

Oct. 7, 1941.

J. COLLARD

2,258,047

WAVE TRANSMISSION SYSTEM

Filed March 6, 1940

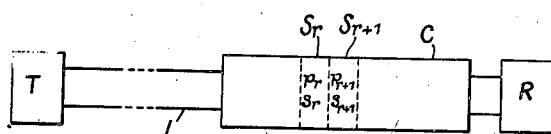


Fig. 1.

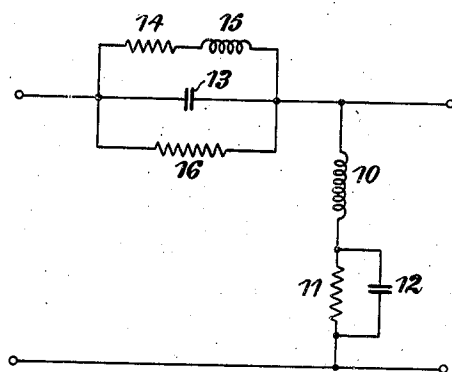


Fig. 2.

Inventor:

J. COLLARD

by: J. O. Allier
attor.

UNITED STATES PATENT OFFICE

2,258,047

WAVE TRANSMISSION SYSTEM

John Collard, Hammersmith, London, England,
assignor to Electric & Musical Industries Limited,
Hayes, Middlesex, England, a company of
Great Britain

Application March 6, 1940, Serial No. 322,453
In Great Britain March 17, 1939

15 Claims. (Cl. 178—44)

This invention relates in general to wave transmission systems, and is concerned more particularly but not exclusively, with equaliser networks such as find application in television systems.

In the specification of United States Patent No. 2,158,978 it is shown how a plurality of sections of the type comprising a series arm composed of capacity shunted by resistance and a shunt arm composed of inductance in series with resistance may be arranged so as to equalise or compensate for the distortion suffered by electric signals covering a wide frequency range when transmitted over a cable. This distortion is of the nature of a variation with frequency of attenuation and delay of transmitted signals. The equalisation of such distortion can be effected, as shown in the aforementioned specification, by distributing the values of a certain parameter in a particular way. This parameter which has the effect of differentiating the various sections from one another may be defined generally as that frequency at which the attenuation of a section falls to an arbitrary fraction of the attenuation at zero frequency; it is characteristic of the section and may be termed hereinafter and in the appended claims the "reference" frequency of the section. If the reference frequencies are chosen so that their spacing corresponds to an equal loss spacing with respect to the attenuation characteristic mentioned above according to the method described in the aforementioned specification, then the equalisation referred to can be effected.

In such an arrangement it is necessary for the range occupied by the reference frequencies to extend considerably beyond the highest frequency in the range of signals to be transmitted, and theoretically there should be no finite upper limit set upon the range of reference frequencies; but in practice it will be obvious that if a section has its reference frequency so far beyond the highest working frequency that its effect other than that of a constant loss, does not extend appreciably to the working range, then it may be omitted. The sections referred to above have been termed sections of the "eight-octave type" since a frequency range of about eight octaves is required for their loss to fall from 99.5 per cent of its zero-frequency value to 0.5 per cent of the same value. It will be appreciated, therefore, that with such "eight-octave" sections the highest reference-frequency must be situated at least about four octaves above the highest working frequency, this value of four octaves being con-

sistent with the definition of the reference frequency as that frequency at which the attenuation falls to half its value at zero frequency. The amount of standing loss thereby introduced is very considerable, and in order to reduce this loss a type of section such as a "four-octave" section has been used. This type of section is disclosed in the specification of United States Patent No. 2,165,838. It is similar in nature to the "eight-octave" section, but it possesses an inductance connected in series with the resistance in the series arm and a capacity shunted across the resistance in the shunt arm; further the range of frequencies in which the variation of its attenuation is substantially completed is about four octaves. By utilizing a section of this kind the overall attenuation can be greatly reduced. There is, however, an attendant disadvantage in using a section having so rapid a change of attenuation; this is due to the fact that at the lower frequencies in the working range the reference frequencies are relatively widely spaced apart so that bumps or irregularities are introduced in the overall characteristics in the region of the lower working frequencies. It is a feature of the invention according to aforementioned Patent No. 2,165,838, however, that all sections are of the same type, e. g., all of the eight-octave type or all of the four-octave type. Thus, according to this feature, there are always certain disadvantages either at low or at high frequencies.

It is one object of the present invention to overcome this kind of disadvantage.

The present invention also enables a further disadvantage to be overcome. This disadvantage arises in equalisers constructed in accordance with the method described in the aforementioned specification on account of the fact that these methods require the zero frequency loss of all sections composing the equaliser to be substantially identical; namely, they require all the sections to be of the same size. They further require that the loss introduced by any particular section at a certain frequency shall be small compared with the loss to be equalised at that frequency. It will be seen, therefore, that the size of section will be determined by the magnitude of the loss requiring equalisation in the region of the low frequencies, with the result that sections having higher reference frequencies are needlessly small apart from the point of view of the second of the above requirements. In accordance with a feature of the present invention it is possible to increase the size of the sec-

tions at the higher reference frequencies so that fewer sections are required, and thereby the construction of the equaliser is simplified. The achievement of such simplification constitutes a further object of the invention.

The present invention is especially applicable to an electric signal transmission system which is designed for the transmission of signals extending over a very wide frequency range extending at least up to 100 kilocycles per second. The invention is also applicable to the case in which the transmission line is designed for the transmission of frequencies from substantially zero frequency up to about two or three megacycles per second, such latter frequencies being ordinarily encountered in the transmission of television signals. When dealing with signals extending over such a wide range of frequencies the variation of loss and phase delay is due to variation with frequency of all four primary constants of the cable and the present invention can accordingly be applied to such a system for equalising simultaneously the greater part of the variation of the loss and phase. The invention may also be applied to transmission lines or cables transmitting signals extending over much smaller frequency ranges. It may also be employed in a transmission line or cable for equalising the effect only of variation with frequency of the resistance and inductance or capacity and leakage. It is also possible to apply it to a cable in which the equalisation is effected by loading the cable at intervals along its length, which intervals are short compared with the wavelength of the highest frequency to be transmitted or to the case in which an arbitrary length of cable or transmission line is equalised as a whole by the use of a plurality of equaliser sections.

According to the present invention there is provided a wave transmission system comprising a transmission path along which oscillations extending over a range of frequencies are caused to travel, in which the path is such as to introduce distortion of said signals, and a compensating path comprising a plurality of equaliser sections whose characteristics are substantially different from one another and vary from one to the other in an arbitrary but substantially finely graded manner in dependence upon the reference frequencies of said sections, wherein said reference frequencies are so chosen that said distortion is substantially compensated.

By suitably varying the said characteristics throughout the range of reference frequencies it will be appreciated that the afore-mentioned objects may be achieved; thus the form of the characteristics may be so graded that while at higher frequencies the attenuation of a section substantially completes its variation in a few octaves, yet at lower frequencies this variation occupies many more octaves, thereby avoiding irregularities in the overall characteristic at the low frequency end of the range. Also by varying the zero frequency loss suitably the second-mentioned object may be achieved and an equaliser constructed in which at every reference frequency the size of section is the maximum consistent with the degree of irregularity tolerable in the overall characteristic.

The present invention also has the advantage, as will become clear later, of not necessitating the distribution of reference frequencies beyond the highest working frequency, so that a con-

siderable reduction in overall loss can be obtained.

The invention, of course, is not limited in its application to equalising, and it may be applied in other cases where a predetermined characteristic (or characteristics) is (or are) required.

In order that it may be clear in what manner the invention may be carried into effect, an example will now be given illustrating broadly the principal features of the invention. Thus, suppose that it is required to equalise an attenuation characteristic represented by $\alpha(\omega)$ where $\omega/2\pi$ represents the frequency; then it will be necessary to provide an equalising path which possesses a characteristic $K - \alpha(\omega)$ where K may be a very large constant. The loss of any section in the compensating path may be written in the form $F(\omega, p)$ where p is the reference frequency of the section as defined in the specification of Patent No. 2,165,838. If p is arranged to have values lying in the range (C, C) where C is equal to or greater than the highest working frequency, and the function $N(p)$ represents the density of distribution of the reference frequencies so that in the range dp there are located $N(p) dp$ sections, then it is required that

$$\int_0^C F(\omega, p) N(p) dp = K - \alpha(\omega)$$

for the purpose of eliminating the constant K both sides of this question may be differentiated with respect to ω , thus:

$$\int_0^C F'(\omega, p) N(p) dp = -\frac{d}{d\omega} \alpha(\omega)$$

where $F'(\omega, p)$ is the partial derivative of $F(\omega, p)$ with respect to ω .

This is an integral equation for $N(p)$ which is soluble by methods known in the mathematical art. An approximate solution of it can be obtained by splitting up the integration so as to cover a comparatively large number of small ranges in the variable p . Thus, suppose that these ranges extend equally to either side of fixed values of p , namely, $p_1, p_2, p_3, \dots$ by amounts $\Delta_1, \Delta_2, \Delta_3, \dots$ so that the ranges $2\Delta_1, 2\Delta_2, 2\Delta_3, \dots$ form a series of contiguous frequency intervals; and let

$$N_1 = \int_{p_1 - \Delta_1}^{p_1 + \Delta_1} N(p) dp$$

$$N_2 = \int_{p_2 - \Delta_2}^{p_2 + \Delta_2} N(p) dp$$

$$N_k = \int_{p_k - \Delta_k}^{p_k + \Delta_k} N(p) dp$$

Also for some fixed value of ω , say ω_1 , let F_{11} be the mean value of the function $F'(\omega, p)$ over the interval surrounding p_1 , F_{12} that over the interval surrounding p_2 , and in general F_{1k} that over the interval surrounding p_k . For other values of ω these means will, of course, assume other values, and quite generally any mean may be written as F_{jk} ; it will be given by

$$F_{jk} = \frac{1}{2\Delta_k} \int_{p_k - \Delta_k}^{p_k + \Delta_k} F'(\omega_j, p) dp$$

With these definitions then the above integral equation may be replaced by the following set of equations:

$$\begin{aligned} F_{11}N_1 + F_{12}N_2 + \dots + F_{1k}N_k + \dots &= -\alpha'(\omega_1) \\ F_{21}N_1 + F_{22}N_2 + \dots + F_{2k}N_k + \dots &= -\alpha'(\omega_2) \end{aligned} \quad 5$$

$$F_{j1}N_1 + F_{j2}N_2 + \dots + F_{jk}N_k + \dots = -\alpha'(\omega_j) \quad 10$$

where

$$\alpha'(\omega) = \frac{d}{d\omega} \alpha(\omega)$$

In these equations the α -terms are determinate from the originally postulated attenuation characteristic, and all the coefficients F_{jk} may be evaluated when it has been decided in what manner the characteristics of the sections are to depend on the reference frequency. It is, therefore, possible to determine the mean values of the distribution function $N(p)$ in the various intervals $2\Delta_1, 2\Delta_2, 2\Delta_3, \dots$. In this way as nearly as may be desired it is, therefore, possible to arrive at the necessary form of $N(p)$.

The principles employed in the above method may be applied in various ways. It may be used to equalise any particular term in an expansion of the loss function $\alpha(\omega)$, for example, a term of the form $A_n\omega^n$ according to the expansion adopted in the analysis set out in the aforementioned U. S. patent specification No. 2,165,838. Thus an equaliser may be constructed of a number of sub-equalisers each sub-equaliser corresponding to one such term $A_n\omega^n$. Such an equaliser has a flexible nature in that it may be constructed so that the coefficients of each power term may be adjusted, one equaliser being rendered capable of equalising a variety of loss characteristics. Preferably, however, when this flexible nature is not required, the loss is equalised directly by a single equaliser.

For the sake of illustrating the invention in more detail, consider an equaliser section of structure like that previously referred to, wherein the shunt arm of the section is formed by an inductance L in series with a parallel arrangement of a resistance R and a capacity C . If the quantities p, q are defined according to the equations

$$p = \frac{R}{L}$$

$$q = \frac{p}{\omega}$$

the loss of such a section may be expressed in the form

$$\frac{1}{2} \log \frac{(k_0 q^2 - s^2)^2 + q^2(1 + s^2 k_0 - 1)^2}{(q^2 - s^2)^2 + q^2}$$

where

$$s = R \sqrt{\frac{C}{L}}$$

if s is zero the section reduces to the eight-octave type of section which has a very gradual variation of loss. As s is increased this variation increases in rapidity, the loss remaining substantially constant for a considerable range of frequencies from zero upwards and then falling away to zero at a rate determined by the magnitude of s . When s^2 attains the value

$$\frac{k_0 + 1}{k_0 - 1} \left(\sqrt{\frac{2k_0}{k_0 + 1}} - 1 \right)$$

the decay of attenuation is the most rapid obtain-

able without there occurring previously a rise in attenuation. A characteristic having this peak in it is not desirable, and consequently the above value for s^2 sets a practical limit on the rapidity of variation of loss. The section that is thereby defined constitutes the four-octave type of section. If the section has a zero frequency loss of 3 db., the value of the above expression for s^2 becomes approximately equal to 0.48.

Figures 1 and 2 of the accompanying drawing illustrate a system and an equaliser section for use in such a system incorporating the features already described.

Referring to Figure 1 the transmitter T feeds signals covering a wide range of frequencies into the line L and these signals after having been corrected by the equaliser C arranged in series with the line L for the distortion impressed upon these by the line are applied to the receiver R . In the equaliser C there are shown diagrammatically two typical sections S_r and S_{r+1} which differ the one from the other not only with respect to the reference frequencies p_r, p_{r+1} but also with respect to the parameter s having the respective values s_r, s_{r+1} . A typical manner in which the parameter s might vary in practice throughout all the sections is set out in the table that is given subsequently. As has already been explained the equaliser C may be formed by a plurality of equalisers each of the type just described but equalising only for loss given by a single term of the form $A_n\omega^n$.

Figure 2 shows a network structure typical for the various sections $S_r, S_{r+1}, \dots$. In this figure 10 is the shunt arm inductance, L , already referred to, 11 the shunt arm resistance, R , connected in series with the inductance 10 and 12 the shunt arm capacity, C , connected in parallel with the resistance 11 ; also the capacity 13 , the resistance 14 and the inductance 15 are the inverses respectively to the shunt arm elements $10, 11$ and 12 and form the series arm; they are formed as inverses with respect to the characteristic impedance of the section the value of which is also the value of the resistance 16 shunted across the series arm by which the section is rendered of the constant-resistance type.

Between the two limiting sections, the one at the lower end of the range of the parameter s and the other at the upper end of this range, a graduation in small steps is effected by gradually varying the value of s . This graduation may be carried out in any arbitrary manner. If s were not varied, but remained constant, all the sections would have characteristics representable in the form

$$f\left(\frac{p}{\omega}\right)$$

This is a condition upon which the methods described in aforementioned patent specification No. 2,165,838 are based. The present invention departs from this condition and the various characteristics must be represented by a function of the form

$$f\left(\frac{p}{\omega}, p\right)$$

This is essentially the form of the above set out expression for the loss involving q, s and K_0 . q according to definition is equal to p/ω ; and in the example given immediately above the second variable p , is made to enter through the variable s , as s is made a function of p ; alternatively p may be made to enter through k_0 by making k_0 a

function of p ; and of course, both s and k_0 together may be made functions of p . With any of these possibilities the loss of a section is representable only in such a form as $F(\omega, p)$ and not as

$$f\left(\frac{p}{\omega}\right)$$

As has been stated earlier in the specification, it is convenient to cause K_0 to increase with p since then an economy in components is possible of achievement.

The accompanying table illustrates the manner in which α^2 might as an example be made to vary in an equaliser in which K_0 is maintained constant:

Kilocycles per sec.	α^2	Total number of sections located in range up to frequency p
1.....	0	0.9
3.....	0	1.2
10.....	0.02	2.3
30.....	0.14	4.2
100.....	0.37	9.2
300.....	0.46	16.2
1000.....	0.48	29.3
2000.....	0.48	43.0

The equaliser is intended to equalise the loss represented by an $\omega^{1/2}$ term which rises to 100 db. at 2 megacycles per second. The third column gives the integral of the distribution function $N(p)$ evaluated up to the particular frequency specified in the first column. Such a table need only be worked out once for a particular form of loss characteristic; thus if the loss at two megacycles per second had not been 100 db. as supposed, but some other value L db., the values of the integral in the third column would merely be the same except for a change in the ratio of L to 100.

It will be noticed that the reference frequencies of sections are only located up to the top working frequency of 2 megacycles per second. The distribution of reference frequencies, however, is such that the required compensating characteristic is produced up to this frequency without there being any need to carry the distribution further.

In practice it is found that equalisers constructed in accordance with the invention so as to correct for loss distortion also correct for phase distortion at the same time.

In the following claims, what is meant by a transmission path, line or cable "of the kind hereinbefore specified," is a transmission path, line or cable in which the loss characteristic of the path, line or cable which introduces distortion and which is to be equalised, can be analysed into one or more component terms of the form $A_n \omega^n$ and in which the phase delay characteristic path, line or cable can be analysed into one or more component terms of the form:

$$A_n \tan \frac{n\pi}{2} \cdot \omega^n$$

where the powers n are always less than unity.

In practice, it is found that most, if not all, cables or transmission lines can have their loss and phase characteristics analysed into the above-mentioned terms.

I claim:

1. A wave transmission system including a transmission path along which oscillations extending over a range of frequencies are caused to

travel and are distorted, and a compensating path for substantially equalising said distortion, said compensating path comprising a plurality of equalizer sections, at least some of said sections having characteristics expressible as a function of the ratio of reference frequency to transmitted frequency, said sections thus represented being substantially different from each other and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and chosen so as to substantially reduce or compensate said distortion.

2. A wave transmission system including a transmission path along which oscillations extending over a range of frequencies are caused to travel and are distorted, said distortion substantially corresponding to a frequency characteristic expressed in the form of a term $X_n \omega^n$, and a compensating path for substantially equalising said distortion, said compensating path comprising a group of equalizer sections at least some of which are capable of having their characteristics substantially expressed as a function of the ratio of reference frequency to transmitted frequency, the equalizer sections thus represented being substantially different from one another and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and chosen so as to substantially reduce or compensate said distortion.

3. A wave transmission system including a transmission path along which oscillations extending over a range of frequencies are caused to travel and are distorted, said distortion substantially corresponding to a plurality of terms of the form $X_n \omega^n$ representing associated frequency characteristics, and a compensating path for substantially equalizing said distortion, said compensating path comprising a plurality of groups of equalizer sections, at least some of the sections of each said group being capable of having their characteristics substantially expressed as a function of the ratio of reference frequency to transmitted frequency, the equalizer sections of each group thus represented being substantially different from one another and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies within each group being different and chosen so as to substantially reduce or compensate said distortion corresponding to one of said terms.

4. A wave transmission system including a transmission path along which oscillations extending over a range of frequencies are caused to travel and are distorted, said distortions differing substantially corresponding to different frequency characteristics each substantially expressed in the form of a term $X_n \omega^n$ but differing from one another by different values of the coefficient $X_n \omega$, and a compensating path for substantially equalizing said distortions, said compensating path comprising a number, one as a minimum, of groups of equalizing sections at least part of which are capable of having their characteristics substantially expressed as a function of the ratio of reference frequency to transmitted frequency, the equalizer sections thus represented being substantially different from one another and varying from one to the other in an

arbitrary but substantially finely graded manner depending upon the different reference frequencies of said sections, the transfer of said number of groups being adjustable so as to substantially reduce or compensate said different distortions by the same equalizing path.

5. A wave transmission system including a transmission path along which oscillations extending over a range of frequencies are caused to travel and are distorted as to attenuation and phase delay, and a compensating path for substantially equalising said distortion, said compensating path comprising a plurality of equalizer sections capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, at least some of said sections thus represented being substantially different from each other and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and chosen so as to substantially reduce or compensate simultaneously said distortions as to attenuation and phase delay.

6. A wave transmission system for transmitting electrical signals including a transmission path along which oscillations representative of said signals and extending over a range of frequencies are caused to travel and are distorted, and a compensating path for substantially equalising said distortion, said compensating path comprising a plurality of equalizer sections, said sections comprised of shunt arms formed by an inductance in series with a parallel arrangement of a resistance and a capacity, said sections capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, at least some of said sections thus represented being substantially different from each other and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and chosen so as to substantially reduce or compensate said distortion.

7. A wave transmission system for transmitting electrical signals, including a transmission path along which oscillation extending over a range of frequencies are caused to travel and are distorted, and a compensating path for substantially equalising said distortion, said compensating path comprising a plurality of equalizer sections, each section comprised of a shunt arm formed by an inductance in series with a parallel arrangement of a resistance and a capacity, said sections capable of having their characteristics expressed as a function of the ratio of reference frequency to transmitted frequency and at least some of those sections being substantially different from each other, the parameter s corresponding to the equation

$$s = R\sqrt{\frac{C}{L}}$$

varying gradually throughout said sections depending on their different reference frequencies, so that the loss characteristics of said sections vary from one to the other in a substantially finely graded manner and said distortion is substantially reduced or compensated.

8. A wave transmission system for transmitting electrical signals, including a transmission path along which oscillation representative of said

signals and extending over a range of frequencies are caused to travel and are distorted, and a compensating path for substantially equalising said distortion, said compensating path comprising a plurality of equalizer sections each comprised of a shunt arm formed by an inductance in series with a parallel arrangement of a resistance and a capacity, said sections capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, at least some of said sections thus represented being substantially different from each other and varying from one to the other in an arbitrary but substantially finely graded manner depending on the reference frequencies of said sections, the zero-frequency loss of said sections being arranged to depend upon their different reference frequencies in a gradually varying manner so that the loss characteristics of said sections vary from one to the other in a substantially finely graded manner and said distortion is substantially reduced or compensated.

9. An electric signal transmission system including a transmission path as exemplified by a cable and a transmission line, along which path oscillations extending over a range of frequencies up to at least 100 kilocycles are caused to travel and in which range variations in the loss and phase of the oscillations with frequency are caused by variation with frequency of the effective resistance, inductance, capacity and leakage of said path, said variations resulting in distortion of a transmitted signal, and a compensating path associated with said transmission path, said compensating path comprising a plurality of equaliser sections at least some of which are capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, said characteristics being substantially different from one another and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and chosen so as to substantially reduce or compensate said distortion.

10. Electrical means for simulating a predetermined frequency characteristic comprising a plurality of electrical networks, at least some of which are capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, said networks thus represented being substantially different from one another and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and chosen so as to substantially simulate a predetermined frequency characteristic.

11. Electrical means for simulating a predetermined frequency characteristic comprising a plurality of electric networks at least some of which are comprised of shunt arms formed by an inductance in series with a parallel arrangement of a resistance and a capacity, said networks being capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, said networks being substantially different from one another and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said networks, said reference

frequencies being different and chosen so as to substantially simulate a predetermined frequency characteristic.

12. Electrical means for simulating a predetermined frequency characteristic comprising a plurality of electric networks at least some of which are comprised of shunt arms formed by an inductance in series with a parallel arrangement of a resistance and a capacity, said networks being capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, the parameters s of said networks given by the equation

$$s = R \sqrt{\frac{C}{L}}$$

varying gradually depending upon their reference frequencies so that the loss characteristics of said networks vary from one to the other in a substantially finely graded manner, said reference frequencies being different and chosen so that a predetermined frequency characteristic is substantially simulated.

13. Electrical means for simulating a predetermined frequency characteristic comprising a plurality of electric networks at least some of which are comprised of shunt arms formed by an inductance in series with a parallel arrangement of a resistance and a capacity, said networks being capable of having their characteristics expressed as a function of the ratio of reference frequency to transmitted frequency, the characteristics of said networks being substantially different from one another and the zero-frequency loss of said networks being arranged to depend upon their reference frequencies in a gradually varying manner so that said characteristics of said networks vary from one to the other in a substantially finely graded manner, said reference frequencies being different and chosen so

as to substantially simulate a predetermined frequency characteristic.

14. A wave transmission system including a transmission path along which oscillations extending over a range of frequencies are caused to travel and are distorted, and a compensation path for substantially equalising said distortion, said compensating path comprising a plurality of equalizer sections capable of having their characteristics expressed as a function of the ratio of reference frequency to transmitted frequency, at least some of said sections thus represented being substantially different from each other and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said sections, said reference frequencies being different and distributed within a range the upper limit of which does not substantially exceed the upper limit of the range of frequencies of the oscillations to be transmitted, said reference frequencies being chosen so as to substantially reduce or compensate said distortion.

15. Electrical means for simulating a predetermined frequency characteristic comprising a plurality of electric networks at least some of which are capable of having their characteristics expressed substantially as a function of the ratio of reference frequency to transmitted frequency, said networks thus represented substantially different from one another and varying from one to the other in an arbitrary but substantially finely graded manner depending upon the reference frequencies of said networks, said reference frequencies being different and distributed within a range the upper limit of which does not substantially exceed that of the frequency range for which the simulating means are to be applied, said reference frequencies being chosen so as to substantially simulate a predetermined frequency characteristic.

JOHN COLLARD.