extremely robust once established, with the synchronization being unaffected by perturbations such as temperature and voltage changes.

However the TLL methodology disclosed in WO 03/038469 A1 requires the reference transmitter and the positioning-unit devices to be in known and fixed locations with respect to a reference coordinate system. Generally the reference transmitter and the positioning-unit devices are ground-based, although it is also possible for positioning-unit devices to receive reference positioning signals from satellites in geostationary orbits, such as Wide Area Augmentation System (WAAS) satellites. If a reference transmitter and a positioning-unit device were to move relative to each other a Doppler shift would be imposed on the reference positioning signals received by the positioning-unit device. This Doppler will be indistinguishable from clock drift, because both Doppler and clock drift manifest as frequency changes. Consequently the positioning-unit device would, in attempting to synchronize itself to the reference transmitter, erroneously slew its clock, severely degrading the accuracy of position solutions calculated by a mobile apparatus. Methods and devices for synchronizing a kinematic location network are therefore highly desirable, to enable the calculation of accurate position solutions for a mobile apparatus receiving signals from a network of positioning-unit devices in which one or more of the positioning-unit devices are moving relative to the others.

Object of the Invention

Embodiments of the present invention overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

Embodiments of the present invention provide a method for synchronizing a positioning-unit device to the timebase of a reference transmitter in situations where the reference transmitter and positioning-unit device are moving relative to each other.

Embodiments of the present invention provide a method for generating frequency coherence between positioning signals transmitted by a reference transmitter and a positioning-unit device, in situations where the reference transmitter and positioning-unit device are moving relative to each other.

Embodiments of the present invention provide a positioning system capable of generating accurate position solutions for a mobile apparatus receiving signals from a network of positioning-unit devices in which one or more of the positioning-unit devices are moving relative to the others.

Summary of the Invention

According to a first aspect of the present invention there is provided a method of chronologically synchronizing a unique positioning signal generated by a positioning-unit device to a reference positioning signal generated by a reference transmitter, wherein said positioning-unit device and said reference transmitter are moving relative to each other, said method comprising the steps of said positioning-unit device:

a) receiving and interpreting said reference positioning signal;

b) generating and transmitting a unique positioning signal, wherein said unique positioning signal is aligned with a steered transmitter clock;

c) receiving and interpreting said unique positioning signal;

d) measuring a frequency difference between the received reference positioning signal and the received unique positioning signal;

e) estimating Doppler associated with the relative movement;

f) adjusting the frequency of said steered transmitter clock by an amount derived from the measured frequency difference and the estimated Doppler;

g) measuring a time difference between the received reference positioning signal and the received unique positioning signal;

h) estimating a reference signal propagation delay between said reference transmitter and itself; and

i) adjusting the generation of said unique positioning signal according to the measured time difference and the estimated reference signal propagation delay,

wherein said positioning-unit device estimates said Doppler and said reference signal propagation delay from trajectory data for said reference transmitter, or trajectory data for itself, or both, such that said unique positioning signal is chronologically synchronized to said reference positioning signal.