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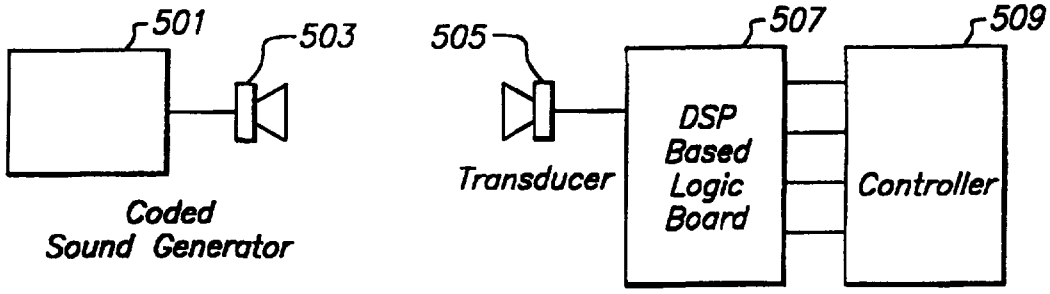

(57) Abstract

A digital communications network is provided using digital sonic and ultrasonic communications, i.e., communications using acoustic energy instead of RF energy. The "acoustic spectrum", as opposed to the RF spectrum, is uncluttered and unregulated, allowing for unfettered commercial development of equipment for ITS applications as well as a wide variety of other applications, including applications that currently employ RF communications. Exemplary applications include electronic toll boothing, controlled entry systems, border crossing systems, etc. Coding and processing techniques are employed that allow acoustic communications, including the communication of digital data, to be reliably transmitted and received even in noisy acoustic environments.

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DIGITAL SONIC AND ULTRASONIC COMMUNICATIONS NETWORKS

1. Field of the Invention

The present invention relates to digital communications networks, and to communications using acoustic energy.

2. State of the Art

An industrial economy depends heavily on transportation infrastructure. The United States enjoys one of the most advanced highway systems in the world. Nevertheless, this system, designed principally in the 1950s, is beginning to show signs of age. Furthermore, because of current budgetary pressures, very few new highways are being planned or built. Instead, attention has been focussed on maximizing the utilization of existing highways through the application of computer and communications technologies. This effort is referred to generally as the Intelligent Transit System (ITS).

The tacit underlying assumption concerning the application of communications technology to transit has been that Radio-Frequency (RF) communications will be used. The widespread use of RF communications in transit applications, however, suffers in concept from a number of disadvantages. The ITS initiative appears to have gained critical momentum just at a time when the scarcity of RF bandwidth is being felt most acutely. The RF spectrum is, quite literally, "cluttered" with a wide variety of users all competing for scarce bandwidth. Federal regulatory approval is therefore required for most RF communications. Furthermore, a great deal of traffic is interstate and even international (particularly in Europe). The result is a patchwork of rules, regulations and practices, from jurisdiction to jurisdiction, concerning RF communications.

What is needed, then is additional bandwidth that may be applied within the context of the ITS and other similar transit applications. Preferably, such bandwidth should be "clutter-free" and unregulated so as to allow for the

consistent commercial use of such bandwidth from jurisdiction to jurisdiction. The present invention addresses this need.

SUMMARY OF THE INVENTION

In accordance with the present invention, generally speaking, a digital communications network is provided using digital sonic and ultrasonic communications-i.e., communications using acoustic energy instead of RF energy. The "acoustic spectrum," as opposed to the RF spectrum, is uncluttered and unregulated, allowing for unfettered commercial development of equipment for ITS applications as well as a wide variety of other applications, including applications that currently employ RF communications. Exemplary applications include electronic toll boothing, controlled entry systems, border crossing systems, etc. Coding and processing techniques are employed that allow acoustic communications, including the communication of digital data, to be reliably transmitted and received even in noisy acoustic environments.

More particularly, in accordance with one embodiment of the invention, a digital acoustic communications apparatus includes one or more digital acoustic communications devices comprising a data processor; memory coupled to the data processor and storing digital data; and means for transmitting and/or receiving digital data acoustically; wherein the acoustic digital communications apparatus, during operation, transmits and/or receives digital data acoustically. In accordance with further aspects of the this embodiment of invention, the memory stores at least one of an identifying code word and a command, and the means for transmitting and/or receiving transmits and/or receives at least one of said identifying code word and said command acoustically. The means for transmitting and/or receiving may be an acoustic digital communications transmitter operating in the human audible range or may be an acoustic digital communications transmitter operating in the ultrasonic range. Alternatively, the means for transmitting and/or receiving may be an acoustic digital communications receiver comprising an analog-to-digital converter, wherein the data processor comprises a digital signal processor coupled to the analog-to-digital converter for filtering a digital representation of a received

acoustic signal and for recovering digital data symbols encoded therein. The acoustic digital communications receiver may operate in the human audible range or may further comprising a downconverter, whereby the acoustic digital communications receiver operates in the ultrasonic range. Still further, the means for transmitting and/or receiving may be a digital acoustic transceiver comprising an input sound transducer, an analog-to-digital converter coupled to the input sound transducer, an output sound transducer, and a digital-to-analog converter coupled to the output sound transducer; in which case the data processor may be a digital signal processor coupled to the analog-to-digital converter for filtering a digital representation of a received acoustic signal and for recovering digital data symbols encoded therein, and coupled to the memory and to the digital-to-analog converter for transmitting the identifying code word or the command stored in memory acoustically. The acoustic digital communications transceiver may operate in the human audible range or in the ultrasonic range. A system in accordance with another aspect of the present invention comprises a plurality of digital acoustic communications devices including a plurality of acoustic digital transmitters and at least one acoustic digital receiver for, when one of said acoustic digital transmitters is within range and transmitting digital information, receiving said digital information. The system preferably further comprises a computer and at least one wide area network communications link established between the acoustic digital receiver and the computer. More preferably, the system comprises multiple acoustic digital receivers and multiple wide area network communications links, one such link being established between each of a plurality of said acoustic digital receivers and said computer.

In accordance with another aspect of the present invention, a method of digital communications comprising the steps of generating a carrier signal; modulating the carrier signal in accordance with digital information to produce a modulated signal; and applying the modulated signal to an acoustic transducer to produce a coded acoustic signal. The coded acoustic signal is propagated across a distance many times a wavelength of the coded acoustic signal.

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