Loran as an Independent Source of UTC in Telecommunication Applications

by

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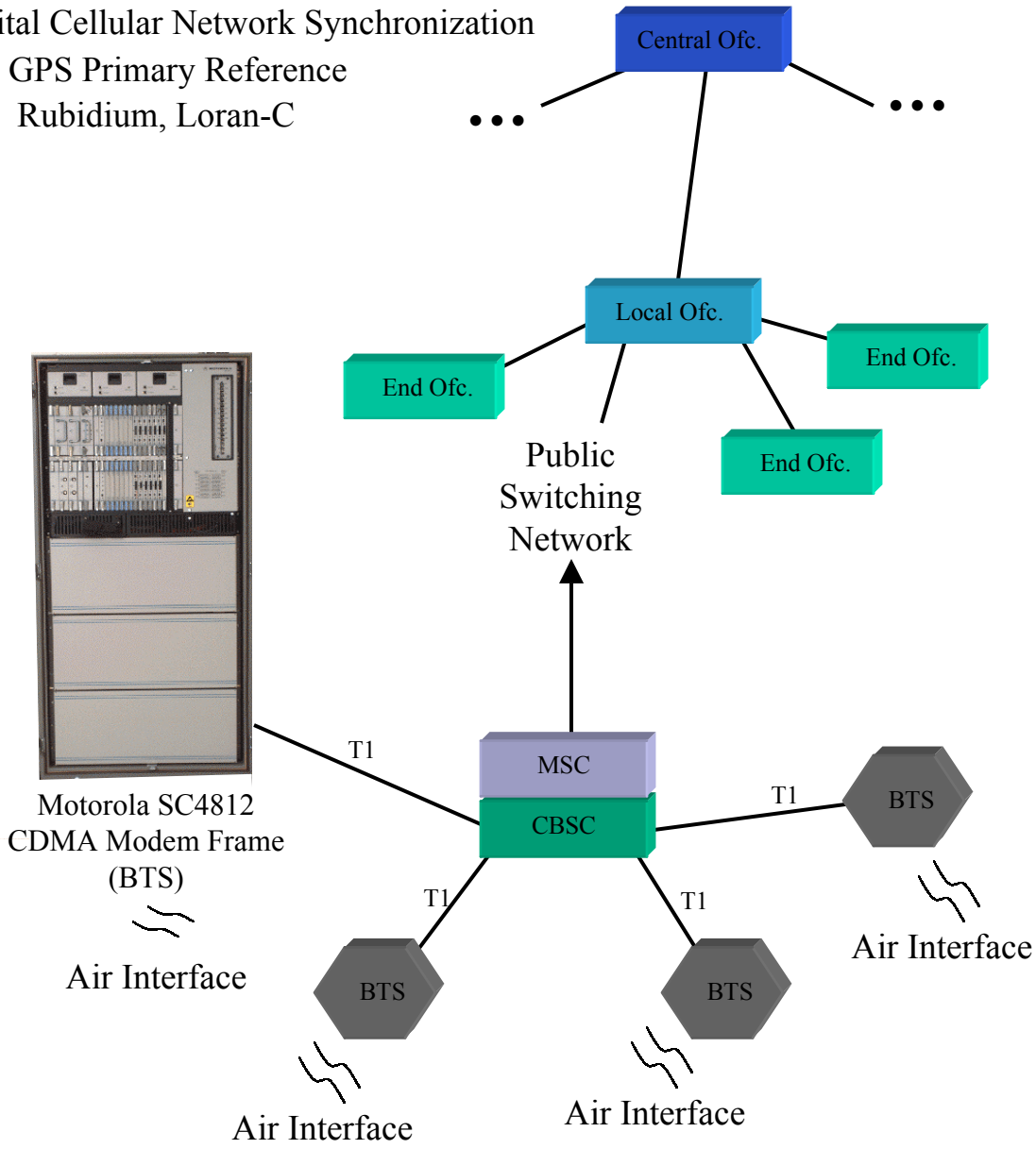
Telecommunications Synchronization Overview

- Public Network Timing / Synchronization Architecture
  - Stratum Hierarchy
- Digital Cellular Network Synchronization
  - GPS Primary Reference
  - Rubidium, Loran-C



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GPS Alone Cannot Provide Necessary Reliability

Real Life Problems Encountered by Motorola:

- Unintentional Jamming
  - Television Stations
  - Spurious Emissions by Paging Transmitters
  - Unknown Sources
  - Known Sources (e.g. Phoenix and Rome, NY)

- Intentional Jamming
  - US government tests

- Poor Satellite Reception
  - Urban Canyons
  - Ice / Snow Buildup on Antennas

- GPS Satellite Failures
  - September 1995 (SVN10)
  - March 18, 1997 (SVN35)

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Benefits of Loran in Telecommunications as Backup Synchronization Source to GPS

- **Independent System - no common mode failures, such as unintentional jamming.**
- **<u>Only</u> other source of UTC - UTC is necessary for base station start-up, when GPS might not be available.**
- **Infinite backup capabilities - can function as primary clock (like GPS), vs short term limitation of Rb**
- **Performance - penetration into urban environments**
- **Reliability - very reliable technology with low support costs (vs Rb)**
- **Proven technology with established user base**
- **Low cost**

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IS-95 CDMA Specification and UTC Requirement

CDMA Network Synchronization Requirements		
Specification	**Requirement**	**Origin**
Transmit Carrier Frequency Accuracy (CTIA 7.1.1.2)	± 0.05 P.P.M.	R.F. Spectrum Allocation
Timing Reference Source (CTIA 7.1.5.1)	(Below)	Synchronization/ Redundancy
Base Station Transmission Time (CTIA 7.1.5.3)	± 1 µS (Colocated Channels) ± 3 µS (GPS Operational) ± 10 µS (GPS Failure)	Mobile Search Window
Pilot to Walsh Cover Time Tolerance (CTIA 7.1.5.3)	± 50 ηS	System Capacity

7.1.5.1 Each base station shall contain a time base reference from which all time critical CDMA transmissions, including pilot PN sequences, frames, and Walsh functions, shall be derived. The time base reference shall be time–aligned to CDMA System Time as described in 1.2. Reliable external means should be provided at each base station to synchronize each base station's time base reference to CDMA System Time. Each base station should contain a frequency reference of sufficient accuracy to maintain time alignment to CDMA System Time, in the event that the external source of System Time is lost.

Note: CDMA requirement was specifically developed to enable use of Rb as backup to GPS, which was to be the primary reference. However, Rb can only meet this specification for a short period of time and cannot generate UTC.

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Block Diagram of Mobile Experimental System

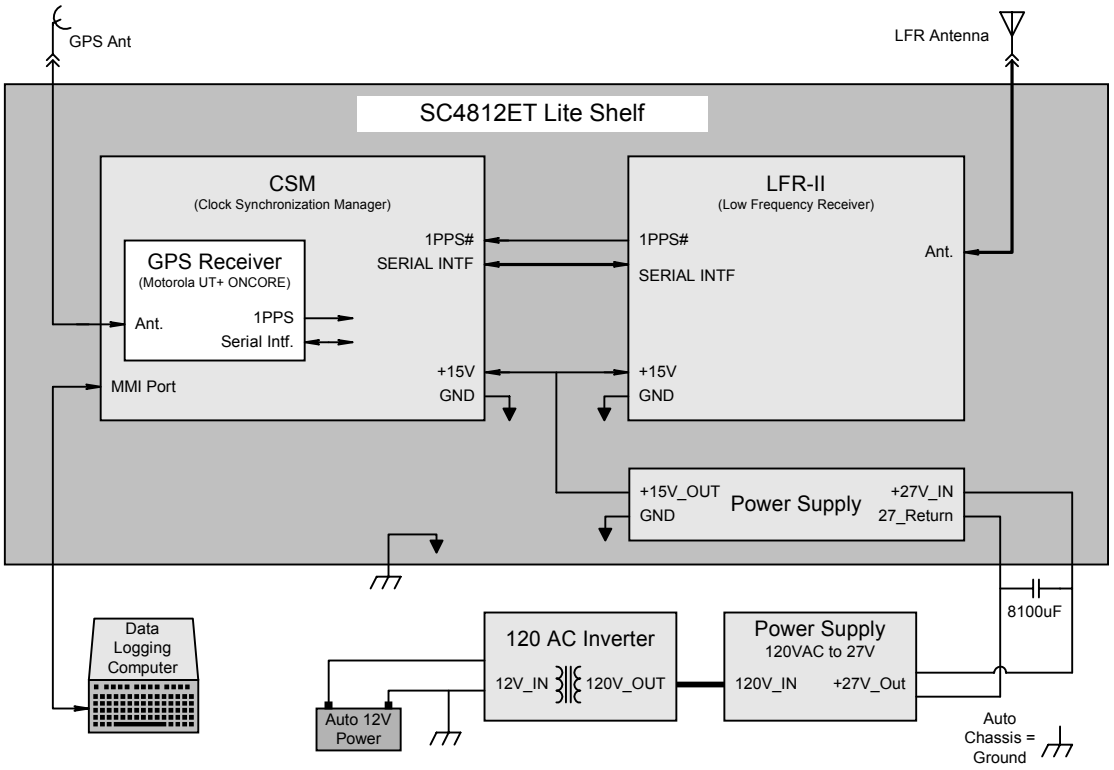

Figure 5 - Mobile LFR-II TAI Measurement Equipment Configuration

Note: system clock operates at 19.6608 MHz, so resolution of these measurements is ~51 nSeconds, which is more than adequate given the CDMA synchronization specification.

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Test Procedure

1. GPS was powered on and allowed to stabilize.

2. Loran was powered on and allowed to stabilize. No ASF corrections were used by the receiver.

3. A command was issued to the Loran receiver to calculate TAI. After the receiver completed the calculation, it moved the 1PPS phase to the TAI.

4. The offset between GPS UTC and Loran TAI was determined by the number of system clock ticks between the 1 PPS outputs of each receiver, which was then multiplied by the system clock cycle.

5. Mobile tests typically took ~30 minutes.

6. Static tests were conducted periodically on September 16 & 17, 2002 in Wilmington, NC.

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Mobile Test Setup

Loran antenna was 18” e-field.

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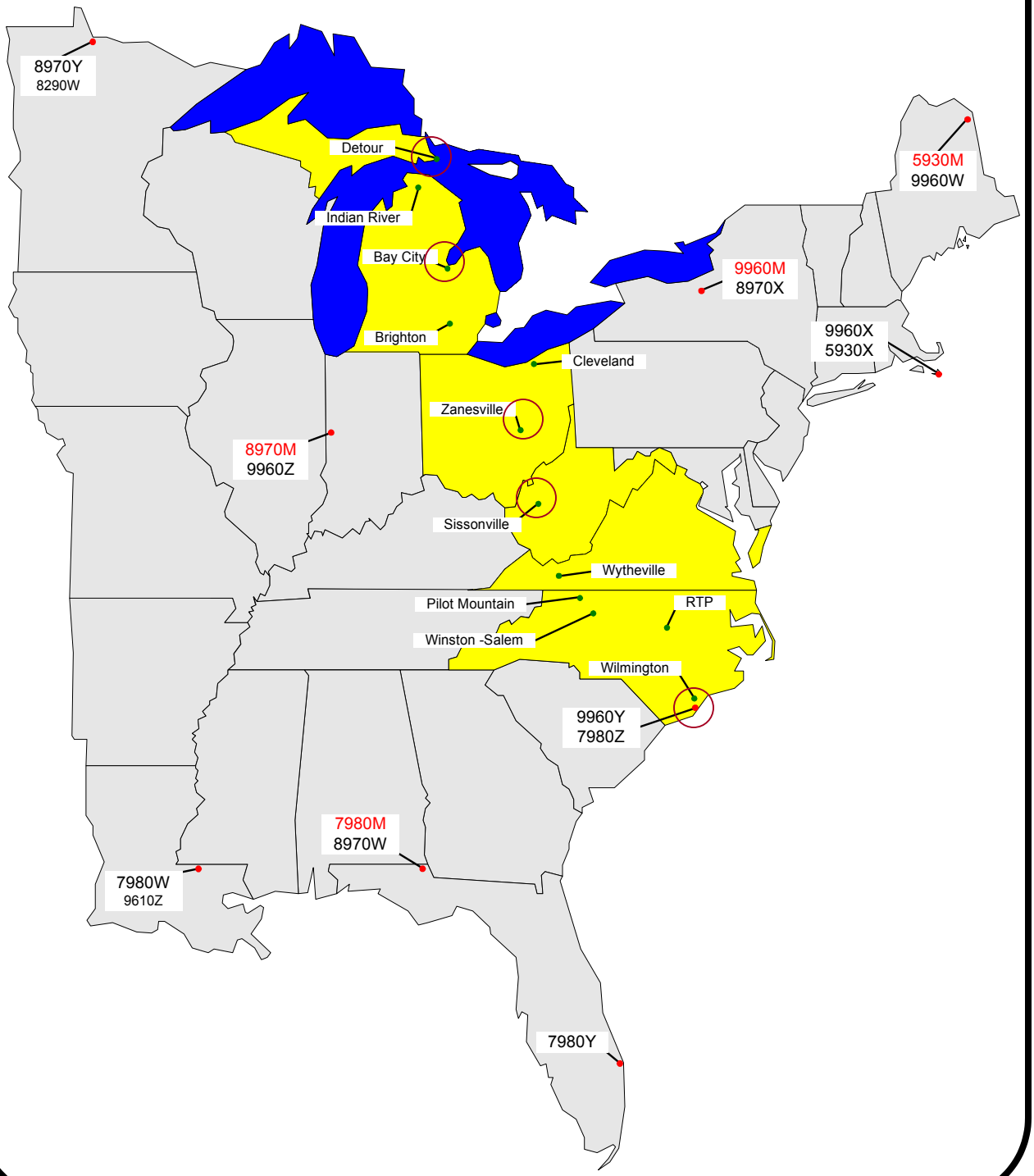
Test Sites and Loran Transmitters



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Mobile Test Results

Detour, MI - August 17, 2002

Loran Station	Distance from Test Site (miles)	Deviation from GPS UTC (microseconds)
7980M	1038	-2.244
8970M	462	0.408
9960M	417	0.918

Bay City, MI - August 17, 2002

7980M	869	-1.989
8970M	314	1.122
9960M	365	0.765

Zanesville, OH - August 17, 2002

7980M	648	-2.703
8970M	317	1.479
9960M	312	-0.408

Sissonville, WV - August 18, 2002

7980M	552	-2.856
8970M	328	0.663
9960M	388	-1.785

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Static Test Results
in Wilmington, North Carolina

September 16_12_19gmt

Loran Station	Distance from Test Site (miles)	Deviation Range from GPS UTC (microseconds)	
		Min	Max
7980M	478	0.561	0.612
8970M	656	0.000	0.255
9960M	588	0.000	-0.102
5930M	1013	-0.153	-1.071
9610M	1415	-3.213	-3.825

September 16_14_53gmt

7980M	478	0.663	0.714
8970M	656	0.051	0.204
9960M	588	0.000	0.102
5930M	1013	-0.102	-1.530
Note - Data collected during heavy thunderstorm			

September 16_21_21gmt

7980M	478	0.510	0.612
8970M	656	0.000	0.153
9960M	588	0.102	0.204

Note Wilmington, NC site is 11nm from Carolina Beach transmitter, so 18” e-field antenna lowered to attentuate signal.

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September 17, 2002 Static Test Results in Wilmington, North Carolina

00_10gmt

Loran Station	Distance from Test Site (miles)	Deviation Range from GPS UTC (microseconds)	
		Min	Max
7980M	478	0.510	0.612
8970M	656	0.000	0.153
9960M	588	0.102	0.255

12_38gmt

Loran Station	Distance from Test Site (miles)	Deviation Range from GPS UTC (microseconds)	
		Min	Max
7980M	478	0.612	0.663
8970M	656	0.000	0.255
9960M	588	0.153	0.306
5930M	1013	-0.306	-1.326

15_49gmt

Loran Station	Distance from Test Site (miles)	Deviation Range from GPS UTC (microseconds)	
		Min	Max
7980M	478	0.561	0.612
8970M	656	0.000	0.153
9960M	588	0.204	0.408

18_22gmt

Loran Station	Distance from Test Site (miles)	Deviation Range from GPS UTC (microseconds)	
		Min	Max
7980M	478	0.612	0.663
8970M	656	0.051	0.255
9960M	588	0.102	0.153

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Summary and Conclusions

- Tests on Loran's ability to provide an independent source of UTC were conducted at 12 sites in 5 states using different master stations for phase locking.

- The specified CDMA synchronization requirement is <10 uS drift per day, with 3 uS drift desirable.

- Loran's UTC accuracy is virtually entirely dependent on ASF, and is a function of distance to the station.

- In all trials where the master was located less than ~1000 miles from the test site, Loran provided UTC accuracy about an order of magnitude better than the required CDMA specification, even without using ASF corrections.

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Summary and Conclusions

- In all test sites, at least two additional Loran masters were nearer than 1000 miles, therefore at least two more redundant sources of UTC are likely to be available.

- Loran easily met system requirements in both near-overload (e.g. 11 nm from transmitter) and far-fringe (e.g. ~1100 miles distant from transmitter) conditions.

- When USCG upgrades tighten Loran timing controls, then:
  - Loran UTC performance will improve
  - Use of secondaries is facilitated by TOE

- With use of ASF corrections and a well controlled infrastructure, Loran UTC performance could be ~2 orders of magnitude better than the CDMA requirement - and synchronization requirements are expected to increase in the future.

- Loran's ability to provide an independent, long term, highly accurate source of UTC is essential to back up GPS in critical applications such as mobile phone systems, where lives, property, or major economic loss might be at stake.