Impedance Matching with an Adjustable Segmented Transmission Line

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Introduction

Impedance matching is the basic requirement in magnetic resonance engineering. It is often a tedious task too, because different sample detectors have different impedance, and even the same detector may have dramatically different impedance under different sample loading conditions. This makes it necessary to build different matching network for different cases, where each matching circuit has limited accessible impedance range. Here, we propose an alternative matching network based on multi-segment transmission line which will promise to have a wider accessible range. There are several attractive features of the adjustable segmented line—it requires no adjustable capacitors, it has no sliding contacts that might wear, and it is capable of matching a very wide range of loads, both inductive and capacitive. These interesting features can allow us to use the same matching circuit for different sample detectors, or for one sample detector under different loading conditions.

Experimental

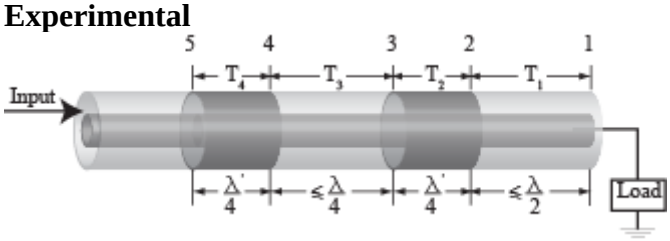

Fig. 1: The schematic representation of the segmented transmission line.

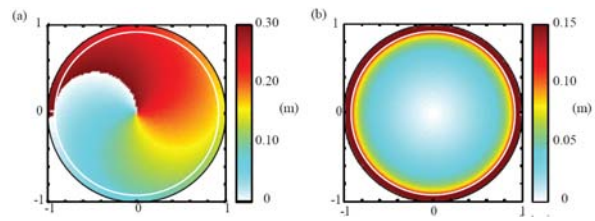

Fig.2: Length of T_1 (a) and T_3 (b) required to match the full range of load reflection coefficients.

The four-segment transmission line was constructed by inserting two dielectric slugs into a rigid coaxial line (Fig. 1). Both the inner and outer tubes of the coaxial line were made of OFHC copper tubing. The outer tube has an OD of 0.625 inch and an ID of 0.571 inch, while the inner rod has an OD of 0.25 inch. This particular dimension was chosen so that the empty coaxial line would have a characteristic impedance of approximately 50 Ω, equal to the system impedance of the spectrometer. The two dielectric slugs were fabricated from Macor (Corning, Inc.). The slugs were fabricated to have an outer diameter of 0.564 in. and an inner diameter of 0.254 in., which gave them enough clearance within the copper tubes to move freely up and down. Each slug was 6.8 cm in length.

Results and Discussion

The adjustable segmented transmission line was used to tune and match a variable angle spinning probe for solid state NMR at a set of four frequencies under different sample loading conditions. We measured the positions of dielectric slugs and compared them with the results of a circuit analysis (Fig. 2). Good agreement is found between experiments and theory. As long as the load reflection coefficient is smaller than a threshold value $\rho_{load}<(\varepsilon^2-1)/(\varepsilon^2+1)$, where ε is the effective dielectric constant of the two mobile slugs, good power efficiency can be obtained.

Conclusions

The adjustable segmented transmission line utilizes the multiple reflections between each segment to achieve overall impedance matching at the input port. By empirically adjusting the position of its two quarter wave slugs, both inductive and capacitive loads can be matched. Although this report has only described the application for solid state NMR, it may have utility in other areas of magnetic resonance, particularly where a single tuning network is needed that can accommodate a great range of load impedance. An example of such an application may be probes for magnetic resonance imaging that are highly loaded, and so are subject to large shifts in load impedance by the range of possible samples or patients.

Acknowledgements

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