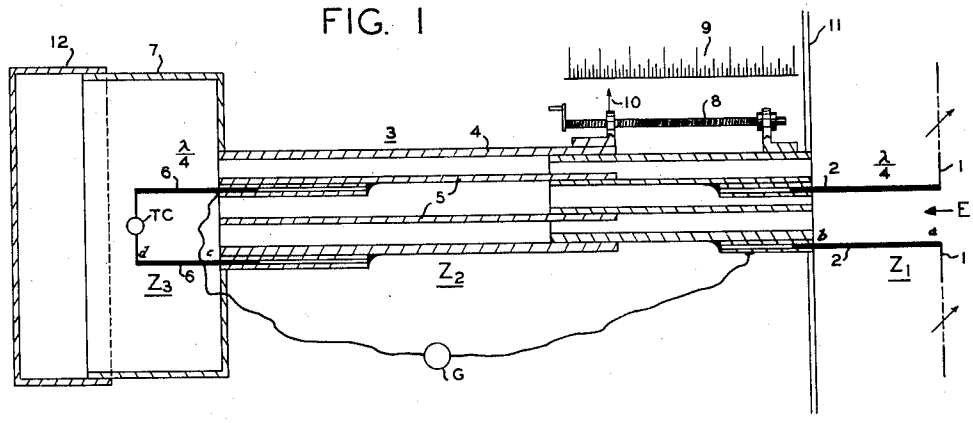
Oct. 10, 1933. A. G. CLAVIER 1,929,878

MICRORAY WAVEMETER

Filed Feb. 29, 1932

FIG. 1



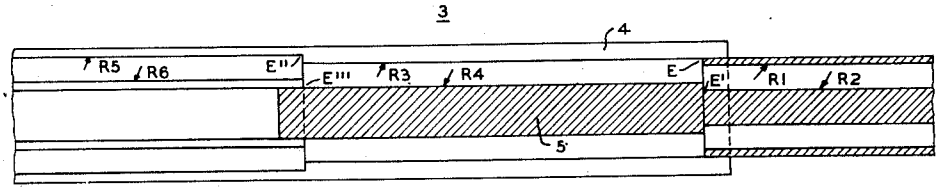


FIG. 2

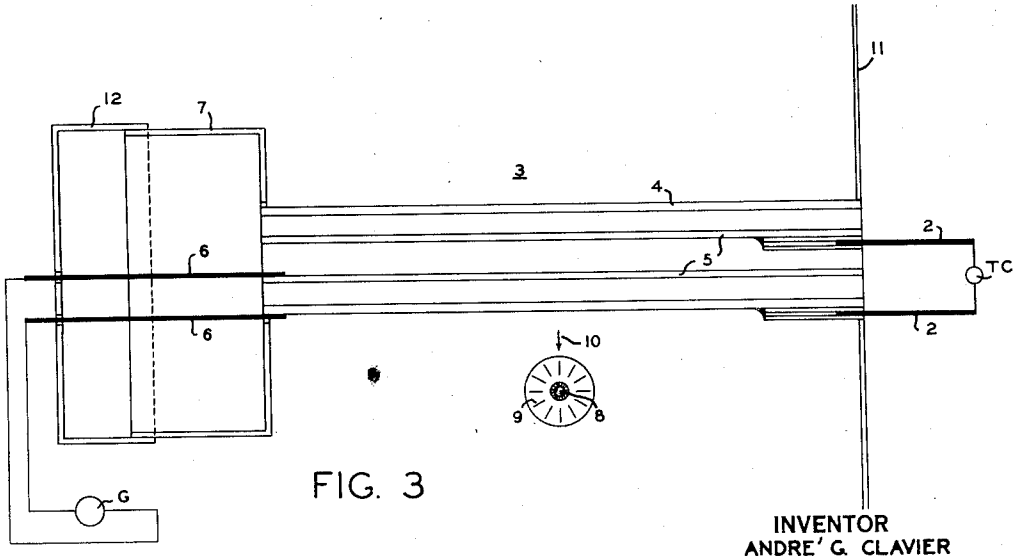


FIG. 3

INVENTOR
ANDRE' G. CLAVIER

BY R C Hopgood

ATTORNEY

Patented Oct. 10, 1933

1,929,878

UNITED STATES PATENT OFFICE

1,929,878

MICRORAY WAVEMETER

André G. Clavier, Glen Ridge, N. J., assignor to International Communications Laboratories, Inc., Newark, N. J., a corporation of New York

Application February 29, 1932. Serial No. 595,764

8 Claims. (Cl. 250—39)

This invention relates to micro-ray wavemeters and transmission lines. In accordance with the disclosure herein a micro-ray transmission line may be so designed that the transmission characteristic of the line is a function of the length of the line and the length of the wave transmitted over the line, so that, by adjusting the length of the line and measuring the adjustments, a suitable wavemeter is obtained.

In accordance with the disclosure herein, it is also possible to design a transmission line so that its transmission characteristics are independent of the length of a certain section of the line. With such a line it is possible to make adjustments in length without setting up disturbances in other parts of a micro-ray signaling system.

By micro-rays is meant electromagnetic waves lying, generally, in the range between 1 and 100 centimeters.

In my U. S. Patent No. 1,928,408 there is disclosed a system for operation in this range.

In the drawing:

Fig. 1 is a diagrammatic sketch of a wavemeter which consists of an adjustable micro-ray transmission line connecting a wave receiving device or antenna to a current measuring device which, in this case, is a thermo-couple connected to a galvanometer;

Fig. 2 is a diagram of a section of a micro-ray transmission line which may be adjusted without changing the characteristic impedance of any part of the same section of the line; and

Fig. 3 is a sketch of a wavemeter, similar generally to that shown in Fig. 1, but in which a wider range of waves may be measured, with a reduced number of adjustments.

In designing a wavemeter in which an adjustable line connects an antenna to a thermo-couple, it is necessary to know the current flowing through the thermo-couple TC, Fig. 1, in terms of the length l of the adjustable line.

In U. S. Patent No. 1,921,117 granted to Rene H. Darbord, such a wavemeter is disclosed. In that patent the adjustable line is connected at each end to a section of line approximately a quarter wave length long, and these sections are connected, respectively, to an antenna and thermo-couple.

Such a system is also shown in Fig. 1, in which an adjustable antenna l is connected to a quarter wave length line 2. This, in turn, is connected to a line 3 which is adjustable as to length and consists of concentric conductors 4 and 5. The adjustable line is connected to another quarter wave length line 6, and the thermo-couple TC is connected across the ends of this line.

We want to find the current flowing through the thermo-couple TC in terms of the length l of the adjustable line. Assume the line itself dissipationless.

Let

ρ be the resistance of the tuned antenna;

ρ' be the high frequency resistance of the thermo-couple;

Z_a be the impedance looking into the wavemeter at point a;

Z_b be the impedance looking into the wavemeter at point b;

Z_c be the impedance looking into the thermo-couple at point c;

Z_1 be the characteristic impedance of the first quarter wave length line;

Z_2 be the characteristic impedance of the adjustable line;

Z_3 be the characteristic impedance of the second quarters wave length line; and

$$\beta=\frac{2\pi l}{\lambda}$$

We have the successive relations:

$$i_a=\frac{E}{p+Z_a} \quad (1)$$

$$\frac{i_b}{i_a}=\frac{Z_1}{jZ_b} \quad (2)$$

$$\frac{i_c}{i_b}=\frac{Z_2}{Z_2\cos\beta l+jZ_c\sin\beta l} \quad (3)$$

$$\frac{i_d}{i_c}=\frac{Z_3}{j\rho'} \quad (4)$$

But:

$$Z_c=\frac{Z_3^2}{\rho'} \quad (5)$$

$$Z_b=Z_2\frac{Z_c\cos\beta l+jZ_2\sin\beta l}{Z_2\cos\beta l+jZ_c\sin\beta l} \quad (6)$$

$$Z_a=\frac{Z_1^2}{Z_b} \quad (7)$$

so that we find:

$$i_d=\frac{Z_3}{j\rho'}\cdot\frac{Z_2}{Z_2\cos\beta l+jZ_c\sin\beta l}\cdot\frac{Z_1}{jZ_b}\cdot\frac{E}{\rho+Z_a} \quad (8)$$

and, finally:

$$i_d=-E\frac{Z_1Z_2Z_3}{Z_2(Z_1^2\rho'+Z_3^2\rho)\cos\beta l+j(Z_1^2Z_3^2+\rho\rho'Z_2^2)\sin\beta l} \quad (9)$$

The amplitude of i_d is found to be:

$$I_d=E\frac{Z_1Z_2Z_3}{\sqrt{Z_2^2(Z_1^2\rho'+Z_3^2\rho)^2\cos^2\beta l+(Z_1^2Z_3^2+\rho\rho'Z_3^2)^2\sin^2\beta l}} \quad (10)$$

Let:

$$A^2=Z_2^2(Z_1^2\rho'+Z_3^2\rho)^2 \quad (11)$$

$$B^2=(Z_1^2Z_3^2+\rho\rho'Z_2^2)^2 \quad (12)$$

Then:

$$I_d=E\frac{Z_1Z_2Z_3}{\sqrt{A^2\cos^2\beta l+B^2\sin^2\beta l}} \quad (13)$$

This gives us the formula for the current through thermo-couple in terms of the characteristics of the lines, the length of the adjustable line, and the frequency of the wave received. We now want to find the conditions for maximum transfer of energy from the antenna to the thermo-couple.

Let:

$$D=A^2\cos^2\beta l+B^2\sin^2\beta l \quad (14)$$

$$\dot{D}\rho=\beta(B^2-A^2)\sin 2\beta l \quad (15)$$

The sign of B^2-A^2 depends on B—A, which may be written:

$$(Z_1^2-\rho Z_2)(Z_3^2-\rho' Z_2) \quad (16)$$

We then have to examine the cases in which the characteristic impedance of the adjustable line, the ratio of the square of the characteristic impedance of the first quarter wave length line to the resistance of the tuned antenna, and the ratio of the square of the characteristic impedance of the last quarter wave length line to the high frequency resistance of the thermo-couple, have different relative values. This gives us six cases to examine, as follows:

(Case *a*)

$$Z_2<\frac{Z_1^2}{\rho} \text{ and } Z_2<\frac{Z_3^2}{\rho'} \quad (17)$$

(Case *b*)

$$Z_2>\frac{Z_1^2}{\rho} \text{ and } Z_2>\frac{Z_3^2}{\rho'} \quad (18)$$

(Case *c*)

$$\frac{Z_1^2}{\rho}<Z_2<\frac{Z_3^2}{\rho'} \quad (19)$$

(Case *d*)

$$\frac{Z_3^2}{\rho'}<Z_2<\frac{Z_1^2}{\rho} \quad (20)$$

(Case *e*)

$$Z_2=\frac{Z_1^2}{\rho} \quad (21)$$

(Case *f*)

$$Z_2=\frac{Z_3^2}{\rho'} \quad (22)$$

In Cases *a* and *b* the sign of $\dot{D}\rho$ is the same as the sign of $\sin 2\beta l$.

In Cases *c* and *d* the sign $\dot{D}\rho$ is apposite to the sign of $\sin 2\beta l$.

In Cases *e* and *f* $\dot{D}\rho$ is always equal to zero.

Let us first discuss Cases *e* and *f*. In these cases $B^2=A^2$ and i_d is independent of *l* and Z_2

$$I_d=E\frac{Z_1Z_3}{Z_1^2\rho'+Z_3^2\rho} \quad (23)$$

$$I_d=\frac{E}{\frac{Z_1}{Z_3}\rho'+\frac{Z_3}{Z_1}\rho} \quad (24)$$

The maximum of i_d occurs when:

$$\frac{Z_1^2}{\rho}=\frac{Z_3^2}{\rho'} \quad (25)$$

so that:

$$I_{dM}=\frac{E}{2\frac{Z_3}{Z_1}\rho}=\frac{E}{2\sqrt{\rho\rho'}} \quad (26)$$

In these cases the current in the thermo-couple is independent of the adjustment of the length of the adjustable line, because this line at one of its ends is looking into a resistance equal to its own characteristic impedance. These cases, then, furnish a means for designing a micro-ray transmission line which may be adjusted as to length without changing the transmission characteristics of the line. This is a valuable property and one which may be made use of in various applications. It is not, however, suitable for use as a wavemeter. It will, therefore, not be considered further in connection with the design of a wavemeter.

Let us now consider Cases *a* and *b*. In these cases, the sign of $\dot{D}\rho$ is the same as the sign of $\sin 2\beta l$. Adjustment of the length of the adjustable line, then, gives us the following results, where M indicates, maximum and *m* indicates minimum:

l	$2\beta l$	$\sin 2\beta l$	D	I_d
0	0	0		
		+		
$\lambda/4$	π	0	M	*m*
		−		
$\lambda/2$	2π	0	*m*	M
		+		
$3\lambda/4$	3π	0	M	*m*
		−		
λ	4π	0	*m*	M

(27)

It will be seen that maximum transfer of energy occurs for adjustments of the length *l* of the adjustable line equal to a multiple of a half wave length of the received wave, that is, when

$$l=k\frac{\lambda}{2}. \quad (28)$$

With this adjustment:

$$I_{dM}=E\frac{Z_1Z_3}{Z_1^2\rho'+Z_3^2\rho}. \quad (28)$$

The maximum transfer of energy is obtained when:

$$\frac{Z_1^2}{\rho}=\frac{Z_3^2}{\rho} \quad (29)$$

as in Cases *e* and *f*, with the same maximum value for i_d.

If we now consider Cases *c* and *d*, in the same manner we find:

l	$2\beta l$	$\sin 2\beta l$	$\dot{D}_1$	D	I_d
0	0	0	0		
		+	−		
$\lambda/4$	π	0	0	*m*	M
		−	+		
$\lambda/2$	2π	0	0	M	*m*
		+	−		
$3\lambda/4$	3π	0	0	*m*	M
		−	+		
λ	4π	0	0		

(30)

The maximum current in the thermo-couple now occurs when the adjustable line has a length equal to an odd multiple of a quarter of a wave length, that is, when:

$$l=(2k+1)\frac{\lambda}{4}. \quad (31)$$

In this case the maximum current:

$$I_{dM}=E\frac{Z_1Z_2Z_3}{Z_1^2Z_3^2+\rho\rho'Z_2^2}. \quad (32)$$

The best adjustment of the lines is obtained when:

$$\frac{Z_1Z_3}{Z_2}=\sqrt{\rho\rho'} \quad (33)$$

that is, when:

$$\frac{Z_1^2}{\rho}\cdot\frac{Z_3^2}{\rho'}=Z_2^2 \quad (34)$$

and, as before, the grand maximum for I_d is

$$\frac{E}{2\sqrt{\rho\rho'}}. \quad (35)$$

We have now found the conditions for the maximum transfer of energy from the antenna to the thermo-couple, under different conditions of the intermediate line, and have also found that the conditions represented by Cases *a*, *b*, *c* and *d* above offer possibilities as wavemeters. The accuracy with which waves may be measured on a wavemeter depends on the sharpness of the resonance curve of the meter. Let us, therefore, now consider the conditions for maximum sharpness of resonance with the different possible cases.

Let us first consider the Cases *a* and *b*. In these cases $B^2-A^2>$zero. In order to estimate the sharpness of the resonance curve, let us find the values of *l* for which the thermo-couple current

$$I_d=\frac{1}{\sqrt{2}}I_{dM} \quad (36)$$

This condition obtains when:

$$A^2=\sin^2\beta l\times(B^2-A^2) \quad (37)$$

and

$$\sin\beta l=\pm\frac{A}{\sqrt{B^2-A^2}} \quad (38)$$

We want the angle βl to be as small as possible, or rather, to differ from π by as small a value as possible, so that we can write:

$$l=\frac{\lambda}{2}\pm\frac{\lambda}{2\pi}\sqrt{-\frac{1}{\frac{B^2-A^2}{A^2}}}. \quad (39)$$

In order to increase the sharpness of the curve, the value of

$$\frac{B^2-A^2}{A^2}$$

should be made as large as possible.

$$\frac{B^2-A^2}{A^2}=\frac{(Z_1^4-\rho^2Z_2^2)\,(Z_3^4-\rho'^2Z_2^2)}{Z_2^2(Z_1^2\rho'+Z_3^2\rho)^2}=F. \quad (40)$$

Differentiation with respect to

$$\frac{Z_1^2}{\rho},\ \frac{Z_3^2}{\rho'}\text{ and }Z_2^2$$

shows that:

$$\dot{F}_{\frac{Z_1^2}{\rho}}\text{ has the sign of }\frac{Z_3^2}{\rho'}-Z_2 \quad (41)$$

$$\dot{F}_{\frac{Z_3^2}{\rho'}}\text{ has the sign of }\frac{Z_1^2}{\rho}-Z_2 \quad (42)$$

$$\dot{F}_{Z_2^2}\text{ has the sign of }Z_2^2-\frac{Z_1^2Z_3^2}{\rho\rho'}. \quad (43)$$

In Case *a*,

$$\frac{Z_1^2}{\rho}\text{ and }\frac{Z_3^2}{\rho'}$$

should be as large as possible, while Z_2 should be chosen as small as possible.

In Case *b*,

$$\frac{Z_1^2}{\rho}\text{ and }\frac{Z_3^2}{\rho'}$$

should be chosen as small as possible and Z_2 as large as possible. The value of sharpness, as given by the change in *l*, required to reduce the value of current in the thermo-couple from a maximum to

$$\frac{1}{\sqrt{2}}$$

of its maximum value, may easily be computed in all practical cases. As seen in the expression (39), the sharpness is better the shorter the wave length. In order to insure maximum transfer of energy at the same time maximum sharpness is obtained, Z_1 and Z_3 should be such that

$$\frac{Z_1^2}{\rho}=\frac{Z_3^2}{\rho'}. \quad (44)$$

In case $Z_1=Z_3$ this can only occur if $\rho=\rho'$. In other words, a suitable type of thermo-couple must be used whose high frequency resistance is the same as the resistance of the antenna.

Let us finally consider Cases *c* and *d*. As before, we estimate the sharpness by means of equation:

$$I_d=\frac{1}{\sqrt{2}}I_{dM} \quad (45)$$

which gives:

$$\cos^2\beta l=\frac{B^2}{A^2-B^2} \quad (46)$$

and

$$l=(2k+1)\frac{\lambda}{4}\pm\frac{\lambda}{2\pi}\sqrt{\frac{1}{\frac{A^2-B^2}{B^2}}} \quad (47)$$

$$F'=\frac{A^2-B^2}{B^2}\,\frac{(Z_1^4-\rho^2Z_2^2)\,(Z_2^2\rho'^2-Z_3^4)}{(Z_1^2Z_3^2+\rho\rho'Z_2^2)^2}. \quad (48)$$

$$\dot{F}'_{\frac{Z_1^2}{\rho}}\text{ has the sign of }Z_2-\frac{Z_3^2}{\rho'} \quad (49)$$

$$\dot{F}'_{\frac{Z_3^2}{\rho'}}\text{ has the sign of }Z_2-\frac{Z_1^2}{\rho} \quad (50)$$

$$\dot{F}_{Z_2^2}\text{ has the sign of }\frac{Z_1^2Z_3^2}{\rho\rho'}-Z_2^2, \quad (51)$$

In Case *c*

$$\dot{F}'_{\frac{Z_1^2}{\rho}}<0\text{ and }Z_1\text{ must be small} \quad (52)$$

$$\dot{F}_{\frac{Z_3^2}{\rho'}}>0\text{ and }Z_3\text{ must be large.} \quad (53)$$

Maximum sharpness occurs when:

$$Z_2^2=\frac{Z_1^2}{\rho}\cdot\frac{Z_3^2}{\rho'} \quad (54)$$

which is also the condition for maximum transfer of energy.

In case *d*

$$\dot{F}_{\frac{Z_1^2}{\rho}}>0\text{ and }Z_1\text{ must be large} \quad (55)$$

$$\dot{F}_{\frac{Z_3^2}{\rho'}}<0\text{ and }Z_3\text{ must be small.} \quad (56)$$

Maximum sharpness occurs, as before, when:

$$Z_2^2=\frac{Z_1^2}{\rho}\cdot\frac{Z_3^2}{\rho'}. \quad (57)$$

The value of maximum sharpness is given by

$$F'_M=\frac{(\rho'Z_1^2-\rho Z_3^2)^2}{4\rho\rho'Z_1^2Z_3^2} \quad (58)$$

If

$$\rho'Z_1^2=\rho Z_3^2,\text{ then }Z_2=\frac{Z_1^2}{\rho}=\frac{Z_3^2}{\rho'}$$

and we find ourselves in Cases *e* and *f*. In view of the fact that maximum sharpness is finite, Cases *c* and *d* do not lead to as good a wavemeter design as Cases *a* and *b*.

U. S. Patent No. 1,921,117 granted to Rene H. Darbord, which has been referred to above, discloses a wavemeter designed in accordance with

Case *b* above. It has already been shown that Cases *e* and *f* are not suitable for wavemeters and that Cases *c* and *d* do not give as good results as Cases *a* and *b*. Case *a*, however, offers possibilities of a wavemeter which is as sensitive as that disclosed in Darbord's above-identified patent and which is more convenient to build and can be used for a wider range of wave lengths. Such a wavemeter is shown in Fig. 1, which has already been partially described.

Since the quarter wave length sections should have a larger characteristic impedance than the adjustable center section, these two sections may be parallel wire lines and the center section may be a concentric line so constructed that the ratio of the internal diameter of the outer conductor to the external diameter of the inner conductor is as small as possible. An antenna 1, which is adjustable in length so that each section of the antenna may be a quarter wave length long, is provided. Means for making such an adjustment in an antenna is disclosed in my co-pending application, Serial No. 581,362, filed December 16, 1931, and is simply illustrated in this application by the arrows shown through the dotted portions of the antenna in Fig. 1 of the drawings. The quarter wave length line 2 is connected to the antenna 1 and is adjustable by sliding it in and out of the adjustable line 3. A suitable screw arrangement may be provided for making this adjustment. The antenna may also be designed to be rotated through an angle of 90°, in order to intercept waves of any polarity which may be incident thereon. The quarter wave length line 6, connected to the opposite end of the adjustable line 3 to that to which the quarter wave length line 2 is connected, is also separately adjustable as to length by sliding it in and out of the adjustable line 3. A screening box 7 may be provided to prevent radiation loss from the section 6 of the line. The radius of this screening box is, preferably, equal to one-eighth of the smallest wave length to be measured, as explained in my U. S. Patent No. 1,928,408, previously mentioned.

A suitable arrangement, which may consist of a screw-drive 8, is provided for varying the adjustment of the adjustable line 3, and a suitable scale 9 and pointer 10 permit this adjustment to be measured accurately. A reflector 11, which may be plane or parabolic, concentrates the incident wave onto the antenna 1. A galvanometer G is connected to the end of the inner conductor of the adjustable line next to the thermo-couple on one side, and to any point on the outside of the external conductor of the adjustable line on the other side. The connection to the end of the inner conductor of the adjustable line should be perpendicular to the plane of the line 6, in order to avoid any undue losses due to induction of high frequency current from the line 6.

The operation of the device is as follows: the antenna 1 and the quarter wave length sections 2 and 6 are first adjusted so that they are approximately one-fourth the length of the wave to be measured. The adjustable line 3 is then adjusted by turning the handle connected to screw 8 until a point is reached where there is a maximum deflection in the galvanometer. When the adjustable line 3 is adjusted, the line 6 and screening box 7 all move as a unit. After the adjustment of the line 3 for maximum deflection on the galvanometer is discovered, the antenna 1 and lines 2 and 6 are again adjusted more carefully for this maximum deflection. The point on the scale corresponding to maximum deflection is then carefully noted. The adjustable line 3 is then re-adjusted by turning the handle connected to screw 8 until another point is reached where there is a maximum deflection in the galvanometer G. The point on dial 9 corresponding to this second adjustment is then also carefully noted and the distance between the two points of adjustment for maximum deflection is measured. This distance will be equal to one-half the wave length of the received wave, with a high degree of accuracy. When the mechanical adjustments are carefully made, an accuracy of one part in ten thousand is obtainable.

For the best results with a wavemeter of this character, it is highly desirable to have an adjustable line 3, the characteristic impedance of which does not vary with changes in its adjustment. Such a line is shown in Fig. 2. The adjustable line shown in this figure is designed for use as the adjustable line of the wavemeter shown in Fig. 1, which has already been described, and is adjusted in any suitable manner such as that shown in Fig. 1. It is also designed for use in the wavemeter of Fig. 3, yet to be described. The parts of the line in Fig. 2 which are shown not cross-hatched are designed to slide over the parts which are shown cross-hatched. In order to have the same characteristic impedance all through the length of an adjustable line, the following condition must obtain, using the notation shown on Fig. 2:

$$\frac{R_1}{R_2}=\frac{R_3}{R_4}=\frac{R_5}{R_6} \quad (59)$$

where R, with the appropriate subscript, is the radius of the portion of the line indicated.

We then have:

$$\frac{R_1}{R_2}=\frac{R_1+E}{R_2+E'}=\frac{R_1+E+E''}{R_2+E'+E'''} \quad (60)$$

so that:

$$\frac{R_1}{R_2}=\frac{E}{E'}=\frac{E''}{E'''}. \quad (61)$$

In order to dispense with the adjustment of the antenna in the type of wavemeter shown in Fig. 1, use may be made of a wavemeter such as that disclosed in Fig. 3, in which similar elements are marked with the same numbers used in Figs. 1 and 2. Instead of an adjustable antenna of the type shown in Fig. 1, a doublet is connected across the ends of the quarter wave length line 2 and the thermo-junction is connected in the line of the doublet. Line 2 is separately adjustable as before, and line 3, which is constructed as shown in Fig. 2, may be adjusted in the manner shown in Fig. 1. Line 6 is also separately adjustable, but this adjustment is now made by adjusting the length of the shielding cylinder 7 by moving its lid 12. Of course, at least one of the leads 6 should be insulated from the lid 12. With this arrangement, the wavemeter is sensitive and may be used conveniently for a wider range of wave lengths than is the case for a wavemeter of the type shown in Fig. 1.

In Fig. 3, if we assume the line 6 to be practically short circuited, the current flowing through the thermo-couple is found to be

$$I_a=\frac{E}{\sqrt{\rho^2+\frac{Z_1^4}{Z_2^2}tg^2\beta l}}. \quad (62)$$

The operation of the device of Fig. 3 is as follows: The lines 2 and 6 are adjusted for approximately one-fourth of the wave length of the wave to be measured, the line 6 being adjusted, as just

mentioned, by moving the lid 12. The line 3 is then adjusted for maximum deflection on the galvanometer G and final adjustments of the lines 2 and 6 are made. The line 3 is then readjusted for another point of maximum deflection on the galvanometer G, and the distance between the two positions of the line 3 for maximum deflection is one-half the length of the wave measured.

In Fig. 3, the shield 7 may be replaced by a plane reflector at the position of the plane portion of the lid 12. In this case the reflector slides along the line 6 just as the lid 12 did, and is positioned the same with respect to the rest of the device. Again, at least one of the leads should be insulated from the reflector.

What is claimed is:

1. A micro-ray wavemeter comprising two lines having a certain value of characteristic impedance and an intermediate adjustable line having a value of characteristic impedance less than the value of either of the two first-mentioned lines.

2. A micro-ray wavemeter comprising two sections of transmission line having equal values of characteristic impedance, and an intermediate section adjustable as to length having a value of characteristic impedance less than the values of said two first-mentioned sections.

3. A micro-ray wavemeter comprising an adjustable antenna, an adjustable section of line having a large characteristic impedance, an adjustable section of line having a small characteristic impedance, a second adjustable section of line having a large characteristic impedance, means connected to said last-mentioned section for measuring the current in said antenna, and means for indicating the adjustment of said low impedance portion whereby the length of an incident wave may be measured.

4. A micro-ray wavemeter comprising an adjustable section of line having a large characteristic impedance, a thermo-couple connected to said section, an adjustable section of line having a low characteristic impedance connected to said first section, and a third section of adjustable line having a large characteristic impedance connected to said second section, and a galvanometer connected to said third section, and means for adjusting said second section of the line whereby an indication of the length of the received wave may be obtained.

5. A micro-ray transmission line connecting two devices acting as resistances, said line comprising three sections, namely, two end sections each having a length equal to an odd number of quarter wave lengths and an intermediate section of variable length, the characteristic impedance of one of the end sections being equal to the square root of the product of the characteristic impedance of the intermediate section and the resistance of the adjacent device so as to ensure an energy transfer independent of the length of the intermediate section.

6. A micro-ray transmission line in accordance with claim 5, in which both end sections have the relationship mentioned with respect to the intermediate line and the respective adjacent devices, so as to ensure maximum transfer of energy independently of the length of the intermediate line.

7. A micro-ray wavemeter comprising two sections of line adjustable to a quarter wave length, and an intermediate section adjustable to half wave lengths, and means for effectively adjusting one of said quarter wave length sections comprising an adjustable shield surrounding said section.

8. A micro-ray wavemeter comprising two sections of line adjustable to a quarter wave length, and an intermediate section adjustable to half wave lengths, and means for effectively adjusting one of said quarter wave length sections comprising an adjustable reflector.

ANDRÉ G. CLAVIER.