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H. NYQUIST ET AL

RADIO TELEPHONE SYSTEM

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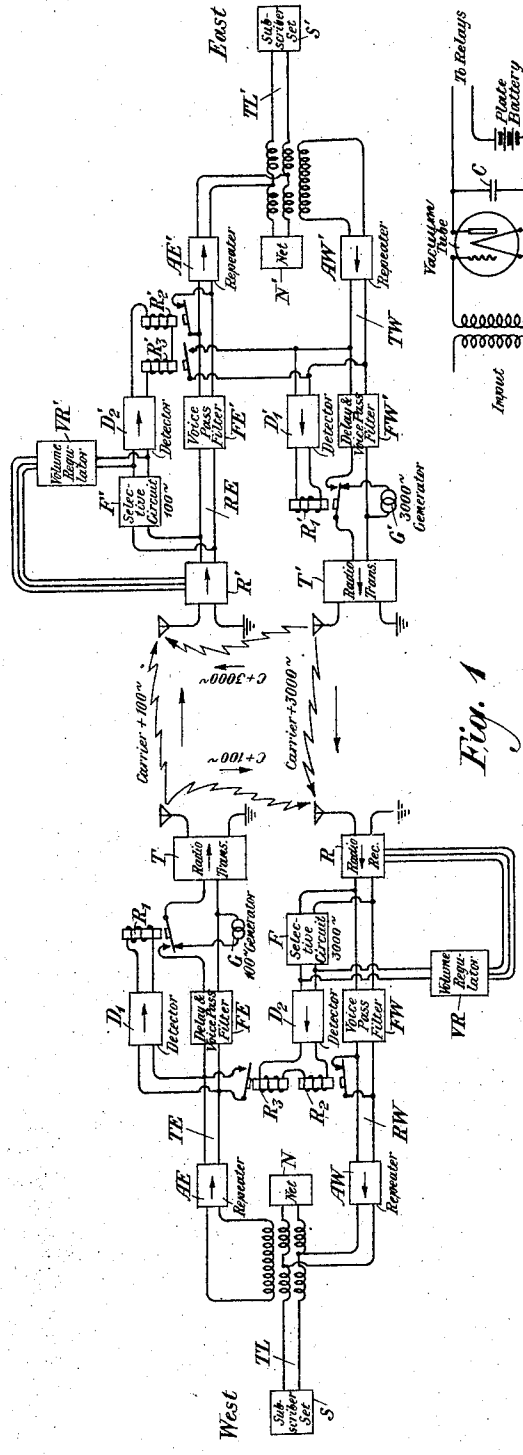


Fig. 1

Fig. 4, Typical Detector.

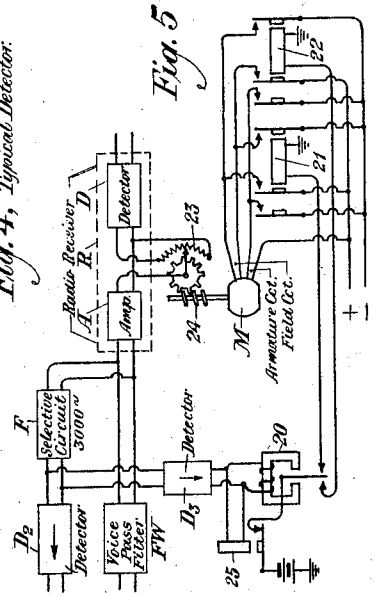


Fig. 5

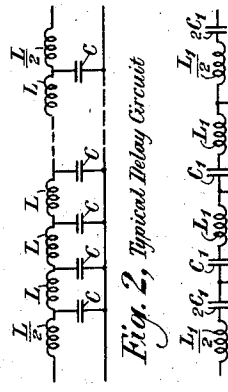


Fig. 2, Typical Delay Circuit

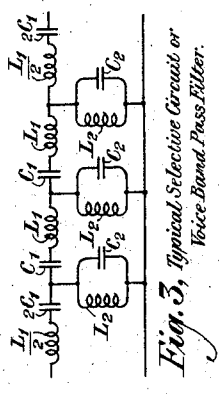


Fig. 3, Typical Selective Circuit or Voice Band Pass Filter.

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RADIO TELEPHONE SYSTEM.

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This invention relates to a two-way telephone system in which echoes and singing are suppressed by means of voice controlled relays, the invention being particularly adapted for use in connection with two-way radio telephone systems.

In a radio telephone system in which the same carrier frequency or the same transmission band is used for transmission in both directions, echo and singing effects are particularly undesirable because outgoing transmission may be received much stronger at the local receiving station than that desired to be received from the distant transmitting station. Another difficulty experienced in systems of this type is that static disturbances tend to operate the voice controlled relays which are used to suppress echoes.

In order to obviate these difficulties, the system of the present invention is so arranged that ordinary voice operated switching devices are used in the transmitting branches at both ends of the system in order to determine the direction of transmission which prevails while a given subscriber is talking. Similar switching devices are also employed at the receiving branches, but in this case they are controlled by means of single frequency currents which are transmitted over the radio channel, these single frequency currents being controlled by relays at the transmitting points. These currents are normally transmitted while no talking is taking place. When the subscriber talks, the controlling current for that direction is cut off, and his voice currents are radiated instead. By using selective circuits which are sharply discriminative to receive these single frequency controlling currents, the effect of static upon the switching devices associated with the receiving channels is relatively small. Furthermore, the use of single frequency currents radiated from one station to the other for control puposes does not interfere with the full use of the available power range of the transmitter for telephone purposes, since the control currents are only radiated at times when the transmitter is not being used for talking purposes.

The invention may now be more fully understood from the following detailed description when read in connection with the accompanying drawing, Figure 1 of which is a circuit diagram illustrating the preferred embodiment of the invention; Fig. 2 is a detailed circuit showing a typical delay network; Fig. 3 is another detail showing a typical selective circuit or voice pass filter; Fig. 4 shows the circuit of a typical vacuum tube detector; and Fig. 5 shows the detailed circuit arrangements of the volume regulator employed in connection with the circuit of Fig. 1.

Referring to Fig. 1, a subscriber's station S is connected over a transmission line TL to the transmitting branch TE and receiving branch RW of a radio system including transmitter T and receiver R. The transmitting and receiving branches are arranged in the usual manner in the form of a four-wire circuit, the terminals of the branches being connected through a hybrid coil to the line TL, which in turn is balanced by the usual network N. At the distant end of the system, the subscriber's set S′ is connected to the transmission line TL′. The transmission line in turn is connected through a hybrid coil and balancing network N′ to the transmitting branch TW and the receiving branch RE arranged in the form of a four-wire circuit leading to the radio transmitter T′ and radio receiver R′, respectively.

The transmitting branches TE and TW are normally open-circuited at the contacts of relays R_1 and R'_1, respectively. Likewise, the receiving branches RW and RE are disabled by short circuits controlled by the relays R_2 and R'_2, respectively. Consequently no free paths for transmission exist in the circuit in its normal condition.

Relays R_1 and R'_1 are controlled by detectors D_1 and D'_1, respectively, which are bridged across the transmitting channels TE and TW. These detectors may be of any known type, such, for example, as a vacuum tube detector of the type illustrated in Fig. 4. The detectors function to rectify or partially rectify voice currents tansmitted over the transmitting channel to thereby cause the operation of the relays R_1 and R'_1. Normally, control currents of different frequencies are supplied continuously from the tansmitting stations T and T′ by means of generators G and G′, respectively, whose circuits are completed over the back con-

tacts of the relays R_1 and R'_1. These frequencies are preferably frequencies lying just outside of the voice band but sufficiently separated therefrom to permit sharp selection. For example, generator G may generate a frequency of 100 cycles which is impressed upon the radio transmitter T to modulate the carrier in the usual way, so that it is radiated and picked up by the distant receiving set R'. Similarly, the generator G' may generate a frequency of 3,000 cycles, which is impressed upon the transmitter T' to modulate the carrier and then be radiated to be picked up by the receiver R.

In connection with the receiving channel RW, a branch circuit is taken off at the output side of the radio receiver R, said branch including a selective circuit F which is sharply selective of the frequency of 3,000 cycles which will normally be detected by the radio receiver. While a tuned circuit may be used for this purpose in some cases, it will be more desirable to use a sharply selective band filter type of circuit such as is illustrated in Fig. 3. A detector D_2 is also included in this branch, said detector being preferably of the type illustrated in Fig. 4, and having relays R_2 and R_3 controlled by its output circuit. The apparatus thus organized causes the relays R_2 and R_3 to be energized during all the time that the 3,000 cycle generator G' is connected to the radio transmitter T'. Similarly, the receiving channel RE at the distant station is provided with a branch including a selective circuit F', selective of the 100 cycle current which will be detected by the radio receiver R'. Likewise, a detector D'_2 is included in this branch and controls the relays R'_2 and R'_3. Relays R'_2 and R'_3 will therefore be energized during such times as the generator G applies 100 cycle current to the radio transmitter T.

The relays and connections used are such that relays R_3 and R'_3 close their contacts promptly on the cessation of the control current but permit a sufficient interval to elapse between the cessation of the voice waves and the opening of the contacts to insure that all echoes from the lines TL and TL' have died out.

A delay circuit FE, which may also function as a voice-pass filter, is connected between the point at which the detector branch D_1 is applied to the transmitting channel TE and the point at which the contact of the relay R_1 is applied to the channel. This delay circuit may be, for example, a low-pass filter of the necessary number of sections such as illustrated in Fig. 2. A similar delay circuit FW' is connected in the transmitting channel TW between the input bridge of the detector D'_1 and the contact of the relay R'_1. The purpose of these delay circuits will presently appear. It is also desirable to provide voice-pass filter circuits such as FW and FE' in the receiving channels RW and RE, respectively. These filters may be of the type shown in Fig. 2 or of the type of Fig. 3, as desired. The purpose of these filters is not to introduce delay, but merely to select the detected voice currents from the corresponding radio receiver to the exclusion of the detected control currents.

Outgoing transmission from the subscriber's station S, for example, passes into the transmitting branch TE and through the delay circuit FE. While the voice currents pass through the delay circuit, a portion of the voice energy enters the detector D_1 (which may include suitable amplifiers) and upon being rectified or partially rectified, it operates the relay R_1. The relay R_1 disconnects the generator G from the radio transmitter T, and, at the same time, closes its front contact to complete the circuit of the transmitting branch TE from the delay circuit FE to the radio transmitter T. The delay circuit FE should introduce sufficient delay to permit this operation to take place before the beginning of the wave leaves the delay circuit.

Normally, a steady control signal having a frequency of say 100 cycles is generated by the generator G and impressed upon the radio transmitter T, thereby modulating the carrier. The modulated signal is radiated and picked up by the radio receiver R' which operates to detect the frequency of 100 cycles which is selected by the filter F' and impressed upon the detector D'_2. This detector rectifies or partially rectifies the received energy and thereby maintains the relays R'_2 and R'_3 energized. Relay R'_2 maintains the receiving channel RE short-circuited, so that the subscriber at the station S' would normally hear nothing. After this tone frequency is removed by the operation of the relay R_1, as just described, relays R'_2 and R'_3 are deenergized. The former removes the short circuit from the receiving channel RE to permit the transmission to be received and transmitted over the line TL' to the subscriber's station at S'. The voice currents transmitted over the channel TE modulate the carrier of the radio transmitter T and are received and detected by the radio receiver R' and then selected by the voice filter FE' for transmission to the line TL. The delay circuit FE of the transmitting channel TE delays this part of the operation long enough for the relay R_1 to close its front contact, and for the relays R'_2 and R'_3 to be deenergized upon the cessation of the tone signal. The delay circuit FE may take care of the entire delay due to these operations, so that the filter FE' need only perform its selective

function. Therefore, the filter FE′ may consist of only a few sections. The relay R'_3, already referred to as being released when the tone was removed, connects a short circuit across the transmitting channel TW to prevent the voice currents selected by the voice-pass filter FE′ from passing back into the transmitting channel TW as echoes. This short circuit is maintained until all echoes from the line TL′ have ceased. This short circuit also functions to short circuit the input of the detector D'_1.

When voice transmission leaves the radio transmitter T, some of it may pass directly to the radio receiver R associated with the west end of the circuit. Any harmful effect resulting from this situation is prevented by having the receiving channel RW normally short circuited by the relay R_2 which is held operated by the 3,000 cycle current detected by the radio receiver R so long as the generator G′ at the distant end of the circuit is connected to the radio transmitter T′. This tone continues to be transmitted even while the subscriber at S is talking, due to the fact that the release of the relay R'_3 short circuited the input side of the detector D'_1, as already described, thus preventing the operation of the relay R'_1 either by echoes or by voice currents transmitted from the subscriber S′. When the subscriber at S finishes talking, the relays restore the circuit to the condition shown in the drawing. When the subscriber at S′ talks, relays similar to those already described will function to clear the circuit for transmission from east to west over the transmitting channel TW and receiving channel RW.

It will be noted that voice-pass filters such as FE and FW are included in both the transmitting and receiving branches to prevent interference between the control currents and voice currents. By using circuits such as F and F′ which are highy selective to the control frequencies, and connecting these circuits in front of the detectors such as D_2 and D'_2, very sharp discrimination is provided against static and noise, thereby preventing false operation of the echo suppressing relay equipment associated with the receiving branches. It will also be noted that in the normal condition of the circuit, the carrier modulated in accordance with the tone from the generator G is radiated from the transmitter T both to the distant receiving apparatus R′ and to the local receiving apparatus R. The tone detected by the latter apparatus is without effect, however, as it can not be selected by the filter F. Similarly, of course, the carrier modulated by a tone of 3,000 cycles is transmitted from the transmitting apparatus T′ to the receiving apparatus R′. The detected tone in this case is also ineffective, as the filter F′ will not pass this frequency.

The tone frequency normally radiated may be utilized to control the transmission level of the receiving equipment as the transmission efficiency of the medium changes. As is well known, the transmission efficiency of the ether varies or "fades" slowly, particularly during certain periods of the twenty-four-hour day, so that it is necessary to make adjustments from time to time to keep the transmission at a uniform level. As the transmission efficiency of the ether changes the volume or amplitude of the received tone will change accordingly, and the change in amplitude of this tone may be used to automatically adjust the transmission level. For this purpose, a volume regulator VR, schematically indicated in Fig. 1, is connected to the output side of the selective circuit F to control the efficiency of the radio receiver R, and, similarly, a volume regulator VR′ is connected to the output circuit of the selective circuit F′ to control the efficiency of the receiver R′. The detailed circuits of these regulators in their operation may be understood from Fig. 5 which shows the details of the regulator VR.

Referring to Fig. 5, a detector D_3 is connected to the output side of the filter F in multiple with the detector D_2 already described in connection with Fig. 1. A voltmeter relay 20 is connected to the output circuit of the detector D_3. The armature of this relay is arranged to swing between two contacts which control relays 21 and 22, respectively. These relays 21 and 22 are so arranged that when either relay is energized, the armature circuit of the motor M is closed. When relay 21 is energized, the field circuit is closed, so that current flows through it in one direction, and when relay 22 is energized, the current flows through the field in the opposite direction. The motor M will therefore be caused to rotate in one direction or the other, depending upon which of the two relays is energized. The motor M is arranged to control an adjustable potentiometer 23 by means of a suitable gearing or other mechanism 24. The potentiometer 23 may be arranged in the radio receiver R at any suitable point, as, for example, between a detector D and amplifier A, as shown.

When the tone frequency selected by the filter F is of normal amplitude, the rectified current appearing in the output circuit of the detector D_3 will energize the winding of the voltmeter 20 to hold its armature in a neutral position with respect to the two contacts. If the transmission medium becomes less efficient, the amplitude of the selected tone decreases and the armature of the relay moves to, say, its left-hand contact, thereby energizing the relay 22 and causing the motor M to rotate in such direction as to adjust the potentiometer 23 to increase the

gain of the amplifier A. The motor M continues to rotate in this direction until the tone frequency is brought back to normal, when the armature of the voltmeter relay 20 is again in a neutral position. If the transmission efficiency of the medium is increased, the voltmeter relay 20 shifts its armature to say its right-hand contact, thereby energizing the relay 21 and causing the motor M to rotate in the opposite direction. This causes an adjustment of the potentiometer 23 which reduces the gain of the amplifier A until the tone frequency is again brought back to its normal level.

It will thus be seen that during the time that the tone frequency is being radiated, the transmission efficiency of the receiving channels will be automatically maintained at a normal level, regardless of changes in the transmission medium. As soon, however, as someone begins to talk so that the tone is removed from the circuit, some provision must be made to prevent the volume regulator from operating to change the setting of the potentiometer. To accomplish this result, a relay 25 is connected in the output of the detector D_3, and the contact of this relay is arranged so that when the relay is energized, battery will be connected to the armature of the voltmeter relay 20. The relay 25 is sufficiently sensitive so that when the amplitude of the tone is decreased, due to a change in the medium, the current passing through the winding of the relay 25 will be sufficient to maintain it energized. When, however, the tone is completely interrupted, there will be no current flowing in the output side of the detector, and relay 25 will therefore release its armature and prevent the armature of the voltmeter relay from completing the motor circuit. Consequently, when anyone commences to talk, the adjusting apparatus will remain in the condition in which it then happens to be until the talk ceases. As the fading which takes place in the type of system here under consideration is relatively slow, there will be no change in the volume level during the period of a brief conversation which will require any adjustment of level.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention, as defined in the following claims.

What is claimed is:

1. In a two-way transmission system, a channel for transmitting in one direction and another channel for transmitting in the opposite direction, an echo suppressor unit associated with one of said channels, means for transmitting a controlling frequency over said channel when said channel is not used for signal transmission, said echo suppressor unit functioning as long as the controlling frequency is transmitted to maintain said channel disabled for signal transmission, and means responsive to the application of signals to said channel to disconnect said controlling frequency whereby said echo suppressor unit renders the channel operative for signal transmission.

2. In a two-way transmission system, a channel for transmitting in one direction and another channel for transmitting in the opposite direction, an echo suppressor unit associated with each channel, means to normally transmit a controlling frequency over each channel during such times as it is not used for signal transmission, means whereby the echo suppressor unit associated with each channel maintains the channel disabled for signal transmission as long as the controlling frequency is applied, and means whereby when signaling currents are applied to either channel, the corresponding controlling frequency is disconnected therefrom, thereby permitting the corresponding echo suppressor unit to render the channel operative for signal transmission.

3. In a two-way transmission system, a channel for transmitting in one direction and another channel for transmitting in the opposite direction, an echo suppressor unit responsive to voice currents associated with each channel near its transmitting end, means controlled by each unit for applying a controlling frequency to the channel during such times as voice currents are not applied, an echo suppressor unit associated with each channel near the receiving terminal thereof, each of said last mentioned echo suppressor units being responsive to the controlling frequency transmitted over the channel to disable the channel for voice transmission, and means whereby when voice currents are applied to a channel, the echo suppressor unit near its transmitting terminal disconnects the controlling frequency from the channel, thereby causing the echo suppressor unit near the receiving terminal to render the channel operative for voice transmission.

4. In a two-way transmission system, a channel for transmitting in one direction and another channel for transmitting in the opposite direction, an echo suppressor unit responsive to voice currents associated with each channel near its transmitting end, means controlled by each unit for applying a controlling frequency to the channel during such times as voice currents are not applied, an echo suppressor unit associated with each channel near the receiving terminal thereof, each of said last mentioned echo suppressor units being responsive to the controlling frequency transmitted over the channel to disable the channel for voice transmission, means whereby when voice

currents are applied to a channel, the echo suppressor unit near its transmitting terminal disconnects the controlling frequency from the channel, thereby causing the echo suppressor unit near the receiving terminal to render the channel operative for voice transmission, and a delay circuit associated with each channel to delay the transmission of voice currents until the echo suppressor units have had time to perform their functions.

5. In a two-way radio telephone system, a radio transmitter and a radio receiver at each terminal, a transmitting connection from the radio transmitter and a receiving connection from the radio receiver at each terminal to a corresponding terminal telephone line, a voice-operated echo suppressor unit associated with each transmitting connection, means controlled by said unit when voice currents are not being transmitted for applying a controlling tone to the radio transmitter, a sharply selective echo suppressor unit associated with each receiving connection, said last mentioned suppressor unit responding to the tone radiated by the distant transmitter to maintain the receiving connection inoperative, and means whereby when voice currents are applied to a transmitting connection, the echo suppressor unit associated therewith disconnects the controlling tone so that the echo suppressor unit associated with the distant receiving connection renders said receiving connection operative for voice transmission.

6. In a two-way radio telephone system, a radio transmitter and a radio receiver at each terminal, a transmitting connection from the radio transmitter and a receiving connection from the radio receiver at each terminal to a corresponding terminal telephone line, a voice-operated echo suppressor unit associated with each transmitting connection, means controlled by said unit when voice currents are not being transmitted for applying a controlling tone to the radio transmitter, a sharply selective echo suppressor unit associated with each receiving connection, said last mentioned suppressor unit responding to the tone radiated by the distant transmitter to maintain the receiving connection inoperative, means whereby when voice currents are applied to a transmitting connection, the echo suppressor unit associated therewith disconnects the controlling tone so that the echo suppressor unit associated with the distant receiving connection renders said receiving connection operative for voice transmission, and a delay circuit interposed between the echo suppressor of a transmitting connection and the corresponding radio transmitter to delay the transmission of voice currents until the echo suppressor has had time to operate.

7. In a two-way radio telephone system, a radio transmitter and a radio receiver at each terminal, a transmitting connection from the radio transmitter and a receiving connection from the radio receiver at each terminal to a corresponding terminal telephone line, a voice-operated echo suppressor unit associated with each transmitting connection, means controlled by said unit when voice currents are not being transmitted for applying a controlling tone to the radio transmitter, a sharply selective echo suppressor unit associated with each receiving connection, said last mentioned suppressor unit responding to the tone radiated by the distant transmitter to maintain the receiving connection inoperative, means whereby when voice currents are applied to a transmitting connection, the echo suppressor unit associated therewith disconnects the controlling tone so that the echo suppressor unit associated with the distant receiving connection renders said receiving connection operative for voice transmission, and a volume regulator associated with each receiving connection and responsive to changes in the volume of the received controlling tone to produce compensating changes in the transmission efficiency of the receiving channel, whereby the over-all transmission of the system is maintained substantially constant.

8. In a two-way radio telephone system, a radio transmitter and a radio receiver at each terminal, a transmitting connection from the radio transmitter and a receiving connection from the radio receiver at each terminal to a corresponding terminal telephone line, a voice-operated echo suppressor unit associated with each transmitting connection, means controlled by said unit when voice currents are not being transmitted for applying a controlling tone to the radio transmitter, a sharply selective echo suppressor unit associated with each receiving connection, said last mentioned suppressor unit responding to the tone radiated by the distant transmitter to maintain the receiving connection inoperative, means whereby when voice currents are applied to a transmitting connection, the echo suppressor unit associated therewith disconnects the controlling tone so that the echo suppressor unit associated with the distant receiving connection renders said receiving connection opertive for voice transmission, a volume regulator associated with each receiving connection and responsive to changes in the volume of the received controlling tone to produce compensating changes in the transmission efficiency of the receiving channel, whereby the over-all transmission of the system is maintained substantially constant, and means to prevent said volume regulator from

producing any change in the transmission efficiency of the system when said controlling tone is completely interrupted.

9. In a two-way transmission system, a channel for transmitting in one direction and a channel for transmitting in the opposite direction, means to apply a controlling tone to each channel during such times as the channel is not being used for signal transmission, means associated with the receiving end of each channel and responsive to the controlling tone for maintaining the channel inoperative for signal transmission, and a volume regulator also associated with each channel near its receiving terminal, said volume regulator being responsive to changes in the amplitude of the controlling tone to produce compensating adjustment in the transmission efficiency of the channel.

10. In a two-way transmission system, a channel for transmitting in one direction and a channel for transmitting in the opposite direction, means to apply a controlling tone to each channel during such times as the channel is not being used for signal transmission, means associated with the receiving end of each channel and responsive to the controlling tone for maintaining the channel inoperative for signal transmission, and a volume regulator also associated with each channel near its receiving terminal, said volume regulator being responsive to changes in the amplitude of the controlling tone to produce compensating adjustment in the transmission efficiency of the channel, said volume regulator being unresponsive to complete interruption of the controlling tone.

In testimony whereof, we have signed our names to this specification this 22nd day of April, 1926.

HARRY NYQUIST.
SUMNER B. WRIGHT.