Oct. 17, 1939. H. J. J. M. DE R. DE BELLESCIZE 2,176,168

FREQUENCY MODULATED SIGNAL

Filed Aug. 21, 1937 3 Sheets-Sheet 1

FIG. 1

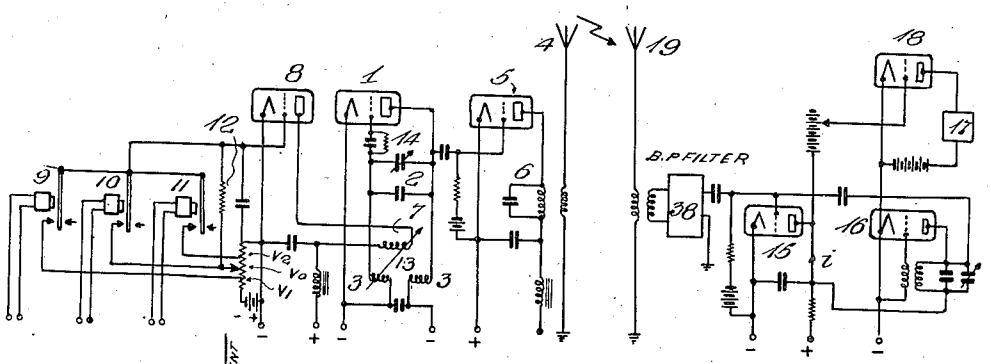


FIG. 2

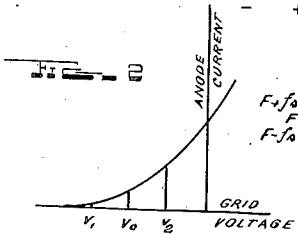


FIG. 3

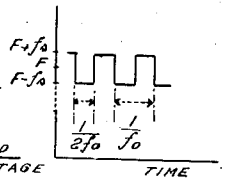


FIG. 4

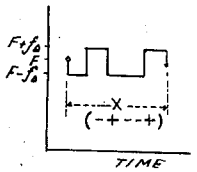


FIG. 5

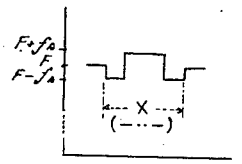


FIG. 6

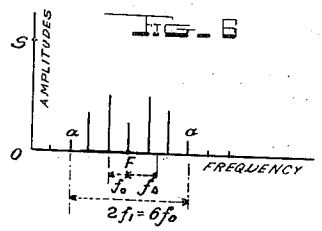


FIG. 9

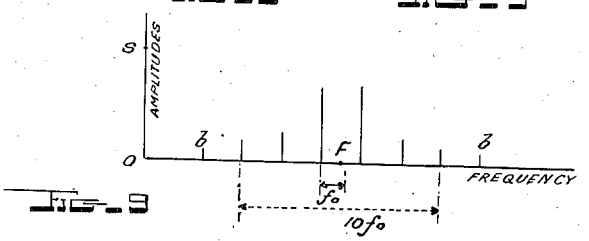


FIG. 7

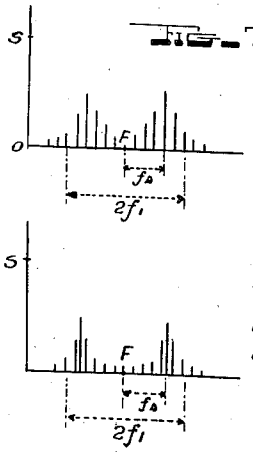


FIG. 10

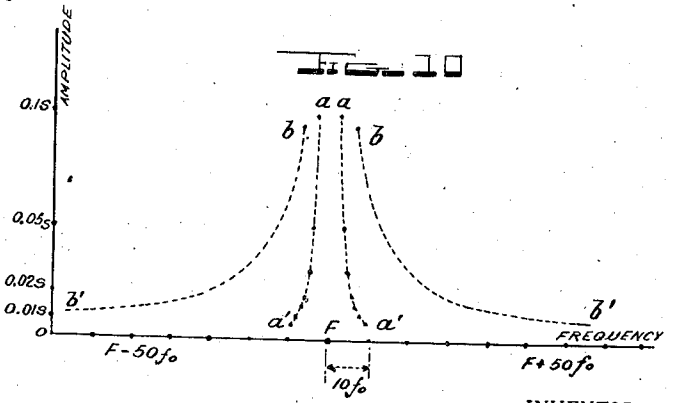


FIG. 8

INVENTOR.

Henri J. J. M. de R. de Bellescize,

BY

John B. Brady

ATTORNEY

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FREQUENCY MODULATED SIGNAL

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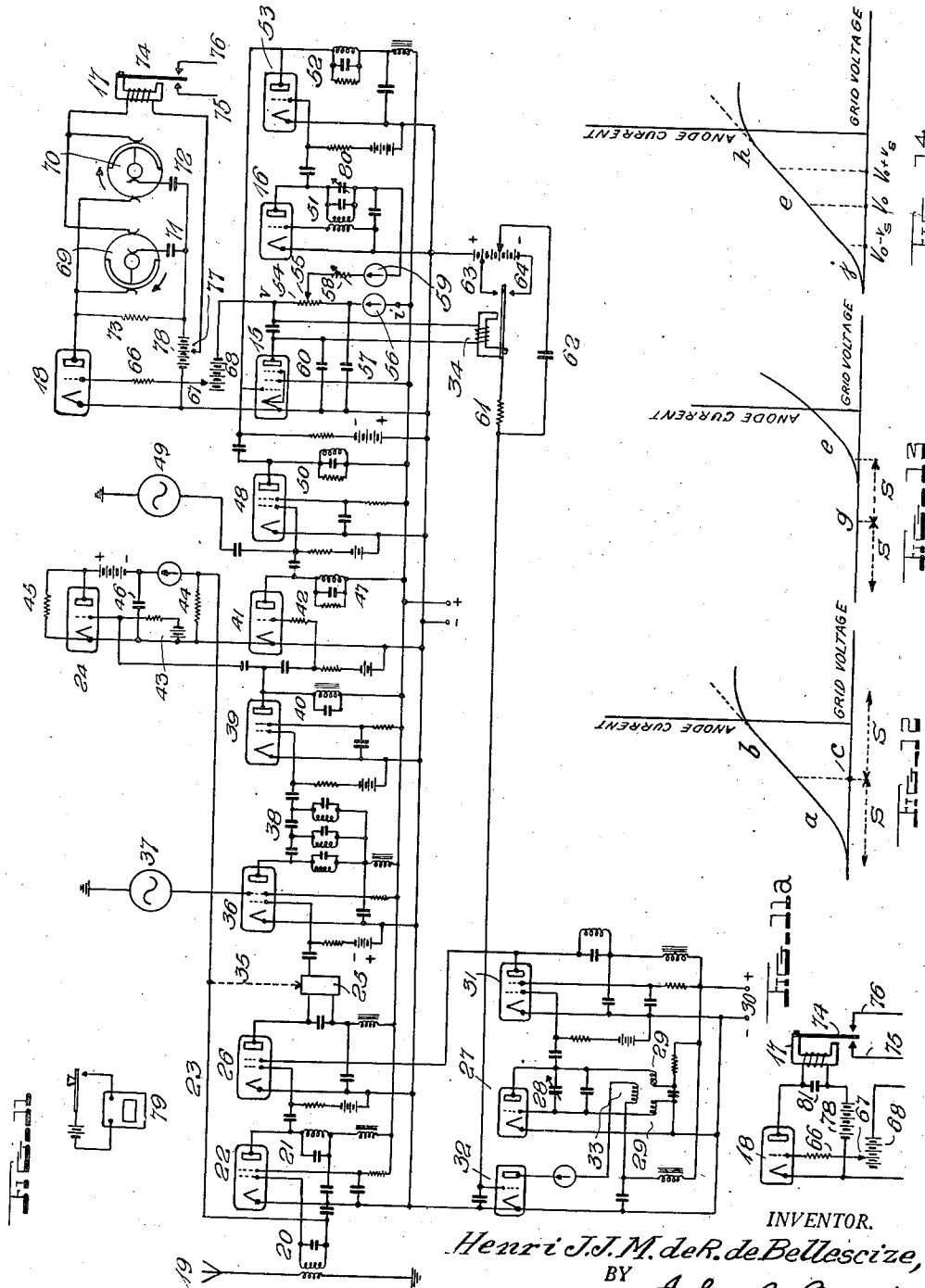


Fig. 14

Fig. 13

Fig. 12

Fig. 11

Fig. 11a

INVENTOR.
Henri J. J. M. de R. de Bellescize,
BY
John B. Brady
ATTORNEY.

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FREQUENCY MODULATED SIGNAL

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Fig. 15

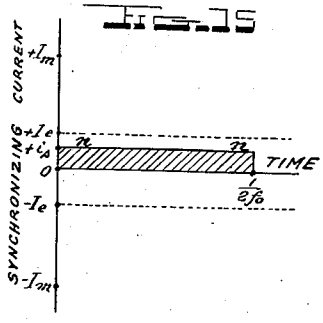
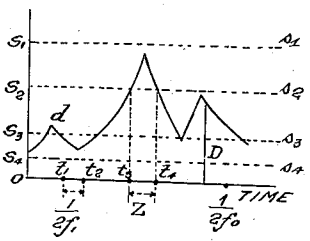


Fig. 16



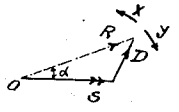


Fig. 17

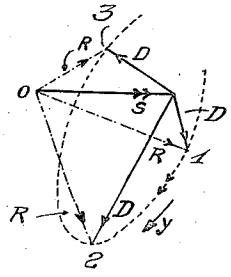


Fig. 18

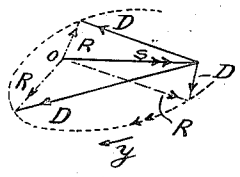


Fig. 19

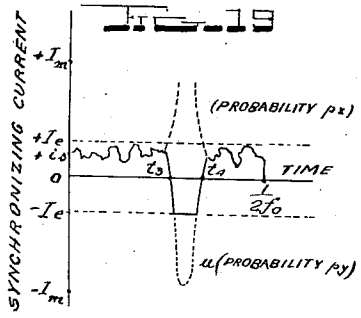
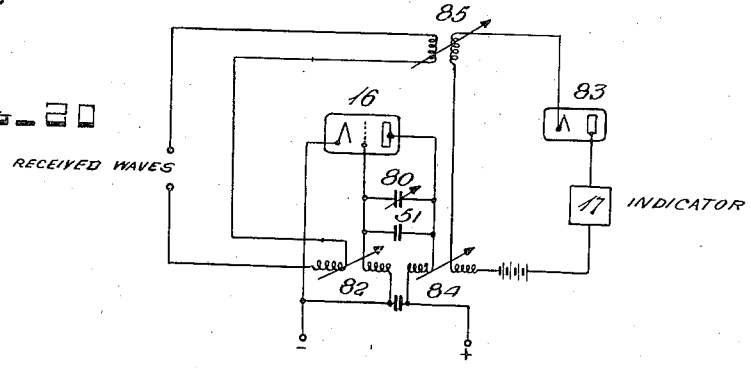


Fig. 20



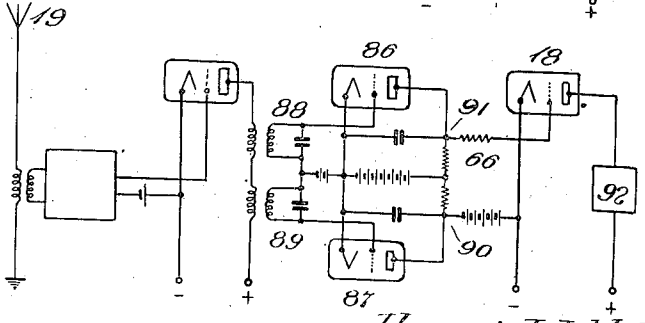


Fig. 21

INVENTOR.

Henri J. J. M. de R. de Bellescize,

BY

John O. Grady

ATTORNEY

Patented Oct. 17, 1939

2,176,168

UNITED STATES PATENT OFFICE

2,176,168

FREQUENCY MODULATED SIGNAL

Henri Jean Joseph Marie de Regnauld de Bellescize, Neuilly-sur-Seine, France

Application August 21, 1937, Serial No. 160,330

14 Claims. (Cl. 250—8)

My invention relates to signalling methods and systems, and more particularly to wireless telegraphy in which emitters radiate an electric wave whose frequency is varied in accordance with a signal, and in which the receiver demodulates this wave by transforming its frequency variations into corresponding intensity or voltage changes. The main characteristics of such systems are well known and may be summarized as follows: at the emitter, signalling is effected by varying the frequency of the signal wave in such a way that each code sign is individually represented by a predetermined value of this frequency; for instance, frequencies $F-f_s$ and $F+f_s$ will correspond to dots or dashes and spaces respectively; the radiated spectrum is wholly defined by the amplitude f_s of the changes imparted to the frequency of the signal wave with respect to the mean value F of this frequency, and by the number f_o of dots which may be transmitted during one second; f_o, proportional to the keying speed, will hereafter be called "signs frequency"; from a work published by B. van der Pol in the Proceedings of I. R. E., July 1930, I found that the width of this spectrum is practically $2f_1=2(f_s+2f_o)=2(m+2)f_o$, where

$$m=\frac{f_s}{f_o}$$

hereinafter called "index" designates the frequency changes to signs frequency ratio. Outside the central band of width $2f_1$, the radiated components appear to be much less important than in amplitude modulation telegraphy, because a frequency modulated wave has a constant amplitude and a phase varying progressively, whereas in other telegraph methods amplitude or phase undergo sudden leaps generating important side components far apart from the carrier frequency; thus, frequency modulation telegraphy permits communications on closely adjacent channels without interference. Usually, the receiver comprises frequency changers, filters, means for stabilizing the amplitude of the incoming wave, and an indicator fed through low frequency circuits by a device in which frequency changes $\pm f_s$ due to signalling are transformed into corresponding changes $\pm i_s$ in the intensity of a detected current; this transformation may be reached through various ways, for instance by utilizing balanced resonators tuned to the extreme signalling frequencies respectively as illustrated at Fig. 1b in my Patent No. 1,612,101 dated December 28, 1926, or a synchronizing current acting as an elastic link for maintaining a local generator of oscillations in locked synchronism with the received wave as disclosed in my Patent No. 2,040,980 dated May 19, 1936.

The first object of the present invention is to provide suitable means for adapting the characteristics of the emitter to those of the receiver so as to supply the detection and recording of the signal with the protection required against both statics and fading. The receiver will be managed so as to derive from each code sign an accumulation effect substantially proportional to the index

$$m=\frac{f_s}{f_o}$$

and thus the index must be increased according as disturbances are growing worse; but frequency changes f_s and signs frequency f_o are transmission characteristics, whereby emitter and receiver are closely dependent on each other. For deriving from each code sign an effect proportional to the index, the frequency change f_s representing this sign will be translated into a detected current i_s of intensity approximately proportional to f_s, and further the electricity supplied by this current will be stored over a space of time τ proportional to the duration $1/2f_o$ of this sign; thus the accumulation effect $(i_s\times\tau)$ derived from the code sign will be proportional to

$$\frac{f_s}{f_o}$$

and therefore to the index.

A second object of the invention is to increase the keying speed practicable at the emitter by lessening as much as possible the index required at the receiver for protecting the signal against disturbances. This improvement will be obtained by inserting between the indicator and the device for transforming frequency changes into current changes a local distributor synchronized with the signs frequency, for successively accumulating in a circuit of large time constant the whole electricity supplied by the detected current over the duration of each code sign and then transferring this electricity to the indicator. With a given index, the effect thus derived from each code sign is much larger than in usual receivers where time constants of low frequency circuits are limited to a small fraction, commonly one sixth, of the signs duration. Thence it follows that the signal effect required for dominating disturbances will be obtained with an index about six times smaller,

whereby keying speed may be increased at the emitter according to

$$f_o=\frac{2f_1}{2(m+2)}$$

where $2f_1$ is the predetermined communication band width and m the smaller index.

Another object of the invention is to obtain a more rapid increase of the index and thus of the protection against disturbances at the receiver, in proportion as these disturbances compel the slowing down of the keying speed at the emitter. This result will be obtained by proportioning frequency changes f_s to signs frequency f_o so as to utilize at all keying speeds the maximum band width $2f_1$ allowed to signalling; in other words, f_s will be varied inversely to f_o according to $2f_1=2(f_s+f_o)$ where $2f_1$ is kept constant, whereby the index

$$m=\frac{f_s}{f_o}=\frac{f_1-2f_o}{f_o}$$

will grow more rapidly than the reverse

$$\frac{1}{f_o}$$

of the signs frequency, contrarily to what happens in usual telegraph systems where f_s is kept constant.

From the foregoing characteristics it follows that my system is particularly adapted for short wave signalling where statics and fading undergo fluctuations of large amplitude: under favorable conditions, one may use a very small index, for instance $m=1$, whereby keying speed and signs frequency compatible with the predetermined band width $2f_1$ are increased; on the other hand, a moderate slowing down of this speed will supply the largest index, for instance $m=8$, required under most unfavorable conditions; from $2f_1=2(m+2)f_o$ where $2f_1$ is now kept constant, it appears indeed that the signs frequency f_o corresponding to $m=8$ is only 3.3 times smaller than that corresponding to $m=1$.

A further object of my invention is to improve telegraph codes by composing them of three constitutive signs instead of two; for instance, dots, spaces and dashes will be represented at the emitter by frequencies $F-f_s$, F, $F+f_s$ respectively, and therefore at the receiver by detected currents $+i_s$, zero, $-i_s$. This improvement permits the transmission of a larger number of words per minute for given signs frequency and communication band; in combination with the large reduction realized on the index, the number of words per minute becomes more than ten times larger than in usual telegraph systems, for a same communication band width and a same signal to noise ratio.

A further important improvement of the invention is to facilitate identification of errors by deriving substantially identical effects from both fading and strong static and placing this common effect in the middle of effects normally due to code signs. This result is obtained by combining several conditions cooperating as follows: A rather large index, for instance $m=8$, is used at the emitter whereby the signs frequency f_o is made small comparatively to the communication band width $2f_1$. At the receiver, the band of the filter selecting the received wave is adjusted to this communication band width $2f_1$ whereby the time constant of the filter is approximately

$$\frac{1}{2f_1}$$

and drift neutralization means are provided for controlling frequency changes preceding the filter so as to maintain the mean frequency of the signal wave in coincidence with the mean frequency F_o of this filter; thence it follows that frequency changes $\pm f_s$ due to signalling become symmetrical with respect to this mean frequency F_o while the oscillations due to static assume all through the duration

$$\frac{1}{2f_o}$$

of each code sign several independent frequencies varying at random on both sides of F_o, since the large index used at the emitter causes the time constant

$$\frac{1}{2f_1}$$

to be small comparatively to

$$\frac{1}{2f_o}$$

Further, the device for transforming frequency changes into current changes is exactly balanced with respect to the same mean frequency F_o of the filter, whereby definite frequency changes $+f_s$ or $-f_s$ caused by code signs with respect to F_o are translated into detected currents $+i_s$ or $-i_s$ of definite directions in accordance with these signs, while frequency changes caused about F_o by static dominating the signal wave are translated into currents of directions reverting at random many times during each code sign. Then, fluctuations undergone by the detected current are limited in both directions to intensities equal to $\pm i_s$ or slightly larger. Finally, the electricity supplied by this current is accumulated over the maximum space of time, i. e., over the whole duration

$$\frac{1}{2f_o}$$

of each code sign, and the indicator is energized by this accumulation effect. Owing to the above characteristics, the accumulation effect due to powerful static becomes comparatively small and thus it takes place in the middle of the extreme effects

$$+\frac{i_s}{2f_o}$$

and

$$-\frac{i_s}{2f_o}$$

normally due to code signs, since the means intensity of currents limited to i_s and reverting at random several times is necessarily small comparatively to i_s. As fading effect is also substantially null, it coincides with the effect derived from strong statics. It must be clearly understood that this system does not avoid static effect, but merely distinguishes this effect from those of code signs.

In pursuance with the above explanations, the invention allows to correct errors by repeating the signal and comparing the texts issued from the successive repetitions; this possibility extends to errors due to both static and fading and to telegraph codes using indifferently two or three signs, whereas previous repetition systems, the Verdan system for instance, permitted the correction of errors due to static only or to fading only in two signs codes only. This improvement proceeds from the fact that both static and fading will be caused to annul the accumulation effect supplied to the indicator; marks due to such disturbances may therefore be confused with the mark due to the central signalling frequency, F at the emitter and F_o after the fre-

quency changers of the receiver, when this central frequency is used for representing code spaces; but disturbances cannot produce same marks as extreme signalling frequencies $F-f_s$ and $F+f_s$ representing dots and dashes respectively; thus, dots and dashes appearing on the tape are certainly correct; as the same sign of a signal is rarely injured during successive repetitions, an accurate text may be reconstituted by repeating systematically the whole signal and by keeping dots and dashes marking on one at least of the successive recordings. These recordings may be compared visually or through automatic means.

Further developments will show that the indicator may remain insensitive to intermittent statics, even when they dominate the signal wave; those only which happen to pass in phase opposition with this wave influence dangerously the detected current by imparting to this current instantaneous changes of very short durations but of considerable amplitudes. Thus dangerous fluctuations of the detected current are rarefied but enlarged, which constitutes a particularly favorable condition for placing amplitude limiters at the output of the device which supplies this current. Such limiters are operatively quite distinct from those eventually preceding the same device for stabilizing the amplitude of the received wave.

My communication method and system will be best understood from the following description and drawings, in which:

Fig. 1 illustrates the communication system comprising the emitter and the receiver.

Fig. 2 is a curve showing the characteristics of one of the tube circuits of Fig. 1.

Figs. 3, 4, 5, illustrate the frequency variations representing code signs.

Figs. 6, 7, 8, illustrate the useful components constituting the communication band, for a constant width of this band and three different keying speeds.

Fig. 9 represents, as a term of comparison, the components of a signal whose signs are transmitted through phase reversals.

Figure 10 illustrates side components produced far apart from the carrier frequency when code signs are represented by frequency changes and phase reversals respectively.

Figs. 11, 11*a*, 12, 13, 14 give a detailed description of the receiver, in which the signal is demodulated by means of a synchronized local generator.

Fig. 15 shows the detected current obtained responsively to a code sign, when the signal wave is free from interferences.

Fig. 16 shows the signal wave received together with a disturbing wave of variable amplitude.

Figs. 17, 18, represent two cases which may occur while the signal wave is dominated by the disturbing wave, according as these waves do or do not pass in phase opposition.

Fig. 19 illustrates the accidental change undergone by the detected current, when the disturbing waves pass in phase opposition.

Fig. 20 represents another way for obtaining the detected current by causing the received wave to interfere with the synchronized local wave.

Fig. 21 illustrates a simplified receiver for obtaining mere blanks responsively to disturbances.

Fig. 1 represents the communication system, in which the emitter and the receiver are arranged to efficiently utilize the band width assigned to the signalling. The emitter radiates a hertzian wave whose frequency is varied for representing the signs of the telegraphic code. The master oscillator 1, 2, 3 excites the aerial 4 through an amplifier 5, 6. The circuit 2, 3 of the oscillator is also coupled by a coil 7 to the anode circuit of a tube 8. As indicated by Fig. 2, the resistance of the anode circuit of tube 8 depends upon the grid bias, which may admit one of the values v_1 v_0 v_2 according as the circuit of one of the relays 9, 10, 11 is closed in correspondence with the code sign to be transmitted. Each bias determines a given anode resistance of tube 8, and thus a given frequency of the oscillator. The intermediate bias v_0 is adjusted so that the corresponding frequency F is the average of the frequencies $F-f_s$, $F+f_s$, obtained for the biases v_1 v_2; furthermore, the grid of tube 8 is connected to the intermediate bias v_0 through a high resistance 12, whereby the oscillator resumes the mean frequency F when all the relays are at rest. The amplitude f_s of the variations imparted by the keying to the frequency of the radiated wave depends upon the coupling 13 of the coils 3, 7; for each keying speed, this coupling is chosen so as to reach the variation f_s which utilizes entirely the band width $2f_1$ allotted to the communication; consequently, when the statics and/or the fading lead to a reduction of this speed, and therefore to a reduction of the code signs frequency f_0, the index grows very rapidly, since in $f_1=f_s+2f_0$,

$$m=\frac{f_s}{f_o}=\frac{f_1-2f_o}{f_o}$$

the numerator increases while the denominator is lessened. Owing to the properties of the receiver, this rapid growth of the index improves the security of the communication, just when the conditions become unfavorable. A small adjustable condenser 14 is provided in the oscillator circuit to maintain the average frequency F at a constant value whatever the coupling 13 might be. The frequency fluctuations f_s can be observed during the signalling by means of a measuring apparatus, as disclosed in my Patent 2,040,980. In the receiver, which will be more fully treated with the aid of Fig. 11, the frequency fluctuations f_s are linearly transformed into the intensity variations of a current i, obtained by combining in a modulator 15 the wave received from the aerial 19 with the wave issued from a local synchronized source 16; these intensity variations impart to the source 16 the frequency corrections preserving its locked synchronism, and also energize the indicator 17 through the amplifier 18. One of the main characteristics of this communication system consists in that the detected current i gets, under the influence of disturbances, an intensity which is the average of those produced by the code signs; this result is reached by managing the emitter in such a way that the index increases according as the signalling becomes more uneasy, and the receiver so as to preserve a perfect coincidence between the mean frequency of the signal wave, the middle of the band selected by the filter 38, and the natural frequency of the source 16. The theory of this working will be briefly disclosed at the end of the description.

The Fig. 3 represents the frequency variations due to the alternative action of relays 9, 11, for transmitting a succession of dots and code spaces whose individual duration is

$$\frac{1}{2f_o}$$

This working is the one for which the spectrum of

the side components is widest; the number of dots per second, then f_0, will be named hereinafter "signs frequency". Either 2 or 3 code signs may be utilized. With the Baudot code, the dots (+) are transmitted by the relay **9**, the spaces (—) by the relay **11**; for the letter *x* (—+——+) the frequency variations are illustrated by Fig. 4. The Morse code may be transmitted as usual, dots and dashes by the relay **9**, spaces by **11**, or inversely; but the speed is greatly increased by transmitting the dots with the relay **9** and the frequency $F+f_s$, the spaces with the relay **10** and the frequency F, and the dashes with the relay **11** and the frequency $F-f_s$; for the letter *x*

(—••—)

the frequency fluctuations are now illustrated by Fig. 5, where the spaces between dots and dashes are suppressed. The index must grow to improve the security according as the communication becomes more difficult; Fig. 6 represents the communication band under favorable conditions, for which the signs frequency f_0 is the highest allowed by the mechanical devices of the emitter; the chosen index is $m=1,5$, which means that the coupling **13** (Fig. 1) is adjusted so as to obtain a frequency variation $f_s=1,5f_0$; the interval between the side components, four of them being important, is f_0; those of amplitude exceeding one tenth (0.1S) of the signal wave amplitude are practically the only useful ones for an accurate reproduction of the signal at the receiver. The width of the communication band is $2f_1=6f_0$.

Fig. 7 concerns less favourable conditions, compelling to reduce by half the keying speed, whereby the signs frequency and the components interval become $0.5f_0$; with the same communication band $2f_1$, the amplitude f_s of the frequency variations may grow up to $f_s=2f_0$, through a suitable adjustment of the coupling **13**. The index, now

$$m=\frac{2f_0}{0.5f_0}=4$$

ensures a better protection against the disturbances of any kind.

Fig. 8 concerns very bad conditions, under which the speed must be reduced to a quarter of the maximum; the signs frequency and the interval between the components, some of which happen to be null since the index is odd, is then $0.25f_0$; for the same band width $2f_1$, the amplitude of the frequency variations becomes $f_s=2.25f_0$, and the index is

$$m=\frac{2.25f_0}{0.25f_0}=9$$

Fig. 9 represents, as a term of comparison, the spectrum of the components whose amplitudes also exceed 0.1S, in a telegraphic signal transmitted through phase inversions; this spectrum is in every respect less advantageous than that of Fig. 6, corresponding to the same signs frequency; its width is $10f_0$ instead of $6f_0$; it contains only two main components, and is therefore more liable to selective fading.

Fig. 10 illustrates the part of the spectrum comprising the components of amplitudes varying from one tenth (0.1S) to one hundredth (0.01S) of that of the signal wave. These components are purely prejudicial, because they are useless for the reproduction of the signal, and moreover produce interference with adjacent communications. The two half curves *aa'*, symmetrical with regard to the carrier frequency F, concern the frequency modulation telegraphy for $m=1.5$; the points *aa* mark the summits of the components also designed by *aa* on the Fig. 6. The curves *bb'*, whose points *bb* correspond to the components *bb* of Fig. 9, concern telegraphy through phase reversals. Thus, as we remove farther from the carrier, the prejudicial components decrease much more quickly with the system of my invention.

Fig. 11 illustrates the receiver: the wave collected by the aerial **19** passes through the r. f. circuits **20**, **21**, **22**, whose amplification is controlled by a conductor **23** connected to the output of a rectifier **24**. A first intermediate frequency is obtained in the circuits **25** by combining in the modulator **26** the signal wave with an oscillation issued from the heterodyne generator **27**, **28**, **29**. It is proven by practice that the frequency of this generator can be badly influenced by the amplification control: the anode resistance of tube **22** varies indeed together with the grid bias, whereby the least coupling between the circuits **21** and **28**, **29** would produce, responsively to the potential fluctuations at **23**, local frequency changes which could be confused with those f_s of the signalling; this drawback is removed by feeding the tube **27** with separated sources **30**, and by connecting the heterodyne oscillator to the modulator **26** through a screen grid tube **31**. Furthermore, the heterodyne frequency is controlled by an auxiliary tube **32**, whose anode circuit is coupled to the circuit **28**, **29** by a coil **33**, and whose grid bias depends upon the synchronizing current *i* through a relay **34**; as shall be explained, this device neutralizes in the modulator **15** the frequency drift of the received wave with respect to the local synchronized source **16**. There is nothing particular about the circuit **25**, tuned to the intermediate frequency; its amplification may also be controlled at **35**. The received wave, the respective middles of their bands being the oscillation of a heterodyne generator **37**, so as to obtain a second intermediate frequency, such as 30 kc:s, allowing an easier construction of the filters **38** whose band width is equal to or somewhat larger than that $2f_1$ of the communication band; thus, the useful components of this band enjoy the best possible protection against interferences; this result proceeds from the fact that the filter will be exactly tuned to the signal wave, the respective middles of their hands being brought to coincide with the natural frequency of the local source **16** as explained hereinafter. After its final selection in the filter **38**, the signal wave amplitude is raised by an amplifier **39**, **40**, to a level allowing its stabilization; this stabilizations is obtained through the combined working of a limiter **41** and of an amplification control ensured by the rectifier **24**. The tube **41** characteristic curve, represented at Fig. 12, has a lower bend *a* and an upper bend *b* caused by the resistance **42**; the grid bias *c* is half way from these bends, and the amplitude of the signal wave in the input of the limiter is normally kept under the control of the detector **24** at a value S coinciding with the straight line *ab*; the amplitude of the oscillation issued from tube **41** remains therefore constant even if the input amplitude is accidentally weakened, as may happen at the outset of a sudden fading. The amplification control works in the usual way: the characteristic curve of the rectifier **24**, represented at Fig. 13, has a bow *e*, beneath which is the grid bias *g* ensured by the source **43**; as soon as the amplitude S of the signal wave tends to exceed the normal value *ge*, the detected current ensuing therefrom

causes in resistor **44** and conductor **23** a potential fall whereby the amplification of the tube **22** decreases; the grid of this tube is suitably biased by the permanent current flowing in **44** through the resistor **45**; the condenser **46** is chosen small enough to ensure a rapid working. A circuit **47**, tuned to the second intermediate frequency, separates the signal wave from the harmonics caused by the nonlinear characteristics of the limiter **41**; this circuit must be damped to transmit equally all the components selected by the filter **38**.

The signal wave is then combined in a modulator **48** with the local oscillation issued from the heterodyne source **49**, to raise the carrier frequency to a final value F_0 much higher than the fluctuations f_s; for instance, if f_s=200 c:s, the carrier frequency will receive a value 2000 times higher, that is 400 kc:s. This has many advantages: the synchronized source **16**, whose time constant is now small, obeys more quickly to frequency corrections; being relatively small, these corrections are almost proportional to their cause, i. e., to the detected current i; the filter **38** is shielded from the influence of the source **16**, since tuned to a very different frequency. At the output of the frequency changer **48**, the signal wave selected in a circuit **50** interferes in the modulator **15** with the local oscillation issued from the source **16**, **51** and from the amplifier **52**, **53**; the resonators **50**, **52**, tuned to F_0, are damped enough for being equally responsive to all the frequencies eventually undergone by the generator **16**; these frequencies are varying between F_0-f_m and F_0+f_m, f_m being the maximum frequency correction. Designating by $90°+A$ the phase difference between the received wave and the local wave, the coaction of these waves is in fact a homodyne frequency changing which linearly transforms the received wave into a current $i=I_m \sin A$; thus, the anode current of tube **15** is I_0+i, I_0 being the steady component when no wave is received. The current i performs three functions: it synchronizes the source **16**, **51**, for compelling this source to follow the frequency fluctuations of the received wave; it neutralizes the frequency drifts for maintaining a permanent coincidence between the average frequency of the received wave and the natural frequency F_0 of the source; it energizes the indicator **17**.

To preserve the locked synchronism, the potential fluctuations caused in a resistor **54** by the synchronizing current i impart to the frequency of the source **16** corrections f neutralizing the difference $(F_0+f)-F_0$ between the instantaneous frequency of the received wave and the natural frequency of the said source, owing to their relative smallness, these corrections are practically proportional to i, whereby the frequency fluctuations are transformed into proportional intensity fluctuations. When the local and received frequencies happen to coincide (f=0), the synchronization requires no correction; then the synchronizing current is null (i=0), and the waves interfering in the modulator **15** are at quadrature (A=0). The code signs, represented at the output of the frequency changer **48** by the frequencies $F_0 \pm f_s$, provide the anode currents $I_0 \pm i_s$. The maximum correction f_m, reached for $i=I_m$, $A=90°$, is adjusted by the potentiometer **55** so as to be about five times larger than f_s ($f_m=5f_s$).

A milliammeter **56**, shunted by a large condenser **57**, enables to survey the changes in the synchronizing current; the average intensity of the anode current in tube **16** is adjusted by means of a resistor **58** and read on a milliammeter **59**. These features have already been disclosed in my Patent 1,976,877, dated October 16, 1934, except in that the condenser **60** does not contribute to the selection of the signal wave: the synchronizing device having now to be very fast, this condenser **60** only by-passes the h. f. components; it is therefore very small and does not influence the time constant of the synchronizing device; according to a relation published in my Patent 2,040,980, this time constant becomes practically

$$\frac{1}{2\pi f_m}$$

for instance, with $f_m=5f_s$, $f_s=mf_0$, m=5, it is about 75 times smaller than the duration.

$$\frac{1}{2f_o}$$

of a code sign.

The coincidence between the average frequency of the received wave and the natural frequency F_0 of the synchronized source **16** is obtained at the outset of the signalling by tuning the condenser **28** of the heterodyne generator **27**, **28**, **29**; it is afterwards maintained by the relay **34** which progressively controls the bias of tube **32** through a circuit **61**, **62**, of very large time constant (for instance 100 seconds). My Patent 1,990,428, dated February 5, 1935, has already disclosed the principle of this method, but a difficulty arises in telegraphy, because the signal wave may assume alternately the frequencies F_0+f_s and F_0-f_s, during the signalling, whereas it keeps the frequency F_0-f_s during the pauses between the telegrams; thus, the mean frequencies are in turn F_0 and F_0-f_s. This difficulty is mastered by utilizing a relay **34** quick enough to follow the keying, so as to close the contact **63** when the anode current of tube **15** is I_0+i_s, and the contact **64** when this current is I_0-i_s. When the mean frequency of the received wave deviates slightly from F_0, the alternative values of the current become I_0+i_s+e and I_0-i_s+e, whereby the contact **63** becomes intermittently closed and **64** always open, or vice versa; whence a slow change in the charge of the condenser **62**, the bias of tube **32**, and the frequency of the heterodyne oscillator **27**; the shift is thus neutralized. On the other hand, the signal wave must keep, between the telegrams, the frequency F_0-f_s, and the anode current the intensity I_0-i_s; this is easily obtained by remarking that one may reverse the direction of the shift in the modulator **15**, according as the heterodyne oscillator **27** is tuned to a frequency higher or lower than that of the signal wave; consequently, it is sufficient to choose the tuning for which the shift tends to decrease the detected current, i. e. to operate the contact **64** which maintains the said current at the intensity I_0-i_s. Similar rules would also allow to preserve the intensities I_0+i_s during the silences and code spaces, and I_0-i_s during dots and dashes.

The potential fluctuations v caused in the resistor **54** by the intensity fluctuations i of the synchronizing current are amplified by the limiter tube **18**, and then energize the indicator **17**. The anode characteristic of tube **18** is used in its straight part e (Fig. 14), comprised between the lower bow j and the upper bow h due to the resistor **66**; a tap **67** is adjusted on the source **68** in such a way that the grid bias V_0, observed when no wave is received, corresponds

to the middle of this characteristic, whose width permits the amplification of potential variations somewhat larger than those $\pm v_s$ issued from the code signs. The recording is preferably managed so as to obey the quantity of electricity

$$\pm q\left(q=\frac{i_s}{2f_o}\right)$$

supplied by the synchronizing current responsively to a code sign; for this purpose, a rotor 69, 70, is synchronized with the signs frequency f_o, so as to store in a condenser 71 the quantity of electricity due to the sign received at the present time, and to discharge through the relay 17 the electricity already stored in another condenser 72 responsively to the preceding sign. The recording is thus continuous, each condenser working in turn to collect one sign on two. Whatever code based on signs of same duration may be used, the dash of Morse code, for instance, being formed by three consecutive dots. The resistance 73 in the anode circuit of tube 18 is much larger than that of the relay 17, and each condenser 71, 72, is given such a capacity that the time constant of the circuits 73—71, 73—72 exceeds the duration

$$\frac{1}{2f_o}$$

of a code sign, whereas the time constant of 17—71, 17—72 is lesser than this duration, consequently, the quantity of electricity issued from each sign is indeed wholly stored at first in one of the condensers, and afterwards wholly discharged through the relay. This relay is adjusted in such a way that its armature 74 closes one or another of the contacts 75, 76, responsively to a positive or negative discharge $\pm 0.5q$ which is only about one half of that normally provided by a sign. The tap 77 is adjusted on the anode source 78 so as to equalize the effects of the signs which supply the currents $+i_s$ and $-i_s$.

Lastly, the receiver comprises means to bring the natural frequency of the generator 16, 51, into coincidence with the middle of the band selected by the filter 38 and displaced by the frequency changer 48; the statics more powerful than the signal wave will then lead the armature of the relay 17 to its neutral position, and produce mere blanks less dangerous than would be the marks of incorrect code signs. Let us observe that the devices previously described do not yet enable the operator to ascertain this coincidence, since the natural frequency of a synchronized source is indeed a purely fictitious and unobservable entity. Special means are therefore necessary; they are based on the fact that the disturbing wave generated in the receiver under the impulses of a musical buzzer 79 takes in turn and at random all the possible frequencies contained in the band of the filter 38; thus, the average frequency of the wave arriving at the modulator 15 is the average frequency of this filter, displaced by the frequency changer 48; if this average frequency coincides with the natural frequency of the generator 16 to be synchronized, the average intensity of the synchronizing current i will obviously be null. Therefore, for tuning this natural frequency to the mean frequency of the receiver, we have only to close the circuit of the buzzer and to adjust the tuning condenser 80 so as to annul the synchronizing current read in the milliammeter 56. This adjustment is verified from time to time, during the pauses of the signalling.

My invention is grounded on several new properties, mainly on the use of the index to shield the signal against interferences; their explanation rests on the following remark: the synchronizing current i is proportional to the difference f between the natural frequency F_o of the generator 16 and the instantaneous frequency F_o+f of the received wave, which may be the resultant of the signal and disturbing waves; during each code sign, this current produces a quantity of electricity

$$q=\int_0^{\frac{1}{2f_o}} i.dt$$

stored in the condenser 71 or 72, and measuring the impulse imparted to the indicator 17; on the other hand, the received wave gets during the same sign a shift

$$\phi=2\pi\int_0^{\frac{1}{2f_o}} f.dt$$

with respect to the fictitious wave whose frequency would be the natural frequency F_o of the generator; as i and f are proportional, so are q and φ; consequently, the impulse imparted to the indicator can also be measured by the shift φ.

When the received wave is merely the signal wave free from interferences, its frequency is for instance F_o+f_s during a code sign. The synchronizing current keeps then a constant intensity i_s, represented by the line nn of Fig. 15, in which $\pm I_m$ designate the maximum intensities and $\pm I_e$ the intensities above which the tube 18 acts as a limiter. The impulses imparted to the indicator, at the end of the sign, may be measured at will by the area

$$\frac{i_s}{2f_o}$$

comprised between the line nn and the time axis, or by the shift

$$\phi=2\pi\int_0^{\frac{1}{2f_o}} f_s dt=2\pi\frac{f_s}{2f_o}=m\pi$$

This effect, hereinafter called "normal effect", is therefore proportional to the index m. As already pointed out, the relay 17 is adjusted in such a way that one of its contacts 75, 76 operates responsively to positive impulses exceeding $\pm 0.5m\pi$, and the other contact to negative impulses lesser than $-0.5m\pi$.

As illustrated by Fig. 16, the wave arriving at the modulator 15 is usually the resultant R of the signal wave S and of a disturbing wave D whose amplitude varies according to some curve d; such a disturbance may be produced by the cumulative action of the statics on the filter 38 of the receiver; it can be more or less powerful, which will be represented by placing successively the signal wave at different levels s_1 s_2 s_3 s_4. The time constant of the filter 38, i. e., the reverse

$$\frac{1}{2f_1}$$

of its band width, is about $(m+2)$ times smaller than the duration

$$\frac{1}{2f_0}$$

of each code sign, since

$$\frac{f_1}{f_0}\approx m+2$$

consequently, the phases observed at two instants t_1 t_2, such as

$$t_2-t_1=\frac{1}{2f_1}$$

are entirely independent of one another, and

the wave d can undergo during each sign $(m+2)$ phase charges varying at random between $-\pi$ and $+\pi$, with respect to a wave which would preserve the natural average frequent F_0 of the receiver. In other words, during every time interval t_1 t_2, the wave d may get any mean frequency comprised between (F_0-f_1) and (F_0+f_1), limits of the selected band; relatively to the signal vector S of frequency F_0+f_s, the vector D can thus turn either in the positive direction x at any speed comprised between 0 and (f_1+f_s), or in the negative direction y at any speed comprised between 0 and $-(f_1+f_s)$. That being granted, and recalling that an incorrect sign would be recorded if the normal effect $+m\pi$ were accidentally replaced by an effect lesser than $-0.5m\pi$, we may determine as follows the index m to be adopted for removing this risk of inaccurate marks:

As long as the signal wave overtops the disturbing wave (level s_1 of Fig. 16), the resulting vector R oscillates at random on both sides of the vector S; the angle α of these vectors is varying with the ratio

$$\frac{D}{S}$$

but cannot exceed

$$\frac{\pi}{2}$$

As the final shift of the vector S at the end of the code sign is $+m\pi$, that of the received wave is comprised between

$$m\pi-\pi=m\pi\left(1-\frac{1}{m}\right)$$

and

$$m\pi+\pi=m\pi\left(1+\frac{1}{m}\right)$$

the relative action

$$\left(\frac{1}{m}\right)$$

of the disturbance is therefore lessened at will by increasing the index. With $m>0.7$, the final impulse imparted to the indicator still exceeds $-0.5m\pi$, whereby blanks, but never incorrect signs, can occur in the recording.

Let us now consider more intense statics overtopping intermittingly the signal wave; this is illustrated in Fig. 16 by the signal level s_2, above which the curve d rises during a time interval Z comprised between the instants t_3 t_4. Two contingencies can now happen, according as the vectors D, S do not pass or pass through phase opposition. The Fig. 17 illustrates the first case; the small oscillations that vector R performed with respect to S before the instant t_3 are merely resumed after t_4 without ever reaching the phase difference π; the large amplitude momentarily got by the disturbing wave has therefore no influence upon the final shift of the resulting received wave. Fig. 18 represents the other case: D comes to opposition whilst it is more intense than S, whereby R gains or loses an angle 2π, and its final shift at the end of the sign becomes $m\pi+2\pi$; to avoid any risk of incorrect marks, the index must then comply with the condition $m\pi-2\pi>-0.5m\pi$, or $m>1.33$; in fact, an index $m=2$ becomes necessary on account of the pendular oscillations preceding t_3 and following t_4. The Fig. 18 proves also that vector R turns more quickly than the disturbing vector D, chiefly at the time of phase opposition; the frequency correction which is to be imparted for maintaining the generator **16** in locked synchronism with the received wave R reaches thus very high values, implying large changes u (Fig. 19) in the synchronizing current; this is quite obvious since the area circumscribed by the hook u represents the large phase shift 2π reached in the very short time Z; as the intensity of the impulse u is considerable, its action upon the indicator will be greatly reduced when limited at the level $\pm I_e$ by the tube **18**.

One may furthermore observe that the vector D can pass through the phase opposition of S by turning either in the positive direction x, or in the negative one y; in the first case, whose probability is p_x, the received wave gains 2π relatively to the signal wave; in the second case, of probability p_y, it loses 2π; now, p_x and p_y can be calculated in function of the time interval Z, since the possible frequencies of the disturbing vector D with respect to the signal vector S are known; this gives the average value $2\pi(p_x-p_y)$ of all the possible accidental impulses which could be undergone by the indicator; said average value proves to be the same one as if the synchronizing current were annulled during the time interval Z; this is easily explainable, since during Z the synchronization falls under the control of the disturbing wave, whose average frequency concides with that of the filters, i. e., with the natural frequency F_0 of the generator **16**.

When the disturbing wave d rises frequently above the signal level during a code sign, as seen at s_3 (Fig. 16), it may happen that the resulting vector R which represents the received wave loses several times the angles 2π with respect to the vector S; k being an integer, the final impulse becomes then $m\pi-2k\pi$; to avoid the mark of an inexact sign, one must comply to the condition $m\pi-2k\pi>-0.5m\pi$, that is increase again the index; this increase is however limited, as the larger k is, the smaller is its probability. As an extreme case, we may during local thunderstorms consider the statics which overtop the signal wave level (S_4, Fig. 16) during the whole of a code sign; the recording of this sign is obviously impossible, since the generator **16** falls under the exclusive control of the disturbing wave, but false marks can still be avoided: relatively to the fictive wave of frequency F_0, the wave d undergoes indeed $(m+2)$ phase changes varying at random between $-\pi$ and $+\pi$; thus, the probable value of its final shift is approximately

$$\frac{\pi}{2}\sqrt{m+2}$$

whose ratio to 0.5 $m\pi$ decreases according as the index m is increased; with about $m=10$, the chance of a final shift exceeding 0.5 $m\pi$ is very small; in other words, the powerful statics will almost certainly bring the indicator to its neutral position and produce merely blanks visible at the first glance.

To sum up, the present system narrows the communication band and almost suppresses the prejudicial components outside of this band. The interferences weaker than the signal wave becomes harmless. Most of the intermittent strays do not act upon the indicator, while the effect of the others is enlarged; these combined rarefaction and enlargement of the disturbing impulses constitute a new and favourable condition for passing the detected current through a limiter. The very strong and durable statics, as well as the fadings, annull the mean intensity of this current, whereby the correction of errors is facilitated. These results are reached by associating a fre-

quency modulated transmission, in which the index is increased according as the signalling becomes more difficult, with a receiver in which the mean frequency of the selected band, the mean frequency of the communication band and the natural frequency of a synchronized generator are maintained in exact coincidence. The indicator is preferably energized by the quantity of electricity supplied by the synchronizing current during each code sign.

As illustrated at Fig. 11*a*, the indicator 17 could of course be directly moved by the synchronizing current amplified by the tube 18; but the above explanations prove that this device is less commendable, chiefly concerning the conditions required for obtaining blanks instead of false signs responsively to powerful statics: as well known, the time constant of the relay 17 and condenser 81 circuit can scarcely exceed the third of the duration

$$\frac{1}{2f_0}$$

of each sign; otherwise, the recorded marks would be lengthened and indistinct. Thus, the comparison of the phase shifts due to the signal and interfering waves rests on a time interval three times shorter than that obtained with the device of Fig. 11; consequently, a three times larger index becomes necessary to avoid incorrect signs; owing to the relation $f_1=(m+2)f_0$ the width of the communication band and of the filters must grow approximately in the same proportion, whereby the ether is badly utilized and the signal to noise ratio loses about 5 decibels at the output of the filter.

Various minor modifications could be introduced in the above description without departing from the scope of my invention, for instance: The modulator 15 which supplies the synchronizing current may be balanced, as disclosed in the Patent 1,450,966 of Affel, dated April 10, 1923; this suppresses the permanent component I_0 of the detected current. The coincidence of the mean frequency of the signal wave, the mean frequency of the receiver and the natural frequency of the synchronous generator, could be ensured by combining two frequency control systems, the one based on the Patent 1,712,051 of Round, dated May 7, 1929, for neutralizing the frequency drift of the received wave with respect to the filter 38, the other based on the Fig. 4 of my Patent 1,990,428, for neutralizing the frequency drift of the generator 16 respectively to the received wave. As illustrated by Fig. 20, the generator 16 can also be maintained in locked synchronism with the received wave, by means of a direct coupling to the r. f. circuit 82 of the receiver; then, the indicator 17 is moved by a detected current issued from the coaction of the synchronized waves in a detector 83 placed outside of the synchronizing device; this modification, disclosed by J. B. Woodyard in the Proceedings I. R. E. of May 1937 (pages 612–619), comes merely to reproduce the image of the synchronizing current in an auxiliary circuit; when correctly realized, it leads therefore to the same results as my Patent 2,040,980; yet, one must observe that the detected current used in my invention enjoys special qualities, such as the insensibility to amplitude fluctuations, because it is a synchronizing current whose intensity is exclusively defined by the frequency corrections which preserve the locked synchronism; these qualities may be more or less injured when the image reproduced in detector 83 is unfaithful, for instance if the couplings 84, 85, are not purely inductive.

The method above described for annulling the detected current responsively to the strong statics, whereby errors at the recording become mere blanks, is one of the possible applications of a general rule which may be stated as follows: in a receiver managed so as to produce responsively to statics or strays a detected current at random positive and negative, the accumulative effect of these impulses in a final device of given time constant is decreasing according as the ratio of this time constant to the time constant of the filters preceding the detector is increased, provided that the amplitude of these impulses be limited at a constant level, for instance that (S) reached by the signal current. This is easy to prove: k being the ratio of the final time constant to the time constant of the r. f. filters, the final device stores k disturbing impulses at random positive or negative; in other words, the average duration of each impulse, and therefore the quantity of electricity produced by this impulse whose amplitude is S, are inversely proportional to k; consequently, the final accumulative effect of the k consecutive impulses varies as

$$\frac{\sqrt{k}}{k}=\frac{1}{\sqrt{k}}$$

and may be reduced at will by increasing the ratio k. Of course this method does not suppress the effect of the statics, since the intermodulation occurring in the limiter causes the signal to disappear, the whole of the received wave (signal + strays) producing a blank, but this blank is preferable to an important variation of the detected current and chiefly to the mark of an incorrect code sign. Though yet new, this method can be used in every receiver managed so as to produce responsively to strays a detected current at random positive and negative. For instance, the synchronizing device disclosed in my Patent 1,976,877, dated October 16, 1934, may be improved by inserting an amplitude limiter between the r. f. filters tuned to the signal wave frequency and the low pass filter selecting the synchronizing current. Another example is illustrated at Fig. 21, comprising two balanced detectors 86, 87, fed by the filters or resonators 88, 89, respectively tuned to the frequencies F_0+f_s and F_0-f_s representing the code signs; owing to this arrangement, the potential difference between the connexions 90, 91, is systematically positive or negative responsively to the signalling, whereas it is at random positive or negative responsively to strays, for cause of symmetry; by limiting at 66, 18, the accidental fluctuations of the detected current, and accumulating the quantity of electricity resulting therefrom in a final device 92 which may comprise the elements 73, 69, 71, 70, 72, 17 of Fig. 11, the statics will produce mere blanks, provided that the time constant of the filters 88, 89, be small enough with respect to the duration of each code sign. This simplified receiver enjoys therefore some of the qualities which characterize that of Fig. 11.

Having thus described my invention and the operation thereof, what I claim is:

1. In a receiver which comprises a demodulator, means for receiving electric waves, a local source of electric oscillations synchronized with the received electric wave by means of an interference current produced by beating the synchronized oscillations and received electric waves in the demodulator, the intensity of said current

being null when the received wave frequency coincides with the natural frequency of the source of oscillations, a system for minimizing the effect of disturbances on the interference current which comprises, in the input circuits of the demodulator a selector tuned to the received wave frequency, in the output circuits of the demodulator a device of time constant much larger than that of the selector for accumulating the fluctuations of the interference current whose direction is reverting at random, and means disposed between the said selector and device for limiting the amplitude of said fluctuations.

2. In frequency modulated telegraphy in which the transmission characteristics are firstly the maximum width assigned to the communication band, secondly the frequency of code signs and thirdly the changes imparted to the frequency of the signal wave for individually distinguishing these signs, the method of protecting the signal against disturbances which comprises at the receiver demodulating the signal wave so as to derive from each code sign a current of intensity substantially proportional to the frequency change representing this sign and further accumulating this current over a space of time proportioned to the duration of this sign, whereby the effect of each code sign is proportional to the index, ratio of frequency changes to signs frequency, and proportioning the transmission characteristics within the communication band so as to increase this index according as disturbances increase in intensity.

3. In frequency modulated telegraphy wherein transmission characteristics are the maximum width assigned to the communication band, the code signs frequency proportional to the keying speed, and the frequency changes imparted to the signal wave for individually representing these signs, the ratio of frequency changes to signs frequency being hereafter called index, the method of assuring under all conditions the highest keying speed compatible with the width of the communication band which comprises demodulating the signal wave so as to transform its frequency changes into substantially proportional changes in the intensity of a current and deriving from this current responsively to each code sign an accumulation effect extending over the whole duration of this sign, whereby the index may be decreased since a same index will supply a larger effect than when the accumulation time constant is a small part of the signs duration, and further proportioning the transmission characteristics by varying the frequency changes inversely to the signs frequency so as to utilize at all keying speeds the maximum band width assigned to the communication, whereby the signs frequency may be increased since appearing at the denominator of an index which is made smaller owing to its larger effect at the receiver while its numerator is varied at the emitter inversely to this sign frequency.

4. In frequency modulated telegraphy wherein transmission characteristics are the maximum communication band width, the code signs frequency proportional to the keying speed and the frequency changes imparted to the signal wave for individually representing these signs, and wherein the receiver is arranged to derive from each code sign an accumulation effect substantially proportional to the index, defined as the ratio of frequency changes to signs frequency, the method of obtaining a rapid increase in this effect according as conditions require reduction of the keying speed which comprises proportioning frequency changes to keying speed so as to use a small index under favorable conditions allowing the maximum keying speed, and proportioning the amplitude of frequency changes inversely to the keying speed for preserving at any speed a predetermined communication band width.

5. In frequency modulated telegraphy wherein code signs are transmitted at a given cadence and translated into definite changes in the frequency of a signal wave, a receiver which comprises means for collecting the signal wave, means for transforming the frequency changes of the collected wave into changes in the intensity of a current, a circuit of time constant larger than the duration of each code sign, an indicator, and a local distributor synchronized to the cadence of signs for successively accumulating in the circuit of large time constant the electricity supplied by the current over the whole duration of each sign and then transferring this accumulation effect to the indicator.

6. A method of telegraphy which comprises employing a three signs code, respectively representing these signs by three approximately equidistant frequencies of the signal wave whereby the mean frequency of this wave represents a sign and the two symmetrically distributed frequencies represent the other signs, demodulating the signal wave so as to transform its changes with respect to the mean frequency into corresponding changes in a current with respect to a zero intensity, recording each sign by means of the accumulation effect supplied by the current over the whole duration of this sign, and proportioning this duration to the disturbances met at the receiver.

7. In wireless telegraphy wherein signalling consists in radiating a signal wave of constant amplitude and individually representing code signs by imparting to a characteristic of this wave definite changes with respect to a predetermined mean value of this characteristic, the method of reception for facilitating correction of errors by deriving from both statics and fading the same effect and placing this effect approximately in the middle of the effects normally due to code signs, which comprises proportioning the time constants of circuits preceding the demodulation to be substantially smaller than the duration of each code sign whereby oscillations caused by statics in these circuits assume over this duration several independent characteristics succeeding each other at random, demodulating the received waves and balancing this demodulation relatively to the mean value of the varied characteristic of the signal wave so as to transform changes with respect to this mean value into currents of directions conditioned by these changes whereby definite changes due to signalling are transformed into currents of definite directions while statics dominating the signal wave are transformed into currents of directions varying several times at random during a code sign, limiting in both directions the intensity fluctuations of these currents, and deriving from the limited currents an accumulation effect extending over the whole duration of this sign, whereby the code signs supply normally final effects of directions in accordance with these signs, while statics dominating the signal wave substantially annul this effect similarly to fading, since the mean intensity of currents of limited intensities and of directions changing many times is necessarily small com-

paratively to the mean intensity of currents of definite directions.

8. A telegraph system for facilitating correction of errors by deriving from strong statics and fading a similar predetermined effect and placing this effect approximately in the middle of the effects individually representing code signs which comprises at the emitter, means for generating and radiating a signal wave of constant amplitude, means responsive to keying for varying a characteristic of this wave with respect to a predetermined mean value of this characteristic, and means for proportioning the keying speed and thus the duration of each code sign so as to provide a signs frequency substantially smaller than the maximum width assigned to the communication band; at the receiver, filters of band width adjusted to this maximum communication band width whereby it follows that the time constant of said filters is substantially smaller than the duration of each code sign as proportioned at the emitter and that oscillations forced by statics in filters assume over this duration several independent characteristics succeeding each other at random, a demodulator balanced with respect to the mean value of the variable characteristic of the signal wave whereby each code sign is normally translated into a detacted current of definite direction in accordance with this sign while oscillations forced by statics dominating the signal wave are translated into detected currents of directions changing at random several times during each code sign, means for limiting in both directions the maximum intensities of the detected currents whereby the mean intensity of limited currents whose directions change many times at random is necessarily small comparatively to the intensities of currents definitely directed according to code signs, and a distributor synchronized with the signs frequency for successively accumulating in a device of large time constant the effect of the detected current over the whole duration of each code sign and then transferring this accumulation effect to the indicator.

9. A telegraph system for facilitating correction of errors due to both static and fading by deriving from these disturbances a similar approximately constant effect, this effect being the average of the extreme effects due to code signs, which comprises at the emitter, means for generating a signal wave, means responsive to keying for varying the frequency of this wave with respect to a predetermined average value of this frequency whereby code signs are individually represented by frequency changes of definite directions, and means for proportioning the duration of each sign for providing a signs frequency substantially smaller than the width of the communication band; at the receiver, a filter of band width adjusted to the communication band width whereby it follows that the time constant of this filter is substantially smaller than the duration ascribed to each code sign at the emitter and that oscillations caused by static dominating the signal wave assume in turn during a sign several independent frequencies distributed at random about the average frequency of the filter, drift neutralization means for maintaining the average frequency of the signal wave in coincidence with the average frequency of the filter, a demodulation device for transforming frequency changes of the received waves into changes in the intensity of a detected current, the said device being balanced with respect to the average frequencies both of the filter and of the signal wave whereby the definite frequency changes due to signalling supply currents of definite directions in accordance with the signs represented by these changes while frequency changes undergone at random by oscillations due to strong statics supply currents of directions reverting many times during each sign, means for limiting in both directions the intensity changes of the detected current, a circuit of time constant substantially larger than the duration of each sign, an indicator, and a local distributor sychronized with the signs frequency for successively accumulating in the circuit of large time constant the effect of the detected current over the whole duration of each sign and then supplying this accumulation effect to the indicator.

10. The system as claimed in claim 9 characterized by the fact that said means responsive to keying impart in turn to the frequency of the signal wave two changes substantially symmetrical with respect to the mean frequency of this wave for respectively representing two code signs, whereby the accumulation effects supplied to the indicator of the receiver responsively to these signs are of opposite directions while the accumulation effect of strong statics and fading is approximately null.

11. The system as claimed in claim 9 characterized by the fact that said means responsive to keying impart in turn to the signal wave three frequencies, one of them coinciding with the mean frequency of this wave and the two others symmetrical with respect to this mean frequency, whereby the accumulation effects supplied to the indicator responsively to these signs are, the one null and the others of opposite directions.

12. The system as claimed in claim 9 characterized by the fact that said demodulation device balanced with respect to the average frequency of the filter for transforming frequency changes into current changes consists in two resonators respectively tuned to two frequencies symmetrical with respect to this average frequency and feeding two detectors in opposition.

13. The system as claimed in claim 9 characterized by the fact that said demodulation device balanced with respect to the average frequency of the filter consists in a local generator of oscillations tuned to this average frequency, this generator being maintained in locked synchronism with the received wave and coacting with this wave in a demodulator.

14. The system as claimed in claim 9 characterized by the fact that said means for limiting in both directions the intensity changes of the detected current comprise in combination means for substantially stabilizing the amplitude of the received wave at the input of the demodulation device and limiters in the output of the said device for limiting instantaneous changes caused in the intensity of the detected current by the rapid frequency changes undergone by this received wave responsively to strong static.

HENRI JEAN JOSEPH MARIE DE REGNAULD DE BELLESCIZE.