Dec. 28, 1937. C. W. HANSELL 2,103,847

SIGNALING

Filed Oct. 2, 1923 2 Sheets-Sheet 1

Fig. 1

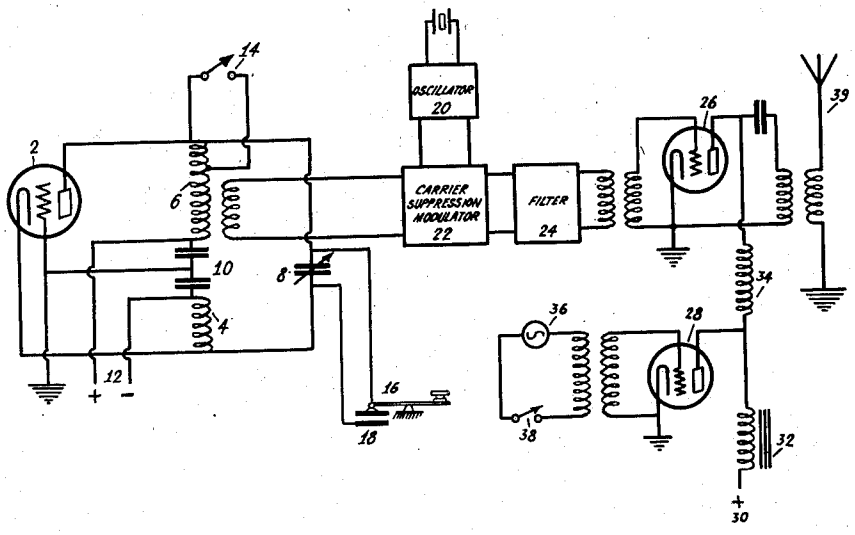
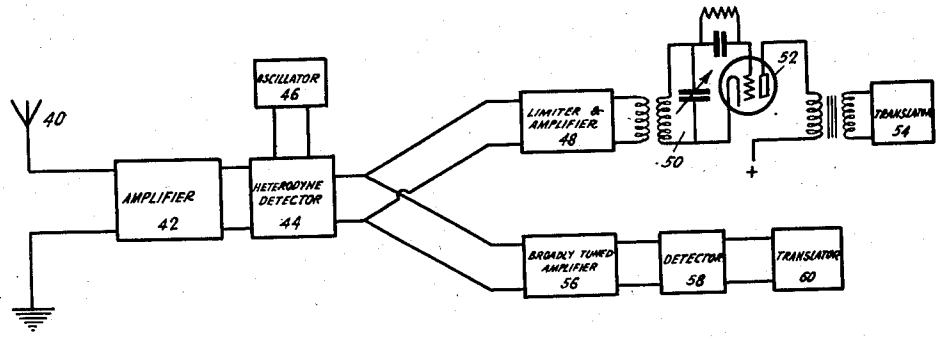


Fig. 2



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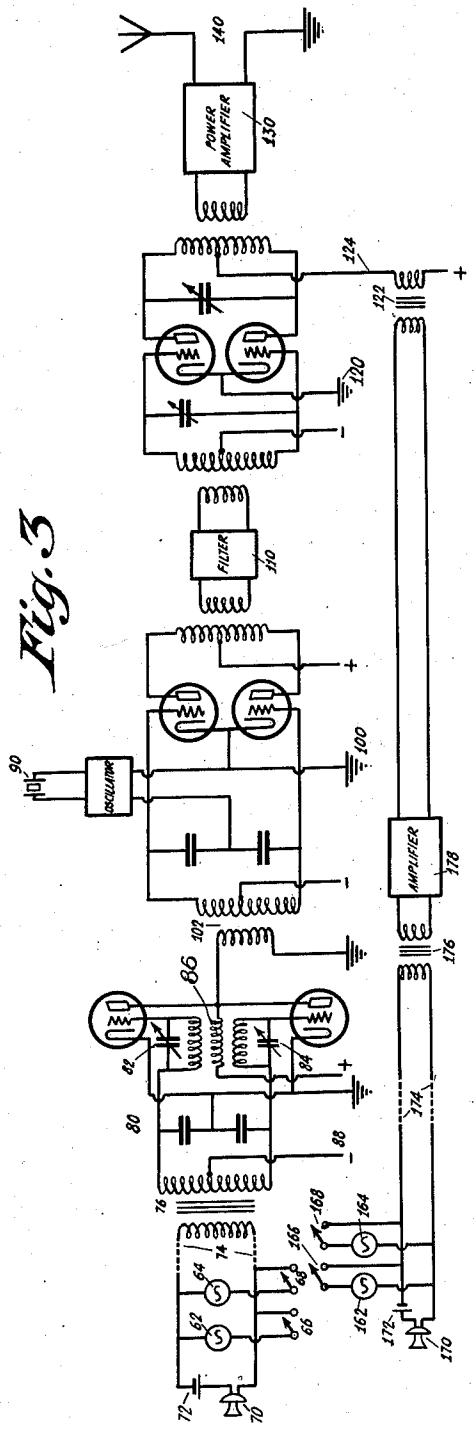


Fig. 3

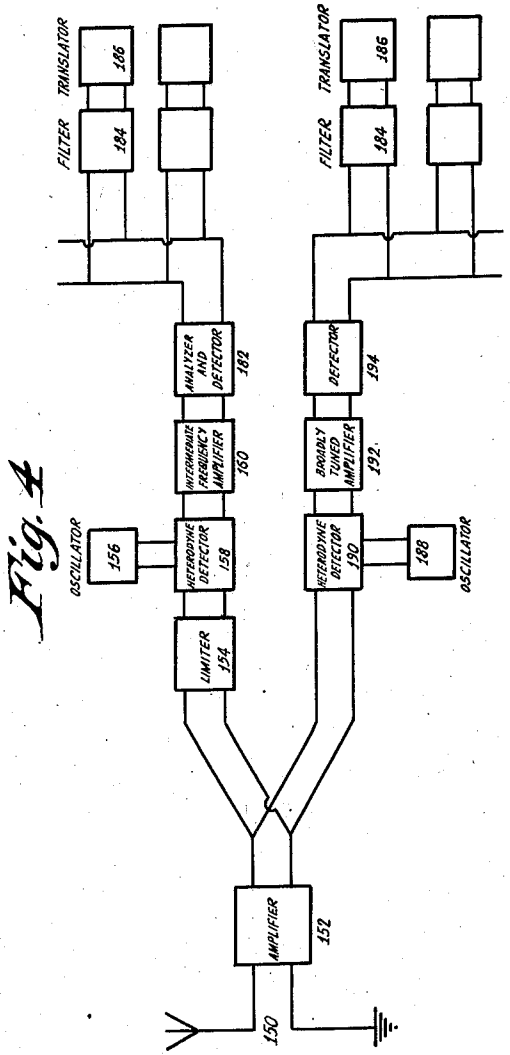


Fig. 4

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2,103,847

SIGNALING

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Application October 2, 1928, Serial No. 309,877

10 Claims. (Cl. 179—15)

This invention relates to signaling, and more particularly to multiplex signaling on a high frequency carrier.

The rapid growth in the number of communication channels needed, coupled with the fixity of the available frequency spectrum, makes multiplexing exceedingly desirable, but most schemes for multiplexing require as broad or broader frequency band than would be required if separate high frequency channels were employed. It is an object of my invention to provide a method and means for multiplexing which will broaden the necessary frequency band as little as possible, and to this end my invention includes frequency modulating a carrier in accordance with one of the signals to be transmitted, and amplitude modulating the carrier in accordance with another of the signals to be transmitted. At the receiver a portion of the received energy may be detected and translated to obtain the signal transmitted by amplitude modulation, while another portion of the received energy is limited to eliminate the amplitude modulation, and thereafter is analyzed, detected, and translated to obtain the signal transmitted by frequency modulation.

Elaborate frequency modulation equipment is designed for continuous high speed operation. For service communication between the operating staffs of the communicating stations continuity and high speed is not needed, but what is desired is that the service channel be independent of the regular message channel, without requiring additional transmitters, and that it shall not interfere with the regular message communication. To provide a service channel which will fulfill these conditions is another object of my invention, entirely irrespective of economy of frequency range, and this I do by amplitude modulating the output of a simplex or multiplex frequency modulation channel for service communication. The regular transmitter provides the necessary carrier. The frequency modulation channels are not interfered with. And in case of a break down in the modulation equipment of the regular message channels the operators still are able to communicate, so long as the transmitter continues to supply carrier energy.

It is a further object of my invention to make available, when desired, a greater number of multiplex channels on a single high frequency carrier. For this object, in the case of either or both the frequency and amplitude modulations, my method includes first signaling on each of a plurality of energies of different low frequencies and combining the low frequency energies. Thereafter the carrier is frequency modulated in accordance with one of the combined energies, and amplitude modulated in accordance with the other of the combined energies. At the receiver the method of separating the frequency and amplitude modulations is like that already mentioned, but after detection, in each case, the detected energy is separated into its constituent low frequency signaling energies, which then are separately translated to obtain the transmitted signals. This method of multiplexing broadens the needed frequency band, but sometimes is desirable for practical reasons, even though theoretically more channels each using a narrower band could also be used, from the standpoint of frequency economy.

The crowding of the frequency spectrum which gives rise to the present invention also necessitates that the mean carrier frequency be kept as constant as possible. To accomplish this is a further object of my invention, which I fulfill by frequency modulating energy of intermediate frequency, modulating high frequency energy from a constant frequency source in accordance with the frequency modulated energy of intermediate frequency, selecting a side band of the resulting modulation to obtain frequency modulated energy of high frequency the mean frequency of which is quite constant, and modulating the amplitude of the frequency modulated high frequency energy in accordance with the signal to be transmitted by amplitude modulation. This I consider a preferred method sequence, though it is possible to amplitude modulate the frequency modulated intermediate frequency energy, and thereafter modulate the high frequency energy, and also to use other variations in the method sequence.

At the receiver, after a portion of the received energy has been limited to eliminate amplitude modulation and partial fading, the frequency modulation is transformed into amplitude modulation by an analyzer, which is a resonant circuit tuned to a frequency lying to one side of the working frequency range, so that it responds unequally to the frequencies impressed upon it, after which the resulting amplitude modulated wave may be detected. To increase the range of frequency modulation relative to the mean frequency, in order to facilitate analysis and detection, I heterodyne the received energy with locally generated energy, obtaining frequency modulated energy having the same range of frequency modulation as before, but on a carrier of

intermediate frequency. The original amplitude modulation of the high frequency carrier may be eliminated by limiting either before or after the step of heterodyning the received energy.

The invention is described more in detail in the following specification, which is accompanied by drawings in which

Figure 1 is a transmitter for multiplexing by frequency and amplitude modulation;

Figure 2 is a receiver for cooperation therewith;

Figure 3 is a transmitter for multiplexing with an increased number of channels; and

Figure 4 is a receiver for cooperating therewith.

Referring to Figure 1 there is an oscillator tube **2**, the cathode to control electrode circuit of which includes an inductance **4**, while the cathode to anode circuit includes an inductance **6**, regeneratively coupled to the inductance **4**. The inductances are tuned to the desired oscillation frequency by a condenser **8**. Blocking condensers **10** serve to separate the steady anode and control electrode potentials which are provided from direct current sources connected to the leads **12**. For code communication the frequency of the oscillator is varied in any suitable manner, here illustrated by either a key **14**, which serves to short circuit a small portion of the inductance of the resonant circuit, or a key **16**, which serves to vary the spacing of a small condenser **18**, connected in parallel with the main tuning condenser **8**.

The oscillator so far described is preferably tuned to an intermediate frequency, which in turn is used to modulate high frequency energy from a source of constant frequency. This has been indicated by the crystal controlled oscillator **20**, the output from which is fed to a carrier suppression modulator **22**, and there is modulated by the frequency modulated output from the intermediate frequency oscillator. Of the two sidebands one is rejected and the other selected by a filter **24**. The selected sideband is amplified in one or more amplifier stages, and one such stage has been indicated at **26**.

To impress the amplitude modulation on the frequency modulated carrier a Heising type of modulation system may be used. A modulator tube **28** is provided, and its anode is fed in parallel with the anode of the amplifier tube **26** from a common direct current source connected to the lead **30**, in series with which there is inserted an audio frequency choke **32**. A radio frequency choke **34** may be inserted between the amplifier and modulator tubes in order to separate the radio and modulation frequencies. Inasmuch as it is not feasible to key the carrier completely on and off, for the carrier is needed to carry the frequency modulation signal, the amplitude modulation is preferably provided by a tone signal generator **36**, keyed by a key **38**. The frequency and amplitude modulated carrier may then be transmitted over wire lines, or radiated from an antenna **39**.

A receiver for the signals radiated from the transmitter described in Figure 1 is indicated in Figure 2, in which signaling energy is collected upon an antenna **40**, amplified in an amplifier **42**, and reduced in frequency by combination in a heterodyne detector **44** with locally generated oscillations from an oscillator **46**. The resulting energy of intermediate frequency is fed partially to an intermediate frequency amplifier **48**, which may be arranged to act as a limiter, so as to eliminate the amplitude modulation and partial fading, after which the frequency modulated energy of intermediate frequency may be analyzed and detected in an analyzer circuit **50** and detector **52**. The analyzing circuit **50** is tuned to a frequency outside of the applied range of frequencies and converts the frequency modulations on the waves into amplitude variations which may be detected in tube **52**. The rectified energy is fed to a translating means **54**.

The detector should preferably be of the balanced type disclosed in a copending application of G. L. Usselman, Serial No. 216,873, filed Sept. 1, 1927, which resulted in U. S. Patent #1,794,932, on March 3, 1931.

For further details concerning the reception and demodulation of frequency modulated signals reference may be made to the disclosure in my copending application Serial Number 212,192 filed Aug. 11,1927, which resulted in U. S. Patent #1,819,508 on Aug. 18, 1931.

Another portion of the energy from the heterodyne detector **44** is supplied to an intermediate frequency amplifier **56**, which is sufficiently broadly tuned so as to pass all of the frequencies in the range of frequency modulation with equal facility, and which is arranged not to have a limiting action. The amplified energy is rectified in the detector **58** to obtain the amplitude modulation component, which is then translated in a suitable translating means **60**, yielding the signal which was transmitted by amplitude modulation.

It should be understood that the essential features of this receiver are merely a detector and translator for obtaining the signal transmitted by amplitude modulation, and an analyzer, detector, and translating device for translating the signal transmitted by frequency modulation, in combination with a limiter somewheres in circuit before the analyzer but not in circuit with the first mentioned detector and translator, so as to eliminate amplitude modulation from only the energy supplied to the analyzer circuit. The heterodyne oscillator is not essential, and if used, may be applied separately to each receiver, or to one or the other receiver alone. I consider its application to the frequency modulation receiver especially advantageous, inasmuch as it then serves to increase the range of frequency modulation, relative to the mean frequency, thereby facilitating analysis and detection of the frequency modulation signal.

Attention is now directed to Figure 3, which is a transmitter adapted for multiplexing with a plurality of amplitude and frequency modulation channels. Referring to that figure there are a plurality of sources **62**, **64**, of energies of different low frequencies, each keyed by a suitable keying means **66** and **68**. If speech telephony instead of or in addition to code signaling is desired a microphone **70** in series with a battery **72** may be provided. The various low frequency energies impressed in the signals by closing the keys or energizing the microphone **70** are combined in a common land line **74**, which leads to the modulation input transformer **76** of a frequency modulator **80**. The modulator may be of any satisfactory type, and in this case is exemplified by a combined oscillator and modulator comprising resonant circuits **82** and **84**, which are tuned to the extreme frequencies of the desired frequency range, and regeneratively coupled to a common anode coil **86**. The upper and lower oscillators must operate at a common compromise frequency lying between the

extreme frequencies, the value of which depends upon the relative strength of oscillation in the two oscillators. This, in turn, depends upon the relative potentials of the control electrodes of the tubes, and these potentials are oppositely varied, relative to a mean bias potential determined by a steady bias source connected to the lead 88, by the secondary of the modulation input transformer 76. For further details concerning the frequency modulator 80 reference may be made to my copending application Serial Number 264,101 filed March 23, 1928, Patent No. 1,787,979, January 6, 1931.

The frequency modulator output preferably is an intermediate frequency, so that the high frequency energy may be supplied from a source more readily adapted to supplying energy of perfectly constant mean frequency. For this purpose high frequency energy is supplied from a crystal controlled oscillator 90 to a carrier suppression modulator 100, while the frequency modulated energy of intermediate frequency is supplied to the input transformer 102, and serves to modulate the high frequency energy. Of the two resulting side bands one is selected and the other rejected by the filter 110. The resulting frequency modulated output of high frequency is fed to a vacuum tube amplifier stage 120, which is arranged to act also as an amplitude modulator, in this case having a transformer 122 connected in series with its anode current supply lead 124. Any one of the regular power amplifier stages may be used, and the Heising scheme for modulation is applicable, just as in Fig. 1.

As in the case of the frequency modulation signals, so in the case of the amplitude modulation signals there are a plurality of sources of energy of low frequency 162, 164, which are keyed by suitable keying means 166, 168, and if desired, a speech microphone 170 and battery 172. The resultant signaling wave is conveyed over a land line 174 to the input transformer 176 of an appropriate amplifier 178. The output of the amplifier is coupled to the transformer 122 and so serves to modulate the amplitude of the frequency modulated high frequency energy passing through the stage 120. This arrangement is simpler than the Heising arrangement, but suffers from the disadvantage that it is difficult to insulate the transformer 122. The frequency and amplitude modulated high frequency energy may be further amplified, if necessary, in a power amplifier 130, and thence transmitted over wire lines or radiated from a suitable antenna 140.

Obviously, the amplitude modulation may consist of a single channel, as in Figure 1, while the frequency modulation includes a plurality of channels, as in Figure 3, or the arrangement may be reversed, so that the frequency modulation is a single channel, while the amplitude modulation includes a plurality of channels, though I prefer the former arrangement, using the simplex amplitude modulation channel for a service channel.

In Figure 4 the receiving antenna 150 is coupled to an amplifier 152, the output from which is divided, and partially fed to the upper receiving system, responsive to frequency modulation, and the lower receiving system, responsive to amplitude modulation.

The upper receiving system includes a limiter 154, for eliminating the amplitude modulation and partial fading, and a local oscillator 156 and a heterodyne detector 158, for reducing the received energy to frequency modulated energy of intermediate frequency, which is amplified in amplifier 160, and fed to an analyzer and detector 182. The rectified output from the stage 182 is fed to parallel connected filters 184, which serve to separate the rectified energy into its constituent low frequency energies, each of which is translated in a suitable translating means 186, to obtain the signals respectively carried thereby.

The lower receiver includes a local oscillator 188 and a heterodyne detector 190, which serve to reduce the high frequency energy to intermediate frequency energy, which then is amplified in an intermediate frequency amplifier 192, and fed to a detector 194. The rectified energy is separated by filters 184, and translated in translating means 186.

It should be understood that in the frequency modulation receiver the limiter 154 may be located after the heterodyne detector, as well as ahead of it, so long as it precedes the analyzer 182. The intermediate frequency amplifier 160 may be made to act as a limiter thereby dispensing with a separate limiter 154. The intermediate frequency amplifier 160 may be sufficiently broadly tuned to pass all of the frequencies of the range of frequency modulation with equal facility, or it may be slightly detuned, like the resonant circuit of the analyzer circuit 182, so that it serves to change frequency modulation to amplitude modulation, but it should not be used both as a limiter and an analyzer.

The amplifier 192 must be sufficiently broadly tuned to pass the entire range of frequency modulation, and must be adjusted not to act as a limiter, and not to act as an analyzer. The local oscillators 156 and 188 and the detectors 158 and 190 may be combined, if desired, or both or either dispensed with.

In the claims signaling on low frequency energy is intended to include telephony as well as code.

I claim:

1. The method of transmitting multiplex signals on a high frequency carrier which includes continuously changing the frequency of the carrier through each frequency of a band of frequencies in accordance with one of the signals to be transmitted, selecting a side band from the resultant modulated energy and amplitude modulating the side band in accordance with another of the signals to be transmitted.

2. The method of transmitting multiplex signals on a high frequency carrier which includes signaling on one or more of a plurality of energies of different low frequencies, combining the low frequency energies, frequency modulating the carrier in accordance with the combined energy, selecting a side band of the resultant modulation to obtain frequency modulated energy, signaling on one or more of another group of energies of different low frequencies, combining the low frequency energies, and amplitude modulating the selected side band in accordance with the combined energy.

3. The method of transmitting multiplex signals on a high frequency carrier which includes frequency modulating through each frequency of a band of frequencies energy of intermediate frequency in accordance with a signal to be transmitted, modulating high frequency energy in accordance with the frequency modulated energy of intermediate frequency, selecting a side band of the resulting modulation to obtain frequency modulated energy of high frequency, modulating the amplitude of the frequency mod-

ulated high frequency energy in accordance with another signal to be transmitted, and transmitting the frequency and amplitude modulated high frequency energy.

4. The method of transmitting multiplex signals on a high frequency carrier which includes signaling on one or more of a plurality of energies of different low frequencies, combining the low frequency energies, frequency modulating energy of intermediate frequency in accordance with combined energy, modulating high frequency energy in accordance with the frequency modulated energy of intermediate frequency, selecting a side band of the resulting modulation to obtain frequency modulated energy of high frequency, signaling on one or more of another group of energies of different low frequencies, combining the low frequency energies, modulating the amplitude of the frequency modulated high frequency energy in accordance with the combined energy, and transmitting the frequency and amplitude modulated high frequency energy.

5. A multiplex transmission system comprising a plurality of sources of energy of different low frequencies, means to signal on one or more of said energies, means to combine the energies, a source of high frequency carrier energy, means to frequency modulate the carrier energy in accordance with the combined energy, means for selecting a single side band of the modulated energy and suppressing the carrier, another plurality of sources of energy of different low frequencies, means to signal on one or more of said energies, means to combine the energies, and means to amplitude modulate the selected side band in accordance with the latter combined energy.

6. A multiplex transmission system comprising a source of intermediate frequency energy, means to frequency modulate the intermediate frequency energy in accordance with a signal to be transmitted, a source of constant high frequency energy, a carrier suppression modulator for modulating the high frequency energy with the frequency modulated intermediate frequency energy, a filter for selecting one of the side bands to obtain frequency modulated energy of high frequency, means to amplitude modulate the frequency modulated high frequency energy in accordance with another signal to be transmitted, and means to transmit the frequency and amplitude modulated high frequency energy.

7. A multiplex transmission system comprising a plurality of sources of energy of different low frequencies, means to signal on one or more of said energies, means to combine the energies, a source of intermediate frequency energy, means to frequency modulate the intermediate frequency energy with the combined energy, a source of constant high frequency energy, a carrier suppression modulator for modulating the high frequency energy with the frequency modulated intermediate frequency energy, a filter for selecting one of the side bands to obtain frequency modulated energy of high frequency, another plurality of sources of energy of different low frequencies, means to signal on one or more of said energies, means to combine the energies, and means to amplitude modulate the frequency modulated high frequency energy in accordance with the latter combined energy.

8. Means for signaling on a plurality of channels simultaneously comprising, a source of high frequency energy, a source of signals of varying frequency connected with said high frequency source for varying the characteristic of said high frequency energy at signal frequency to produce resultant signal modulated energy, means for selecting from said resultant energy a signal modulated side band of substantially constant amplitude and suppressing the carrier, and means for modulating in amplitude the selected side band in accordance with another signal.

9. Means for signaling simultaneously on a plurality of channels by means of a high frequency carrier wave comprising, means for combining the signals from a plurality of low frequency sources, means for producing an intermediate frequency, means for varying the characteristics of said intermediate frequency other than the amplitude in accordance with the combined low frequency signals, means for superimposing the resultant energy on a high frequency carrier to produce resultant modulated energy, means for selecting a side band of the resultant modulated energy, said side band being of substantially constant amplitude, means for combining energy from another group of low frequency signal energy sources, and means for modulating in amplitude the selected side band in accordance with the combined energy resulting from the last named group of low frequency signal sources.

10. The method of transmitting a plurality of signals on a single high frequency carrier simultaneously which includes the steps of, signaling on a plurality of different low frequencies, combining the low frequencies, varying the wave length of an intermediate frequency in accordance with the combined energy, varying the characteristic of the carrier frequency in accordance with the signal modulated intermediate frequency, selecting a side band of the resultant modulation to obtain signal modulated energy of high frequency, signaling on one or more of a group of different low frequencies, combining the last named group of low frequency energies, and modulating the amplitude of the signal modulated high frequency energy in accordance with the combined energy.

CLARENCE W. HANSELL.