Method for Electronically Setting Transmit Gain for non-1H Imaging and Spectroscopy

S. J. Kohler[1], and W. T. Dixon[2]

[1]ASL, General Electric Company, Niskayuna, NY, United States, [2]GRC, General Electric Company, Niskayuna, NY, United States

Introduction. The power needed to achieve the B_1 desired for a pulse sequence depends on the size and position of the sample or subject within the transmit coil. Typically adjusting transmitter gain (TG) is part of the prescan procedure performed before each scan. This process is a minor burden for proton imaging but is more difficult for non-proton imaging. Recent *in vivo* studies with hyperpolarized ^{13}C have awakened interest in ^{13}C imaging and spectroscopy and created the need for new strategies to prepare for scans. Exogenous, hyperpolarized ^{13}C provides enormous signal enhancements (hence the feasibility of ^{13}C imaging), but this signal decays in a matter of seconds, cannot be regenerated in the scanner, and thus is unsuitable for prescan procedures. Obstacles to the observation of endogenous carbon for scan setup include fewer carbon than hydrogen atoms in tissues, its four times weaker magnetic moment than ^1H, lower natural abundance of the active isotope (1%), and, should signal averaging be needed, longer T_1.

Rationale. We investigated purely electronic measures as a practical means for setting the transmitter power. A small loop to couple directly to the transmit coil either capacitively or inductively should give an output directly proportional to B_1. Loading by the subject or sample should not affect this proportionality as long as the loaded Q remains high. For a given transmit coil, an initial calibration using an enriched sample would provide calibration of the signal from the pickup coils. Pulses of standard duration are applied and their strength is adjusted to find the null signal when a 180 pulse is applied. Knowing the pulse flip and duration, its B_1 is known. Dividing this B_1 by the probe voltage gives a calibration constant for the coil. When that coil is used later, B_1 can be determined with no NMR measurement by multiplying the probe voltage by the calibration constant.

Experiments. Carbon experiments were done with a 16-rung birdcage coil, 9 cm in diameter and 18 cm long. This coil, described elsewhere, can be linearly driven either at the carbon resonance frequency (16.06 MHz) or, orthogonally, at the sodium resonance frequency (16.89 MHz). The sample was a 3 mL cylindrical vial of sodium ^{13}C-1-acetate, centered in a ½ liter, saline-filled, plastic bottle. A single loop approximately 1 cm in diameter taped to the inside of the plastic birdcage form served as the pickup coil. Varying the saline concentration controlled the coil loading. For each salt concentration, TG was adjusted to give a 180 pulse (TG180). Figure 1 shows the transmitter power needed for a 180 pulse as a function of coil loading. The voltage in the pickup coil at TG180 measured as a function of coil loading is shown in Figure 2. The observed voltage in the pickup coil and thus the B_1 was constant for all experiments.

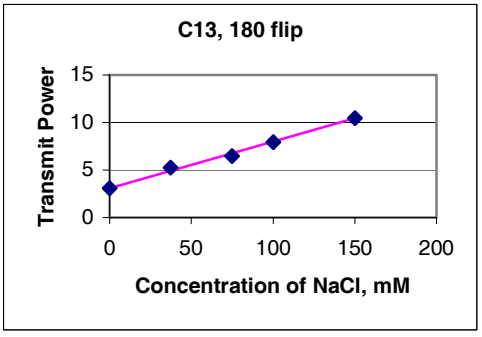

Figure 1. Transmit power as a function of sodium chloride concentration.

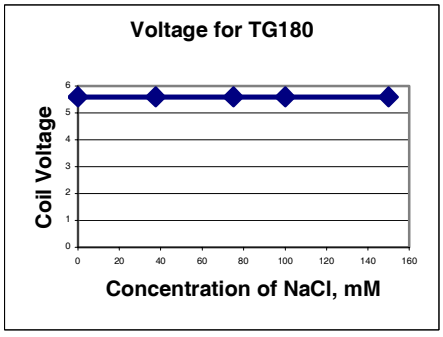

Figure 2. Pick-up coil voltage as a function of coil loading.

In another experiment, a small sample of nearly saturated sodium chloride solution was placed in the same birdcage coil operated at the sodium frequency. Two pieces of meat were used as a phantom to mimic the loading of a coil that a rat might produce. Two pickup coils were placed in the coil, and the voltages for TG180 under the various loading conditions were measured. Again, the voltages measured in the pickup coils when the transmitter power was manually set to TG180 remained approximately constant under the various loading conditions. Similar results were obtained when this method was used to set the TG for ^1H imaging. Figure 3 shows a series of ^1H images obtained from a 28 cm diameter spherical phantom. The images of the first row were acquired with the phantom inserted in a conductive ring that loads the coil and thus changes the power requirements. TG was set to the proper power for a 90 degree pulse as determined by the automatic prescan (APS) process (column 1) and with an extra 5.7, 6.0, 6.3, and 6.6 dB of power to produce images with flip angles in the region around 180 degrees. The second row is a repeat of the experiment of the first row without the loader. Again, APS was used to determine the power for a 90 flip and then images were taken with increased power levels to probe the region around 180 flips. Visual examination shows that the autoprescan process sets TG to within approximately 0.3 – 0.6 dB (a shift of one-two columns). A similar accuracy is seen when setting the TG by means of matching the voltage in the pickup coils to that measured when using APS. The images of rows 3 & 4 were obtained by setting TG to match the voltages observed in the pickup coils for the images in row 1. The images in rows 3 and 4 match those in row 1 with a shift of 1-2 columns, an error of 0.3 – 0.6 dB.

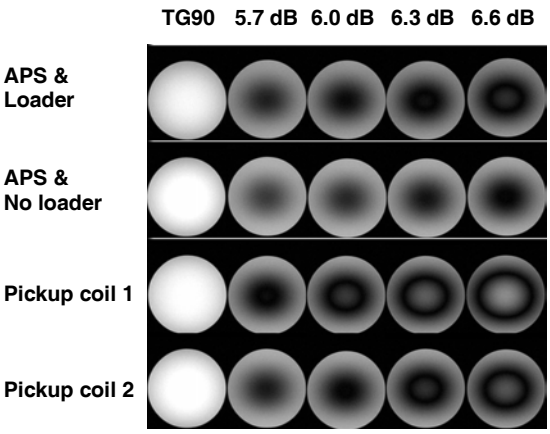

Figure 3. ^1H images as a function of transmit power.

Conclusions. Our experiments have demonstrated the feasibility of using electronic means for setting the transmitter gain without observing nuclear signals. This technique may be useful for either sodium or carbon imaging in cases where there is insufficient endogenous signal for direct prescan. This method could be used as well for setting the transmit power for imaging and spectroscopy of other non-^1H nuclei such as ^{15}N where low endogenous signal precludes direct prescan.