(54) Title: INTERFERENCE MITIGATION FOR A VELOCITY SENSING CONTROLLER

(57) Abstract: In an example embodiment, a method for mitigating channel interference while sensing true ground velocity, comprises: transmitting a first radio frequency ("RF") signal, wherein the first RF signal is transmitted at a first transmit frequency; receiving a first reflected signal at a first receive antenna on the device, the first reflected signal having a first reflected signal frequency, wherein the first reflected signal frequency is offset from the first transmit frequency by a first offset; transmitting a second RF signal from the transmit antenna, wherein the second RF signal is transmitted at a second transmit frequency, receiving a second reflected signal at the first receive antenna, the second reflected signal having a second reflected signal frequency, wherein the second reflected signal frequency is offset from the second transmit frequency by a second offset; and determining whether a velocity threshold has been exceeded based on the first and second offset.
INTERFERENCE MITIGATION FOR A VELOCITY SENSING CONTROLLER

Cross-Reference to Related Applications

This application claims priority to U.S. Provisional Application No. 62/043,932, entitled "Velocity Sensing Controller Interference Mitigation Techniques," which was filed on August 29, 2014, the contents of which are hereby incorporated by reference for any purpose in their entirety.

Field

The present disclosure relates generally to interference mitigation in vehicle velocity sensing.

Background

For various reasons, it is desirable to know the speed of a moving vehicle, such as a truck, car, or train. In many vehicles, a speedometer is used for this purpose. Analog speedometers can display the speed of the vehicle based on the speed of rotation of the drive shaft. This method is not able to show the speed in reverse. Some digital speedometers use Hall-effect sensors on a gear on the vehicle's transmission to determine the speed of the vehicle. These methods must be calibrated, and are not accurate if the tire size is changed without recalibration. These methods further do not account for wheel slippage, where the rotation of the wheel does not completely translate into movement of the vehicle. Sources of error due to tire diameter variations include wear, temperature, pressure, vehicle load, and nominal tire size. For these and other reasons, most speedometers have tolerances of plus or minus 10%, and typical speedometers do not provide true vehicle speed.

Another method of determining true vehicle speed is the use of air speed indicators utilizing the pitot-static system based on air pressure differences. Air speed indicators provide an indicated air speed, but not the true vehicle speed. Other methods include use of Global Positioning System (GPS) data to determine the speed of a vehicle, which can be calculated by dividing the distance between two points by the time it took to travel between those points. GPS systems can be limited in accuracy by the satellite signal quality, altitude considerations, and the positional error. GPS devices also tend to be more accurate at higher speeds. Doppler radar based methods can be limited by channel interference from nearby vehicles. Furthermore, as noted above, many of the methods described above fail to determine the velocity (speed and direction) of the vehicle. Thus, a need exists for improved...
methods of determining true ground velocity and mitigating channel interference.

**Summary**

In an example embodiment, a method for mitigating channel interference while sensing true ground velocity, comprises: transmitting a first radio frequency ("RF") signal from a transmit antenna on a device, toward ground at an angle from perpendicular to ground, wherein the first RF signal is transmitted at a first transmit frequency; and receiving a first reflected signal at a first receive antenna on the device, the first reflected signal having a first reflected signal frequency, wherein the first reflected signal frequency is offset from the first transmit frequency by a first offset. The method further comprises: transmitting a second RF signal from the transmit antenna, wherein the second RF signal is transmitted at a second transmit frequency; and receiving a second reflected signal at the first receive antenna, the second reflected signal having a second reflected signal frequency, wherein the second reflected signal frequency is offset from the second transmit frequency by a second offset.

The method further comprises determining whether a velocity threshold has been exceeded based on the first offset and the second offset.

In another example embodiment, a device comprises a housing and a transceiver coupled to the housing. The transceiver comprises a transmit antenna to transmit a first RF signal and a second RF signal toward ground at an angle from perpendicular to ground, wherein the first RF signal is transmitted at a first transmit frequency and wherein the second RF signal is transmitted at a second transmit frequency. The transceiver also comprises a first receive antenna to receive a first reflected signal and a second reflected signal, the first reflected signal having a first reflected signal frequency, the second reflected signal having a second reflected signal frequency. The transceiver further comprising a monolithic microwave integrated circuit (MMIC) to receive the first reflected signal and the second reflected signal from the first receive antenna. The MMIC further comprises a mixer to down-convert the first reflected signal with the first RF signal to generate a first offset, and to down-convert the second reflected signal with the first RF signal to generate a second offset, wherein the first reflected signal frequency is offset from the first transmit frequency by the first offset, and wherein the second reflected signal frequency is offset from the second transmit frequency by the second offset. The transceiver further comprising a velocity sensing controller to determine whether a velocity threshold has been exceeded based on the first offset and the second offset.

In another example embodiment, a method for mitigating channel interference from
nearby vehicles while sensing true ground velocity of a vehicle, comprises transmitting a first radio frequency ("RF") signal, from a transmit antenna associated with a transceiver fixed to the vehicle toward ground at an angle from perpendicular to ground, wherein the first RF signal is transmitted at a first transmit frequency. The method further comprises receiving a first reflected signal, at a first receive antenna associated with the transceiver, the first reflected signal having a first reflected signal frequency, wherein the first reflected signal frequency is offset from the first transmit frequency by a first offset. The method further comprises: determining whether a velocity threshold has been exceeded based on the first offset, and electronically re-configuring the transceiver by changing the frequency of the first transmit frequency to mitigate channel interference from the nearby vehicles.

**Brief Description of the Drawing Figures**

FIGS. 1A, IB, and 1C are perspective and side views of an example cargo trailer with deployable tail structure;

FIG. 2A is side view of a velocity sensing device as installed under a cargo trailer;

FIG. 2B is a rear view of the velocity sensing device as installed under the cargo trailer;

FIG. 3 is an exploded perspective view of the velocity sensing device;

FIG. 4 is a block diagram of an example velocity sensing device;

FIG. 5 is a block diagram of an example method for mitigating interference while sensing true ground velocity;

FIG. 6 is a high level state diagram for a velocity sensing device; and

FIG. 7 is a detailed block diagram example method for automated tail fin deployment and warning.

**Detailed Description**

Reference will now be made to the example embodiments illustrated in the drawings, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Alterations and further modifications of the features illustrated herein, and additional applications of the principles illustrated herein, which would occur to one skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the disclosure.

As discussed above, although various devices and methods exist for estimating the speed of a vehicle, there is a need for better systems that can determine the true ground
velocity of the vehicle. In this regard, radar systems using a Doppler computation can be used to determine the true ground velocity of the vehicle. But, this method can be limited if there are multiple vehicles in close proximity to each other. In such a situation, the transmitted signal from one vehicle can be received at another vehicle, and this interference can cause erroneous determination of the vehicle velocity. This could be particularly likely to occur at truck stops, on busy freeways, and the like, where several trucks using such radar devices may be in close proximity.

Moreover, it is desirable to have automated actions take place when a vehicle is moving faster than a particular speed threshold, or moving in a particular direction, or moving in a combination of above a particular speed threshold and in a particular direction. However, there are limitations to how the speed of the vehicle can be communicated between the speedometer (located, for example, in the cab of a tractor trailer) and an electronic device (located for example on the trailer). Thus, there is a need for channel interference mitigating systems that can provide the true velocity of the vehicle in a way that can be used to command an action, such as deploying a tail fin on a semi-trailer or providing a warning alarm to a driver when the tractor trailer is moving in reverse and has the tail fin deployed.

FIGS. 1A, IB, and 1C are perspective and side views of an example cargo trailer 100 with a tail fin 150. In the illustrated embodiment, the cargo trailer 100 is an unpowered vehicle (semi-trailer) towed by a powered vehicle, such as a tractor-cab 120. However, principles of this disclosure can be applied to trailers with an integrated tractor-cab, e.g., a full-trailer. In the illustrated embodiment, the cargo trailer 100 is operable for carrying cargo. The cargo is enclosed within a container or at least partially exposed, such as in a cattle carrying trailer. The cargo trailer 100 can have as few axles as a single axle, or multiple axles.

The tail fin 150 is also known as a deployable tail structure, sail, or drag-reduction device. In general, a low-pressure region is created behind a trailer as it drives forward. This low pressure region creates drag and causes the trailer to use more energy to deliver its cargo. In the illustrated embodiment, a tail fin 150 is attached to the rear of the trailer to reduce that drag. This is particularly valuable for long-haul tractor-trailers, because the benefit is more pronounced at higher speeds. It is estimated that adding tail fins to the rear of all cargo trailers could save the global trucking industry billions of dollars in fuel costs. Thus, tail fins can be employed by a trucking company for a more sustainable, environmentally friendly, and less expensive method of delivering cargo.

In various embodiments, the tail fin 150 is made of metal, thermoplastic material,
carbon composite material, and/or the like. Various types of tail fin structures are known, but it is often desirable that the tail fin be convertible from a compact state to a deployed state. In the illustrated embodiment, in the compact state, the tail fin 150 is out of the way for loading/unloading and tight maneuvering of the trailer in docking / local / urban settings. In the deployed state, the tail fin 150 can provide the aerodynamic savings described above. Unfortunately, if the deployment of the tail fin is a manual process, it will not be used as often as it could be used, and the value of installing the tail fin will decrease. Therefore, it is desirable that the tail fin 150 be automatically deployable. Stated another way, it is desirable to eliminate driver involvement in the deployment of the tail fin.

Thus, in the illustrated embodiment, the tail fin 150 is attached to the rear of the cargo trailer 100 and capable of being automatically deployed. In the illustrated embodiment of FIG. 1B, the tail fin 150 is un-deployed, flat, or folded. In the illustrated embodiments of FIGS. 1A and 1C, the tail fin 150 is deployed, unfolded, or unfurled. In its deployed state, at appropriate vehicle speeds, the tail fin 150 reduces aerodynamic drag near the back of the cargo trailer 100.

To automate the deployment of the tail fin 150, in the illustrated embodiment, a velocity sensing device 101 is attached to the trailer 100. Velocity sensing device 101, in an example embodiment, is operable to provide accurate, low cost velocity sensing. In the illustrated embodiment, the cargo trailer 100 is connected to a tractor-cab 120. Although the tractor-cab 120 has a speedometer, this speedometer is less helpful because the speed data can be inaccurate, the speed may be only in analog form, information may not be available regarding whether the trailer is moving backwards, and/or the like. Thus, in an example embodiment, the velocity sensing device 101 is operable to determine true velocity of the cargo trailer 100, forward or in reverse, to compare that velocity to a velocity threshold, to provide a signal automatically deploying the tail fin 150, when the true ground velocity exceeds the velocity threshold, and/or to provide a warning (e.g., audible alarm or light-emitting-diode "LED" light) to the driver when the vehicle is moving backwards and the tail fin 150 is deployed. The alarm speaker or the LED light (both not shown) may be located in the tractor-cab 120.

The term velocity represents a speed in a particular direction. Similarly, a velocity threshold represents a speed threshold in a particular direction. In an example embodiment, the velocity threshold is 35 miles-per-hour (mph) in the forward direction. Moreover, the velocity threshold can be other suitable speeds in the forward direction. The velocity sensing device 101 is operable to automatically sense the true ground velocity of a cargo trailer 100
and send a signal deploying the tail fin 150 when the true ground velocity exceeds the
velocity threshold. However, after an extended period of time driving, the truck driver may
have forgotten that the tail fin 150 is deployed. Thus, the velocity sensing device 101 is
operable to sense that the cargo trailer 100 is backing up, and if the latch sensor signal
indicates that the tail fin is still deployed, to send a warning signal, such as a blinking LED
light, to the operator of the tractor-cab 120.

In the illustrated embodiment, velocity sensing device 101 is located underneath the
cargo trailer 100, approximately midway front to back and side to side. However, in other
embodiments, the velocity sensing device 101 is located closer to the front or rear of the
trailer, or even on the tractor-cab 120. The advantage to locating the velocity sensing device
101 on the trailer is that there are fewer connections needed between the trailer and the
tractor-cab. The velocity sensing device 101 can just connect to trailer power from the
tractor-cab 120, and provide a warning signal back to the tractor-cab 120. This also
facilitates the interchangeability of tractor-cabs 120 and cargo trailers 100. In accordance
with various aspects, the velocity sensing device 101 is located anywhere there is a clear field
of view of the surface of the ground.

FIG. 2A is side view of the velocity sensing device 101 as installed under the cargo
trailer 100. In the illustrated embodiment, the velocity sensing device 101 is connected to
structural steel 200, or another structure located under the cargo trailer 100. In the illustrated
embodiment, the velocity sensing device 101 is connected to the structural steel 200 of cargo
trailer 100 by way of a bracket 202 that is clamped or bolted to the structural steel.
Moreover, other attachment methods and devices can be used to permanently or semi-
permanently attach the velocity sensing device 101 to the cargo trailer 100. In the illustrated
embodiment, the velocity sensing device 101 is connected underneath the cargo trailer 100.
In other embodiments, the velocity sensing device 101 is connected to the trailer at any
suitable location that affords a view of the ground, as described herein.

In the illustrated embodiment, the velocity sensing device 101 is oriented such that the
boresight of the antenna(s) of velocity sensing device 101 is (are) pointed at an angle 240
relative to the direction that is perpendicular to a surface 250 just under the cargo trailer (e.g.,
the surface of the ground or a road). For example, the angle 240, in various embodiments, is
between 20 degrees and 70 degrees, between 25 degrees and 50 degrees, between 25 degrees
and 40 degrees, and between 25 degrees and 35 degrees; where 0 degrees represents a
boresight perpendicular to the surface 250, and 90 degrees represents a boresight parallel to
the surface 250. Moreover, the angle 240 can be an angle between 0 degrees and 90 degrees,
non-inclusive. In an example embodiment, the surface 250 is approximately flat, with some
degree of roughness, in the localized area from which the transmit beam is reflected.

In this manner, a transmit signal 210 from the velocity sensing device 101 will reflect
off of the surface 250 forming (1) a reflected away signal 220 that is reflected away from the
velocity sensing device 101, and (2) a reflected back signal 230 that is reflected back towards
the velocity sensing device 101. The offset frequency between the transmit signal frequency
of the transmit signal 210 and the reflected back signal frequency of the reflected back signal
230 is a function of the velocity of the vehicle (or of velocity sensing device 101) and the
angle 240.

In the illustrated embodiment, the trailer 100 moves in a forward direction when
traveling in the direction indicated by arrow 204. The direction opposite arrow 204 is the
direction of the trailer 100 moving backwards or traveling in reverse. In the illustrated
embodiment, the velocity sensing device 101 is angled in the backwards direction. In other
example embodiments (not shown), the velocity sensing device 101 is angled in the forwards
direction.

FIG. 2B is a rear view of the velocity sensing device 101 as installed under the cargo
trailer 100. In the illustrated embodiment, the velocity sensing device 101 further includes a
transmit antenna 260 and a first receive antenna 271. In the illustrated embodiment, the
velocity sensing device 101 further includes an optional second receive antenna 272. In the
illustrated embodiment, the transmit antenna 260, the first receive antenna 271, and/or the
second receive antenna 272 are oriented with respect to each other horizontally across the
back of the cargo trailer 100 and pointing at an angle in a direction towards the rear of the
cargo trailer 100 or behind the cargo trailer 100.

FIG. 3 is an exploded perspective view of the velocity sensing device 101. In the
illustrated embodiment, the velocity sensing device 101 includes a housing 310, a transceiver
320, a cover 330, and a connection cable 340. In the illustrated embodiment, the transceiver
320 is coupled to the housing. For example the transceiver 320 is coupled to the housing
using screws 322 or other suitable attachment devices and methods. The housing 310, for
example, protects the transceiver 320 from environmental harm. In one embodiment, the
housing 310 is a metal housing or other suitable structure material. The housing 310 may
have "feet" for attachment to a bracket or attachment directly to the underside of the truck.

In the illustrated embodiment, the velocity sensing device 101 includes a transmit
antenna 350, a first receive antenna 351, and optionally a second receive antenna 352. In the
illustrated embodiment, the antennas 350, 351, 352 are located on the transceiver 320, such as
on a printed wiring board. The transmit antenna 350 is operable to transmit a first RF signal and a second RF signal toward the ground at an angle from perpendicular to the ground. The transceiver, via transmit antenna 350, is operable to transmit the first RF signal at a first transmit frequency and the second RF signal at a second transmit frequency.

In an example embodiment, the first transmit frequency is at 24.088 GHz. In an example embodiment, the second frequency is at 24.09633 GHz. In an example embodiment, the frequency range is 125 MHz from 24.088 GHz to 24.213 GHz in 8.33 MHz steps. Moreover, the first transmit frequency, second transmit frequency, frequency range, and frequency step size can be other suitable frequencies, frequency ranges, and frequency step sizes as applicable. Moreover, the bandwidth between the first transmit frequency and the second transmit frequency, i.e., the frequency step size, is larger than the oscillator error.

In the illustrated embodiment, the first receive antenna 351 is operable to receive a first reflected signal and a second reflected signal. The first reflected signal may have a first reflected signal frequency based on the first transmit frequency and the second reflected signal may have a second reflected signal frequency based on the second transmit frequency. In various example embodiments, the velocity sensing device 101 is operable to determine a first offset comprising the difference between the first reflected signal frequency and the first transmit frequency. The velocity sensing device 101 may further be operable to determine a second offset comprising the difference between the second reflected signal frequency and the second transmit frequency. In various example embodiments, the first offset and second offset are proportional to the true ground velocity of the device (assuming no channel interference).

In the illustrated embodiment, the second receive antenna 352 is operable to receive the first receive signal and the second receive signal. The velocity sensing device 101 is operable to combine signals received at the first receive antenna 351 and second receive antenna 352 to null signal interference from other velocity sensing devices that may be near enough to velocity sensing device 101 that their signals are captured by the first receive antenna 351 or second receive antenna 352.

In the illustrated embodiment, the cover 330 protects the transceiver and the antennas of velocity sensing device 101. The cover 330 is connected to the housing like a lid, and in general encloses the internal components of velocity sensing device 101 in a protected environment. Cover 330 may be made of plastic or other materials that are RF transparent at velocity sensing device 101 operating frequencies. In one embodiment, the cover 330 forms a hermetically sealed environment for the transceiver and antennas.
In the illustrated embodiment, velocity sensing device 101 includes a signal interface or connection cable 340. The connection cable 340 may be operable to provide power to the velocity sensing device 101. For example, the connection cable 340 may provide 12 volt DC power, and a ground path, to the velocity sensing device 101. The connection cable 340 may further provide a warning signal from the velocity sensing device 101, and/or provide a latch signal from the velocity sensing device 101 to deploy a tail fin when the device is moving forward and moving over the speed threshold.

FIG. 4 is a block diagram of an example velocity sensing device 101. In the illustrated block diagram, the velocity sensing device 101 (or "transceiver") includes a DC conditioning circuit 410, a microcontroller circuit 420, a mixed signal circuit 430, a monolithic microwave integrated circuit (MMIC) 440, and an antenna section 450. The velocity sensing device 101 is operable to transmit and receive RF signals, and to provide signals to activate alarms and/or deploy a tail fin.

In the illustrated embodiment, the DC conditioning circuit 410 receives power (e.g., +12 volts) at a power input, conditions that power via a DC-DC converter and a voltage regulator, and provides power to the microcontroller circuit 420, mixed signal circuit 430, and MMIC 440. For example, the DC conditioning circuit 410 is operable to deliver power to portions of the velocity sensing device 101. The power may be provided, for example, from the tractor-cab power system (not shown).

The power may also be distributed to switches that control external devices. For example, DC conditioning circuit 410 may further include a warning switch 411 and a latch switch 412. The warning switch 411 is operable to receive a warning control signal from the microcontroller circuit 420 that operates the warning switch 411 for powering an LED warning light, audible alarm, or other warning device in the tractor-cab 120. Similarly, the latch switch 412 is operable to receive a latch control signal from the microcontroller circuit and to switch power provided to a latch (not shown) to open or close the latch based on the latch control signal. When the latch is commanded to open, the latch releases (automatically deploys) the tail fin 150. The power input, latch power, or warning power can interface with the DC conditioning circuit individually or bundled in an interface cable. Thus, the interface cable can comprise various wires for communicating power and signals with the DC conditioning circuit 410.

In the illustrated embodiment, a left sensor signal and a right sensor signal are provided directly to the microcontroller circuit 420 to provide an indication of the deployment status of the tail fin. In an alternative embodiment (not shown), the left sensor
signal and right sensor signal are passed through the DC conditioning circuit to the microcontroller circuit 420. Thus, velocity sensing device 101 is connected to the tractor-cab 120 and/or other portions of the trailer 100 for communicating signals and/or power.

In the illustrated embodiment, the microcontroller circuit 420 includes a velocity sensing controller 425, a first analog to digital converter ("ADC") 421 and a second ADC 422, and optionally a third ADC 423 and a fourth ADC 424. In the illustrated embodiment, the mixed signal circuit 430 includes amplifier/filter circuits. In the illustrated embodiment, the MMIC 440 includes a first low noise amplifier (LNA) 441, a first mixer 443, a power amplifier 445, a voltage controlled oscillator (VCO) 449, and optionally a second LNA 442, and second mixer 444. In the illustrated embodiment, the antenna section 450 comprises a transmit antenna 350 and a first receive antenna 351. The antenna section 450 may additionally include a second receive antenna 352.

In this illustrated embodiment, the velocity sensing controller 425 is operable to provide a frequency control signal to the VCO 449 to adjust the frequency of a transmit signal generated by the VCO 449. The frequency control signal can, for example, be a 16 bit word provided to a digital to analog converter to fine tune the frequency of the transmit signal. In this manner the velocity sensing controller 425 can change the frequency of the transmit signal from a first transmit frequency to a second transmit frequency up to an Nth transmit frequency. Moreover, the velocity sensing controller 425 can use other suitable methods of changing the transmit frequency. The VCO is operable to provide the transmit signal to the power amplifier 445 to amplify the transmit signal and provide the amplified transmit signal to the transmit antenna 350. The transmit antenna 350 is operable to radiate the amplified transmit signal from the transmit antenna 350 towards the ground, at a suitable angle to the surface of the ground.

The first receive antenna 351 and the second receive antenna 352 are operable to receive a reflected signal bounced back from the surface of the ground to the antenna section 450 and to pass the received signal (e.g., a first reflected signal or a second reflected signal) to the first LNA 441 and second LNA 442 of the MMIC 440, respectively. In one embodiment, the transmit antenna 350 is located horizontally in a row and in-between the first receive antenna 351 and the second receive antenna 352. In one embodiment, the transmit antenna 350 is located a distance of approximately one-half wavelength, at the lowest operating wavelength, from the first receive antenna 351 and from the second receive antenna 352.

First LNA 441 is operable to amplify the receive signal from the first receive antenna
351 and to provide the amplified receive signal to the first mixer 443. The first mixer 443 is
operable to down convert the amplified receive signal with the transmit signal from the VCO
449 to create a baseband signal from the RF receive signal. The first mixer 443 is also
operable to output both a quadrature baseband receive signal and an in-phase baseband
receive signal and provide these two signals respectively to first and second amplifier/filters
of mixed signal circuit 430. The baseband receive signals represent a first offset or first
phase difference between the first transmit signal frequency and the first reflected signal
frequency. When a second transmit signal frequency is used, the baseband receive signals
represent a second offset or second phase difference between the second transmit signal
frequency and the second reflected signal frequency. In each case, the first or second offsets
are proportional to the true ground velocity if there is no channel interference.

Similarly, second LNA 442 is operable to amplify the receive signal from the second
receive antenna 352 and to provide the amplified receive signal to the second mixer 444. The
second mixer 444 is operable to down convert the amplified receive signal with the transmit
signal from the VCO 449 to create a baseband signal from the RF receive signal from the
second LNA 442. The second mixer 444 is also operable to output both quadrature and in-
phase baseband receive signals and provide them respectively to third and fourth
amplifier/filters of mixed signal circuit 430.

The first through fourth amplifier/filters of mixed signal circuit 430 are operable to
low pass filter and amplify the Q and I phase baseband signals. For example, the baseband
signals is filtered to remove those frequency offsets that are high enough or low enough that
they cannot be related to the original transmit signal. For example, if the offset is greater
than 3.222 Hz in the forward direction, the data must be noise and excluded through filtering.
Moreover, the low pass filtration levels / thresholds may be set at other appropriate levels. In
one example embodiment, the offsets are Doppler effect frequency offsets that are
approximately 35.8 Hz per 1 MPH when the mounting angle is 30 degrees. The direction can
be determined by the phase relationship between the in-phase and quadrature phase signals,
with the quadrature signal lagging by 90 degrees in one case and leading by 90 degrees in the
other case. The first through fourth amplifier/filters of mixed signal circuit 430 are operable
to pass their output signals to respective first through fourth ADC’s 421-424.

The first-fourth ADC’s are operable to sample analog signals from the mixed signal
circuit 430 to create digital signals, ADC output signals, and provide them to the velocity
sensing controller 425. In an example embodiment, the velocity sensing controller 425
receives a time series of I and Q data from both receivers. In an example embodiment, this

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data is converted to a phase difference and a magnitude. The zero degree phase difference represents a signal received directly back down the boresight, and a phase difference that is not equal to zero represents signals received from off center of the boresight. This phase information will be important because the area of surface of the ground illuminated by the transmit antenna is much larger than one wavelength of the transmitted signal. In some cases, the received reflections from one portion of the illuminated area may be of equal amplitude and opposite phase of the received reflections from another portion of the illuminated area, thus creating the effect of destructive interference commonly known as multipath fading.

The velocity sensing controller 425 is operable to store the data in RAM (not shown). The RAM may be located on microcontroller circuit 420 or remotely. In one example embodiment, the velocity sensing controller 425 is operable to first take samples (e.g., 32 samples from each antenna during a first pass) and to use this data in determining the phase difference information. Next, the velocity sensing controller 425 is operable to take multiple sets of 64 samples and use the phase difference information to add the in-phase and quadrature data together in a vector summation with varying phase rotation applied to one of the two receive channel's data. In other words, the data samples of each pass are added together while adjusting the beam steering of the receive beam based on the phase information from the first pass. This technique is useful for mitigating multipath interference.

The velocity sensing controller 425 is operable to perform a fast Fourier transform (FFT) on the data for each of the multiple sets of samples, converting the data to the frequency domain. The magnitude data is stored in RAM for each FFT frequency bin and added to one or more running summations that effectively averages the offset frequency.

In a first example embodiment, the velocity sensing controller 425 is operable to determine summations of four offset frequency categories: positive offset, negative offset, offset above, or offset below the speed threshold (an offset threshold). The velocity sensing controller 425 is operable to make a determination of whether the vehicle is moving forward or backward based on the relative difference between the positive offset summation and negative offset summation. Similarly, the velocity sensing controller 425 can determine that the vehicle has exceeded the speed threshold based on the relative difference between the summation above and below the offset threshold (representing speeds above or below the speed threshold).

In a second example embodiment, the velocity sensing controller 425 is operable to
average the 15 readings and to use the center of gravity of average frequency shift to calculate the true ground velocity. This determined true ground velocity can then be logged, transmitted to the trailer owner, used by the ABS system, etc. Moreover, the true ground speed and direction can be used to determine the direction and whether a speed threshold has been exceeded. In addition to true ground velocity, when the antennas are pointed at other surfaces besides the ground, a similar technique could be used to determine the angular velocity of tire rotation, velocity of water flow, etc. In some embodiments, the velocity information may be coupled with real time clock information from a clock to perform an odometer function to replace hub odometers. That information could be used by the trailer owner to schedule maintenance or invoice customers renting the trailer based on miles traveled. The velocity sensing controller 425 may also store maximum speeds or histograms of speed to offer trailer owners information about trailer driver behavior.

Thus, the velocity sensing controller 425 is operable to determine whether a velocity threshold has been exceeded based on the first offset and the second offset. In one example embodiment, the determination by the velocity sensing controller 425 is a multistep process that comprises making a first determination based on the first offset, and then making a second determination based on the second offset, and then using the second determination to confirm the validity of the first determination. In another example, the determination by the velocity sensing controller 425 comprises averaging the first offset and the second offset to generate an average offset and basing the determination on the average offset. In one example embodiment, the determining whether a velocity threshold has been exceeded further comprises determining the direction the device is moving. For example, if the offset is negative or a decrease, then the device is moving away from the direction of the beam, which is forward if the beam is pointing to the rear of the truck. On the other hand, if the offset is positive or an increase, then the device is moving somewhat in the same direction as the beam direction, which is backwards where the beam is pointing to the rear of the truck. In another example embodiment, the determining whether a velocity threshold has been exceeded further comprises determining whether a speed threshold has been exceeded.

The velocity sensing controller 425 is operable to provide signals to the DC conditioning circuit 410 based on the determinations of direction and speed. For example, the signals can cause a latch switch 412 to open a latch deploying a tail fin, or to cause a warning switch 441 to power a warning LED light or audible alarm.

**Interference Mitigation**

In an example embodiment, velocity sensing controller 425 is operable to mitigate
channel interference via at least one or more of the techniques described herein. For example, various channel interference mitigation techniques involve changing the frequency of the transmit signal. In this regard, velocity sensing controller 425 is operable to change the frequency adjust signal that it provides to VCO 449 to change the frequency of the transmit signal.

Another channel interference mitigation technique involves reducing the amplification level of the power amplifier 445, and/or the LNA's 441, 442. The amplification level is reduced to the lowest amount of amplification possible while still maintaining an acceptable signal to noise ratio. In an example embodiment, the velocity sensing controller 425 is operable to set the amplification level of the receive signal at the ADC's to a particular fixed level amplitude. In this manner, assuming all similar velocity sensing devices 101 are using the same low amplification, signals received from other velocity sensing devices in the vicinity will be low enough in power to not interfere with the intended signals. In this regard, the velocity sensing controller 425 is operable to provide a transmit gain adjust signal to the power amplifier 445 to adjust the gain level of the power amplifier. Similarly, the velocity sensing controller 425 is operable to provide a receive gain adjust signal to the LNA 441/442 to adjust the gain level of the LNA. Thus, the amplitude of the transmitted signal and/or the receive signal can be lowered as controlled by the velocity sensing controller 425.

In an example embodiment, the velocity sensing controller 425 is also operable to process the reflected signals from the first receive antenna 351 with those from the second receive antenna 352, to null out signals from nearby trucks, and thereby mitigate channel interference.

FIG. 5 is a block diagram of an example method for mitigating channel interference while sensing true ground velocity. A method 500 of mitigating interference includes: transmitting a first radio frequency ("RF") signal (510), receiving a first reflected signal at a first receive antenna (520), transmitting a second RF signal (530), receiving a second reflected signal at the first receive antenna (540), and determining whether a velocity threshold has been exceeded based on a first offset and a second offset (550).

In the illustrated method, the first RF signal is transmitted at a first transmit frequency and the second RF signal is transmitted at a second transmit frequency that is different from the first transmit frequency. The first RF signal and second RF signal are both transmitted from the transmit antenna located on the velocity sensing device 101. The first RF signal and second RF signal are both transmitted in a direction oriented towards the ground under the vehicle whose velocity is being sensed. The transmitted signals are directed in a direction
that is at an angle of 20-70 degrees from perpendicular to the ground.

In the illustrated method, the first reflected signal has a first reflected signal frequency and the second reflected signal has a second reflected signal frequency. In this method, the first offset is the offset between the first reflected signal frequency and the first transmit frequency. Similarly, the second offset is the offset between the second reflected signal frequency and the second transmit frequency.

In accordance with one embodiment, the determining (550) is a multistep process that includes making a first determination based on the first offset, and then making a second determination based on the second offset, and then using the second determination to confirm the validity of the first determination. Thus, if the first determination is that the vehicle is moving forward, and the second determination confirms the first determination, then that assessment can be used to draw conclusions, take action, and send signals as described herein. To the contrary, if the first and second determinations conflict, the determinations can be deemed to have been impacted by interference and discarded. In an alternative embodiment, the determining (550) includes averaging the first offset and the second offset to generate an average offset and basing the determination on the average offset.

In one embodiment, the determining whether a velocity threshold has been exceeded (550) further includes determining the direction the device is moving. Here, for example, if the offset is a negative offset (correlating with a Doppler-effect decrease in frequency), then the velocity sensing controller can determine that the device is moving away from the direction of the beam. In the embodiment where the beam is pointing to the rear of the truck, this would represent a forward motion. To the contrary, if the offset is a positive offset (correlating with a Doppler-effect increase in frequency), then the velocity sensing controller can determine that the device is moving in the general direction of the beam. Again, in the embodiment where the beam is pointing to the rear of the truck, this would represent a backwards motion, or driving in reverse.

In another embodiment, the determining whether a velocity threshold has been exceeded (550) further includes determining whether a speed threshold has been exceeded. Without channel interference, the magnitude of the offset is proportional to the true ground speed, so the determination of whether a speed threshold has been exceeded is made by comparing whether the magnitude of the offset exceeds a predetermined offset threshold.

In various embodiments, the method (500) further includes sending a signal (560) based on the determination. For example, the signal in one embodiment is suitable for providing a warning when the device is moving backward and the tail fin is deployed. For
example, the signal may be provided to the driver in the tractor-cab 120. The warning signal may be such as to cause a warning light, such as an LED light in the tractor-cab 120 to light up. The warning signal may also, or alternatively, be operable to cause a speaker to generate a warning noise to alert the driver of the deployed tail fin. The signal may be generated by the velocity sensing controller 425 and provided via the DC conditioning circuit 410 to the tractor-cab 120.

In another example, the signal is operable for causing a tail fin 150 to be automatically deployed when the device is moving forward and moving over the speed threshold. The signal may be generated by the velocity sensing controller 425 and provided via the DC conditioning circuit 410 to a latch at the rear of the trailer 100.

In various embodiments, the method (500) provides further mitigation of channel interference by periodically electronically re-configuring the transceiver by making additional changes to the frequency of the transmitted signal (570) through one or more techniques described herein. In a first example technique, the velocity sensing controller 425 is operable to step through a predetermined number of transmit frequencies in a fixed sequence. For example, the frequencies may comprise frequencies $f_1, f_2, f_3, \ldots f_N$, where each frequency $f_i-N$ is higher than the last, and the velocity sensing controller 425 is operable to start with $f_1$ and change to $f_2$, and then to $f_3$, on up to $f_N$ at predetermined time intervals. Moreover, the fixed sequence can be in other orders that are not necessarily sequential from a frequency perspective. The number of intervals and the size thereof may be determined by the operating frequency band and regulations for spectral emissions divided by the frequency span over which the system's high stability oscillator varies. In an example embodiment, the frequency range is 125 MHz from 24.088 GHz to 24.213 GHz in 8.33 MHz steps. Moreover, the frequency range, and frequency step size can be other suitable frequency ranges, and frequency step sizes as applicable.

In a second example technique, the velocity sensing controller 425 is operable to randomly step through a predetermined number of transmit frequencies. This second technique is like the first, but makes it unlikely that two trucks started at the same time would continuously interfere with each other by changing from one interfering frequency to a second interfering frequency, endlessly.

In a third example technique, the velocity sensing controller 425 is operable to step through a predetermined number of transmit frequencies in a fixed sequence (as in the first example technique), but in this embodiment the predetermined time intervals are a fixed or constant time interval between all the steps. Thus, the velocity sensing controller 425 may
change the frequency every 10 minutes or another suitable fixed time interval. In a fourth example technique, the predetermined time intervals are not all the same length. In this embodiment, the switch from a first transmit frequency to a second transmit frequency may occur after 10 minutes, but the switch from the second transmit frequency to the third may be after 5 minutes or 15 minutes. This variation in the time interval between steps may be fixed or random.

In a fifth example technique, the velocity sensing controller 425 is operable to step through a predetermined number of transmit frequencies in a fixed sequence and re-start the fixed sequence at random times. This technique would make it so that even if the velocity sensing device 101 on a truck were to be accidentally in sync with that of another truck, it would soon not be in sync because the truck would start over at the beginning of the fixed sequence at a time different from the other truck restarting.

In a sixth example technique, the velocity sensing controller 425 is operable to step through a predetermined number of transmit frequencies in a fixed sequence, where the starting point in the fixed sequence is changeable. For example, the starting point could be the fifth frequency in the sequence one time and the third frequency the next time. Thus, the starting point could be completely randomly generated, or the device could start at a different starting frequency in the sequence of frequencies along some pseudo random pattern, such as incrementing or decrementing the starting point each time. These techniques help reduce the likelihood that the starting point of a first truck would be the same as that of a neighboring truck.

In a seventh example technique, velocity sensing controller 425 is operable to step through a predetermined number of transmit frequencies in a fixed sequence, with some variation in a frequency step size associated with each of the transmit frequencies. For example, the frequency step size between all of the frequencies may be 5 MHz between each of the frequencies during a first "session", and when restarted the frequency step size between frequencies may be 4 MHz in a second session.

In these example embodiments, where a linear feedback shift register is used, there may be $2^N$ transmit frequencies, where N is the number of bits in the linear feedback shift register. However, other numbers of transmit frequencies can be used.

In accordance with various embodiments, the velocity sensing controller 425 is operable to mitigate channel interference through automatic gain control, by adjusting the transmit signal strength to transmit with no more power than necessary to have adequate SNR in the receive signal. This will have the effect that an adjacent truck would not receive a
sufficiently strong signal to interfere with the intended signal. In another embodiment, the
velocity sensing controller 425 is operable to mitigate channel interference through automatic
gain control, by adjusting the LNA amplification level to have a desired signal strength level
at the ADC’s to reduce the strength of signals (at the ADC’s) received from other trucks.

In accordance with another embodiment, where the velocity sensing device 101
includes a second receive antenna, the velocity sensing controller 425 is operable to add
signals together from both antennas to create nulls where interference from adjacent similar
devices would be expected, thus reducing signal interference.

The velocity sensing device 101 may further include a grid array of antennas in both
the horizontal and vertical direction, and can perform beam steering. Highly reflective
surfaces, such as wet road after a rain, can result in insufficient return reflection for
determining the velocity of the velocity sensing device 101. In this example embodiment
(not shown), the beam steering in the elevation direction is used to adjust for the degree of
reflectiveness of the surface of the ground, to improve the signal to noise ratio and overall
performance of velocity sensing device 101.

In various embodiments, the method (500) further includes determining one or more
performance metrics associated with the first received signal and the second received signal,
and further mitigating channel interference based on the determined one or more performance
metrics. For example, the one or more performance metrics is selected from a group
consisting of received signal strength, pre-detection SNR, post-detection SNR. If
interference is identified based on the performance metrics, the velocity sensing controller
425 is operable to implement one or more additional channel interference mitigation
techniques described herein. Thus, in an example embodiment, the velocity sensing
controller 425 is operable to implement multiple frequency channel interference mitigation
techniques.

In an example embodiment, the method 500 facilitates isolated automation to cause
tail fin deployment and warnings without any signals or data from off the trailer.

FIG. 6 is a high level state diagram 600 for a velocity sensing device 101. The
velocity sensing device 101 includes three main states: Idle 610, Frequency Calibration 620,
and Velocity Measurement 630. In the Idle state 610, the device is inactive. Typically this is
when there is no power to the velocity sensing device 101. When power, e.g., +12 volt
power, is applied to the velocity sensing device 101, the system transitions (power up) from
the Idle state 610 to the Frequency Calibration state 620. This may occur, for example, when
the tractor-cab starts its engine. Similarly, when the power is removed, such as when the
tractor-cab turns off its engine, the system transitions (power down) from the Frequency Calibration state 620 to the Idle state 610.

In the illustrated embodiment, during the Frequency Calibration state 620, the velocity sensing device 101 attempts to achieve phase lock loop and tuning parameters within certain prescribed limits. When this has been accomplished, the velocity sensing device 101 transitions to the Velocity Measurement state 630. The velocity sensing device 101 can remain in the Velocity Measurement state 630 until the device power's down and it returns to the Idle state 610, or until a change in temperature causes a transition back to the Frequency Calibration state 620. For example, if the change in temperature is greater than 10 degrees C (or another suitable maximum temperature change) from the temperature of the last calibration, it may be appropriate to recalibrate the velocity sensing device 101. During the velocity measurement state, the velocity sensing device 101 is operable to mitigate channel interference.

FIG. 7 is a detailed block diagram example method 700 for mitigating interference in the velocity sensing device 101. The method 700 includes making measurements, performing calculations, and then making decisions based on the velocity (speed and direction) of the vehicle and the state of the tail fin deployment. For example, the method 700 may start 701 by acquiring Doppler time series 703. This may be done by sampling data from one or both receive antennas. In an example embodiment, 16 data samples are taken. The system may assess the receiver gain setting based on individual channel magnitude and retake the data samples if it assesses that the system is in over-drive. The method 700 further includes transforming the data samples to the frequency domain 705.

Once the direction and speed have been determined, the method 700 can further include assigning logic levels for direction and speed 707. The method 700 further includes making decisions based on the direction and speed and latch status 710. For example, if the direction determination is "reverse", then if one or more of the latches for the tail fin is open, an LED alarm is set to flash to warn the driver that the tail fin is deployed. In the "reverse" mode, if the latches are both closed, then the LED remains on to indicate that the tail fins are not deployed and it is safe to back up. On the other hand, if the direction determination is "forward", and the speed is greater than 35 mph, if the latches are both open, the LED is set to "off" to indicate that the tail fin is properly deployed. In this scenario if one or more latches are closed, the logic will send a command to try to open the closed latches, and if unsuccessful will alert that the system has a fault. Assuming the closed latches open, then the LED light is set to off to indicate that the tail fins are now properly deployed. Meanwhile, if
the direction determination is "forward", the speed is less than 35 mph, and both latches are closed, then the tail fins are properly stowed and the LED is set to "on" to indicate that the tail fins are not deployed. In this scenario, if one or more of the latches are open, the LED is set to off to indicate that one or more of the tail fins are deployed. In this illustrated embodiment, the velocity sensing device 101 is operable to automatically deploy the tail fin above a velocity threshold and to warn the driver if the tail fin is deployed when backing up.

In describing the present disclosure, the following terminology will be used: The singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to an item includes reference to one or more items. The term "ones" refers to one, two, or more, and generally applies to the selection of some or all of a quantity. The term "plurality" refers to two or more of an item. The term "about" means quantities, dimensions, sizes, formulations, parameters, shapes and other characteristics need not be exact, but may be approximated and/or larger or smaller, as desired, reflecting acceptable tolerances, conversion factors, rounding off, measurement error and the like and other factors known to those of skill in the art. The term "substantially" means that the recited characteristic, parameter, or value need not be achieved exactly, but that deviations or variations, including for example, tolerances, measurement error, measurement accuracy limitations and other factors known to those of skill in the art, may occur in amounts that do not preclude the effect the characteristic was intended to provide.

Numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also interpreted to include all of the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3 and 4 and sub-ranges such as 1-3, 2-4 and 3-5, etc. This same principle applies to ranges reciting only one numerical value (e.g., "greater than about 1") and should apply regardless of the breadth of the range or the characteristics being described. A plurality of items may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list.
solely based on their presentation in a common group without indications to the contrary.

Furthermore, where the terms "and" and "or" are used in conjunction with a list of items, they are to be interpreted broadly, in that any one or more of the listed items may be used alone or in combination with other listed items. The term "alternatively" refers to selection of one of two or more alternatives, and is not intended to limit the selection to only those listed alternatives or to only one of the listed alternatives at a time, unless the context clearly indicates otherwise.

It should be appreciated that the particular implementations shown and described herein are illustrative and are not intended to otherwise limit the scope of the present disclosure in any way. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical device.

It should be understood, however, that the detailed description and specific examples, while indicating exemplary embodiments of the present invention, are given for purposes of illustration only and not of limitation. Many changes and modifications within the scope of the instant invention may be made without departing from the spirit thereof, and the invention includes all such modifications. The corresponding structures, materials, acts, and equivalents of all elements in the claims below are intended to include any structure, material, or acts for performing the functions in combination with other claimed elements as specifically claimed. The scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given above. For example, the operations recited in any method claims may be executed in any order and are not limited to the order presented in the claims. Moreover, no element is essential to the practice of the invention unless specifically described herein as "critical" or "essential."

The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope and spirit of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being
distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items (for example, a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates a disjunctive list such that, for example, a list of "at least one of A, B, or C" means A or B or C or AB or AC or BC or ABC (i.e., A and B and C).

Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.
Claims

What is claimed is:

1. A method for mitigating channel interference while sensing true ground velocity, comprising:
   transmitting a first radio frequency ("RF") signal from a transmit antenna on a device, toward ground at an angle from perpendicular to ground, wherein the first RF signal is transmitted at a first transmit frequency;
   receiving a first reflected signal at a first receive antenna on the device, the first reflected signal having a first reflected signal frequency, wherein the first reflected signal frequency is offset from the first transmit frequency by a first offset;
   transmitting a second RF signal from the transmit antenna, wherein the second RF signal is transmitted at a second transmit frequency;
   receiving a second reflected signal at the first receive antenna, the second reflected signal having a second reflected signal frequency, wherein the second reflected signal frequency is offset from the second transmit frequency by a second offset; and
   determining whether a velocity threshold has been exceeded based on the first offset and the second offset.

2. The method of claim 1, wherein the determining whether the velocity threshold has been exceeded comprises:
   making a first determination of whether the velocity threshold has been exceeded based on the first offset;
   making a second determination of whether the velocity threshold has been exceeded based on the second offset; and
   using the second determination to confirm the validity of the first determination.

3. The method of any one of the proceeding claims, wherein the determining whether the velocity threshold has been exceeded comprises averaging the first offset and the second offset to generate an average offset and basing the determination on the average offset.

4. The method of any one of the proceeding claims, wherein the determining whether the velocity threshold has been exceeded further comprises determining a direction the device is moving.
5. The method of claim 4, further comprising sending a warning signal to provide a warning when the device is moving backward and a tail fin is deployed.

6. The method of claim 5, further comprising sending a command signal to deploy the tail fin when the device exceeds the velocity threshold by moving forward and moving over a speed threshold.

7. The method of any one of the proceeding claims, wherein the determining whether the velocity threshold has been exceeded further comprises determining whether a speed threshold has been exceeded in a forward direction.

8. The method of any one of the proceeding claims, wherein the receiving the first reflected signal further comprises:
   converting the first reflected signal from an RF signal to a baseband signal;
   sampling the baseband signal with an analog to digital converter ("ADC") to form an ADC output signal; and
   converting the ADC output signal to the frequency domain.

9. The method of any one of the proceeding claims, further mitigating channel interference by at least one of:
   stepping through a predetermined number of transmit frequencies in a fixed sequence;
   randomly stepping through a predetermined number of transmit frequencies;
   stepping through a predetermined number of transmit frequencies in a fixed sequence with a fixed time interval between steps;
   stepping through a predetermined number of transmit frequencies in a fixed sequence with at least some variation in the time interval between steps;
   stepping through a predetermined number of transmit frequencies in a fixed sequence and re-starting the fixed sequence at random times;
   stepping through a predetermined number of transmit frequencies in a fixed sequence, wherein a starting point in the fixed sequence is changeable; and
   stepping through a predetermined number of transmit frequencies in a fixed
sequence, with some variation in a frequency step size associated with each of the transmit frequencies.

10. The method of any one of the proceeding claims, further comprising determining one or more performance metrics associated with the first reflected signal and the second reflected signal, and further mitigating channel interference based on the determined one or more performance metrics.

11. The method of claim 10, wherein the one or more performance metrics is selected from a group consisting of received signal strength, pre-detection SNR, and post-detection SNR.

12. The method of any one of the proceeding claims, further comprising periodically electronically reconfiguring a transceiver associated with the transmit antenna to switch operating transmit frequencies.

13. The method of any one of the proceeding claims, further comprising:
   receiving a third reflected signal at a second receive antenna on the device, the third reflected signal having a third reflected signal frequency, wherein the third reflected signal frequency is offset from the first transmit frequency by a third offset; and
   receiving a fourth reflected signal at the second receive antenna on the device, the fourth reflected signal having a fourth reflected signal frequency, wherein the fourth reflected signal frequency is offset from the first transmit frequency by a fourth offset.

14. The method of claim 13, further comprising beam steering the first and second receive antenna to mitigate channel interference.

15. A device comprising:
   a housing;
   a transceiver coupled to the housing and comprising:
   a transmit antenna to transmit a first radio frequency (RF) signal and a second RF signal toward ground at an angle from perpendicular to ground, wherein the first RF signal is transmitted at a first transmit frequency and wherein the second RF signal is transmitted at a second transmit frequency; and
a first receive antenna to receive a first reflected signal and a second reflected
signal, the first reflected signal having a first reflected signal frequency, the second
reflected signal having a second reflected signal frequency;
a monolithic microwave integrated circuit (MMIC) to receive the first
reflected signal and the second reflected signal from the first receive antenna, the
MMIC further comprising a mixer to down-convert the first reflected signal with the
first RF signal to generate a first offset, and to down-convert the second reflected
signal with the first RF signal to generate a second offset, wherein the first reflected
signal frequency is offset from the first transmit frequency by the first offset, and
wherein the second reflected signal frequency is offset from the second transmit
frequency by the second offset; and
a velocity sensing controller to determine whether a velocity threshold has
been exceeded based on the first offset and the second offset.

16. The device of claim 15, wherein the determination of whether the velocity threshold
has been exceeded comprises:
   making a first determination of whether the velocity threshold has been exceeded
   based on the first offset;
   making a second determination of whether the velocity threshold has been exceeded
   based on the second offset; and
   using the second determination to confirm the validity of the first determination.

17. The device of any one of claims 15 or 16, wherein the determination of whether the velocity threshold has been exceeded comprises averaging the first offset and the second
offset to generate an average offset and basing the determination on the average offset.

18. The device of any one of claims 15-17, wherein the determination of whether the velocity threshold has been exceeded further comprises determining whether a speed
threshold has been exceeded in a forward direction.

19. The device of any one of claims 15-18, wherein determination of whether the velocity threshold has been exceeded further comprises determining a direction the device is moving.

20. The device of claim 19, further comprising a warning signal output, and a latch signal
21. A semi-trailer comprising a tractor-cab having a light emitting diode (LED) light or a speaker, a tractor trailer, and the device of claim 20 in fixed connection with the tractor trailer, wherein the device is operable to send a warning signal via the warning signal output to provide a warning via at least one of the LED light or the speaker when the device is moving backward and a tail fin is deployed.

22. The device of claim 21, wherein the device is operable to send a command signal, via the latch signal output, to deploy the tail fin when the device is moving forward and moving over a speed threshold in a forward direction.

23. The device of any one of claims 15-22, further comprising a second receive antenna to receive a third reflected signal and a fourth reflected signal, wherein the device is responsive to signals received via both the first receive antenna and the second receive antenna for nulling out signals from nearby trucks.

24. A method for mitigating channel interference from nearby vehicles while sensing true ground velocity of a vehicle, comprising:

   transmitting a first radio frequency ("RF") signal, from a transmit antenna associated with a transceiver fixed to the vehicle, toward ground at an angle from perpendicular to ground, wherein the first RF signal is transmitted at a first transmit frequency;

   receiving a first reflected signal, at a first receive antenna associated with the transceiver, the first reflected signal having a first reflected signal frequency, wherein the first reflected signal frequency is offset from the first transmit frequency by a first offset;

   determining whether a velocity threshold has been exceeded based on the first offset;

   and

   electronically re-configuring the transceiver by changing the frequency of the first transmit frequency to mitigate channel interference from the nearby vehicles.
TRANSMITTING A FIRST RF SIGNAL TOWARDS THE GROUND AT AN ANGLE

RECEIVING A FIRST REFLECTED SIGNAL AT A FIRST RECEIVE ANTENNA

TRANSMITTING A SECOND RF SIGNAL TOWARDS THE GROUND AT AN ANGLE

RECEIVING A SECOND REFLECTED SIGNAL AT THE FIRST RECEIVE ANTENNA

DETERMINING WHETHER A VELOCITY THRESHOLD HAS BEEN EXCEEDED BASED ON A FIRST OFFSET AND A SECOND OFFSET

SENDING A SIGNAL BASED ON THE DETERMINATION (WARNING SIGNAL AND/OR TAIL FIN DEPLOYMENT SIGNAL)

MAKING ADDITIONAL CHANGES TO THE FREQUENCY OF THE TRANSMITTED SIGNAL

FIG. 5
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

G01S 7/02 G01S13/60
B62D 37/02

according to International Patent Classification (IPC) or to both national classifications and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S B62D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
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<td>paragraphs [0015] - [0026], [0036]; figures 1-3</td>
<td>5, 6</td>
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<td>US 5 579 012 A (IWAKUNI MI KI0 [JP] ET AL) 26 November 1996 (1996-11-26)</td>
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
   * A* document defining the general state of the art which is not considered to be of particular relevance
   * E* earlier application or patent but published on or after the international filing date
   * L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
   * O* document referring to an oral disclosure, use, exhibition or other means
   * P* document published prior to the international filing date but later than the priority date claimed

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"A" document member of the same patent family

Date of the actual completion of the international search: 12 November 2015

Date of mailing of the international search report: 26/01/2016

Name and mailing address of the ISA:
European Patent Office, P.B. 5818, Patentlaan 2 NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Fax. (+31-70) 340-3016

Authorized officer: Lupo, Emanuel a
**INTERNATIONAL SEARCH REPORT**

**Box No. II**  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III**  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

   1-8, 15-22

**Remark on Protest**

- The additional search fees were accompanied by the applicant’s protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant’s protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.
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This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-8, 15-22
   
   Ground velocity determination using two transmitting frequencies.

2. claims: 9, 12, 24
   
   Interference mitigation techniques based on changing the transmitting frequencies.

3. claims: 10, 11
   
   Interference mitigation by adjusting the transmitting signal strength.

4. claims: 13, 14, 23
   
   Interference mitigation by using an additional receiving antenna.