GEOLOCATION USING GUIDED SURFACE WAVES

CROSS REFERENCE TO RELATED CASES

[0001] This application claims priority to, and the benefit of, U.S. Patent Application No. 14/850,051, entitled "Geolocation Using Guided Surface Waves" and filed on September 10, 2015.

[0002] This application is related to co-pending U.S. Non-provisional Patent Application entitled "Excitation and Use of Guided Surface Wave Modes on Lossy Media," which was filed on March 7, 2013 and assigned Application Number 13/789,538, and was published on September 11, 2014 as Publication Number US2014/0252886 A1. This application is also related to co-pending U.S. Non-provisional Patent Application entitled "Excitation and Use of Guided Surface Wave Modes on Lossy Media," which was filed on March 7, 2013 and assigned Application Number 13/789,525, and was published on September 11, 2014 as Publication Number US2014/0252865 A1. This application is further related to co-pending U.S. Non-provisional Patent Application entitled "Excitation and Use of Guided Surface Wave Modes on Lossy Media," which was filed on September 10, 2014 and assigned Application Number 14/483,089. This application is further related to co-pending U.S. Non-provisional Patent Application entitled "Excitation and Use of Guided Surface Waves," which was filed on June 2, 2015 and assigned Application Number 14/728,507. This application is further related to co-pending U.S. Non-provisional Patent Application entitled "Excitation and Use of Guided Surface Waves," which was filed on June 2, 2015 and assigned Application Number 14/728,492.

BACKGROUND

[0003] For over a century, signals transmitted by radio waves involved radiation fields launched using conventional antenna structures. In contrast to radio science, electrical power distribution systems in the last century involved the transmission of energy guided along electrical conductors. This understanding of the distinction between radio frequency (RF) and power transmission has existed since the early 1900's.

SUMMARY

[0004] Disclosed is a navigation unit for performing geolocation using guided surface waves. The navigation unit includes a charge terminal elevated over a lossy conducting medium; a receiver

network coupled between the charge terminal and the lossy conducting medium, the receiver network having a phase delay (Φ) that matches a wave tilt angle (Ψ) associated with the guided surface wave, the wave tilt angle (Ψ) based at least in part upon characteristics of the lossy conducting medium in a vicinity of the navigation unit; a processor; a memory; and an application stored in the memory and executable by the processor, wherein the application causes the navigation unit to perform at least the following actions when executed by the processor: identify when a guided surface wave was received by the receiver network; identify when a reflection of the guided surface wave was received by the receiver network; calculate an amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave; and determine a location of the navigation unit based at least in part on the amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave. In one or more embodiments, the causing the navigation unit to determine a location of the navigation unit is based at least in part on the amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave further includes causing the processor to at least: divide the amount of time in two to generate a halved amount of time; multiply the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the receiver network; and set the location of the navigation unit along a circumference of a circle centered on the antipode, wherein the circle has a radius equal to the distance between the antipode and the navigation unit. In one or more embodiments, causing the navigation unit to determine a location of the navigation unit is based at least in part on the amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave further includes causing the processor to at least: divide the amount of time in two to generate a halved amount of time; multiply the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the receiver network; subtract the distance between the antipode and the guided surface wave receive structure from a value equal to half of the circumference of the Earth to generate a distance between the probe associated with the guided surface wave and the receiver network; and set the location of the navigation unit along a circumference of a circle centered on the probe, wherein the circle has a radius equal to the distance between the probe and the navigation unit. In one or more embodiments, the application, when executed by the processor, further causes the navigation unit to at least identify an approximate position of the navigation unit based at least in part on inertial data associated with the navigation unit, wherein the inertial data is stored in the memory of the navigation unit. In some of these embodiments, causing the navigation unit to determine the location of the guided surface wave receive structure is further based at least in part on the approximate position of the navigation unit. In one or more embodiments, the application, when

executed by the processor, further causes the navigation unit to at least identify an approximate position of the guided surface wave receive structure based at least in part on an identity of a cellular network tower within range of the guided surface wave receive structure. In some of these embodiments, causing the navigation unit to determine the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure. In one or more embodiments, the application, when executed by the processor, further causes the navigation unit to at least identify an approximate position of the guided surface wave receive structure based at least in part on an identity of a radio transmission tower within range of the guided surface wave receive structure. In some of these embodiments, causing the navigation unit to determine the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure. In one or more embodiments, the charge terminal is height adjustable such that a change in a height of the charge terminal causes a change in the phase delay (Φ).

[0005] Disclosed is method for performing geolocation using guided surface waves. The method includes receiving a guided surface wave using a guided surface wave receive structure; receiving a reflection of the guided surface wave using the guided surface wave receive structure; calculating an amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave; and determining a location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave. In one or more embodiments, determining the location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave further includes: dividing the amount of time in two to generate a halved amount of time; multiplying the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the guided surface wave receive structure; and setting the location of the guided surface wave receive structure along a circumference of a circle centered on the antipode, wherein the circle has a radius equal to the distance between the antipode and the guided surface wave receive structure. In one or more embodiments, determining the location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave further includes: dividing the amount of time in two to generate a halved amount of time; multiplying the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the guided surface wave receive structure; subtracting the distance between the antipode and

CLAIMS

Therefore, the following is claimed:

1. A navigation unit, comprising:

a charge terminal elevated over a lossy conducting medium;

a receiver network coupled between the charge terminal and the lossy conducting medium, the receiver network having a phase delay that matches a wave tilt angle associated with a guided surface wave, the wave tilt angle based at least in part upon characteristics of the lossy conducting medium in a vicinity of the navigation unit;

a processor;

a memory; and

an application stored in the memory and executable by the processor, wherein the application causes the navigation unit to perform at least the following actions when executed by the processor:

identify when the guided surface wave was received by the receiver network;

identify when a reflection of the guided surface wave was received by the receiver network;

calculate an amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave; and

determine a location of the navigation unit based at least in part on the amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave.

2. The navigation unit of claim 1, wherein causing the navigation unit to determine a location of the navigation unit is based at least in part on the amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave further comprises causing the processor to at least:

divide the amount of time in two to generate a halved amount of time;

multiply the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the receiver network; and

set the location of the navigation unit along a circumference of a circle centered on the antipode, wherein the circle has a radius equal to the distance between the antipode and the navigation unit.

3. The navigation unit of claim 1, wherein causing the navigation unit to determine a location of the navigation unit is based at least in part on the amount of time elapsed between receipt of the guided surface wave and receipt of the reflection of guided surface wave further comprises causing the processor to at least:

divide the amount of time in two to generate a halved amount of time;

multiply the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the receiver network;

subtract the distance between the antipode and the guided surface wave receive structure from a value equal to half of the circumference of the Earth to generate a distance between the probe associated with the guided surface wave and the receiver network; and

set the location of the navigation unit along a circumference of a circle centered on the probe, wherein the circle has a radius equal to the distance between the probe and the navigation unit.

4. The navigation unit of claims 1-3, wherein the application, when executed by the processor, further causes the system to at least identify an approximate position of the system based at least in part on inertial data associated with the system, wherein the inertial data is stored in the memory of the system; and

wherein causing the system to determine the location of the guided surface wave receive structure is further based at least in part on the approximate position of the navigation unit.

5. The navigation unit of any of claims 1-3, wherein the application, when executed by the processor, further causes the navigation unit to at least identify an approximate position of the guided surface wave receive structure based at least in part on an identity of a cellular network tower within range of the guided surface wave receive structure; and

wherein causing the system to determine the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure.

6. The navigation unit of any of claims 1-3, wherein the application, when executed by the processor, further causes the navigation unit to at least identify an approximate position of the guided surface wave receive structure based at least in part on an identity of a radio transmission tower within range of the guided surface wave receive structure; and

wherein causing the navigation unit to determine the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure.

7. The navigation unit of claims 1-6, wherein the charge terminal is height adjustable such that a change in a height of the charge terminal causes a change in the phase delay.

8. A method, comprising:

receiving a guided surface wave using a guided surface wave receive structure;

receiving a reflection of the guided surface wave using the guided surface wave receive structure;

calculating an amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave; and

determining a location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave.

9. The method of claim 8, wherein determining the location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave further comprises:

dividing the amount of time in two to generate a halved amount of time;

multiplying the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the guided surface wave receive structure; and

setting the location of the guided surface wave receive structure along a circumference of a circle centered on the antipode, wherein the circle has a radius equal to the distance between the antipode and the guided surface wave receive structure.

10. The method of claim 8, wherein determining the location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the guided surface wave and receiving the reflection of guided surface wave further comprises:

dividing the amount of time in two to generate a halved amount of time;

multiplying the halved amount of time by a speed of the guided surface wave to generate a distance between an antipode of a probe associated with the guided surface wave and the guided surface wave receive structure;

subtracting the distance between the antipode and the guided surface wave receive structure from a value equal to half of the circumference of the Earth to generate a distance between the probe associated with the guided surface wave and the guided surface wave receive structure; and

setting the location of the guided surface wave receive structure along a circumference of a circle centered on the probe, wherein the circle has a radius equal to the distance between the probe and the guided surface wave receive structure.

11. The method of any of claims 8-10, further comprising:

identifying an approximate position of the guided surface wave receive structure based at least in part on inertial data associated with the guided surface wave receive structure; and

wherein determining the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure.

12. The method of any of claims 8-10, further comprising:

identifying an approximate position of the guided surface wave receive structure based at least in part on an identity of a radio transmission tower within range of the guided surface wave receive structure; and

wherein determining the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure.

13. The method of any of claims 8-10, further comprising:

identifying an approximate position of the guided surface wave receive structure based at least in part on an identity of a cellular network tower within range of the guided surface wave receive structure; and

wherein determining the location of the guided surface wave receive structure is further based at least in part on the approximate position of the guided surface wave receive structure.

14. The method of any of claims 8-13, wherein the guided surface wave comprises a first guided surface wave, the guided surface wave receive structure comprises a first guided surface wave receive structure and the method further comprises:

receiving a second guided surface wave using a second guided surface wave receive structure;

receiving a reflection of the second guided surface wave using the second guided surface wave receive structure;

calculating an amount of time elapsed between receiving the second guided surface wave and receiving the reflection of second guided surface wave;

receiving a third guided surface wave using a third guided surface wave receive structure;

receiving a reflection of the third guided surface wave using the third guided surface wave receive structure;

calculating an amount of time elapsed between receiving the third guided surface wave and receiving the reflection of third guided surface wave; and

determining a location of the guided surface wave receive structure based at least in part on the amount of time elapsed between receiving the second guided surface wave and receiving the reflection of second guided surface wave and the amount of time elapsed between receiving the third guided surface wave and receiving the reflection of third guided surface wave.

15. The method of claims 8-14, wherein the guided surface wave receive structure comprises:

a charge terminal elevated over a lossy conducting medium; and

a receiver network coupled between the charge terminal and the lossy conducting medium, the receiver network having a phase delay that matches a wave tilt angle associated with the guided surface wave, the wave tilt angle based at least in part upon characteristics of the lossy conducting medium in a vicinity of the charge terminal.