ATOMIC CLOCK AUGMENTATION FOR RECEIVERS USING THE GLOBAL POSITIONING SYSTEM

by

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(ABSTRACT)

For receivers using the Global Positioning System (GPS), it is standard procedure to treat the receiver clock bias from GPS time as an unknown. This requires four range measurements to the satellites in order to solve for three dimensional position and clock offset. If the receiver clock could be synchronized with GPS time, the extra range measurement would not be necessary. To achieve this synchronization, a stable frequency reference must be incorporated into the GPS user set. This concept is known as clock aiding or clock augmentation of GPS receivers.

Clock augmentation increases the availability of the navigation function because only three GPS satellites are required. Also, it is shown that clock augmentation improves vertical accuracy by reducing the vertical dilution of precision (VDOP), which is a unitless multiplier that translates range measurement error into vertical position error. This improvement in vertical accuracy is particularly beneficial for applications involving final approach and landing of

aircraft using GPS, because GPS typically provides better horizontal accuracy than vertical accuracy.

The benefits of atomic clock augmentation are limited by factors that cause a loss of synchronization either between the receiver and GPS time, or between ground station and airborne receivers processing GPS data in differential mode (DGPS). Among the error sources that cause a clock offset are antenna rotation, hardware drifts due to temperature variations, and relativistic effects for GPS receivers on moving platforms. Antenna rotation and temperature effects are addressed and supported by experimental data. It is shown that two particular relativity terms thought to be missing from GPS receiver algorithms are not evident in data collected during a flight test experiment.

Upon addressing the error sources, the dissertation concludes with analysis of DGPS data collected during a flight test at the Federal Aviation Administration (FAA) Tech Center in Atlantic City, during which external rubidium oscillators were used by airborne (Boeing 757-B) and ground station GPS receivers. A new method of clock modeling is introduced, and this clock model is used to demonstrate the improvement in vertical accuracy, as well as three-satellite navigation.

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LIST OF ABBREVIATIONS

CCW	Counter-Clockwise
CDMA	Code Division Multiple Access
CW	Clockwise
DC	Direct Current
DD	Double Difference
DGPS	Differential GPS
DLL	Delay Lock Loop
DME	Distance Measuring Equipment
DOD	Department of Defense
DOP	Dilution of Precision
ECEF	Earth-Centered Earth-Fixed
ECI	Earth-Centered Inertial
FAA	Federal Aviation Administration
FDMA	Frequency Division Multiple Access
GDOP	Geometric Dilution of Precision
GLONASS	Global Navigation Satellite System
GMT	Greenwich Mean Time
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
HOW	Handover Word
LAAS	Local Area Augmentation System

LIST OF ABBREVIATIONS (continued)

LEO	Low Earth Orbit
LORAN-C	Long Range Navigation-C
LOS	Line-of-Sight
NAVSTAR	Navigation Satellite Timing and Ranging
OCXO	Oven Controlled Crystal Oscillator
PLL	Phase Lock Loop
PPS	Precise Positioning Service
PR	Pseudorange
PRN	Pseudorandom Noise
RHCP	Right Hand Circular Polarization
SD	Single Difference
SA	Selective Availability
SPS	Standard Positioning Service
SV	Satellite Vehicle
TCXO	Temperature Compensated Crystal Oscillator
TD	Time Difference
TDOP	Time Dilution of Precision
TLM	Telemetry Word
TOA	Time of Arrival
TOT	Time of Transmission
UNI	University Airport

LIST OF ABBREVIATIONS (continued)

VDOP	Vertical Dilution of Precision
VOR	Very High Frequency Omnidirectional Range