^{19}F[-^{1}H] Time-Share Decoupling Using a Whole Body 1.5 T NMR System and Surface Coils Suitable for Clinical Studies

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Introduction

In vivo ^{19}F MRS studies of the anti-cancer drug 5-fluorouracil and its metabolites in patients suffer from low signal-to-noise ratios (S/N) and poor resolution. For some metabolites (e.g. FBAL) this is caused by J-coupling between the ^{19}F nucleus and neighbouring ^{1}H nuclei, producing a multiplet structure (Fig 2a). Both S/N and spectral resolution are hence improved by ^{19}F[-^{1}H] decoupling. However the close frequencies of the two nuclei means increased noise in the spectrum originating from the ^{1}H decoupler; the receiver may also be driven to saturation by the strong ^{1}H pulse.

To overcome this the authors previously implemented the time-share modulation method [1] on a whole body 1.5 T system. Superior S/N performance compared with the WALTZ-4 method was demonstrated when coils of high isolation (-30dB; 2 cm ^{19}F solenoid orthogonal to 17cm ^{1}H Helmholtz) were used [2]. However coils suitable for clinical studies (e.g. double-resonant surface-coil systems) generally have much poorer isolation between the ^{19}F and ^{1}H components. This abstract demonstrates how time-share decoupling may be achieved with such coil systems.

The Time-Share Modulation Method

In this method, the ^{1}H decoupling pulses are interleaved with the ^{19}F ADC sampling points (Fig. 1), giving the least interaction between the two channels during data acquisition, thus reducing the observable ^{19}F noise which originates in the decoupler.

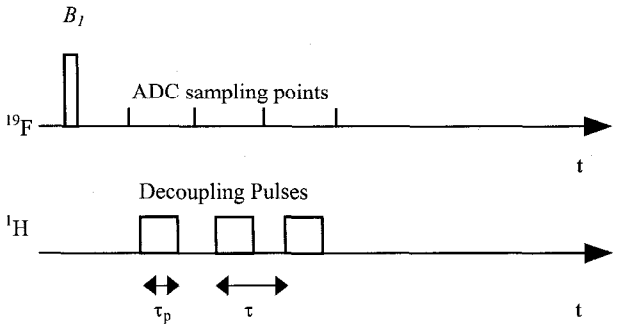

Fig. 1 Schematic diagram of the time-share decoupling method.

Decoupling Bandwidth: The frequency response of the pulse train is a series of discrete components separated by $1/\tau$. Each component is a sinc function with bandwidth of $2/\tau_{dec}$, where τ_{dec} is the total length of the pulse train. Hence, for an experiment with a dwell time (τ) of 1 ms and a τ_{dec} of 120 ms, the spectral width would be ±500 Hz, adjacent decoupling frequency components would be 1000 Hz apart, and the bandwidth of each decoupling frequency component would be 17 Hz. Only the central frequency component contributes to the decoupling.

Increasing the Isolation between ^{19}F and ^{1}H Surface Coils

Our double-frequency coil setup is a 10 cm diameter ^{19}F surface coil surrounded by a flexible 15 cm ^{1}H butterfly coil [3]. When loaded the measured isolations between the coils were -13 dB (^{19}F frequency) and -16 dB (^{1}H frequency). The isolation was improved by using: (i) Two RF filters (a notch and a bandpass) in both the ^{1}H transmit and the ^{19}F receive lines; (ii) A programmable attenuator placed between the duplexer and the pre-amplifier in the ^{19}F channel. For the time-share experiment, a synchronised trigger signal was supplied from the SMIS system (see below) to the attenuator such that the attenuator would be activated only when the ^{1}H pulses were on, thus providing extra isolation (-38.5dB) between the probe and the receiver system. The continuous ^{1}H pulse in the WALTZ-4 method means this switching cannot be applied to the WALTZ-4 experiment.

Experimental Method

Studies were performed using a Siemens Vision 1.5 T whole body system (for magnet and ^{19}F channel) and a triggered SMIS MRS console (^{1}H channel). Since FBAL is hard to obtain, a 130 ml sphere of 47 mM 4-fluoro-dl-glutamic acid (FGA) was used for testing the method; FGA exhibits a multiplet structure identical to that of FBAL. The ^{1}H coil was loaded with saline bags to provide similar loading to that of *in vivo* studies.

The pulse-and-acquire ^{19}F sequence had a dwell time of 1 ms. The ^{1}H decoupling sequence used τ_p=600 μs and τ=1 ms. For comparison, a WALTZ-4 experiment (1 ms for each 90° pulse element) was also performed. Decoupling pulses were applied during the first 120 ms (τ_{dec}) of the acquisition time in each scan. The acquisition parameters were: TR=2 s., 8 acquisitions, 1 pre-scan, 512 sampling points, and 0.61 W average power (the power required for proper WALTZ-4 decoupling) for both sequences. The time-share experiment was repeated with a 4 W power.

Results

Fig. 2b shows that the WALTZ-4 method introduced a large amount of decoupling noise (the first 120 ms of the FID). Moreover, the decoupled peak had "disappeared" from the spectrum. This was found to be a result of the receiver system having been saturated and hence no longer able to amplify and detect signals properly. Fig. 3 shows results from the time-share method, where negligible decoupling noise was introduced and no receiver saturation was induced. Power deposition simulation shows that when the above time-share sequence is used, the SAR limit (8W/kg over 5 mins. in any 1 gram of tissue in the head and torso regions) is not exceeded even when an average decoupling power of 4 W is applied; this therefore permits *in vivo* applications of the time-share method.

Conclusion

The time-share method is shown to give superior S/N performance over the WALTZ-4 scheme using the same filter arrangement and average power. The use of a programmable attenuator prevents receiver saturation even when a clinical coil system is used with poor isolation between the ^{19}F and ^{1}H coils. Hence, the time-share method can be implemented on a standard clinical NMR system to perform ^{19}F[-^{1}H] decoupling *in vivo*. Clinical studies using the time-share decoupling method on patients receiving 5-fluorouracil treatment are now commencing.

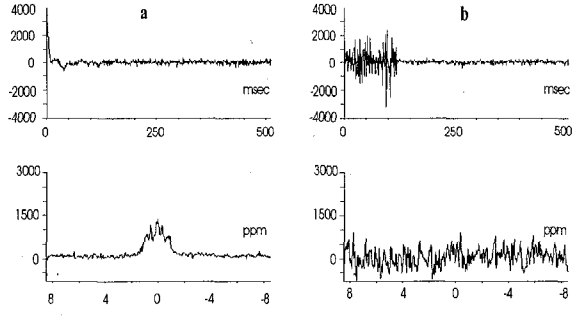

Fig.2 *In vitro* FGA FIDs/spectra: (a) Without decoupling; (b) Decoupled using WALTZ-4 (0.61 W). Decoupling on for the first 120 ms.

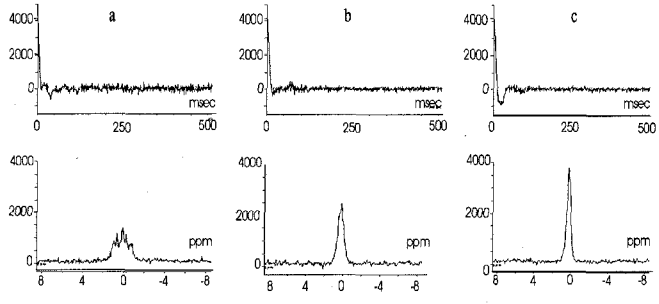

Fig.3 *In vitro* FGA FIDs/spectra: (a) Without decoupling; (b,c) Decoupled using time-share (0.61 W (b), 4 W (c)). Decoupling on for the first 120 ms.

References

[1] Jesson, J.P., *et al., J. Am. Chem. Society,* **95,** 618 (1973)
[2] Li, B.S.Y., *et al., ISMRM Abstracts,* 1891 (1998)
[3] Murphy-Boesch, J., *et al., ISMRM Abstracts,* 1430 (1996)

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