Base Transceiver Station Synchronization

January 1999

Symmetricom™

The world has seen phenomenal growth in deployment of wireless cell site equipment, with close to 200,000 wireless base stations by the end of 1998, according to estimate, and over 60,000 in the United States alone. Forecasts are that phenomenal growth will continue for at least a few more years, with the total number more than doubling by the year 2001.

Synchronization is essential to the effective operation of telecommunications networks. Wireless infrastructure networks have the same synchronization requirements as other wireline networks, while the cell site equipment deployed at the network edge that interconnects the wireless infrastructure to the mobile handset (in other words, wireless base stations) have similar yet different requirements.

As illustrated below, the cell site interfaces with the wired infrastructure to allow routing of calls from the "air interface" to the wireless infrastructure, which includes base stations controllers (BSC) and the mobile switching center (MSC), and then on to the Public Switched Telephone Network (PSTN).

Air interfaces include European cellular (900 MHz), European DCS (1800 MHz), North American cellular (800 MHz) and North American PCS (1900 MHz). Other wireless systems such as specialized mobile radio (SMR), cordless telephony (e.g., DECT) and wireless local loop also require proper synchronization.

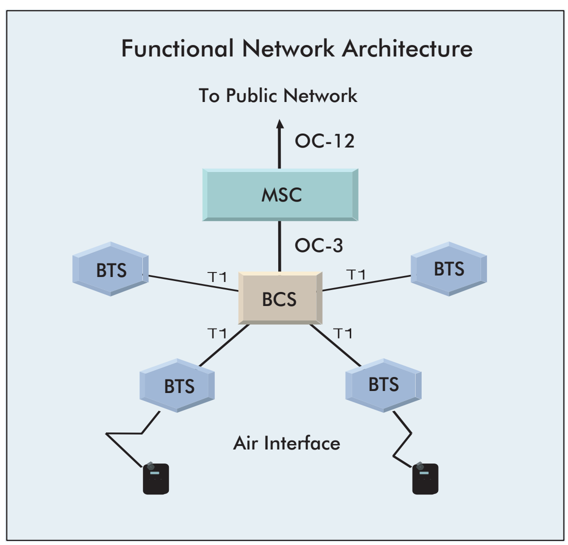
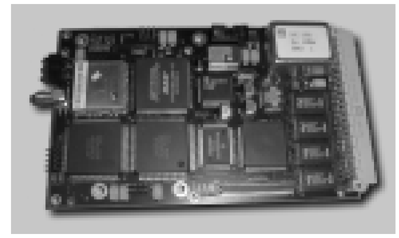


Figure 1.

Base Stations Need to be Synchronized



Every wireless base station (or BTS, short for "base transceiver station") needs to be synchronized.

As with any other network element, they need synchronization to ensure voice and data communications are transported undisturbed by transmission impairments such as jitter and wander. In this respect, a BTS shares the synchronization requirements of SONET add-drop multiplexers (ADM) and other network edge devices such as digital loop carrier systems. Transport synchronization requirements are specified in ANSI T1.101, with DS1 mask conformance required for network end nodes such as cell sites. If these requirements are met, voice and data traffic should be unimpaired between the BTS and BSC/MSC.

Additionally, a BTS needs synchronization to ensure stable frequency for the "on air" wireless channels. All types of digital wireless service require precise frequency, with GSM and CDMA requiring 0.05 parts per million (ppm) frequency stability and TDMA requiring 0.5 ppm frequency stability. CDMA also requires a precise time reference, while GSM and TDMA don't. Additionally, since synchronization devices are used to manage the pilot frequencies of the mobile radio interface, low phase noise requirements are needed for spectral purity. Phase noise requirements for BTS design are typically as expressed below:

Phase Noise	-70 dBc/Hz at 1 Hz
	-120 dBc/Hz at 100 Hz
	-130 dBc/Hz at 1 kHz
	-135 dBc/Hz at 10 kHz, 100 kHz and 1 MHz

CDMA Base Station Synchronization Requirements

CDMA systems use the GPS time scale to synchronize the system as well as produce a stable frequency reference for cellular (800 and 900 MHz) and PCS/DCS (1800 and 1900 MHz) frequencies. CDMA systems require, per IS-95 (Section 7.1.5.2), that all base stations transmit their pilot sequence within 3 microseconds (μs) of the precise CDMA system time. In meeting this requirement, the industry has standardized on the deployment of GPS timing receivers in all base stations. The GPS subsystem is coupled with a local oscillator for provision of precise time and frequency. Each base station manufacturer sets its own clock holdover specifications (performance of the system during the loss of GPS signals), typically ±7 μs over 24 hours. A standby high stability oscillator (HSO), typically rubidium or high stability ovenized quartz crystal oscillators, is used to meet the holdover requirement.

Mobile switching centers (MSC) and base station controllers (BSC) also need precise time signals to assure uninterrupted handoffs when the user is in transit. CDMA MSC and BSC sites are typically equipped with Primary Reference Source (PRS) and Building Integrated Timing Supply (BITS) systems, following deployment guidelines of wireline offices. This approach keeps costs down while meeting time and frequency needs. Symmetricom's products for this application include the TimeSource 3000, DCD-LPR and DCD-523. (See application notes on MSC/BSC synchronization and TimeSource 3000 PRS.)

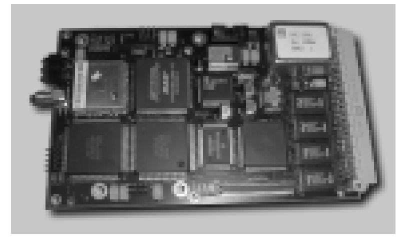
GSM/TDMA Synchronization Requirements

GSM/TDMA carriers require stable cellular and PCS/DCS frequencies but do not require GPS for a precise time reference. In these systems, the MSC and BSC is equipped with PRS and BITS equipment. The BITS at these sites maintains the frequency stability required by the wireline transport facilities interconnecting MSC, BSC and cell sites by depending on PRS traceable timing signals received from a connected wireline carrier. The cell site equipment is dependent upon its own internal oscillators, typically high quality quartz, for proper operation of "on air" cellular/PCS frequency.

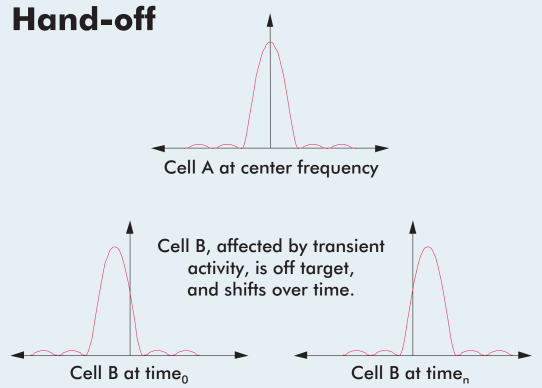
Emerging Requirements for Cell Site Synchronization

To date, the most common synchronization method for GSM and TDMA base stations has been, as described above, a master-slave arrangement distributed over the traffic-carrying network. The other approach, taken by CDMA, is an overlay synchronization network that directly embeds GPS into the base station. Whatever the approach taken, one must consider: (1) frequency stability requirements; (2) emerging requirements for 3rd generation wireless and mobile handset location; and (3) migration of MSC-BSC-BTS transport technologies away from T1/E1, where recovered network clock is available, to new technologies that do not provide a Stratum 1 traceable frequency reference. A short discussion of each of these areas follow.

- Frequency stability must be maintained within CDMA, GSM and TDMA specifications or center frequencies of "on air" channels will drift, resulting in co-channel interference. In the CDMA environment, frequency stability is maintained to 1 part in 10^{12} by disciplining the oscillator(s) to GPS, so drift of center frequencies is highly unlikely. In GSM



and TDMA base stations, the oscillator is either free running, requiring network operations personnel to re-tweak frequencies periodically; or the oscillators are locked to a span line reference, so the synchronization system must live with span line transmission impairments. As illustrated below, if the base station is locked to the span line and the span line has a poor frequency reference, the cell site synchronization modules will follow span line frequency drift, resulting in movement of the "on air" channel center frequencies. Center frequency drift may move one direction at cell site A and in an opposite direction at neighboring cell site B causing co-channel interference and reduced efficiency in inter-cell handoffs. Many times, deploying Symmetricom's DCD-LPR, TimeSource 3000 or TimeSource 2500 equipment at MSC and BSC locations solves these problems. For a more detailed description of this application, please refer to the MSC/BSC synchronization application note.



Poor control of the transmit frequency due to poor quality frequency reference derived from the T1 spanline can lead to dropped calls, slow hand-off between cells, and interference between channels.

During call initialization and hand-off, the RBS broadcasts a series of instructions to the mobile handset for changes in frequency and time slot. Under the influence of timing transients, the RBS may be forced to send numerous corrective instructions, adjusting frequency and time slot parameters. Precision timing at each RBS prevents this problem.

Figure 2.

- New services such as locating mobile handsets and 3rd generation wireless may require more stringent frequency stability, and a new precise time reference. The only viable solution to these emerging requirements is to embed GPS reference directly into cell site clock synchronization modules. Symmetricom's TimeSource 1000 offers this capability, plus it can also operate in a master-slave relationship by using timing references in addition to GPS. The TimeSource 1000's BesTime® clock algorithm allows use of recovered frequency reference from span lines and from neighboring CDMA or GSM base stations. Thus, a master base station may be locked to GPS while neighboring base stations (slaves), without line of site to the GPS satellites, get their time and frequency reference from the master base station.

Presented below is an example of a location determination technology, called Enhanced Observed Time Difference (E-OTD), that uses the observed time difference data available in the mobile handset in conjunction with GPS time and frequency in the base station to determine handset location.

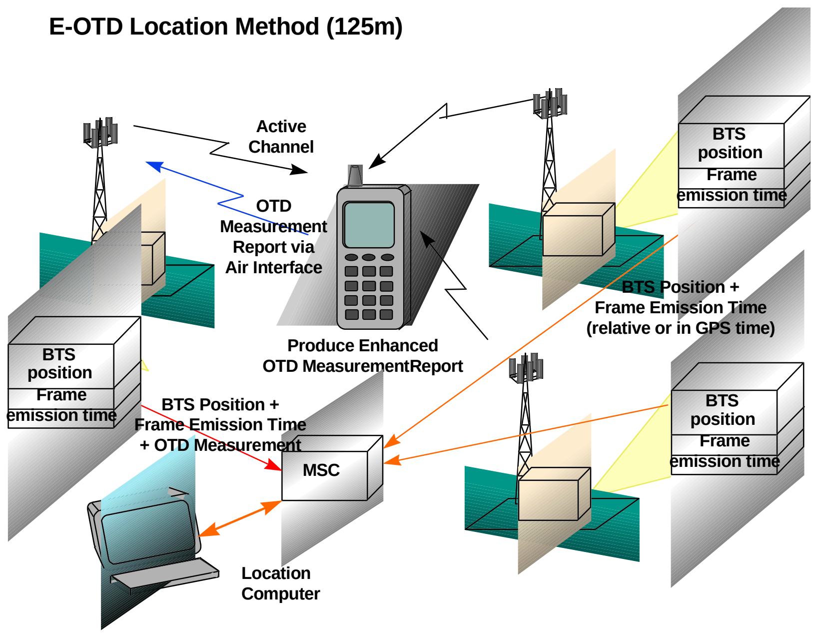


Figure 3.

For more information on the location application, please see Symmetricom's application note on "Sync for Location."

- T1/E1 span line connectivity from the BTS to the BSC/MSC is standard today, but a migration is expected away from traditional T1 or E1 span line connectivity to some other transport technology that does not allow a good frequency or time reference, such as ATM, backhaul radio, DSL, and ISDN. Each cell site will become its own synchronization island, with base stations losing traceability to a Stratum 1 reference (e.g. DCD-LPR equipment located at the MSC). New GSM base station designs have begun to include a GPS clock module like the Symmetricom TimeSource 1000 as standard equipment. As illustrated below, these new GSM base stations are guaranteed stable time (e.g., 1 pulse per second, GSM frame (120/26 ms) and GSM burst (15/26 ms)) plus stable frequency based upon a quality oscillator disciplined to GPS.

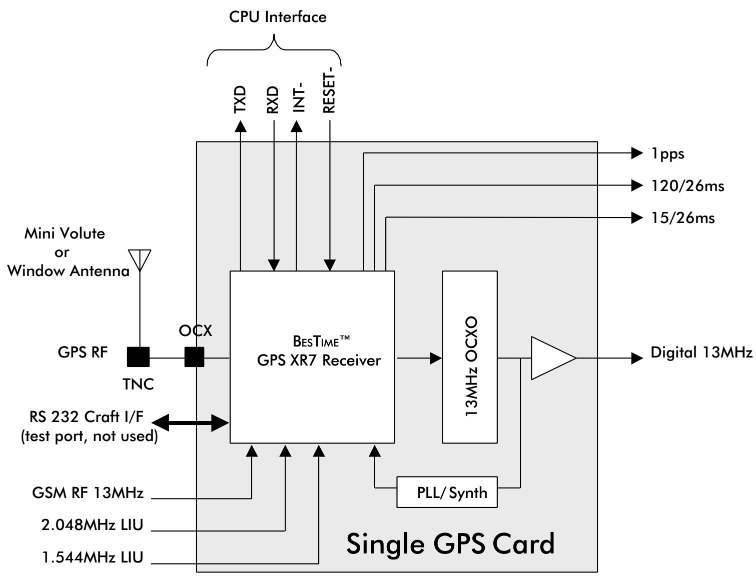
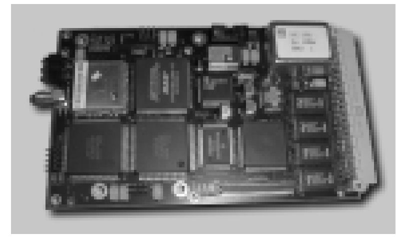


Figure 4.



Design Considerations for Next Generation Base Station Synchronization Modules

Current generation wireless base stations meet synchronization requirements through GPS clocks in the case of CDMA or Stratum 3E clocks in the case of GSM and TDMA. As new generation base stations are designed, product development engineers should keep in mind that T1/E1 network references may not be available, base stations may have to provide time and frequency for mobile handset location, and base station synchronization modules should provide compatibility with 3rd generation (3G) wireless interface requirements.

It is still unclear what technology the industry will settle on for 3G systems. North American manufacturers tend to line up behind CDMA innovator Qualcomm in supporting CDMA 2000. European GSM manufacturers tend to support the W-CDMA initiative led by Ericsson. The battles between W-CDMA and CDMA 2000 have been the focus of the debate, capturing most of the ink in the trade press. The “dark horse” in this battle is the UWC-136 standard promoted by manufacturers of TDMA equipment. Should CDMA 2000 win (likely within North America and Asia), base stations will require GPS clocks to support synchronization needs. The synchronization ramifications of the other two technologies is unclear; however, it is well understood that the better the time and frequency synchronization, the better frequency re-use and capacity optimization. Conclusion, GPS clocks within new base station designs is a safe bet.

Symmetricom recommends that base station designers consider the following when implementing new clock synchronization modules:

- clocks must be small in size and low in cost
- next generation GPS receiver solutions, such as Symmetricom's two-chip XR7 design, offer enhanced performance at acceptable installed costs
- ability to meet stringent time and frequency specifications by using high precision oscillator and GPS receiver designs
- optionally, use additional sources of time and frequency to either improve performance (e.g., holdover) or operate in locations where line of sight to GPS satellites is not always available
- ability to meet specifications with single oven quartz oscillator instead of double oven quartz oscillators or rubidium designs, substantially reducing oscillator costs
- base station synchronization systems should be designed for deployment in master-slave configuration, allowing slave stations to operate at peak performance even if line of sight to GPS is not available
- GPS clock subsystems should offer integrated synchronization MIB (management information base), allowing comprehensive monitoring and management
- simplified design that lets designers treat GPS clocks like other high end subsystems, such as microprocessors and digital signal processors-leading to "GPS everywhere" due to ease of integration and low cost

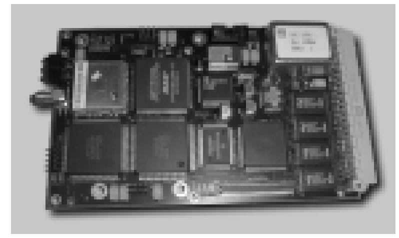
Summary

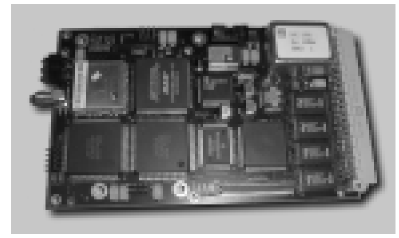
Currently, synchronization requirements for digital base stations are met by deploying GPS clocks in CDMA base stations and by using high precision oscillators that are free running or locked to a span line reference in GSM and TDMA base stations. Synchronization requirements will become more demanding because:

- GSM, CDMA and TDMA will migrate to a common "air interface" referred to as 3rd generation wireless.
- New services such as location of mobile handsets require precise time reference and even more stable frequency.
- Precise synchronization required "everywhere." A solution solely based upon GPS falls short, as some cell site locations will not offer economical line of site to the GPS satellite constellation.

- Use of all available time and frequency references allows enhanced performance and ubiquitous deployment. Innovative clock algorithms such as Symmetricom's BesTime allow ease of deployment and enhanced performance while meeting the stringent cost and environmental requirements of new base station solutions.
- As wireless backhaul technologies migrate away from traditional T1 and E1 span lines offering acceptable frequency references, cell sites will become timing islands. The best means of maintaining traceability to a Stratum 1 reference will be solutions that put GPS in the base station.

If you are searching for innovative synchronization solutions for new cellular or PCS/DCS base station designs, please give Symmetricom a call at one of the numbers below, or visit our web site at www.symmetricom.com.





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