Dec. 20, 1960 J. L. BARKER 2,965,893

VEHICLE DETECTOR

Filed May 31, 1955 2 Sheets-Sheet 1

Fig. 1.

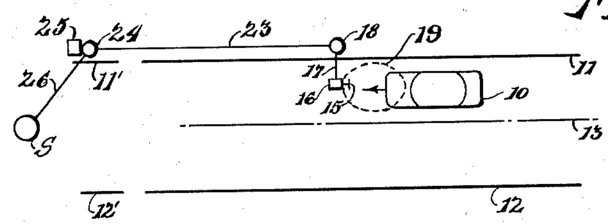


Fig. 2.

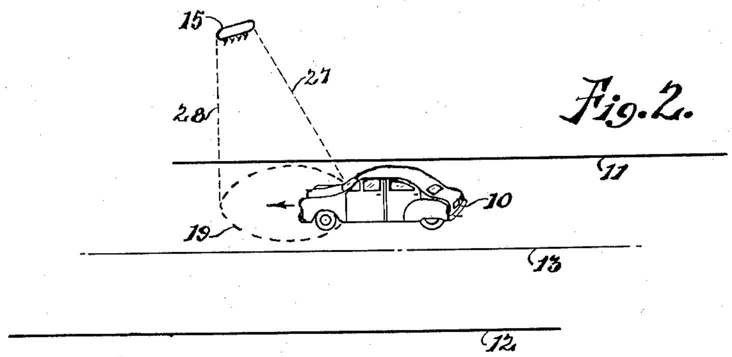


Fig. 3.

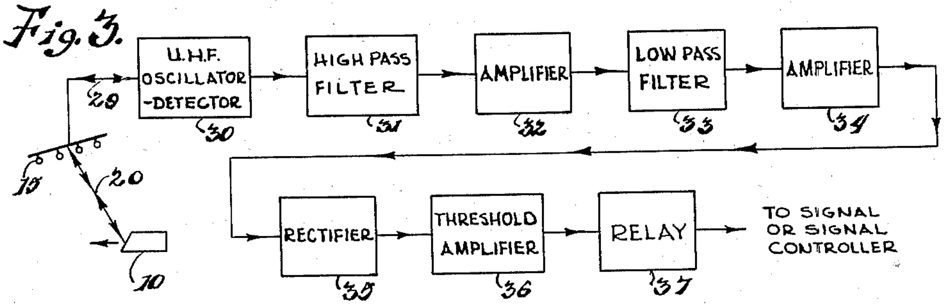
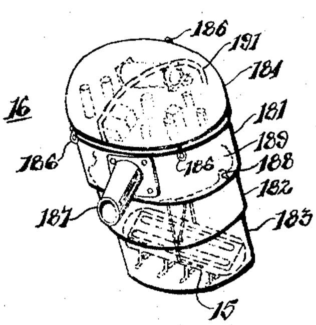


Fig. 5.

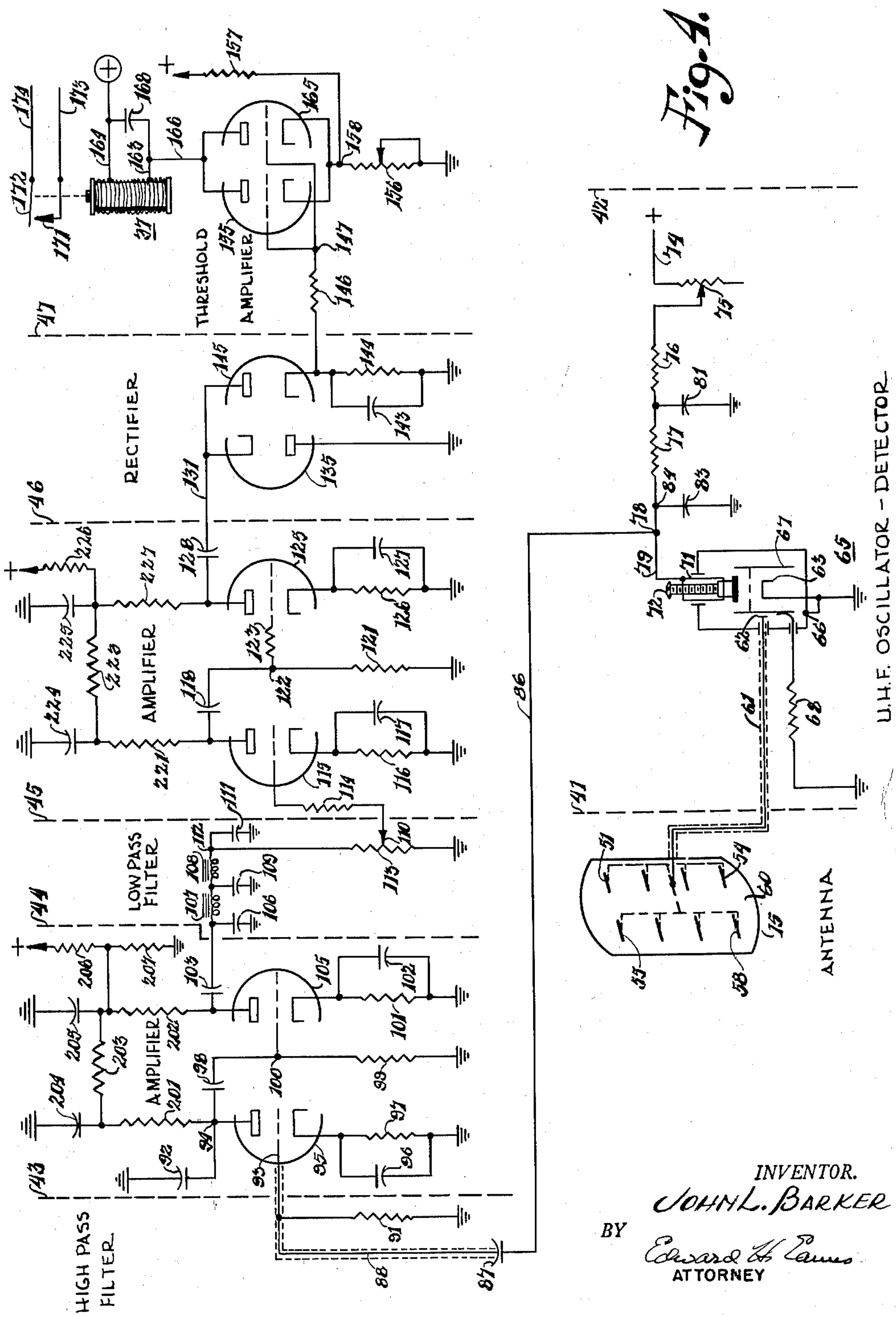


INVENTOR.
JOHN L. BARKER
BY
Edward H. Eames
ATTORNEY

Dec. 20, 1960 J. L. BARKER 2,965,893

VEHICLE DETECTOR

Filed May 31, 1955 2 Sheets-Sheet 2



INVENTOR.
JOHN L. BARKER
BY Edward H. Eames
ATTORNEY

United States Patent Office 2,965,893
Patented Dec. 20, 1960

2,965,893

VEHICLE DETECTOR

John L. Barker, Norwalk, Conn., assignor to Eastern Industries, Incorporated, East Norwalk, Conn., a corporation of Delaware

Filed May 31, 1955, Ser. No. 511,995

18 Claims. (Cl. 343—7)

This invention relates to a traffic signal control employing ultra high frequency radio waves reflected from a moving vehicle in the roadway to actuate a traffic signal, and to a greatly improved road vehicle detection system employing the Doppler effect on such radio waves from such a moving vehicle.

More particularly the invention relates to a traffic signal control or traffic detection system deriving brief actuation pulses from vehicles passing a desired detection point in the roadway and distinguishing substantially from all other objects and influences ordinarily found associated with road traffic conditions.

It is a general object of the invention to provide a traffic signal control or traffic detection system employing radio reflection, and of compact and low cost construction and highly reliable operation to enable the practical control of traffic actuated signals by radar, and thus avoid the need for treadle switches, magnetic or other devices in or under the pavement of the roadway.

It is also an object of the invention to provide such a control or system which will provide a series of brief pulses from a close succession of spaced passing vehicles such that the number of pulses will indicate in substantial degree the number of vehicles passing, whereby this system may serve in traffic actuated signal and other control systems apportioning signal time or otherwise responding to the volume or rate of flow of traffic.

Other objects will be apparent from the following description and appended claims.

Traffic actuated control systems employing means for detecting approaching vehicles on one or more of the roads or streets at a traffic intersection are already well known for controlling traffic signals.

Such traffic actuated control systems are widely recognized as of great benefit to the general public using the roadway in their ability to initiate a traffic signal time cycle in response to traffic requirements and in adjusting the length of the go periods of the respective roads at the intersection in accordance with the actual needs of traffic as the latter varies from moment to moment as well as from the heavier peak traffic periods to the lighter off-peak times of day.

Such systems have in the past employed most largely treadle switches set in the surface of the roadway or magnetic detector elements set in or under the pavement of the roadway, in position to be actuated by approaching vehicles, ordinarily at a distance of 50 to 300 feet or more in advance of the intersection. At high speed traffic intersections such detector devices are sometimes set considerably more than 300 feet from the intersection. Examples of such traffic actuated control systems may be found in the U.S. Patent 2,219,310 of H. A. Haugh, and in my U.S. Patent 2,265,991.

While such treadle switches and magnetic detectors have served quite well in the detection of approaching traffic in connection with such systems, the installation of such devices is costly because of the need of breaking into the pavement and providing adequate foundation for

the installation of such devices, and also has a serious disadvantage in the need for blocking of the roadway temporarily during the installation period, which is not only hazardous to workers but also to the users of motor vehicles on the roadway and in many cases is a considerable traffic handicap where heavy traffic streets in cities are involved for example.

Furthermore, the more efficient of such traffic actuated control systems for the traffic signals take in account the traffic on the several parallel lanes on multi-lane approaches in very heavily travelled streets for example in order to make the maximum use of the intersection and to reduce the delays to traffic to a minimum, and thus these former pressure contact type treadle detectors and magnetic detectors have ordinarily been placed in adjacent traffic lanes on multi-lane streets and roadways on the approach to intersections in order to take account of the traffic in the several lanes, and it has been found to be important in this connection to have the detector devices respond to a large degree to individual cars or axles of cars.

It is also an advantage in traffic actuated signal systems to obtain an actuation pulse from vehicles of variable time length in accordance with the speed of the vehicles, such that the "go" signal time may be extended for such vehicles for a time period variable in accordance with the time needed for the vehicles to travel from the detector device to the signal, as in the U.S Patent 2,044,907 to F. G. Kelly for example.

In endeavoring to work out a practical radar vehicle detector to meet the particular needs and problems of road traffic and of sufficiently low cost and small bulk to serve therefor, I have found that a remarkably simplified compact and effective such radar detecting device can be provided using the Doppler radio echo principle in a particular novel manner peculiar to road traffic conditions such that these radar detecting devices may be placed at a desired distance from the signal or road intersection, to respond substantially only to approaching vehicles, and to provide a series of brief output pulses from a succession of such vehicles sufficiently comparable to the pulses derived from the earlier pressure contact and magnetic detecting devices to operate traffic actuated control systems reliably and efficiently. My new radar vehicle detector also provides an output actuation pulse whose time length varies in large degree in inverse proportion to the speed of the vehicle.

At the same time this new radar detector can be adjusted readily in position and sensitivity to enable its use to detect vehicles in two adjacent traffic lanes if desired for example, and thus reduce the cost of traffic detection as compared with the earlier systems as well as providing a device which avoids entirely cutting into the pavement of the roadway. The latter point is of particular importance in connection with the frequent resurfacing or rebuilding of roadways.

This new radar detector is of such construction that it can readily be left in place while such work is proceeding on the roadway, is not subject to the wear and tear of traffic contact, and can readily be moved to a more desirable position or detection point along the roadway if traffic conditions change.

Referring now to the several drawings illustrating a preferred embodiment of the invention:

Fig. 1 shows a plan view of a section of roadway with a radar vehicle detector on the approach to a signal in accordance with one aspect of the invention.

Fig. 2 shows an enlarged elevation view of the radar detector antenna in relation to a roadway and a vehicle thereon.

Fig. 3 shows a block diagram of a preferred form of the invention.

Fig. 4 shows a schematic circuit diagram of a preferred form of the invention.

Fig. 5 illustrates a preferred form of antenna unit and associated transmitter-receiver and electrical response circuit in a compact housing suitable for support by a mast arm over the road.

Referring to Fig. 1 in more detail a vehicle **10** is shown schematically proceeding to the left of the figure, as indicated by the arrow, along a roadway whose edges are indicated at **11** and **12** and whose center line is indicated at **13**. Supported over the roadway is an ultra high frequency radio antenna unit **15**, illustrated as of the dipole type. This antenna unit is associated with a box or housing **16** which may support or contain the antenna unit and its associated electrical apparatus as shown in Figs. 3 and 4 for example.

The antenna unit **15** is supported over the side of the roadway on which it is desired to detect approaching vehicles as for example over the right side of a roadway in which traffic drives to the right, as illustrated by the vehicle **10** approaching the signal S. The antenna unit on a two way roadway as illustrated is preferably mounted slightly nearer the side of the road than the center line of the road, by means of a supporting arm and connections **17** from a pole or post **18** and directs a beam of ultra-high frequency radio waves downward to produce an approximately elliptical pattern **19** on the same side only of the roadway and with its long axis substantially parallel to the roadway and extending from approximately directly under the antenna unit outward toward approaching traffic.

The edges of the roadway **11** and **12** are indicated as broken and extending on to the left at **11'** and **12'** to indicate some distance to the signal S which may indicate a traffic signal, as for example a traffic right-of-way signal associated with an intersection of the road **11—12** with another road not shown. The antenna detector unit **15—16** is illustrated as connected via line **17**, line **23** to a pole **24** and associated signal controller **25** and thence along line **26** to control the signal S. The line **26** may also represent a support for signal S from the pole or post **24**. It will be appreciated that under some circumstances the radar detector unit **15—16** might be connected directly to control the signal and in other circumstances might be connected to the signal controller **25** which in turn would control the signal as a part of a traffic actuated control system. In the latter case the system might involve the use of additional radar detector units for other or all of the approaches to an intersection for control of the traffic signal.

It will be appreciated that the antenna unit **15** and its associated electrical circuit apparatus of Figs. 3 and 4 might be mounted as one unit over the roadway with only its output connection extended to the controller **25** or signal S, or the antenna unit **15** alone might be mounted over the roadway and the remainder of its associated apparatus located at the side of the roadway on the pole **18** for example, or the electrical apparatus might be suitably divided between the pole and over the roadway to permit some adjustment of sensitivity for example from the side of the road.

The preferred relation of the antenna unit to the roadway for approaching traffic is illustrated more fully in Fig. 2, to enable the detector unit according to the invention to derive a brief actuation pulse from an approaching vehicle, that is a vehicle on the approach side of the roadway, and to substantially disregard vehicles on the opposite side of the roadway. It will be noted that the antenna unit is mounted at a slight angle to the horizontal, which is preferably of the order of 15 degrees, so that its transmitting axis is at a corresponding slight angle from the vertical, and the antenna beam pattern between half power points is approximately 30 degrees between the lines **27** and **28**, the line **28** representing one edge of such beam pattern extending substantially vertically downward from the antenna to the roadway and the outer edge **27** extending outward along the roadway toward approaching vehicles at an angle of approximately 30 degrees, thus providing the approximately elliptical pattern **19** of the radiant wave energy within the one side of the roadway on which it is desired to detect the vehicles. It will be appreciated that there is a diminishing amount of radiated wave energy somewhat outside of this pattern but the sensitivity of the electrical apparatus can be adjusted, in association with its particular frequency response feature described below, to substantially eliminate detection of vehicles on the opposite side of the road. The entire assembly is adjusted to respond ordinarily to a moving vehicle approximately at and somewhat beyond the position shown in Figs. 1 and 2 for example, although it will be understood that this may vary somewhat in actual practice with different types of vehicles and conditions, and in this connection a suitable height for mounting the antenna unit has been found to be about 16 feet above the roadway for example.

Referring now to Fig. 3 the ultra high frequency antenna unit **15** is illustrated at an angle to transmit a radio beam downward and reflected back from vehicle **10** along lines **20**, the ultra high frequency energy for transmission from the antenna and the reflected energy both travelling on the common line **29**, the transmitted energy being derived from the ultra high frequency oscillator-detector **30**, and the received energy bearing the Doppler frequency shift effect from moving vehicle **10**, being mixed in this oscillator-detector to provide a Doppler beat frequency output.

Since the radiant wave energy is directed downward at an angle toward the approaching vehicle in a substantially limited pattern, as indicated by the ellipse **19** in Figs. 1 and 2, the motion of the vehicle **10** will be at a considerable angle with respect to the radiant energy beam, and consequently the Doppler frequency shift effect produced on the radiant wave energy by the motion of the vehicle will be very much reduced in relation to the vehicle speed along the road. The Doppler frequency shift will be proportional to the road speed times the cosine of the angle of the latter speed direction with the shortest radial direction to the antenna at each instant of vehicle passage through the beam.

In accordance with the invention this is designed to derive a brief low frequency Doppler wave train as an actuating pulse as the vehicle passes through the beam. For vehicles moving at ordinary traffic speeds this appears at the antenna and at the input side of the oscillator-mixer at line **29** as a low frequency Doppler modulation of the transmitted ultra high frequency wave energy and appears as a low frequency output in the audio or sub-audio range at the right side of the oscillator-mixer **30**, with a transmitting frequency of 2455 megacycles per second for example. This particular low frequency output is distinguished by the filter combination **31—33** having the overall effect of a band pass filter, with this low frequency amplified and rectified to control the relay **37** via the threshold amplifier **36** which derives the substantial operating current for the relay at a desired threshold voltage level output of rectifier **35** characteristic of a desired minimum amplitude of input beat frequency.

In the preferred circuit arrangement the low Doppler beat frequency output from oscillator-detector **30** is applied first to the high-pass filter **31** which passes frequencies only above a very low level of the order of 20 cycles per second for example in order to distinguish from spurious very slowly moving reflections, before amplification. The output of the filter **31** is applied to the amplifier **32** and the output of the latter is applied to the low-pass filter **33** which cuts off frequencies substantially above the order of 40 cycles per second for example. The resulting low frequency band of the order of 20 cycles width centering on 30 cycles per second for example, is supplied to amplifier **34**. The output of amplifier **34** is rectified to derive a direct current voltage at rectifier **35** which is supplied to the threshold amplifier **36** to control relay **37**. The output of the relay is supplied directly to a signal or to a signal controller as desired.

Thus by employing an antenna pattern as described and illustrated the Doppler beat note from the moving vehicle is subject to a very large cosine angle factor which goes to essentially zero as the vehicle passes directly under the unit, and by selection of the Doppler beat note of low frequency value by means of filtering, it is possible to prevent vehicles approaching the detector at a distance from producing a Doppler shift of low enough beat frequency to get through the low-pass filter. However, as the vehicle approaches close to the antenna unit, the change in the cosine of the angle of the vehicle's motion with respect to the angle of the radiant energy between the antenna and the vehicle, as this angle approaches ninety degrees in passing, causes each passing vehicle to produce a Doppler beat note in the low end of the frequency range such that even for high speed vehicles a very low frequency is derived as the vehicle approaches under the unit. This essentially limits the actuation range of the unit to a few feet in advance of the unit.

By using a constant transmitting frequency of the order of 2455 megacycles for example and using the entire antenna for continuous transmitting and receiving, it has been found possible to obtain a narrow antenna pattern as indicated with a compact eight element dipole in-phase broad side array with each dipole extending substantially horizontally transverse to the road for horizontal polarization for best reflection from vehicles, and to obtain the cosine factor modified Doppler beat frequency within the range of 20 cycles per second to 40 cycles per second for operation of the output relay only by a vehicle passing substantially under and immediately in advance of the antenna unit.

Angling the antenna unit about 15 degrees so that most of the energy is directed on to the roadway on the approach side also assures that only one pulse is secured for each vehicle travelling under the detector.

With this arrangement also, for higher speed vehicles the cosine factor must be considerably lower in order for the Doppler beat note to fall below the high end of the low-pass filter, or in other words the high speed vehicle must be nearer to the unit within the beam pattern for actuation than the low speed vehicle. Thus with this design the effective range of the detector along the roadway is larger for a slow moving vehicle than a fast moving vehicle, which produces a wave train of longer time length for slower vehicles and a resulting output pulse from the relay which is in large degree inversely proportional to the speed of the vehicle.

Thus this design according to the invention enables individual pulses to be obtained from successive vehicles to a very high degree in a single lane of roadway, and although there is some slight loss in this relationship where the detector unit is used to cover two adjacent lanes of vehicles, the individual relationship of pulses to vehicles is maintained in the latter case to a large degree suitable for traffic actuated control systems as previously described.

Referring now to Fig. 4 showing the schematic circuit diagram, this diagram is divided into sections, identified with corresponding parts of the block diagram of Fig. 3 by the broken lines **41**, **42**, **43**, **44**, **45**, **46** and **47**, for convenience of reference between Figs. 3 and 4.

The operation of the circuit of Fig. 4 is as follows. The antenna assembly **15** is shown schematically at the lower left of the drawing, the antenna assembly including two columns of four dipoles each side by side, from dipole **51** to dipole **54** on the right and from dipole **55** to dipole **58** on the left, all mounted on the reflector backing plate **60**.

The antenna assembly is connected via coaxial line **61** to the coupling element **62** in the cavity of the ultra high frequency oscillator tube **65**. This tube is a conventional co-planar triode of the lighthouse type 2C40 for example with a re-entrant type associated cavity **66**.

This oscillator tube **65** generates the ultra high frequency energy which is transmitted via line **61** to the antenna assembly and also receives the reflected wave energy as Doppler shifted in frequency, modified by the cosine factor with respect to a speed of the vehicle. Thus the generated and reflected wave energies are mixed in the oscillator-detector, and the Doppler beat frequency, that is the Doppler shift frequency difference as modified by the cosine factor, will appear as a periodic change in anode current on line **79**, **78** and through resistor **77** and capacitor **81**. This change of current produces a periodically varying voltage across resistor **77** in accordance with the low Doppler beat frequency, the oscillator also thus serving as a detector of this low frequency output.

Capacitor **83** serves to partially attenuate high frequency signals outside the desired range. The low Doppler beat frequency signal appearing with respect to ground across resistance **77** and capacitor **81** is applied via line **86** and blocking capacitor **87** and line **88** to the input of the first amplifier.

The variable resistor **75** connected at line **74** to a regulated D.C. positive power supply serves to control the average anode current supplied via resistors **76** and **77** to the anode circuit **71** of tube **65** thereby providing a means whereby the generated ultra high frequency output of the tube may be controlled.

Bias for the oscillator tube is provided via grid resistor **68** to ground, with the cathode **63** connected to ground and to the cavity at **66**. The heater circuit for this tube, and those for the other tubes in the circuit, are conventional and are not shown.

The Doppler beat frequency signal is partly filtered by the capacitor **87** in relation to resistance **91**, the latter resistor being connected between ground and the lead **88** at the input to control grid **93** of tube **95** of the first amplifier stage. Thus the combination of capacitor **87** and resistor **91** serves as a high-pass filter to substantially attenuate frequencies appreciably below 20 cycles per second and pass all frequencies above this level, this combination therefore serving as the high-pass filter **31** in the block diagram of Fig. 3.

The tube sections **95** and **105** and their associated circuits between the broken lines **43** and **44** comprise a conventional two stage resistance capacitor coupled amplifier having relatively high gain, with capacitor **92** providing some by-pass to ground from the anode circuit at **94**, for high frequencies and noise.

The output of tube section **105** of this amplifier is coupled from its anode circuit by blocking capacitor **103** to the low-pass filter comprising capacitors **106**, **109**, **111**, inductors **107** and **108**, and load resistance **113**. The inductors **108** and **107**, connected in a series with the resistance **113** from the output side of the blocking capacitor **103** and ground, and the successive shunting capacitors **106**, **109** and **111** of this low-pass filter provide substantial attenuation of frequencies above 40 cycles per second with severe attenuation of frequencies appreciably above 50 cycles per second.

Since the high-pass filter comprising coupling capacitor **87** and resistance **91** primarily sets the low limit of frequency which can be passed by the circuit as previously described, and this high-pass filter rapidly attenuates frequencies below 20 cycles and severely below 10 cycles, the low-pass filter between the broken lines **44**, **45** and the high-pass filter to the left of the broken line **43** together provide in effect a band pass filter having a pass band of approximately 20 cycles, with the pass characteristic of the circuit peaked at approximately 30 cycles and with quite rapid attenuation above 40 cycles and below 20 cycles, although the considerably reduced signals between 20 and 10 cycles and between 40 and 50 cycles may have some limited effect for strong input signals with high sensitivity adjustment.

It has been found that a band pass arrangement over this range has additional advantages since hum voltages corresponding to 60 and 120 cycles from alternating current power supply and related sources are severely attenuated so as not to effect the circuit.

The output of the low-pass filter is obtained by adjustable tap **110** on resistance **113** serving as a potentiometer adjustment of sensitivity of the entire circuit when it is connected into the input of the two stage amplifier illustrated between the broken lines **45** and **46** and associated with the tube sections **115** and **125**.

This is a conventional resistance capacitance coupled amplifier with the addition of series resistance **114** in the grid input to tube **115** and series resistance **123** in the grid input to tube **125** to prevent blocking of the amplifier by any excessive input signal strength.

The output of this amplifier is coupled from the anode circuit of tube **125** via coupling capacitor **128** to the dual diode rectifier detector **135, 145**, the tube section **145** providing a D.C. voltage across load resistor **144** in its cathode circuit of a positive value generally proportionate to the amplitude of the Doppler beat frequency signal as attenuated by the band pass filter arrangement. This rectifier is connected for doubler action so that the maximum voltage can be secured from its output.

The output of the rectifier-detector tube section **145**, appearing across load resistance **144**, is essentially a D.C. voltage and is connected via resistance **146** to the parallel connected grids of the dual tube **155, 165** serving as a threshold amplifier to supply operating current to the relay **37** above a desired voltage value of the D.C. voltage output of tube section **145**. The cathodes of both tube sections **155** and **165** are connected in parallel via adjustable resistance **156** to ground and are also connected at junction **158** at the upper end of resistance **156** via resistance **157** to the B+ supply. The anodes of the tube sections **155** and **165** are also connected in parallel and via wire **166** through the coil of the relay **37**, the other side of this coil being connected via wire **164** to an A.C. power supply indicated by plus in a circle. The coil of the relay is shunted by capacitor **168** to sustain the action of the relay on the A.C. power supply.

Thus the tube sections **155** and **165** are parallel connected and together are operated on fixed bias provided by the connection of the cathode to junction **158** on the potential divider provided by resistances **157** and **156** between the B+ supply and ground. This bias may be adjusted at the adjustable resistance **156** so that sufficient anode current to operate the relay will be provided at a desired D.C. voltage with respect to ground applied to the grids at junction **147**, this voltage corresponding to the voltage output of the rectifier-detector **135, 145**.

The sensitivity control **110, 113** provides means whereby slight changes in the amplifier gain characteristics and in the antenna and radio frequency power output, may be adjusted for to provide best operation in response to vehicle actuation.

Since the effective zone laterally with respect to the roadway may be increased by either broadening the antenna beam or increasing the sensitivity of the unit, this sensitivity control also serves as a means for adjusting the lateral coverage.

The contacts **171, 172** are controlled by the coil of the relay **37** to close the output circuit on lines **173** and **174** for example to actuate a signal or a traffic actuated signal controller for example in response to passage of a vehicle on the approach side of the road at the vehicle detector antenna location for example.

Referring now to Fig. 5, there is illustrated a preferred mounting and housing arrangement for the antenna **15** and its associated transmitter-receiver and electrical response circuit of Figs. 3 and 4 for example.

In Fig. 5 the assembly is shown turned in the opposite direction to that in Fig. 1 and Fig. 2 to illustrate the slip-fitter or mounting bracket **187** on which the unit may be mounted on a mast arm for example. Thus the position of the unit in Fig. 5 is turned 180 degrees from the position shown in Figs. 1 and 2, merely for the purpose of convenience of illustration in Fig. 5.

The overall housing of the antenna unit and its associated electrical apparatus is designated **16** in Fig. 5 to correspond with the box similarly designated in Fig. 1. This housing includes a main shell having an upper section **181** and a lower slightly recessed section **182**, the recess being primarily for strengthening of the shell and for appearance. The lower section **183**, housing the antenna unit **15**, serves as a radome or protective cover for the antenna unit and is made of a fiberglass-polyester resin composition for example to permit the radio frequency energy to pass through it. The unit **16** is provided with a removable cover **184** at the top which may be attached to the shell by the catches **186**.

The antenna unit in the lower section and some of the associated electrical apparatus in the upper section together with the lifting handle or bail **191** are shown in broken line outline. The entire inner assembly within the shell **181—182—183** may be lifted out of the shell for inspection or replacement if desired.

A portion of a shelf member **189** in the middle section is also illustrated in broken line outline with an indentation cooperating with a keying projection **188** to assure that the antenna and its associated assembly inside the outer shell will be set in desired relationship in assembly or in connection with replacement after removal. The shelf can be provided with two notches to cooperate with the keying projection at 180 degrees spacing so that the entire internal unit can be turned at 180 degrees if desired to be used at the left side of an approach road from a mounting on a central esplanade on a divided roadway for example. Alternatively a single notch in the shelf may be provided with a removable keying projection which may be transferred from one 180 degree position to the other.

Although a preferred form of circuit for the invention has been illustrated and described above, it will be appreciated by those skilled in the art that other forms of filtering may be provided to pass the desired narrow band of Doppler beat frequency characteristic of close passage of vehicles through the angled radio beam, as by a Wien bridge filter circuit for example, and the filtering may be applied at a different stage in the amplifying circuit, if desired in applying the teachings of the invention.

In providing a radar detection device according to the invention it has been found that the antenna assembly **15** may be of the order of 6 inches by 10 inches by 1½ inches in size, and thus this unit and the entire assembly of Fig. 5 may be of sufficiently compact size to serve as a practical radar detector unit for road traffic, one which may be easily transported and readily and rigidly mounted over the roadway for reliable operation by desired moving vehicles and not by undesired vehicles or other extraneous moving objects or changing reflections.

It will be obvious that although the beam has been illustrated as angled toward approaching traffic in the preferred form, it will be understood that this angle could be reversed 180 degrees with respect to such approaching vehicles so that the beam would be similarly angled along the same side of the roadway away from such approaching vehicles so as to detect such approaching vehicles as they pass beyond the antenna unit or in other words are departing from said antenna unit in passing through such oppositely angled beam.

It will be obvious to those skilled in the art that various other modifications may be made in the assembly of the apparatus and in the connections and circuit arrangements and parts thereof without departing from the spirit of the invention within the scope of the appended claims.

I claim:

1. In a traffic controlled signal system, a generator of ultra-high frequency waves having a wave length very much smaller than the width of ordinary road vehicles, means including a directional antenna disposed above a road and mounted with its transmitting axis at a slight angle from the vertical for transmitting a narrow divergent beam of said ultra-high frequency waves from said generator downward over a limited width of said road corresponding to the path of vehicular traffic approaching said signal and angled from the vertical for a limited distance along such path and for receiving back and supplying to said generator reflections of such waves as shifted in frequency by the Doppler effect of a vehicle passing through said angled beam, means responsive to a narrow band of frequency of said Doppler frequency shift at a low frequency to provide a brief output pulse as the vehicle passes through a part of said beam, and control means connected to said responsive means to be controlled by the output of the latter in response to such passage of a vehicle.

2. A combination as in claim 1 in which said responsive means includes means responding only to such a low frequency of such Doppler shift as to provide a brief output pulse only as the vehicle passes through the part of the beam nearing a maximum angle with respect to the line of travel of the vehicle along the road.

3. A combination as in claim 1 in which said responsive means includes means for deriving a brief output pulse varying in time length in substantial proportion inversely to the speed of vehicles passing along said road through said beam.

4. A combination as in claim 1, with said beam angled toward traffic approaching said signal.

5. In combination, means mounted over a roadway for transmitting a narrow beam of ultra-high frequency radio wave energy downward on to the roadway at a slight angle from vertical toward approaching vehicles and for receiving back such wave energy reflected from a moving vehicle in said beam as shifted in frequency by the Doppler effect of the component of vehicle speed toward the transmitting and receiving means caused by movement of the vehicle along the roadway through such angled beam and for mixing said transmitted and reflected wave energies and deriving the Doppler beat frequency therefrom, means for amplifying said beat frequency and means for filtering said beat frequency to derive a very low frequency component therefrom characteristic of passage of such vehicle through such angled beam, and means for controlling an output circuit in response to said low frequency amplified component.

6. In combination, means mounted over a roadway for transmitting a narrow beam of ultra-high frequency radio wave energy downward on to the roadway at a slight angle from vertical toward approaching vehicles and for receiving back such wave energy reflected from a moving vehicle in said beam and as shifted in frequency by the Doppler effect of the component of vehicle speed toward the transmitting and receiving means caused by movement of the vehicle along the roadway through such angled beam and for mixing said transmitted and reflected wave energies and deriving the Doppler beat frequency therefrom, means for amplifying said beat frequency and including means for filtering said beat frequency to derive a very low frequency component therefrom characteristic of passage of such vehicle through such angled beam, means for rectifying said low frequency component to provide a direct current voltage in accordance with the amplitude of the low frequency component, means for providing a rapidly increasing current output above a desired threshold value of such direct current voltage, and relay means controlled by said current output.

7. A combination as in claim 6 and said filtering means deriving a narrow low frequency band characteristic of the Doppler shift component as the frequency of the latter passes through such band as the vehicle passes through said beam.

8. A combination as in claim 5 and said filtering means deriving a narrow low frequency band characteristic of the Doppler shift component as the frequency of the latter passes through such band as the vehicle passes through a part of said beam.

9. In combination, means mounted over a roadway for transmitting a narrow beam of ultra-high frequency radio wave energy downward on to the roadway at a slight angle from vertical toward approaching vehicles and for receiving back such wave energy reflected from a moving vehicle in said beam as shifted in frequency by the Doppler effect of the component of vehicle speed toward the transmitting and receiving means caused by movement of the vehicle along the roadway through such angled beam and for mixing said transmitted and reflected wave energies to derive a brief wave train of reducing Doppler beat frequency as the angle of the vehicle's motion increases in passing through said beam, and means for filtering and amplifying only a narrow frequency band near the lower frequency end of said reducing frequency to provide a brief output pulse for the passing vehicle.

10. A combination as in claim 9 in which said output pulse varies in length in substantially inverse degree to the speed of said vehicle along the road.

11. A combination as in claim 9 in which said ultra-high frequency is of the order of 2400 megacycles per second and said frequency band is of the order of 20 cycles per second at substantially 30 cycles per second.

12. In combination, an ultra-high frequency oscillator for generating constant frequency radio waves, an antenna mounted over a road and connected to said oscillator for directing a narrow beam of such waves from said oscillator downward on to the roadway and at a slight angle with vertical toward approaching vehicles and for receiving such waves as reflected from a vehicle moving along the road through said beam and shifted in frequency in accordance with the Doppler effect of the radial component of such vehicle speed in said beam and for supplying said reflected wave energy to said oscillator, said oscillator serving to mix said generated and reflected waves and to detect the Doppler beat frequency therefrom, a high pass filter to attenuate extraneous low frequency components of the Doppler beat frequency level characteristic of passage of the vehicle out of the final part of said beam, an amplifier for the output of said high pass filter, a low pass filter for passing only low frequency components from said amplifier characteristic of said frequency shift as said Doppler component reduces toward zero in the passage of the vehicle through said beam, a second amplifier for the output of such low pass filter, a rectifier to derive a direct current voltage from the output of said second amplifier, a threshold response amplifier to provide a current output in response to said direct current voltage above a desired value of the latter, and a relay operated by said current output.

13. A combination as in claim 12, in which the angle of said beam with the vertical approximates 15 degrees.

14. A combination as in claim 12 in which said beam has a total angle of substantially 30 degrees between half power points and extending from substantially directly under said antenna outward for such 30 degrees toward approaching vehicles.

15. In combination, means mounted over a roadway for transmitting a narrow beam of ultra-high frequency radio wave energy downward on to the roadway at a slight angle from vertical and parallel with the direction of the roadway, with the major portion of the beam extending from directly under said means in one direction

along the path of vehicles passing along the roadway, and for receiving back such wave energy reflected from a moving vehicle in said beam as shifted in frequency by the Doppler effect of the component of vehicle speed with respect to the transmitting and receiving means caused by movement of the vehicle along the roadway through such angled beam and for mixing said transmitted and reflected wave energies and deriving the Doppler beat frequency therefrom, means for amplifying said beat frequency and including means for filtering said beat frequency to derive a very low frequency component therefrom characteristic of passage of such vehicle through such angled beam, and means for controlling an output circuit in response to said low frequency amplified component.

16. In combination, in a road vehicle detection system, a unitary assembly for mounting over the road for detection of vehicles approaching closely thereunder along the road by radio echo from such vehicles, said unitary assembly including a housing, a directive antenna assembly for ultra-high frequency waves and removably mounted in the lower part of said housing at a slight angle with horizontal with its transmitting axis at a slight angle from the vertical to provide a beam angle along a line parallel with the direction of the roadway in a desired direction with respect to passing vehicles, means associated with said housing and said antenna assembly and including a projection on one of the last two mentioned elements and cooperating with a recessed part of the other of said last two mentioned elements for keying said antenna in such relationship when so mounted, and ultra-high frequency transmitter and receiver means connected with said antenna and mounted above the latter in said housing to be removable from said housing.

17. A combination as in claim 16, and in which said antenna assembly and said transmitter and receiver means are assembled and removable as a unit from said housing, and in which said housing includes a removable cover.

18. In combination, means mounted over a roadway for transmitting a narrow beam of ultra-high frequency radio wave energy downward on to the roadway at a slight angle from vertical in one direction along the path of vehicles proceeding in a desired direction for detection in the roadway and for receiving back such wave energy reflected from a moving vehicle in said beam as shifted in frequency by the Doppler effect of the component of vehicle speed with respect to the transmitting and receiving means caused by movement of the vehicle along the roadway through such angled beam and for mixing said transmitted and reflected wave energies and deriving the Doppler beat frequency therefrom, means for amplifying said beat frequency and including means for filtering said beat frequency to derive a very low frequency component therefrom characteristic of passage of such vehicle through such angled beam, means for rectifying said low frequency component to provide a direct current voltage in accordance with the amplitude of the low frequency component, means for providing a rapidly increasing current output above a desired threshold value of such direct current voltage, and relay means controlled by said current output.

References Cited in the file of this patent

UNITED STATES PATENTS

2,521,683	Barker	Sept. 12, 1950
2,545,503	Tucker	Mar. 20, 1951
2,620,470	Rather	Dec. 2, 1952
2,622,140	Muller et al.	Dec. 16, 1952
2,785,395	Platzman	Mar. 12, 1957