April 8, 1930. V. K. ZWORYKIN 1,753,961

SIGNALING SYSTEM

Filed Nov. 19, 1927 3 Sheets-Sheet 1

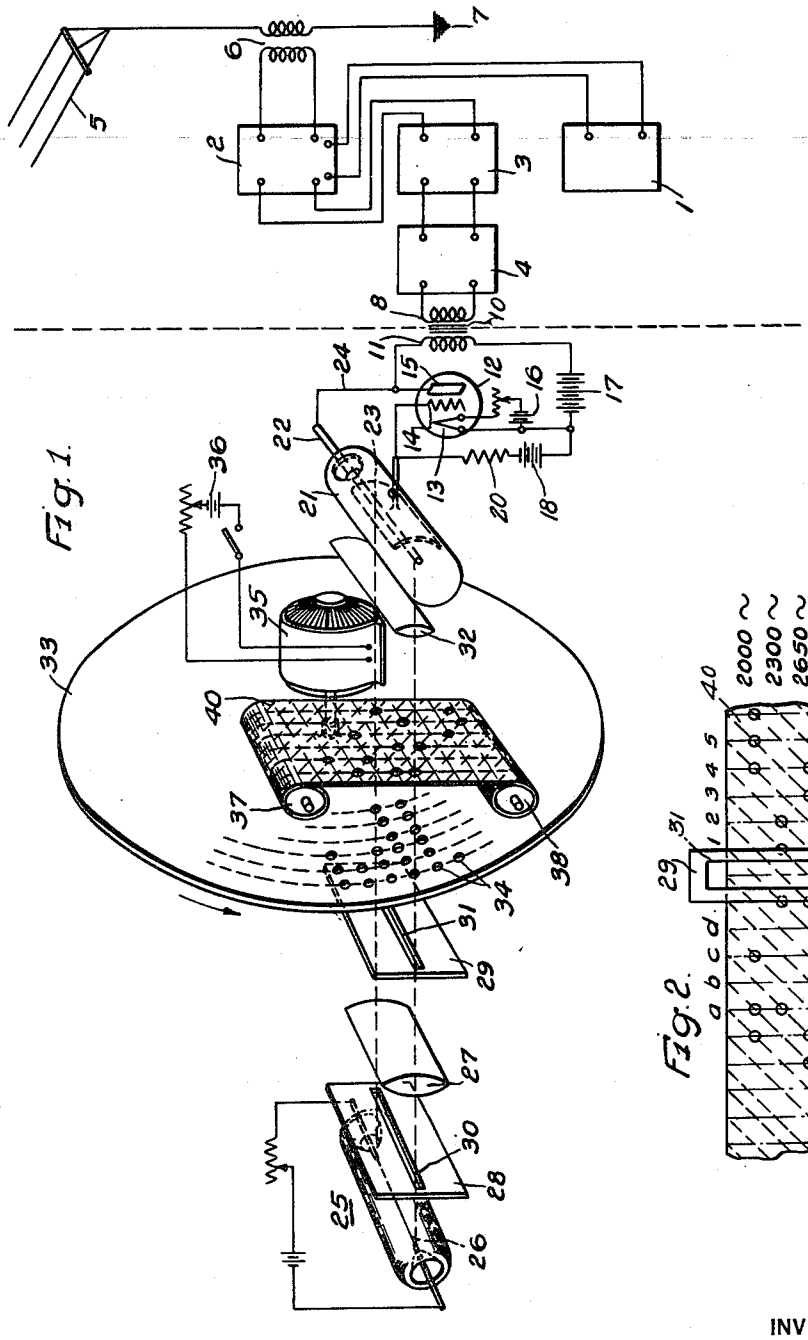


Fig. 1.

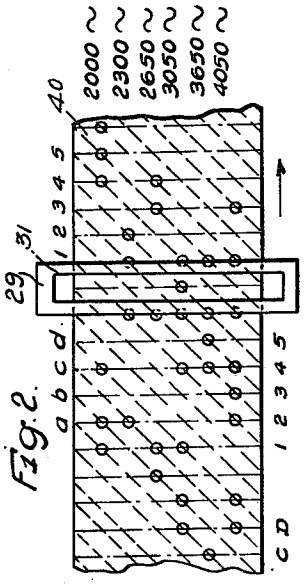


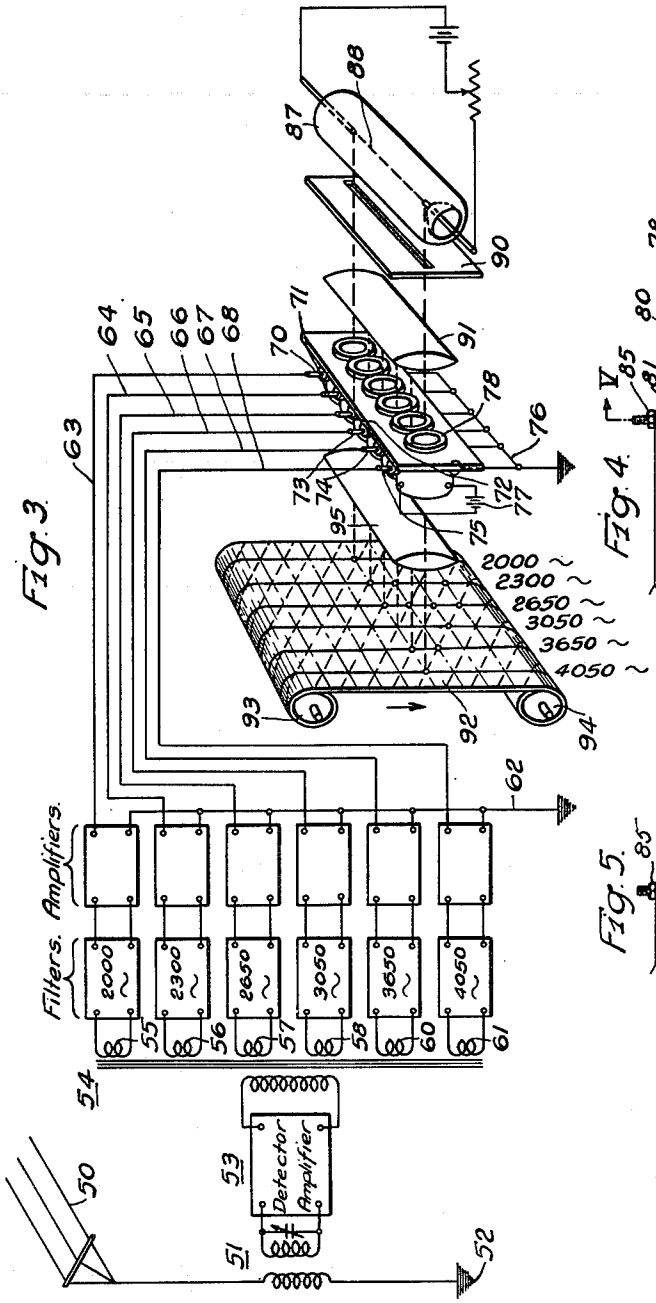
Fig. 2.

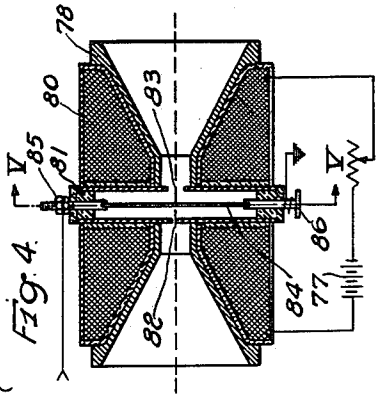
INVENTOR
Vladimir K. Zworykin.
BY
Chesley Gilbert
ATTORNEY

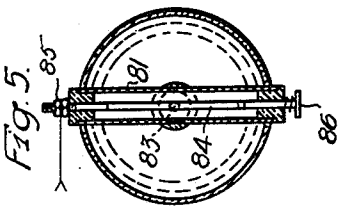
April 8, 1930. V. K. ZWORYKIN 1,753,961

SIGNALING SYSTEM

Filed Nov. 19, 1927 3 Sheets-Sheet 2







INVENTOR
Vladimir K. Zworykin.
BY
Wesley G. Carr
ATTORNEY

April 8, 1930. V. K. ZWORYKIN 1,753,961

SIGNALING SYSTEM

Filed Nov. 19, 1927 3 Sheets-Sheet 3

Fig. 6.

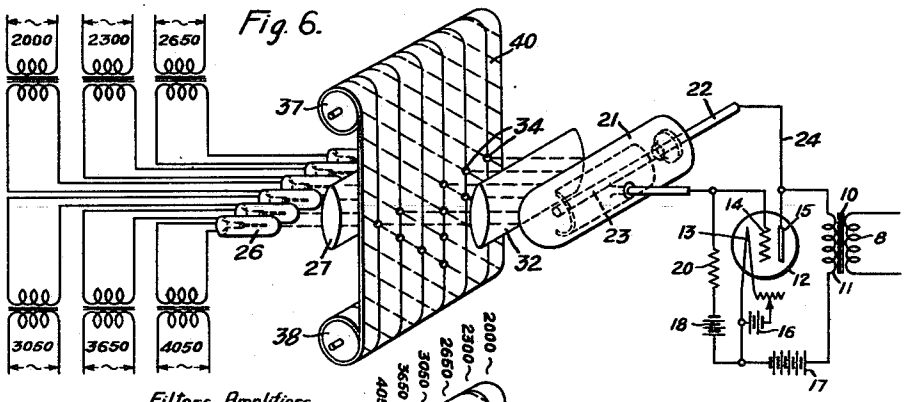


Fig. 7.

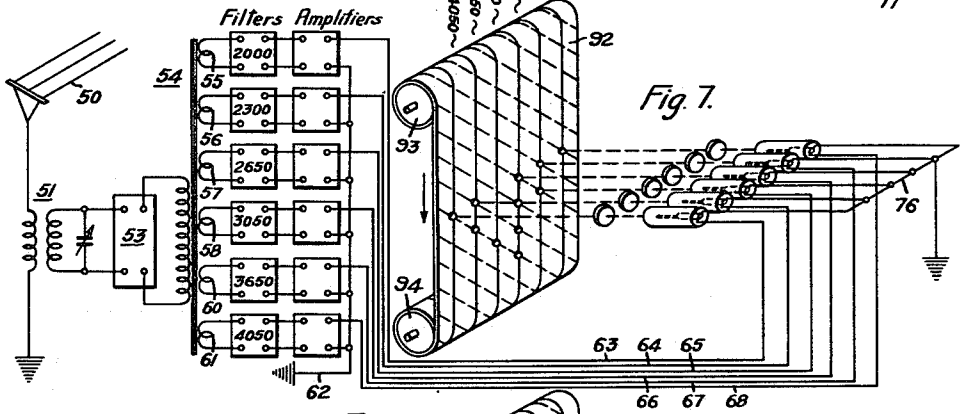


Fig. 8.

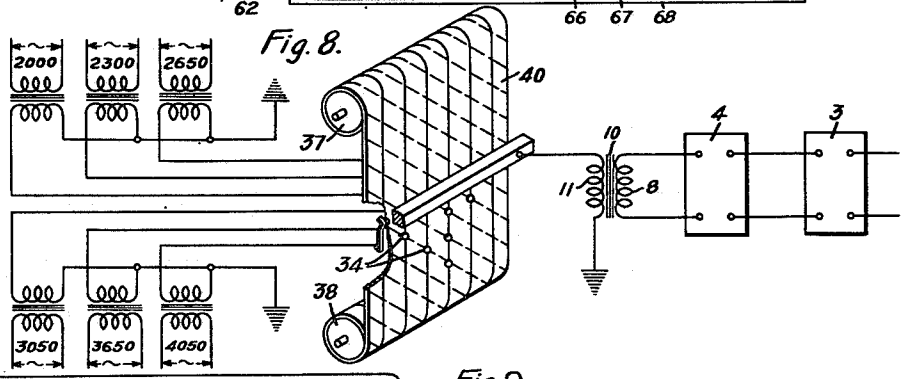
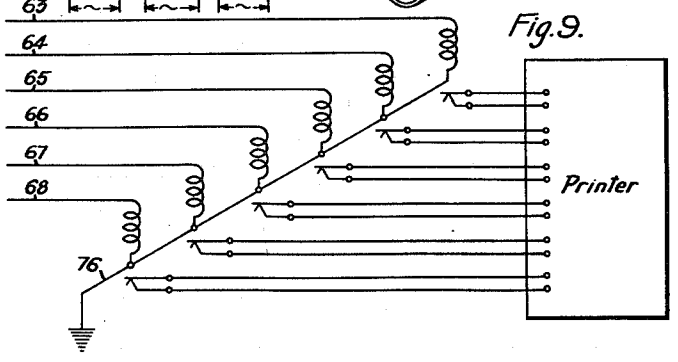


Fig. 9.



INVENTOR
Vladimir K. Zworykin.
BY
Wesley G. Carr
ATTORNEY

Patented Apr. 8, 1930 1,753,961

UNITED STATES PATENT OFFICE

VLADIMIR K. ZWORYKIN, OF SWISSVALE, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA

SIGNALING SYSTEM

Application filed November 19, 1927. Serial No. 234,371.

My invention relates to signaling systems, and it has particular relation to radio or wired-radio telegraph transmitting and receiving methods and apparatus.

Substantially all modern high-speed radio telegraph transmitting systems utilize apparatus controlled by a tape which has been perforated according to a prearranged code to represent signals for varying the continuity of the emitted carrier wave. In order that the charge per word shall be kept low, the sending speed of tape-controlled transmitters has gradually been increased until at the present time it is not at all uncommon to find stations transmitting at the rate of 300 letters per minute.

With the increase in speed, however, it has been found that static and other disturbances render the reception of messages increasingly difficult. The static disturbances, which vary in duration, obliterate a much larger proportion of the transmitted signals at high speed than at low speeds, as would naturally be expected, and in some instances entirely destroy so much of a message that its meaning is lost.

It is, accordingly, an object of my invention to provide a high-speed signaling system that is substantially unaffected by static disturbances of short duration or other interference.

Another object of my invention is to provide a signaling system wherein the speed of transmission and reception may be materially altered without militating against its freedom from static interference.

In accordance with my invention, I provide means for generating and radiating a carrier wave of constant frequency, and means whereby the carrier wave may be modulated by the simultaneous action of a plurality of definite lower frequencies. I assign a definite zone transversely of a control-tape to each of the modulating frequencies, and to each of a plurality of position-combinations on the tape I assign a letter of the alphabet, a numeral, or a symbol.

In order to transmit a message, the tape is first provided with a plurality of successive groups of perforations, each group representing a letter or a symbol, and the groups being arranged along lines diagonally positioned with reference to the edges of the tape. The tape is then passed at high speed through a device that controls the modulation of the carrier wave by the simultaneous action of the several frequencies corresponding to the transverse zones of the tape, the modulating frequencies being effective only when perforations corresponding in position thereto are passing through the device. At any given instant, therefore, as the tape passes through the modulation-controlling device, the carrier wave is modulated by a plurality of frequencies that represent tape-positions corresponding to minor portions of each of a plurality of code-groups representing letters or symbols adjacent to one another longitudinally of the tape.

At the receiving station the carrier wave is demodulated, and the simultaneously-present modulation frequencies representative of tape-positions are utilized to control the admission of light to the photo-sensitive surface of a moving tape, the positions of the exposed portions transversely of the tape being dependent upon the various frequencies.

The tape, when developed and fixed, exhibits a plurality of diagonally positioned groups of blackened areas which correspond in sequence and size to the perforations in the transmitting tape.

Static, if present, will not usually be of sufficient duration to cause the obliteration of an entire code-group representing a letter or a symbol, but will mar only minor portions of a plurality of groups representing successive letters or symbols. In such event it is much easier to decipher the message than if entire letters or symbols are destroyed, as is the case when systems arranged according to the teaching of the prior art are employed.

Among the novel features of my invention are those particularly set forth in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with further objects and advantages thereof, will best be understood from a consideration of the following description of a specific embodiment, taken in

connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of the transmitting portion of a singaling system arranged according to a preferred embodiment of my invention.

Fig. 2 is a view of a portion of a tape provided with perforations representative of symbols.

Fig. 3 is a diagrammatic view of the receiving end of a signaling system arranged according to my invention.

Fig. 4 is a view in cross-section of a single light-controlling unit, and

Fig. 5 is a cross-sectional view taken along a line corresponding to the line V—V of Fig. 4.

Fig. 6 is a diagrammatic view showing a modification of the transmitting device.

Fig. 7 is a diagrammatic view showing a modification of the receiving device.

Fig. 8 is a diagrammatic view of another modification of the transmitting device; and

Fig. 9 is a diagrammatic view showing another modification of the receiving device.

Referring particularly to Fig. 1, the elements shown to the right of the dotted line comprise conventional means for generating and radiating a carrier wave, while those illustrated to the left of the dotted line comprise the elements arranged according to my invention for impressing on the carrier wave a plurality of modulating frequencies representative of symbols constituting a message which is to be transmitted.

The carrier wave generating and radiating apparatus preferably comprises a master oscillator 1, a power amplifier 2, a modulator 3, an intermediate amplifier 4 and a radiating system comprising an antenna 5, a coupling transformer 6 and a ground connection 7. The construction and arrangement of the several units comprising the wave generating portion of the system is now so well known to those skilled in the art that a more detailed description is hardly deemed necessary.

The input circuit of the intermediate amplifier comprises the secondary 8 of an audio frequency transformer 10, the primary 11 of which is included in the output or plate circuit of a thermionic device 12. The device 12, which may be of relatively low power, has a filament 13, a grid 14 and a plate 15, and is provided with a source 16 of filament power and a source 17 of plate potential.

The grid of the thermionic device is biased the proper operating potential by a "C" battery 18 and a resistor 20 connected in series between it and the filament.

A photo-electric cell 21 having an extended cylindrical anode 22 and an elongated cathode 23 is so arranged that the anode thereof is connected to the plate 15 of the thermionic device by a conductor 24 and the cathode thereof is connected to the junction between the grid of the device and the aforementioned resistor 18.

A light source 25, preferably an incandescent lamp, having an elongated illuminable filament 26 is so positioned that the filament lies in a plane which passes through the anode 22 of the photo-cell, and is substantially parallel thereto.

A lens system, exemplified by a cylindrical lens 27, a plurality of shields 28 and 29 having slots 30 and 31 extending therethrough, and a second cylindrical lens 32, is arranged to concentrate the light from the filament 26 in a narrow line on the inner surface of the photoelectric cell cathode 23.

A rotatable disc 33, provided with a plurality of openings 34 extending therethrough and arranged in circles concentric to the axis thereof, is interposed between the slotted shield 29 and the lens 32 and is provided with a driving motor 35, preferably of the constant speed type, which may be energized from a suitable potential source 36. A plurality of spaced rollers 37 and 38, or analogous devices, are interposed between the perforated disc 33 and the lens 32, with their axes positioned in a plane parallel to the plane of the disc. One of these rollers is utilized as a magazine for a pre-perforated tape 40 which is withdrawn therefrom and wound up on the other roller at an appropriate speed in order that the perforations may be caused to successively traverse the line of light which would fall thereon were it not for the interposition of the perforated disc.

Although not so shown on the drawing, the rollers may be driven from the motor which drives the disc, by means of appropriate gearing, or a belt.

A short section of the tape is illustrated in Figure 2. It may be considered as divided longitudinally into a plurality of zones corresponding in number to the number of circles of perforations extending through the disc. In the specific apparatus illustrated this number is chosen as 6, which is sufficient for all practical purposes.

The tape is provided with a plurality of series of aligned perforations, each individual series representing a symbol. The several series are arranged in lines diagonally of the surface of the tape, the diagonal lines being spaced longitudinally of the tape a distance commensurate with the speed at which the tape is to be passed between the disc 33 and the photo-cell 21.

The operation of the device illustrated in Fig. 1 may be described as follows:

The disc, when revolving at a constant speed between the light source and the photo-cell, interrupts the light reaching the cathode of the cell a definite number of times per second, depending upon the circle of perforations through which the light passes. The number of interruptions per second depends

upon the speed of the disc and upon the actual number of perforations in the uncovered circle. The disc is preferably so provided with perforations and is rotated at such a speed that the peripheral circle of perforations will give, say 4,000 interruptions per second, the innermost circle approximately 2,000 interruptions per second, while the intermediate circles of perforations give interruption frequencies which provide a series of easily differentiated frequencies intermediate the two frequencies fixed by the inner and outer circles.

The conductivity of the photo-cell varies at a rate corresponding to the variation in the light impinging on the cathode thereof, thus causing a variation in the amount of current passing through the cell under the combined influence of the plate potential source 17 and the "C" battery 18. The variations in current flow cause varying voltage changes across the resistor 20, the voltage changes serving to alter, at the same rate, the potential of the grid of the thermionic device with respect to its filament. In accordance with the well-known action of thermionic devices, the output current of the device, which traverses the primary of the audio frequency transformer 10, will be an amplified reproduction of the grid excitation. Inasmuch as the carrier wave is modulated by the fluctuations in current existing in the transformer 10, the variations in the light falling on the photo-cell will be faithfully represented by a corresponding modulation of the said carrier wave.

The relative rate of travel of the tape and the revolutions per minute of the perforated disc are so adjusted that, when the innermost circle of disc-perforations is uncovered by perforations in the tape, at least forty complete cycles of the 2,000 cycle modulating frequency are impressed on the carrier wave for each perforation in the tape corresponding to the said innermost circle of disc perforations.

As the tape passes in front of the rotating disc, the perforations of each series representing a symbol successively permit the light passing through the circles of disc-perforations, corresponding to the zones in which the tape-perforations lie, to impinge upon the photo-cell, and to cause its output to vary in frequency accordingly.

By reason of the fact that a second series of perforations and perhaps a third or fourth series, as well may be passing through the line of light determined by the slot 31 before the first series is completed, it is apparent that the photo-cell is simultaneously subjected to light-interruption frequencies which are representative of minor portions of several series of perforations representative of letters or symbols that are adjacent to one another in a message. No confusion results in the transmission, however, since, as is well known in the art, a carrier wave may simultaneously be modulated by substantially any number of different frequencies.

The carrier wave, at any instant of time, represents various minor portions of a plurality of symbols, which portions are shifted in time either ahead or behind the position they would occupy if each symbol were completely transmitted before the transmission of the following signal is commenced. The transmission, accordingly, is semi-secret in character, and the message cannot be readily deciphered without appropriate receiving equipment which will function to record the message and to automatically introduce the proper factors to restore the minor portions of each signal to their proper sequential positions.

Such a receiving system is illustrated in Fig. 3, and comprises a radiant energy collecting structure preferably consisting of an antenna 50, a coupling transformer 51 and a ground connection 52. A detector-amplifier 53 of any conventional type is inductively, or otherwise, associated with the energy collecting structure, and has an output circuit comprising a transformer 54 provided with a plurality of secondary windings 55, 56, 57, 58, 60 and 61. Each of the secondary windings is associated with a filter, the constants of the several filters being so chosen that they are respectively transparent to the several modulating frequencies generated by the rotating disc and the photo-cell, as indicated, and are respectively opaque to different frequencies.

An amplifying device, preferably of the multi-tube thermionic type, is associated with each of the filters. One terminal of the output circuit of each of the amplifying devices is connected to a grounded conductor 62. The ungrounded terminals of the amplifying devices are connected by conductors 63, 64, 65, 66, 67 and 68 to the input terminals of a plurality of aligned light-valves 70, 71, 72, 73, 74 and 75, respectively, the circuit through the light-valves being completed through a grounded conductor 76 common thereto. Each light-valve preferably comprises apparatus of the type illustrated in Figs. 4 and 5, and all of the valves are energized from a battery 77.

Referring to Figs. 4 and 5, a circular core 78 of magnetic material, shaped somewhat like an hour glass, is provided with a winding 80 adapted to be energized from the battery 77. A tube 81 of insulating material, having diametrically positioned openings 82 and 83 in the wall thereof, extends transversely through the core 78, and so intersects the restricted central passage that the openings 82 and 83 lie in the axis thereof. A metallic ribbon 84, or a relatively thin wire, is supported axially of the tube 81 between a

fixed conducting element 85 positioned in one end of the tube and a resilient conducting element 86 carried in the other end thereof. The ribbon, when in its normal position, and not carrying current, completely closes the opening 83 in the wall of the tube and prevents the passage of light therethrough.

A light source, preferably an incandescent lamp 87 having a linear filament 88, is so arranged that the filament lies in a plane determined by the alignment of the axes of the light-valves. A slotted shield 90 and a lens 91 are provided for focusing an image of the filament on the small openings in the walls of the insulating tubes extending through the several light-valves.

A photo-sensitive tape 92 is carried by a plurality of rollers 93 and 94, or equivalent devices, and is so arranged that its surface moves in a plane perpendicular to the plane in which lie the filament 88 and the small openings 83 in the light-valves. A cylindrical lens 95 is interposed between the light-valves and the photo-sensitive tape to concentrate on the latter the light passing through the valves.

In the operation of the receiving system illustrated, the incoming carrier wave is demodulated and amplified and the component modulation frequencies, which correspond to the perforations in the transmitting tape, are separated out by the filters. The output of each filter is further amplified, and is applied to the input circuit of the light-valve connected thereto. The output currents of the amplifiers are pulsating, but are in the same direction and, consequently, the ribbon element of a light-valve is moved aside to uncover the small openings lying axially thereof whenever the corresponding amplifier delivers current thereto. Accordingly, each modulation-frequency received will cause a corresponding light-valve to be opened, and a zone on the photo-sensitive tape 92, corresponding in position to the modulation frequency, will be exposed to light from the source 87 for an interval of time commensurate with the duration of the modulation frequency.

In order that the areas of the photo-sensitive tape exposed by the light-valves shall be clean-cut, I have found it desirable to highly damp the moving wires. For this purpose, the wires are preferably immersed in and surrounded by a somewhat viscous damping medium, such as an insulating oil, or the like.

As many zones across the tape will be simultaneously exposed as there are modulation frequencies simultaneously existing on the carrier wave. The tape, therefore, when developed, will exhibit a plurality of exposed and darkened areas corresponding to the perforations in the tape utilized for transmission.

There is no necessity for close synchronization of speed between the transmitting and receiving tapes, a difference in speed merely causing the angularity of the successive symbol-series on the receiving tape to differ from the angularity of the perforations of the transmitting tape. It is, however, desirable that both the transmitting and receiving tapes shall travel at constant speeds, even though the speed of one differs from that of the other.

Communication between the transmitting and receiving station may, accordingly, be said to be carried on over a plurality of non-interfering portions of a single energy-conveying channel. Each non-interfering portion comprises the means for modulating the carrier wave at the transmitting end at a definite frequency, the carrier wave, and the demodulator-filter-amplifier-light-valve system at the receiving end, which system is responsive only to a single definite frequency, to the exclusion of the other modulating frequencies.

If static or other interference is momentarily present, it will obliterate only those portions of the various symbols which correspond to the perforations in the transmitting tape that are momentarily aligned with the narrow beam of light projected from the filament 26 through the perforations in the rotating disc onto the photo-cell. To obliterate an entire symbol, therefore, would necessitate an interference enduring over a period of time equivalent to the time required for the transmitting tape to pass through a distance equal to the length of one of the diagonal symbol-series multiplied by the cosine of the angle which the symbol-series makes with the edge of the tape. In other words, referring to Fig. 2, the interference, in order to obliterate the symbol "*d*", would have to endure for a length of time corresponding to the passage of the tape from the point "5" to the point "*d*", at the lower edge thereof.

If interference is not very pronounced, the angle at which the symbol-series lie with respect to the edges of the tape may be made to approach 90°, but if much static is present, it is necessary to slant the symbol-series considerably more.

By utilizing a tape having six significant zones and a rotating disc giving six distinct and easily separable frequencies, 63 separate characters can be obtained. It is preferable, however, to utilize no more than four of the significant zones on the tape for each character, and even when the number is limited to four, I am enabled to provide 37 distinct combinations. This number is sufficient to transmit the alphabet, the nine numerals and two additional characters, such as a period, an interrogation-mark, or the like.

The rotating disc described in connection with the transmitting equipment is not an absolutely essential part of my invention. It is entirely feasible to replace the disc by a

plurality of separate light sources which vary in intensity at the specified rates. This is illustrated for the transmitting station by Fig. 6 and for the receiving station by Fig. 7. Instead the tape could be passed between contact devices that control in a direct manner the application of individually generated modulating frequencies to the carrier-wave radiating apparatus. This is illustrated by Fig. 8. At the receiving end, the light-valves could be replaced by tuned relays controlling the actuating of an automatic printing device, if desirable. This is illustrated by Fig. 9.

The freedom from static of a signaling device constructed and arranged according to my invention has been previously commented upon. In addition, I have found that the transmission speed can be very materially increased by arranging the transmitting tape in the manner disclosed, a speed of over 300 words of five letters each per minute being quite easily attained.

No absolute synchronization of the moving parts in the intermediate and receiving stations is necessary, which is of great advantage on account of the difficulty in obtaining such synchronization between stations which are separated by considerable distances.

My improved system is also of advantage whenever the phenomenon of fading is encountered, since the loss of portions of symbols by reason of the fading is seldom so great as to render entire words illegible.

Additional advantages of my invention, as well as numerous modifications thereof will be apparent to those skilled in the art. My invention, therefore, is not to be limited except in so far as is necessitated by the prior art or by the spirit of the appended claims.

I claim as my invention:

1. The method of signaling which comprises generating a carrier-wave, simultaneously impressing on said wave a plurality of modulating frequencies representative of minor portions of symbols adjacent to one another in a message to be transmitted, radiating said modulated wave, receiving said wave and producing therefrom a perceptible indication of said message.

2. The method of signaling which comprises generating a carrier-wave, simultaneously impressing on said wave a plurality of modulating frequencies representative of minor portions of symbols adjacent to one another in a message to be transmitted, receiving said wave, separately deriving from said received wave said modulating frequencies, and deriving from said modulating frequencies a perceptible indication of said message.

3. The method of signaling which comprises generating a carrier-wave, generating a plurality of frequencies different from said carrier-wave frequency, causing said carrier-wave to be simultaneously modulated by certain of said frequencies to represent minor portions of frequency-groups representative of symbols adjacent to one another in a message to be transmitted, radiating said modulated wave, receiving said wave, deriving said modulating frequencies from said received wave, and utilizing said frequencies to control the formation of a perceptible indication of said message.

4. The method of signaling which comprises generating a carrier-wave, generating a plurality of frequencies differing from the frequency of said wave, causing to be successively impressed on said wave a plurality of groups of said frequencies, each group being representative of a plurality of minor portions of frequency-combinations corresponding to symbols occuring adjacent to one another in a message to be transmitted, radiating said modulated wave, receiving said wave, and deriving from said modulating frequencies a perceptible indication of said message.

5. The method of signaling which comprises generating a carrier-wave, impressing successively thereon a series of modulating frequencies representative of a symbol, impressing successively thereon another series of modulating frequencies representative of a symbol adjacent in the message to the first referred-to symbol, and so adjusting the periods required for the transmission of each symbol that the series of frequencies representing the second symbol begins before the series representing the first symbol has terminated.

6. The method of signaling over a plurality of portions of an energy-conveying channel, which comprises impressing successively on said portions a series of variations representing a symbol, impressing successively in the same order on said portions variations representing another symbol, and so allocating the periods of time required for the transmission of each series that one series begins before an earlier started series terminates.

7. The method of signaling over a communication system comprising a plurality of portions each capable of conveying signal impulses without interfering with the other portions which consists in sending signaling impulses, one over each of selected ones of said portions in succession, said signaling impulses together constituting a signaling symbol, sending another succession of impulses over selected ones of said portions to constitute another symbol and so timing said symbols that some impulses belonging to the one symbol occur during the sending of the other symbol.

8. In a signaling system, means for generating and radiating a carrier-wave, a tape provided with perforations representative of a message to be transmitted and means controlled by said tape for sequentially modu-

lating said carrier wave by a plurality of frequencies, the said perforations being so arranged that minor portions of adjacent symbols in a message are represented by a plurality of co-existent modulating frequencies.

9. In a signaling system, means for establishing between a transmitting point and a receiving point an energy conveying channel having a plurality of non-interfering portions, means for impressing successively on certain of said portions a series of impulses constituting a signaling symbol, said means serving to simultaneously impress on others of said portions other series of impulses constituting signaling symbols, in combination with means at the receiving point for giving an indication of said several series of symbols.

10. In a signaling system, means for generating and radiating a carrier-wave, modulating means therefor, means for energizing said modulating means at a plurality of frequencies, a tape provided with a plurality of diagonally positioned groups of perforations representative of signals, and means whereby the frequencies simultaneously impressed on said modulating means are determined by minor portions of adjacent groups of the said perforations.

In testimony whereof, I have hereunto subscribed my name this 12th day of November, 1927.

VLADIMIR K. ZWORYKIN.