Aug. 6, 1946. W. S. HALSTEAD ET AL 2,405,501

SIGNALING SYSTEM

Filed Sept. 16, 1943 4 Sheets-Sheet 1

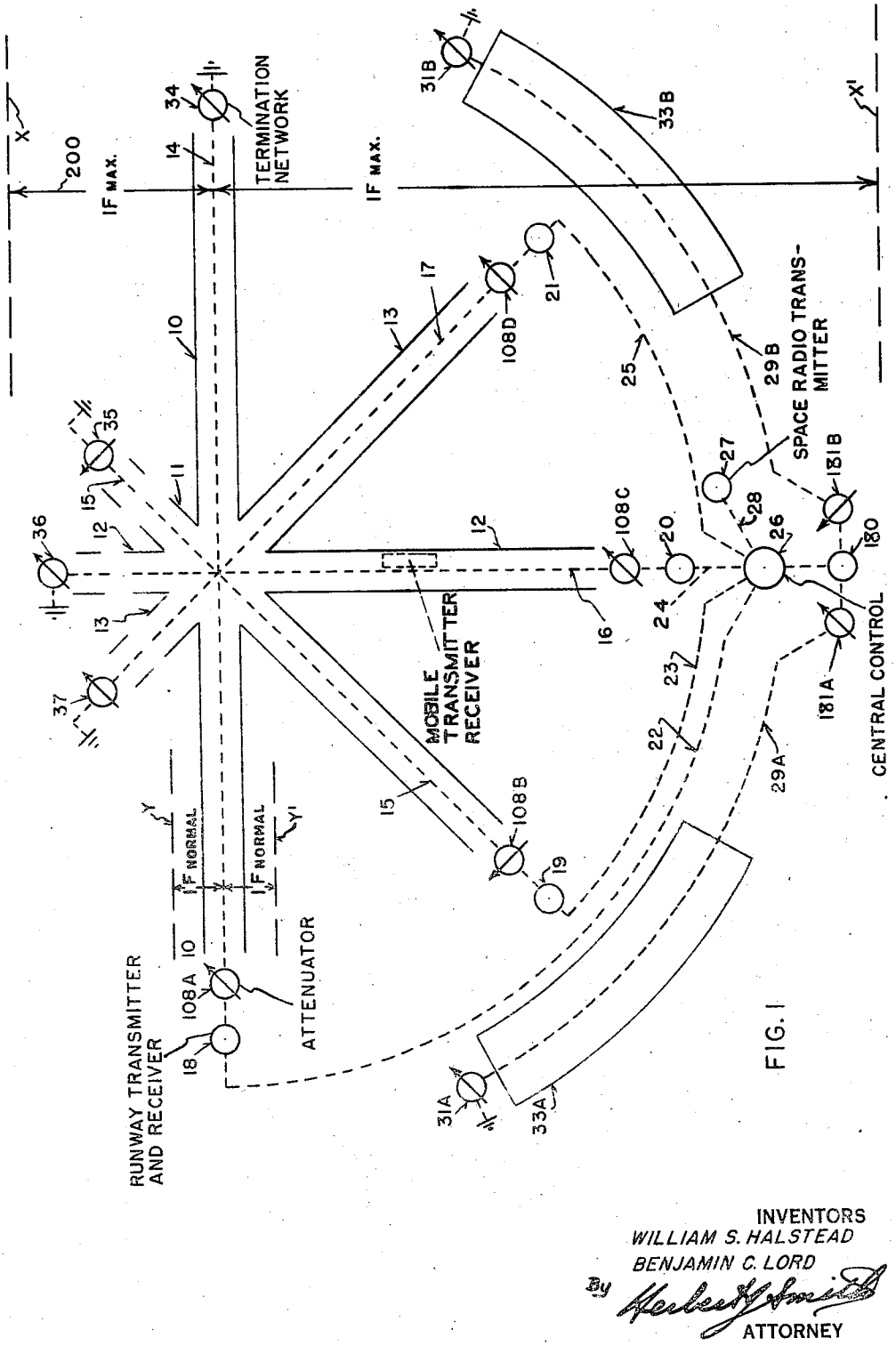


FIG. 1

INVENTORS
WILLIAM S. HALSTEAD
BENJAMIN C. LORD
By Herbert J. Smith
ATTORNEY

Aug. 6, 1946. W. S. HALSTEAD ET AL 2,405,501

SIGNALING SYSTEM

Filed Sept. 16, 1943 4 Sheets-Sheet 2

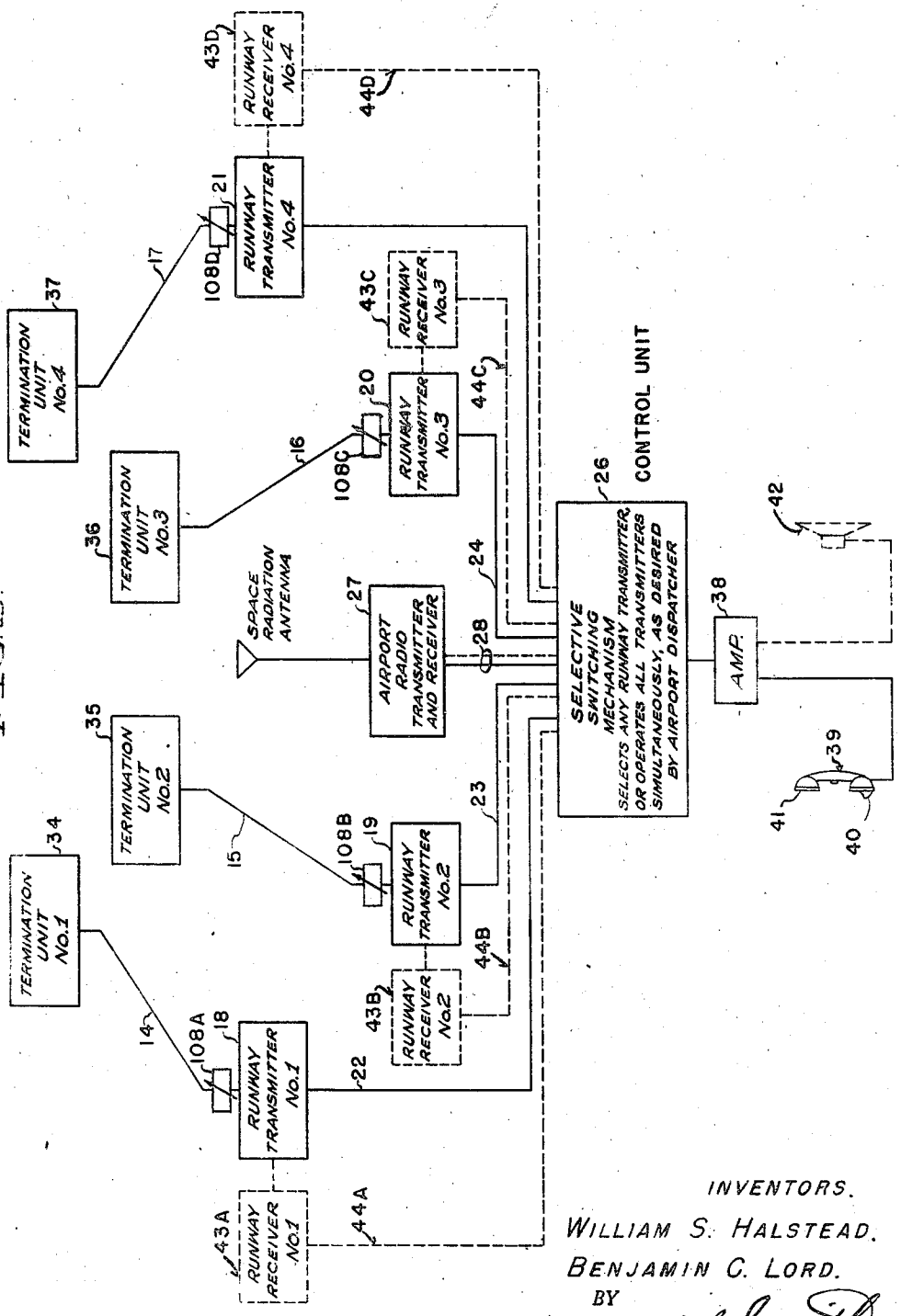


FIG. 2.

INVENTORS.
WILLIAM S. HALSTEAD.
BENJAMIN C. LORD.
BY
Herbert J. Smith
ATTORNEY.

Aug. 6, 1946. W. S. HALSTEAD ET AL 2,405,501

SIGNALING SYSTEM

Filed Sept. 16, 1943 4 Sheets-Sheet 3

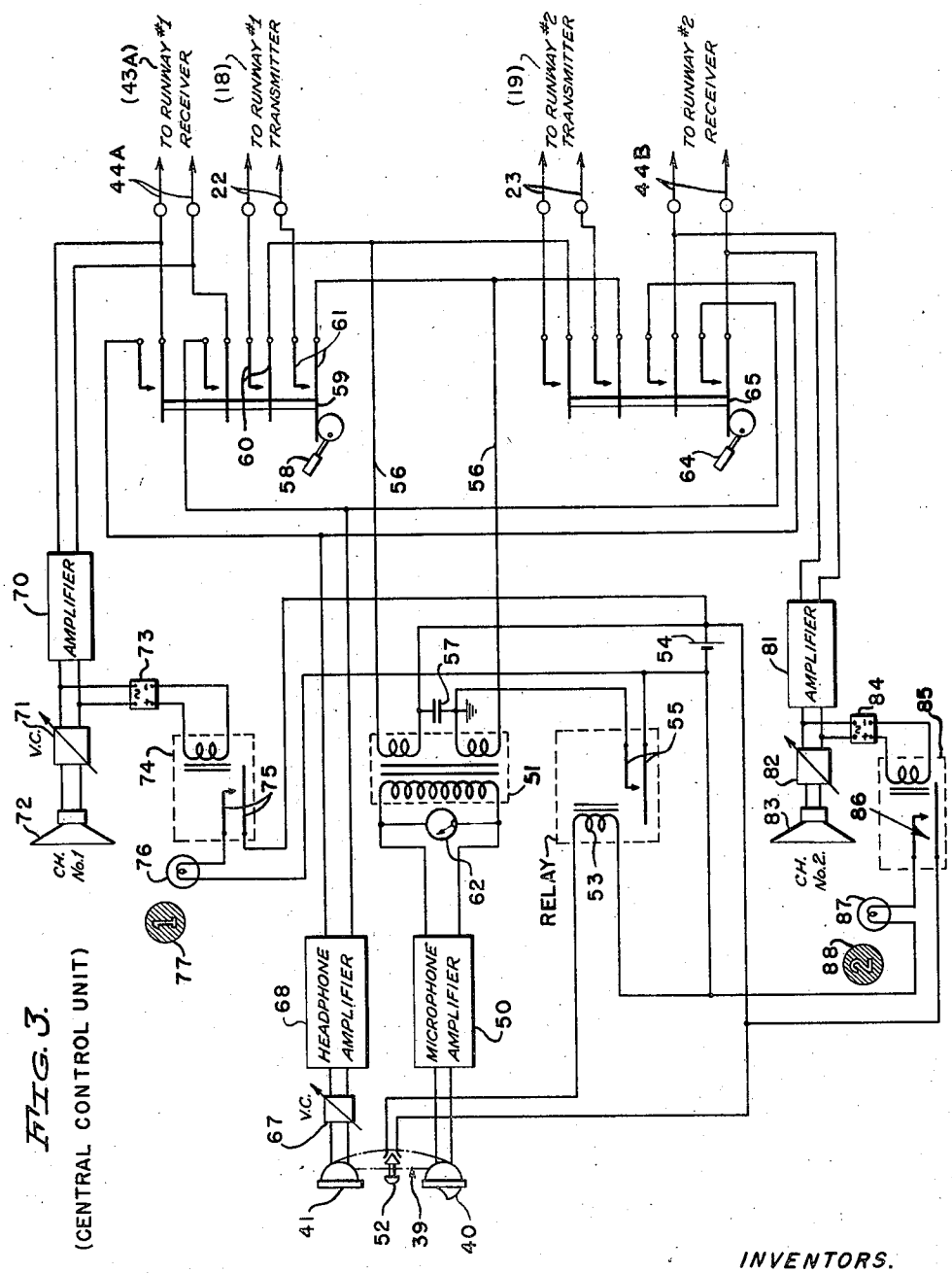


FIG. 3.

(CENTRAL CONTROL UNIT)

INVENTORS.

WILLIAM S. HALSTEAD.

BENJAMIN C. LORD.

BY

Herbert J. Smith

ATTORNEY.

Aug. 6, 1946. W. S. HALSTEAD ET AL 2,405,501

SIGNALING SYSTEM

Filed Sept. 16, 1943 4 Sheets-Sheet 4

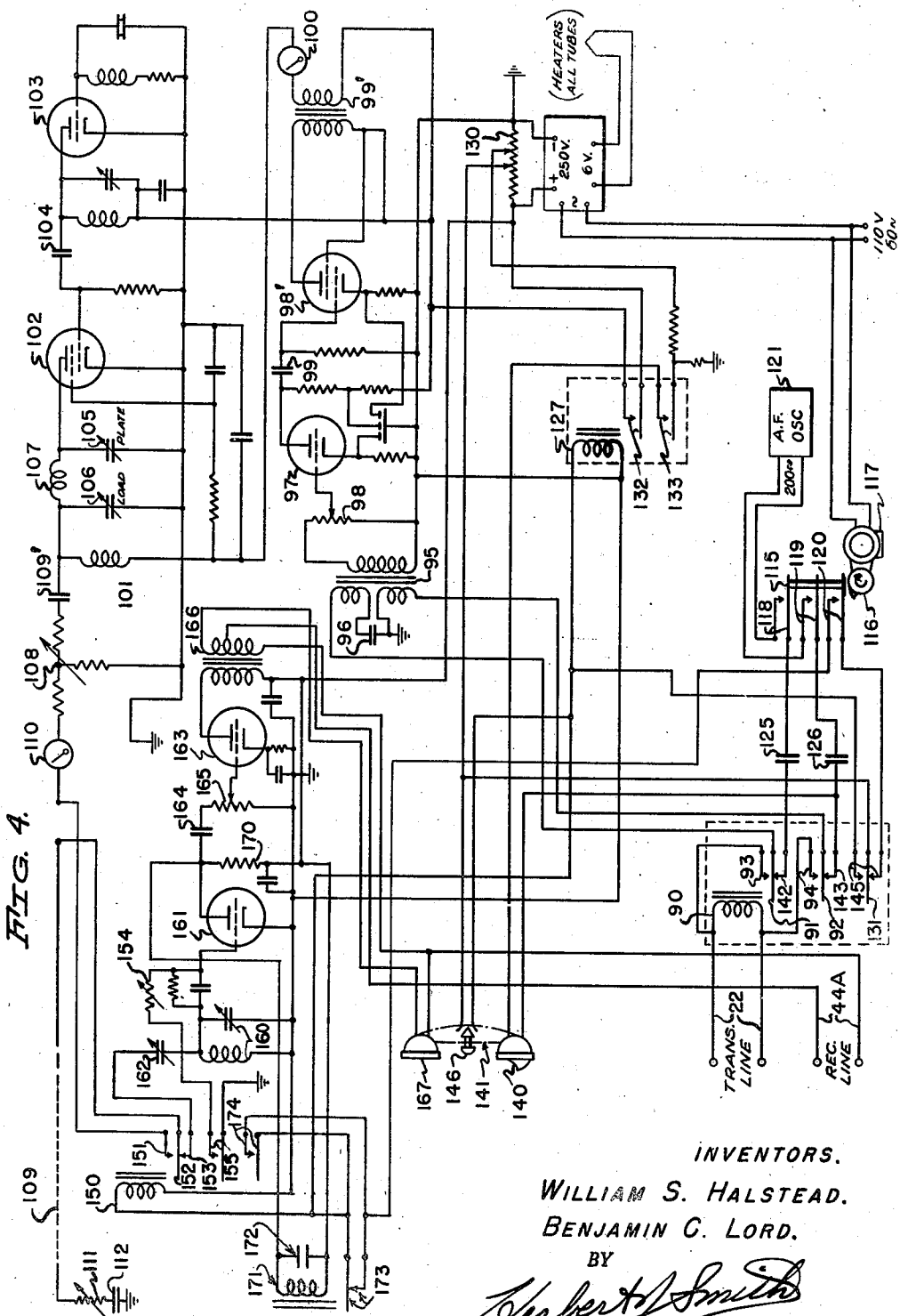


FIG. 4.

INVENTORS.
WILLIAM S. HALSTEAD.
BENJAMIN C. LORD.
BY
Herbert J. Smith
ATTORNEY.

Patented Aug. 6, 1946

2,405,501

UNITED STATES PATENT OFFICE

2,405,501

SIGNALING SYSTEM

William S. Halstead, Huntington, and Benjamin C. Lord, Valley Stream, N. Y., assignors, by mesne assignments, to Farnsworth Television & Radio Corporation, Fort Wayne, Ind., a corporation of Delaware

Application September 16, 1943, Serial No. 502,626

24 Claims. (Cl. 179—2)

1

This invention pertains to signaling systems and more particularly to a system for selectively transmitting, by electronic signaling apparatus, intelligence addressed to operators of aircraft or other vehicles, and/or individuals in various portions of an airport or other restricted signaling area.

With the development of large municipal and military airports, in which many runways may be installed, a need has arisen for more effective and efficient methods of communicating with pilots of surface-borne aircraft on various runways and on aprons of the airport area without further congesting over-taxed radio channels or adding to the traffic load carried by radio facilities.

Heretofore information addressed to pilots of ground-borne aircraft has been transmitted by the normal space radio equipment of the airport. Such use of the same radio facilities to handle ground and air traffic not only complicates the effective handling of such traffic, but seriously delays or prevents altogether the transmission of detailed information to pilots awaiting take-off.

Present systems utilizing normal space radio further limit the number of dispatchers who may control many ground and air operations at the airport traffic control tower. In addition, during wartime, the use of normal space radio at coastal airports and at advanced air bases in combat zones, often precludes the transmission of important last-minute information to pilots immediately prior to take-off for reasons of military security.

With the system of the invention, a surface-borne aircraft located in any portion of the airport area may be reached independently through a selective switching system which, when combined with the employment of controlled-range induction signaling means, delineate the signaling zone in which communication is to be established.

If desired, all aircraft on the ground at all parts of the airport area may be reached simultaneously through the same system by means under the control of operators in the control tower. The system further permits the use of a plurality of dispatchers at the control tower, each dispatcher being enabled to communicate with aircraft in his control area without mutual interference between adjoining areas, even though the same operating frequency is utilized for this function. In addition, by means recited hereinafter, the electromagnetic induction field

2

utilized in the system of that invention, is effective only within a relatively short distance from each runway area. Radiation of wave energy beyond the confines of the airport area is so limited that it is ineffective in producing a useful signal in receivers beyond a predetermined distance. Such limitation of range of the ground-borne traffic communications system prevents interference with concurrent space-radio transmissions to aircraft in normal flight in the vicinity of the airport, though the same operating frequency may be used for both ground traffic and ground-to-plane communications services.

The lack of space radiation of effective wave energy beyond the confines of the airport, further precludes interception of information, addressed to pilots of military aircraft, by unauthorized persons or by enemy forces having receivers which may be located within a short distance of the airport beyond the effective induction signaling range.

The present invention as described herein, is applied illustratively in airport communications service, wherein the system is utilized in two-way signaling between operators of aircraft or other personnel on or adjacent runway or apron areas and a central control point, such as an airport control tower, without radiation of radio wave energy beyond a predetermined lateral distance from the transmitting system. Such illustrative application does not, however, restrict the use of the same system for other purposes.

In the present disclosure a ground-laid or subsurface transmission line or wave guide is used for the purpose of employing the induction field of the energized transmission line to establish a localized signaling zone adjacent the transmission line. By utilizing this system it is possible to employ transmission lines on an airport in such a manner as to have the transmission lines and their respective signaling zones extend angularly, or toward a common point so that they may converge. Also, a single transmission line may be utilized so that by increasing the signaling energy impressed thereon, the effective signaling area may be increased so as to cover an entire airport. Thus, one of the transmission lines employed for an independent runway may be used to provide the entire airport with effective signaling coverage. When this is done, the transmitter associated with this particular runway may be used.

However, if the particular runway does not happen to fit in with the desired location of the transmission line, then an individual transmis-

sion line may be employed with one of the regular transmitters, or an independent transmitter may be installed to take care of the transmission line which is to be used for embracing the desired airport coverage.

In the present disclosure the signaling zones are established so as to create a plurality of individual signaling zone patterns, with the major axes of the individual signaling zones converging at substantially a common point. The transmission lines are connected at one end thereof to their respective transmitters, and are terminated at the opposite ends thereof somewhere along the runway, which point is frequently beyond the converging point of the different signaling zones, as set forth in the present disclosure.

An individual transmitter, preferably, is utilized for each of the transmission lines, while a central control unit usually located in the signal control tower, is connected directly with each of the individual runway transmitters.

A switching system is located in the central control tower, or control unit so that there may be a selection of the particular runway transmission lines upon which it is desired to impress signal intelligence, particularly of the voice type of communications.

The control tower and the individual control units are both equipped so that the individual runway or zone transmitters-receivers may be used and monitored from either the location of the runway transmitter or control tower. In the absence of speech communication from the control tower or the individual runway transmitters, a signaling tone is impressed upon the various runway transmission lines. In this way there is always signal supervision of the runways per se by either a tone, which may be keyed, or voice communication.

In the absence of voice communication impressed upon the runway transmission lines, a checking tone, either keyed or constant, is impressed upon the transmission lines.

When the operator of the central control unit operates the key to cut in the runway transmitter and receiver, the tone from the transmitter of that particular runway is automatically discontinued and the central control unit may then control and monitor the runway transmitter. Visual indicating means, selectively actuated by signal energy received from a mobile unit on or adjacent a particular runway, is also embodied in the central control equipment of the system of the invention to designate the specific communications channel and runway being utilized.

Signal attenuators, which may be adjusted to effect a desired lateral extension of the induction signaling field about a particular runway area, may be disposed in each runway transmission line circuit, and located adjacent each runway transmitter, or these attenuators may be located on a single panel in the control tower to enable the operator to regulate the extent of the signaling field with respect to each runway, or the entire field area, as desired.

It is an object of the present invention to provide a system of communicating with surface-borne traffic in an individual signaling zone, with surface-borne traffic in a multiplicity of signaling zones, or concurrently with air-borne traffic.

It is an object of the system of the present invention to provide a selective signaling system for surface-borne traffic wherein communications with traffic in various adjoining signaling zones

may be established on a common frequency without interference between adjacent zones, said communications being controlled from a central point.

It is a further object of the present invention to provide a signaling system for surface-borne traffic wherein one or more localized signaling zones are established by controlling the lateral extent of an induction field surrounding a metallic conductor extending substantially parallel to a lane of traffic.

It is an additional object of the present invention to provide an induction signaling system wherein the effective signaling range contiguous to a particular runway or other area, may be controlled by a variable attenuator associated with the particular runway or other area, without varying substantially the output loading of the transmitter or affecting its modulation.

It is a further object of the invention to provide an induction signaling system wherein the effective signaling range may be established by controlling, in predetermined stages, the amount of attenuation of carrier energy impressed on a transmission line, thereby regulating the desired effective signaling coverage within a given area.

It is an object of the present invention to provide a selective communication and signaling system for surface-borne traffic wherein localized signaling zones have their major axes converging at substantially a common point.

It is a further object of the invention to provide a signaling system wherein a plurality of individual transmitters or transmission lines employed in establishing communications in various converging signaling zones are selectively controlled from a central control unit.

It is a further object of the invention to provide a signaling system for surface-borne traffic wherein a plurality of combination transmitter-receiver units associated with traffic lanes or particular zones within a given area are controllable from a central point, with supervisory aural and visual indicators located at the central control point.

It is a further object to provide means for selective transmission of intelligence to surface-borne traffic, said means including a plurality of individual transmitter-receiver units selectively controllable from a central point, said means also effecting transmission of a regularly recurrent tone signal to said traffic in the absence of voice communications.

With certain of the objects set forth herein, it is to be understood that many other objects may be and may become apparent to one skilled in the art from a perusal of the disclosure herein and the subjoined claims.

In the drawings:

Fig. 1 represents, in schematic form, a typical plan view of an airport having a plurality of intersecting runways with transmission lines or signaling conductors disposed along or adjacent the runways, and runway transmitter-receiver units for the individual runways controllable from a central control unit in communicating with surface-borne traffic.

Fig. 2 is a block diagram with more complete legends to pictorially represent the disclosure of Fig. 1.

Fig. 3 is a schematic diagram of a central control unit having selective switching means for controlling a plurality of individual runway transmitter-receiver units, the central control unit having aural and visual signal units therein,

and means for impressing voice communications upon the signal system.

Fig. 4 is a schematic diagram of a runway transmitter-receiver unit which is controllable from a central control unit and which transmitter-receiver unit has means for keying a tone on the runway transmitter in the absence of voice communication thereon.

To avoid confusion in terminology, it is pointed out that any reference to surface-borne traffic means any traffic that is borne directly or indirectly on the surface of land, or water, the deck of a ship, runways of any kind, structures generally, or substantially immediately adjacent thereto.

Any reference to a signaling system, or communication system refers to any system wherein intelligence of electrically transmittable nature may be provided for the ultimate use of the operator of a unit of surface-borne traffic.

Any reference to a transmission line, wave guide, or induction cable means any conductor which may be used to provide a localized signaling zone, whether or not it is a single conductor having the end opposite the transmitter grounded, a metallic conductor such as a power or telephone line wherein the signal intelligence is superimposed thereon, or whether one or more conductors are utilized having a suitable termination unit adjacent the end opposite the radio transmitter. In general, any conductor may be employed that will permit suitable establishment of an adequate induction signaling field.

Referring to the illustrations in detail, Fig. 1 represents, in schematic form, a typical plan view of an airport for a plurality of intersecting runways 10, 11, 12 and 13, runway signaling conductors, or transmission lines 14, 15, 16 and 17, associated respectively with each of said runways, runway cables, and a plurality of transmitters 18, 19, 20 and 21, also associated respectively with each of said runways. Connecting each of said runway transmitters are remote control lines 22, 23, 24 and 25. The control lines, as illustrated, terminate at a central control point, or dispatch station 26, commonly within the control tower of an airport. Also controllable from the same central unit is a space radio transmitter and receiver 27, of any conventional type, with its control line 28.

In order to accomplish carrier signaling via the same general communications system, a wave guide, transmission line, or signaling conductor, installed between the various hangars, such as 33A and 33B, and the central control unit 26, is utilized.

If transmission lines, such as 29A and 29B, are employed, these lines are terminated at their far ends by means of matching, or termination networks 31A and 31B.

However, if conductors, such as 29A and 29B, are power lines, the termination unit or networks, such as 31A and 31B, will not be employed.

At the far ends of each of the transmission lines, such as 14, 15, 16, and 17, associated with the runways, the transmission lines are terminated by a matching or termination network 34, 35, 36 and 37, respectively, similar to termination networks 31A and 31B.

Referring to the block diagram of Fig. 2, the central control unit 26 includes a selective switching mechanism for selecting any runway transmitter, or operating all transmitters simultaneously as desired by the airport dispatcher. Included with the central control unit is a speech

amplifier 38, handset 39, with microphone 40, receiver 41 and loudspeaker 42. Runway transmitter No. 1 (shown in legend) corresponding to 18, Fig. 1, is connected with an induction cable or transmission line 14 and termination unit 34, indicated in Fig. 1. The remote control circuit 22 is connected to the selective switching mechanism portion of the central control unit 26.

In order to effect two-way communication, the aircraft on specific runways, or on one runway if desired by the airport dispatcher, utilizes runway No. 1 (shown in legend), such as receiver 43 (shown dotted), which is associated with its respective transmitter, such as 18. The output circuit of receiver 43A, 43B, 43C, and 43D may be connected by means of circuit 44A, 44B, 44C, and 44D with the selective switching mechanism of the control unit 26, as shown. The runway receiver employs the same transmission line in reception that is utilized by runway transmitter 18 in transmission. The method employed in effecting two-way operation of the receiver and transmitter may be better understood after reading the descriptive material pertaining to Figs. 3 and 4. In similar manner, a receiver associated with each of the runway transmitters may be connected to the control unit. It is pointed out in this connection that the receiving unit may be employed with the transmission line, if desired, in receiving modulated carrier energy from a normal airplane located within the effective signaling range of the induction field of the airplane transmitter.

In limited range transmission from the aircraft, the aircraft transmitting system is operated without the aircraft antenna connected. In other words, the electromagnetic field surrounding the aircraft's power supply, cables, and radio equipment develops a localized induction field which embraces the transmission cable. The voltage induced in the runway cable or wave guide from the local aircraft transmitter is thereupon amplified, rectified by the receiver, and is impressed on the control circuit leading to the control tower. It is also pointed out that the runway receiver may be kept in operation during dispatcher's transmitting periods as well, thereby serving as a remote monitoring device at the runway transmitting point.

In Fig. 2, the runway transmitters No. 1, 2, 3, and 4 are designated by character references 18, 19, 20, and 21 with transmission lines 14, 15, 16, and 17, respectively. The receivers for the respective transmitters are shown dotted with respective connecting circuits from the receivers to the control unit 26.

Fig. 3 represents a detail drawing of the selective switching mechanism employed in the central control unit 26. The microphone 40 of the handset 39 is connected to microphone amplifier 50 whose output circuit is connected to line transformer 51. The press-to-talk switch 52 of handset 39 is connected in series with relay coil 53 and a source of E. M. F. 54. Upon closing switch 52, the contacts 55 of the relay 53 are closed. This applies voltage from source of E. M. F. 54 across lines 56. Condenser 57 is employed between the two halves of the output secondary winding of transformer 51 as shown. The control voltage applied to lines 23 will be impressed upon the control lines 22, leading to runway transmitter No. 1 (18) when the dispatcher presses the lever 58 of the control switch 59 in a downward position, thereupon closing contacts 60 and 61. Voice

energy applied to microphone amplifier 50 by means of microphone 40 may be impressed on lines 22 or 23, or both, through line transformer 51. A speech level meter 62 is employed across the input winding of line transformer 51, as shown. As long as the lever 58 of control switch 59 is in a downward position, speech energy as well as D. C. control voltage from source of E. M. F. 54 will be applied to control lines 22.

In similar manner, by control of movement of lever 64 associated with switch 65, D. C. control voltage as well as voice signal energy may be impressed on control lines 23, connected with runway No. 2 transmitter (19). Should the dispatcher wish to talk over both runway transmitters simultaneously, he would depress the levers 58 and 64, associated with switches 59 and 65, respectively.

Referring in further detail to Fig. 3, the receiver 41 of handset 39 is connected through volume control 67 to the output circuit of an audio frequency amplifier 68. The amplifier 68 is connectable to lines 44A, associated with the output circuit of runway No. 1 receiver (43A). In the diagram, the lines 44A are connectable with the headphone amplifier 68 when control lever 58 is in the transmit position. In this manner, signal voltage from runway No. 1 receiver is fed back into headphone 41, thereby serving as a monitoring device and indicating to the operator that runway No. 1 transmitter is functioning properly. In two-way communications service, the output of runway No. 1 receiver is connected through amplifier 70, and volume control 71, to a loudspeaker 72. In order to provide visual indication at the dispatching point as to which runway receiver is responsive to an aircraft transmitter, rectified signal energy supplied by amplifier 70 is impressed on the input of a rectifier unit 73, the output of which is connected to the winding of relay 74. Upon closing of the contacts 75 of relay 74, a visual indicator 76 is energized. By means of a translucent disc 77, on which the number of the runway is impressed, the dispatcher can tell quickly which runway system is responsive to signal energy.

In similar manner, signal energy on receiver lines 44B is impressed on the input of headphone amplifier 68 and receiver 41 during periods in which runway No. 2 transmitter is being employed. Likewise, signal energy from runway No. 2 receiver is impressed on the input circuit of amplifier 81, volume control 82, and loudspeaker 83. Signal energy from amplifier 81 is rectified by means of rectifier 84 and thereafter serves to energize the winding of relay 85. Closure of contacts 86 applies energizing voltage to lamp 87 and therefore illuminates translucent channel-identifying disc 88.

It is pointed out that the channel-identifying means 77 and 88 are illuminated during transmitting periods when runway No. 1 transmitter and runway No. 2 transmitter are being employed, thus serving as a visual check on proper operation of the remote runway transmitters.

Referring to Fig. 4, D. C. energizing voltage from transmitter control lines, such as 22, is applied to relay 90. Relay armatures 91 and 92 in moving to the upper contacts 93 and 94 respectively apply such signal energy to the input winding of line transformer 95. D. C. keying voltage is prevented from short-circuiting to ground through the input winding of transformer 95 by means of condenser 96. Voltage from the secondary winding of line transformer 95 is impressed on the grid of vacuum tube 97 through potentiometer 98, as shown. Amplified signal energy is thereupon impressed upon the grid of amplifier tube modulator 98' through coupling condenser 99 in well-known manner. The secondary winding of modulation transformer 99' is connected through plate milliammeter 100 and R. F. choke 101 to the plate and screen grid circuit of the R. F. power amplifier tube 102 in conventional manner. R. F. energy from a crystal oscillator tube 103 is impressed on the grid of power amplifier 102 through coupling condenser 104, as indicated. Plate tuning condenser 105 and loading condenser 106 together with plate inductor 107 constitute the output circuit network of the power amplifier tube 102. R. F. energy is thereafter applied to an R. F. attenuator unit 108 through coupling condenser 109'.

In connection with R. F. resistive attenuator unit 108, it is pointed out that by the means of a variable attenuator, preferably having resistors arranged in T-pad connection, as shown in Fig. 4, it is possible to control the amount of R. F. energy applied to the transmission line 109 without varying the output load of the transmitter or affecting its tuning or modulating adjustments in any way. This is important inasmuch as a constant load across the transmitter will enable the transmitter to be properly modulated at all times. The variable attenuator 108, by maintaining a substantially constant load will not, as it is adjusted to control the amount of power impressed on the line, affect the modulation of the transmitter. Furthermore, by maintaining a substantially constant resistive load across the transmitter, difficulty with harmonics or with spurious radiation is greatly reduced. Reduction of harmonics is an important factor in the effective operation of the system described herein for the reason that the $\lambda/2\pi$ relationship is based on frequency with respect to lateral extension of the induction field from the transmission line.

It is pointed out that the attenuator normally is of the step-by-step type, that is, the various portions of the T-section are brought into the attenuator circuit by means of a gang-switch with which the various resistors are connected in a T-pad arrangement. The various steps, or operating positions of the switch, may be numbered or graduated in terms of feet so as to facilitate the provision of a predetermined lateral extension of the induction signaling field with respect to the position of the attenuator switch. In this manner an operator may, by turning a particular attenuator, such as attenuator 108A, Fig. 1, associated with transmission line 14 on runway 10, to a designated position on the attenuator scale, regulate the lateral extent of the induction signaling field from a normal runway coverage (shown in Fig. 1 as arrows I F normal which extend either side of the transmission line to Y—Y') to the extended range of the induction field so as to cover the entire airport area by utilizing transmission line 14. The maximum extension of the induction field, with maximum signaling setting of the attenuator, is shown by the arrows of I F max., which extend laterally equidistant either side of transmission line 14 to the outer boundaries designated by X—X'.

In practical installations of the system of the invention the attenuators associated with the various runways as well as the runway transmitters and receivers may be located in the central

control tower so that the control operator may vary the extent of the signaling field of any runway, or cover the entire field from any runway system as desired. For the latter purpose, if desired, the different attenuators may be ganged together on a single shaft, or by a suitable mechanism in such a manner that a single control dial will adjust all attenuators simultaneously and thereby vary the induction field about all runways simultaneously.

In instances where it is not convenient to locate the attenuators in the control tower, and where it is desirable to regulate the induction field from time to time, the various attenuators may be remotely controlled by means of line connection with the control tower by any well-known remote control mechanism, such as self-synchronous motors, relays, or step-by-step switches.

A "transmit-receive" relay 150 is in parallel with relay 127 so that relay 150 is energized at the same time as relay 127. The R. F. energy after attenuation is applied to contact 151 which engages armature 152, which armature is connected to the induction cable or wave guide 109. When the "transmit-receive" relay is de-energized, the induction cable or wave guide 109 is connected to the condenser 162 of the receiver due to the armature 152 engaging the lower contact 153. A variable resistor 154 is connected from the grid of tube 161 to ground by means of contact set 155 when the "transmit-receive" relay 150 is energized so as to be in the transmit position. The purpose of the parallel resistor 154 is to ground the grid of tube 161 when the transmitter is in operation so that it prevents "blocking" of the receiver by preventing excess energy from being impressed upon the grid of tube 161. The blocking resistor 154 also reduces received signal energy sufficiently to prevent acoustic feed-back during periods of transmission between the loudspeaker and microphone at the central point. It will be observed that the shunting resistor 154 is variable. When the "transmit-receive" relay is de-energized or in the receive position, the shunting resistor 154 is excluded from the circuit.

In order to provide a regular check on the integrity of the communicating system, an automatic motor-driven pulsing switch 115 is employed in automatically energizing the transmitter and concurrently modulating the transmitter with an audio frequency tone signal. The manner in which this functions has been outlined in some detail in the copending Halstead application Ser. No. 350,972 for Radio traffic control system.

A cam 116 operated by electric motor 117, during rotation, closes the contacts 118, 119 and 120 associated with switch 115. Audio frequency signal energy from audio frequency oscillator 121 is impressed on the primary winding of line transformer 95 through coupling condensers 125 and 126 as long as armatures 91 and 92 of relay 90 are in normal downward position, as shown. The contacts 120 of motor-driven switch 115 apply D. C. energizing voltage derived from bleeder resistor 130 to the winding of relay 127 as indicated in Fig. 4, as long as armature 131 of relay 90 is in the normal or downward position, shown in illustration. Upon application of D. C. voltage to winding of relay 127, contacts 132 and 133 of relay 127 are closed. Closing of contacts 132 applies plate voltage to the transmitter, as shown. Contacts 133 of relay 127 are not utilized during automatic pulse transmission but are provided in order to apply voltage to the microphone 140 of a local handset 141.

It will be understood, after reading the foregoing and after a study of the diagram, that the motor-driven switch will automatically apply D. C. energizing voltage, as well as an audio frequency signal to the transmitter, thereby causing it to emit an audio frequency tone signal at regular time intervals. In order to permit speech transmission without interruption by the automatic pulse system, the lower contacts 142 and 143 of relay 90 are disconnected from armatures 91 and 92 as long as remotely controlled relay 90 is energized from the central control point. In order to permit priority of control from the central control station in the event that the local handset 141 is to be employed, D. C. energizing voltage can only be applied to winding of relay 127 as long as armature 131 is resting against lower contact 145 as shown. In this manner, if the dispatcher wishes to utilize the transmitter, relay 90, upon closing, will break the control circuit between the press-to-talk switch 146 of handset 141 and the control relay 127, as shown in the diagram.

Local handset 141 is utilized ordinarily in talking from a taxiing point to a plane on a specific runway, whereas handset 39 is utilized by the dispatcher, who will have supervisory control of all runway operations.

A small amount of R. F. energy is fed through a tuned input circuit 160 of detector tube 161 through variable coupling condenser 162, as shown. Demodulated signal energy is applied to the grid of audio amplifier tube 163 through coupling condenser 164 and potentiometer 165, as illustrated. Amplified signal energy from audio amplifier tube 163 is applied to the primary of output transformer 166, the secondary of which is connected to the receiver element 167 of handset 141. The secondary winding is also connected to the receiver line 44 associated with the runway transmitter and receiver control circuits.

In order to prevent interference by the automatic pulsing signal during reception of signals from mobile or other transmitters within the signaling zone, relay 171, connected in shunt with plate resistor 170, is employed to automatically suspend pulse transmission whenever carrier wave energy is being received from transmitters other than that associated with the receiver. This relay is actuated by increase of plate current in the detector tube 161 during reception of carrier wave energy from a mobile unit or other external transmitters. The contacts 173 of relay 171 are opened during reception of carrier wave energy from an external transmitter, thereby opening the automatic pulse keying circuit in which contacts 120 and 173 are in series connection. This suspends the pulse transmission as long as the carrier from an external transmitter is being received. Contacts 174, associated with transmit-receive relay 150, are in parallel with contacts 173 and are closed during perods in which the transmitter associated with the detector 161 is energized. This assures continuation of pulsing when the transmitter associated with the receiver is in operation, and prevents interruption of pulse transmission by the opening of relay contacts 173. Condenser 172, disposed in parallel across the winding of relay 171, is an R. F. by-pass condenser.

It will therefore be seen that through the system of the invention it is possible to establish restricted-range two-way communications, with

automatic checks on the integrity of the system, between a control point and aircraft or other units adjacent a particular runway, or between a control point and aircraft on all runways simultaneously.

It is also pointed out that, with the same system, communications may be established with personnel in hangars or other fixed points of the airfield area. This function is effected in a manner similar to that described above by means of transmission lines 29A and 29B associated with hangars 33A and 33B, respectively. Zone transmitter 180, which is controllable from the central control unit 26, is employed to supply carrier wave energy to transmission lines 29A and 29B, while attenuator units 181A and 181B, similar to attenuator 103 of Fig. 4, are employed in regulating the amount of R. F. energy on transmission lines 29A and 29B, respectively. Termination units 31A and 31B, equivalent to the network in which variable resistor 111, Fig. 4, is a part, are employed at the termination of transmission lines 29A and 29B, respectively. By means of properly regulating the R. F. attenuators 181A and 181B and termination units 31A and 31B, the lateral extent of the effective induction signaling field may be expanded to includes the "aprons" and other parts of the field in addition to the hangar area. In this connection, it is pointed out that, in similar manner, a single transmission line on the field, such as 14, Fig. 1, may provide, by proper regulation of the attenuator and termination units, such as 108, and the network 111—112, respectively (Fig. 4), associated with the transmission line, an effective induction signaling field having a lateral and longitudinal extension sufficient to cover, with military security, a wide area, including all buildings and other points within the desired signaling zone. In event of bombing, or in other emergencies, when certain transmission lines, such as 29A and 29B, might be rendered unserviceable, any operative transmission line within the signaling area may be brought into service to provide the necessary communications facilities for the entire area without space radiation of wave energy which could be detected at a distance of approximately a mile or more from the airport.

The attenuator, such as 108A in Fig. 1, may be adjusted to vary the intensity of the signal strength impressed upon the transmission line. The lateral extent of the normal induction signaling field employed for individual runway communications is schematically represented in Fig. 1 by legend "I F normal." The legend I F normal is associated with arrows on either side of the transmission line 14 and extends substantially equidistant on either side thereof to the broken lines Y—Y'.

The attenuator, such as 108A, may be adjusted to increase the lateral extent of the induction signaling field to a maximum which is indicated by legend "I F max." The legend I F max. is associated with arrows on either side of the transmission line 14 and is schematically represented as establishing an effective signaling area to the extent of the broken lines X—X'. The maximum effective induction field extends substantially equidistant on either side of the transmission line 14. In the drawings, the portion of the maximum induction field on one side of the transmission line 14 is represented as 200. While the arrow I F max. on both sides of the transmission line 14 should be the same length, it is pointed out here that limitations of space on the drawing paper prevents the suitable extension of this line to equal the length of the arrow on the opposite side of the transmission line 14. The extent of the arrows I F max., however, is clearly representative that the maximum induction field embraces the entire airport area or desired effective signaling area.

It will therefore be seen that, by the proper choice of frequency, proper type of transmission line, proper regulation of amount of R. F. energy impressed on the line, and proper termination of the line, an effective induction signaling field, which may be controlled within definite predetermined limits with regard to lateral and longitudinal extension of the field, may be established in such manner as to blanket a given area without need for a conventional radio system utilizing an antenna and its attendant propagation of radio wave energy over distances which are relatively unpredictable.

It is pointed out, however, that in airport installations of the system of the present invention, means have been incorporated for selectively energizing a space-radiating transmission system, employing a conventional antenna, for use in communicating with planes in the air, or with other mobile units at an appreciable distance from the airport, when military security permits the employment of conventional radio system. If desired, both the induction signaling system, and the space-radiation system with its associated antenna, may be operated on a common frequency without causing interference in air-borne receivers from signals transmitted by the induction system used for ground-communications. Such common-frequency operation presents an advantage in certain cases where standard aircraft receivers are employed and where it is undesirable, from an operations viewpoint, for aircraft personnel to retune their receivers from the ground frequency to the airway frequency, or vice versa, in leaving the field, or in landing on the field. Inasmuch as the entire system, including both the induction signaling and space radiation methods, is under continuous selective control of the airport operator, transfer of communications from the ground system to the airways system may be made instantly.

It is anticipated, however, that inexpensive induction radiotelephone receiving equipment, tuneable over the range of frequencies employed in the ground signaling system and pretuned to a designated ground frequency in this band, will be employed as standard equipment in aircraft to completely divide the communications load at airports, thus differentiating between ground and air-borne traffic. In this application, the induction receiver, pre-tuned to the ground communications frequency, will be utilized by aircraft and by other mobile units, or by key personnel, in all ground operations, while the conventional aircraft radio receivers will be employed as at present for communications with aircraft in flight.

It is also pointed out, that the system of the invention, in addition to its provision of voice communication means individual to each zone, also discloses means whereby visual signals actuated by a signal received from an aircraft on a particular runway or adjacent the runway, as in landing or in taking off, will visually indicate in the control tower the presence and location of the vehicle with respect to a particular runway. The runway is usually identified by the appearance of an illuminated numeral on the control

panel in the control tower during periods when the operator of an aircraft on the runway is transmitting signals to the control tower.

The system of this invention utilizes the concentrated electromagnetic induction field surrounding a ground-laid cable, in contradistinction to the space radiation field which normally exists about ordinary antenna systems beyond distances of $\lambda/2\pi$, where λ is the wavelength in meters. The relationship between the induction and radiation fields about the transmission line utilized in the illustrative application of the invention is such that at a distance of $\lambda/2\pi$, the induction field equals the radiation field. At distances less than $\lambda/2\pi$ the induction field predominates, and becomes much stronger than the radiation field as the distance from the transmission line is decreased. At distances greater than $\lambda/2\pi$ the induction field falls off rapidly, and the radiation field predominates, decaying inversely as the distance.

The attenuation network permits the adjustment to a substantially predetermined value of the total field, that is the induction field plus the radiation field, at a distance of $\lambda/2\pi$. Normal practice is to restrict the total field strength at this distance to the noise level, which is normally about 15 to 20 microvolts per meter at frequencies in the 200 to 400 kc. band, which have been employed in practical applications of the invention.

It should be noted that the restriction of the total field strength to 15 microvolts per meter at a distance of $\lambda/2\pi$, which equals 500 feet at 300 kc., will result in a radiation field of about 5.2 microvolts per meter at a distance of 1000 feet, and that this is about one third of the normal noise level encountered at this frequency. Therefore, the signal will not be detectable, even though excellent communication is possible at distances of 200 or 300 feet from the transmission line of the system of the invention.

The termination unit is employed to match the impedance of the transmission line at its far end. When properly adjusted, this unit restricts the formation of standing waves on the transmission line, thereby producing a substantially uniform response in receivers on vehicles traversing the length of the line between the attenuator unit and the termination unit.

If the field were not uniform, and standing waves existed on the line, much higher field strength at the antinodes would be required in order to produce a uniform signal in receivers in various parts of the signaling zone extending parallel to the transmission line. Such increase in field strength, which would counteract the null points, would produce a radiation field which would be effective at distances of several miles and possibly farther.

The distance at which this method of induction signaling is effective is, of course, dependent upon the amount of radio frequency energy impressed on the transmission line, as determined by the setting of the variable attenuation network, as well as the attenuating characteristics of the line at its operating frequency.

It is obvious that with a system of this type, in which the total induction and radiation fields are limited to predetermined distances within a given area, receiving devices located outside of the area will not be effected, and therefore, communications cannot be intercepted. It is also possible with a system of this type, to provide restricted range communications services on a common frequency in adjoining areas without mutual interference. This feature is of importance in closely spaced airports, or in railroad terminal areas where several railroads have terminal facilities within a short distance of each other.

What we claim as new and desire to secure by Letters Patent of the United States is—

1. An electrical signaling system for communicating intelligence to and from mobile units in a plurality of traffic zones from a single control point, comprising an electronic transmitter and receiver for each of said traffic zones, a plurality of separate transmission lines one disposed along each individual one of said traffic zones and individual thereto, each one of said transmission lines being connected directly to its respective electronic transmitter and receiver, all said transmitters being controllable from said single control point, a central control unit disposed at said single control point, metallic conductors connecting each of said traffic zone electronic transmitters separately to the central control unit, and switching means positioned wholly at the central control unit for selectively completely connecting one or more of said electronic transmitters directly with the central control unit, and independently of any other transmitter or any switching device not so positioned.

2. An electrical signaling system for communicating intelligence to mobile units in a plurality of traffic zones, from a single central point, comprising an electronic transmitter and receiver for each of said traffic zones, a plurality of separate transmission lines, one disposed along each individual one of said traffic zones, each said transmission line being connected to its own respective electronic transmitter and receiver independently of any other transmission line, a central control unit, a separate circuit for connecting each one of said electronic transmitters and receivers directly to the central control unit, and switching means located wholly at the central control unit for selectively connecting one or more of said electronic transmitters and receivers with the central control unit, independently of any other transmitter, or any other switching device not so located.

3. A traffic signaling system for communicating signal intelligence to and from traffic units in a plurality of traffic zones individually controlled from a single central point, comprising an electronic transmitter and receiver for each of said traffic zones, a discrete transmission line disposed along each of said traffic lanes, each said transmission line being connected directly to its respective electronic transmitter and receiver, independently of any other transmitter, a central control unit, a plurality of conductive channels, each separate conductive channel connecting one only of said electronic transmitters and receivers directly to the central control unit, independently of any other transmitter, selective switching means located completely at the central control unit for selectively and directly connecting one or more of said electronic transmitters and receivers with the central control unit, independently of any other transmitter, or any distant switching device, and a microphone and an aural signal device selectively connectable directly to each of said electronic transmitters and receivers, said switching means located wholly at said central control unit acting to establish all said connections independently of the position of any traffic unit in any zone.

4. A traffic signaling system for communicating signal intelligence to traffic units on a plural-

ity of diverging traffic lanes comprising an electronic transmitter and receiver for each of said traffic lanes, a transmission line disposed along each of said traffic lanes, said transmission line being connected to each of its respective electronic transmitters and receivers, a central control unit, conductors connecting each of said electronic transmitters and receivers to the central control unit, selective switching means at the central control unit for selectively connecting one or more of said electronic transmitters and receivers with the central control unit, a microphone and an aural signal device connectable to each of said electronic transmitters and receivers, and a microphone and an aural signal device connectable at the central control unit to the various electronic transmitters and receivers when the selective switching means is in operative position connecting the central control unit with any of the electronic transmitters and receivers.

5. A traffic signaling system for communicating signal intelligence to traffic units on a plurality of diverging traffic lanes comprising an electronic transmitter and receiver for each of said traffic lanes, a transmission line disposed along each of said traffic lanes, said transmission line being connected to each of its respective electronic transmitters and receivers, a central control unit, conductors connecting each of said electronic transmitters and receivers to the central control unit, selective switching means at the central control unit for selectively connecting one or more of said electronic transmitters and receivers with the central control unit, a microphone and an aural signal device connectable to each of said electronic transmitters and receivers, a microphone and an aural signal device connectable at the central control unit to the various electronic transmitters and receivers when the selective switching means is in operative position connecting the central control unit with any of the electronic transmitters and receivers, and a visual indicator at the central control unit for each of the electronic transmitters and receivers and controllable by said selective switching means to indicate the particular transmitters and receivers operatively connected to the central control unit.

6. A traffic signaling system for communicating signal intelligence to surface-borne traffic units in at least one of a plurality of traffic zones, all controlled from a common point, comprising an electronic transmitter for each individual one of said traffic zones, a separate transmission line disposed along each of said traffic zones, said transmission line being connected directly to its respective electronic transmitter, a central control unit, conductors connecting each of said electronic transmitters directly to the central control unit, and switching means located entirely at the central control unit and controllable solely thereat for selectively connecting one or more of said electronic transmitters with the central control unit, directly and without the intermediary of any other switching means not so located.

7. A traffic signaling system for communicating signal intelligence to surface-borne traffic units in at least one of a plurality of traffic zones, all controlled from a common point, comprising an electronic transmitter and receiver for each of said traffic zones, each such electronic element being connected for only a single zone, a transmission line disposed along each of said traffic zones, said transmission line being connected directly to its respective electronic transmitter and receiver only, a central control unit, conductors connecting each of said electronic transmitters and receivers directly to the central control unit, independently of the conductors leading to any other transmitter, and switching means at the central control unit for selectively connecting one or more of said electronic transmitters and receivers directly with the central control unit, said switching means being controlled solely and completely from said central control unit and the connection established thereby to any one of said transmitters and receivers being independent of any connection to any other transmitter and receiver.

8. A signaling system for selectively communicating signal intelligence to surface-borne and air-borne traffic units comprising a radio transmitter having a space radiation antenna connected to the output thereof, a second radio transmitter having a transmission line connected with the output thereof, a termination unit connected to the far end of the transmission line with said transmission line being grounded through said termination unit to substantially restrict formation of an appreciable standing wave on said transmission line, a control unit including a selective switching mechanism for selectively connecting either the first of said transmitters or the second of said transmitters to the control unit, both, said first and said second radio transmitters, being operative on a common carrier frequency, to the end that communication may be established with surface-borne traffic by utilizing the second of said radio transmitters without signal reception by air-borne traffic.

9. A signaling system for communicating signal intelligence to surface-borne and air-borne traffic units comprising a radio transmitter having a space radiation antenna connected to the output thereof, a second radio transmitter having a transmission line connected with the output thereof, a termination unit connected to the far end of the transmission line with said transmission line being grounded through said termination unit to substantially restrict formation of an appreciable standing wave on said transmission line, a control unit including a selective switching mechanism for selectively connecting either the first of said transmitters or the second of said transmitters to the control unit, both, said first and said second radio transmitters, being operative on a common carrier frequency, and a radio receiver for each of said transmitters, said receivers being connectable to the control unit through the selective switching mechanism.

10. A signaling system for communicating signal intelligence to surface-borne units of traffic comprising a radio transmitter, a transmission line having one end thereof connected to said radio transmitter, said transmission line being disposed along a traffic lane and having one end thereof connected to said radio transmitter, a termination unit connected to the opposite end of said transmission line to prevent standing waves thereon, and a variable attenuator connected to the radio transmitter to vary the signaling energy impressed thereon, whereby an induction field established about the transmission line may be varied in intensity by said attenuator from a normal induction field for a single lane of traffic to a maximum induction field to cover a multiplicity of traffic lanes.

11. A signaling system for communicating signal intelligence to surface-borne units of traffic comprising a radio transmitter, attenuator means for adjusting the carrier output of said transmitter without varying the degree of modulation thereon, a transmission line disposed along a traffic lane and having one end thereof connected to said attenuator, and a termination unit connected to the opposite end of said transmission line to prevent standing waves thereon.

12. A signaling system for communicating signal intelligence to surface-borne units of traffic comprising a radio transmitter, means for adjusting the carrier output of said transmitter without varying the degree of modulation thereon, a transmission line connected to the carrier output adjusting means and having a predetermined disposition in relation to the signaling area established when the system is in operation, and means connected to the transmission line to restrict the formation of standing waves thereon to the end that radiation of radio wave energy produced by said standing waves is substantially eliminated.

13. A signaling system for communicating signal intelligence to surface-borne units of traffic from a central control station, comprising a central control station, a multiplicity of individual zone radio transmitters connected to said central control station, a transmission line and a termination unit associated with each of said individual zone radio transmitters for establishing an induction field signaling zone, and an attenuation means disposed intermediate each of said individual zone radio transmitters and its associated transmission line, said attenuation means including adjustment means for adjusting the degree of localization of the induction signaling field without changing the percentage of modulation, whereby any one of the attenuator means may be employed to establish a signaling area embracing one or more of the normal induction field signaling zones.

14. A signaling system for communicating signal intelligence to surface-borne units of traffic from a central control station, comprising a central control station, a multiplicity of individual zone radio transmitters connected to said central control station, a transmission line and a termination unit associated with each of said individual zone radio transmitters for establishing an induction field signaling zone, an attenuation means disposed intermediate each of said individual zone radio transmitters and its associated transmission line, said attenuation means including adjustment means for adjusting the degree of localization of the induction signaling field without changing the percentage of modulation, and a space radio transmitter connected to the central control station and operating on the same frequency as the individual zone radio transmitters.

15. A combination electrical signal transmitter and plurality of distribution lines selectively energized thereby, singly and in multiple, including at the output of said transmitter, a variable attenuator presenting a substantially constant input load impedance to said transmitter throughout the range of attenuation, while changing the amount of energy selectively delivered to one or more of said distribution lines, from a minimum value to a maximum value.

16. In an induction radio transmitting system for restricted-area communications, a carrier wave transmitter, means for modulating said transmitter, a signal attenuator having an input

circuit of substantially constant impedance connected across the output of said transmitter, the degree of attenuation presented by said attenuator serving to establish the maximum communications range of said transmitter, a transmission line having one end connected to said attenuator, and a line termination unit connected to the other end of said transmission line to inhibit the formation of standing waves on said transmission line, whereby the induction field surrounding said transmission line predominates over the radiation field within $\gamma/2\pi$ distance from said transmission line.

17. An induction radiotelephone system for effecting restricted-range communication within one or more designated zones with radiation of radio wave energy being substantially suppressed outside of the zone or zones, including a carrier wave transmitter having an audio frequency input circuit and a radio frequency output circuit, means for modulating said transmitter, a variable attenuator having an input circuit of substantially constant impedance connected across the output circuit of said transmitter and an output circuit of substantially constant impedance, circuit means in said attenuator whereby it presents a substantially-constant load to said transmitter throughout its range of variation, a transmission line having one end connected to the output circuit of said attenuator, and a termination unit connected to the other end of said transmission line, said termination unit including a non-inductive resistor approximating the surge impedance of the line to inhibit formation of standing waves on said line.

18. An induction radiotelephone transmitting equipment for restricted-range communications along traffic lanes comprising a carrier wave transmitter having signal input and output circuits, means for modulating said transmitter connected with said signal input circuit, a variable attenuator unit connected across the output circuit of said transmitter, circuit means in said attenuator unit whereby a substantially constant load is presented to the transmitter over the range of variation of said attenuator, circuit means in the output circuit of said attenuator unit whereby the amount of signal voltage in the output circuit of the attenuator unit may be varied from maximum to minimum without causing a substantial change in the loading of said transmitter, and a transmission line connected across the output circuit of said attenuator unit and extending in a longitudinal direction along a lane of traffic wherein a restricted-range induction radio field is to be effective.

19. In an induction radio transmitting system for restricted range communications, a central control station, a plurality of zone transmitters controllable from said central control station, a plurality of zone receivers connectable with said central control station, a separate transmission line connected to each of said zone transmitters and receivers and disposed along a traffic zone, a mobile transmitter and receiver for two-way communications between a mobile unit and said central control station, and visual indicating means at said central control station responsive automatically to signal energy received by said receivers and emanating from said mobile unit transmitter to indicate at the central control station the particular traffic zone in which the mobile unit transmitter is disposed.

20. In an induction radio signaling system for two-way restricted range signaling, a control

transmitter and receiver, a transmission line connectable to said control transmitter and receiver for establishing a localized induction-radio field extending about said transmission line and useful for two-way signaling within a localized signaling zone extending parallel to said line and for a restricted lateral distance from said line, a remote transmitter and receiver disposed within the effective induction signaling range of said control transmitter, and visual indicating means disposed at said control receiver and responsive to signal energy emanating from said remote transmitter, whereby the signal energy from the remote transmitter will operate the visual indicator at the control receiver to indicate the presence of the remote transmitter within the localized signaling zone.

21. In an induction radio communications system for two-way restricted range communications a control transmitter and receiver, a transmission line connectable to said control transmitter and receiver for establishing a localized induction radio field extending about said transmission line and useful in a zone extending parallel to said line and for a restricted lateral distance from said line, a remote transmitter and receiver disposed with said zone, an attenuator for varying the amount of signal energy impressed on said transmission line by said control transmitter without substantially changing the load presented across the output of said transmitter, whereby variation of said attenuator broadens or narrows the lateral extent of the effective induction radio field about said transmission line.

22. In an induction radio communications system for two-way restricted range communications, a control transmitter and receiver, a transmission line connectable to said control transmitter and receiver for establishing a localized induction radio field extending about said transmission line and useful in a zone extending parallel to said line and for a restricted lateral distance from said line, a remote transmitter and receiver disposed within said zone, attenuating means for varying the amount of signal energy impressed on said transmission line by said control transmitter without substantially changing

the load presented across the output of said transmitter, said attenuating means being connected between said transmitter and said transmission line, whereby variation of said attenuating means broadens or narrows the lateral extent of the effective induction field about said transmission line, and a termination unit connected to the end of said transmission line remote from the transmitter, said termination unit approximating the surge impedance of the transmission line, whereby radiation of wave energy is ineffective for communications substantially beyond $\lambda/2\pi$ distance from said transmission line.

23. An electrical signaling system for two-way communications between a central control station and mobile units in a plurality of traffic zones, comprising an electronic transmitter and receiver for each of said traffic zones, a central control station, means for connecting said central control station with the transmitter and receiver in each of said traffic zones, a mobile transmitter and receiver, and visual indicating means at said central control station for indicating to the operator thereof the particular zone in which the mobile transmitter is located.

24. A system for establishing two-way carrier wave communications between a central station and mobile units in any one or all of a plurality of communications zones, including, a plurality of carrier wave zone transmitters, each serving a predetermined communications zone, a plurality of normally-on carrier wave zone receivers, each serving a predetermined communications zone, a remote control line connecting each of said zone transmitters and receivers with a central station, switching means at said central station connectable with one or all of said remote control lines whereby any one or all of said remote control lines may be used for two-way communications between said central station and mobile units in any one or all of said zones, and a visual indicating means at said central station selectively operable by received signal energy from any one of said zone receivers to identify the zone in which the signal originates.

WILLIAM S. HALSTEAD.
BENJAMIN C. LORD.