

Oct. 15, 1946.

P. F. G. HOLST ET AL

2,409,208

SIGNALING SYSTEM

Filed Dec. 24, 1941

2 Sheets-Sheet 1

Fig. 1.

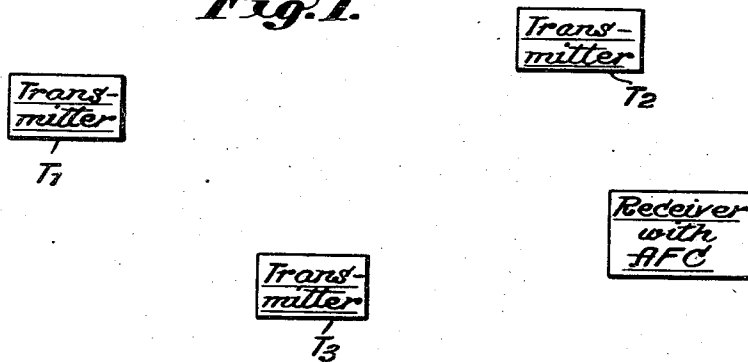


Fig. 3.

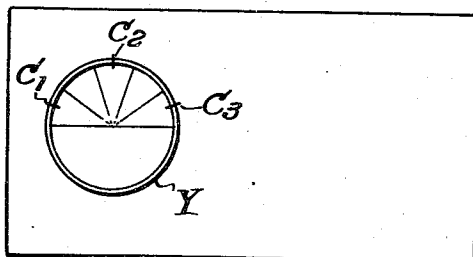
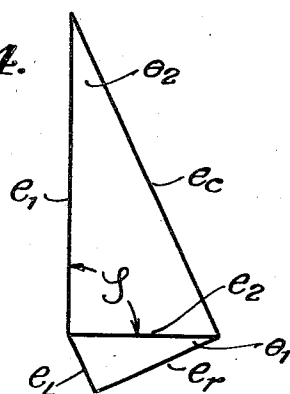


Fig. 4.



INVENTORS
Paul F. G. Holst, Loren R. Kirkwood
BY *H. S. Brower*
ATTORNEY

UNITED STATES PATENT OFFICE

2,409,208

SIGNALING SYSTEM

Paul F. G. Holst and Loren R. Kirkwood, Oaklyn,
N. J., assignors to Radio Corporation of Amer-
ica, a corporation of Delaware

Application December 24, 1941, Serial No. 424,298

4 Claims. (Cl. 250—6)

1

This application relates to a new and improved method of and means for signaling and in a sense may be considered a multiplex system since a plurality of transmitters operating simultaneously on different carriers are used to transmit signals to at least one receiver having a tuning range covering substantially only the band necessary to receive the transmitters.

In our system, the plurality of transmitters normally are transmitting simultaneously on their individual carriers. The carriers may or may not be modulated and a receiver tuned to the same must rely on the carrier frequency alone to identify the particular transmitter being received. The several carriers transmitted in the system may be modulated or one or more thereof may be modulated. The modulating signals may be the same on all carriers and per se are insufficient for identification purposes. As a consequence, it is of extreme importance that the receiver be of the single signal type, that is, receive or respond only to the carrier to which it is tuned.

If the normal methods such as are known in the broadcast art were applied here, image frequency reception, poor selectivity causing cross-talk, squeals due to harmonics of the receiver oscillator frequency beats with incoming signals, and phantom responses due to beats between channels would all work to provide in the receiver responses which would not be a true indication of the transmitter frequency and, as a consequence, could not be relied on to identify the particular transmitter being received. This would nullify entirely the very purpose of our system which, as stated above, is to provide means whereby a receiver can be tuned successively to a plurality of simultaneously transmitting transmitters and rely totally on carrier reception, modulated or unmodulated, for identification of the transmitters or the receiver, if this was to be avoided, would be unduly cumbersome and expensive.

In our system, frequency modulated transmitters are used and these transmitters do not include automatic frequency control means, nor do they include crystal stabilizing means. The one or more receivers, each of which covers all of the transmitters of one set-up, has an automatic frequency control system which will insure correct tuning regardless of whether the receiver was initially mistuned or whether that particular transmitter drifts for any reason during the time the receiver is tuned to it. Thus we may say that in our system selectivity and frequency stability

2

reside in the receiver, not in the transmitter as is usual.

The above condition results from the fact that in our novel system the transmitters are by necessity located at remote spaced points, are unattended, and are of short life since they must operate on batteries, which are of short life. The operating voltages of the transmitter may vary one half during the life of the batteries and therefore the frequency of the transmitter may vary considerably during operation which may extend over a range of, say, 4 or 5 hours. As a consequence, as stated above, the stability in the system resides primarily in the receiver which includes automatic frequency control means and which has been described in United States application, Serial No. 421,900, filed December 6, 1941, now Patent No. 2,367,352, granted January 16, 1945.

Our invention then relates to transmission of signals in a multi-channel system and has an object to select within a given frequency band the intermediate frequency for the receiver as well as the signal carrier and modulation frequencies which permit the minimum mutual interference between the signals. This and other objects of our invention, which will appear hereinafter, are attained primarily because both the transmitters as well as the receiver are under the control of one common producer and as a consequence it is possible to avoid almost completely the interference between the various channels by properly relating the intermediate frequency of the receiver, the radio frequencies at the transmitters, the receiver response and the spacing between transmitters. This in turn permits a simplified receiver arrangement which is advantageous from a production as well as a cost point of view. The last remarks apply as well to any multichannel system of transmission and reception where both transmitters and receivers may be designed as a unit.

In describing our invention in detail, reference will be made to the attached drawings wherein:
Fig. 1 illustrates diagrammatically our novel system comprising a plurality of transmitters and at least one receiver;

Fig. 2 illustrates a transmitter satisfactory for use in our system, this transmitter including a reactance tube modulated wave generator with the necessary amplifiers and frequency multipliers;

Fig. 3 illustrates diagrammatically a receiver including a schematic showing of a tuning control thereof, while

Fig. 4 is a vector diagram used in explaining the operation of the reactance tube phase shifting network of the transmitter of Fig. 2.

The problem to be considered is to transmit simultaneously in a number of channels with minimum interference. The interference may result from a large number of causes, principally:

- (A) Insufficient selectivity causing cross-talk.
- (B) Image signals. (1st order.)
- (C) Image signals. (2nd, 3rd, etc., order.)
- (D) Squeals due to harmonics of the oscillator frequency beats with incoming signal.
- (E) Phantom responses due to beat between channels.

The various causes will now be considered in detail:

(A) It is normal in a radio receiver that the sideband attenuation improves when the interfering signal is farther removed from the frequency to which the receiver is tuned. We can therefore determine the minimum frequency difference there should be between our transmitters from:

- (1) The expected selectivity of the receiving system.
- (2) The maximum expected "drift" of the transmitter frequency.

(B) The first order image response will fall at frequencies which are $2 \times f_{if}$ (f_{if} =intermediate frequency) removed from the frequency to which the receiver is tuned and they may therefore be avoided if the receiver covers a band which is less than $2 \times f_{if}$ wide.

(C) Let f_{if} be intermediate frequency, f_t be transmitter frequency, f_o be oscillator frequency, f_r be frequency to which the receiver is tuned.

Then $f_r - f_o = \pm f_{if}$, depending on whether the oscillator frequency is located above or below the signal frequency.

Let the oscillator be located below the signal frequency, then

$$f_r - f_o = +f_{if}$$

Spurious responses will be found when:

$$n_1 f_t - n_2 f_o = \pm f_{if}$$

Where n_1 and n_2 are whole and positive, eliminating f_o from the above equations, we have:

$$f_r = \frac{n_1 f_t}{n_2} + f_{if} \left(1 \pm \frac{1}{n_2} \right) \quad (1)$$

Similarly, if the oscillator is located above the signal frequency, then

$$f_r - f_o = -f_{if}$$

or, eliminating f_o ,

$$f_r = \frac{n_1 f_t}{n_2} - f_{if} \left(1 \pm \frac{1}{n_2} \right) \quad (2)$$

Inasmuch as we are only concerned with the spurious responses falling nearest to interfering signal f_t , we may investigate what these frequencies are.

First, let $n_1 = n_2 = n$, in which case

$$f_r = f_t + f_{if} \left(1 \pm \frac{1}{n} \right)$$

for the oscillator frequency located above the signal frequency, and

$$f_r = f_t - f_{if} \left(1 \pm \frac{1}{n} \right)$$

for the oscillator frequency located below the

signal frequency, which, in view of the above statement that only the response nearest f_t simplifies to

$$f_r = f_t + f_{if} \left(1 - \frac{1}{n} \right) \quad (1a)$$

and

$$f_r = f_t - f_{if} \left(1 - \frac{1}{n} \right) \quad (2a)$$

The nearest spurious response will then in both cases occur for $n=2$ and they will fall at:

$$f_r = f_t + \frac{1}{2} f_{if} \quad (1b)$$

$$f_r = f_t - \frac{1}{2} f_{if} \quad (2b)$$

Indicating that for $n_1 = n_2 = n$, spurious responses may be avoided if the receiver covers a band less than one half of the intermediate frequency.

Next let us consider the case where $n_1 \geq n_2$ and let us decide to restrict the receiver frequency band in accordance with the statement made above. Then, if the oscillator is located below the signal frequency,

$$f_r = \frac{n_1}{n_2} f_t + f_{if} \left(1 \pm \frac{1}{n_2} \right)$$

Responses for the lowest order harmonics will be found when:

$$n_1 = n_2 \pm 1$$

or,

$$f_r = \left(1 \pm \frac{1}{n_2} \right) f_t + \left(1 \pm \frac{1}{n_2} \right) f_{if}$$

(It will be noted that the $(\pm)$ signs are independent of each other)

Now let us examine the signs:

(a) ++ or,

$$f_r = \left(1 + \frac{1}{n_2} \right) f_t + \left(1 + \frac{1}{n_2} \right) f_{if}$$

or the spurious responses will never fall within the assigned band.

(b) -- or,

$$f_r = \left(1 - \frac{1}{n_2} \right) f_t + \left(1 - \frac{1}{n_2} \right) f_{if}$$

Interference may occur when

$$f_r > f_t - \frac{1}{2} I. F.$$

or,

$$\left(1 - \frac{1}{n_2} \right) (f_t + f_{if}) > f_t - \frac{1}{2} f_{if}$$

or,

$$1 - \frac{1}{n_2} > \frac{f_t - \frac{1}{2} f_{if}}{f_t + f_{if}}$$

$$-\frac{1}{n_2} > -\frac{\frac{3}{2} f_{if}}{f_t + f_{if}}$$

or,

$$\frac{1}{n_2} < \frac{\frac{3}{2} f_{if}}{f_t + f_{if}}$$

or,

$$n_2 < \frac{3}{2} \left(1 + \frac{f_t}{f_{if}} \right)$$

(c) +- or,

$$f_r = \left(1 + \frac{1}{n_2} \right) f_t + \left(1 - \frac{1}{n_2} \right) f_{if}$$

It will immediately be seen that under the

5

above limitations no interference can be caused.

(d) - + or,

$$f_r = \left(1 - \frac{1}{n_2}\right)f_i + \left(1 + \frac{1}{n_2}\right)f_{if}$$

As under (b), interference may exist if

$$f_r > f_i - \frac{1}{2} \text{ I. F.}$$

or,

$$f_i + f_{if} + \frac{1}{n_2}(f_{if} - f_i) = f_r > f_i - \frac{1}{2} \text{ I. F.}$$

$$\frac{1}{n_2}(f_{if} - f_i) > -\frac{1}{2} \text{ I. F.}$$

$$-n_2 < \frac{2f_{if} - f_i}{3f_{if}}$$

or,

$$n_2 > \frac{2}{3} \left(\frac{f_i}{f_{if}} - 1 \right)$$

It will be noticed that lower order harmonics will be received under condition (d), which therefore will be the only case considered.

Next let us consider the case where the oscillator is located above the signal frequency. For this case:

$$f_r = \frac{n_1}{n_2}f_i - f_{if} \left(1 + \frac{1}{n_2}\right)$$

Similarly, let $n_1 = n_2 \pm 1$
and

$$f_r = \left(1 \pm \frac{1}{n_2}\right)f_i - f_{if} \left(1 \pm \frac{1}{n_2}\right)$$

Let us examine the signs:

(a₁) + + or,

$$f_r = \left(1 + \frac{1}{n_2}\right)f_i - f_{if} \left(1 + \frac{1}{n_2}\right)$$

Interference may occur if

$$f_r < f_i + \frac{1}{2}f_{if}$$

$$\left(1 + \frac{1}{n_2}\right)(f_i - f_{if}) < f_i + \frac{1}{2}f_{if}$$

$$\frac{1}{n_2} < \frac{3/2f_{if}}{f_i - f_{if}} n_2 > \frac{2}{3} \left(\frac{f_i}{f_{if}} - 1 \right)$$

(b₁) - - or,

$$f_r = \left(1 - \frac{1}{n_2}\right)f_i - f_{if} \left(1 - \frac{1}{n_2}\right)$$

which will never produce spurious signals within the above mentioned band.

(c₁) + - or,

$$f_r = \left(1 + \frac{1}{n_2}\right)f_i - f_{if} \left(1 - \frac{1}{n_2}\right)$$

If

$$f_r < f_i + \frac{1}{2}f_{if}$$

then

$$f_i - f_{if} + \frac{1}{n_2}(f_i + f_{if}) < f_i + \frac{1}{2}f_{if}$$

$$\frac{1}{n_2} < \frac{3/2f_{if}}{f_i + f_{if}}$$

$$n_2 > \frac{2}{3} \left(1 + \frac{f_i}{f_{if}} \right)$$

(d₁) - + or,

$$f_r = \left(1 - \frac{1}{n_2}\right)f_i - f_{if} \left(1 - \frac{1}{n_2}\right)$$

which will never cause interference.

In this case (a₁) will be the most severe re-

6

quirement, and it will be noted that interference of the same order harmonics will be experienced for the oscillator above and below the signal frequency.

(D) Squeals due to intermediate frequencies falling within the assigned band. This trouble may be avoided if the assigned band of frequencies is located between the frequencies $n f_i$ and $(n + 1) f_{if}$, where n is any whole positive number.

(E) Phantom responses may be experienced if two stations f_{i1} and f_{i2} differ in frequency by the intermediate frequency. This, however, can not be the case if the band is narrower than the intermediate frequency. Under unusually severe conditions the second harmonic may cause interference. This may be avoided if the band is narrower than one half the intermediate frequency.

(F) Interference caused by radio frequency signals within the intermediate frequency band may be avoided if the intermediate frequency is located in a part of the frequency spectrum, where there are no strong local stations, and by providing the receiver with sufficient attenuation in the radio frequency amplifier to attenuate such signals as may be present.

We are now in a position to specify a system in which interference is kept at a minimum.

1. Locate the transmitter frequencies as close together as the transmitter stability and adjacent channel selectivity of the receiver will permit.

2. Choose an intermediate frequency which is greater than twice the required band for which none of the harmonics falls within the band.

3. This system will have none of the spurious responses specified under (A), (B), (C), (D), and (E), with the exception that the responses under (C) may be present in an order higher than specified by the formula:

$$n > \frac{2}{3} \left(\frac{f_i}{f_{if}} - 1 \right)$$

As a specific case, we have provided a transmission system in which the frequencies 70.8, 71.5, 72.2 megacycles were used for three channels together with an intermediate frequency of 5 megacycles and a receiver band from 70.4 to 72.6 megacycles.

It will be seen that no spurious responses will be found with the exception of

$$n_2 > \frac{2}{3} \left(\frac{70.4}{5.0} - 1 \right) n_2 > 9.39$$

or

$$n_2 \geq 10$$

In other words, no harmonic below the 10th will be harmful.

In Fig. 1, we have shown three transmitters constructed in accordance with our invention and located at spaced points and a single receiver cooperating therewith. It will be understood that more transmitters and other receivers may be used.

The transmitters T₁, T₂, and T₃ may be of the nature described. In one application of our invention the transmitters may be located in a zone wherein it is suspected an enemy craft is operating. The disturbances produced by the enemy craft may modulate one or more of the transmitters. The receiver R, by tuning over the band it covers, as given above, can tune in the several transmitters successively and, due to the absence of interfering signals, can definitely identify each transmitter whether modulated or not. Any modulations caused by disturbances

set up by an enemy craft may be used to determine the position thereof relative to the several transmitters and steps may be taken to render the enemy craft harmless.

Other uses to which our system may be put will be obvious to those skilled in the art.

The frequency modulated wave receiver in Fig. 3 may, as stated above, be as disclosed in my United States application, Serial No. 421,900, filed December 6, 1941, now Patent No. 2,367,352, granted January 16, 1945, and includes as a tuning means a control element X which actuates tuning reactances in such a manner that the carrier of one transmitter, say T₁, comes in at a point, say C₁, the transmitter T₂'s carrier comes in at C₂, and the transmitter T₃'s carrier comes in at C₃. In the example given hereinbefore, the point C₁ may represent a carrier of a frequency 70.8 megacycles, C₂ a carrier of 71.5 megacycles, C₃ a carrier of 72.2 megacycles. Note that at this point the spacing between said carriers is 0.7 of a megacycle so that the frequency separation is a relatively small fraction of the transmitter frequency even as compared to, say, the broadcast system. Moreover, it will be seen that the plurality of transmitters cover a range of 1.4 megacycles whereas the receiver itself is arranged to have a tuning range of 2.2 megacycles since, as stated above, it is to have a frequency range of 70.4 to 72.6 megacycles. Furthermore, the intermediate frequency is of 5 megacycles, thereby being over twice as great as the receiver band. Note that here again systems such as the ordinary broadcast system do not satisfy these conditions, and the difference between our system and systems known heretofore, such as the broadcast system, accounts for the ability of our system to get in the receiver a single response on which we may rely as an identification of the transmitter sending so that we do not have to rely on the modulation of the carrier for such identification. As the reader is aware, no such reliance can be made on any signal received in the broadcast band or in systems of that nature known heretofore.

A transmitter satisfactory for use in our system has been illustrated in Fig. 2. This transmitter comprises a modulation input 10, such as a microphone, connected by a transformer 12 to a modulation amplifier 14, which may be a resistance coupled high-gain amplifier of a multi-tube type. The amplified output is supplied, as will be described more in detail hereinafter, to a control electrode 36 of reactance tube 30, associated with an oscillation generator tube 40 to modulate the frequency of the oscillations generated and supply them to a doubler stage including a tube 60, which in turn feeds a pair of parallel amplifiers 80 and 90, having their outputs connected with a tank circuit including inductances L₁₂ and variable trimmer condensers C₃₇ and C₃₈ with the inductance L₁₂ coupled to a load circuit such as a radiator by an inductance L₁₃.

The oscillation generator including tube 40 has its control grid 41 and screening grid electrode 42 (serves as oscillator anode) coupled by an inductance L₃, a point on which is connected to the cathode 44 to form a Hartley oscillator. The lead between the control grid 41 and inductance L₃ includes a grid leak and condenser arrangement comprising resistance R₁₅ and condenser C₂₀. The inductance L₃ is shunted by a tuning condenser C₁₈ and forms the oscillator tank circuit. The oscillator is of the grounded anode type, screen grid 42 being connected to ground

by coupling condenser C₁₉ with the anode 45 connected in an output circuit comprising inductance L₆ and condenser C₂₅ electronically coupled to the generating electrodes and circuits and tuned to a frequency double the frequency of the oscillations generated.

The tank circuit C₁₈—L₃ is shunted by the complex reactance between the anode 32 and cathode 34 of the reactance tube 30 so that the reactance of tube 30 is included in the tank circuit of the oscillator and as a consequence may control the frequency of the oscillations generated. The reactance tube 30 has its anode 32 connected by the coupling condenser C₁₇ to the high potential end of the tank circuit L₃—C₁₈. The cathode 34 is connected to ground by a blocking and coupling condenser C₁₅. The anode 32 is connected by a small coupling and phase shifting condenser C and a phase shifting resistance R and small phase shifting inductance L to ground by way of coupling condenser C₁₀. The elements C, R, and L form a phase shifting circuit by means of which a voltage is produced between C and R substantially in phase quadrature with the voltage on the anode 32. This voltage is supplied to the control grid 36 to provide in the tube the reactive effect. The cathode is also connected to ground by a biasing resistor R₂₁ shunted by a high frequency bypass condenser C₁₁.

In reactance tubes of the type known heretofore a full 90 degrees phase relation is not obtained between the voltage on the anode with respect to the voltage on the control electrode. In our arrangement, by the use of the inductance L in the phase shifting circuit, a full 90 degrees phase relation may be obtained. This insures a somewhat purer reactance effect and reduces the resistive component introduced into the tank circuit reactance tube.

Moreover, development of reactance tube circuits for oscillator frequency control as used in A. F. C. or F. M. modulator circuits gets increasingly difficult as the frequency is raised because the input impedance of the reactance tube assumes values comparable to those of the circuit constants. In the circuit disclosed, the effect of the tube constants has been rendered harmless by arranging the circuits in a manner which lets them add to the circuit constants rather than counteract the circuit constants as was the case in earlier circuits. The resistance load of the reactance tube may be removed entirely or even made negative with the disclosed circuit.

The vector diagram in Fig. 4 shows the phase relation between the voltage e_1 at the input of the network, i. e., between the point X and ground, and the voltage e_r at the network output, i. e., the voltage across R applied to the grid of the reactance tube 30. In this vector diagram, e_1 is the vector representing the voltage at the input to the network which is, as stated above, equal to the voltage across the output of tube 30. Vector e_c represents the voltage across the condenser C, e_L represents the voltage across the inductance L, e_r represents the voltage across R, and e_z represents the voltage across the resistance R and L. e_z also represents the fractional voltage on the grid 36 of the reactance tube. It will be seen that the angle ϕ will be 90 degrees when angle θ_1 equals angle θ , which will be the case when

$$\frac{r}{Z_c - Z_L} = \frac{Z_L}{r}$$

It is to be noted the Z_L is a very small impedance. The advantages of this circuit are: (1) It is possible to obtain a perfect 90 degrees phase shift between primary and secondary voltages, resulting in complete absence of a resistive component in the effective plate loading in the oscillator tank circuit; (2) the loading which the phase shift circuit given on the tuned circuit adds on the oscillator tank is very small because it is predominantly capacitive; (3) the tube constants (input capacitance and resistance) adds to the lumped constants in the phase shifting circuit and their effect is therefore not harmful, that is, the impedance of R, etc. is of the tube constants and adds thereto rather than counteracts them as was the case in certain earlier arrangements wherein the reactance tube anode is coupled to the cathode by a resistance and condenser in series in the order given with the grid connected to the junction point between the resistance and condenser.

By controlling the mutual conductance of the reactance tube, the size of the complex reactance provided thereby may be controlled. In our system we apply the modulating potentials from the amplifier 16 by way of coupling condenser C_9 to resistor R_{11} and through inductance L and resistance R to the control grid 36 to thereby control the conductivity of the reactance tube and the size of the reactive effect.

The frequency modulated oscillations are supplied, as stated above, to the anode 45 due to electron coupling in the tube 40 and produces in the output circuit L_6-C_{25} oscillations of double the oscillator frequency. These oscillations are fed to the control grid 62 of the amplifier tube 60, again doubled therein, and supplied from the anode 64 to the tuned tank circuit L_9-C_{29} . This tank circuit is tuned to double the frequency of the voltages applied at the input of tube 60 so that the frequency to which this tank circuit is tuned is now 4 $\times$, that is, four times the fundamental frequency f of the oscillations generated by the oscillation generator at 40. The voltages of the fourth harmonic set up in tank circuit L_9-C_{29} are supplied by a tap on L_9 , which steps down the voltage, to the control grids 70 and 72 of the parallel amplifiers 80 and 90 wherein the fourth harmonic voltages are amplified and supplied from the anodes 74 and 76 to the output circuit including inductance L_{12} and condensers C_{37} and C_{38} .

The filamentary heaters 38, 48, 58, 78, and 88 are supplied by current as shown from a filament supply battery 101. The heaters 48, 58, 78, and 88 are supplied by way of a ballast resistor 100 in order to regulate in so far as possible the filament voltage to maintain the frequency of operation of the transmitter as stable as possible under the particular circumstances encountered here. A direct current source, designated B, supplies the anode and screen grid potentials, as shown, by way of the necessary resistances, radio frequency chokes L_2 , L_4 , L_8 and L_{11} , radio frequency bypass condensers BP, C_{30} , etc. The filament heating circuits are likewise supplied with radio frequency filtering including chokes and bypass condensers, the oscillator and two amplifiers having individual filters comprising respectively, inductance L_5 and condenser C_{23} , inductance L_7 and condenser C_{27} , and inductance L_{10}

and condensers C_{34} and C_{35} . This filtering prevents coupling between stages.

What is claimed is:

1. A signaling system consisting of a plurality of spaced transmitters each radiating a carrier wave, the several carrier waves being separated from each other by small frequency spacings as compared to the carrier wave frequencies, and at least one heterodyne receiver with a tuning range covering substantially only a band of frequencies sufficient to receive all of the transmitted waves and with an intermediate frequency more than twice the greatest frequency separation between the plurality of transmitted carrier waves.

2. In a signaling system, a plurality of spaced transmitters each producing and radiating a carrier wave, the several carrier waves being separated from each other by a small frequency spacing as compared to the carrier wave frequencies, and at least one receiver of the heterodyne type with a tuning range covering substantially only a band of frequencies sufficient to receive all of the transmitted waves, with an intermediate frequency more than twice the greatest frequency separation between the plurality of transmitters and a tuning range less than one half the intermediate frequency.

3. In a signaling system, a plurality of spaced wave energy transmitters operating at different frequencies which are separated in the frequency spectrum by frequency bands which are a small fraction of the frequency at which each transmitter operates, and means at a remote point for identifying transmission from the individual transmitters by noting only the frequencies of the transmitted wave energy comprising, a tunable receiver of the heterodyne type responsive to radiation from said transmitters, said receiver having a tuning range which covers substantially only the frequency spectrum covered by the wave energy transmitted by the several transmitters, and having an intermediate frequency which is over twice as great as the said receiver tuning range, said transmitter frequencies, receiver tuning range and intermediate frequency being so chosen that a single response only for each transmitter is obtained in said receiver.

4. In a signaling system, a plurality of spaced wave energy transmitters operating at different frequencies which are separated in the frequency spectrum by frequency bands which are a small fraction of the frequency at which each transmitter operates, and means at a remote point for identifying transmission from the individual transmitters by noting only the frequencies of the transmitted wave energy comprising, a tunable receiver of the heterodyne type responsive to radiation from said transmitters, said receiver having a tuning range which covers substantially only the frequency spectrum covered by the wave energy transmitted by the several transmitters and having an intermediate frequency which is over twice as great as the receiver tuning range and twice as great as the greatest frequency separation between wave energies transmitted, said transmitter frequencies, receiver tuning range and intermediate frequency being so chosen that a single response only for each transmitter is obtained in said receiver.

PAUL F. G. HOLST.
LOREN R. KIRKWOOD.