

Aug. 6, 1946.

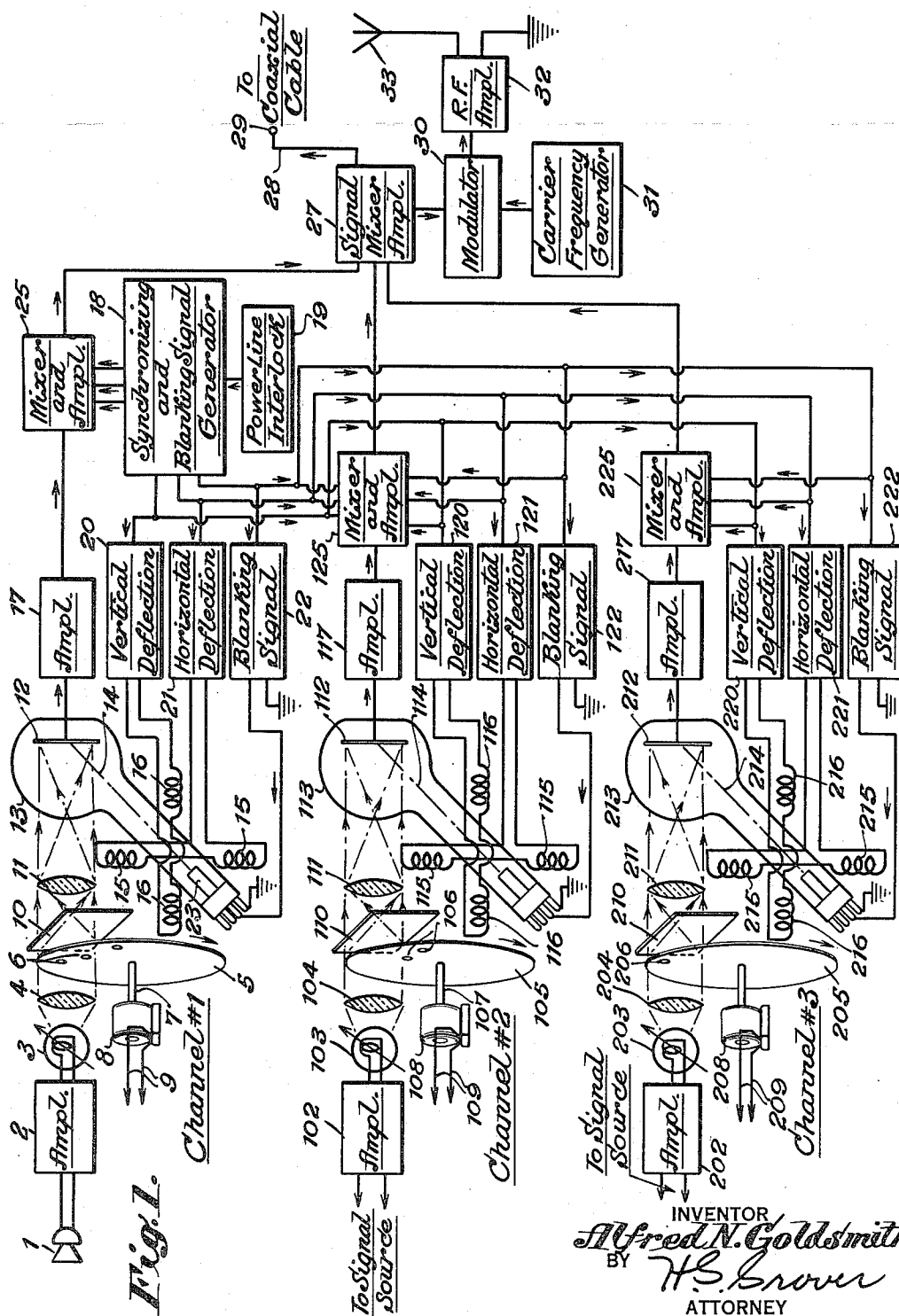
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2,405,252

SECRET COMMUNICATION SYSTEM

Filed July 22, 1942

4 Sheets-Sheet 1



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Aug. 6, 1946.

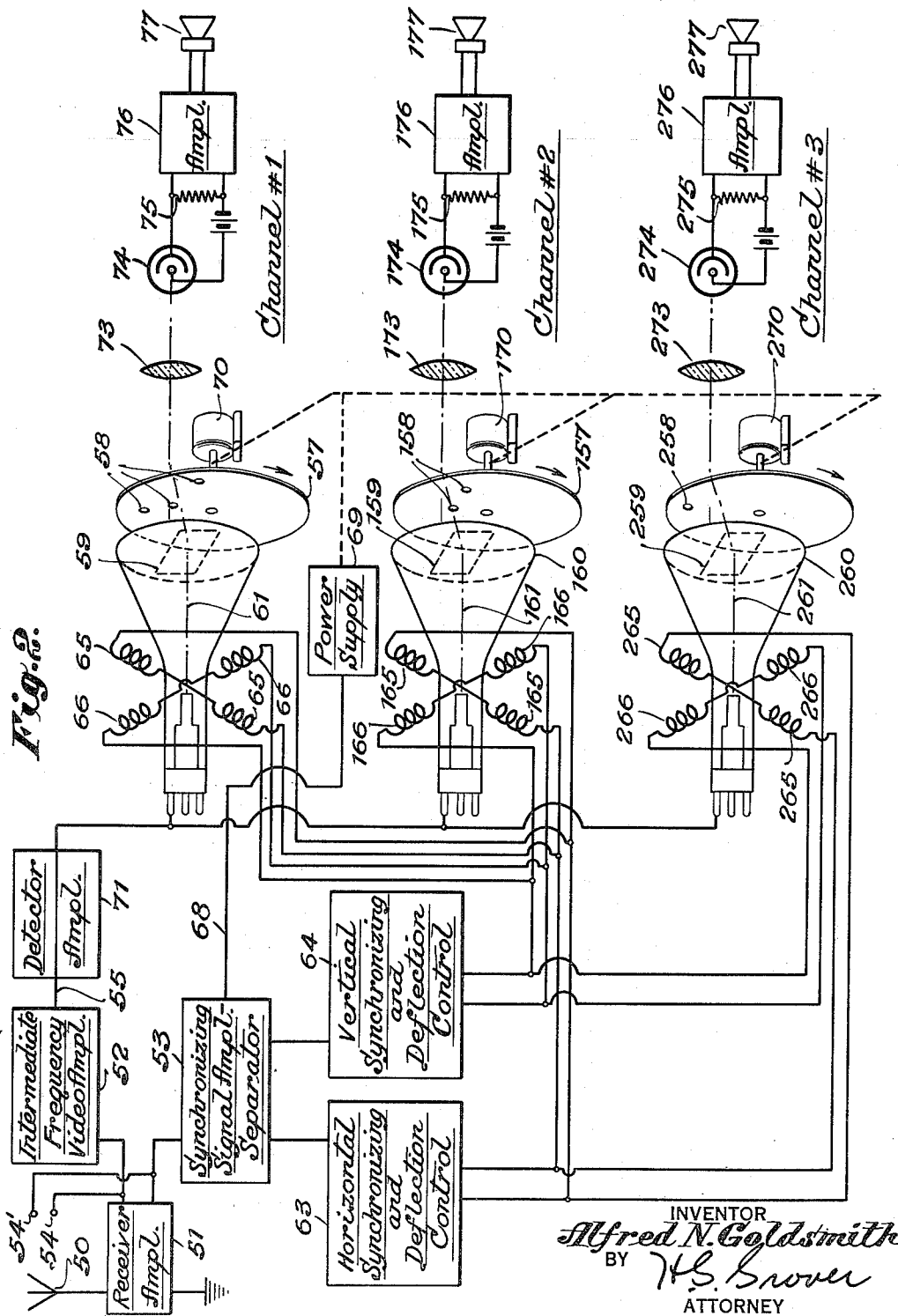
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SECRET COMMUNICATION SYSTEM

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4 Sheets-Sheet 2



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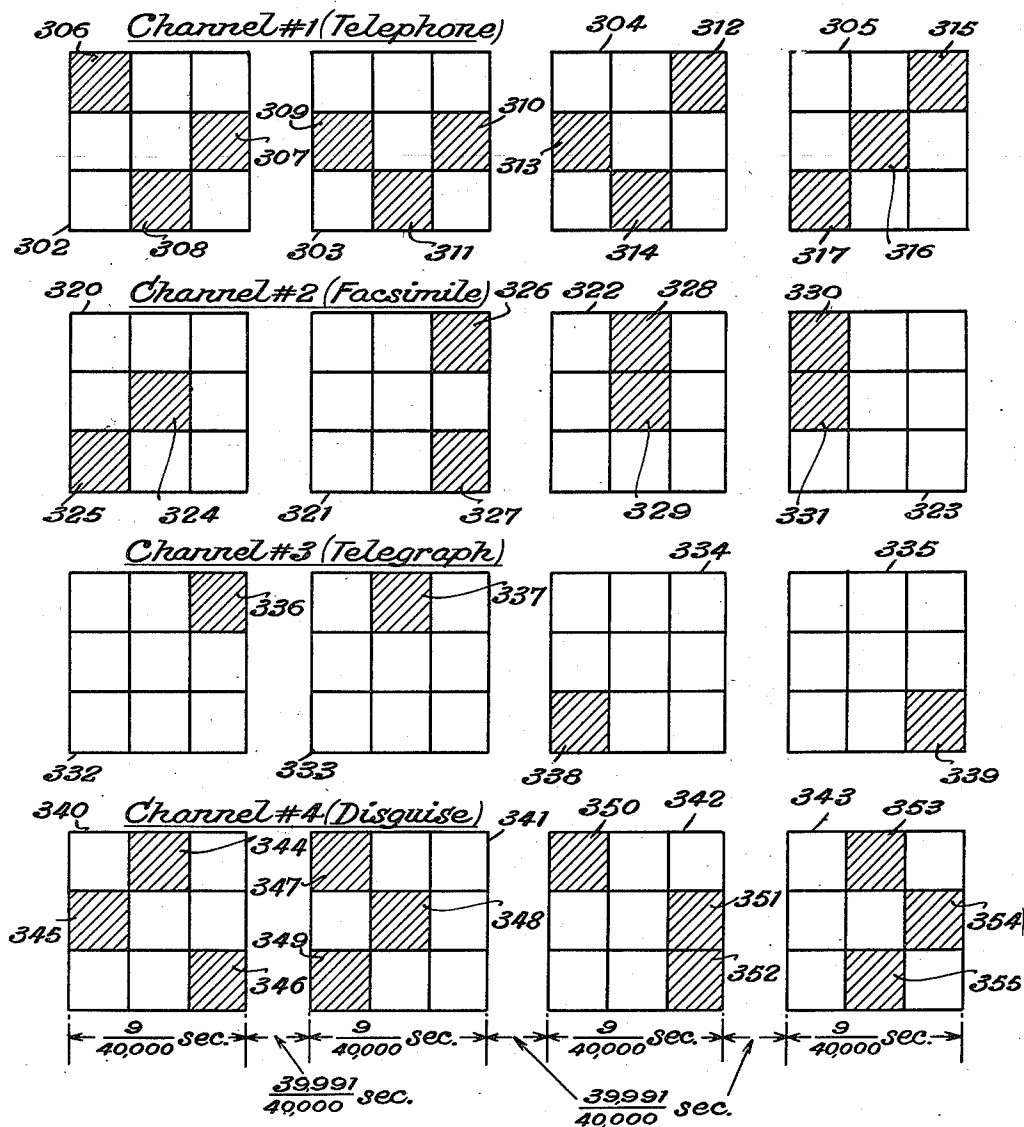
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SECRET COMMUNICATION SYSTEM

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4 Sheets-Sheet 3

Fig. 3.



Raster assumed

A-I	A-II	A-III
B-I	B-II	B-III
C-I	C-II	C-III

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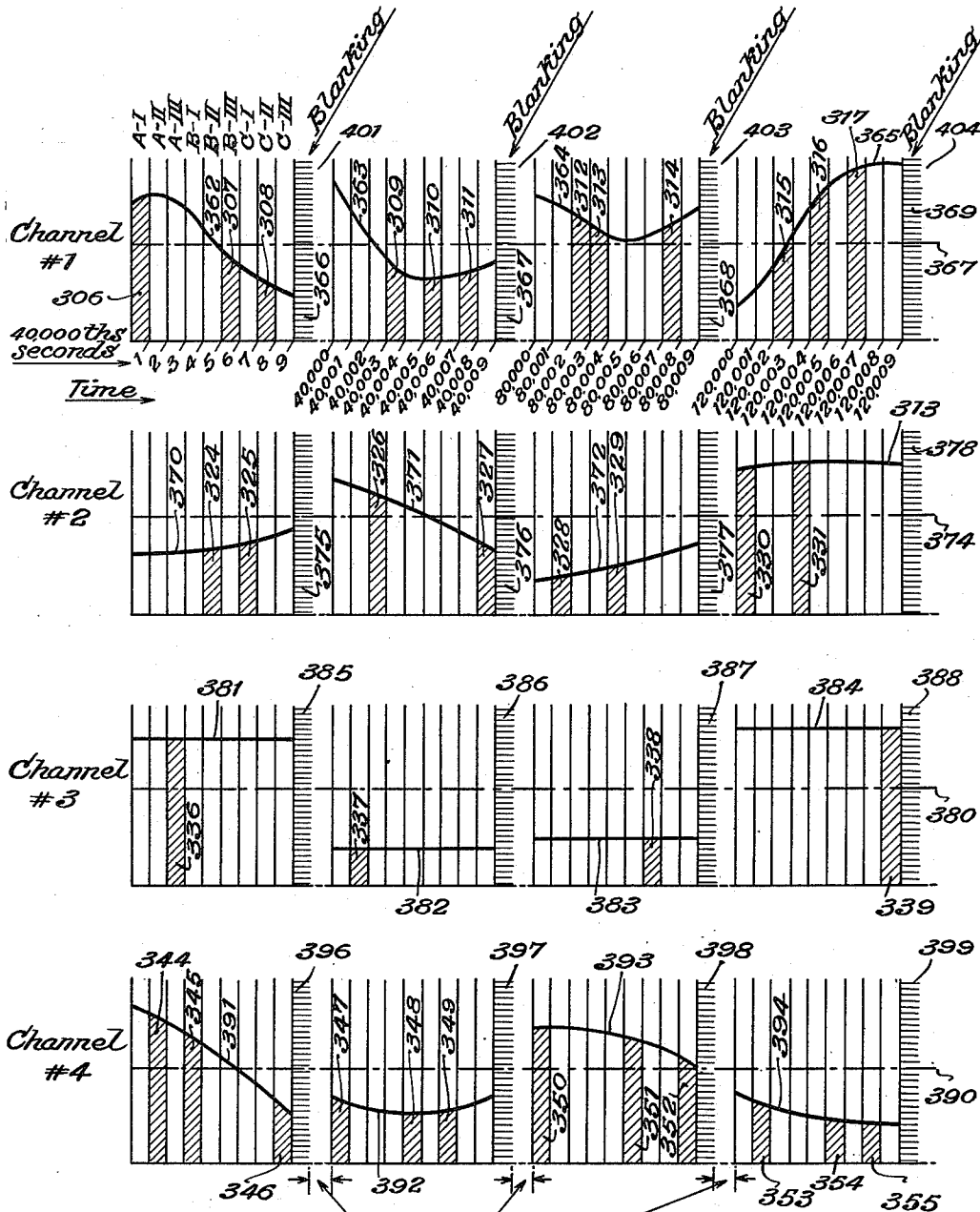
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SECRET COMMUNICATION SYSTEM

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4 Sheets-Sheet 4

Fig. 4.



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2,405,252

SECRET COMMUNICATION SYSTEM

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Application July 22, 1942, Serial No. 451,855

27 Claims. (Cl. 179-1.5)

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This invention is directed to communication systems and in one of its important forms to that type of communication system in which the maintenance of secrecy with accurate transmission and reception is a primary objective. In one of its broad aspects, the system is adapted particularly for use in secretly conveying intelligence in the form of either telephonic, telegraphic and/or facsimile messages from a central transmitting point to any desired number of receiving points whereat the message is automatically decoded and reproduced.

Among the objects of the invention are those of affording an essentially secret wire or radio telephonic communication system through an efficient use of ultra high frequency or short wave wide band radio communication channels. In the case of wire communication channels, the system is predicated upon the use of coaxial cables or wave guides capable of affording transmission channels of the order of from hundreds of kilocycles to several megacycles wide, such as are now customarily used for television transmissions.

Another object of the invention is to afford a secret ordinary or high speed facsimile communication system by radio or wire communication channels, as well as to enable secretly carrying on ordinary or high speed telegraphic communications.

Still a further object of the invention is that of multiplexing on the same transmission, and with retention of secrecy and high operating speeds, either a number of telephonic, facsimile or telegraphic communications, or mixtures of these three representative types of communications.

Another important object of the invention is to reduce or eliminate signal fading and selective frequency absorption or distortion in each of the multiplexed signals.

It is a further object and advantage of the system and the invention to provide for a reduction in the frequency bands required as guard bands for a group of communications.

A still further object of the invention is to provide for guard band savings for different types of communications related to the type of transmission; and a still further object is that of providing an efficient type of impulsive transmitter of high relative power rating.

Other objects and advantages of the invention, of course, will be apparent and at once suggest themselves to those skilled in the art by reading the following specification and claims in con-

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nection with the accompanying drawings, wherein:

Figure 1 represents diagrammatically one form of transmitter system;

5 Figure 2 indicates diagrammatically and schematically a form of receiver system for receiving the transmissions from Figure 1, and at the same time automatically de-coding or deciphering the message sent out from the transmitter arrangement;

10 Figure 3 is a schematic representation of a simple luminous field raster, which, for purposes of illustration, will be assumed to contain only nine scanning elements arranged in three rows and three columns; and,

15 Figure 4 is a schematic representation of the electrical regime corresponding to the schematic representation of Figure 3.

In these specifications, reference will be made frequently to a secret communication system, and by this is meant a system of communication which is substantially unintelligible on ordinary pick-up and which (in the absence of the receiver and adjunct devices herein disclosed) requires for its de-coding or deciphering a period of time which is long in comparison with the utility period of the communication in question, and which, during the period of utility of the communication, can readily have the coding and de-coding methods simultaneously and secretly modified. In connection with the reference to multiplexing the transmission is meant a system in which two or more communications are independently transmitted and effectively separated one from the other and received at the receiving point.

20 The methods of the present invention essentially involve a modified form of transmission superficially resembling, in some respects, television transmission, in that a sequence of shaded fields or patterns are transmitted and received. The material which is transmitted, however, does not necessarily correspond to any object or scene and is not visually observed at the transmitting station, except, if desired, for monitoring, and the material received likewise is not necessarily a luminous repetition of any object or scene and usually is not visually observed or de-coded. The shaded pattern which is transmitted and received rather comprises within itself at one or more locations on the scanning raster of a cathode ray tube of shadings which are variable in time and indicative of a particular telephonic, facsimile, or telegraphic or even televisual communication or signal.

In connection with the form of transmission herein disclosed, it is possible to provide a relatively crude televisual field which will show simple pictorial or textual material, and to use such a field for the purpose of concealing or disguising the actual message. Such fields tend to form deceptive visual arrangements in the disguise channel, but have the disadvantage, in some cases, that almost all of the field must be used for disguise purposes and thus to limit, to some extent at least, the number of useful messages which may be multiplexed. In any case, for some forms of the transmission herein disclosed, it is desirable to use the moving image or textual fields as all or as a part of the disguise portion of the total luminous field.

Further, the standards of transmission and reception, according to the present invention, differ radically from those which would customarily be used in visual transmission and reception. In its preferred form, the invention is so predicated that the number of field representations which are transmitted per second is at least the same as, and preferably of a slightly higher order of magnitude than, the highest modulation frequency corresponding to or contained in that particular form of communication which has the highest modulation frequency and is included in the groups of multiplexed transmissions.

To make a reference to a particular example of this nature, if it is planned to multiplex medium-fidelity telephonic communication, ordinary facsimile communication and ordinary telegraphic communication, which for purposes of illustration may be assumed to require, respectively, about 3,500 cycles, a few hundred cycles, and a few tens of cycles for their highest modulation frequencies, the number of scanning fields or complete scanning rasters reproduced per second might be chosen at a value of 4,000 for instance. As a natural consequence, and in order to maintain the transmission within what is now regarded as a reasonable over-all channel width, the number of picture elements per field or per second must be considerably reduced below that used for television, where it has been customary to transmit approximately 60 fields per second but a great number of picture elements. For instance, if in this invention 4,000 fields were transmitted per second with only 1,500 points to be represented in each field, the channel width in the spectrum would be approximately of the same order as for the transmission of 60 (interlaced) picture fields in present-day television, where each field is formed from about 100,000 picture points. As a natural consequence, in order to maintain the transmissions within a reasonable channel width, it is evident that the number of individual point or picture elements to be reproduced in each field will be considerably reduced below that used for television if the band width in the frequency spectrum is to remain within usual or reasonable limits.

From what has been here said, to make reference to another example, for instance, in television the number of picture elements in each field is of the order of hundreds of thousands, whereas, in the present method of secret communication and multiplexing method, the number of elements per field will be of the order of thousands (or even hundreds or tens). Similarly, for the telephonic secret and multiplexed communications herein described, the number of fields per second, according to the present invention, is of the order of 100 times that in television as pres-

ently practiced, whereas the number of field "picture elements," so to speak, is of the order of $1/100$ (or less) of that used in television. It is to be noted that the reference to the term "picture elements" herein for the secret or multiplexed transmissions is merely illustrative, since, as previously noted, no actual picture transmission in the visual sense is necessarily involved, nor is the position of the basic picture elements completely fixed on the raster at all times.

Making further reference to the present system, the method of transmission as herein disclosed involves the preliminary selection and description of one or more definite scanning spot locations on the raster, and the position on the raster of each of these points will be referred to herein as the "significant locations." Thus, one of the points, for instance, might be the 4th scanning spot location on the 5th scanning line. The next might be the 17th scanning spot location on the 22d scanning line. And the third and last might be the 33d scanning spot location on the 35th scanning line. By the "4th scanning spot location," above mentioned illustratively, is meant an area having the dimensions of the scanning spot and centered at a distance $3\frac{1}{2}$ times the scanning spot width from the left end of the corresponding scanning line, assuming a smooth raster. There are thus established a group of significant locations on the raster which correspond to a given one of the secret and multiplexed communications.

In the present illustration of the invention as it is applied to the schematic representation of Figures 1 and 2, a medium-fidelity telephonic communication is taken as typical with modulation frequencies extending up to about 3,500 to 3,600 cycles approximately, since it is well known that such a communication would be of excellent intelligibility. In fact, it is also known that the median frequency for telephony which gives equal intelligibility contributions for all frequencies above the median frequency and all frequencies below the median frequency is only 1,500 cycles.

The sound wave corresponding to the telephonic communication, according to the present invention, is first picked up by a microphone, for instance, and the resultant pulsations of energy are then amplified and caused to control, correspondingly, the instantaneous brightness of a suitable light source, so that the light from this modulated source then carries the speech as a modulation in the usual photophonic fashion. The light source may be of any controllably variable type and, for instance, may be a gas lamp, a steady light source used in combination with the Kerr cell, or a steady light source and an electromagnetic light valve, all of which may be controlled by the output energy or modulation wave from the microphone, facsimile scanner, telegraphic key (or even an Iconoscope), or the like, at the transmitter. Such controlled light sources are well known in the art and presently available.

After the message signals have been amplified and caused to modulate the light from the light source, the modulated light is caused to spread out over the entire surface of the mosaic of a pick-up or camera tube, which may be of the general type now known in the art and used for television transmissions by the trade designations "Iconoscope" and "Orthicon," as disclosed particularly by Zworykin, Iams and Rose, or the device may be of the general type shown and dis-

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closed in Farnsworth Patent No. 1,773,980, which is known as the "Dissector" tube. This tube may also be the well known "Monoscope" type of tube with the scanning raster appropriately lined and impressed thereon or otherwise distinguishably created thereon. The essential point is that the light is caused to reach and influence an electronic scanning instrumentality which forms one element in the translation system.

The next important point in connection with the system, as so far described, is that there is placed in the path of the light, at some point intermediate the modulated light source and the mosaic of the scanning tube, and at an appropriate optically selected position, a masking device which is opaque except at the predetermined points, areas or portions thereof, which are perforated or light transmitting. The light transmitting areas of the masking element are in such an arrangement that light can pass through the mask and fall on the camera tube mosaic only at the predetermined and chosen significant locations on the raster. The motion of the scanning beam or its equivalent across the scanning tube or upon the light sensitive surface of the tube generates the resultant signal output. The result is that there appears, for each scanning in the output of the camera tube, a group of brief impulses which correspond individually to the instantaneous amplitude of the telephonic sound wave at the moment that the scanning spot in the camera tube passes over a significant location on the mosaic which is spatially related to the area in the masking element through which the modulated light is revealed to the light translating device. The impulses generated by the scanning device are then sent, either in the form of modulation of an ultra high frequency or short wave carrier for radio communication, or as direct impulses or a correspondingly modulated carrier wave over a coaxial cable circuit or wave guide, or by some combination of such methods, to suitable receiving points.

It is well known that there may be an extraneous shading effect or "dark spot" produced during the scanning of any Iconoscope image as a result of the return to the mosaic of the electrons emitted from any portion thereof under the scanning beam impact. Such re-distribution of emitted electrons results in shading or video signal response changes not related quantitatively to the image itself according to any simple law. However, the shading effect is largely compensated by impressing locally generated voltages varying according to a predetermined and controllable law on the video signal. Thus, a combined original video signal and the shading correction signal produce a final video signal corresponding closely to that of an Iconoscope or camera tube in which no shading effect existed. The method of controlling or eliminating the shading effect is disclosed for example in Bedford Patent No. 2,166,712, of July 18, 1939.

In the present invention, shading effect elimination or correction may, under some conditions, be necessary to enable the desired degree of modulation of the video signal originating at each point of the raster in accordance with the modulation of the light falling on that point of the raster as produced by the variable light sources 3, 103, 203, etc. Shading effects at each point of the raster must be reduced to such an extent that for the desired maximum upward or downward modulation of the light falling on

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that point of the raster the video signal that is produced from that point shall follow with close proportionality the luminescent modulation. If the shading effect were excessive at any point of the raster, saturation effects, on one hand, or low-level distortion, on the other hand, would result in the output video signal from that point of the raster.

At the receiving points the developed signals are caused to produce bright spots on a picture reproducing tube of the cathode ray type. Such a tube as is frequently designated in the art as the so-called "Kinescope." The bright spots produced in the tube are then caused to appear at the predetermined and chosen significant locations corresponding to those in the scanned mosaic at which the light of the modulated source was revealed by the masking device. It is, of course, readily apparent that the conventional synchronizing signal and background control circuits, and methods known and used in the television art and all refinements of such television technique, are applicable and should be used to the requisite extent in connection with the present system. However, such forms of synchronizing signal transmission and generating means are so well known in the art that they need not be again described in detail in this disclosure, and further reference may be had to such arrangements by making reference to any of the so-called patented art and other standards set for the manufacturers of television equipment by the Federal Communications Commission.

There is appropriately placed in the receiver, at an optically appropriate location, a masking element in such relation to the picture or luminous field reproducing screen or target that only light from the significant locations on the mask can pass through the apertures of an otherwise opaque mask. The light passing through the apertures of such a mask then is caused to be concentrated and to fall upon a photoelectric cell whose output is suitably amplified and caused to pass through appropriate smoothing circuits, such as low pass filters, if desired, and caused then to activate a loud speaker or telephone receiver where the original speech is reproduced. Essentially the same process may be used for facsimile or telegraphic communications (or even for televisual communications of the available detail), except that the corresponding type of modulation wave at the transmitter is used to control the light source which illuminates the camera tube mosaic through the code mask, that is, the mask carrying the significant location apertures, and the amplified output of the photocell at the receiver is used to control a corresponding facsimile or telegraphic reproducer.

For a second and multiplexed telephonic communication it is necessary only to have a second microphone, amplifier, controllable light source, code mask, and camera tube, whose output is mixed or added to that of the first camera tube. It is, however, necessary for non-interference between the multiplexed telephonic communication channels, that the significant locations on the mask of each individual separate communication channel shall, at substantially all times, be at different points on the raster of the scanning tubes from those of every other individual communication channel, and this, of course, is a requirement which can be readily fulfilled in view of the large number of points available on

any scanning raster. In referring to a "point" on the scanning raster, it is, of course, apparent that what is meant is an area substantially the size of a scanning spot, although, in accordance with what will hereinafter be described, this area may be modified to a size greater than that of a scanning spot in a manner which will later become fully apparent.

The transmission methods described in this disclosure, insofar as what has been mentioned up to the present time is concerned, of course, have little secrecy value, inasmuch as the limited number of bright spots at significant locations in the receiving picture tube screen or target could be identified and thus used to reproduce the desired communication after a relatively short period of time. However, a number of expedients and methods are added to what has been hereinabove illustrated and described so as to introduce a high degree of secrecy into the communication system.

In one form of the arrangement whereby the high degree of secrecy is introduced, it is apparent that the system may be so constituted that systematically mobile masks are used at the transmitter for each of the multiplexed communications. By such an arrangement, the mask carrying the apertures at the significant locations is capable of being moved in linear, rotary, or other curvilinear fashion at a predetermined rate where provision is made so that the corresponding mask at the receiver point shall move in homologous, equi-frequent and identically phased relationship with the corresponding mask at the transmitter. Under such circumstances, a great number of parameters are available for controlling the relation between the masked positions or significant locations and the corresponding time. Thus, the encipherment code, so to speak, is continually altered in an unknown fashion from the viewpoint of the attempted interloper. By this disclosure, and from the apparatus which will be described herein, provision is illustratively made for providing a combination of rotary and linear motions of the code masks.

In an alternative form, a constant shaded or variably shaded background may be used throughout the transmission to disguise the actual communication channels. Thus, for instance, audio-frequency shadings of moderate amplitude impressed in the final modulation mixer will afford one way of disguising the structure of each field and alternatively masks carrying apertures corresponding to non-significant locations or areas may have misleading or interfering communications or fields of various sorts impressed therethrough on a camera tube mosaic by means similar to those used for the actual communications, and the output of such non-significant camera tubes may be mixed with those of the significant camera tubes whereby the final signal or shading of the field will be a complicated and continually changing mixture, according to unknown timing rates, of significant and non-significant signals.

Thus, the raster will consist of a limited number of significant locations corresponding to the actual communications, with the significant locations changing according to a law unknown to the interloper and may contain, as well, a large number of non-significant locations similarly changing according to an unknown law and carrying interfering or misleading signals. If the

receiver picture tube screen or target is thus focussed on a photocell whose output is amplified and fed to a loud speaker, there will be only a babel of unintelligible and meaningless sounds emitted from the loud speaker to be heard. Furthermore, an attempted analysis of the raster point by point will be of no help because a particular point on the raster will at one instant be a significant location for a particular communication but at many other times will not in any sense be a significant location for that communication in view of the continued motion of the code masks according to a law which is unknown and unlikely to be worked out by the interloper within the useful period of a given communication. It is, of course, apparent that the law in question can be changed according to a predetermined and prearranged requirement of the system which would make it substantially impossible for an interloper to catch up with the changes in the code.

Such conclusions of secrecy are readily reached from the fact that in any effective system of cryptography there must be many available normally fixed parameters and preferably many variable parameters. There must also be an accuracy of correspondence between the selected instantaneous values of the parameters at the transmitter and those at the receiver.

It thus becomes apparent that the systems herein described can readily be combined with other forms of coding as desired, so that telegraphic communications, according to the system, may themselves be enciphered, for example, either by tabular or machine methods. Similarly, speech over such a system may be inverted or otherwise systematically and secretly modified. Likewise, facsimile communication can similarly be disguised or altered in any desired fashion.

With these thoughts in mind, it will be apparent, from a further reference to the particular apparatus which represents one of the several forms which the system may follow, that the secrecy will depend upon the fact that methods, equipment, and knowledge of the code for proper reception of all of the following factors must be available to the intercepting station, namely, (a) the number of transmitted fields per second; (b) the number of elements per field and the aspect ratio in case the aspect ratio is not the usual value of unity; (c) the scanning regime, if this differs from the usual up-down and left-right type, including the extent of the scanning and blanking periods; (d) the location of the significant locations for each of the multiplexed transmissions at a specific epoch or point of time, and (e) the laws governing the spacial changes of the significant locations over the raster with time, as to direction, speed, rate of occurrence, and the like. For example, for translatory or rotary or reciprocating motion of the code mask, the law governing the frequency, phase, or time-versus-position of the mask must be known. Consequently, it can be seen that a system embodying the foregoing principles will provide for transmitting messages with almost complete certainty that the message will not be intercepted and deciphered or decoded or made otherwise intelligible within the period of usefulness of the message; and with the code changing from time to time it is, of course, apparent that once solving the code at any particular time will have no particular value for future solutions.

It was above mentioned that the presently described invention had, as one of its objects, that of reducing the frequency bands required as guard bands for a group of communications. Under such circumstances, it might be assumed that where there are n communications of the same type, such as telephonic, facsimile or telegraphic, and where the guard band between adjacent channels has a certain width w , then the total number of guard bands ascribable to the n communications in question will have an aggregate width of n times w (of course, under such circumstances, attributing one of the outside guard bands to the next communication not comprised in the group).

However, in the system herein disclosed, the total guard band required will be w in width. This is calculated on the basis that the synchronization of the impulses of the transmitter, and those at the receiver are arcuate and absolute. Otherwise, any guard time between adjacent impulses in each impulse group utilized in the multiplexed communications would extend the requisite frequency band by a fraction equal to the ratio of the guard time to the impulse time.

In any event, the saving in the total frequency width realizable by the use of the system herein disclosed is dependent in some measure upon the type of communication, or, expressed more strictly, it depends upon the ratio of the modulation frequency band required for the specific type of communication to the necessary guard band. For instance, in facsimile, the ratio is somewhat larger than in telephony, and, therefore, the saving in the guard band frequency width will be much greater when the invention is applied to facsimile than to telephony. Similarly, in the case of telegraphy, the ratio becomes still larger, and, therefore, greater economies in the total channel width necessary for a group of telegraphic communications may be realized than is apparent for telephonic or facsimile communications.

Now, making particular reference to the drawings for the showing of one schematic embodiment of the invention, and for instance, a form of the invention as applied to telephonic communication, sound waves corresponding to the spoken message are caused to impinge upon a sound pick-up or microphone 1 where output energy is amplified in any well known type of vacuum tube amplifier 2 and used to control or modulate the brightness of a light source 3, which modulation is schematically indicated by the arrow to show its variable character. In one of its forms the light source 3, as hereinbefore noted, may be the ordinary gas tube whose brightness is directly controlled by the amplifier output energy and whose brightness is further directly proportional to the potentials impressed upon it from the amplifier 2. In an alternative form, the light source 3 may be a combination of a light source of constant intensity and a light valve of any desired type, such, for instance, as the Kerr cell type disclosed, for instance, by Karolus Patent No. 1,885,604. Under such circumstances, the well known polarizing and analyzing prisms are interposed in the light path and the output of the amplifier 2 is caused to influence or modulate the potential applied to the plates of the said light valve electrostatically in order to vary the light emerging from the analyzer, all as shown by the Karolus patent. Alternatively, the Faraday electromagnetic or other electrostatic or electromagnetic types of light valves may be conventionally employed.

Whatever light is generated by the light source 3 is caused to be directed by the lens element 4 to strike or impinge upon the code mask 5, which has the code apertures 6 placed in suitable locations thereon to identify significant locations of the light points on the raster traced upon the camera tube, later to be described. The lens 4 serves as a collimating lens to spread the light from source 3 uniformly over the area 10 (later to be described) except as the light is intercepted by the opaque areas of the masking disc 5. The code mask 5, in the particular embodiment shown, is arranged to be rotated on a motor shaft 7 by means of a suitable motor or other equivalent driving device 8. The motor 8 may be either a synchronous motor driven from suitable A. C. power line (to which the scanning tube deflection system is interlocked) connected at the points 9, or the motor may be a variable speed motor of which the speed varies in accordance with some predetermined speed variation pattern for the purpose of secrecy, as will herein be apparent. The motor design, and associated gearing, if used, should be such that hunting (systematic speed oscillations) of the rotating mask shall not be inadvertently introduced.

The motor 8 may also be so arranged that it is movable as a whole with shaft 7 and mask 5, in directions generally perpendicular to the shaft, so that the disc 5, as it is rotating in the direction shown by the arrow, for instance, may simultaneously be shifted in a lateral, vertical or oscillatory manner in directions normal to the axis of rotation according to a preestablished pattern. Such a motion of the disc 5 permits the light from the source 3 which is permitted to pass through the apertures 6 to fall upon the translucent screen 10 after being suitably controlled in intensity by the source 3. However, due to the disc motion from field to field the points at which the light passing through the apertures 6 are permitted to reach the screen 10 may change from field to field in accordance with the shifting of the disc position. This shifting will have the effect of continually changing the code, so to speak.

The drawings do not show specifically the arrangement for moving the disc 5 in directions perpendicular to the axis of rotation 7, but it should be obvious that such motion may readily be accomplished by raising or lowering disc 5 or producing a lateral shift in a reciprocating manner, or by causing it to describe any desired orbital path normal to the shaft 7 with the shaft 7 remaining within the orbital path. So operated, the motion of the motor 8 is controlled, for instance, by a second motor (also interlocked with the same power supply), causing it to be reciprocated in the desired direction, or the orbital path may readily be described by using the second motor to drive a suitably designed cam surface to control the instantaneous position of the first motor 8.

In a further alternative arrangement, the effect of an instantaneous shifting position of the motor 8 upon its shaft 7, so as to give the effect of a motion of the disc 5 relative to the screen 10 may be obtained by forming the disc in sections. In one form, the disc may then comprise various segmental or sector portions.

These sectors have an effective area included therein and in general close to their periphery which, when optically projected or overlaid on the mosaic of the camera tube, is preferably equal to the dimensions of the scanned area of the

mosaic. The significant locations are represented by apertures or transparent portions in each sector, and are preferably changed from each sector to the next adjacent sector.

The ratio of sector widths on the disc, as optically overlaid on the mosaic of the camera tube, to the width of the significant scanned area and elements on the mosaic may be a whole number, a commensurable or a fractionally expressed number, or an incommensurable number. In the last-mentioned case, particular mask positions with reference to the raster do not effectively recur, at least in theory, at any time (neglecting the finite dimensions of the masked apertures). Thus the duration of the recurrence cycle for a given group of significant locations is infinite in length according to an idealized theory wherein the scanning elements are of infinitesimal dimensions, and is very long in actual practice when scanning spots of finite dimensions are used. This is a desirable feature in practice.

The light of the source 3 which passes through the apertures 6 of the rotating disc 5 is caused to fall upon the translucent screen 10, and the entire actively illuminated area of the screen 10 is then suitably focussed by a lens 11 onto the light sensitive mosaic 12 of a scanning tube 13, which is preferably of the "Iconoscope" or "Orthicon" type and hereinafter more particularly designated as the "camera tube."

As is well known in the art, light falling upon the mosaic 12 contained within a tube 13 of the above named type causes electrostatic charges to be developed upon the mosaic and these charges are removed and converted into electrical energy by causing a scanning beam 14, acting under the influence of energy in deflecting coils 15 and 16, to traverse the mosaic 12 according to a bi-dimensional pattern at a rate such that the complete number of traversals of the mosaic made by the beam shall coincide with the number of fields transmitted per second for the type of transmission desired. If, for instance, as above noted, the transmission is to be at the rate of 4000 complete fields per second and each field is to consist of N active scanning lines, then it is apparent that the beam 14 must traverse the mosaic 12 in one direction at a rate of 4000 times per second and in the other direction at least N times as fast (allowance being also required for the line-return or blanking period), and during the traversal signals will be released to an amplifier circuit 17 for amplification.

This amplifier 17 may be of the form generally known as the pre-amplifier, or it may include a pre-amplifier and one or more stages of the video signal amplifier, and, accordingly, the diagrammatic representation of the drawings is to be considered purely conventional in nature. The energy which is to be supplied to the deflecting coils 15 and 16 (arranged suitably about the neck of tube 13) for causing the cathode ray beam 14 to sweep across the mosaic 12 is generated under the control of the synchronizing signal and blanking signal generator, conventionally represented as the generator 18.

This type of generator may be of any general form and designed according to television technique, preferably, and, accordingly, it may follow that form described, for instance, by Bedford and Smith in an article entitled "A Precision television synchronizing signal channel," which was published in the "RCA Review" for July, 1940, commencing on page 51 and continuing through page 68. It is obvious that many of the circuit

constants there disclosed will be changed in the final design of the present system in order to provide for the different field frequency deflection hereinabove specified, but essentially, the described publication sets forth one general form of circuit applicable to this usage.

The energy generated in the synchronizing and blanking signal generator 18 is developed in a predetermined phaseal relationship relative to the frequency of the energy in the power lines connected to terminals 9 and used, for instance, to drive the motor 8. To provide such an arrangement and to provide for interlocking the deflection generator with the synchronizing and blanking signal generator a power line interlock means is conventionally represented at 19. This arrangement may be of the general form disclosed, for instance, by Smith Patent No. 2,132,655, or, where desired, the interlock may follow the general nature and principles of the apparatus described and claimed in the Tolson Patent No. 2,124,478. In this way, it is apparent that an interlocked, definite, fixed and predetermined phaseal relationship may be had between the rotation of the disc 5 and deflection of the cathode ray beam 14. The energy developed in the synchronizing and blanking signal channel 18 is supplied to the vertical deflection control element 20 and the horizontal deflection control element 21 to control the operation in known manner. These deflecting elements may comprise presently known types of arrangements for developing energy which when fed or supplied to the deflecting coils 15 and 16 will cause the development of suitable strength electromagnetic fields (or electrostatic fields in the case of electrostatic deflection) to cause the cathode ray beam 14 to traverse the target or mosaic 12, according to saw-tooth (or even in some instances non-saw-tooth) traversal patterns.

Such arrangements for controlling the beam motion are obviously many and may include those illustrated, for instance, by Tolson Reissue Patent No. 20,338 of April 20, 1937; Hoover et al. Patent No. 1,978,461 of October 30, 1934; Vance Patent No. 2,137,039 of November 15, 1938, or many others.

Because of the saw-tooth deflection of the beam 14 within the tube 13, it is apparent that the beam should be suppressed during the snap-back period in each of the vertical and the horizontal saw-tooths, and accordingly, energy for blanking the beam during these periods is supplied under the control of the synchronizing and blanking signal generator 18 by way of the blanking signal amplifier 22, whose output energy is supplied to bias the control electrode element of the electron gun 23 of the tube 13 in such a manner that the beam 14 is suppressed or cut off (either completely or partially as may be necessary).

The synchronizing and blanking signal generator 18 is likewise arranged so that its output energy is caused to be supplied to the mixer and amplifier system 25 to which the energy output of the amplifier 17 is also supplied. At this point in the system, the synchronizing and blanking signals are combined with the picture signal output (meaning, by "picture signal," the useful output from the tube 13), so that the sequence of output energy from the mixer and amplifier 25 includes signals representative of the intelligence to be transmitted and signals which will control or synchronize the receiving apparatus and at the same time provide for all necessary blanking at receiving points. The mixer and amplifier 25 is

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shown in conventional form, since circuits of this type are so widely used as not to require illustration.

Because the system herein disclosed is adaptable for use in multiplexed transmissions, it is frequently desirable to feed the output from the mixer and amplifier 25 to a further mixer and amplifier 27 to the input of which are supplied the signals from other channels in the complete transmission system. Output energy from the signal mixer and amplifier 27 may then be supplied by a conductor 28 to a terminal point 29, whereat is connected the usual form of coaxial transmission cable, or the output of the signal mixer and amplifier may be supplied with the well known type of modulator tube conventionally represented at 30.

Energy of a carrier frequency generator 31 is supplied to the modulator in the conventional manner indicated, and where necessary for transmission, the output energy from the modulator 30 may then be suitably amplified by the radio frequency amplifier 32 and supplied to the transmission antenna 33. Obviously, the antenna 33, per se, forms no part of the present invention, and, therefore, it has been conventionally shown as the non-directional radiator, but it is, of course, apparent that directional radiation and controlled transmission paths may be utilized where desired.

It was above explained that the system herein disclosed was applicable for use with a plurality of signal channels, and that one such channel might comprise a telephonic communication, another a facsimile communication, and a third a telegraphic communication, or various combinations of these. For illustrative purposes, two additional channels, designated channel 2 and channel 3, have been shown by Figure 1 of the drawings, and the reference numerals there used correspond to those of channel 1, except that the numerals are increased by a unit of 100 for channel #2, and by a unit of 200 for channel #3. It is further to be understood that the message transmission, in either of channels #2 or #3, can be any one of the three forms of messages hereinabove mentioned, or the energy transmission in channels 2 and 3 may consist solely of unintelligible signal masking, confusion or disguise energy which readily can be filtered out at receiving points, and, of course, under some circumstances such signals may be injected at any desired points in the transmitter portion, for example, at amplifier 117 so that a special tube to generate them is unnecessary.

In systems of communication, it usually is preferable to provide switching connections for switching one or all, or a part, of the mixer and amplifier arrangements 25, 125, 225, so as to supply energy to the signal mixer and amplifier 27. For convenience of reference, the various forms of signal initiating means applicable for use in channels 2 and 3 are not shown, since the output of any well known forms of arrangements may be supplied to the input of the amplifiers 102 and 202 as desired, and, in any case, the light sources 103 and 203 are modulated as above explained with regard to the light source 3. The outputs from the scanning tubes of channels 2 or 3 are passed to the signal mixer and amplifier circuit 27, as indicated, where these signals are mixed with the output of channel 1. If required, delay circuits may be introduced into the input conductors of the signal mixer and amplifier 27

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to equalize the phase shifts in circuits associated with tubes 13, 113, and 213, for instance, so as to maintain the desired time relationships between the various signal impulses. It is, of course, to be understood that while the disc elements 5, 105 and 205 are all shown as being synchronously driven and controlled from a single source, the code mask provided by the location of the apertures 6 is different in each case, so that different significant locations are determined upon the translucent screens 10, 110 and 210. This will be further explained in connection with the analysis of Figures 3 and 4.

It is, of course, apparent that where the motors 8, 108 and 208 are driven from the A. C. power lines connected at the terminals 9, 109, or 209, it is usually desirable that the field frequency be related in some sense to the frequency of the power line supply. While 4,000 fields per second has herein been suggested as illustrative of one suitable field frequency, it is, of course, readily apparent that even for telephonic communication a field frequency of 3,600 or 4,200 fields per second, for example, might be used in order to relate the field frequency directly to the usual 60 cycle power supply. Also, at the former field frequency, it is readily apparent that synchronous motors operating at 1,800 R. P. M. (30 R. P. S.) may be so geared that the discs 5, 105 or 205 are driven with a step-up gearing of 120 to 1.

It is, of course, perfectly apparent that while this relationship is desirable for simplicity of operation, it is in no way essential to the invention.

In the receiver instrumentality diagrammatically depicted by Figure 2 all parts have again been schematically illustrated. In general, the receiver arrangement follows, to some extent, usual television technique. In cases where the signals have been radiated from a transmitting antenna 33, as in Fig. 1, these signals are received upon a receiving antenna 50 and suitably amplified in a receiver amplifier 51.

In the receiver amplifier, by well known means (not shown) the received radio frequencies are converted by usual beat frequency methods into intermediate frequencies then separated at intermediate frequencies from the accompanying control or synchronizing signals. The intelligence signals, herein termed for convenience the "picture signals," are supplied to an intermediate frequency video amplifier (termed video amplifier because of its general characteristics) and amplified to the necessary degree. The control or synchronizing signals are separated in suitable manner, as, for instance, according to well known television practice, and supplied to what may herein be termed the synchronizing signal amplifier-separator 53. In cases where the transmission from the transmitting system of Figure 1 has been by way of a co-axial cable connected to the terminal point 29, the resulting signals may be supplied to the terminal points 54 and 54' to be supplied to the intermediate frequency amplifier 52 and the control or synchronizing signal amplifier-separator 53. The output energy from the intermediate frequency video amplifier 52 is supplied by way of the conductor 55 so as to be impressed, after detection and such further amplification as is necessary, upon the control electrode system of each of the tubes 56, 156 and 256 respectively of what may be con-

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veniently represented as channels 1, 2 and 3 to be coordinated in turn with channels bearing like indications in the conventional representation of the transmitter in Figure 1.

As was the case at the transmitter, a code or masking disc element 57, 157 and 257 is arranged in cooperative relationship with each of the tubes 56, 156 and 256 respectively, so that masking apertures 58, 158 and 258 in the discs alternately reveal and eclipse the light produced upon the luminescent targets 59, 159 and 259 forming the end walls 60, 160 and 260 of the respective tubes 56, 156 and 256. In this way, whenever a light point or area is generated upon the luminescent targets of the respective tubes by the impact of the cathode ray beam 61, 161 and 261 thereon, it is caused also to impinge upon the discs 57, 157 and 257 and to pass therethrough at times when there is coincidence between the illuminated elemental area of the luminescent targets and the areas revealed by the apertures in the discs.

In order to reproduce the messages transmitted over channel 1, for instance, according to the system of Figure 1, it is essential that the scanning beam 61 generated within tube 56 shall be so controlled as to operate synchronously and co-phasedly with the scanning beam 14 of the tube 13 of the transmitter. Similarly, the scanning beam 161 of the tube 156 should move synchronously and co-phasedly with the scanning beam 114 of the transmitter tube 113 in order to repeat the message sent over channel 2, and, likewise, it will herein be assumed that the scanning beam 261 generated in the tube 256 of the receiver operates synchronously and co-phasedly with the motion of the scanning beam 214 of the transmitter tube 213 so that the message applied to channel 3 shall be repeated.

The synchronizing signals which were developed in the generator 18 of the transmitter, and which were transmitted along with the intelligence signals, are, as above noted, received and applied to the synchronizing signal amplifier-separator 53, from the output of which signals intended to control horizontal deflection of the cathode ray beams are applied to the horizontal synchronizing and deflecting control 63, and signals which are to control the motion of the cathode ray beams in the vertical direction are supplied to the vertical synchronizing and deflecting control unit 64. For convenience of illustration, the output energy from the horizontal synchronizing and deflecting control 63 and the vertical synchronizing and deflecting control 64 is each shown as applied directly to the horizontal coils 65, 165 and 265, and the output energy from the vertical synchronizing and deflecting control 64 is shown as being applied directly to the vertical deflecting coils 66, 166 and 266. Of course, with such an arrangement, it would indicate that the rate of deflection in each of the tubes 56, 156 and 256 was identical, but such may or may not be the case. However, since there is a fixed relationship between the deflections of the beams in all of the tubes, it is apparent that the output energy from the horizontal synchronizing and deflection control unit 63 and the vertical synchronizing and deflection control unit 64 may be applied directly to the coils of one of the tubes, for instance, tube 56, and may be applied through a separate control unit to control the deflection within the tube 156. In this way the beam deflection may be

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properly coordinated with the horizontal deflection control 121 and the vertical deflection control 120 of the tube 113. Likewise, the deflection of the beam 261 within the tube 256 is coordinated in the horizontal direction with the horizontal deflection control 221, and in the vertical direction with the vertical deflection control 220 of the tube 213 of the transmitter. However, to avoid confusion in the drawings, these instrumentalities have not been shown because of their well known character and because it is so readily appreciated that deflection may be controlled under the influence of received signals in so many ways.

Furthermore, the output of the synchronizing signal amplifier-separator 53 is fed by way of a further connection 68 to a power supply control unit 69 which is connected with the driving motors 70, 170 and 270 by which the disc elements 57, 157 and 257 are rotated in synchronism with the discs 5, 105 and 205 respectively of the transmitter.

As was above pointed out, the picture signal energy received is amplified suitably by the intermediate frequency amplifier 52, and then supplied to the detector amplifier 71 and caused to influence each of the tubes 56, 156 and 256, so that the cathode ray beams developed therein are modulated and the brightness of the spots appearing upon the luminescent targets of the various tubes is controlled.

The modulation of the beam within the tube 61 is coordinated, for instance, with the signal energy developed in the output of the tube 13 of the transmitter, in accordance with the light revealed to the mosaic 12 by the disc element 5, and the instantaneous position of impact of the cathode ray beam within the tube 56 is made to coincide with the instantaneous position of the beam 14 on the mosaic target 12 of the tube 13, and this, of course, is controlled by the energy applied to the deflecting coils 65 and 66. There will appear on the luminescent screens 59, 159, 259, etc., of the receiver kinescope a luminous field each point of which is active (that is, in process of luminous modulation) at each instant. These fields in each kinescope are identical or homologous at any given instant. Each one of them contains, in the form of luminous modulation of the individual raster scanning elements, all the video signals which in their totality have been fed into the signal mixer-amplifier 27 in Figure 1 of the transmitter. Further, all of these signals appearing in predetermined sequential form have been derived from the output of detector-amplifier 71 of the receiver in Figure 2. The differentiation or separation of the individual channel signals from this total or conjoint mixture of all of them is necessary and is effectuated for each signal by the action of the corresponding mask 57, 157, 257, etc. These masks, which show the significant location for each signal channel, are homologous with the masks 5, 105, 205, etc., of the transmitter in Figure 1, are moved proportionately at the same rate or frequency, and are in like phase relationship to each other, as compared with those at the transmitter, at any given instant as will herein be further apparent.

By causing the mask or disc elements 57, 157 and 257 of the receiver to rotate synchronously in a phase coincidence, so as to be at all times in like instantaneous position relative to the raster corresponding to like elements of the disc of the transmitter, it is apparent that the light revealed

through the apertures 53, 153 and 253 in the receiver discs will correspond exactly to the light revealed to the mosaics of the various transmitting tubes, provided the receiver discs operate in the precise frequency and phaseal relationship which corresponds to the transmitter discs. Accordingly, any light viewed through the discs of the receiver beyond the receiver tube will represent adequately smooth variations in brightness of the significant locations of the light falling upon the mosaic targets of the transmitter tubes. Whatever light is permitted to pass through the apertures of the discs of the receiver is caused to fall upon and be collected by the lens elements 73, 173 and 273, and then focussed upon photo-electric tubes or cells 74, 174 and 274. Photo-electric cells produce output energy proportional to the light intensity falling thereupon, and the output energy is furthermore caused to be generated only at times when light energy falls upon the various photo-cells.

In known manner, the electron current flowing through the various photo-cells causes a voltage drop to appear across the output resistors 75, 175 and 275 (assuming the D. C. connection schematically shown herein), and this voltage is then suitably amplified in amplifiers 76, 176 and 276 and caused to energize loud speakers, or sound reproducers, 77, 177 and 277. All of the amplifiers 76, 176 and 276 and so forth, have inputs which are of brief impulse, characteristic of the corresponding instantaneous amplitudes of the signal wave forms. The output from these amplifiers, however, represents, to a close degree of approximation, the actual signal wave form. It is therefore apparent that smoothing action, so to speak, occurs within these amplifiers, that is, the time constants of the amplifiers and their output circuits, even including the sound reproducers or equivalent apparatus 77, 177 or 277, are of such a wave form that the input impulses are transformed into the output wave forms which would coincide with those applied to the input amplifiers 2, 102 and 202 of the transmitter. All of these circuits are of characteristics generally well known and are not specifically illustrated. Where desired, suitable low-pass filters may be introduced into the loud speaker circuits to restrict the actuating energy to the desired range of frequencies, say for instance, ranges below 3500 cycles. From what has been above stated, it is apparent that under such circumstances the light impulses reaching the photo-cells 74 will, to a close degree of approximation, have an envelope which closely corresponds to the original speech impressed upon the microphone 1 of the transmitter, and consequently these sounds may readily and directly be reproduced by the sound reproducer or loud speaker 77. Similarly, the light impinging upon the photo-cells of channels 2 and 3 will correspond to the light developed by the light sources 103 or 203 of channels 2 and 3 of the transmitter, and, accordingly, may be reproduced in any suitable manner.

It is, of course, further to be understood that while loud speakers or sound reproducers have been shown as the reproducing elements of channels 2 and 3, it is equally apparent that well known facsimile recorders may be energized by the output of the amplifiers 176 or 276, or that suitable recorders to produce telegraphic or code markings may replace either of these elements. It is further apparent from what has been stated above, that a 3600 cycle audio frequency com-

ponent in the telephonic speech is usually identified, as in channel 1, by at least three points or significant locations on the raster traced on the mosaic 12 of the scanning tube 13 of the transmitter, and, accordingly, three light impulses reach the photo-cell of the receiver to recreate the individual wave of the 3600-cycle speech component. These pulses are thus usually adequate to give an adequate representation of the sound wave in question and, in this connection, it should be pointed out that the lower frequency components of the sound, for instance, in the speech, would each be identified by more and more impulses or flashes of light per full wave to activate the photo-cell 74, so that if it were assumed, for instance, that three pulses of light were available on the average to represent audio frequencies of 3600 cycles, an audio frequency of only 400 cycles would be represented by 9 times as many light flashes per wave, so that the lower frequency wave herein assumed would be reproduced by at least 27 flashes on the average of light influencing the photo-cell 74. Accordingly, a very accurate plot of the wave form of the speech wave, corresponding with the lower frequency, would, of course, result, and this would give a completely acceptable and extremely accurate representation of the original wave form.

In the instance illustrated by Figures 1 and 2 where the transmission is assumed to comprise 4000 picture fields per second it is, of course, apparent that the vestigial side band transmission is used occupying slightly over 4 megacycles, which corresponds rather closely to present-day practice in television, and under the circumstances each picture or field would comprise approximately 1800 elements; and if it is assumed that the aspect ratio of the traced raster is unity, which is preferred for the purpose of a secrecy system because of the excellent utilization of the screen area of conical or cylindrical iconoscopes, kinescopes, or dissector tubes, there will be approximately 42 picture elements per scanning line. Since only three of the total of 1800 elements per picture field need be utilized even for a telephonic transmission and likely only two for a facsimile transmission and only one significant location for a telegraphic communication system, it is obvious that a great number of multiplex transmissions may be simultaneously sent and transmitted by such a system.

In a short-wave application of the methods of this invention, using a frequency band of the order of 100 or 200 kilocycles in width for the signal modulation, the corresponding raster of the luminous field may have approximately 50 to 100 elements with 4000 fields per second. Thus, there will be between approximately 7 and 10 elements per line and per column in this illustrative embodiment of the invention. This number is considered to be quite adequate for secret multiplexed communications of reduced fading characteristics.

In Figure 3, the area 301 represents for simplified illustration a luminous-field raster containing only nine scanning elements in three lines and three columns. These elements are systematically indicated in rows and columns by letters and characters such as A—I, B—I, etc. In the example herein to be described, there is assumed 4000 fields per second. The blanking period between successive scanings is assumed to be equal in length to the time of scanning a single element (that is, 10% return time). A complete mask change, which is to be understood as in-

volving the change of at least one significant location in the raster, is considered to take place once per second. In the conditions assumed by Figure 3, there are four variations of the mask for each signal or channel, thus giving a complete mask-changing cycle once every four seconds where it can be considered that the system is formed in its totality of four separate channels as follows: channel #1 is telephony and requires three significant locations; channel #2 is for facsimile transmission and requires two significant locations; channel #3 is for telegraphy and will be assumed to require only one significant location; and channel #4 is to be utilized for disguise signals which may be either speech or noise or a combination thereof and will include, for purposes of illustration, three significant locations. These values are of course merely illustrative and selected for convenience of depiction.

Referring now more particularly to Figure 3, it will be seen that channel #1 initially uses, as indicated by 302, the significant locations 306, 307 and 308, which correspond to locations A—I, B—III and C—II of the scanning raster. These selected significant locations are changed either gradually or stepwise in such fashion that, at the end of one second, the mask has the significant location shown on the raster 303, namely the areas 309, 310 and 311 which correspond to the significant points B—I, B—III, and C—II of the raster 301. One second later the mask configuration is shown by the raster 304, namely with significant locations 312, 313 and 314, and, one second later, the raster 305 with significant locations 315, 316 and 317 will represent the mask. One second thereafter, the mask has become identical with the raster 302, thus completing the mask-changing cycle according to the simple example herein given.

It is presumably not necessary to describe similarly the sequence of masking for channels #2, #3 and #4. However, it should be pointed out that, from what was mentioned hereinabove, a channel, such as channel #2 for instance, over which facsimile messages are to be transmitted, will not require the transmission of a number of impulses as great as a channel, such as channel #1, which is assumed to be used for telephony. Accordingly, with channel #2, the raster 320, for instance, may be formed from only two significant locations, designated schematically as the locations 324 and 325, which, as the raster changes following the end of one second, the new raster 321 will be changed to the significant locations 326 and 327. The other significant locations shown for the succeeding rasters 322 and 323 are again assumed, merely by way of arbitrary choice.

In a channel such as one to be used only for telegraphy, such as channel #3 for instance, the number of significant locations required, due to the lower speed and the lower frequencies for the transmission of completely intelligible signals is reduced, so that it may be assumed that a telegraphic communication could be accurately portrayed by the transmission of one significant location, such as the location 336 only, within a raster 332. The significant location 336 may then be assumed to change from raster to raster, or field to field, to occupy the positions 337, 338 and 339, which again are chosen in a purely arbitrary manner.

As far as the disguise or masking signals, intended to be schematically portrayed by channel #4, are concerned, the various rasters 340, 341, 342 and 343 may be assumed to be changed from

significant locations 344, 345 and 346 for the first raster, and these significant locations then change from raster to raster, or field to field, so that three other significant locations are occupied.

It is important to be noted, from what is hereinabove shown, that no two masks, at any given moment, show the same significant locations, and it is also to be noted that all significant locations on the raster are occupied by the totality of the masks for any given predetermined time period, such as the one-second period herein illustrated by way of example. This latter point may be more fully appreciated by noting that the shaded areas representing different locations on the raster for each of the four assumed channels, sum up to the nine significant locations identifiable in the raster 301.

The corresponding electrical regime is schematically indicated in Figure 4. Thus, in channel #1, the modulation wave of the signal during the first $\frac{1}{40000}$ of a second is shown by the wave 362. The corresponding generated impulses are 306, 307 and 308 which are cross-shaded as shown and are generated at points in the scanning raster like those shown by the numbers on Figure 3. The blanking period 166 is horizontally shaded and, for illustration, shown as having greater amplitude than the other signals. The modulation wave can be reproduced during $\frac{1}{40000}$ of a second and the blanking period occupies $\frac{1}{40000}$ of a second, thus giving together $\frac{1}{4000}$ of a second (which corresponds to the assumed 4,000 fields per second). At the line 401 a lapse of time of $\frac{39999}{40000}$ of a second is intended to occur and is shown schematically, for reasons of convenience, by the mere break in the diagram. At this particular moment, at the end of the first second, the modulation wave is supposed to be 363. In accordance with mask pattern 303, which is now active in channel #1, the signal impulses for the shown period of $\frac{1}{40000}$ of a second at the beginning of the second second is shown by the impulses 309, 310 and 311 as in Figure 3. These impulses are followed by another blanking period 367. At point 402 there is again the same lapse of time as at 401, and at the beginning of the third second the modulation wave is supposed to be 364 which is represented by the impulses 312, 313 and 314 in accordance with the action of raster pattern or mask 304 for channel #1 at the beginning of the third second. It is not necessary to continue the analysis of channel #1 beyond pointing out that at point 404 on the diagram, which represents the beginning of the fifth second, the impulse positions for the modulation wave of channel #1 existent at that time will be as indicated by the designations 306, 307 and 308, but in suitable relation to the amplitudes of the signal wave at that time.

The actions for channels #2-#4 are similarly indicated in Figure 4. It will be noted that by looking directly up the page of the drawings, held obliquely, it is readily seen that an impulse in the conjoint multiplexed signal occurs at all times save during the blanking periods. Further, the slopes or rates of change of the exemplary modulation waves for the selected types of communication will, of course, be greater for channels #1 and #4 than for channel #2, in view of the nature of the signals, and, similarly, will be greater for channel #2 than for channel #3.

In a system utilizing the secrecy principle it is, of course, apparent that some of these multiplex transmissions may be bona fide transmissions and

others may be false transmissions, and still others may be merely meaningless and erratic background or confusing disguise transmissions. Several hundred channels might ultimately be multiplexed on ultra high frequency bands by such a method comprising essentially the traffic of a good sized switchboard at a military headquarters.

Particularly in connection with systems where it is desired to use light modulation for modifying the light passing through one of the code discs of the transmitter, the brightness of the light source in question may first be adjusted to a median value of approximately half brightness. In this way the modulation wave causes the brightness of the controlled light source to vary in both directions from the median value required and thus admits of modulation for both the positive and the negative portions of the modulating wave. However, at the receiver point it is not essential to use any additional luminous bias, so to speak, on the receiving and reproducing cathode ray tubes, since the received impulses which correspond broadly to the video signals in television, but in general have no visual function in the present system, form the modulation wave in its entirety consisting of both the positive and negative portions by the envelope of their brightness curves.

It is obviously further to be understood that while masks of the type where the various apertures are spaced as desired about the periphery are shown, such masks may readily be replaced by other masks which give the instantaneous positions of the significant locations on the raster for any specific signal but are made variable with time by an arrangement analogous to the motion of the components of a vernier system relative to each other. Thus two overlaid masks may carry groups of perforations only one of which is in register in both masks for any group of such group of perforations. If these two masks are then rotated or otherwise moved relative to the other, it is seen that vernier action will change the relative position of the aperture which is in registry in both masks and therefore in momentary use. In fact, it is necessary to move one mask relative to the other only by a distance equal to the dimensions of the scanning spot to change the location of the common aperture. Accordingly, such aperture positions and consequently new codes will be readily set up and shifted either by stepwise motion or by continuous motion where suitable signals are transmitted to control the stepwise or continuous motion. Furthermore, where it is desired to disguise the appearance of the raster and of the significant locations thereon to a further degree, such as might be done by random interfering signals or, at least in part, by the injection of sufficiently elaborate and peculiar raster patterns, it is possible to produce such patterns by taking recourse to the method disclosed by C. E. Burnett in the August, 1937, issue of the "Proceedings of the Institute of Radio Engineers," where various circuits were described for studying kinescope resolution and for developing unique and unusual patterns which are described particularly on pages 1010 and 1011 of the said paper.

Where desired, there may be inserted in the output of the microphone, the facsimile scanner or the telegraphic key, a low-pass filter which will permit the passage therethrough of currents having a frequency up to the highest modulation frequency required for the corresponding form of communication but not beyond. Thus, on a telephonic communication and for the illustrative

example given in these specifications, the low-pass filter, not shown, inserted in the output of the microphone amplifier, would cut off at approximately 3600 or 3800 cycles.

On other conditions, it may be desired to make the system still more secret and where time may be allowed to decipher the message, each of the communications sent by the methods described herein may themselves be coded in any desired fashion, which would, of course, involve merely the addition of another parameter or a multiplicity of parameters into the transmission, with a correspondingly increased difficulty in decoding by unauthorized persons or in increased breakdown time for the communication.

It is also possible to shift the signal inputs between the various channels according to a pre-arranged sequence at both transmitter and receiver provided the number of significant locations utilized on each channel remains sufficient to carry or represent the modulation wave in adequate fashion. Further, mechanical or electrical arrangements for rapidly shifting from one mask to another at both the transmitter and the receiver may be used. Thus the number of available variable parameters can be controllably increased.

In the foregoing description, the masking feature has been shown as provided generally by physical instrumentalities, and the appropriate motion during the masking regime has been illustrated as being mechanically, or electro-mechanically, controlled. It should be understood particularly that such illustration and description has been made solely for the purpose of making clear one form of the invention, but the actual masking can be carried out electronically in a number of embodiments.

For instance, in a composite system, the masking can be electronically carried out, but its variation or motion is accomplished by mechanical means. Under such circumstances, for instance, an "Iconoscope" may be used in the transmitter in each channel with its photo-sensitive surface or mosaic masked, removed, or even totally absent, except at the desired significant locations.

Such a device is in the nature of a specialized "Monoscope" with a pattern already formed upon the impacted electrode. At the receiving end of such a system, the corresponding "Kinescope" or cathode ray image reproducing tube will be provided with a screen surface masked, or limited, or removed in such fashion that only the significant locations, corresponding only to the locations of the significant areas of the transmitting "Iconoscope" or "Monoscope," are caused to fluoresce under the impact of the signal controlled scanning beam.

It is possible to shift the relative positions of the "Iconoscope" or "Monoscope" target area, and the center of the area thereon scanned may readily be shifted by a systematic variation of the vertical and the horizontal deflection biases applied at the transmitter. At the receiver end of the system, the central position of the scanned area of the "Kinescope" screen would similarly be shifted in an identical frequency and phase synchronized manner by controlling the horizontal and vertical beam deflection biases applied to control the scanning beam in the cathode ray image producing tube of the receiver.

The method used for controlling these biases may be mechanical or electro-mechanical, or entirely electrical. In any case, the control of the receiver must be under the influence of the trans-

mitter at all times. In connection with the synchronization of the selector means of the receiver with the transmitter, it is of course apparent that practically any form of time indicating signal which is desired may be transmitted. Such a time indicating signal may of course be impulsive or of other types, as is well known from television practice. These synchronizing signals which will be transmitted, for instance, may be made to occur either during or at the termination of the blanking periods, such as are indicated in one form by the blanking periods 366, 367, 368, etc., in Figure 4. Further details of such forms of synchronizing are considered to be well known and unnecessary to include for a full understanding of this invention.

Still further methods of controlling the masking may be made use of with extremely high speed counter circuits, for instance, those of the type known as "Eccles-Jordan" scale of two-type counters. Broadly, the method involved is that such counter circuits may be caused to render active or inactive any given channel and any given point in the channel, or on the raster, so as to cause the different points to become significant locations, were desired. Such methods, of course, are purely electronic and have the advantage of being independent of the deflection variations and mechanical limitations. Further, they can be set to a given code relatively easily. But, like all electronic counter circuits, some disadvantages are experienced in that they become somewhat complicated through the inclusion of a great number of tubes. Other modifications, falling within the field of what has herein been disclosed, are, of course, equally obvious.

From the foregoing it is apparent that the system is capable of many and various modifications, and therefore I believe myself to be entitled to make and use any and all of such modifications as fairly fall within the spirit and scope of what is herein disclosed and as the invention is defined by the claims appended.

What I claim is:

1. In a multiplex transmitter, means to generate a plurality of separate signal energy waves, means for selecting from each such wave impulsive sections representing the instantaneous wave amplitudes at times which, on the average, occur for each wave at a frequency of the order of the highest signal modulation frequency of that wave, means for continually changing the time periods of production of the impulsive sections of each wave for codification thereof, means for intermingling in time the said selective impulsive signal sections of the separate signal energy waves, a signal transmitter means, and means for modulating the transmitter means by the thus temporally intermingled impulsive sections.

2. In a multiplex transmitter, means to generate a plurality of separate signal energy waves, means comprising electronic storage apparatus cooperatively arranged with progressively changing masking elements for selecting from each such wave at continually changing and cipherably determinable times which are different for each wave impulsive sections representing the instantaneous wave amplitudes at said times which, on the average, occur for each wave at a frequency of the order of the highest signal modulation frequency of that wave, mixer apparatus for intermingling in time the said selective impulsive signal sections of the separate signal energy waves, and means for supplying the thus

temporally intermingled impulsive sections to a transmission channel.

3. In a multiplex transmitter, means to generate a plurality of separate signal energy waves, selecting apparatus for deriving impulsive energy sections from each such wave which are different for each wave, said impulsive sections representing the instantaneous wave amplitudes at times which, on the average, occur for each wave at a frequency of the order of the highest signal modulation frequency of that wave, means for continually changing the time periods of selection of each of the impulsive sections for codification thereof, a combining circuit for intermingling the said selected impulsive signal sections in time relationship, a load circuit connection means, and means for energizing the said load circuit connection means by said intermingled impulsive sections.

4. A multiplex channel communication system comprising a plurality of signal channels upon which signals are to be applied for transmission, selector means for independently selecting and energizing each channel sequentially in a predetermined non-overlapping variable order to produce quasi recurrent detailedly variable groups of impulses, means for codedly changing the time order during which the produced impulses are allocated to each signal channel, means to generate energy impulses representative of the instantaneous amplitude of the signal in each channel during the energization time for each of said groups to produce energy impulses wherein each group frequency is of the same relative order as the highest modulation frequency produced by any of the signals, and means to limit the duration of the signal energy impulses of each individual channel to time periods fractionally related to the group period.

5. A multiplex channel communication system comprising means for deriving signal energy from each of a plurality of separate signal sources each having modulation frequencies within the range of predetermined limited values, which signals are to be applied for transmission to a plurality of signal channels, selector means for independently selecting and energizing each channel sequentially in a predetermined non-overlapping variable order to produce quasi recurrent detailedly variable groups of impulses, means for selecting impulse periods according to a substantially continually changing sequence within each of said group periods allotted to each of said channels, means to generate energy impulses representative of the instantaneous amplitude of the signal in each channel during the energization time for each of said groups to produce energy impulses wherein each group frequency is of the same relative order as the highest modulation frequency produced by any of the signals, means to limit the duration of the signal energy impulses of each individual channel to time periods fractionally related to the group period, and means to supply the said energy to a transmission channel as groups of temporally intermingled impulsive sections.

6. A multiplex channel communication system comprising means for deriving signalling energy from a plurality of sources of signal energy which are to be applied to associate its signal channels for transmission, selector means for independently selecting and energizing each channel sequentially in a predetermined non-overlapping variable order to produce quasi recurrent detailedly variable groups of impulses and for

allocating time to each of said channels in accordance with a predetermined variable schedule, means to generate energy impulses representative of the instantaneous amplitude of the signal in each channel during the energization time for each of said groups to produce energy impulses wherein each group frequency is of the same relative order as the highest modulation frequency produced by any of the signals, means to limit the duration of the signal energy impulses of each individual channel to time periods fractionally related to the group period, and means to shift the times selected within the group period in accordance with a predetermined schedule.

7. In a multiplex signal transmission system having a plurality of sources of signal energy, means for selecting signal outputs from the several sources at predetermined time periods, said signal outputs representing the instantaneous wave amplitude of the signal outputs at the said selection time periods, means for codifying the selected signal outputs at a frequency closely related to the order of the highest signal modulation frequency developed from each source, electronic means for generating signal energy impulses under the control of the said codification means, a signal mixing channel for temporally commingling the energy from all of the electronic means, and a transmitter means for transmitting the combined and intermingled energies.

8. In a multiplex energy transmission system a plurality of sources of signal energy, codification and selector means for deriving impulsive energy sections from the several sources at predetermined time periods where the derived energy represents the instantaneous wave amplitude of the signal energy at the said time selection period and which codification occurs at a frequency closely related to the order of the highest signal modulation frequency developed from each source, means including a storage type cathode ray device for generating signal energy impulses under the control of the said codification and selector means, and means for supplying the generated energy to a communication channel.

9. A multiplex communication system comprising a plurality of separate sources of signal wave energy each having frequencies in a range between different predetermined minimum values and predetermined maximum values for each signal source, a plurality of electronic means to develop signal energy, the number of said electronic means corresponding to the number of signal energy sources, means for selecting from each source of signals at predetermined time periods impulsive sections which are different for each source of signals and which each represent the instantaneous signal energy amplitude at the time when the selection is made, means for substantially continually and cipherably changing the time at which the selected impulsive signal portions are chosen for codifying the group of impulses into substantially non-repeating series, means for energizing each electronic means under the control of the developed impulsive signal energy of the separate sources, means for causing the selection to occur at a frequency of the order of the highest frequency modulation of the separate sources, means for developing output energy from each electronic device, means for combining the output energy of all of said electronic means, and means for supplying the combined energy to a communication channel.

10. A multiplex communication system com-

prising a plurality of separate sources of signal wave energy each having frequencies in a range between a predetermined minimum value and a predetermined maximum value, a plurality of electronic means to develop signal energy, the number of said electronic means corresponding to the number of signal energy sources, a selector means for independently energizing each electronic means under the control of a separate one only of the developed signal energies of the separate sources by selecting from each source of signal energy at predetermined times impulsive sections which are different for each source of signal energy and which each represent the instantaneous signal energy amplitude at the selected times, means for causing the impulsive energy selection periods to occur at a group frequency of the order of the highest frequency modulation of the separate sources, means to shift, according to a predetermined schedule, the times of selection of impulsive energy from each signal source in each group period, means to derive output energy from each electronic means, means for mixing the output energies of all of said electronic means, and means for supplying the combined energy to a communication channel.

11. A multiple channel communication system comprising a plurality of signal channels upon which signals are adapted to be applied for transmission, selector means for independently selecting signal outputs from each signal channel cryptographic means for sequentially allocating time to each selection of signals in a non-overlapping variable and continually changing order to produce quasi recurrent and detailedly variable groups of signals, an electronic switching means to generate signal energy impulses representative of the instantaneous amplitude of the signal in each channel during the energization time for each of said groups to produce signal energy impulses where the group frequency is of the same relative order at the highest modulation frequency of any signal in any channel, means for combining the several developed signals in timed relationship, and means for supplying the combined signal to a transmission channel.

12. A multiple channel communication system comprising a plurality of sources of signals from which separate signals are adapted to be derived for transmission, means to convert each of the developed signals into independent radiations of light energy whose intensities are each instantaneously proportional to the envelope of a related signal energy wave, a light sensitive storage type scanning tube positioned to receive the light energy produced by the signals of each signal channel, said scanning tubes each having a mosaic electrode upon which electrostatic charges are adapted to be developed under the application of light from said light sources, means for developing a cathode ray beam within each scanning tube, means for scanning the mosaic electrode of each tube by said scanning beam to develop output signal energy from said tube with the output proportional to the charge magnitude, obturating means interposed between each of the said light sources and the related mosaic for eclipsing and revealing the light developed to the mosaic according to a predetermined variable pattern, means to vary the instants of light eclipsing and light revealing periods for each channel from time to time according to a prestablished schedule while maintaining the number of eclipsing and revealing periods constant over predetermined unit time periods, means to relate

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the scanning by the developed scanning beam to predetermined points of light revealed to the mosaic at instantaneous periods of time, means to combine the output signals from all of the storage type tubes, and means to supply the combined energies to a transmission channel.

13. A multiple channel communication system comprising a plurality of signal channels upon each of which separate signals are adapted to be applied for transmission, means to convert developed signals into light energy whose intensity is instantaneously proportional to the envelope of the signal wave, a light sensitive storage type scanning tube associated with each signal channel and having a mosaic electrode adapted to receive the light from said light source, means for developing a cathode ray beam within each scanning tube, means for scanning the mosaic electrode of each tube by said scanning beam to develop signal energy output from the said tube, obturating means interposed between the said light source and the mosaic for eclipsing and revealing the light developed according to a predetermined variable pattern, means to relate the scanning by the developed scanning beam to predetermined points of light revealed to the mosaic at instantaneous periods of time, means to combine the output signals from all of the storage type tubes, and means to supply the combined energies to a transmission channel.

14. Signal receiving apparatus comprising a receiving device to receive signal energy where the signal includes temporally intermingled impulsive sections and is representative of a plurality of signals grouped into a plurality of non-overlapping variable order series of quasi recurrent impulses, electronic apparatus responsive to the received signals to convert said signal energy into controllably transferrable energy, selector means for selecting from the controllably transferrable energy a series of non-overlapping variable time-spaced impulses, and deciphering means operable synchronously and simultaneously with the means for temporally intermingling the signals at the transmission point so as to convert the said impulses into energy of a form substantially corresponding to that from which the signals were initiated.

15. Signal receiving apparatus comprising a receiving device to receive signal energy from a signal communication channel wherein the signal includes temporally intermingled impulsive sections and is representative of a plurality of intermingled signals grouped into a plurality of non-overlapping variable order series of quasi recurrent impulses, electronic apparatus including a cathode ray tube for each signal channel responsive to the received signals to convert said signal energy into controllably transferrable energy, selector means for selecting from the controllably transferrable energy a series of non-overlapping time-spaced impulses, and decodifying means to convert the said impulses into output signals which continually and systematically vary substantially to correspond to the form in which the signals were initiated.

16. Signal receiving apparatus comprising a receiver instrumentality to receive signal energy from a communication channel where the signal energy is representative of a plurality of signals grouped into a plurality of non-overlapping variable order series of quasi recurrent impulses, electronic apparatus responsive to the said signals to convert the received signal energy into

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electrical energy impulses, a plurality of electronic devices corresponding in number to the number of signal messages received for converting the produced electrical energy into light energy, selector means for selecting from the developed light energy a series of non-overlapping variable time-spaced light impulses, and light responsive apparatus to convert the selected light energy into energy of a form substantially corresponding to that from which the received signals were initiated.

17. Signal receiving apparatus comprising a receiver instrumentality to receive signal energy from a communication channel where the signal energy is representative of a plurality of signals grouped into a plurality of non-overlapping variable order series of quasi recurrent impulses, electronic apparatus responsive to the said signals to convert the received signal energy into electrical energy impulses, a plurality of cathode ray devices corresponding in number to the number of signal messages received, means for energizing the cathode ray devices under the control of the received signals for converting the produced electrical energy into light energy, selector means for selecting from the developed light energy a series of non-overlapping variable time-spaced light impulses, and light responsive apparatus to convert the selected light energy into energy of a form substantially corresponding to that from which the received signals were initiated.

18. Signal receiving apparatus comprising receiver means for receiving signal energy representative of a plurality of signals grouped into a plurality of non-overlapping variable order series of quasi recurrent impulses, a plurality of cathode ray tubes of a number coinciding with the number of separate signals received, each of said cathode ray tubes having included therein means for developing a cathode ray beam and a target upon which the developed cathode ray beam is adapted to produce light upon impact, beam deflecting circuits associated with each of said cathode ray tubes to cause the developed beam normally to trace a predetermined raster pattern upon the tube to produce light energy, means to control the intensity of the beam in its production of the raster under the influence of the received signals, selector means associated with the said cathode ray tubes to reveal the produced light upon the raster at predetermined time periods, and light responsive means to convert the revealed light into energy of substantially the same form as that from which the signals were originated.

19. The apparatus claimed in claim 18 comprising, in addition, means to adjust the selector means according to a predetermined time cycle, whereby a progressive shifting of revealed areas of the tube raster is provided.

20. The apparatus claimed in claim 18 wherein the selector means consists of a rotary obturating element having included therein a plurality of apertures spaced in predetermined position thereon, means for rotating the selector means relative to the raster pattern traced upon the cathode ray tube, and means for revealing the light of the raster to the light responsive means only at time periods where there is coincidence between the impacted area of the raster and an aperture in the selector.

21. A multiplex communication system comprising means at the transmitter to generate a plurality of separate signal energy waves, means

at the transmitter for converting each signal energy wave into a series of impulsive sections representing at each instant the amplitude of the signal energy wave, selector means synchronously operating at each of the transmitter and the receiver for translating the signal energy into a discontinuous sequence and for converting the discontinuous sequence into the effect of a substantially continuous sequence, codifying means for continually and cryptically intermingling the series of selected impulse signal sections for transmission in timed relationship, means to transmit the energy over a communication channel to receiving points, and means at the receiver including the synchronously operating selector and decodifying apparatus to produce, under the influence of received signals, energy of a form substantially corresponding to that of the signal energy at the transmitter.

22. In a multiplex transmitter, means to generate a plurality of separate signal energy waves, selecting means for obtaining from each such wave impulsive sections representing the instantaneous wave amplitudes at said selection times which, on the average, occur for each wave at a frequency of the order of the highest signal modulation frequency of that wave, codifying means for continually changing the selection at substantially continually variable and non-repeating time periods which are different for each wave, mixer apparatus for intermingling in time the said selective impulse signal sections of the separate signal energy waves, means for supplying the thus intermingled impulsive sections to a transmission channel, signal receiving means responsive to the intermingled impulsive sections appearing in the transmission channel, electronic means responsive to the received signals to convert the said signal energy into controlledly transferrable energy, signal selector and decodifying means synchronously operating with the selecting means of the transmitter for selecting from the controlledly transferrable energy impulsive sections representing the instantaneous wave amplitudes of the signals initiating the separate signals at the transmitter so that there is produced in the receiver controlledly transferrable energy occurring in a series of non-overlapping variably time-spaced impulses, and means to convert each of the groups of the said produced energy impulses into a form of energy substantially corresponding to that from which the individual signals of the plurality of separate signal energy waves of the transmitter were generated.

23. In a multiplex transmitter, means to generate a plurality of separate signal energy waves, means comprising electronic apparatus for selecting from each such wave at variably predetermined times which are different for each wave impulse sections representing the instantaneous wave amplitudes at said times which, on the average, occur for each wave at a frequency of the order of the highest signal modulation frequency of that wave, mixer apparatus for commingling such impulsive signal sections, means for supplying the thus intermingled frequencies to a transmission channel, signal receiving means responsive to the intermingled frequencies appearing in the transmission channel, electronic means including a cathode ray device responsive to the received signals to convert the said signal energy into radiant energy impulses, selector means synchronously operating with the selecting apparatus of the transmitter for selecting

from the produced radiant energy impulsive sections representing the instantaneous wave amplitudes of the signals initiating the separate signals at the transmitter so that there is produced in the receiver controlledly transferrable energy occurring in a series of non-overlapping variably time-spaced impulses, and means to convert each of the group of the said produced energy impulses into a form of energy substantially corresponding to that from which the individual signals of the plurality of separate signal energy waves of the transmitter were generated.

24. A multiplex channel communication system comprising a plurality of signal channels upon which signals are to be applied for transmission, selector and cryptographic means for independently developing from each channel a sequentially predetermined non-overlapping order to produce quasi recurrent detailedly variable groups of impulses which are progressively changed continually with time, means to generate impulsive energy sections representative of the instantaneous amplitude of the signal in each channel during the energization time for each of said groups to produce energy impulses wherein each group frequency is of the same relative order as the highest modulation frequency produced by any of the signals, means to limit the duration of the signal energy impulses of each individual channel to time periods fractionally related to the group period, means to supply the produced signal energy impulses to a transmission channel for transmission to receiving points, means at the receiving points for receiving the transmitted signals, electronic apparatus at the receiving point responsive to the received signals for converting the said signals into controlledly transferrable energy, selector means at the receiving point for selecting from the controlledly transferrable energy independent series of non-overlapping variable order impulses, means for operating the receiver selector means synchronously with the transmitter selector means, and means to convert each of the groups of the produced impulses into energy of a form substantially corresponding to that from which the individual signals were initiated at the transmitting point.

25. A multiplex channel communication system comprising a plurality of signal channels upon which signals are to be applied for transmission, selector means for independently selecting and energizing each channel sequentially in a predetermined non-overlapping variable order to produce quasi recurrent detailedly variable groups of impulses, means to generate energy impulses representative of the instantaneous amplitude of the signal in each channel during the energization time for each of said groups to produce energy impulses wherein each group frequency is of the same relative order as the highest modulation frequency produced by any of the signals, means to limit the duration of the signal energy impulses of each individual channel to time periods fractionally related to the group period, means to supply the produced signal energy impulses to a transmission channel for transmission to receiving points, means at the receiving points for receiving the transmitted signals, electronic apparatus including a cathode ray device at the receiving point responsive to the received signals for converting the said signals into light energy, selector means at the receiving point for selecting from the produced light energy independent series of non-

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overlapping variable order impulses, means for operating the receiver selector means synchronously with the transmitter selector means, and means to convert the produced light energy impulses into energy of a wave form substantially corresponding to that from which at least one of the transmitted signals was initiated at the transmitting point.

26. In a multiplex transmitter for transmitting a plurality of separate signal energy waves, means for selecting from each of the signal energy waves at predetermined time periods of minute duration which are different for each wave a single impulsive section representing the instantaneous wave amplitudes at said times which, on the average, occur for each wave at a frequency of the order of the highest signal modulation frequency of the wave from which the selection is made, codifying means for intermingling the said selective impulsive signal sections of the separate signal energy waves in time relationship and in a substantially progressively and continually changing order, and means for

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supplying the thus temporally intermingled impulsive sections of the plurality of separate signal energy waves to a transmission channel for transmission to suitable receiving points.

27. In a multiplex transmitter having supplied thereto a plurality of separate signal energy waves, means comprising electronic apparatus for selecting from each of the plurality of separate signal energy waves at variably predetermined time periods which are different for each wave single impulsive sections representing at the instant of selection the wave amplitude, said impulsive sections being selected, on the average, at frequencies of the order of the highest signal modulation frequency of the wave, codifying means for intermingling the said selected impulsive signal sections of the separate signal energy waves in selected timed orders and sequences which are substantially continually changing, and means for supplying the thus temporally intermingled impulse sections to a transmission channel.

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