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Nuclear Magnetic
Double Resonance Experiments

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ABSTRACT

A simple, inexpensive transmission line filter is described. The unit will pass 14 MHz with 0.15 db loss per section, and attenuate 56 MHz with 20.5 db attenuation per section.

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INTRODUCTION

Experiments over the past few years have demonstrated the enormous capability of nuclear magnetic double resonance techniques to probe details of chemistry and structure of molecules in the solid state.¹⁻⁴ It is frequently a requirement of such experiments that low level (microvolt) signals at one frequency (e.g., 14.1 MHz for ^{13}C at 14 Koe) are to be detected in the presence of high level (hundreds of volts) signals at another (e.g., 56 MHz for ^1H). In particular, experiments requiring a homogeneous H_1 field, e.g., those leading to heteronuclear dipolar modulated chemical shift spectra for the determination of geometrical information in randomly oriented solids, almost demand a single coil configuration. The filtering requirements in such experiments are quite severe relative to crossed coil configurations, and even the best available single coil probes^{2,4} still require considerable filtering of the high frequency in order to receive signals at the lower frequency. The present paper describes a filter which is simple and inexpensive to construct, which can be used at high (~ 1 Kw) or low powers, and which for two frequencies differing by roughly a factor of four yields 0.15 db insertion loss to the low frequency, and 20.5 db attenuation of the high frequency per section.

I. CIRCUIT DESCRIPTION

One section of the filter is shown in Fig. 1. The filter makes use of the fact that a shorted quarter wavelength transmission line will exhibit a maximum resistive impedance when measured at any point (except the shorted end) along the line. This fact may be shown as follows: the admittance of a lossless transmission line of length D wavelengths, with characteristic impedance Z_0 , and load impedance Z_L (c.f., Fig. 2a) is⁵

$$Y_D = \frac{Z_0 + jZ_L \tan 2\pi D}{Z_0(Z_L + jZ_0 \tan 2\pi D)} \quad (1)$$

This result may be applied to the problem of calculating the admittance, Y_P , of a shorted, quarter wavelength cable when determined at any point, P (see Fig. 2b), at a length d along the cable. In this case, the circuit consists of two admittances, Y_d and $Y_{(0.25-d)}$, in parallel. The admittance of section d is calculated with an infinite load impedance, $Z_L = \infty$, and length, $D=d$, from equation (1). The admittance of section $(0.25-d)$ is calculated from (1) using $D = 0.25-d$, and $Z_L = 0$. The admittance of the two parallel circuits is

is therefore infinite, and the circuit acts as a shorted quarter wavelength for any value of $d \neq 0.25$. If in addition the distance, d , is chosen to be a quarter wavelength for some higher frequency, f_H , with wavelength λ_H , then at the point P the impedance for this frequency is zero. Signals at f_H will therefore be highly attenuated at point P. It need not concern us here that for the case chosen the lower frequency, 14.1 MHz, is almost exactly a quarter of the higher frequency, 56 MHz, and that therefore the shorted stub will be $3\lambda/4$ at 56 MHz, since the admittance of the open and shorted section in parallel will still be infinite, and therefore the impedance at point P will still be zero at 56 MHz.

In the actual filter shown in Fig. 1, f_H will see a high impedance looking into the filter because the short at point a will experience a quarter-wave transformation by $\lambda_H/4$. The filter will appear as a section of transmission line at f_L .

II. FILTER EFFECTIVENESS

A filter designed to pass 14.1 MHz in the presence of 56 MHz was constructed from RG 58 CU coaxial cable, with a total length of $\lambda_L = 351$ cm, and $\lambda_H/4$ of 88 cm. In order to demonstrate the capabilities of the unit at these frequencies two experiments were performed. In the first, a pulsed signal of 14.1 MHz, with a peak to peak voltage of 200 volts was fed into the input, and detected at the output of four series

sections of the filter. The output was found to be 187 volts peak to peak, indicating an insertion loss of 0.6 db, or .15 db per section. The results of this experiment are shown in Fig. 3. The second experiment tested the capability of the unit to filter 56 MHz. A pulsed 56 MHz signal, 200 V_{pp} was fed into the input of four sections of the filter, and the output monitored, as shown in Fig. 4. The output during the center of the pulse was found to be 0.015 V_{pp}, indicating a total attenuation of 82 db at 56 MHz.

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FIGURE CAPTIONS

Figure 1. One section of a transmission line filter. The unit will pass a low frequency, with wavelength λ_L , and attenuate a high frequency, with wavelength λ_H .

Figure 2. a) Section of transmission line with characteristic impedance Z_0 , load impedance Z_L , and length D .

b) Section of transmission line tapped at point P. Circuit in this case consists of two parallel sections of length d and $0.25 - d$. The total length is 0.25 wavelengths.

Figure 3. Measurement of insertion loss at $f_L = 14.1$ MHz. Signal to left is 200 V_{pp} signal at input of filter. Signal to right is output of filter, which is 187 V_{pp} . Total insertion loss is 0.6 db for four sections of filter.

Figure 4. Measurement of attenuation of $f_H = 56$ MHz. Signal in, 200 V_{pp} , above. Signal out, 0.015 V_{pp} , below. Attenuation = 82 db for four sections.

TRANSMISSION LINE FILTER (ONE SECTION)

Figure 1.

Figure 2.

a

b

Figure 3.

Figure 4.