What peak power do I need from my amplifiers for multi-transmit?

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Purpose To discuss the different factors that affect the power requirements of multi-transmit MRI, with the aim of making it easier to decide what power amplifiers are necessary for a given multi-transmit system.

Outline of Content To the best of our knowledge, very few papers have been published regarding the power requirements for multi-transmit systems. Some publications [e.g. 1-5] mention what power amplifiers they use, but there is little or no discussion of why those amplifiers were chosen. Amplifier peak powers seem to range from 500 W to 1 kW per channel, but with amplifier cost increasing significantly with peak power rating and the number of transmit channels desired, it can be very helpful to determine exactly what power rating is required when purchasing or building a multi-transmit system.

We shall assume that each coil in our multi-transmit array needs to be able to generate a flip angle of 180^0 in the centre of the FOV. We take 180^o as this is generally the highest flip angle required for a pulse sequence. We choose the centre of the FOV as we assume that if we wanted to generate B_1^+ any further away, we would use the coil on the opposite side of the FOV from our transmit array instead. A theoretical maximum power requirement is assumed which is then translated into a required B_1^+ for a given field strength and pulse duration (T = 2 ms) using $\theta = \gamma B_1^+ T$, where θ is the flip angle, and γ is the gyromagnetic ratio.

A simple electromagnetic simulation using commercial software [6] then calculates the B_1^+ generated (β) by 1 W of input power in a phantom from a typical transmit element. From this we can deduce the power needed to be delivered to the coil in order to generate our target of an 180^o flip angle in the centre of the FOV. We can then assume an average power loss between the amplifiers and coil (factor L), and also take into consideration the duty cycle (D) of the amplifier to get a required power rating for our amplifier.

Combining all this information, we can produce a "rough" equation for required amplifier power:

$$\text{Power rating} = (B_1^+ \text{ required} / \beta)^2 * L / D$$

For an example of a 25 cm dipole coil operating at 7T, we have a required B_1^+ of 0.839 µT and a simulated B_1^+ of 0.1 µT from 1 W (see Figure 1 for the simulation geometry). In this example we used a homogenous phantom with the same properties as human muscle ($\varepsilon_r = 58$, $\sigma = 0.77\ Sm^{-1}$, $\rho = 1041\ kgm^{-3}$) that roughly approximated the human torso, with arms by the body side, in shape (i.e. and oval cross-section 22 cm high and 45 cm wide). If we also assume a typical duty cycle of 10% and that we are using remote amplifiers (thus giving a loss factor of 2), our required power rating becomes

$$\text{Power rating} = (0.839 / 0.1)^2 * 2 / 0.1 \approx 1.4 \text{ kW}$$

A further literature review of B_1 shimming papers reveals that, in general, when using multi-transmit systems in practice the power required is reduced when compared to conventional imaging, e.g. ~70% drop in peak power is reported in [4]. It has also been observed that the power required to use multi-transmit *in vivo* is lower than that required for phantom imaging, e.g. ~20% drop in peak power is reported in [5]. We can therefore conclude that our "rough" estimate of power required is closer to an upper limit to power requirements, rather than a lower one.

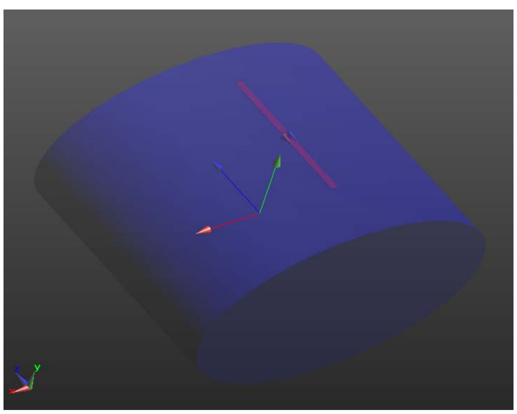

Figure 1 – Simulation geometry for our example of a 25 cm dipole.

Summary Using a combination of some simple simulations and basic MR physics it is possible to establish a "rough" estimate of the peak power required from amplifiers for multi-transmit systems. The values obtained from such calculations are approximately two to three times higher than amplifier values currently in use [1-5], although this method is intended as a simple upper estimate of amplifier power rather than a precise calculation.

References [1] Seifert et al., JMRI 26:1315-1321 (2007). [2] Brunner and Pruessmann, MRM 63:1280-1292 (2101). [3] Wu et al., JMR 205:161-170 (2010). [4] Metzger et al., MRM 59:366-409 (2008). [5] Hetherington et al., MRM 63:9-19 (2010). [6] SEMCAD X by SPEAG, www.speag.com.