To all whom it may concern:

Be it known that we, Michael I. Pupin, a citizen of the United States, residing at Norfolk, county of Litchfield, State of Connecticut, and Edwin H. Armstrong, a citizen of the United States, residing at Yonkers, county of Westchester, State of New York, have invented certain new and useful Improvements in Selectively Opposing Impedance to Received Electrical Oscillations; and we 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 an improvement in transmission of electrical signals which consists in prolonging the time necessary for an electrical action impressed upon the receiving conductor to arrive at a local power source or resistance compensator which, through its reaction, will produce negative resistance in the receiving conductor, whereby actions impressed upon the receiving conductor which last a time shorter than the time of their transmission to the local power source will not be aided by the power source. In other words, the interaction between the local power source and the receiving conductor is not instantaneous and therefore the local power source will not be excited to aid an electrical action of a duration shorter than a fixed minimum time interval.

For the purpose of illustrating the manner in which this invention is carried out in practice, reference is made now to the diagrammatic drawing which forms a part of this specification.

This diagram represents an antenna of a radio-receiving system in which a high resistance is inserted for the purpose of dissipating the energy of the incoming waves and which is provided with a source of power which, at the signalling frequency, will compensate these losses. In the arrangement shown this high resistance is inserted in the form of distributed resistance along the length of the antenna 1, as indicated by $I_1$, and the additional concentrated resistance $R_2$ near the lower end of the antenna. The method of compensation employed is not in itself any part of the present invention, but it is illustrated and described here for the sake of completing the disclosure. The method consists, broadly speaking, in providing a local source of energy, together with means, responsive to received waves of predetermined frequency, for impressing this local energy upon the receiving conductor to compensate, for that particular frequency, the energy losses incident to the high resistance of the conductor. The means employed consist of an electric valve, in this case, an audion, upon the grid of which the received oscillations are impressed thereby releasing energy from the local battery in the output circuit of the audion. This energy is transmitted through the transformer 7 and the circuits associated therewith, including the coil 11 and the companion coil 3, into the antenna, a second electric valve 8 being arranged in cascade with the valve 6, if desired, to increase the negative resistance reaction of the compensator. This compensating arrangement is already known. The additional element introduced into the receiving system described here is a wave conductor system—the well known artificial line—denoted by 5 and consisting of a suitable number of preferably equal inductances 12, 13, 14, ... and equal condensers 15, 16, 17, ... When an electrical pulse is impressed upon the antenna it is communicated, as is well known, to the exciting circuit of the resistance compensator 6, 7, 8, through the mutual inductance 4, 22. This action will be transmitted from 22 to the local energizing circuit over the artificial line and its time of transmission is determined by the total inductance, capacity and resistance of the line. Let $L$, $C$, and $R$ be the total inductance, capacity and resistance of the artificial line, then the time of transmission $t_1$ will be approximately

$$ t_1 = 10^{-8} \sqrt{1/C}, \text{ seconds} $$

Let

- $L = 6 \times 10^{-2}$ henrys
- $C = 12 \times 10^{-2}$ microfarads
- $t_1 = 8.4 \times 10^{-5}$ seconds.

If then, the time of action of the pulse upon the antenna and the process of discharge of the energy deposited by the pulse upon the 105 antenna is less than $8.4 \times 10^{-5}$ seconds, the local source of power cannot give any assistance to the pulse or the subsequent process of discharge of the energy deposited by it. It is obvious that any pulse will set up 110
in the artificial line free oscillations the duration of which, in the example given, may exceed $8.4 \times 10^{-4}$ seconds, although their amplitude will be greatly reduced by the uncompensated high resistance of the antenna. These oscillations can always be adjusted in such a way that their frequencies will be very different from the signalling frequency to which the resistance compensator is selectively adjusted. In the example given above the highest natural period will be less than 23000 P. P. S. if the line consists of six equal sections; and oscillations of this frequency will not be assisted by a resistance compensator selective to a signalling frequency of 25000 P. P. S.

If the signalling frequency is 25000 P. P. S. the artificial line will develop approximately two wave lengths for this frequency and, therefore, there will be a shift in phase of 120 degrees between the steady signalling waves and the energy introduced by the energizing circuit of the resistance compensator through the inductance 3—11 into the receiving antenna. This shift in phase cannot and does not, obviously, produce any detrimental effect upon the efficiency of interchange of energy between the energizing circuit and the antenna in response to the excitation of the steady signalling waves, and, therefore, the negative resistance produced in the antenna by the local power source is independent of this phase relation, so long as the signalling wave is simple harmonic or departs from the simple harmonic form slowly.

The phase relation between the action of the signalling waves and the reaction of the resistance compensator may be adjusted in well known ways as by varying the inductance of the artificial line or the tuning elements of the compensator. These tuning elements include, as is well known, the condensers and inductances in the grid and plate circuits of the electric valves 6 and 8.

For the purpose of detecting the received signals, it is only necessary, as is well known, to associate with one of the circuits of the receiving system, and preferably with the output circuit of the last valve, a suitable detector circuit. We have here illustrated a coil 20 associated with the coil 11 and connected in series with a rectifying detector 21 and a telephone 19, but it will be understood that this arrangement is merely illustrative.

It is obvious that the above described arrangement, by virtue of its different reactions to waves of the same frequency but of different duration, is capable of excluding from the receiving system even those disturbing impulses, or impulse components, which are of the signalling frequency but are of shorter duration than the signal.

What we claim is:

1. A receiving conductor in energy-transferring relation to the energizing circuit of a resistance compensator effective upon the receiving conductor, and a wave conductor system connecting the receiving conductor to the exciting circuit of the resistance compensator and having a predetermined inductance, capacity and resistance affording a substantial time interval of energy transmission over the wave conductor, whereby the positive resistance of the receiving conductor is opposed to received electrical disturbances of short duration but is compensated for received harmonic impulses of longer duration.

2. A receiving conductor in energy-transferring relation to the energizing circuit of a resistance compensator effective upon the receiving conductor, and a wave conductor system connecting the receiving conductor to the exciting circuit of the resistance compensator and having inductance capacity and resistance affording a substantial time interval of energy transmission over the wave conductor and attuned to electrical impulses of predetermined frequency, whereby the positive resistance of the receiving conductor is opposed to received electrical disturbances of short duration but is compensated for received harmonic impulses of longer duration and of the predetermined frequency.

3. A receiving conductor offering high initial impedance to received electrical wave energy, a local source of energy, and means excited by persistent received waves for transferring energy from the local source to the receiving conductor, after a predetermined time interval, to compensate the energy losses in the receiving conductor.

4. A receiving conductor offering high initial impedance to received electrical wave energy, a local source of energy, and means responsive to persistent received waves of a predetermined frequency for transferring energy from the local source to the receiving conductor, after the application of waves of that frequency through a predetermined time interval to compensate the energy losses in the receiving conductor for waves of that frequency.

5. A receiving conductor offering high initial resistance to received electrical wave energy, a resistance compensator in energy-transferring relation thereto and excited by wave energy received thereby, and means for delaying the compensating action for a time sufficient substantially to prevent its full development with respect to received electrical disturbances of short duration.

6. In a wave signalling system, a local power source, means for exciting said source by the action of the electrical signalling waves to produce a reaction, and means for adjusting the phase relations between the action of said waves and the reaction pro-
duced by the local power source after a fixed time interval.

7. In a wave signalling system, means for exciting a local power source by the action of the electric waves to produce a reaction comprising an electric valve, means for increasing the effect of the reaction, and means for aiding the effect of the electric waves by the reaction produced by the local source after an interval of time.

In testimony whereof we affix our signatures.

MICHAEL I. PUPIN.
EDWIN H. ARMSTRONG.