Oct. 9, 1923. **1,470,088**

F. LOWENSTEIN

ART OF WIRELESS COMMUNICATION

Filed Nov. 29, 1918

Fig. 1.

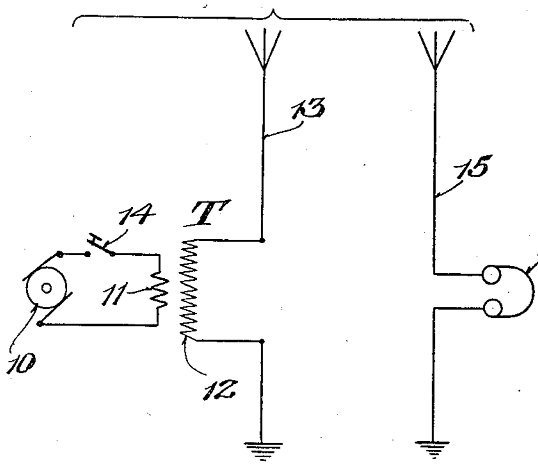


Fig. 3.

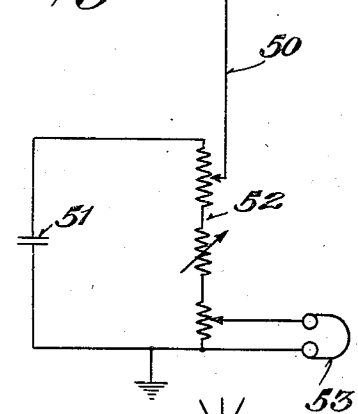
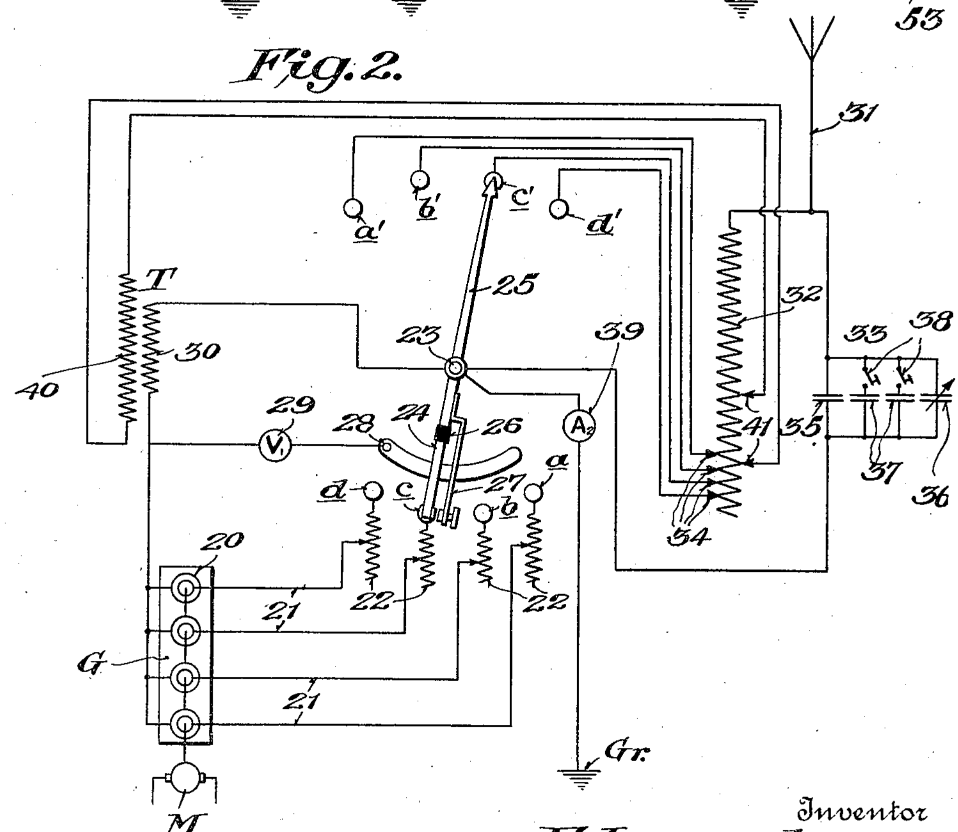


Fig. 2.



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UNITED STATES PATENT OFFICE.

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ART OF WIRELESS COMMUNICATION.

Application filed November 29, 1918. Serial No. 264,642.

To all whom it may concern:

Be it known that I, FRITZ LOWENSTEIN, a citizen of the United States, residing at New York, in the county of New York and State of New York, have invented certain new and useful Improvements in the Art of Wireless Communication; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to the art of wireless communication. More particularly, it relates to wireless transmission and reception of signals or messages by means of sinusoidal alternating current impulses of relatively low frequency. The invention comprises both the method of transmitting and receiving signals or messages, and apparatus whereby the method may be carried out.

Methods of wireless communication available heretofore comprise ordinary radio or high frequency transmission, visual methods of various kinds, and acoustic methods, such as submarine acoustic signaling. A principal object of the present invention is to provide a new method of communication which can be used in addition to or in conjunction with the methods heretofore available, without interfering with such methods or being interfered with by them. Another object of the invention is to enable limitation of the effective transmitting range to be a relatively small and comparatively well defined radius, within which radius the transmitted signals are of ample strength or intensity to permit of ready reception, but beyond which their intensity diminishes so rapidly that they cannot be successfully received.

In high frequency or true radio transmission, the wave lengths employed are much less than the transmitting distances, ordinarily only from one one-thousandth to one one-hundredth of the transmitting distances. With this type of transmission, the intensity of signals received at the receiving station or stations varies approximately inversely as the distance from the sending station. Thus, in the case of two receiving stations, one ten times as far from the sending station as the other, the intensity of the signal received at the first station will be about one-tenth as strong as that received at the nearer station. The diminution of intensity is obviously not abrupt or rapid, however. Since in practice it is necessary or desirable that the signal shall have an audibility at the desired receiving station of at least about 10 (i. e., 10 times the usual arbitrary standard unit of audibility), it is therefore evident that in high frequency operation, the signal may and usually does come in, at distances from the sending station much greater than the desired receiving station, strongly enough to be picked up by unauthorized or hostile operators, or to interfere with signals of about the same wave length sent out by other operators far beyond the desired range of transmission from the first sending station.

These disadvantages are avoided in my invention, and important novel advantages are secured, by employing frequencies very much lower than have been used heretofore in transmitting radio signals from a sending station to a receiving station. Generally speaking, I employ a frequency so low that the length (λ) of the transmitting wave is at least as great as the intended transmitting distance (d), and most desirably very much greater. For example, the wave length may be from ten to one hundred or more times the transmitting-distance. Under the conditions assumed, and especially when the wave length is more than three or four times the transmitting distance, the electric intensity of the wave diminishes with great rapidity, that is, substantially as the third power of the distance from the sending station. This fact appears from a consideration of Hertz' formula for electric force (E) of an electric radiator, which may be written

$$E = 2\frac{Qh}{d^3}\sqrt{1-4\pi^2\left(\frac{d}{\lambda}\right)^2+16\pi^4\cdot\left(\frac{d}{\lambda}\right)^4}$$

where Q is the electric charge given to the antenna and h is the height of the charge above ground. Where λ is much greater than d, it is evident that the signal may be so weak at a comparatively short distance beyond the receiving station as to be incapable of reception by practical receiving means.

In radio transmission it has been customary heretofore to employ frequencies of from 30,000 to 500,000 cycles per second corresponding to wave lengths of 10,000 meters to 600 meters; and, very rarely, as low as 10,000 cycles, corresponding to a wave length of 30,000 meters. The present method involves frequencies of a much lower order of magnitude, say 500 to 1,000 cycles per second, corresponding to wave lengths of from 600,000 meters to 300,000 meters. These frequencies evidently are not included in what are commonly termed radio frequencies in the art. Frequencies below 10,000 cycles are referred to herein as relatively low frequencies.

The novel method herein described evidently has some very important advantages. Thus, for signaling between ships of a naval fleet, it has the great advantage of secrecy not possessed by present radio methods. For example, if an enemy receiver be located ten times as far from the transmitter as the intended friendly receiver, the intensity of the impulse reaching the enemy receiver is approximately only one one-thousandth of the intensity at the friendly receiver, whereas with ordinary radio transmission it would be one-tenth. From the standpoint of secrecy, therefore, the odds in favor of low frequency transmission are 100 to 1 under the conditions assumed.

Again, the great difference in frequency between the currents used in my method and those used in ordinary radio transmission permits employing receiving devices in my method which are unresponsive to impulses of customary radio frequency, thus ensuring non-interference in simultaneous operation. If, as in the specific examples hereinafter described, the frequency employed is within the range of audibility for which the human ear is sensitive, a telephone may be used directly for reception. Freedom from interference with signals even of identical frequency being transmitted in a region somewhat beyond the intended transmitting range, is also ensured.

A further advantage of the new method lies in the simplicity of the transmitting and receiving apparatus, as will more fully appear hereinafter.

Still another advantage is that, at the low frequencies in question, the antenna behaves simply as a capacity reactance, so that any variation in the size of the antenna may be perfectly compensated for, when a tuned antenna circuit is used, by correspondingly varying capacity in parallel with the antenna.

The continuous character of the alternating currents employed makes possible a high degree of selectivity, so that any number of communications may be carried on simultaneously within the same transmitting region at frequencies differing from one another by as little as approximately 2 per cent, without unreasonable size and cost of the receiving device.

The principles of the invention can be most readily explained further in connection with typical concrete examples which are hereinafter described in detail for the sake merely of illustration and not with the intention of restricting the invention thereto.

In the accompanying drawings, which are more or less diagrammatic in character,

Fig. 1 represents a very simple type of non-selective system embodying the invention; and

Figs. 2 and 3 represent a tuned system for selective signaling by means of which the invention can be practiced with special advantage, Fig. 2 representing the transmitting part of the system, and Fig. 3 the receiving part.

Referring to Fig. 1 which illustrates a simple arrangement of sending and receiving stations, the transmitter comprises in this particular instance an alternating current generator 10 having in circuit therewith the primary 11 of a step-up transformer, whose secondary 12 is in circuit with the antenna 13. The primary circuit contains the operating key 14. The receiving station here shown comprises simply an antenna 15 having a telephone 16 inserted in circuit therewith. In an actual installation, the generator was a 500 cycle, 220 volt, alternator, of well known construction, and the transformer stepped the voltage up to 22,000 volts. The wave length used was approximately 600,000 meters. In ship tests, it was estimated that at 1200 yards the received signal had an audibility of 5000; and at 2800 yards, about 5. At 4000 yards, no signal could be heard. Roughly speaking, the operating wave length was about 500 times the transmitting distance in the first case, 200 times in the second case, and 150 times in the third case. At the relatively low voltage employed, and under the particular conditions of the test, the effective transmitting range was evidently limited to somewhat more than one sea mile of 2000 yards, within which range the signals were loud and clear. At slightly greater distances, the transmitted signals could not be detected.

For most purposes, an arrangement in which the transmitting wave length may be varied either by predetermined steps, or in a smoothly continuous manner, and in which both the sending and receiving antenna circuits are sharply tuned to permit accurate selective sending and receiving, is preferable to the simple embodiment of the invention shown in Fig. 1. A desirable form of such selective system is illustrated in Figs. 2 and 3. The transmitter arrangement shown in Fig. 2 has the further important advantage that it enables the use of power generating apparatus directly proportional in size and rating to the actual kilowatt output, instead of to the kilovolt-ampere output of the system. It is thus possible to use a small generator for the small power output required for inter-ship communication in fleet signaling, for example, and at the same time to secure the necessary voltage on the antenna and other essential conditions of operation.

The transmitter system here illustrated comprises a primary power circuit supplying power to a sharply tuned or sharply tunable antenna circuit. Means of any suitable character are provided in the power circuit for generating alternating current of several low frequencies at which it may be desired to send. In the present example, a special type of generator, capable of delivering current at any one of several frequencies for a given running speed, is employed. Said generator is indicated generally at G, and its driving motor at M. As its specific construction is not material to my novel method and system, considered as a whole, it will not be described in detail herein. It may be stated, however, that in this example the generator comprises several sets of cooperating rotors and stators, corresponding, respectively, to the several operating frequencies desired, the rotors being mounted upon and driven by a single shaft, and the necessary excitation being provided by field windings of appropriate character.

Current generated at any one of the several available frequencies can be obtained at will by suitable connection to one of the corresponding terminals 20. As here shown, leads 21 connect said terminals, respectively, through variable reactances 22, to corresponding switch contacts *a*, *b*, *c* and *d*, this side of the power circuit being most desirably connected to ground *Gr* any suitable manner by way of any one of the said switch contacts. In the present embodiment of the invention, connection to ground is effected by means of a combined wave change switch and key device pivoted at 23. A conductive member 24 forming a part of said device, is arranged to engage any one of the generator contacts *a*, *b*, *c*, and *d* as the wave change device is swung about its pivot in one direction or the other. Another conductive member or arm 25 of said device is normally insulated from member 24 by insulation 26 but may be electrically connected therewith by means of the operating key 27 which is suitably pivoted on the arm 25. For convenience in determining the generator voltage at each of the several operating frequencies, the member 24 may be arranged also to engage a conductive strip 28 which is connected through the volt meter 29 to the other side of the generator circuit. The particular arrangement just described is merely one desirable form of mechanism which may be employed in this connection, and further detailed description thereof is unnecessary here.

The other side of the generator circuit includes a primary transformer winding 30 connected to ground *Gr* as indicated.

In the specific and very desirable embodiment of the invention here illustrated, the antenna 31 forms part of a sharply tunable radiating circuit having two branches comprising, respectively, an inductance 32 and a variable capacity indicated generally at 33 in parallel therewith. The proportion of inductance 32 in circuit is variable in accordance with the transmitting wave length to be employed. To this end are provided adjustable taps 34 which are respectively connected to corresponding terminal contacts *a′*, *b′*, *c′*, and *d′*, which in turn correspond respectively with terminal contacts *a*, *b*, *c* and *d* of the oscillation circuit. One end of the arm 25 of the wave change handle or switch is arranged to engage any one of the terminals *a′*–*d′* selectively, the arrangement being such that corresponding pairs of contacts in the two series are simultaneously connected to ground through the pivot 23 on which the switch turns. The variable capacity is most conveniently made up of a fixed condenser 35, a variable tuning condenser 36, both always in the antenna circuit and arranged in parallel with respect to each other, and additional condensers 37, normally out of circuit, but capable of being placed in parallel with the other condensers, when necessary, by switches 38. The condensers 36 and 37 are provided primarily for use in case the length of the antenna proper becomes altered for any reason, as by having a portion shot away. This branch of the antenna circuit is also connected to ground through the switch pivot 23, as shown. A hot wire ammeter 39 may be placed in the antenna circuit.

Energy is suitably transferred from the closed oscillation or power circuit to the antenna circuit, in this instance through the high tension transformer secondary 40, cooperating with the primary 30, and connected as shown to variable points 41 on the antenna inductance 32, this part of the arrangement constituting a step-up auto-transformer. It is evident, therefore, that the desired voltage on the antenna is secured in the present arrangement by stepping up the generator voltage twice. In a typical instance, the generator may give 5 amperes at 50 volts, this voltage being stepped up to 10,000 in the first transformer, and to an antenna voltage of 40,000 in the second transformation. This arrangement has special advantages, among which may be mentioned simplifying of transformer design.

In a typical instance, the generator may be designed to produce current at frequencies differing from say 650 to 800 cycles by steps of 50 cycles. By adjustment of the tapping points 34 on the inductance 32, and, if necessary, also adjusting the reactances 22, the apparatus can be properly set by means of preliminary tests made at each of the desired operating frequencies to give the proper antenna voltage at each of said frequencies. At the same time, the variable condenser 36 may also be set, in the course of the preliminary tests, to such a value that the antenna circuit is properly tuned at each of said operating frequencies. The preliminary tests having enabled the apparatus to be set for proper operating voltage and tuned at each frequency to be used, it is then only necessary for the operator to swing the wave change handle to engage any one of the respective pairs of contacts *a a'*, *b b'*, etc., and to press the key 27, to close the oscillation circuit and send signals at the selected frequency, the key being at ground potential and the operator being thus protected against injury.

Most desirably the variable connections 34 should be arranged near the ground end of the inductance winding 32, as here shown, in order to simplify adjustments for obtaining the proper antenna voltage. The transformer connections 41 should also be arranged as near the same end of the inductance 32 as practicable in order to reduce as far as possible the difference of potential between the transformer secondary 40 and ground.

In place of the simple untuned receiver illustrated in Fig. 1, it is much more desirable in practice to employ a tuned receiving system. This may take various forms within the scope of the invention, but a particularly desirable arrangement is illustrated in Fig. 3, where the antenna 50 is connected to ground through a two branch circuit which may comprise a condenser 51 and a variable inductance 52. A telephone receiver 53 may be adjustably shunted around part of said inductance and arranged to receive the incoming signals directly without the interposition of a detector. For the protection of the operator, the telephone is best connected on one side to the ground end of the inductance winding.

The connection of the antenna to the branched circuit is most desirably variable, as shown. Where the antenna is connected to ground through only a part of the total inductance, as here illustrated, signals of less intensity can be received than where the connection to ground is through the total inductance on the one hand and the condenser on the other.

While the systems above described are deemed particularly desirable, it is to be understood that the invention is not limited to the specific arrangements here chosen for purposes of explanation. As an example of changes falling within the scope of the invention, it may be noted that the non-selective transmitter shown in Fig. 1 may be used with the tuned receiver of Fig. 3; or the selective transmitter of Fig. 2 may be used with the non-selective receiver of Fig. 1.

What I claim is:

1. Apparatus for wireless communication comprising a unitary multi-frequency generator capable of delivering continuous alternating current at any one of several frequencies below 10,000 cycles, an antenna, and means whereby said antenna may be energized by said generator at any one of said frequencies selectively, in combination with signaling means in the generator circuit.

2. Apparatus for wireless communication comprising a closed oscillation circuit including a generator of continuous alternating current at audio frequency, a sharply tunable closed circuit, means for transferring energy from said oscillation circuit to said sharply tunable circuit and stepping up the voltage, and a radiating device arranged to draw energy from said sharply tunable circuit and to radiate it at the generator frequency.

3. Apparatus for wireless communication comprising a power circuit including a generator of continuous alternating current at audio frequency, an antenna, and an oscillatory branched circuit whereby said antenna may be connected to ground, the branches of said circuit containing, respectively, inductance and capacity, said power circuit being arranged to energize said branched circuit, and the system being so tuned that the antenna radiates energy at the generator frequency.

In testimony whereof I hereunto affix my signature.

FRITZ LOWENSTEIN.