

Sept. 10, 1946.

R. LORENZEN ET AL

2,407,308

METHOD AND APPARATUS FOR SECRET SIGNALING

Filed Jan. 16, 1941

5 Sheets-Sheet 1

Fig. 1A

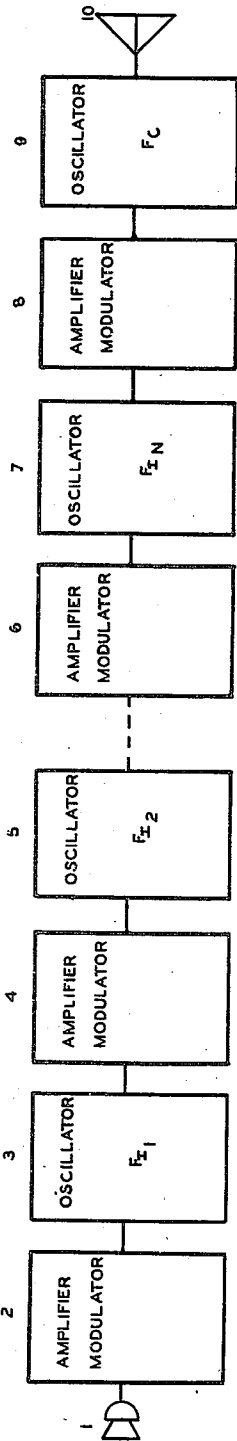
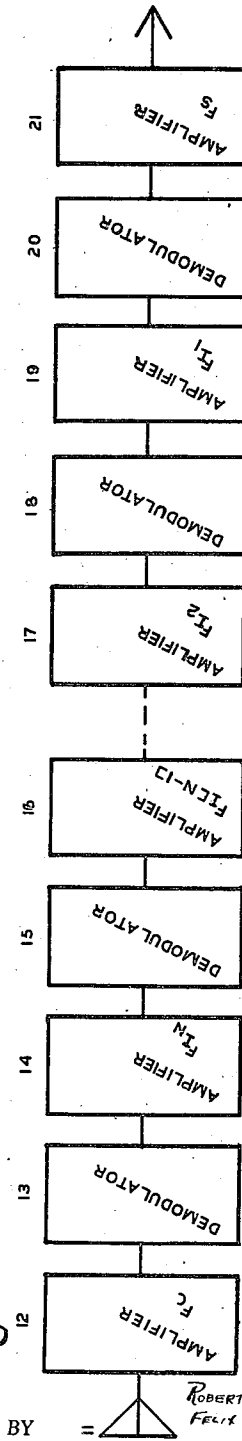


Fig. 1B



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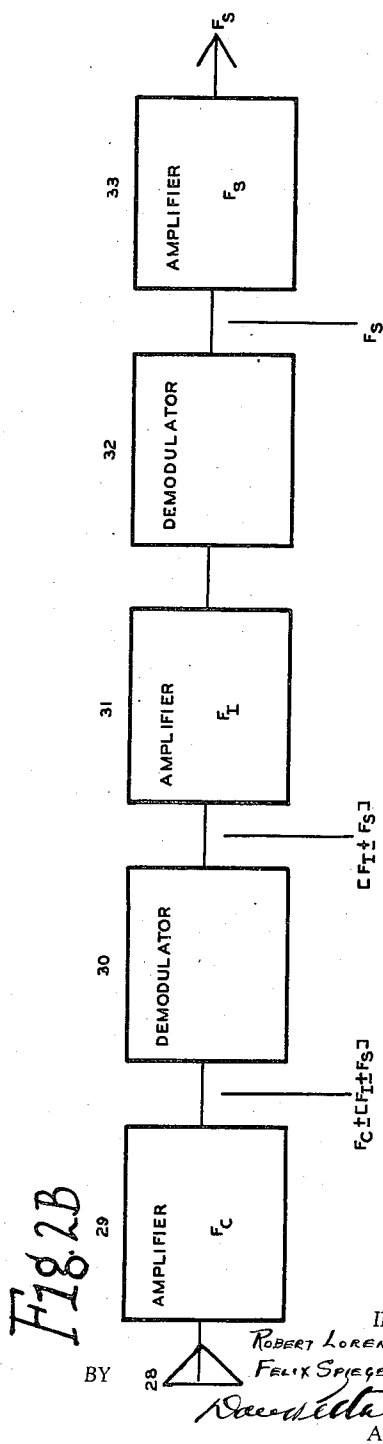
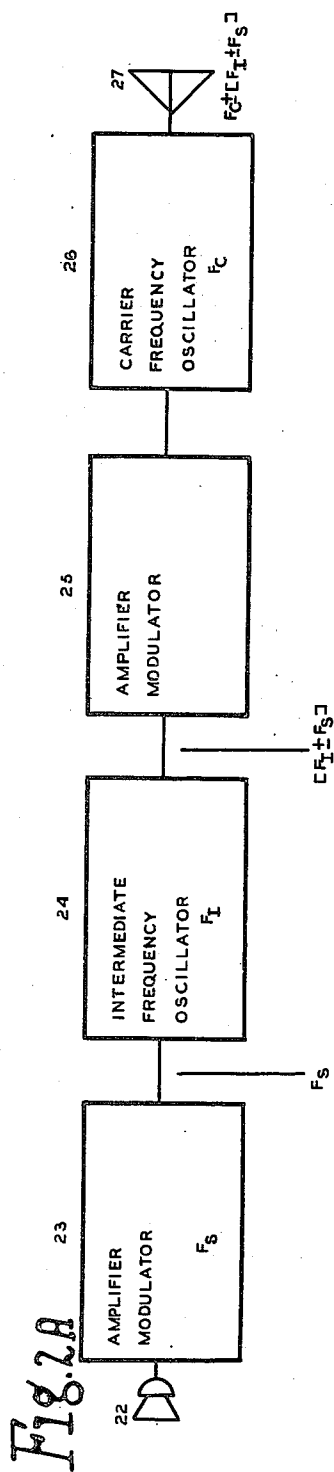
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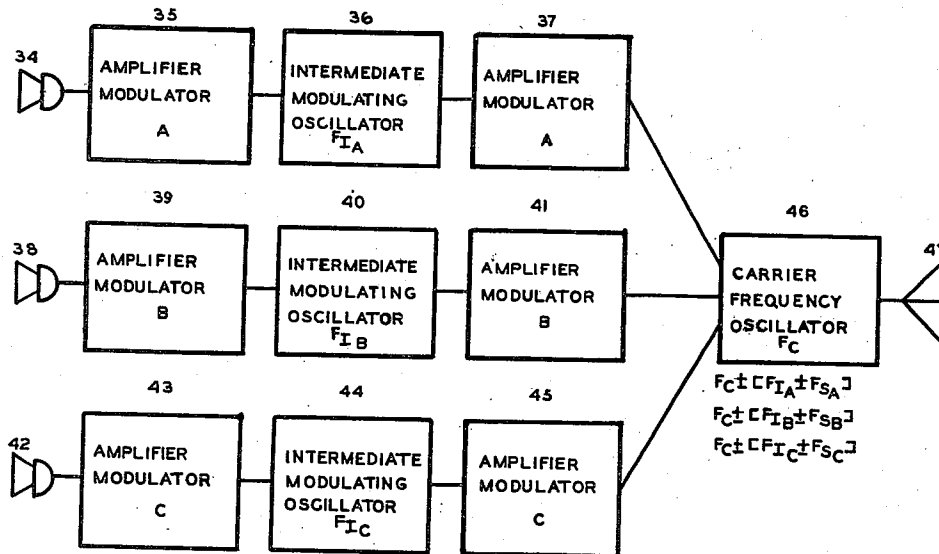


Fig. 3A

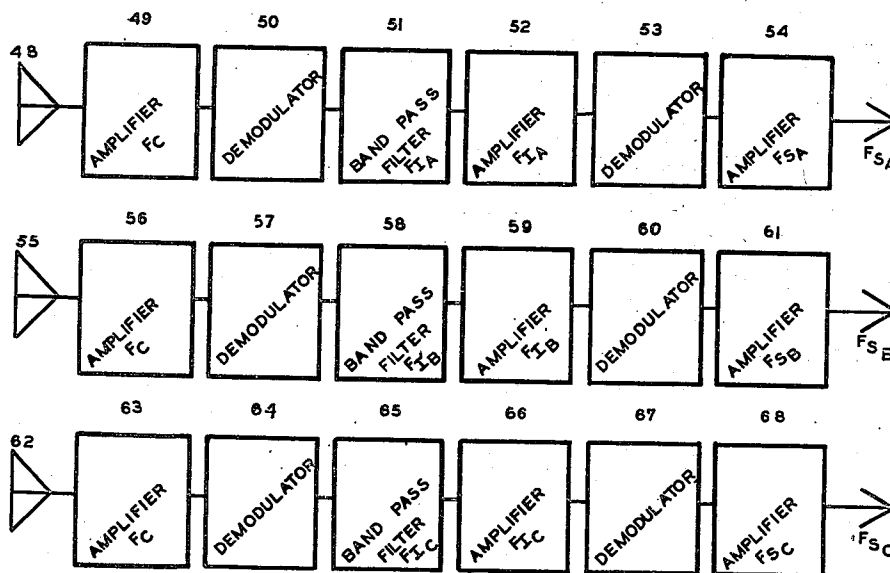


Fig. 3B

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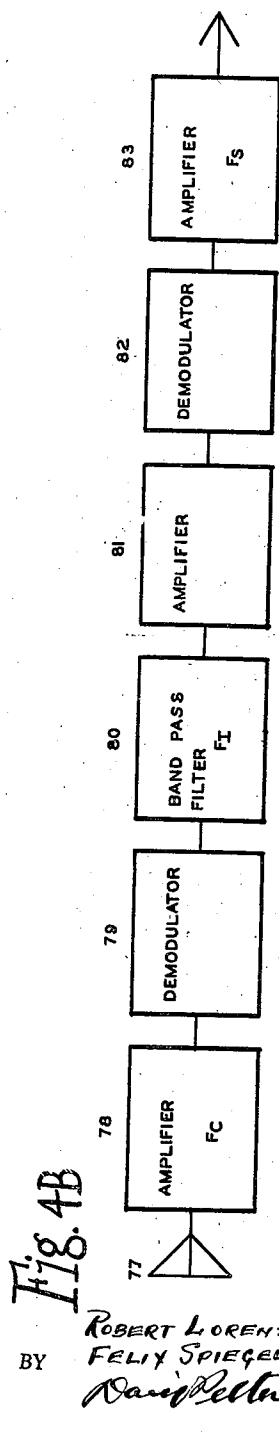
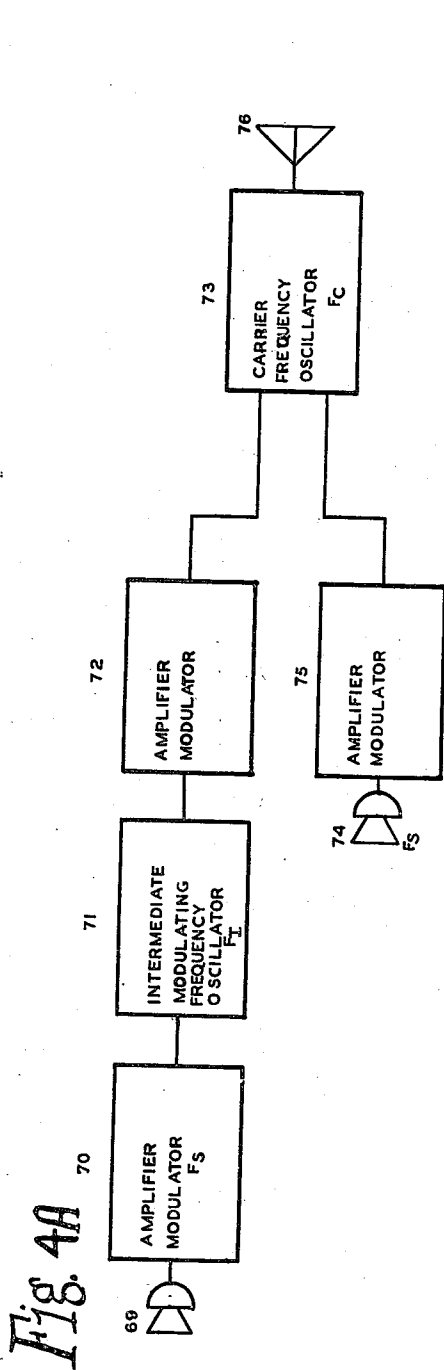
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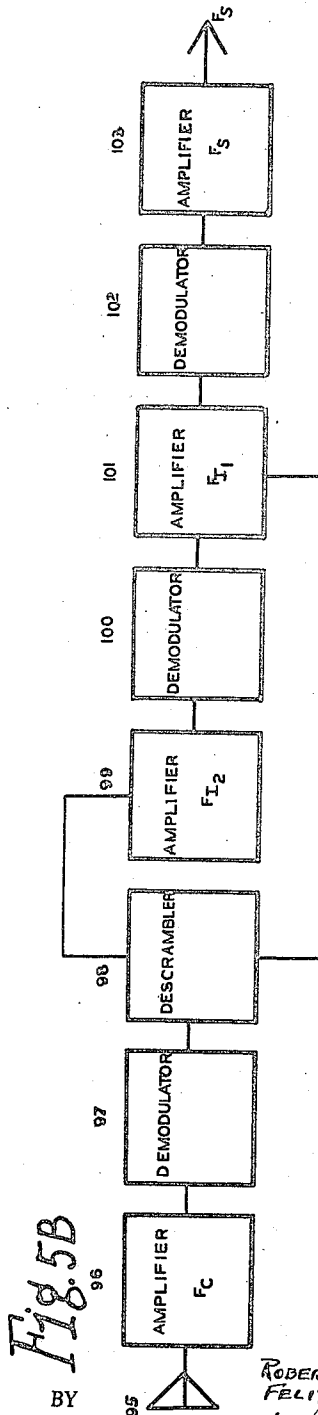
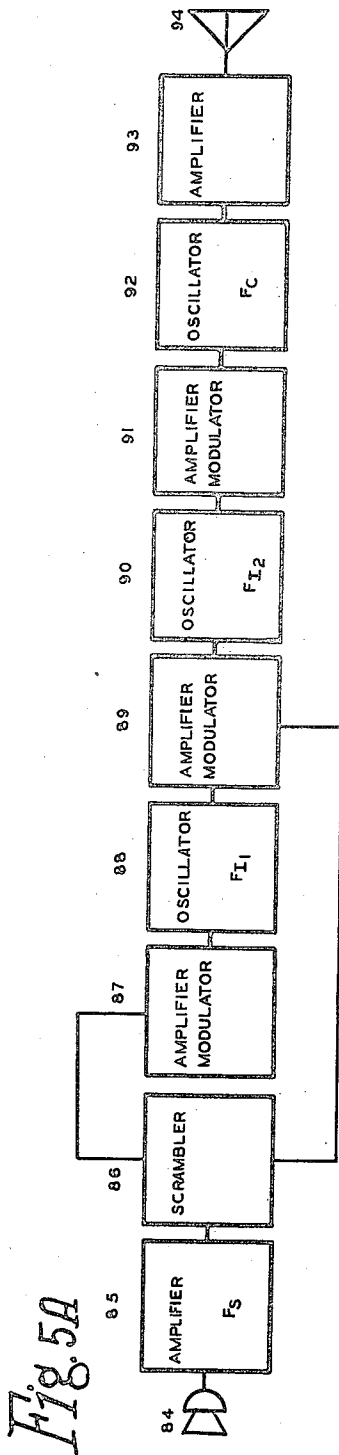
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METHOD AND APPARATUS FOR SECRET SIGNALING

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2 Claims. (Cl. 179—1.5)

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The present invention relates to methods and apparatus for secret signaling.

The disadvantages of present existing communication systems are: (1) the possibility of blanketing-out or jamming the audiofrequency signal modulation by a third party, thereby disrupting communication service, and (2) the possibility of a third party intercepting signals that are desired to be kept secret.

The need for new communication systems is to obviate the above mentioned disadvantages and shortcomings of present systems, for the present invention introduces a multiplicity of communication systems which can either be used alternately or in conjunction, whenever the need arises. Thus, if by remote chance one of the hereinafter mentioned systems should fall into the hands of a third party so that this third party discovers the technique employed in the new system, it is merely necessary to adopt one of the manifold alternate systems.

The possibility of employing a multiplicity of alternative communication systems is obviously of considerably greater advantage than would be the case if the number of communication systems were limited to three as at present, for if it is assumed that any one of the multiplicity of the new systems is employed, then any means for blanketing-out or jamming the conventional existing transmissions will leave the new system unaffected, despite the fact that the means employed by the third party have effectively paralyzed the conventional existing means of communication. By the employment of the new systems, hereinafter to be described, the desired communication is enabled to be continued without interruption or interference.

One of the objects of this invention is to show how an infinitely large number of different communication systems are made available instead of merely the present limited number of available systems, namely, three.

Another object of the present invention is to show how uninterrupted communication may be maintained between two parties, despite the fact that a third party may, by the process of creating artificial noise and interference, cause the jamming of conventional communication systems so as to result in a complete disruption of communication service.

Still another object of this invention shows how it is possible to maintain uninterrupted communication between two parties even though some third party has discovered the principle of

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operation of one of the manifold of communication systems herein described.

One of the principal objects of the present invention is the application of the new principle to radio communication systems.

Another object of the invention is to show the application of the new principle to supersonic signaling, i. e., its application to communication systems which employ ultra-audible waves in a material medium as a means of communication.

Still another object of the present invention is to show how the herein described principle may be applied to communication systems which employ electromagnetic waves of a non-radio character as the carrier of the transmitted signals. Typical of such systems are those which utilize a light-beam as the means of transmission, or infra-red rays as the carrier of the transmitted signals, or ultra-violet as the signal carrier.

Another object of the invention is to show the application of the present system to those communication systems which employ wired wireless, i. e., where the signals are transmitted along either a conductor or a dielectric guide.

Another principal object of the present invention is the simultaneous transmission of different signals when but a single carrier frequency is employed.

Still another object of the invention is the simultaneous transmission of the desired signals and false signals, so that, although only the desired signals are received by the two parties between whom communication is established, any outside third party receives only the false signals and is thereby deceived as to the real content of the transmitted messages.

Still another object of the invention concerns itself with a new method of scrambling signals so as to make the interception of transmitted messages impossible to any outside third party who is not informed both as to the method of scrambling and the principles underlying these new communication systems.

The present invention will be described with reference to the accompanying drawings, but it will be realized that other applications and embodiments lie within the scope of the invention, for it should be understood that the scope of the present invention is so broad that only the general features are herein disclosed. Subsequent patent applications will describe the various specific embodiments and give in more concrete form the manifold applications and modifications of the principle herein described.

Fig. 1A represents the generalized set-up of a

transmitter which employs multiple modulation, while Fig. 1B represents a receiver which is capable of receiving such multiply-modulated transmissions.

Fig. 2A represents a transmitter wherein only one intermediate-modulating-frequency is employed, while Fig. 2B represents a receiver which is capable of receiving such a doubly-modulated transmission.

Fig. 3A represents a transmitter which is capable of simultaneously transmitting a number of different signals on a single carrier frequency, while Fig. 3B represents a receiver for such transmissions.

Fig. 4A represents a transmitter which is capable of transmitting both the desired as well as false signals, while Fig. 4B represents a receiver for receiving the desired signals.

Fig. 5A represents a transmitter employing triple modulation in which the signals are scrambled in such a manner that part of the scrambled signals modulate the first intermediate-modulating frequency and the other part of the scrambled signals modulate the second intermediate-modulating frequency. Fig. 5B represents a receiver for the reception of such scrambled transmission.

In the conventional communications system, at the transmitter a signal frequency modulates a carrier frequency, this latter being propagated through space, this, in turn, is received at a receiver, where, after suitable demodulation, the original signal frequency is obtained. As will hereinafter be disclosed, the present conventional method is but a very special case of the new general principle, which concerns itself with means and methods for producing and utilizing superimposed and multiple modulation of signals. In order to reduce the complexity of description, the principles underlying multiple modulation will first be discussed. Again, although later descriptions will utilize various combinations of amplitude, frequency, and phase modulation, further simplicity of description will at this time be secured by making the two following assumptions: (1) amplitude modulation is employed throughout, and (2) spurious modulation products are disregarded. In addition, although it will shortly be seen that the new principle is applicable to other than its employment in radio transmission and reception, the preliminary description will restrict itself to its application to radio communication.

Referring to Fig. 1A, which represents in block diagram form a transmitter employing multiple modulation, 1 represents either a source or pickup of the signals f_s . Signals from 1 go to the amplifier-modulator 2, the output of which is employed to modulate an oscillator 3 which is oscillating at the frequency f_n . Oscillator 3, which shall be called the first intermediate-frequency oscillator produces an oscillation which is some multiple, not necessarily integral, of the frequency of the signal frequency. If the signal is comprised of a band of frequencies, as would be the case when the signal consists of speech or music, the first intermediate frequency oscillator will have a frequency which is some multiple of the highest signal frequency. The output of intermediate frequency oscillator 3 feeds into the input of the amplifier-modulator 4, where the signal-modulated f_n frequency is amplified and then employed to modulate the second intermediate frequency oscillator 5, whose oscillation frequency f_{I_2} is some multiple of that of the

first intermediate oscillation frequency f_n . The foregoing process continues, as indicated by the dashed lines, until the multiply-modulated resulting signal is fed into the amplifier-modulator 6, the output of which is employed to modulate the n th intermediate frequency oscillator 7, whose oscillation frequency f_n is some multiple of the $(n-1)$ th intermediate frequency oscillator. The output of the n th intermediate frequency oscillator 7 goes to an amplifier-modulator 8, which is employed to modulate the carrier frequency oscillator 9. The modulated output of the carrier frequency oscillator 9 is then either directly, or after further amplification, fed into a radiator 10, which in the case of radio transmission would consist of an antenna system.

At the receiving station, as illustrated in Fig. 1B, the multiply-modulated signal is picked up by antenna 11 which is connected to amplifier 12. This amplifier 12 is capable of amplifying the carrier frequency and should have an amplifying bandwidth capable of amplifying the accompanying multiply-modulated signal. After suitable amplification by amplifier 12 the signal is fed to demodulator 13, which removes the carrier frequency f_c and leaves only the multiply-modulated signal f_n . The output of demodulator 13 goes to amplifier 14, which amplifies the signal at frequency f_n , and which possesses a bandwidth capable of amplifying the accompanying multiple modulation. The output of amplifier 14 goes to demodulator 15 which removes the n th intermediate modulating frequency, so that the output of demodulator 15 consists of the multiply-modulated $(n-1)$ th intermediate modulating frequency. This signal is fed to amplifier 16, which amplifies at the $(n-1)$ th intermediate modulating frequency and which has an amplifying bandwidth suitable for amplifying the accompanying multiply-modulated signal. This process is repeated, as indicated by the dashed lines, until only the multiply-modulated second intermediate frequency remains, this being amplified by amplifier 17, after which it is fed to demodulator 18. Demodulator 18 removes the second intermediate-modulating frequency, thereby leaving only the signal-modulated first intermediate-modulating frequency. The output of demodulator 18 goes to amplifier 19, which is capable of amplifying the first intermediate-modulating frequency and its accompanying signal modulations. The output of amplifier 19 goes to demodulator 20 which removes the first intermediate-modulating frequency and leaves only the original signal frequency. The output of demodulator 20 then goes to amplifier 21 which amplifies the original signal frequency. After sufficient amplification the original signal frequency may be taken from the output of amplifier 21 to actuate any suitable device, such as, for example a loudspeaker or telephone receiver.

Having explained the general principle of multiple modulation, there will now be considered a simple example of multiple modulation, namely, when only a single intermediate modulating frequency is employed. The symbol f_s will be used to designate the signal frequency, which, for convenience, may consist of those frequencies of which music or speech sounds are comprised. The symbol f_i will be used to represent the intermediate modulating frequency, which, in this case, we may assume to be a fixed frequency of 100,000 cycles. Similarly, the symbol f_c shall be used to designate the carrier frequency, which, in this

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case, should preferably be greater than one megacycle.

Referring to Fig. 2A, which shows a block diagram of the transmitter, the microphone 22 picks up the speech sounds which it is desired to transmit. The microphone connects to the amplifier-modulator 23, which first suitably amplifies the signal frequency and then is employed to modulate the intermediate-modulating frequency f_i produced by the intermediate-frequency oscillator 24. In consequence, the resulting output is comprised of the intermediate modulating frequency f_i in conjunction with the sum and difference sideband frequencies due to the signal frequency f_s . This resulting output then goes to the amplifier-modulator 25, where, after suitable amplification, it is used to modulate the carrier frequency oscillator 26 which is oscillating at a frequency f_c . As a result there is obtained an output which is comprised of the carrier frequency in combination with the sum and difference sideband frequencies due to the complex of the signal frequency and the intermediate-modulating frequency. After suitable amplification, if desired, the doubly modulated carrier is radiated into space by means of the antenna 27.

At the receiver, as shown in Fig. 2B, the doubly-modulated carrier impinges upon antenna 28 and is then amplified by amplifier 29. The output of amplifier 29 consists of the doubly-modulated carrier frequency and this is fed to the demodulator 30 which removes the carrier frequency and leaves only the signal-modulated intermediate-modulating frequency. This, in turn, is amplified by amplifier 31 and is then fed to the demodulator 32 which removes the intermediate-modulating frequency and leaves only the original signal frequency f_s . After suitable amplification by means of amplifier 33 the resulting signal frequency may be used to actuate a loudspeaker.

It is therefore seen that even when using such a simple set-up as the one just described, a considerable degree of secrecy of message communication may be obtained. For, if in the attempt to intercept a message from the transmitter of Fig. 2B, an ordinary receiver were tuned to the carrier frequency f_c , nothing would be heard for the resulting demodulated frequency would be the intermediate-modulating frequency f_i , and since this was chosen to be about 100,000 cycles it is beyond the audible frequency range and would not, therefore, be heard. Only a receiver which doubly demodulates the doubly-modulated carrier would be capable of properly receiving the transmitted message.

In a similar manner, two intermediate-modulating frequencies may be employed to obtain a triply-modulated carrier, thereby making it still more difficult for the uninformed to intercept the transmitted message. It is unnecessary to describe such a system at this point, as this type will later be used when the description of superimposed modulation as used in conjunction with multiple modulation is described.

At this point it will be well to examine the number of different communication systems which are possible as a result of the employment of multiple modulation.

When only one intermediate modulating frequency is employed it will be seen that: (1) The signals may modulate the intermediate-modulating frequency by means either of amplitude, frequency, or phase modulation, and (2) the intermediate-modulating frequency can modulate the

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carrier frequency by either amplitude, frequency, or phase modulation. Under these conditions the number of permutations is nine, so that nine different communication systems result. This may be seen from the following table.

Method by which signal modulates intermediate-modulating frequency	Method by which intermediate-modulating frequency modulates the carrier frequency
Amplitude	Amplitude
Do.	Frequency
Do.	Phase
Frequency	Amplitude
Do.	Frequency
Do.	Phase
Phase	Amplitude
Do.	Frequency
Do.	Phase

In a similar manner, when two intermediate modulating frequencies are employed, it will be seen that: (1) The signals may either amplitude-modulate, frequency-modulate, or phase-modulate the first intermediate-modulating frequency; (2) the first intermediate modulating frequency may either amplitude-modulate, frequency-modulate, or phase-modulate the second intermediate-modulating frequency, and (3) the second intermediate-modulating frequency may either amplitude-modulate, frequency-modulate, or phase-modulate the carrier frequency. Accordingly, since the number of permutations is twenty-seven, it is seen that twenty-seven different possible communication systems are possible when two intermediate modulating frequencies are utilized.

Similarly, when three intermediate-modulating frequencies are employed, the resulting number of different communication systems is eighty-one.

In general, when n intermediate-modulating frequencies are employed the resulting number of different communication systems is $3^{(n+1)}$.

Since all of these different systems may be simultaneously employed, the total number N of different communication systems, and including the conventional single modulation, which result is given by the expression

$$N = 3^1 + 3^2 + 3^3 + 3^4 \dots 3^{(n+1)}$$

where n represents the number of intermediate-modulating frequencies. It is readily seen, therefore, that the number of different communication systems which become available increases very rapidly as the number of intermediate-modulating frequencies is increased. The rapidity with which different communication systems become available is shown by the following chart.

Number of intermediate-modulating frequencies	Number of available communication systems
0	3
1	12
2	39
3	120
4	363
5	1,092
ad infinitum	ad infinitum

This enormous number of possible communication systems is to be contrasted with the small number, namely three, which have hitherto been available.

It is well to remember, however, that while the

employment of an ever-increasing number of intermediate-modulating frequencies, and consequently an ever-increasing number of different communication systems, is theoretically capable of indefinite extension, there are, nevertheless, practical limitations which mitigate against such indefinite extension. This practical limitation is dependent upon the amount of frequency band-width available, for, as the number of intermediate modulating frequencies are increased, so, likewise, is the necessity for an increased frequency band-width. Consequently, as more and more intermediate-modulating frequencies are employed the higher must the frequency of the carrier become in order to maintain the frequency band-width required at some given percentage of the carrier frequency.

The intermediate-modulating frequency f_i is not restricted to any single frequency and may assume various values, such as f_{i1} , f_{i2} , f_{i3} , etc. Thus, for any given carrier frequency f_c , the same (or different) station may employ the intermediate-modulating frequencies f_{i1} , f_{i2} , f_{i3} , etc., to modulate the carrier. Since, in this event, band-pass filters would be employed to prevent any interaction or interference of the various intermediate-modulating frequencies, it is seen that the simultaneous transmission of diverse signals may be transmitted and received although but a single given carrier frequency is employed.

A typical example of a transmitter which enables the simultaneous transmission of different signals when but a single carrier frequency is employed is illustrated in Fig. 3A. For simplicity of description only one intermediate-modulating frequency is used, as the extension of the method so as to employ two or more intermediate-modulating frequencies is obvious. The microphone 34 picks up the speech signals f_{sa} at point A and these are fed to the amplifier-modulator 35. The intermediate-modulating oscillator 36, whose oscillation frequency f_{ia} may, for example, be 100,000 cycles, is modulated by amplifier-modulator 35. This modulated output then goes to amplifier-modulator 37, which, in turn, modulates the carrier frequency oscillator 46. The doubly-modulated wave is then fed into the antenna 47.

In a similar manner, microphone 38 picks up the speech signals f_{sb} at point B and are then suitably amplified by means of amplifier-modulator 39. The intermediate-modulating oscillator has a frequency f_{ib} which is different from that of intermediate-modulating oscillator 36, and it may be assumed, for example, that the intermediate-modulating frequency f_{ib} is 200,000 cycles. Amplifier-modulator then causes this resulting signal to modulate the carrier frequency oscillator.

The microphone 42, the amplifier-modulator 43, the intermediate-modulating oscillator 44, and the amplifier-modulator 45 operate in a similar manner. Again the frequency f_{ic} of intermediate-modulating oscillator 44 is different from that of the intermediate-modulating oscillators 36 and 40, so that, for example, the oscillation frequency f_{ic} of intermediate-modulating oscillator 44 may be 300,000 cycles.

It is, of course, not necessary that the single carrier frequency oscillator 46 be employed. Instead, separate carrier frequency oscillators may be used; the carrier frequencies of the separate oscillators being the same or different as desired.

Returning to the preceding case, the complex of waves radiated by transmitting antenna 47 are picked up by antennas 48, 55, and 62 of Fig.

3B. Considering the first of these receivers, antenna 48 connects to amplifier 49 which amplifies the carrier frequency. After suitable amplification the complex signal is demodulated by demodulator 50, thereby eliminating the carrier. The output of the demodulator will contain all of the intermediate-modulating frequencies and their accompanying modulations. Accordingly, a band-pass filter 51 is inserted in the output circuit of demodulator 50. This band-pass filter should be operative at frequency f_{ia} , namely, at the frequency of the intermediate-modulating oscillator 36 of the transmitter, and it should have a pass-band sufficiently wide as to pass the original signals of frequency f_{sa} without undue attenuation. The output of the band-pass filter will then contain intermediate-modulating frequency f_{ia} which has been modulated by the original signal frequency f_{sa} . This is then amplified by amplifier 52 and then demodulated by demodulator 53 so that the intermediate-modulating frequency f_{ia} is removed. The remaining signal frequency f_{sa} is then amplified by amplifier 54, the output of which goes to any suitable device, as for example, a loud speaker or ear-phones.

The operation of the second receiver is similar to that just described. Antenna 55 receives the complex of signals radiated by transmitting antenna 47 and this is fed to the amplifier 56 which amplifies at the carrier frequency, after which demodulator 57 removes the carrier frequency. Since in this case it is desired to receive the signal frequency f_{sb} the band-pass filter 58 operates at frequency f_{ib} corresponding to frequency f_{ib} of oscillator 40 in the transmitter.

It is now possible to examine how this new communication system may be utilized so that the regular transmission of unimportant signals which employ the customary direct modulation may be simultaneously transmitted in conjunction with multiply-modulated signals containing the essential information, in order to deceive any third party who may make the attempt to intercept the desired signals. A typical transmitter for performing this function is shown in Fig. 4A. The desired signals f_s are picked up by microphone 68, are amplified by amplifier-modulator 73, and are then employed to modulate the intermediate-modulating frequency oscillator 71. The frequency of oscillation f_i of the intermediate-modulating frequency oscillator 71 may be any suitable value, as, for example, 100,000 cycles. The modulated output of intermediate-modulating frequency oscillator 71 is fed to the amplifier-modulator 72, which latter is used to modulate the carrier frequency oscillator 73, and these signals are radiated into space via antenna 76. Simultaneously with the preceding, the false signals F_s are picked up by microphone 74, are amplified by the amplifier-modulator 75, which latter also modulates the carrier frequency oscillator 73, after which these false signals are also radiated into space via the antenna 76.

It is therefore seen that the radiations emanating from antenna 76 consist of the desired signals and the false signals. A conventional receiver which is tuned to receive the carrier frequency f_c will receive only the false signals since it will be unresponsive to the intermediate-modulating frequency f_i .

In order to receive the desired signals a receiver of the type shown in Fig. 4B may be employed. Antenna 77 picks up the signal radiated from antenna 76. This doubly-modulated signal is

amplified by amplifier 78. The demodulator 79 removes the carrier frequency so that the output of demodulator 79 contains the desired signal-modulated intermediate-modulating frequency and the false signals. The band-pass filter 80 permits only the signal-modulated intermediate-modulating frequency to pass through, so that the output of band-pass filter 80 does not contain the false signals. After further amplification by means of amplifier 81 the signal-modulated intermediate-modulating frequency goes to demodulator 82 which removes the intermediate-modulating frequency and leaves only the original desired signals. After further amplification by amplifier 83 the desired signals may be utilized to actuate any suitable device, as, for example, a loudspeaker or earphones.

The signaling system just described is not limited merely to the use of a single intermediate-modulating frequency, but may employ multiple-modulation using any number of intermediate-modulating frequencies, as desired.

There will now be described a typical method whereby the desired signals are scrambled so that the separately scrambled portions of the scrambled signals modulate different intermediate-modulating frequencies. One of the manifold of transmitters for accomplishing this purpose is shown in Fig. 5A. The desired signal f_s is picked up by microphone 84, these signals then being suitably amplified by means of amplifier 85. From here the signals go to a scrambler 86 which breaks the signals up in any desired manner. One portion of these scrambled signals feeds into the amplifier-modulator 87 while the other portion of these scrambled signals feeds into the amplifier-modulator 89. That portion which went to amplifier-modulator 87 is utilized to modulate the first intermediate-modulating frequency oscillator 88, the output of which also goes to amplifier-modulator 89. Amplifier-modulator 89 then modulates the second intermediate-modulating frequency oscillator 90. In other words, the second intermediate-modulating frequency oscillator 90 is modulated both by a portion of the scrambled signals and by the signal-modulated first intermediate-modulating frequency. The output of oscillator 90 consisting of the superimposed modulations then goes to amplifier-modulator 91, which latter modulates the carrier frequency oscillator 92. After further amplification, if desired, by means of amplifier 93 the scrambled complex of triply-modulated and doubly-modulated waves are radiated into space by means of antenna 94. Although for the sake of simplicity it has not been shown, it is obvious that the system just described can be used in conjunction with the transmission of false signals.

The reconversion of the original desired signals is accomplished by means of a receiver of the type shown in Fig. 5B. Antenna 95 picks up the complexly-modulated carrier which is then amplified by means of amplifier 96. The process of demodulation by means of demodulator 97 removes the carrier, the output of the demodulator then going to the descrambler 98. Descrambler 98 is arranged to act in synchronism with the scrambler 86 of the transmitter, and is so adjusted that the doubly-modulated portion goes to amplifier 99, while the single-modulated portion goes to amplifier 101. After suitable ampli-

fication by means of amplifier 99 the doubly-modulated portion is demodulated by demodulator 100, so that the second intermediate-modulating frequency is removed. The output of demodulator 100 then goes to amplifier 101, as did also one portion of the descrambled signals coming from descrambler 98. After suitable amplification by amplifier 101, demodulator 102 removes the first intermediate-modulating frequency, so that the original signal now appears in the output of the demodulator. After suitable amplification by means of amplifier 103, the output of this amplifier may be utilized to actuate any suitable device, such as, for example, a loudspeaker or earphones.

The principle herein described is not limited in its scope merely to radio transmission and reception, for the principle of multiple-modulation may be utilized in conjunction with supersonic signaling, to wired wireless, as well as to signaling by means of other non-radio electromagnetic radiations, such as light-beam signaling, infrared signaling, and ultraviolet signaling.

Thus, in supersonic signaling, if 10 in Fig. 1A, 27 in Fig. 2A, 47 in Fig. 3A, 76 in Fig. 4A, and 94 in Fig. 5A represent supersonic output sources, the transmitters described in these various figures may be employed to transmit multiply-modulated supersonic waves. Similarly, if 11 in Fig. 1B, 28 in Fig. 2B, 48, 55, and 62 in Fig. 3B, 77 in Fig. 4B, and 95 in Fig. 5B consist of supersonic pickup devices, the various receivers described in these various figures may be employed to receive multiply-modulated supersonic waves.

In a similar manner, a third party who attempted to intercept the signals of multiply-modulated light-beam, infrared beams, or ultraviolet beams would receive the false transmissions if such were transmitted, but would not, for the reasons already given, be able to intercept the real signals which it was desired to transmit.

The principle herein described, together with the various systems evolving from this principle is not, of course, limited in scope to the double-sideband transmissions which were used for illustrative purposes only, but may utilize the various other forms of transmission technique as, for example, single-sideband transmission, asymmetric-sideband transmission, suppression of the carrier at the transmitter, as well as the other transmission techniques known to the art.

We claim:

1. A radio signaling system including a transmitter and a receiver, and in which the transmitter is provided with a pickup device and a carrier frequency oscillator, and interposed modulators and companion oscillators employing amplitude, phase, and frequency modulations; and in which the receiver is provided with a receiving element and a translating device, and interposed modulators and oscillators for receiving from the receiving element such amplitude, phase, and frequency modulations as originated in the transmitter and delivering same to the translating element.

2. A radio signaling system as claimed in claim 1, wherein the number of oscillators and their companion amplitude, phase, and frequency modulators are arrangeable in a selected sequence.

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