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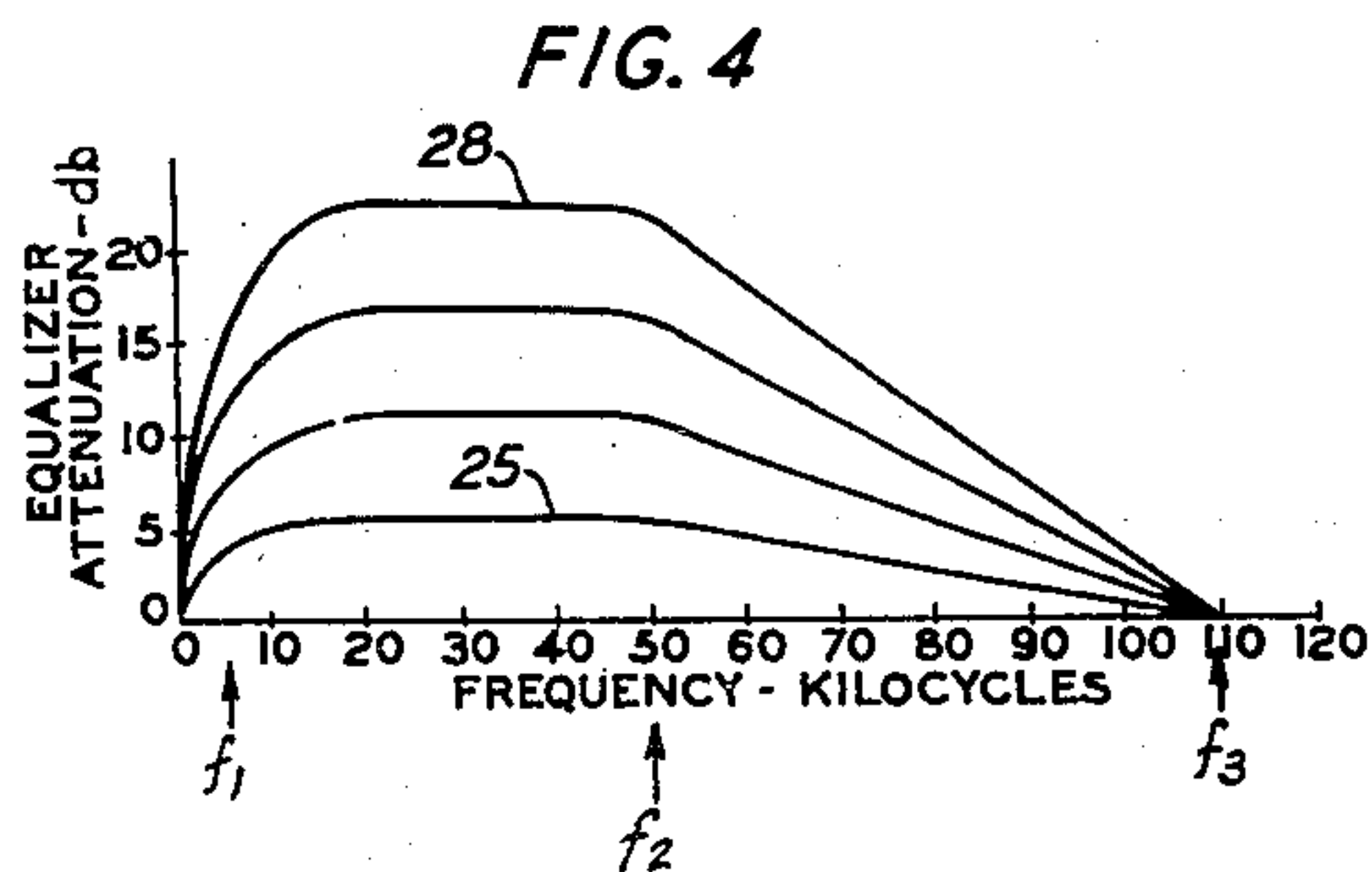
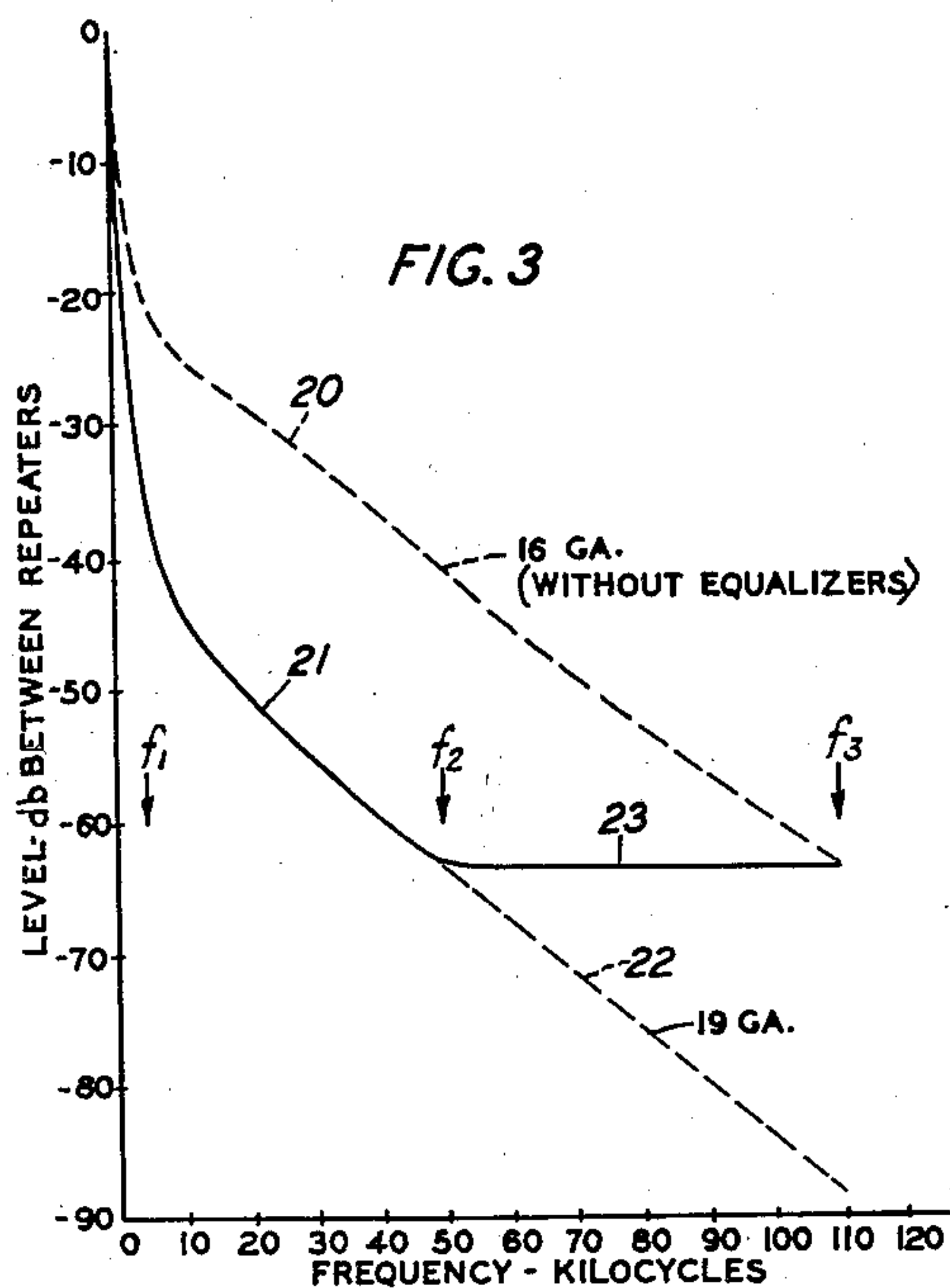
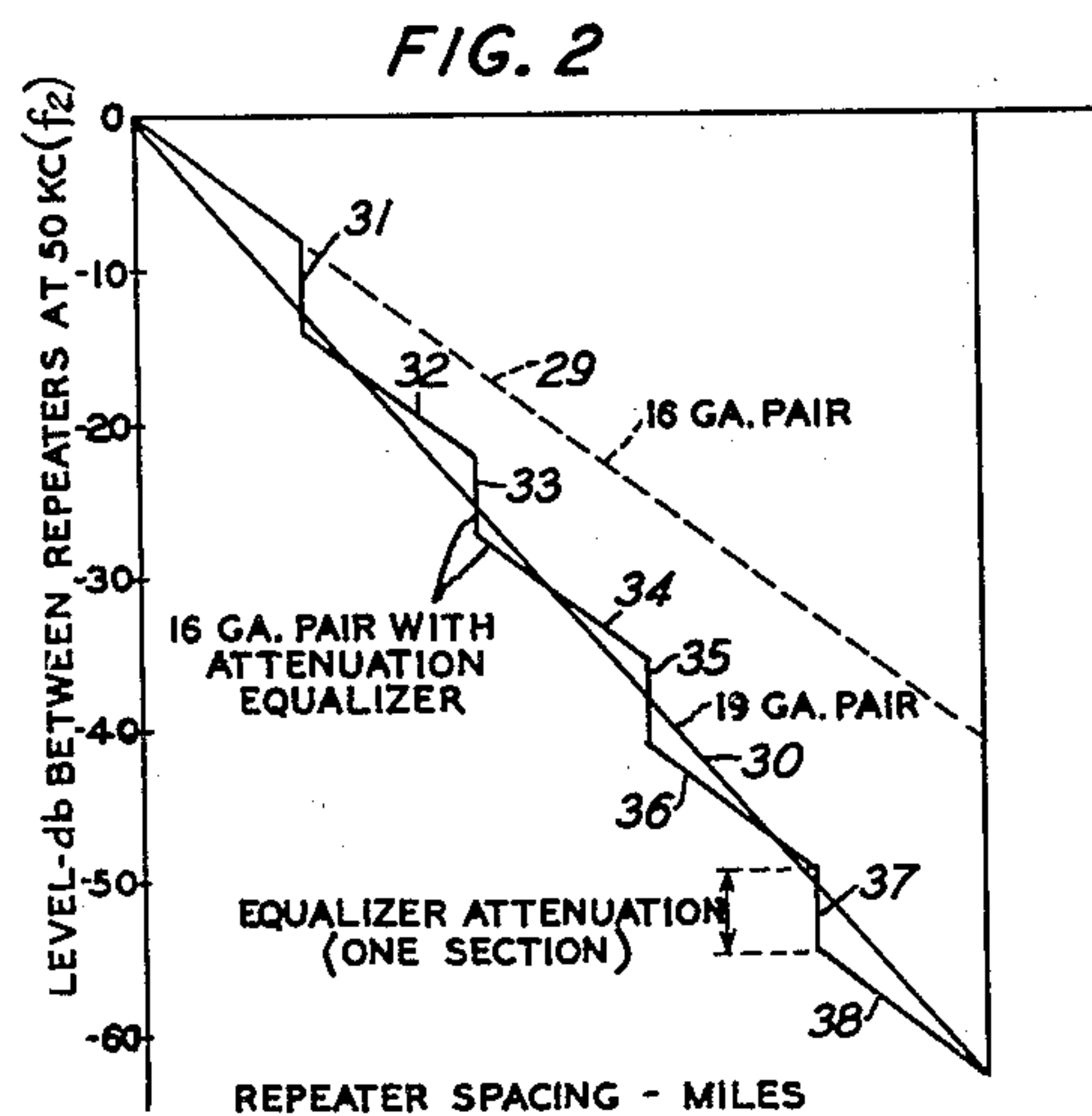
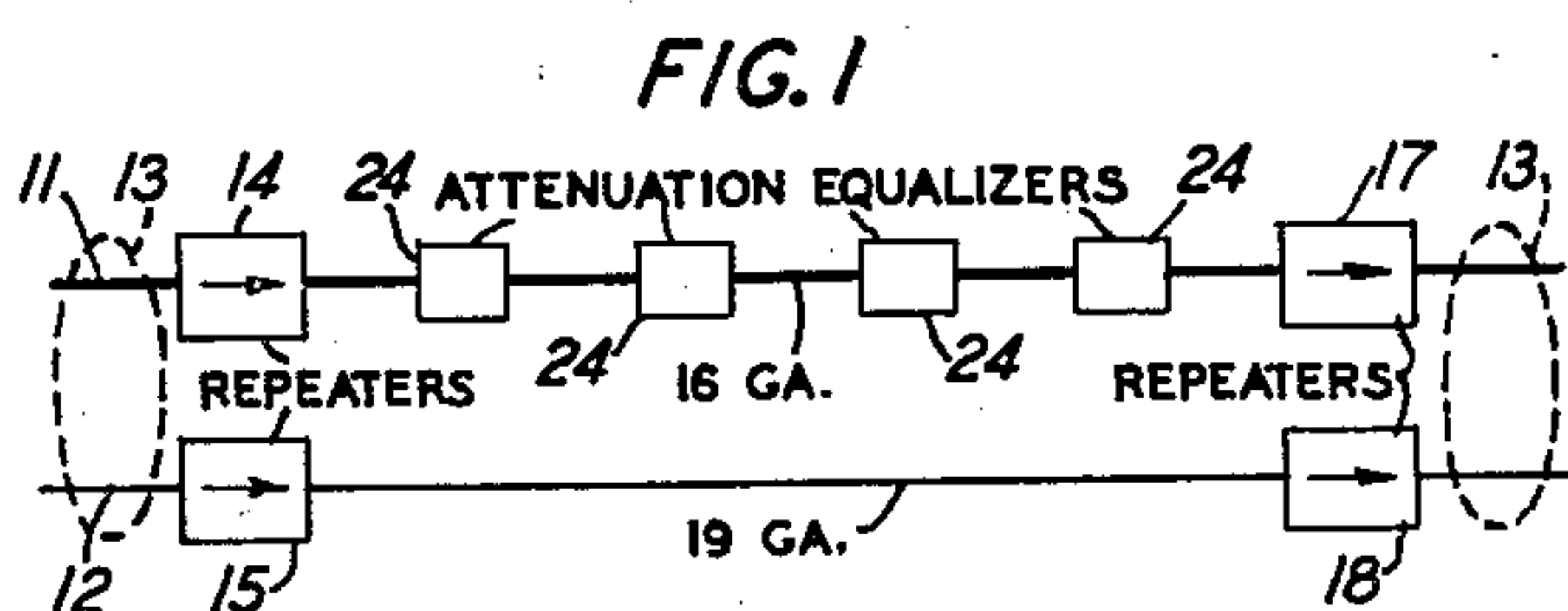
H. NYQUIST

2,051,529

HIGH FREQUENCY SIGNALING SYSTEM

Filed Oct. 17, 1935

3 Sheets-Sheet 1



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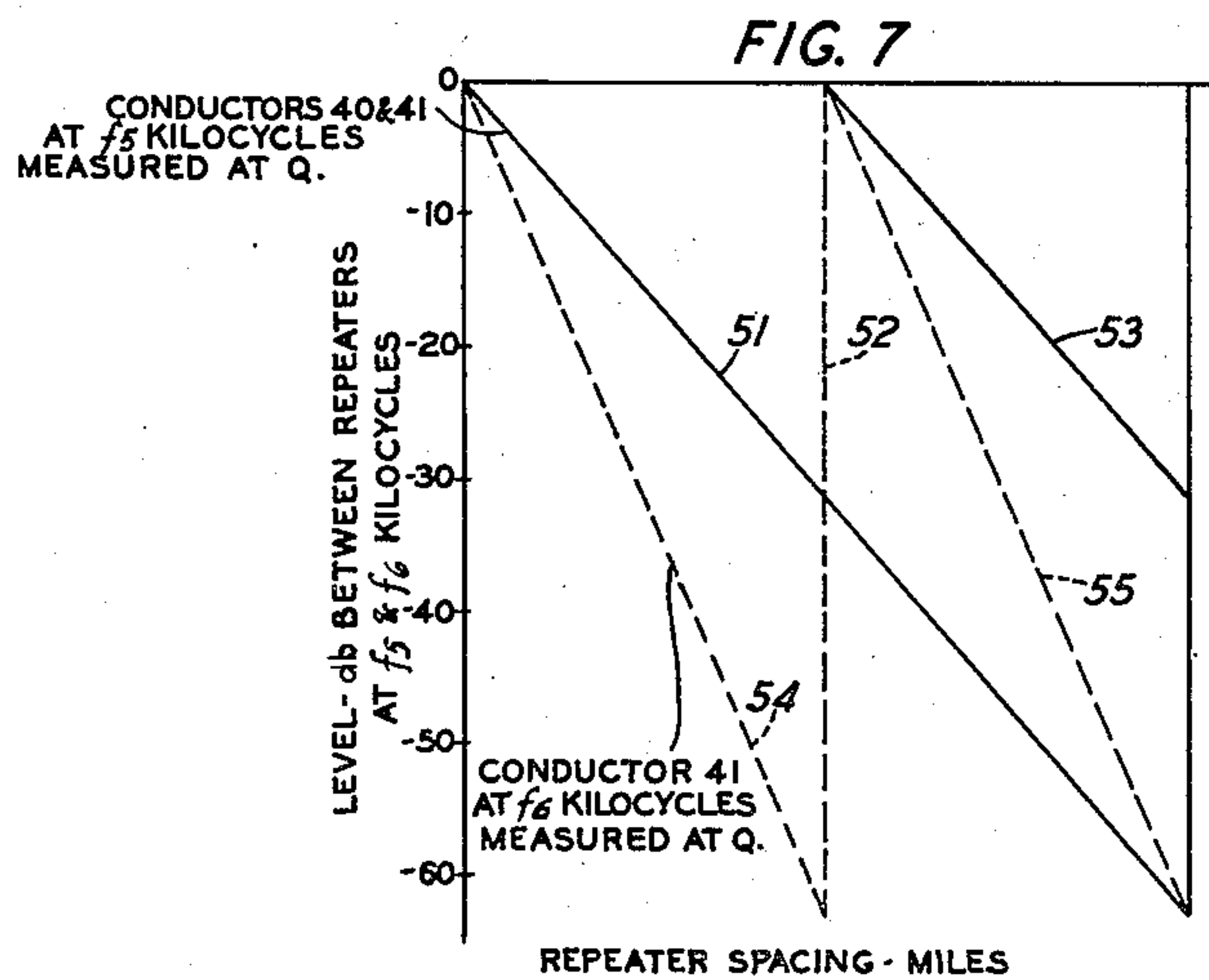
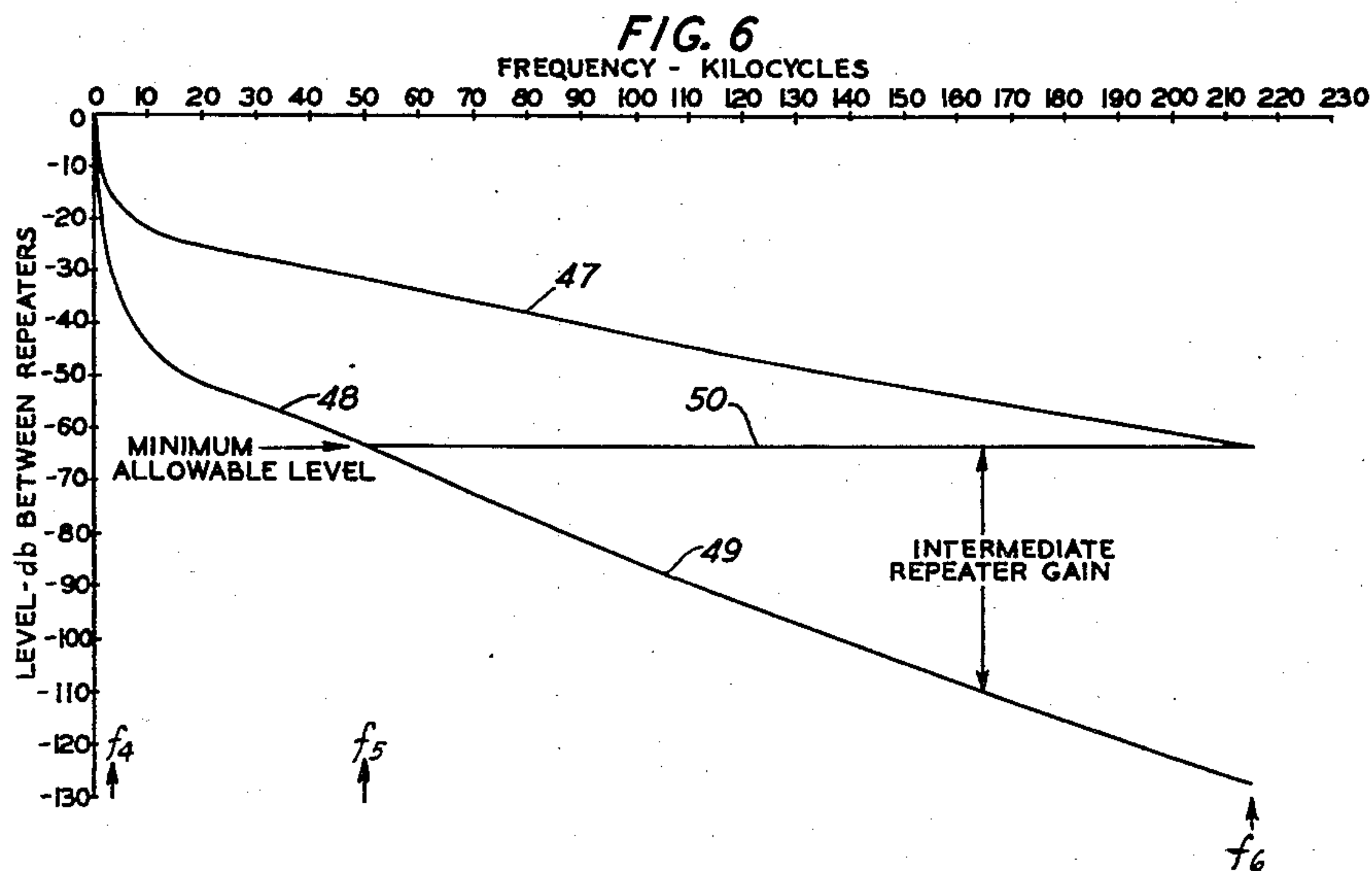
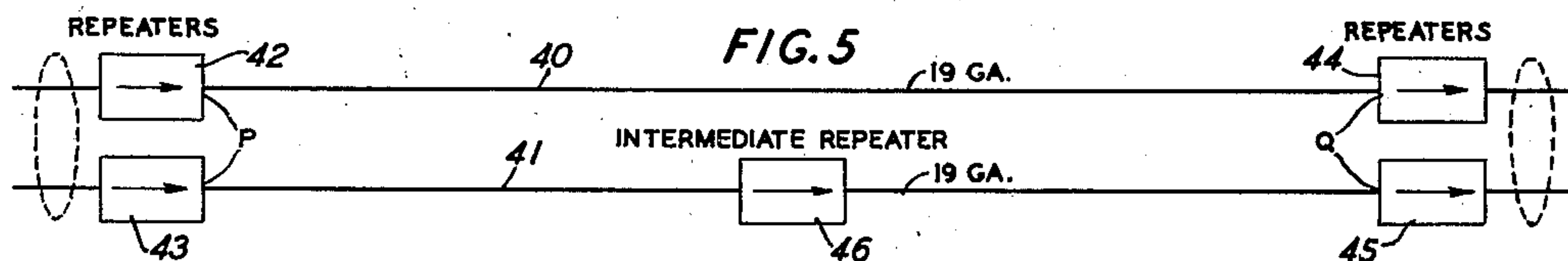
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3 Sheets-Sheet 2



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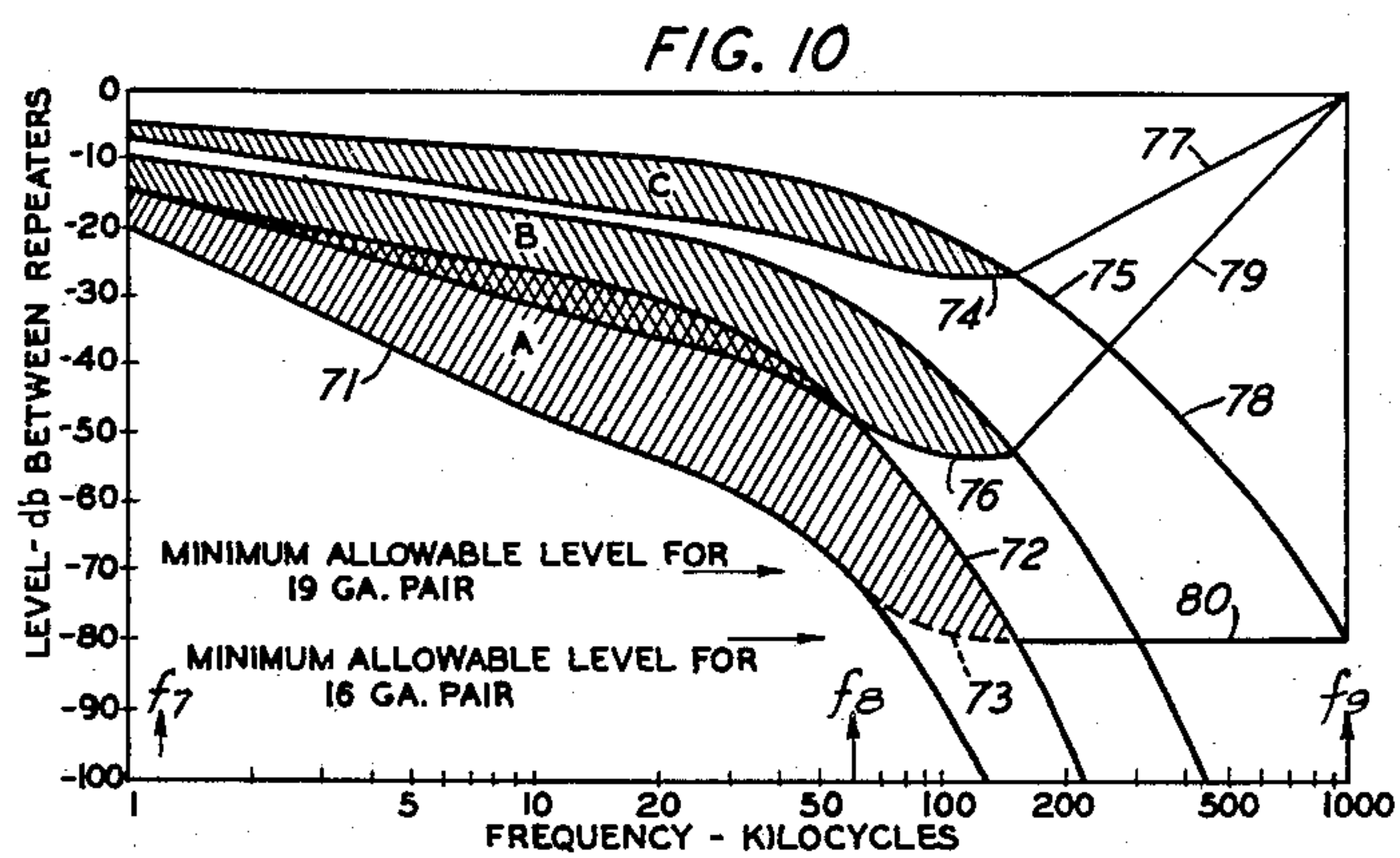
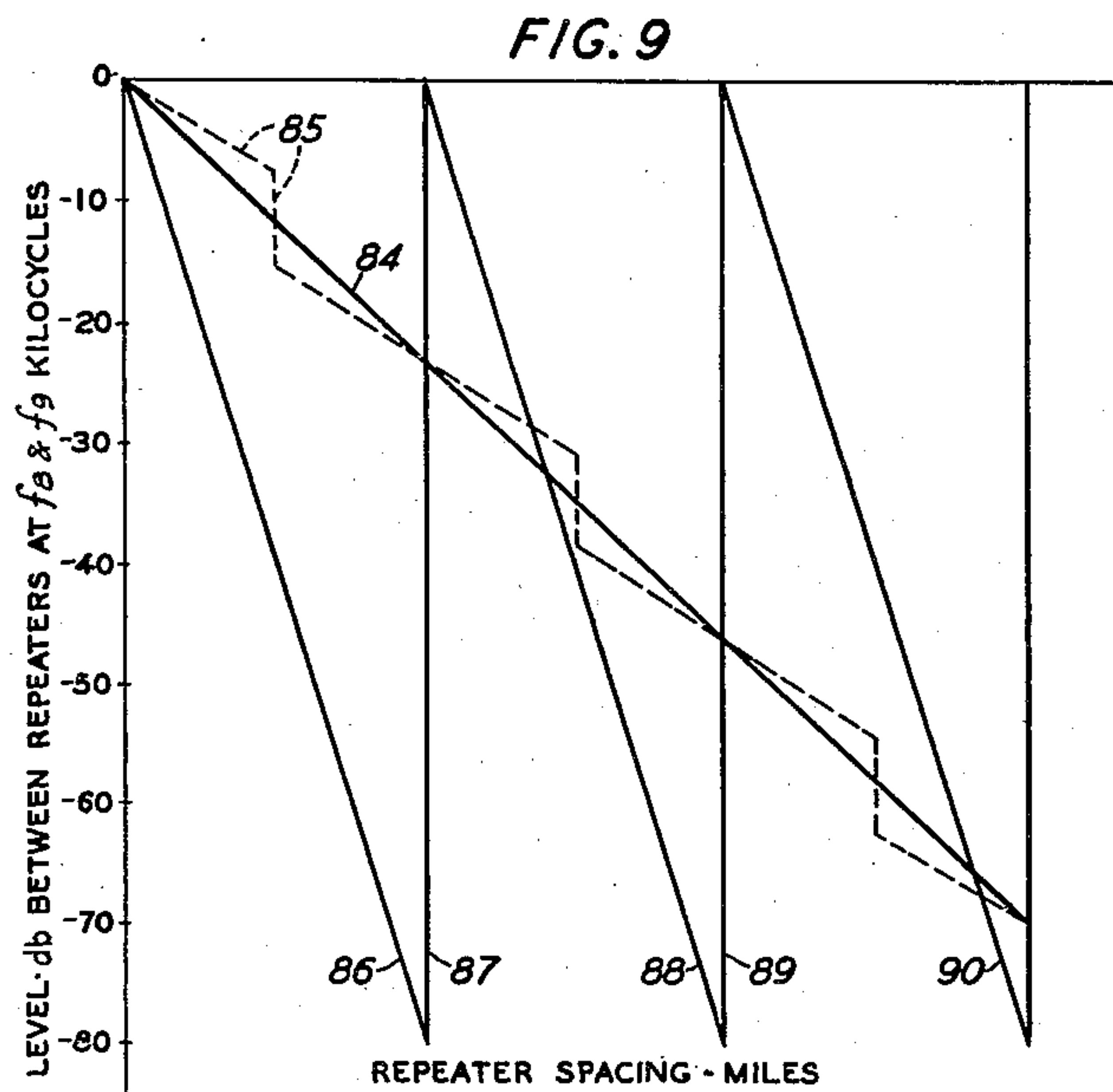
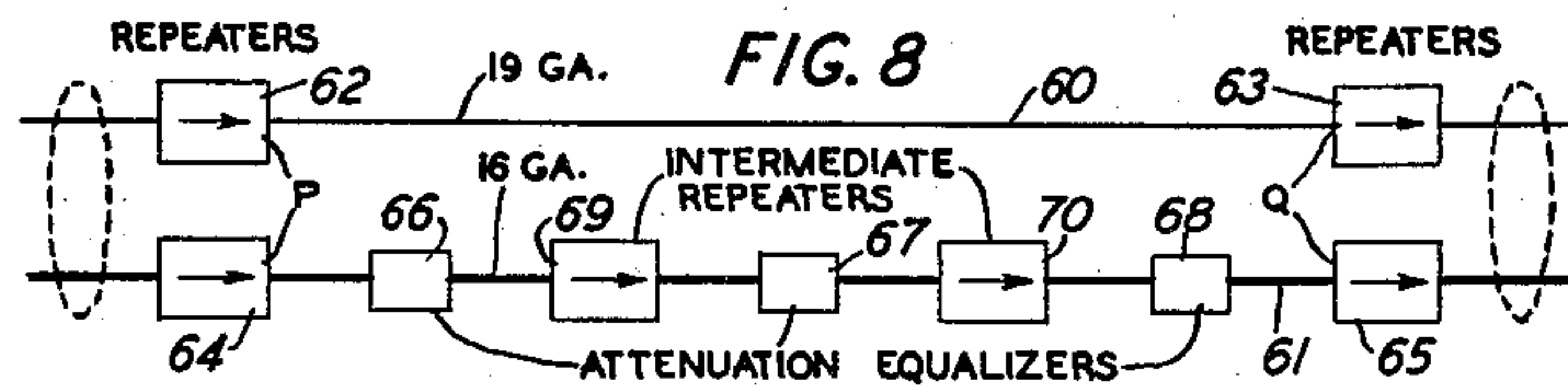
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HIGH FREQUENCY SIGNALING SYSTEM

Filed Oct. 17, 1935

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,051,529

HIGH FREQUENCY SIGNALING SYSTEM

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Application October 17, 1935, Serial No. 45,512

9 Claims. (Cl. 179—78)

This invention relates to high frequency signaling and has for an object to reduce cross-talk between adjacent signaling systems.

When two or more signaling systems are operated in the same cable one of the principal problems encountered is to reduce cross-talk or mutual interference due to inductive or capacity effects between adjacent systems.

In order to prevent cross-talk in adjacent voice frequency signaling systems it is customary to transpose the pairs of wires at intervals which are short relative to the wave lengths of the currents employed. In carrier current signaling systems, however, where the wave lengths involved are relatively short, transpositions are required at much more frequent intervals and the problem of reducing cross-talk becomes increasingly difficult. This is particularly true when different band widths of frequencies are transmitted over adjacent conductors in the same cable.

When it is desired to transmit signaling currents over different sized gauges of wire through the same cable cross-talk difficulties immediately become apparent if these signaling currents are of sufficiently high frequency. Because of the different attenuation of the two gauges at any given frequency the signal levels on the respective gauges cannot be set the same at more than one point in the circuit. At other points, therefore, the normal cross-talk from the circuit at the higher level to the circuit at the lower level is increased by this difference in the levels, which additional cross-talk may amount to a substantial value. When different gauges are used it is desirable to use a somewhat broader frequency band on the heavier gauge conductors than on the lighter ones in order to utilize them at their full efficiency, without requiring different repeater locations for the two groups of circuits. In such a situation the cross-talk difficulty is caused by the lower attenuation of the heavier gauge circuit in the frequency range where its lower attenuation is not of conspicuous transmission advantage—that is, in the lower frequency range of the broader band circuit. In accordance with one form of this invention it is proposed to make the attenuation of the two gauges of conductor substantially equal in this region so that the respective signal levels throughout the frequency range where the two circuits overlap may be made substantially equal throughout the length of a repeater section. This is preferably achieved by inserting a plurality of spaced attenuation equalizers in the

heavier gauge circuit to bring its attenuation in the common frequency range up to that of the finer gauge circuit. Above this frequency range the equalizers may taper off to give less and less added attenuation until at the high frequencies at which the heavier gauge is to be operated they add substantially no attenuation. Thus the equalizers have no effect in the frequency range where the lower attenuation of the heavier gauge pair is of the greatest transmission importance.

The same general principles may be applied to the condition where it is desired to transmit frequency ranges of different widths over adjacent conductors of equal gauge where the transmission of the higher frequency range over one pair is made possible by introducing one or more intermediate repeaters in the said one pair so as not to allow the level of the higher frequency band to fall below the minimum allowable amount. In order to prevent the signaling level at the output of such an intermediate repeater from being high enough to cross-talk unduly into the adjacent non-repeated circuit it is proposed in accordance with this invention that the gain of such an intermediate repeater be made zero over the frequency range common to both circuits, allowed to be appreciable only at frequencies above this range, and to become normal (canceling the attenuation coming before it) in the neighborhood of the maximum frequencies in the wider band. This may be accomplished by associating with the intermediate repeater an equalizer network so that the combination of the two has the desired characteristic.

It will be apparent that the foregoing principles may also be employed in the case where it is desired to transmit a very large band width of frequencies over a heavy gauge circuit and a comparatively narrow band width over the finer gauge circuit. In such a situation the heavier gauge circuit should have intermediate repeaters with zero gain for those frequencies corresponding to the frequency band transmitted over the smaller gauge circuit and with attenuation equalizers spaced at intervals in the heavier gauge circuit to bring its attenuation for the common frequency band up to that of the smaller gauge.

Referring to the drawings,

Figure 1 illustrates an arrangement for reducing cross-talk between conductor pairs of different gauges where a common frequency band is transmitted by both pairs;

Fig. 2 shows for a certain frequency the change

in transmission level that occurs for the two conductor pairs of Fig. 1 between adjacent repeater points;

Fig. 3 represents the variation at a receiving repeater point of the transmission level in each conductor pair of Fig. 1 for the frequency band transmitted over both conductor pairs;

Fig. 4 represents the characteristics of the attenuation networks added to the heavier conductor pair of Fig. 1 to reduce the cross-talk;

Fig. 5 illustrates another arrangement for reducing cross-talk between conductor pairs of the same gauge where one pair transmits a wider frequency band than the other pair;

Fig. 6 represents the variation at the receiving terminals of a common repeater point of the transmission level of each conductor pair of Fig. 5 for the frequency band transmitted over both pairs;

Fig. 7 shows for a certain frequency the change in transmission level that occurs for the conductor pairs of Fig. 5 between adjacent common repeater points;

Fig. 8 illustrates an arrangement for reducing cross-talk between conductor pairs of different gauges where the heavier gauge is utilized to transmit a wider frequency band than the other pair;

Fig. 9 for certain frequencies the change in transmission level that occurs for the conductor pairs of Fig. 8 between common repeater points; and

Fig. 10 represents at the receiving terminals of a common repeater point the variation in transmission level for the frequency band transmitted over both pairs.

The form of the invention illustrated in Fig. 1 is concerned with the transmission of different band widths of frequencies in the same cable using different sized gauges and equal repeater spacings. Lines 11 and 12 represent two conductor pairs located in the same cable sheath 13 for transmitting bands of frequencies in the same direction as indicated by the arrows while conductor pairs not disclosed but which may be in another adjacent cable are employed for transmitting the frequency bands in the opposite direction. For illustrative purposes conductor pair 11 is assumed to be No. 16 gauge and conductor pair 12 No. 19 gauge. Each of the lines has a repeater 14, 15 at one common repeater point and a repeater 17, 18 at the next adjacent common repeater point.

Assuming equally spaced repeaters and the same minimum allowable transmission level for both lines at the input of a receiving repeater it will be apparent that due to the lower attenuation of the heavier gauge pair 11, pair 11 is capable of transmitting a wider band of frequencies than pair 12 while still keeping above the minimum transmission level at the input of repeater 17. But each frequency in the common frequency band transmitted by both lines will arrive at the receiving repeater 17, 18 at different transmission levels on the two lines and hence serious cross-talk is likely to result.

Fig. 3 shows how the transmission levels for the two conductors 11 and 12 vary as a function of the frequency when a signal of a given power is sent over each line at the output of the transmitting repeaters 14, 15. The measurements indicated in Fig. 3 are taken at the input of receiving repeaters 17, 18 and the power output from the transmitting repeaters 14, 15 will, for convenience, be considered at zero level.

Curve 20 illustrates the transmission level versus frequency characteristic for the No. 16 gauge pair 11 with networks 24 omitted, and the full line 21 down to the point marked f_2 plus the added extension 22 represents the transmission level versus frequency characteristic for the No. 19 gauge pair 12. The difference in level between the two circuits at any given frequency is clearly seen by comparing curve 20 with the curve 21, 22. Let it be assumed that the minimum allowable transmission level at the input of receiving repeaters 17, 18 for any transmitted frequency is -63 db., that is, 63 db. below the level of the output of transmitting repeaters 14, 15. It follows that a band of frequencies, say, from 5000 cycles (f_1) up to 50,000 cycles (f_2) can be transmitted over the No. 19 gauge pair without going below the minimum allowable transmission level. From the curve 20 it will be apparent that frequencies up to 110,000 cycles (f_3) can be transmitted over the No. 16 gauge pair without going below the minimum allowable transmission level. Consequently the inherent attenuation characteristics of the two gauges are such as to offer the possibilities of transmitting two bands of frequencies, one band from frequency f_1 to frequency f_2 and the other band from frequency f_1 to frequency f_3 provided the transmission levels between these pairs do not depart more than the maximum amount allowable for cross-talk purposes.

In order to prevent an increase in the cross-talk difficulties that would be brought about by the level differences between the two circuits as indicated by curve 20 and curve 21, 22 it is proposed in accordance with this invention to provide attenuation networks of certain characteristics at intervals between the repeaters in the No. 16 gauge pair. The number of such networks per repeater section will depend on the extent to which it is necessary to keep the levels between the different gauges as nearly alike as possible. For illustrative purposes, Fig. 1 shows four equally spaced attenuation networks 24 connected in tandem in the No. 16 gauge pair between the adjacent repeater points.

The curves of Fig. 4 which are plotted on the same scale as Fig. 3 illustrate the characteristics these attenuation networks should have in order that each frequency in the common frequency band will arrive with the same transmission level at the input of the receiving repeaters for both conductor pairs. Curve 25 shows the frequency-attenuation characteristic each of the attenuation networks 24 should have. When four of such networks are connected in tandem their total attenuation characteristic is given by curve 23 and the intermediate curves between curve 25 and curve 23 show the combined attenuation of two and three of the networks. Bearing in mind that the curve 20 of Fig. 3 is the attenuation characteristic of the No. 16 gauge pair without the attenuation networks it follows that curve 28 of Fig. 4 when combined with curve 20 of Fig. 3 should give a resultant attenuation curve for the No. 16 gauge pair which is the same curve as curve 21 within the common frequency band from frequency f_1 to f_2 . In other words, for the common frequency band between f_1 and f_2 the attenuation characteristic of the No. 16 gauge pair with the inserted attenuation networks is given by curve 21 of Fig. 3 and not curve 20. For the frequency range from f_2 to f_3 which is transmitted solely by the No. 16 gauge pair the No. 16 gauge pair with the atten-

uation networks may have a substantially constant attenuation as indicated by line 23, Fig. 3, which line does not fall below the minimum allowable transmission level assumed above.

That is, the No. 19 gauge pair has an attenuation versus frequency characteristic shown by curve 21 between the frequency f_1 and f_2 and the No. 16 gauge pair with the attenuation networks has an attenuation versus frequency curve 21 between the frequencies f_1 and f_2 and an attenuation-frequency curve 23 for the frequency range between f_2 and f_3 .

Fig. 2 shows the changes in level that occur along the lines 11 and 12 for a given repeater spacing at a given frequency. In particular, Fig. 2 is a plot of the transmission level for 50 kilocycles versus the repeater spacing in miles. Dotted line 29 represents the variation in level on the No. 16 gauge pair without the attenuation networks 24 and the straight line 30 represents the variation in level on the No. 19 gauge pair, where zero output level is assumed at the output of the transmitting repeaters 14 and 15. When the four spaced attenuation networks 24 are inserted in the No. 16 gauge pair the transmission level for the corrected No. 16 gauge pair follows line 29 until the first attenuation network is reached when there is a drop due to the added attenuation indicated by line 31 to give an attenuation value somewhat below the corresponding attenuation in the No. 19 gauge pair after which the attenuation of the No. 16 gauge pair proceeds along a line parallel to line 29 until the second attenuation network is reached where the total attenuation again drops somewhat below the attenuation in the No. 19 gauge pair at the corresponding point. In other words, the transmission level for the No. 16 gauge pair with the inserted attenuation networks is represented by the solid line portion of line 29 and then lines 31 to 33, inclusive. It is assumed that the departure of the lines 31 to 33, inclusive, from the straight line 30 is not sufficient to indicate serious cross-talk but it is apparent that a smaller maximum departure in the No. 16 gauge pair over the No. 19 gauge pair may be secured by increasing the number of attenuation networks inserted in each repeater section of the No. 16 gauge pair. It will be noted that for the assumed frequency of 50 kilocycles the transmission level at the input of the receiving repeater 18 of the No. 19 gauge pair is the same as for the No. 16 gauge pair with the inserted networks as indicated by lines 30 and 38 terminating at the same point in the lower right-hand corner of Fig. 2. It will also be apparent that the same general relation between the transmission level in the two pairs 11 and 12 will hold for each of the other frequencies in the common frequency band f_1 to f_2 .

The electrical network comprising each attenuation equalizer 24 may be of any suitable type following the principles disclosed, for example, in the Hoyt U. S. Patent 1,453,980, Zobel U. S. Patent 1,603,305 and Stevenson U. S. Patent 1,606,817.

The procedure outlined above for making the transmission level along the No. 16 gauge pair substantially equal to the transmission level along the No. 19 gauge pair may be applied to more than two sizes of conductor by making the transmission level along the heaviest gauge pair and the transmission level along the intermediate gauges substantially the same as the finest

gauge pair for the common frequency band transmitted over all the pairs.

As another illustration of this invention it may be assumed that it is desired to transmit different band widths of frequencies over the same cable using gauges of the same size but with unequal repeater spacings. A means for accomplishing this without introducing the harmful level differences discussed above is shown in Fig. 5 and the accompanying curves of Figs. 6 and 7. Fig. 5 shows two No. 19 gauge pairs 40 and 41 with repeaters 42 to 45 at two spaced common repeater points, while pair 41 has an intermediate repeater 46 halfway between the common repeater points. Conductor pairs 40, 41 are located in the same cable and it may be assumed that it is desired to transmit a band width from frequency f_4 to frequency f_5 on conductor 40 and a greater band width from frequency f_4 to frequency f_6 on conductor 41 without producing objectionable cross-talk. This purpose will be fulfilled if in the design of intermediate repeater 46 an amount of equalizer attenuation is added by any convenient means so that its frequency gain characteristic will have zero gain over the common frequency range from f_4 to f_5 and will supply the needed amplification over the higher frequency range f_5 to f_6 to maintain the transmission of this higher frequency range above the minimum transmission level when measured at the input to repeater 45.

Let P be designated the output terminals of the repeaters 42, 43 and let Q designate the input terminals of repeaters 44, 45. Fig. 6 shows the relation between the frequency and the transmission level measured both at the midpoint of each pair and at the point Q assuming zero level at P. It may be assumed that curve 47 shows the variation in level with frequency of both conductors 40, 41 when the level is measured at the midpoint of the repeater section without intermediate repeater 46. This curve shows that a frequency band from f_4 to f_6 can be transmitted to the midpoint of the repeater section without going below the minimum allowable transmission level, namely, -63 db. However, when the level is measured at the point Q for the full repeater section without intermediate repeater 46, curve 48, 49 gives the transmission level for both conductors 40 and 41 and shows that only the frequency band f_4 to f_5 can be transmitted between the point P and Q without falling below the minimum allowable limit. This indicates that the narrow band f_4 to f_5 can be transmitted over line 40. As shown by curve 47 the band f_4 to f_6 arrives at the input of intermediate repeater 46 without going below the minimum transmission level and hence in order that this broad band may arrive at Q at a satisfactory level it is necessary for intermediate repeater 46 to have a frequency gain characteristic that will not allow the level between intermediate repeater 46 and the point Q for the frequency range f_5 to f_6 to fall below -63 db. Beginning with the frequency f_5 intermediate repeater 46 should have a gain increasing with frequency such that when the level is measured at Q with the intermediate repeater included the resulting curve will be similar to curve 48, 50 instead of curve 48, 49. If intermediate repeater 46 is adjusted to have zero gain for the frequency band f_4 to f_5 it follows that the curve 48 represents the transmission level at Q for the frequency band f_4 to f_5 which may be transmitted over pair 40 and the curve 48, 50 represents

the transmission level at Q over pair 41 for the entire frequency band f_4 to f_6 . Thus it is seen that the two lines 40, 41 of Fig. 5 have the same transmission characteristic for the common frequency range, f_4 to f_5 , and that the level for the extra frequency band f_5 to f_6 transmitted solely over pair 41 does not fall below the minimum allowable level.

Fig. 7 shows the changes in level along conductors 40, 41 between repeaters 42, 43 and repeaters 44, 45 for the individual frequencies f_5 and f_6 where the transmission level is plotted against repeater spacing in miles. Line 51 shows the linear variation in level along both conductors 40 and 41 at the frequency f_5 which is the maximum frequency common to both lines. If it were not for the suppression of the gain of intermediate repeater 46 for the frequency f_5 and the lower frequencies, the level along conductor 41 for f_5 would be given by the three line characteristic 51, 52, 53 which, of course, would be undesirable because of cross-talk due to the different transmission levels in conductors 40 and 41. The three line characteristic 54, 52, 55 gives the variation level along conductor 41 for the frequency f_6 which is the maximum frequency to be transmitted over that conductor.

The preferred characteristic of repeater 46, namely zero gain for frequencies f_4 to f_5 and a gain increasing with frequency between f_5 and f_6 , indicated by the area between lines 49 and 50 of Fig. 6, may be secured by incorporating in the repeater 46 an attenuation equalizer network of any suitable type designed along the principles outlined in the previously mentioned patents.

When dealing with gauges of different size in the same cable it is possible to transmit different band widths without introducing the harmful level differences discussed above, by using a combination of spaced equalizer networks and intermediate repeaters. In Fig. 8 the No. 19 gauge pair 60 and the No. 16 gauge pair 61 are assumed to be located in the same cable. One repeater section is shown with repeaters 62, 64 at one common repeater point and repeaters 63, 65 at the next common repeater point. Line 61 also has three spaced attenuation equalizers 66, 67 and 68 and two intermediate repeaters 69, 70.

In Fig. 10 curves 71 and 72 show the frequency level characteristic for pairs 60, 61 respectively, when measured at the receiving end Q, there being no equalizers or intermediate repeaters in conductor 61. In the first place a minimum allowable level must be selected for transmission over both gauges. For the No. 19 gauge pair 60 which is, for example, to transmit a plurality of voice carriers, a minimum level of -70 db. may be chosen, which, according to curve 71 indicates that conductor 60 can be used to transmit a frequency band from f_7 to f_8 , without going below the minimum allowable transmission level. If we assume that conductor 61 is a television circuit the minimum transmission level may be somewhat lower, for example -80 db. It then becomes necessary to add sufficient attenuation to the No. 16 gauge pair 61 so that its frequency level characteristic for the band f_7 to f_8 will be the same as the No. 19 gauge pair 60 so as to avoid cross-talk difficulties. Since the minimum level required for the No. 16 gauge pair 61 is somewhat lower than for the No. 19 gauge pair 60 the added attenuation for the No. 16 gauge pair may be designed to slope off gradually for frequencies above f_8 as indicated

by the dotted portion 73 of the level characteristic, which dotted portion it will be noted does not fall below -80 db. The cross-hatched area A lying between curve 72 and curve 71 and 73 represents the total attenuation that must be added to the No. 16 gauge pair 61. As previously stated it is assumed that the No. 16 gauge pair has three spaced attenuation equalizers in each repeater section. The cross-hatched area C is one-third of area A and represents the attenuation produced by the attenuation network 66 located midway between the transmitting repeater 64 and the first intermediate repeater 69. The curve 74 shows the level when measured at the input to the first intermediate repeater 69 while curve 75 shows the level at the same point without the attenuation network 66. The cross-hatched area B is two-thirds of area A and represents the attenuation added by the two equalizing networks 66, 67. The second network 67 is located halfway between the input repeaters 69 and 70. Curve 76 shows the level when measured at the input of the second intermediate repeater 70 with both the networks 66 and 67 included. The addition of the third attenuation network 68 gives the total attenuation desired, so that when the level is measured at the receiving point Q on the No. 16 gauge pair it has the same level as the No. 19 gauge pair measured at the same point for the band of frequencies between f_7 and f_8 .

In regard to the intermediate repeaters 69 and 70 these should have characteristics similar to the intermediate repeater of Fig. 5, that is, the net amplification characteristic must be such as to give zero gain over a part of the frequency range and give the desired amplification over the remainder of the frequency range. Since the minimum level for the No. 16 gauge pair has been assumed to be slightly lower than that for the No. 19 gauge pair these intermediate repeaters do not begin to give increased gain directly at the frequency f_8 (the limiting frequency for the No. 19 gauge pair) but the gain starts at the first frequency reached at the minimum allowable level for the No. 16 gauge pair. For example, when measuring the level at the output of intermediate repeater 69 the characteristic is given by curves 74, 77, while without the intermediate repeater 69 the characteristic measured at the same point would be that indicated by curve 74, 78. With the two intermediate repeaters 69, 70 in the circuit and the level measured at the output of repeater 70 the characteristic is given by lines 76, 79. When the level is measured at the receiving point Q with the three equalizer networks and the two intermediate repeaters included in line 61 the resultant level characteristic is represented by lines 71, 73, 80. Bearing in mind that the characteristic for the No. 19 gauge pair is given by line 71 it is thus seen that the attenuation for the No. 16 gauge pair and the No. 19 gauge pair is made identical for the frequency band f_7 to f_8 and that the transmission level of the band f_8 to f_9 over the No. 16 gauge pair is never allowed to fall below the minimum requirements.

It is not only necessary to make the overall attenuation characteristic of both gauges the same over the common frequency range but the difference in levels at any point along the pairs between common repeater points must not exceed an amount beyond which cross-talk difficulties arise. Fig. 9 shows these level characteristics for the circuits of Fig. 8 where the trans-

mission level is plotted against repeater spacing in miles. At the frequency f_8 , the maximum frequency transmitted by the No. 19 gauge pair, the straight line 84 shows the variation in level along the No. 19 gauge pair between repeaters 62 and 63. At this same frequency the dotted characteristic 85 shows the change in level along the No. 16 gauge pair, the irregularities being due solely to the added attenuation networks since the intermediate repeaters have zero gain for the frequency f_8 . At the frequency f_9 , the maximum frequency transmitted by the No. 16 gauge pair, the attenuation networks have no effect so that the straight lines 86 to 90, inclusive, show the change in level along the No. 16 gauge pair for that frequency. In other words, at the frequency f_9 the two intermediate repeaters carry the level back to zero in each case at their outputs. It is, of course, to be understood that in each repeater section, conductor 61 may have a still larger number of spaced attenuation equalizers and intermediate repeaters, and the above example is for illustrative purposes only.

It is to be understood that this invention is capable of still other embodiments commensurate with the scope of the appended claims.

What is claimed is:

1. In combination, a plurality of adjacent carrier current transmission lines transmitting a given band of carrier frequencies over one of said lines and transmitting over a second of said lines a wider band of carrier frequencies including at least a portion of the frequency band transmitted by said first line, said second line tending to transmit the frequency band common to the two lines at a higher energy level than said first line, and means inserted in said second line for reducing the energy level of the common frequency band in said second line to substantially the same level as in said first line while affecting to a lesser degree the energy level of those frequencies transmitted only in said second line.

2. In combination, a pair of adjacent carrier current transmission lines transmitting a given frequency band of carrier frequencies over one of said lines and transmitting on a second of said lines a wider band of carrier frequencies including at least a portion of the frequency band transmitted by said first line where said second line has a lower attenuation than said first line for a given frequency, and means inserted in said second line for making the attenuation of said pair substantially equal for each frequency in the frequency band common to said pair, said means having a negligible effect on the highest frequencies transmitted by said second line.

3. In combination, a plurality of adjacent carrier current transmission lines with equal repeater spacings, one of said lines transmitting a given band of carrier frequencies and a second of said lines transmitting a wider band of carrier frequencies including the band transmitted by said first line and a band of higher frequencies, said second line comprising a heavier gauge wire than said first line, and means inserted in said second line at a plurality of points between two adjacent repeaters for making substantially equal throughout the length of a repeater section the signal levels in said two lines for that frequency range where said two lines overlap.

4. In combination, a plurality of adjacent carrier current transmission lines transmitting in the same direction, a common repeater point for

said lines, a second common repeater point for said lines spaced from said first repeater point, one of said lines transmitting a given band of carrier frequencies and the second of said lines transmitting a wider band of carrier frequencies including the band transmitted by said first line and a band of higher frequencies, said second line between said repeater points tending to have a lower attenuation than said first line for said common band of frequencies, and means for substantially equalizing the transmission level in said two lines for said common band of frequencies.

5. In combination, a cable containing a plurality of carrier current transmission lines transmitting in the same direction, a common repeater point for said lines, a second common repeater point for said lines spaced from said first repeater point, one of said lines transmitting a given band of carrier frequencies and the second of said lines transmitting a wider band of frequencies including the band transmitted by said first line and a band of higher frequencies, said second line comprising a line conductor of larger cross-sectional area than the line conductor for said first line, and means spaced at intervals in said second line between said repeater points for preventing said second line from transmitting said common band of frequencies at a substantially higher level than said first line.

6. In combination, a cable containing a plurality of carrier current transmission lines transmitting in the same direction, a common repeater point for said lines, a second common repeater point for said lines spaced from said first repeater point, one of said lines transmitting a given band of carrier frequencies, a second of said lines transmitting a wider band of frequencies including the band transmitted by said first line and a band of higher frequencies, said lines utilizing between said repeater points line conductors of substantially the same cross-sectional area, an intermediate amplifying repeater in said second line for said band of higher frequencies, and means for causing currents of said common frequency band to arrive at said second repeater point at substantially the same transmission level in both of said lines.

7. In combination, a plurality of adjacent carrier current transmission lines transmitting a given band of carrier frequencies over one of said lines and transmitting over a second of said lines a wider band of carrier frequencies including at least a portion of the frequency band transmitted by said first line, said second line comprising a heavier gauge conductor than said first line and a plurality of spaced attenuation equalizing networks in said second line having such attenuation characteristics that the combined overall attenuation of said second line with said networks for any frequency in said common frequency band is substantially identical with the attenuation of said first line for the same frequency.

8. In combination, a cable containing a plurality of carrier current transmission lines transmitting in the same direction, a common repeater point for said lines, a second common repeater point for said lines spaced from said first repeater point, one of said lines transmitting a given band of high frequencies, a second of said lines transmitting a wider band of frequencies including the band transmitted by said first line and a band of higher frequencies, said

lines utilizing between said repeater points conductors of substantially the same cross-sectional area, and an intermediate repeater in said second line, said intermediate repeater having substantially zero gain for said common frequency band and for higher frequencies a gain increasing with the frequency to maintain above the minimum allowable transmission level said higher frequency band as measured at the input to said second common repeater point.

9. In combination, a cable containing a plurality of high frequency transmission lines transmitting in the same direction, a common repeater point for said lines, a second common repeater point for said lines spaced from said first repeater point, one of said lines of a given gauge transmitting a given band of high fre-

quencies, a second of said lines of a heavier gauge transmitting a wider band of frequencies including the band transmitted by said first line and a band of higher frequencies, a plurality of spaced attenuation equalizer networks in said second line for increasing the attenuation of said second line to a value substantially equal to the attenuation of said first line for said common band of frequencies, said networks having negligible effect on frequencies in said higher frequency band and an intermediate repeater for said second line given substantially zero gain for the common frequency band and an appreciable gain for frequencies in said higher frequency band.

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