r = 17.5$ corresponds to a wave impedance that is the geometric mean of the wave impedances in the former (188.5 Ω) and phantom (43.2 Ω), and is expected to behave as a tapered line [6] which minimizes reflected power at the dielectric boundaries. Permittivity $\varepsilon_r = 75$ is roughly equal to that of the phantom ($\varepsilon_r$=75, σ=0.8 S/m).

Table I: Transmit performance of the array.

| | $\varepsilon_r$=1 | $\varepsilon_r$ =17.5 | $\varepsilon_r$ =75 | $\varepsilon_r$ =150 |
|---|---|---|---|---|
| **$S_{11}$ (dB)** | -13.78 | -30.23 | -14.1 | -8.1 |
| **$S_{12}$ (dB)** | -7.7 | -7.7 | -8.2 | -9.6 |
| **$Z_{12}$ (Ω)** | 1.95-j22.7 | 0.34-j25.5 | -4.7-j34.3 | -22.8-j45.5 |
| **$B_1^+$(Avg)/ $\sqrt{\text{Deposited power}}$** | 0.54e-6 | 0.53e-6 | 0.47e-6 | 0.47e-6 |
| **$B_1^+$ Field inhomogeneity (RMS)** | 29.7% | 24% | 20.7% | 21.88% |
| **Resonant frequency of liner (MHz)** | – | 571 | 303 | 216 |

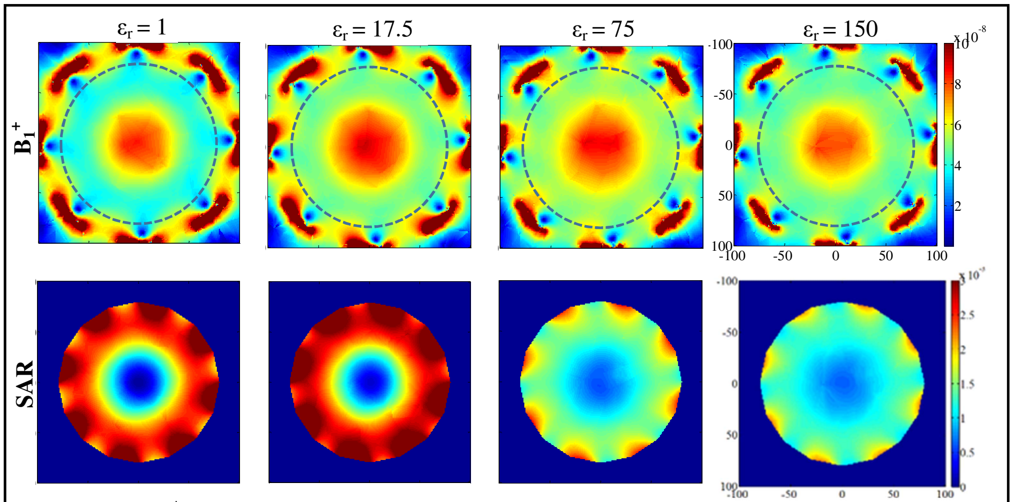


**Figure 2**. $B_1^+$ field local SAR in a central transverse slice with different liner permittivities.

**Results** Simulation results (Fig. 2) are summarized in Table I where it is shown that $\varepsilon_r = 17.5$ yields the best match (lowest $S_{11}$) and reduces resistive coupling by more than four-fold relative to $\varepsilon_r = 1$ while maintaining similar levels of sensitivity. Higher values of permittivity ($\varepsilon_r = 75, 150$) degrade coil matching, and increase mutual impedance (especially mutual resistance) between elements. Furthermore, RF field homogeneity which is calculated over a slice in the transverse plane in the phantom, does not improve monotonically with increasing permittivity, and there is a slight degradation between $\varepsilon_r = 75$ and $\varepsilon_r = 150$. At this permittivity the lowest resonant frequency of the isolated liner is also unsafely close to the Larmor frequency.

**Conclusion** The permittivity of a dielectric liner must be optimized to avoid degrading array performance. In this example we have verified that a permittivity equal to the geometric mean of those of the phantom and former avoids degradations in transmit efficiency and increases in mutual resistance between array elements. Extreme values are therefore not needed and not beneficial. Depending on the application and coil type, a compromise between field homogeneity and array efficiency may be needed.

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**References** [1] Qing X. Yang et al., J. Magn Reson Imaging. Aug 2013; 38(2): 435–440, [2] A.G. Webb, Conc. in Magn. Reson. Part A, Vol. 38A (4) 148–184 (2011), [3] C. M. Collins et al., Proc. Intl. Soc. Mag. Reson. Med., 404 (2014), [4] C. Sica et al., Proc. Intl. Soc. Mag. Reson. Med., 405 (2014), [5] A. Maunder et al., IEEE Trans. Micro. Theory Tech. 61(12) 4667–4677, [6] David M. Pozar, "Microwave Engineering", 4th edition, Wiley (2012).