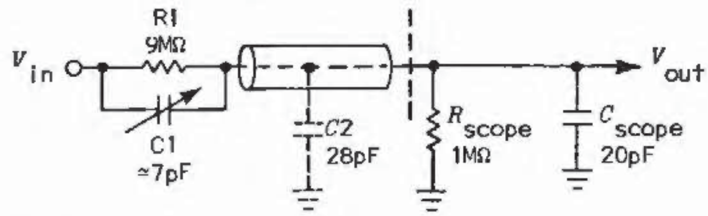

Fig. 2-7. Compensated 10X probe with 8 pF/ft *R* cable.

Let us determine the required value of C1. For a 3.5 ft cable with 8 pF/ft, C2 is 28 pF. C_{scope} and C_2 shunt R_{scope} by 48 pF, however, about 2 pF should be added for connector capacitance. C1 can reasonably be approximated at 5.5 pF. Again add about 1.5 pF for probe tip capacity to obtain 7 pF at the probe tip. The capacity shunting R1 has been reduced by a factor of 2 (from 14 pF to 7 pF) by the use of *R* cable!

We must resort to transmission line theory to analyze the response of this passive circuit to high speed signals. To obtain the best results from any transmission line, we should terminate the line in its characteristic impedance. The characteristic impedance of a coaxial cable is given by:

$$Z_0 = \sqrt{\frac{R_{series} + j\ \omega\ L}{G_{shunt} + j\ \omega\ C}}$$

In a lossless cable, G_{shunt}, the dielectric loss, is insignificant and the series resistance of the high conductance wire is also insignificant. Letting *R* and *G* go to zero, we obtain the familiar formula for the characteristic impedance of a lossless line.

$$Z_0 = \sqrt{L/C}$$

In a lossy line, the dielectric losses can also be ignored but the series resistance is significant. Thus, letting G_{shunt} go to zero and rearranging the terms we have:

$$Z_0 = \sqrt{\frac{j\ \omega\ L}{j\ \omega\ C} + \frac{R_{series}}{j\ \omega\ C}}$$

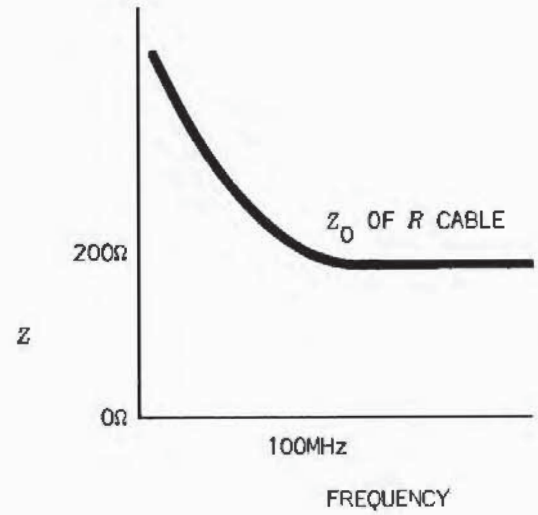

Fig. 2-8. Z_0 of R cable vs frequency.

The term on the left reduces to the familiar $\sqrt{L/C}$ which is independent of frequency. The term on the right varies with frequency. As frequency increases, $j\omega C$ increases. Thus we state that Z_0 goes to $\sqrt{L/C}$ as frequency goes to infinity. In practice, Z_0 approximates $\sqrt{L/C}$ when the applied frequency is greater than 100 MHz. See Fig. 2-8. For Tektronix probe cables, the $\sqrt{L/C}$ ranges from 175 Ω to 200 Ω.

The response of R cable to a step function input is shown in Fig. 2-9. The output signal is an attenuated fast rise followed by a slow "dribble up" to the amplitude of the input step signal. The amplitude of the fast rise portion is inversely proportional to the resistance of the center conductor. We note some ringing exists on the dribble-up portion of the output signal because the cable is not terminated. For oscilloscopes with 30% down frequencies of 30 MHz or less, an unbypassed resistor in series with the cable at the probe head will meet the requirements of a termination. See Fig. 2-10B.

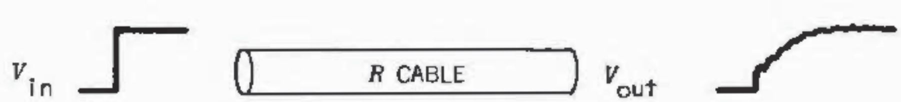

Fig. 2-9. Response of R cable to fast rise pulse.