

June 4, 1946.

M. G. CROSBY

2,401,618

PULSE COMMUNICATION SYSTEM

Filed April 30, 1941

2 Sheets-Sheet 1

Fig. 1.

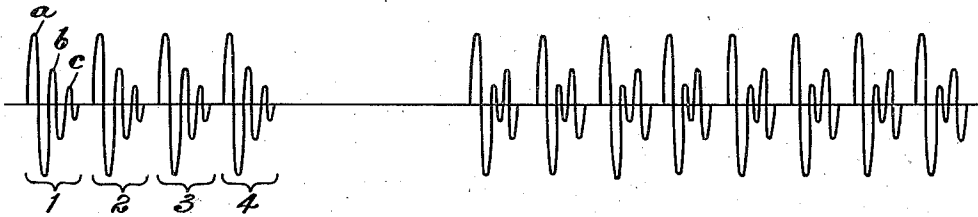


Fig. 2.

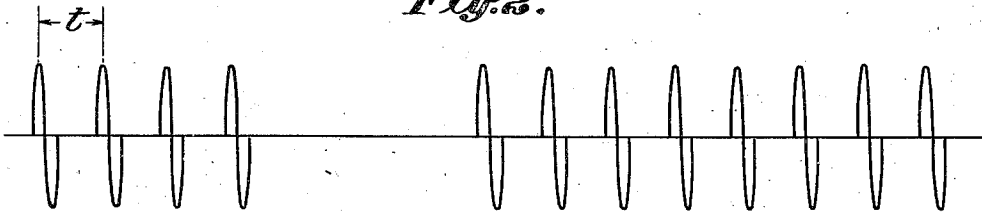
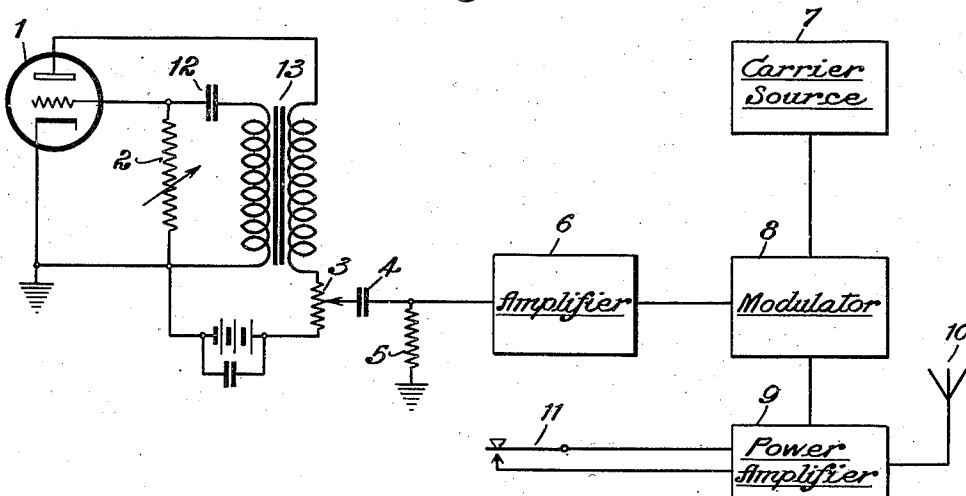


Fig. 3.



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2 Sheets-Sheet 2

Fig. 4.

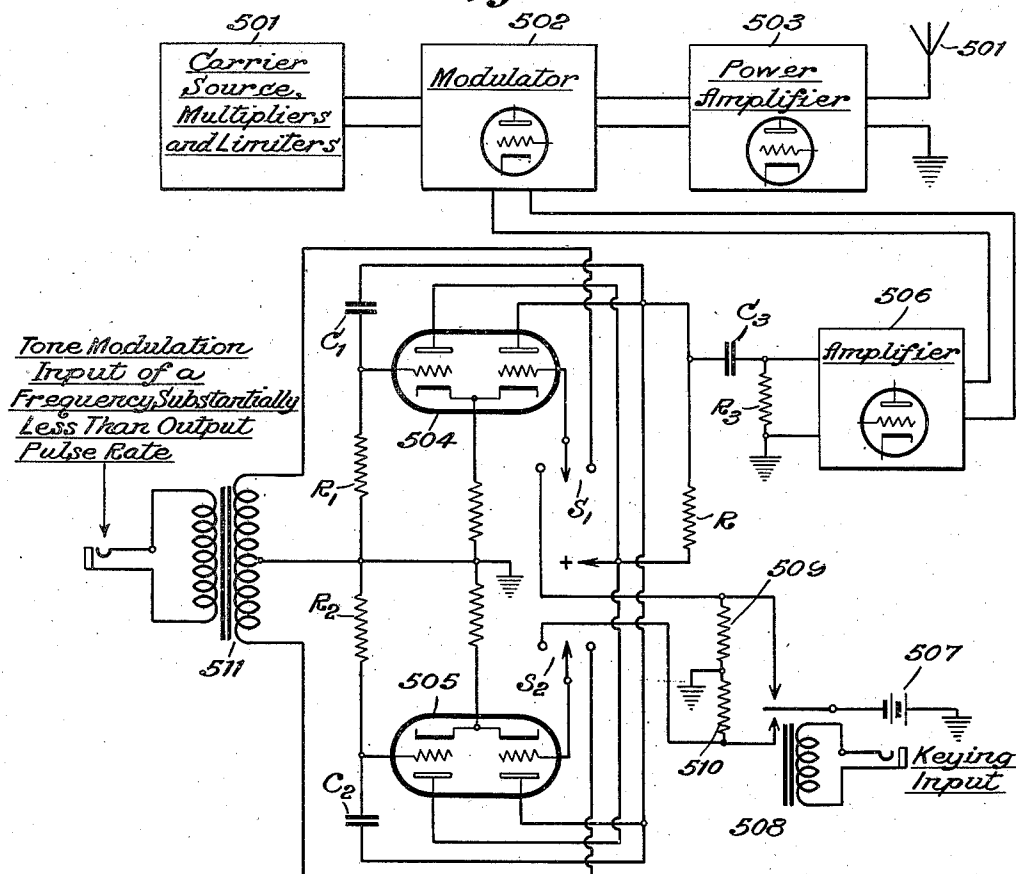


Fig. 5a.

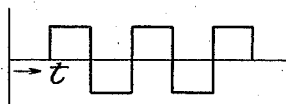
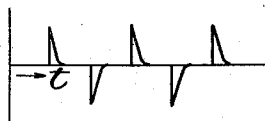


Fig. 5b.



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PULSE COMMUNICATION SYSTEM

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Application April 30, 1941, Serial No. 391,059

18 Claims. (Cl. 250-6)

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This invention relates to improvements in radio communication over long distances, and particularly toward reducing the effects of multipath transmission in communication systems.

It has been known in the radio art that long distance radio transmission is accompanied by the arrival of signal power at the receiver over more than one path. The multiple paths are produced because the waves which reach the receiver have been refracted and reflected between the ionosphere and the earth a number of times, because of refraction from different ionized layers or regions in the atmosphere and because of magneto ionic splitting of the waves into components of different velocities. There have also been many instances of transmission simultaneously around the earth in different directions. A common result of the multipath transmission between transmitter and receiver is that useful signal modulations arriving at the receiver are badly distorted and do not faithfully reproduce the modulations of the transmitter. It often happens that the difference in phase relations between the signals arriving over several paths produce complete fade-out.

It is known to transmit keyed signals by keying a steady unmodulated carrier (continuous wave) or to key a carrier which is modulated by a sinusoidal or approximately sinusoidal wave (interrupted continuous wave). Where interrupted continuous waves have been employed, it has been the practice to apply the modulation as an amplitude, phase or frequency modulation, and to key the wave in the usual make and break manner. It has been found that both of these known types of keyed signals are subject to fading due to the multipath phenomenon, and that the steady unmodulated carrier (continuous wave) is affected more adversely by multipath fading than the interrupted continuous wave.

The primary object of the invention is to minimize or substantially reduce the effects of fading and signal distortion caused by the multipath phenomenon. To achieve this object, it is proposed to transmit signals by means of pulses which are so short that when received over multiple paths the resulting succession of pulses do not overlap. Putting it another way, it is proposed to transmit the pulses with spacing between adjacent pulses greater than the delay time between the first and last significant or important pulses received over the multiple paths for each transmitted pulse. Thus, it will be evident that by means of the present invention there is obviated the possibility of the energy arriving at a

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receiver over one of the multiple paths cancelling that arriving over another path, and there is thus removed the underlying cause of fading due to the multipath phenomenon.

A more detailed description of the invention follows in conjunction with drawings, wherein:

Figs. 1 and 2 are graphs given to aid in an understanding of the present invention:

Figs. 3 and 4 show schematically, transmitter circuits for transmitting spaced pulses in accordance with the principles of the present invention; and

Figs. 5a and 5b are graphs given to aid in an understanding of the operation of the system of Fig. 4.

Referring to Fig. 1, there are shown a plurality of groups of pulses 1, 2, 3, 4, etc., each group of pulses representing the pulses received at a receiving station over a plurality of paths as a result of a single pulse transmitted at a remote station. By referring to each group of pulses of Fig. 1, it will be noted that each group is made up of a series of pulses constituted by an initial pulse *a* followed by later arriving pulses *b* and *c*. The relative intensities of the pulses in each group vary erratically, depending upon the conditions of the paths over which they arrive at the receiver. And, although the first pulse *a* is shown to be of greater amplitude than the succeeding pulses *b* and *c*, it should be understood that in practice the first arriving pulse of each group may be of smaller amplitude than a later arriving pulse. Each pulse group of Fig. 1 comprising the pulses *a*, *b* and *c* is representative of a series of pulses which may be received at a receiver when a single transmitted pulse is transmitted in accordance with the graph of Fig. 2. It is proposed, in accordance with the invention, to space the transmitted pulses at the transmitter (as shown in Fig. 2) so that the time *t* between succeeding transmitted pulses is greater than the time delay between the first and last significant important pulses (here shown as *a* and *c*) received over the multipaths for each transmitted pulse. As an illustration, the impulses sent out at the transmitter may have a frequency of recurrence of 1000 per second, in which case the time *t* shown in Fig. 1 would be $\frac{1}{1000}$ of a second. This illustration of 1000 impulses per second is not to be construed as a limitation, since obviously the recurring pulses may have different frequencies so long as the essential limitation concerning the spacing between impulses, as mentioned above, is followed. This rate of recurrence of the impulses trans-

mitted often depends upon multipath conditions existing at the time of transmission, and also upon the frequency of the transmitted carrier.

Fig. 3 illustrates one method by which suitably spaced impulses can be transmitted in order to achieve the primary object of the present invention. Referring to this figure, there is shown a transmitter circuit composed of a high frequency source of carrier waves 7 which feeds into a suitable modulator 8, the output of which is coupled to a power amplifier 9 for radiating the transmitted pulses from an antenna 10. A suitable keying device 11 is shown coupled to the power amplifier 9 for keying the radiated power in the usual make and break fashion. This keying device may be replaced by any known system of amplitude modulation for applying tone or similar modulation to the power amplifier 9.

In order to interrupt the carrier wave, and produce suitably spaced pulses, there is provided an impulse generator 1 in the form of a blocking oscillator of a type well known in the art for obtaining impulses in television systems. This impulse generator is shown as an electron discharge device whose anode is coupled to one winding of a transformer 13, the other winding of which is shown coupled to the control grid through a condenser 12 and a variable grid leak 2, thus providing an inductive feedback oscillator. The value of the grid leak 2 determines the rate of recurrence of the impulses generated by the blocking oscillator 1. Only the essential elements of this oscillator have been shown, since it forms no part of the present invention per se. Output energy from the impulse generator 1 is taken from the potentiometer 3 in series with one winding of the transformer 13 and is fed through a high frequency pass circuit consisting of a condenser 4 and a resistor 5 to the input of an amplifier 6. This high pass circuit 4, 5 filters out the audio oscillations which may be produced in the blocking oscillator circuit, and prevents these from being passed on to the amplifier 6. The impulses passing through the circuit 4, 5 which are impressed upon the amplifier 6 occur at the start and stop of the square wave form dot produced in the blocking oscillator 1 and may take the form of an extremely sharp pulse. Amplifier 6 serves to augment the intensity of the sharp impulses impressed upon it to a level sufficient to completely modulate energy from carrier 7 fed into modulator 8. Modulator 8 may be a grid-modulated stage chosen so that no radio frequency energy passes therethrough until an impulse arrives from impulse generator 1 and amplifier 6. That is, a high bias may be applied to the grid of the modulator so that no radio frequency energy is passed by the modulator until the grid thereof is biased positive or to its working point by the voltage from the amplifier 6. The radio frequency output radiated from antenna 10 is represented by the spaced impulses of radio frequency energy, as shown in Fig. 2. In referring to Fig. 2, the first four impulses represent a dot, while the last eight impulses represent a dash, the intervening time between the dot and the dash representing a space.

Fig. 4 illustrates a system for applying frequency modulation to a pulse generator wherein the carrier is steady in frequency and the radiated energy is chopped into short pulses by means of an amplitude modulator. In this system, the frequency modulation is applied to the pulse generator so that the number of pulses per second is modulated in accordance with the mod-

ulation. That is, in the case of telegraph keying, a "mark" might produce 1000 pulses per second, while a "space" might produce 800 pulses per second. The pulse generator of Fig. 4 comprises, in effect, a pair of dual-triode electron discharge devices 504 and 505, each of which is arranged in a multivibrator circuit in accordance with the system described in my pending application Serial No. 273,460, filed May 13, 1939, now United States Patent 2,269,417, to which reference is made. A condenser C₁ and a resistor R₁ in circuit with certain electrodes of the dual triodes 504 (as shown in the drawings) control the frequency of oscillation of this particular vacuum tube. Similarly, condenser C₂ and resistor R₂ in circuit with certain electrodes of dual-triode 505 control the frequency of oscillation of this last electron discharge device. In both devices the oscillation frequency is determined by the time constants or values of the particular condensers C₁, C₂ and resistors R₁, R₂. Actually, the two time constant circuits C₁, R₁ and C₂, R₂ are tuned to different frequencies so that if each dual-triode is excited separately different frequencies of oscillation would be obtained in their common output represented by the plate resistor R. Because the two tubes are coupled together through the common plate resistor R, they are locked in step and the frequency of oscillation when both are working simultaneously is mid way between the individual frequencies for the unmodulated condition. Modulation is applied to the grids of the two tube structures not directly associated with the time constant elements, in order that the relative amplitudes of oscillation may be varied. In this way, the frequency of the output is modulated between the individual frequencies of the two vacuum tube circuits.

The dual-triodes 504 and 505 of Fig. 4 constitute, in effect, a generator of square wave pulses whose wave form is represented in Fig. 5a. The square waves of Fig. 5a produced by the pulse generator 504 and 505 are impressed upon high frequency pass circuit C₃, R₃ which converts the wave form of Fig. 5a to the wave form of Fig. 5b, prior to passing the energy on to the amplifier 506. In effect, the high frequency pass circuit C₃, R₃ may be considered a differentiating circuit which gives an output proportional to the rate of change of the applied voltage, in order to produce pulses as shown in Fig. 5b. Either the positive or negative impulses of Fig. 5b may be used to affect the modulator 502 after being amplified in 506. Amplifier 506 serves to raise the level of the wave form of the energy applied thereto, as represented in Fig. 5b, to a level sufficient to properly modulate the energy applied by apparatus 501 to the modulator 502. Apparatus 501 represents a stable source of carrier frequency, which, if desired, may be followed by frequency multipliers and amplitude limiters. The output from the modulator 502 is amplified in a power amplifier 503 before being radiated over an antenna 501 in the form of spaced radio frequency pulses with a variable recurrence rate. From what has been given above, it will be noted that the relative amplitudes of the two pulse generators 504 and 505 are modulated by the signal and the rate of pulse generation is modulated between the two pulse rates of the individual generators.

If the modulation applied to Fig. 4 is telegraph keying, the keying voltage is fed to the coil of relay 508. Switches S₁ and S₂ are thrown to the left so as to connect the right-hand grids to re-

sistors 509 and 510, and to the relay contacts. The arm of the relay 508 is connected to battery 507 so that when contact is made to one of the relay points, the particular right-hand grid to which it is connected is biased by the battery 507. This unbalances the relative amplitude of oscillation so that the frequency of the square-wave-form dots is shifted towards the circuit of the tube with the strongest oscillation amplitude.

If tone or similar modulation is to be applied, the signal is applied to the primary of transformer 511. The secondary of this transformer differentially modulates the two right-hand grids so that their relative amplitudes of oscillation are varied. For this type of modulation, switches S₁ and S₂ are thrown to the right to connect the grids to the transformer.

Condenser C₃ and resistor R₃ form the differentiating circuit which converts the square-wave form of Fig. 5a to the impulses of Fig. 5b. The duration of the pulse may be adjusted to be very short by adjusting the bias on amplifier 506 and modulator 502 so that only the peaks of the impulse operate the modulator. For longer pulses, the biases are adjusted so that more of the pulse is effective.

Reception of this type of pulse transmission, where the pulse rate is frequency modulated, is accomplished with an amplitude modulation receiver which feeds a frequency modulation subcarrier receiver. The output of the amplitude modulation receiver consists of a variable frequency which has the frequency of the pulse rate. This variable frequency tone is fed to a frequency modulation receiver which consists of a limiter and a means for converting the variable-frequency subcarrier into an amplitude modulated subcarrier. The amplitude modulated subcarrier is detected in the normal manner. The output of the subcarrier receiver thus corresponds to the frequency variations applied to the pulse rate.

The impulse transmitter of Figs. 3 and 4 is advantageous from the standpoint of transmitter economy. Since the impulse is only present for a fraction of the time that a steady carrier would be, the power drawn by the power amplifier is reduced and the tube heating is also reduced. This allows a heavier loading of the power tubes and a consequently higher tube output.

What is claimed is:

1. The method of reducing fading in a radio circuit produced by multipath effects in the atmospheric signal medium between a transmitter and receiver which comprises radiating signal energy in pulses having an audio frequency rate of recurrence, each pulse having a time duration which is less than the delay time between the first and last significant or important pulses received over the multiple paths for each radiated pulse, and modulating the number of pulses per second prior to radiation in accordance with the signals to be transmitted.

2. The method of reducing fading in a radio circuit produced by multipath effects in the atmospheric signal medium between a transmitter and a receiver which comprises producing square-wave form pulses, modulating the amplitude of the pulses in accordance with signals to thereby produce a corresponding modulation of the pulse rate, obtaining sharp pulses from the slopes of said amplitude modulated square wave form pulses, modulating a stable carrier frequency by said sharp pulses to produce interrupted radio frequency pulses having a spacing therebetween which is greater than the delay time between the

first and last significant or important pulses received over the multiple paths for each radiated radio frequency pulse.

3. In combination, a square-wave form oscillator comprising a pair of electrode structures, each structure having an anode, a cathode and a grid; a frequency determining circuit coupled to the anode of one structure and the grid of the other structure; a common cathode resistor for both said structures; an output circuit coupled to the anode of said one structure; signal modulating means coupled to the grid of said one structure; said output circuit comprising elements so arranged as to transform the square-wave pulses of said oscillator into shorter pulses which are proportional to the rate of change of the square wave applied to said output circuit; a source of carrier radio frequency oscillations; and a modulator for modulating said source by said transformed pulses to produce interrupted radio frequency pulses.

4. A system for reducing fading in radio circuits caused by the multipath phenomenon in the signal medium comprising, in combination, a square-wave form audio frequency oscillator constituted by a pair of electrode structures, each structure having an anode, a cathode and a grid; a frequency determining circuit coupled to the anode of one structure and the grid of the other structure; a common cathode resistor for both said structures; an output circuit coupled to the anode of said one structure; signal modulating means coupled to the grid of said one structure; said output circuit comprising elements so arranged as to transform the square wave pulses of said oscillator into shorter pulses which are proportional to the rate of change of the square wave applied to said output circuit; a stable source of carrier radio frequency oscillations; and a modulator for modulating said source by said transformed pulses to produce interrupted radio frequency pulses, the spacing between transformed pulses of the same polarity being greater than the delay time between first and last significant or important pulses received over the multiple paths for each transmitted radio frequency pulse.

5. In combination, a square wave form oscillator comprising a pair of electrode structures, each structure having an anode, a cathode and a grid; a frequency determining circuit coupled to the anode of one structure and the grid of the other structure; a common cathode resistor for both said structures; another similar square wave form oscillator having a different frequency than said first oscillator; signal modulating means coupled to the grid of said one structure of both oscillators; a common output circuit coupled to the anode of said one structure of both oscillators, said output circuit comprising elements so arranged as to transform the square wave pulses of said oscillators into pulses which are proportional to the rate of change of the square wave applied to said output circuit, a stable source of carrier radio frequency oscillations; and a modulator for modulating said source by said transformed pulses to produce interrupted radio frequency pulses.

6. A transmitter system for reducing fading in radio circuits caused by the multipath phenomenon in the atmospheric signal medium comprising a source of high frequency waves, a modulator coupled to said source, an impulse generator coupled to said modulator for interrupting said carrier wave, an amplifier in the output of said

modulator, an antenna coupled to said amplifier, and an amplitude modulation system coupled to said amplifier, said impulse generator including a differentiator circuit and being so constructed and arranged that it produces interruptions in said carrier wave, the durations of which are greater than the delay time between the first and last significant or important pulses received over the multiple paths for each pulse transmitted over the antenna.

7. A transmitter system for reducing fading in radio circuits caused by the multipath phenomenon in the atmospheric signal medium comprising a source of high frequency waves, a modulator coupled to said source, an impulse generator coupled to said modulator for interrupting said carrier wave, an amplifier in the output of said modulator, an antenna coupled to said amplifier, and a signal modulation system coupled to said amplifier, said impulse generator including a differentiator circuit and being so constructed and arranged that it produces interruptions in said carrier wave, the durations of said interruptions being greater than the delay time between the first and last significant or important pulses received over the multiple paths for each pulse transmitted over the antenna, and a characteristic of the modulated interrupted carrier wave varying in accordance with the signal modulation applied thereto.

8. A transmitter for sending out pulses of carrier waves comprising a source of carrier waves, a modulator coupled to said source, an amplifier coupled to the output of said modulator, an antenna coupled to said amplifier, an impulse generator in the form of a blocking oscillator for producing a wave of rectangular form, a high frequency pass filter coupled to said blocking oscillator for producing sharp pulses from the slopes of the rectangular wave produced by said oscillator, an amplifier for amplifying said sharp pulses, and a connection from said last amplifier to said modulator for causing said modulator to pass pulses of carrier oscillations, and means for modulating a characteristic of said oscillations.

9. A radio transmitter for radiating pulses of power of constant high frequency carrier oscillations, including a pulse generator for modulating the pulse rate in accordance with the signal modulation, said pulse generator comprising a pair of oscillators which produce different frequencies of oscillation when excited individually and which produce a frequency of oscillation midway between the individual frequencies when excited simultaneously.

10. A radio transmitter for radiating pulses of power of constant high frequency carrier oscillations, including a pulse generator for modulating the pulse rate in accordance with the signal modulation, said pulse generator comprising a pair of oscillators which produce different frequencies of oscillation when excited individually and which produce a frequency of oscillation midway between the individual frequencies when excited simultaneously, each of said oscillators having a time constant circuit composed of a resistance and a condenser for determining the frequency of oscillation thereof, said time constant circuits being tuned to different frequencies, a common anode resistor for said oscillators, and means for applying signal modulating potentials to the inputs of said oscillators, whereby the frequency of output of said pulse generator is modulated between the individual frequencies of the two oscillators and the generator produces

said midfrequency for the unmodulated condition.

11. A radio transmitter for radiating pulses of power comprising a carrier source, a modulator coupled to said source, a power amplifier coupled to said modulator, an antenna coupled to the output of said power amplifier, and an impulse generator also coupled to said modulator for causing an interrupted flow of carrier frequency oscillations through said modulator, said impulse generator producing pulses of different frequencies in response to modulating potentials.

12. A transmitter for sending out pulses of carrier waves comprising a source of carrier waves, a modulator coupled to said source, an amplifier coupled to the output of said modulator, an antenna coupled to said amplifier, an impulse generator in the form of a blocking oscillator for producing a wave of rectangular form, a high frequency pass filter coupled to said blocking oscillator for producing sharp pulses from the slopes of the rectangular wave produced by said oscillator, an amplifier for amplifying said sharp pulses, and a connection from said last amplifier to said modulator for causing said modulator to pass pulses of carrier oscillations, and means for keying said pulses of carrier oscillations.

13. A pulse type transmitter comprising a source of radio frequency carrier waves, a modulator coupled to the output of said source, a pulse generator coupled to the input of said modulator for producing an output from said modulator composed of pulses of radio frequency carrier waves, and means for modulating the pulse rate in accordance with signals to be transmitted.

14. A pulse type transmitter comprising a source of radio frequency carrier waves, a modulator coupled to the output of said source, a pulse generator coupled to the input of said modulator for producing an output from said modulator composed of equal width pulses of radio frequency carrier waves, and means for modulating the pulse rate in accordance with signals to be transmitted.

15. A pulse type transmitter comprising a source of radio frequency carrier waves, a modulator coupled to the output of said source, an electron discharge device pulse generator, means coupled between the output of said pulse generator and the input of said modulator for producing short impulses which occur at the start and stop of the longer duration pulses produced by said pulse generator to thereby cause said modulator to produce pulses of radio frequency carrier waves, and means for controlling the number of pulses to be sent out in accordance with signals to be transmitted.

16. A pulse type transmitter comprising a source of radio frequency carrier waves, a modulator coupled to the output of said source, an electron discharge device pulse generator, means coupled between the output of said pulse generator and the input of said modulator for producing short impulses which occur at the start and stop of the longer duration pulses produced by said pulse generator to thereby cause said modulator to produce equal length and equal duration radio frequency carrier wave pulses which are short compared to the time intervals between them, and means for transmitting two different trains of said pulses in accordance with two different signal code characters.

17. The method of reducing fading in a radio circuit produced by multipath effects in the at-

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atmospheric signal medium between a transmitter and a receiver which comprises radiating signal energy in pulses having a predetermined frequency rate of recurrence, each pulse having a time duration which is less than the delay time between the first and last significant or important pulses received over the multiple paths for each radiated pulse, and interrupting the radiation of said pulses in accordance with two different signal code characters to produce different trains of pulses of different recurrence rates.

18. A transmitter for sending out pulses of carrier waves comprising a source of carrier waves,

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a modulator coupled to said source, an amplifier coupled to the output of said modulator, an antenna coupled to said amplifier, an impulse generator in the form of a blocking oscillator for producing a wave of rectangular form, a high frequency pass filter coupled to said blocking oscillator for producing sharp pulses from the slopes of the rectangular wave produced by said oscillator, means coupling said filter to said modulator for causing said modulator to pass pulses of carrier oscillations, and means for keying said pulses of carrier oscillations.

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