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ATTENUATING LINE FOR ULTRA HIGH FREQUENCIES

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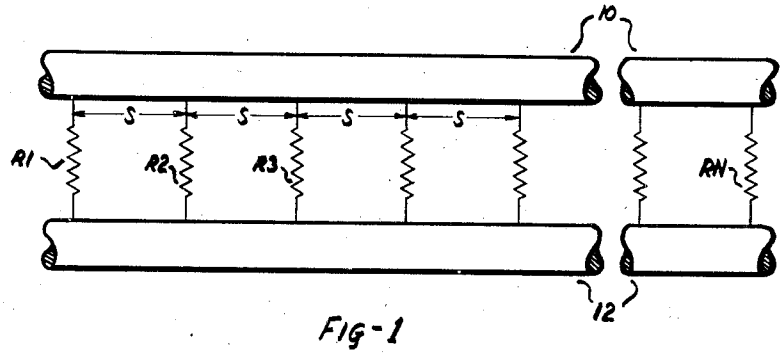


FIG-1

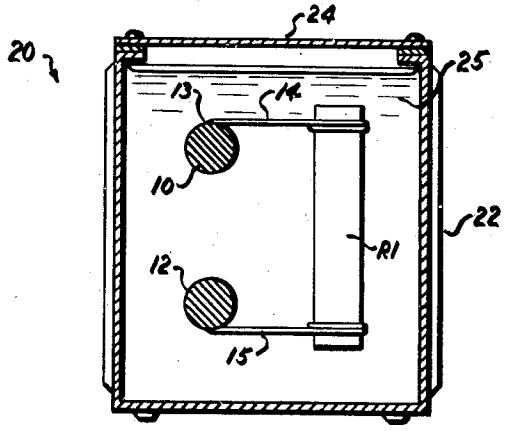


FIG-2

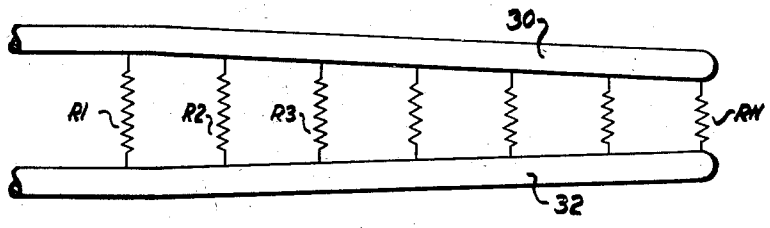


FIG-3

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ATTENUATING LINE FOR ULTRA-HIGH FREQUENCIES

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2 Claims. (Cl. 178—44)

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This invention relates to resistors, and more particularly to attenuating lines for ultra-high frequencies.

I have discovered that a small compact attenuating line can be made, which is capable of simulating at ultra-high frequencies some of the electrical characteristics of an actual line many wavelengths long. The attenuating line in accordance with my invention may comprise a short piece of dual transmission line bridged at spaced points therealong by a plurality of high resistance resistors. The conductors of the line may be either parallel or they may be so disposed that the spacing therebetween is tapered. I find that by selecting highly resistant resistors having low inductance and low distributed capacitance, and spacing them along the length of the section of transmission line, the conductors being arranged in parallel or tapered relation as desired, the spacing between adjacent resistors being very small compared to the wavelength and the resistance of each resistor being large compared to the surge impedance, a compact attenuating line may be constructed which is capable of behaving satisfactorily over a wide waveband at ultra-high frequencies.

A wave, upon entering the attenuating line, behaves very nearly as it would if there were no resistors present. That is, the voltage and current relation is determined mostly by the propagation constants of the line disregarding the resistors. However, as the wave progresses down the line, each resistor, as the wave passes by, subtracts a small amount of power from the wave. Thus, the power remaining in the wave becomes less and less the farther down the line it progresses. If the line is sufficiently long, the power in the wave is very small by the time it reaches the end of the line. Thus, viewed from the input of the line, there is no reflected wave present, but only a forward wave and the applied power is substantially wholly absorbed. This is the condition for a flat or "matched" line, and the impedance looking in is substantially independent of frequency.

The resistors selected for the attenuating line may be of any suitable material such as plain carbon and carbon compositions capable of dissipating power at the rate of about one or one-half watt. These resistors may be used with insulating covering or coating but I prefer to use them without insulation. By using a large number of these resistors to avoid danger of overloading, I find that the attenuating line so constructed will dissipate the absorbed power without injurious effects.

The resistors may be all of the same value or they may be graded, the resistance in the latter case decreasing in the direction away from the input end of the line. By properly grading

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the resistances of the resistors, either consecutively or by groups, the heat dissipation may be substantially evenly distributed throughout the length of the line.

The attenuating line may be immersed in a suitable liquid to increase the dissipation of heat and vary the impedance of the line.

It is one of the objects of this invention, therefore, to provide a small compact attenuating line capable of simulating the attenuation characteristics of an actual line many wavelengths long.

Another object of the invention is to provide an attenuating line capable of behaving satisfactorily as a dissipating load over a wide waveband at ultra-high frequencies.

Still another object of the invention is to provide an attenuating line capable of dissipating the power absorbed thereby without injurious effects to the structure thereof.

The above objects and others ancillary thereto will become further apparent upon consideration of the following detailed description to be read in connection with the accompanying drawing, in which:

Fig. 1 is a schematic illustration of a portion of the attenuating line constructed in accordance with this invention;

Fig. 2 is a cross-sectional view of an attenuating line of this invention showing the manner in which the resistors may be connected to the conductors of the line; and

Fig. 3 is a schematic illustration of another form of attenuating line of this invention.

Referring to Figs. 1 and 2 of the drawings, the attenuating line of this invention may be used on a frequency range of from about 5 or 10 megacycles to several hundred megacycles, the line comprising a pair of transmission line conductors 10 and 12. These conductors may be about a foot, more or less, in length and bridged by a plurality of high resistance resistors R1 to RN and spaced apart along the length thereof. The resistors may each be of the same resistance throughout the length of the line, but in order to obtain substantially equal dissipation of energy throughout the length thereof, the resistors may be graded, the resistance of the resistors in the latter case decreasing from R1 at the input end to a smaller resistance at RN adjacent the opposite end of the line. The grading may be gradual, that is, 200 or 300 ohms, more or less, between consecutive resistors, or the grading may be made by groups of resistors each group comprising two or more like resistors.

By way of example, I caused an attenuating line having graded resistors to be made which was used satisfactorily as a load, dissipating about 10 watts at a frequency of 330 megacycles. The line used is about 10 inches long and has a surge impedance of 215 ohms. Thirteen one-watt re-

sistors bridge the conductors of the line at about one centimeter intervals. The thirteen resistors have the following values starting with the resistor at the input end of the line: 3400, 3100, 2800, 2500, 1800, 1500, 1200, 900, 550, 380, 220, 140 and 60 ohms, respectively.

In a construction designed to maintain the inductance and capacitance of the line at a minimum so that the line has the appearance of substantially pure resistance load, I use straight ordinary bar-like carbon and carbon composition resistors which are obtainable in the market. These carbon resistors are provided at the ends thereof with leads **14** and **15** soldered or otherwise secured thereto which may easily be soldered to the conductors **10** and **12** as indicated at **13** in Fig. 2.

The spacing S between adjacent resistors may be chosen at about 1 cm. so as to make a compact attenuating line. This spacing S is not critical but should be sufficient to prevent the carbon resistors from touching each other.

Ideally, the resistance of any single resistor R should be large compared with the surge impedance of the line while the spacing S should be quite small compared with the operating wavelength. The value of the resistors may be as low as about 10 times the surge impedance of the line and still produce, where 10 or more resistors are used, a substantially flat line effect. By using a larger number of resistors having values higher than 10 times the surge impedance of the line, a more nearly exact flat line effect can be produced. The attenuating line constructed in accordance with my invention closely approximates this ideal attenuation, and the following approximate formulae can be derived neglecting

$$\left(\frac{G}{\omega C}\right)^2$$

compared to unity:

$$\text{Surge impedance } Z_0=\sqrt{\frac{L}{C}\left(1+j\frac{G}{2\omega C}\right)}$$

Attenuation constant

$$\alpha=\frac{G}{2}\sqrt{\frac{L}{C}}=4.35GZ_0 \text{ db./unit length approximately}$$

where L and C are inductance and capacitance per unit length of line, respectively, G is conductance per unit length, ω is the angular frequency and $j=\sqrt{-1}$.

By way of example, a line made up of resistors of 9500 ohms each, spaced one centimeter apart, and a surge impedance Z_0 of the line being equal to about 215 ohms, the attenuation of the line may be solved thus:

$$\text{Conductance } G=\frac{1}{R}=\frac{1}{9500}=106\times10^{-6} \text{ mho/cm.}$$

$$\text{Attenuation}=4.35GZ_0=4.35\times106\times10^{-6}\times215$$

Attenuation=.099 db./cm.=9.9 db./meter

The attenuating line of my invention may be provided with a tapered transmission line such as indicated by conductors **30** and **32** (Fig. 3). By bridging between the conductors a plurality of high resistance resistors R a short tapered line may be made. The resistors may be either of the same resistance or graded as described in connection with the form shown in Fig. 1.

In order to increase the dissipation capability of the attenuating line, the line may be immersed in a suitable liquid **25** contained within a housing **20** having corrugated side walls **22** and a cover **24**. In this way, the heat liberated by the resistors R1 to RN of the line may be equally distributed and dissipated by the liquid contacting the extended radiating surfaces of the housing **20**.

Since different liquids may be used for this purpose, I am able by my invention to select a liquid having a desired dielectric constant and thereby vary the capacitance of the line should it be desirable to increase or reduce, as the case may be, the surge impedance of the line. In this way, I am able better to control the impedance characteristics of the line and make it have, over a wide band of frequencies, an appearance more closely approximating pure resistance.

From the foregoing, it will be readily apparent that many variations in the construction and arrangement of the resistors relative to the conductors of the line may be made without departing from the invention. It will be understood, therefore, that the embodiments herein shown and described are to be regarded as illustrative of the invention only and not as restricting the appended claims.

What I claim is:

1. A substantially flat load of the type adapted to terminate an ultra-high frequency circuit operating at a frequency of more than five megacycles, consisting of a compact attenuating line comprising a pair of spaced-apart conductors, and a plurality of high resistance resistors having low inductance and low capacity bridged between said conductors, the spacing between adjacent resistors being small compared to the wavelength of the applied frequency, said resistors being so graded that the resistances thereof decrease in a direction away from the input of the line, the power applied thereto being dissipated substantially evenly along the length of the line.

2. A substantially flat load of the type adapted to terminate an ultra-high frequency circuit operating at a frequency of more than five megacycles, consisting of a compact attenuating line comprising a pair of spaced-apart conductors, and a plurality of high resistance resistors having low inductance and low capacity bridged between said conductors, the spacing between adjacent resistors being small compared to the wavelength of the applied frequency, said resistors being so graded that the resistances thereof decrease in a direction away from the input of the line, the power applied thereto being dissipated substantially evenly along the length of the line, at least some of said resistors having a resistance at least ten times the value of surge impedance of the line.

CHESTER B. WATTS, JR.

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