Feb. 17, 1942. R. VON RADINGER 2,273,547

OHMIC RESISTANCE FOR ULTRA-SHORT WAVES

Filed Oct. 19, 1939

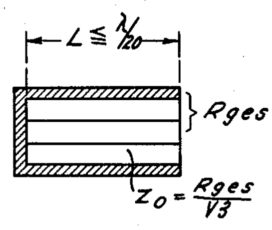

Fig. 1

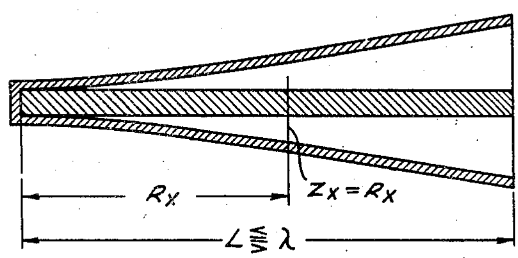

Fig. 2

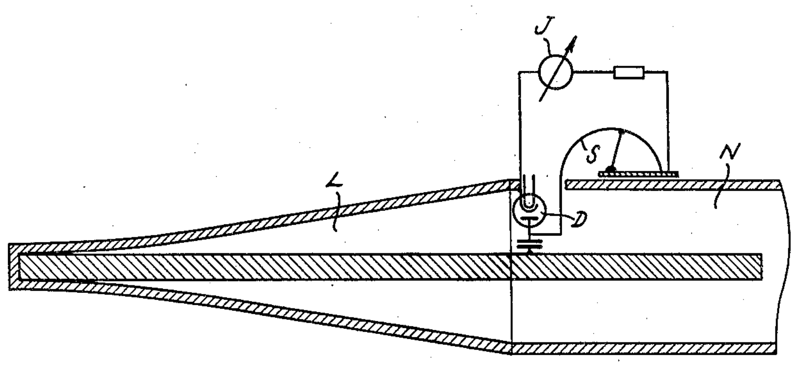

Fig. 3

INVENTOR.
RUDOLF VON RADINGER
BY H. S. Grover
ATTORNEY.

Patented Feb. 17, 1942

2,273,547

UNITED STATES PATENT OFFICE

2,273,547

OHMIC RESISTANCE FOR ULTRA-SHORT WAVES

Rudolf von Radinger, Berlin, Germany, assignor to Telefunken Gesellschaft für Drahtlose Telegraphie m. b. H., Berlin, Germany, a corporation of Germany

Application October 19, 1939, Serial No. 300,161
In Germany October 28, 1938

3 Claims. (Cl. 178—44)

Resistances are required for measuring work the value of which, inside a given frequency band, is independent of the frequency and purely ohmic. For work within the meter-wave range resistances have been used in the past consisting of an insulation support in tubular or rod shape upon which a tenuous coat of resistance material was brought. Fundamentally speaking, these resistances are useful in practice as long as the said coat is thin compared with the depth of penetration of the current for the material and the measuring frequency which are used, and this probably always is practically possible. However, where ultra-high frequencies are dealt with, say, from 10^8 to 10^9 cycles per second the inductance component of such a resistance, even when of short length, is no longer negligible. The same situation holds good for the capacitive shunt (leakance).

It is known in the art that in such cases nearly purely ohmic resistances are obtainable up to a maximum frequency having values which do not appreciably differ from the direct current resistance if the inductance and the capacitance of the resistance per unit of length bear a definite relationship to each other. (Chaperon winding, winding of the Wagner-Wertheimer type with wire resistances and relatively low frequencies). For ultra-high frequencies, it is only the coat or layer resistance referred to above which are of practical use. For resistances of this type a proximate method has been disclosed in German Patent No. 618,678 according to which a very close mutual compensation of series inductance and shunt capacitance is obtained if the resistance is so built that it results in a line having the characteristic impedance

$$Z_0=\frac{R_{ges}}{\sqrt{2}}$$

where R_{ges} stands for the aggregate ohmic resistance. Over and above this result an appreciably better compensation is securable by choosing

$$Z_0=\frac{R_{ges}}{\sqrt{3}}$$

However, such a compensation of the reactances is effective only for frequencies in the presence of which the length of the resistance is not over $\lambda/20$ (see Fig. 1), and this is provable by theory.

If the length of the resistance (or resistor) must exceed the $\lambda/20$-mark, say, for thermal reasons, then a solution may be found by the following consideration. Let us suppose first, a piece of resistance according to the above formula having a length less than $\lambda/20$ and a D. C. resistance R_0 and the characteristic impedance

$$\frac{R_0}{\sqrt{3}}$$

the RF input resistance of which therefore is purely real and equal to R_0, and second, that this resistance R_0 is terminated with a piece of line with losses, that is, series resistance, the data thereof being so fixed that the input resistance of this piece of length Δl is again purely real and equal to $R_0+R\Delta l$. From equations relating to a line involving loss or dissipation, for low values of γl there is

$$\text{where } \gamma=\sqrt{(R+j\omega L)(G+j\omega C)}$$

$$R_a=\frac{R_0+R\Delta l+j\omega L\Delta l}{1+j\omega c\Delta lR_0}$$

Now, since the assumption is that $R_a=R_0+R\Delta l$ is strictly real there is

$$\frac{R_0+R\Delta l}{1}=\frac{j\omega L\Delta l}{j\omega c\Delta lR_0}=\frac{L}{cR_0}=\frac{Z^2}{R_0}$$

or $Z^2=R_0(R_0+R\Delta l)$; $Z=R_0$ for Δl tending towards zero. In other words, the characteristic impedance of the line element connected in series with the purely ohmic terminating resistance R_0 must be equal to R_0. This outcome is entirely plausible for it implies and means nothing else but that the characteristic impedance of each line element must be equal to the portion of terminating resistance above it in order that the line may be terminated purely real and perfectly free from frequency dependence. The total length of the line may be of any value at all, in fact, it may be chosen readily of a large value compared with the wavelength.

In its concrete and practical form such a resistance may consist of a conical concentric or co-axial line, the cone obeying an exponential law. The characteristic impedance at each point of the line is chosen equal to the D. C. resistance of the line as far as the short-circuiting point of the line as illustrated in Fig. 2. There is no need for the resistance R being uniformly distributed along the line as assumed in the embodiment Fig. 2. If the resistance layer or coat is non-uniformly distributed (with the layer consisting generally of a surface coat forming an ohmic resistance on the double-wire line, say, a metallic coat or carbon coat applied by means of a plating process or by vaporization), this means that the outer shape of the line must be different and be in accordance with the distribution of the resistance. But the last portion of the line in the neighborhood of the short-circuiting point is preferably dimensioned as shown in Fig. 1 inasmuch as a reduction down to zero level of the characteristic impedance is unfavorable from a technical viewpoint, particularly where air cooling for high-load resistances is to be used. But what must be kept in mind in such case is that this introduces again a certain frequency dependence of the resistance. What must also be taken into consideration is that, since characteristic impedances of any desired high value at all can not be made commercially, it follows that ohmic resistances of any desired high value at all can not be made by this method.

The arrangement of the invention may be used also as RF voltage dividers. What has to be kept in mind in this connection is that the resistances can be made purely real only for a definite load of the tap. But the voltage dividing ratio is always complex.

Fig. 3 shows an arrangement by which the power of ultra-high-frequency transmitters may be determined. Referring to Fig. 3, the resistance line designed according to Fig. 2 is denoted by L. At its input end it is united with the coaxial line N which is brought to the ultra-short-wave transmitter the power of which is to be measured. The ultra-short-wave transmitter, if the input resistance of line L is equal to the characteristic impedance of line N, is terminated with an ohmic resistance being equal to the input resistance of L. The drop of potential occurring at this resistance will then give directly the power to be measured. For this purpose are provided a diode D and a D. C. measuring instrument J. Inasmuch as the input resistance is purely real and independent of the frequency, it follows that the power dissipation of the resistance is determinable by voltage measurement at the resistance input end. The reactance of the diode in this scheme is suitably compensated by a paralleled inductance S for the frequency involved. But this will be necessary only when the diode is not directly connected at the beginning of the resistance.

The invention is not restricted to the exemplified embodiments here described, in fact, any combination of outer line form and distribution of the series and shunt resistances is admissible as long as the above general demand that the characteristic impedance should be equal to the portion of the terminating resistance connected above is fulfilled.

I claim:

1. A circuit arrangement exhibiting substantially pure ohmic resistance characteristics especially for use in ultra-short wave work, characterized by a dissipative double-wire transmission line unilaterally short-circuited and of a length exceeding one twentieth of the wave length, and being of such a form that the characteristic impedance of each line element is equal to the ohmic resistance of the line portion between this line element and the short-circuited line end.

2. Ohmic resistance as claimed in claim 1, with the characteristic feature that the line or series resistance is uniformly distributed over the length of the line, and the ratio of the diameter of the inner and the outer conductors diminishes in accordance with an exponential law towards the short-circuited end of the line.

3. A system comprising a two-conductor transmission line for use in ultra-short wave work, one pair of adjacent ends of said conductors being connected together, input terminals connected to the other pair of adjacent ends, said line exceeding one-twentieth of the wave length and being composed of material having appreciable resistance, the characteristic impedance of said lines at any point thereof being equal to the resistance measured between the conductors at said point.

RUDOLF VON RADINGER.