Alcatel·Lucent

TECHNOLOGY WHITE PAPER

Synchronization in Microwave Networks

Network transformation, driven by IP services and Ethernet technologies, presents multiple challenges. Equally important to introducing a packet-transport solution in an SDH/SONET network is meeting TDM- or packet-based synchronization requirements. In mobile networks, 2G/3G/4G mobile technologies with multiple traffic types and synchronization requirements must find common ground for a cost-effective solution. Using a synchronization and timing-distribution strategy based on the interworking of IEEE 1588v2 and ITU-T Synchronous Ethernet, and ensuring synchronization continuity that leverages existing SDH/SONET networks, the Alcatel-Lucent 9500 MPR platform guarantees carrier-class transport while reducing the need for external synchronization sources. This paper explains the functionality and benefits of the synchronization technologies and describes how the Alcatel-Lucent 9500 MPR uses them in mobile backhaul networks.

Table of contents

1	**1. Introduction**
1	**2. Today's synchronization challenges: setting the scene**
3	2.1 Embedded Radio Link Synchronization
3	2.2 Synchronous Ethernet
3	2.3 IEEE 1588-2008 (1588v2)
3	2.4 E1/T1 PDH line clock
3	2.5 STM-1 SDH/SONET OC-3
3	2.6 BITS (sync-in/sync-out ports)
4	2.7 Clock recovery
4	**3. Synchronization with the Alcatel-Lucent 9500 MPR**
6	3.1 Clock-source selection
7	3.2 Synchronization in microwave applications
7	3.3 Synchronization in ring-network topologies
8	**4. Use cases**
8	4.1 Mobile backhauling
9	4.2 Vertical applications
9	4.3 Key benefits
10	**5. Conclusion**
10	**6. Acronyms**
11	**7. Contacts**
11	**8. References**
12	**9. Appendix A: Test bed for standard compliancy**
13	9.1 Test results
15	9.2 1588v2 tunneling transport and frequency synchronization test results

1. Introduction

Convergence toward a packet-transport network is widely discussed by mobile network operators, who are aiming to seamlessly carry their existing TDM traffic while scaling to handle higher capacities and new IP services and technologies, such as Long Term Evolution (LTE).

While targeting network transformation, most operators are focused on interoperability with the existing installed base.

The introduction of native IP/Ethernet base stations requires a new paradigm for timing distribution and synchronization. Industry-recognized ITU-T Synchronous Ethernet (SyncE) and IEEE 1588™ Version 2 (1588v2) Precision Time Protocol (PTP) work synergistically, with a high degree of accuracy, to address synchronization in packet networks.

Alcatel-Lucent Microwave Packet Radio platforms are designed to offer synchronization based on SyncE and 1588v2, complementing line-clock distribution to offer a flexible, high-performance solution that satisfies the most stringent synchronization requirements and is tailored for mobile applications.

Multiple advantages result from this implementation design:

- SyncE is indispensable for addressing native IP/Ethernet base stations to ensure their evolution to packet-transport backhaul networks.
- 1588v2 is delivered to obtain packet-based frequency synchronization as well as phase synchronization.
- Support of line-clock distribution ensures synchronization continuity, leveraging existing networks.

The Alcatel-Lucent 9500 Microwave Packet Radio (MPR) provides a unique solution for mobile backhaul, enabling transformation to all-IP traffic and supporting a mix of synchronization solutions to meet current mobile-access generations as well as future generations such as LTE.

2. Today's synchronization challenges: setting the scene

One of the challenges network operators face while approaching network convergence toward a Packet-Switched infrastructure is effective frequency and time distribution. The requirements for synchronization distribution vary because multiple services and applications coexist. In mobile backhaul networks, different technology generations — Second Generation (2G): TDM, Third Generation (3G): ATM/Ethernet, 4G (Fourth Generation): IP/Ethernet — are delivered over the same transport network.

While offering similar end-user services, these mobile technologies have different synchronization requirements. For example, time accuracy (phase) is required in CDMA, Universal Mobile Telecommunications System (UMTS) Time Division Duplex (TDD), LTE TDD, and WiMAX®, but it is not needed in Global System for Mobile Communications (GSM) or UMTS Frequency Division Duplex (FDD). A carrier-class backhaul network must be able to meet the synchronization requirements of all the services it supports, regardless of the technologies it uses to transport and deliver them. A variety of dedicated "network-clock" synchronization interfaces are defined in standards (see Table 1).

The emulation of TDM services, such as the transport of an E1/T1 TDM signal as a sequence of packets across a Packet-Switched network, requires the availability of synchronization in the network to recover the original TDM-flow frequency. "Service-clock" methods provide synchronization to a transport service of the packet network. Two of the typical methods employed for service-clock recovery are adaptive clock recovery (ACR) and differential clock recovery (DCR).

The relationship between network clocks and service clocks in a packet-based end-to-end network is shown in Figure 1. In this general case, synchronization is provided from a central controller to a remote base station. Because they are capable of transferring the network clock, the two devices at the border of the backhaul network are synchronized, and they implement an InterWorking Function (IWF) to convert/recover a TDM flow to/from an emulated circuit.

Figure 1. Alcatel-Lucent 9500 MPR deployment in end-to-end networks

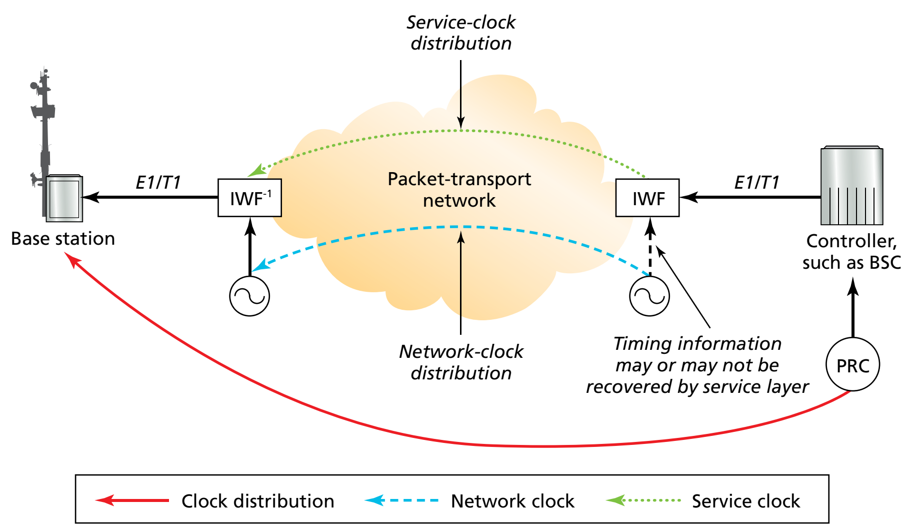


Table 1 lists the synchronization technologies and interfaces discussed in this paper and their relevant fields of application.

Table 1. Synchronization technologies and interfaces

	PHYSICAL LAYER	PACKET LAYER
Network clock at UNI/NNI	SyncE, E1/T1 PDH, STM-1, SDH/OC-3 SONET, embedded radio link synchronization	IEEE 1588v2 (PTP)
Network clock at dedicated synchronization interfaces	BITS (2.048, 5, 10 MHz)	
Service clock	Node retiming	ACR, DCR

BITS building integrated timing source
SDH Synchronous Digital Hierarchy
NNI network-to-network interface
STM Synchronous Transport Mode
PDH Plesiochronous Digital Hierarchy
UN user network interface

2.1 Embedded Radio Link Synchronization

At the core of the 9500 packet radio technology is an inherent ability to transport a synchronization signal across the radio link. This is referred to as “symbol rate” and allows a pair of 9500 MPR devices to relay a network clock reference from one site over a microwave link to another site. While this capability is available in traditional SDH and SONET based microwave products, it is rare in Packet Radio devices and is a key strength of the 9500 MPR.

This capability allows for an extremely reliable end to end synchronization distribution plan. This functionality interoperates with the Synchronous Ethernet, T1/E1, OC3/STM1, and BITS synchronization interfaces described below.

2.2 Synchronous Ethernet

ITU-T SyncE technology is designed to distribute a reference frequency on the physical layer of an IEEE 802.3™ network. Built using the foundation provided by SDH/SONET synchronization, SyncE delivers the same level of performance, allowing the seamless introduction of an element in an existing SDH/SONET network. SyncE and SDH/SONET must connect all nodes in a timing domain that relies on a physical-layer synchronization technology.

2.3 IEEE 1588-2008 (1588v2)

IEEE 1588-2008, also known as “1588v2” or “PTPv2”, is a protocol designed to distribute time and/or frequency across networks. Unlike SyncE, which is a physical-layer technology, IEEE1588v2 is a packet-layer technology, so it can work across a network that includes nodes that do not directly support the technology. This specific functionality makes it easier to introduce IEEE 1588v2 in existing networks, including hybrid deployments.

Because IEEE 1588v2 is a packet-layer technology, it may be subject to performance impairments that are caused by packet queuing and scheduling delays due to congestion in the packet network. IEEE 1588v2’s On Path Support (OPS) mechanisms (transparent-clock and boundary-clock capability) compensate for these effects so that the protocol can provide the accuracy and precision required for even the most demanding telecommunications-network applications. Another means of mitigating these possible effects and improving performance is to use IEEE 1588v2 together with SyncE and/or SDH/SONET.

2.4 E1/T1 PDH line clock

Any E1/T1 signal available at an input traffic interface can be selected as the synchronization source to derive the network clock.

2.5 STM-1 SDH/SONET OC-3

An STM-1 SDH or SONET OC-3 line signal can be selected as the network-clock source.

2.6 BITS (sync-in/sync-out ports)

Sync-in/sync-out ports can be used to accept external synchronization sources and therefore also provide a synchronization waveform signal to another part of the network. The common network clock is transferred to the downstream network nodes through the radio links that connect them. Timing is transferred at the radio physical layer to guarantee immunity to Packet Delay Variation (PDV).

2.7 Clock recovery

Three possible techniques can be implemented on a Circuit Emulation Service (CES) to recover synchronization at the packet layer:

- *Adaptive clock recovery* – ACR is used when there is no common reference clock among the network elements. The main tasks of the ACR algorithm are to filter out irregularities in the packet delay of frames crossing the network and to recover a stable clock source.
- *Differential clock recovery* – DCR uses timestamps in packets and a common reference-clock frequency, making the recovered signals less subject to impairments due to PDV in the packet network. The common reference-clock frequency for DCR can be delivered by IEEE 1588v2, or by a physical-layer technology such as SyncE or radio carrier.
- *Retiming or node timing* – This technique takes one incoming E1/T1 signal as the reference and performs retiming of all other E1/T1 signals in the node. All E1/T1 signals in the node are synchronous with each other.

3. Synchronization with the Alcatel-Lucent 9500 MPR

The Alcatel-Lucent 9500 MPR product family supports a full range of local and end-to-end network-synchronization solutions for a wide variety of applications. Regardless of the technology used as the synchronization source, synchronization at far end of the network can be delivered using any of the ingress/egress options.

At the first node of a microwave network, the clock can be locked to any one of the following sources:

- SyncE
- E1/T1 line clock from any input interface
- STM-1 SDH/SONET OC-3 line clock
- Dedicated sync-in port for a waveform frequency signal at 2.048, 5 or 10 MHz

The embedded radio link synchronization can then relay the clock information across the air interface(s) to the end of the microwave network.

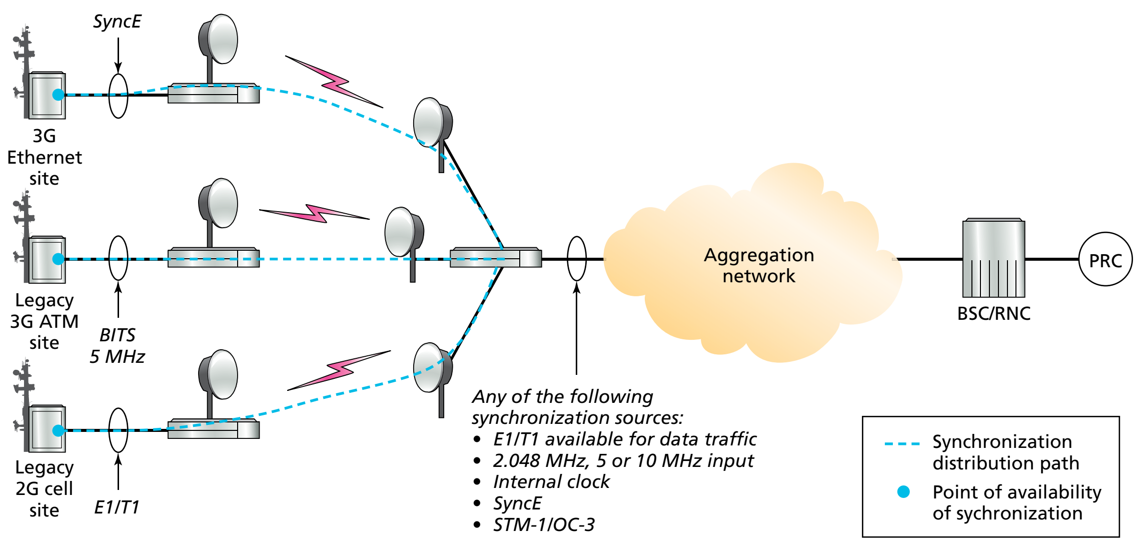
At the egress of the microwave network, synchronization is made available using any one of the following sources:

- SyncE
- E1/T1 line clock from any output interface
- STM-1 SDH/SONET OC-3 line clock
- Dedicated sync-out port for a waveform frequency signal at 2.048, 5 or 10 MHz

A feature of the Alcatel-Lucent 9500 MPR is that the clock source derived from the aggregation and the clock signal provided to a base station do not have to be the same. As an example, the network clock at the ingress could be SyncE, transported over the microwave network and delivered through the line-clock E1 interface at the egress.

Furthermore, the synchronization methods used across a microwave access networks can be flexibly mixed, as the next picture suggests.

Figure 2. Alcatel-Lucent 9500 MPR deployment in mobile backhauling

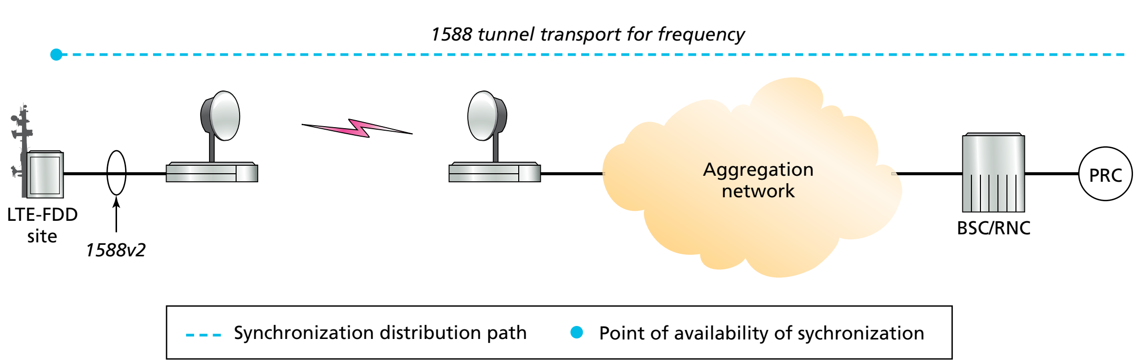


On the radio channel, the Alcatel-Lucent 9500 MPR transfers the reference clock to an adjacent Alcatel-Lucent 9500 MPR device using the radio-carrier frequency at the physical layer. This method offers two main advantages:

- No bandwidth consumed for synchronization distribution
- Total immunity to the network load

As shown in Figure 3, the Alcatel-Lucent 9500 MPR transparently carries IEEE 1588v2 across the microwave network, supporting end-to-end scenarios where frequency synchronization is requested.

Figure 3. Alcatel-Lucent 9500 MPR deployment in mobile backhauling



9500 MPR supports an optimed transport of 1588v2 frames to provide frequency synchronization, suitable for LTE-FDD, through a feature called tunnel transport. For a detailed description of this feature and test results, please refer to paragraph 9.2.

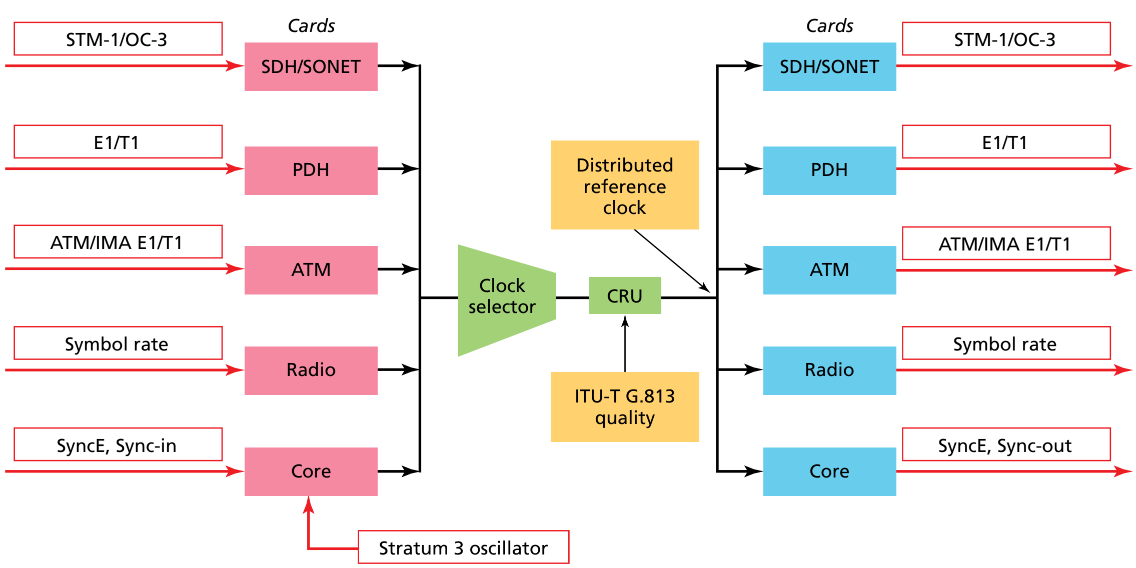
The Alcatel-Lucent 9500 MPR can be deployed in a mixed-technology network such as 2G, 3G and/or 4G, connecting to base stations using their native-interface E1/T1 PDH, E1/T1 ATM or Ethernet links. Depending on the adopted transport network, hybrid- or packet-mode synchronization solutions can be used:

- *Hybrid mode* – TDM, ATM and Ethernet services are delivered at the handoff point to the metro network in their native format. Synchronization is delivered using any of the synchronization formats.
- *Packet mode* – TDM, ATM and Ethernet services are delivered at the handoff point to the metro network as Ethernet aggregated streams using Ethernet or Multi-Protocol Label Switching (MPLS) — for example, Ethernet Line (E-Line) services or pseudowires. Synchronization at the metro site is SyncE and is delivered to different base stations in the most convenient format (SyncE, line clock, or sync-in/sync-out ports). 1588v2 can also be employed.

3.1 Clock-source selection

The Alcatel-Lucent 9500 MPR has an embedded reference clock that is distributed to each board of the network element. The clock is generated in the clock reference unit (CRU) of the core card (controller), as shown in Figure 4.

Figure 4. Clock-source selection and distribution



3.2 Synchronization in microwave applications

A key differentiator of the Alcatel-Lucent 9500 MPR is its support of multiple applications, all available through the same set of common elements in the Alcatel-Lucent 9500 MPR portfolio.

Table 2 highlights the supported applications and outlines how synchronization is obtained from an aggregation network and provided to a mobile base station: Base Transceiver Station (BTS), NodeB, or enhanced NodeB.

Table 2. Applications supported by the Alcatel-Lucent 9500 MPR

APPLICATION	ALCATEL-LUCENT 9500 MPR CONFIGURATION	TYPICAL DEPLOYMENT	SYNCHRONIZATION
Split-mount/ full indoor Point-to-point	IDU and ODU	Alcatel-Lucent 9500 MPR is deployed at the cell site, as the tail of a microwave distribution tree	• Modem board recovers the radio symbol rate (locks to the same frequency as the TX side) • CRU provides the clock to the selected output board • Depending on the specific case, synchronization is transferred using one of the available methods, such as E1/T1, SyncE, or 2 MHz signal
Split-mount/ full indoor Nodal	IDU and several ODUs	Alcatel-Lucent 9500 MPR is at a hub site: • Grooms several access radio directions • Hands them off to the aggregation network (using a microwave or wireline connection)	General split-mount case: • Synchronization is derived from the aggregation (for example, SyncE or line clock) • Synchronization is delivered to tail systems using the radio symbol rate
Full outdoor	• No IDU is present • Alcatel-Lucent 9500 MPR-e (stand-alone unit) directly connects to an Ethernet-based base station • Alternatively, Alcatel-Lucent 9500 MPR-e can connect to a CPE or transport-network equipment	Alcatel-Lucent 9500 MPR-e is deployed at the cell site, as the tail of a microwave distribution tree	• Modem board recovers the radio symbol rate (locks to the same frequency as the TX side) • Frequency is provided to the base station or any network equipment using a standard GigE connection (optical or electrical) that provides SyncE

CPE customer premises equipment GigE Gigabit Ethernet IDU Indoor Unit ODU Outdoor Unit TX transmit

3.3 Synchronization in ring-network topologies

The propagation of synchronization in ring networks poses the challenge of selecting the most appropriate path from the reference timing source to the network element to be synchronized.

To cope with this, both Ethernet [8] and SDH [10] technologies define a Synchronization Status Message (SSM) to carry information over the selected ring direction to all nodes in the ring.

The Alcatel-Lucent 9500 MPR supports SSM handling in both microwave applications that are suitable for ring or meshed networks, as listed in the Table 3.

Table 3. Synchronization over rings

APPLICATION	ALCATEL-LUCENT 9500 MPR CONFIGURATION	SSM HANDLING
Split-mount/ full indoor	IDU and two ODUs	• IDU selects the direction of the ring associated with the synchronization trail, based on the distribution of the most accurate timing source • Should status change — for example, as the result of a line interruption or failure — an SSM message containing a reference-clock variation is received from the standby synchronization direction • Accordingly, CRU selects the new port as the synchronization source
Full outdoor	• No IDU is present • Two Alcatel-Lucent 9500 MPR-e (standalone) units connect to networking gear	• Same behavior as above • Only difference is that the network equipment takes care of selecting the most appropriate ring direction

4. Use cases

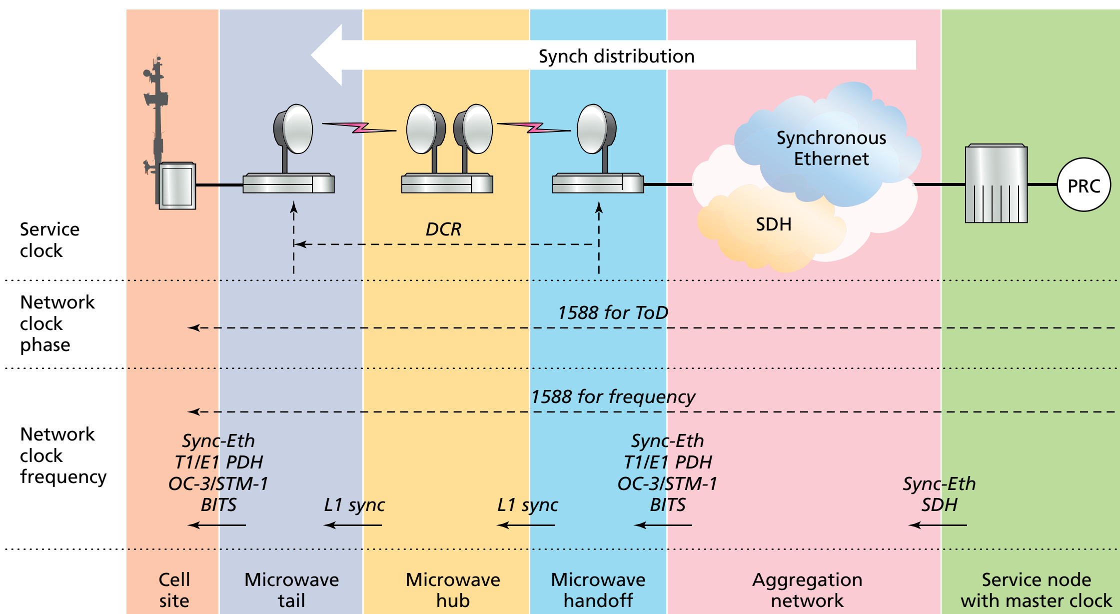
This section presents two synchronization-distribution use cases: mobile backhauling and vertical applications. Most of the technical discussion covers mobile backhauling, the most important application for microwave. A short use case addresses the emergence of a demand for microwave in strategic markets.

4.1 Mobile backhauling

The most common scenario is characterized by the availability of a time source at the ingress of the microwave backhaul network, derived from the primary reference clock (PRC). Synchronization (frequency) is delivered to the cell-site SyncE, 1588v2, E1/T1 line clock, SDH line clock or sync-in/sync-out ports. If time of day (ToD) is required, such as for LTE TDD, IEEE 1588v2 is adequately serviced by the Alcatel-Lucent 9500 MPR, guaranteeing the support for the appropriate service level.

Figure 5 shows the distribution flow of synchronization in a typical microwave network.

Figure 5. Service clock locked to the network clock



At the handoff site, the microwave equipment can connect to a SyncE or SDH-synchronized network. A key advantage of the Alcatel-Lucent 9500 MPR is its capability of connecting to a full ITU-T G.803 [11] synchronized chain, carrying synchronization inbound from the radio channel to the microwave network tails and regenerating the SDH or SyncE signal toward the base stations. Configuration of the synchronization source to be delivered to cell sites is dictated by the site connectivity. Any of the available options can be made available regardless of the synchronization-source type.

The emulated services all derive their synchronization information from the network clock, as shown in Figure 5. The service clock is therefore perfectly aligned with the network clock and provides maximum precision for recovery of the original stream at the egress of the backhaul network. Each E1/T1 circuit can recover a clock independently from the others, maintaining synchronicity with the native stream.

Either 2G/3G Ethernet base stations and LTE eNodeBs can also be synchronized in frequency through 1588v2. As already mentioned, 9500 MPR implements the "tunneling transport" feature through which 1588 frames are carried across a microwave network as guaranteed traffic so that the typical synchronization mask of 16 ppb is respected. Please refer to paragraph 9.2 for more details.

4.1.1 Alcatel-Lucent 9500 MPR-e standalone full-outdoor scenario

Figure 4 shows a general case, with tail systems still formed by an IDU and ODU. The Alcatel-Lucent 9500 MPR product family also supports a new full-outdoor scenario, suitable for pure Ethernet backhaul with 2G/3G BTSs that have already migrated to Ethernet or LTE Evolved Node Bs (eNodeBs).

In this new scenario, the Alcatel-Lucent 9500 MPR-e — the standalone, full-outdoor Ethernet version of the Alcatel-Lucent 9500 MPR — connects to a base station through a standard Ethernet cable. The connection between the Alcatel-Lucent 9500 MPR-e and the base station has electrical and optical options:

- *GigE optical connection* – An optical cable for data transport and a coaxial cable for power, with lightning protection, are used to interconnect the Alcatel-Lucent 9500 MPR-e with the local terminal site. These cables are bound into a single cable cover to have a single run for deployment. This configuration enables bidirectional distribution of a SyncE signal. (The TX/receive (RX) directions on each side can
- *GigE electrical connection* – A standard copper cable (shielded Cat-5) is used for both data transport and Power over Ethernet (PoE[1]) feed. The cable is provided with lightning protection. While some implementations of SyncE over copper have restrictions on the direction of synchronization flow, the 9500 MPR-e allows for bidirectional SyncE over copper.[2]

If the Alcatel-Lucent 9500 MPR-e is connected to transport-network equipment rather than a base station, the same previously described synchronization solution is applicable.

For a valuable reference to interworking scenarios, see [17].

4.2 Vertical applications

Some applications require clocking with stringent accuracy. One example is a rail operator that is looking to migrate its GSM – Railway (GSM-R) network infrastructure from SDH to IP/Ethernet transport. To enable the rapid migration of these networks, SyncE — and IEEE 1588v2 in some cases — may be an easy, quick way to achieve frequency synchronization for the internal communications network, allowing the benefits of Ethernet transport without changing the TDM voice application.

Traditionally supported on an SDH network, GSM-R is a secure platform for voice and data communications between railway operational staff. GSM-R base stations need to be fed with the synchronization of E1 circuits. The Alcatel-Lucent 9500 MPR is ideal for supporting the continuity of frequency distribution when moving from SDH to SyncE aggregation because the variation of ingress synchronization is handled using a pure configuration command.

4.3 Key benefits

Network operators can experience a range of benefits from the synchronization capabilities of the Alcatel-Lucent 9500 MPR:

- E1/T1, STM-1 SDH/SONET OC-3, BITS, SyncE and 1588v2 provide a highly reliable, carrier-class solution for frequency distribution on the physical layer to support specific network needs, especially in mixed networks — for example, a mobile network with 2G, 3G and LTE requirements.

[1] The reference standard is Power over Ethernet as defined in IEEE 802.3 at [18]. The MPR-e full outdoor solution uses an adaptation of the standard (PFoE) to increase the radio system gain.

[2] Standard SyncE over electrical Ethernet is mono-directional. This comes from auto-negotiation that imposes knowledge of which side is the master clock. As a result, the two TXs on each side are associated: they need to know which is the master. Alcatel-Lucent 9500 MPR supports bidirectional SyncE over copper, so that synchronization can be distributed in both directions.

- SyncE and 1588v2 enable a smooth evolution and transition toward an evolved, packet-based network, ready to support the introduction of LTE with improved network maintainability and reduced operational costs.

5. Conclusion

The trend of network transformation to packet-based network infrastructures has not eliminated the need for or importance of synchronization in networks. Instead, new challenges and requirements for tools and technology have emerged. The fundamental target remains the same: to provide efficient technology to enable operators to develop their networks according to their preferred pace and direction.

Alcatel-Lucent Microwave Packet Radio platforms embody synchronization technologies in an integrated solution, allowing easy network transformation from TDM to the packet world and synchronization continuity as the network evolves. The support of standard clock-reference distribution methods and the use of market-recognized leading solutions such as SyncE guarantee flexibility in network design and definition of the best strategy for operators moving toward all-IP backhauling.

6. Acronyms

9500 MPR	Alcatel-Lucent 9500 Microwave Packet Radio
2G, 3G, 4G	Second Generation, Third Generation, Fourth Generation
ACR	adaptive clock recovery
ATM	Asynchronous Transfer Mode
BITS	building integrated time source
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CES	Circuit Emulation Service
CPE	customer premises equipment
CRU	clock reference unit
DCR	differential clock recovery
E-Line	Ethernet Line
E1	E-carrier system
eNodeB	Evolved Node B
FDD	Frequency Division Duplex
GigE	Gigabit Ethernet
GPS	global positioning system
GSM	Global System for Mobile Communications
GSM-R	GSM - Railway
IDU	Indoor Unit
IEEE	Institute of Electrical and Electronics Engineers
IMA	Inverse Multiplexing over ATM
IP	Internet Protocol
ITU-T	International Telecommunication Union – Telecommunication Standard
IWF	InterWorking Function
LTE	Long Term Evolution
MPLS	Multi-Protocol Label Switching
NNI	network to network interface
NTP	Network Time Protocol
ODU	Outdoor Unit
PDH	Plesiochronous Digital Hierarchy
PDV	Packet Delay Variation
PoE	Power over Ethernet
PRC	primary reference clock
PSN	Packet Switched Network
PTP	Precision Time Protocol (IEEE 1588v2)
RNC	Radio Network Controller
RX	receive
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SONET	Synchronous Optical Network
SSM	Synchronous Status Message
STM-1	Synchronous Transport Mode 1
SyncE	Synchronous Ethernet
T1	T-carrier system
TDD	Time Division Duplex
TDM	Time Division Multiplexing
ToD	time of day
TX	transmit
UMTS	Universal Mobile Telecommunications System
UNI	user network interface
WiMAX®	Worldwide Interoperability for Microwave Access (IEEE 802.16 http:// www.wimaxforum.org

7. Contacts

For more information about Alcatel-Lucent 9500 MPR solutions, please visit www.alcatel-lucent.com or contact your Customer Team representative.

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18. IEEE 802.3 at (2009) "Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications – Amendment 3: Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements"

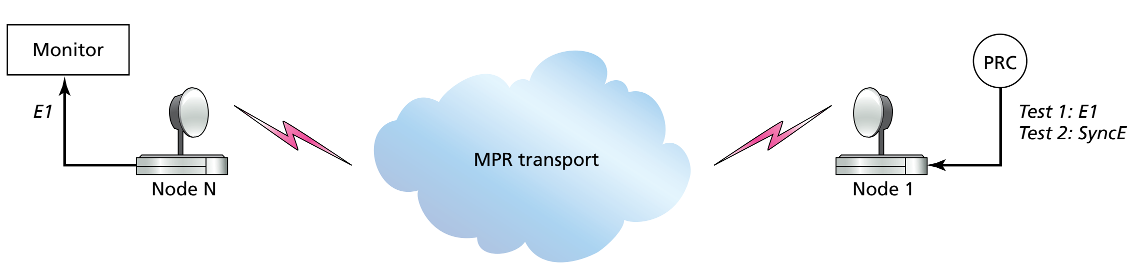
9. Appendix A: Test bed for standard compliancy

ITU-T recommendations define a "reasonable worst-case" network scenario [15, Annex A] to measure the quality of the distributed synchronization. Specifically, ITU-T G.823 [15], ITU-T G.825 [16] and ITUT G.803 [11] define the network limit to be compliant with when measuring synchronization quality: the limit is one PRC (defined in ITU-T G.811 [12]) followed by 20 network-element clocks (compliant with ITU-T G.813 [14]). Figure 6 and Figure 7 are high-level representations of the test bed as defined by these recommendations.

Test set 1 measured synchronization quality using compliance of an E1 data line to the mask at the network egress, as shown in Figure 6. Two cases were tested:

1. An E1 data line was used to carry synchronization at the network ingress.
2. The test was repeated with SyncE.

Figure 6. Test set 1: synchronization measurement for an egress E1 data line, N = 20



Test set 2 was defined to measure the quality of synchronization using STM-1 SDH at the ingress and egress of the test bed, as shown in Figure 7.

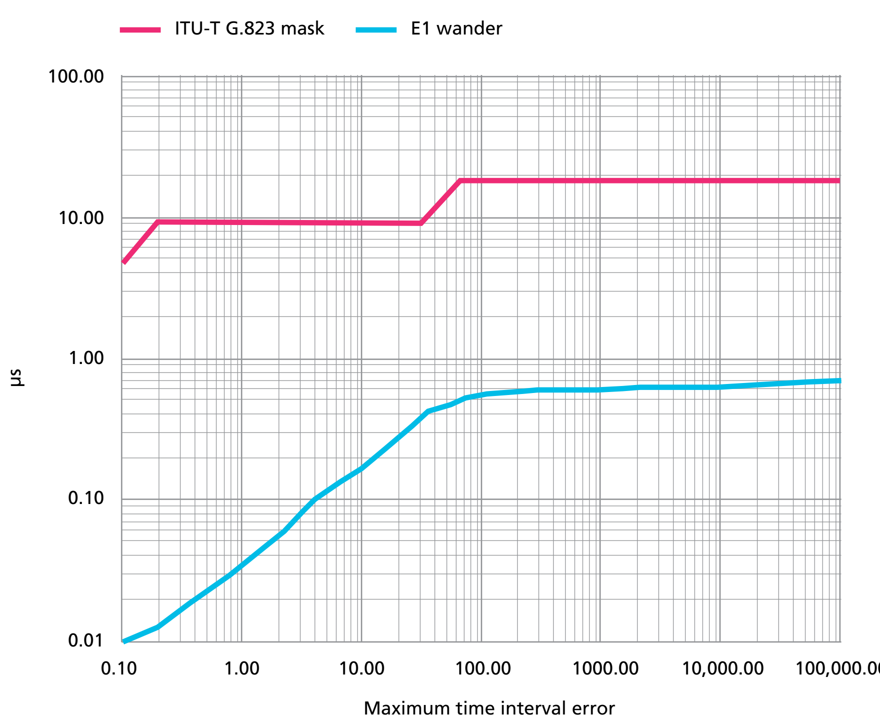
Figure 7. Test set 2: synchronization measurement for STM-1, N = 20

9.1 Test results

Under the three test-case conditions, the synchronization methods supported by the Alcatel-Lucent 9500 MPR yielded the following test results.

- Case 1 (Figure 8):
  - ¬ Ingress: E1 PDH
  - ¬ Egress: E1 PDH
  - ¬ Reference standard: [15]

Figure 8. Case 1: E1 PDH MTIE performance over the Alcatel-Lucent 9500 MPR



- Case 2 (Figure 9 and Figure 10):
  ¬ Ingress: SyncE
  ¬ Egress: E1 PDH
  ¬ Reference standards: [15] for equipment clock, [16] for transport of synchronization in networks

Figure 9. Case 2a: E1 PDH MTIE conformance to ITU-T G.813 (SyncE synchronization ingress)

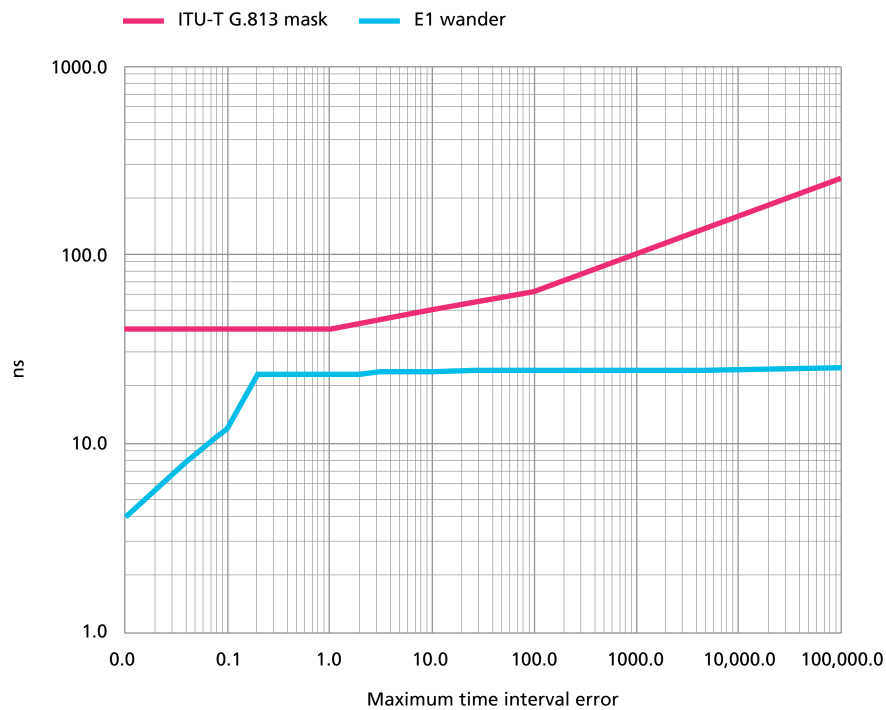
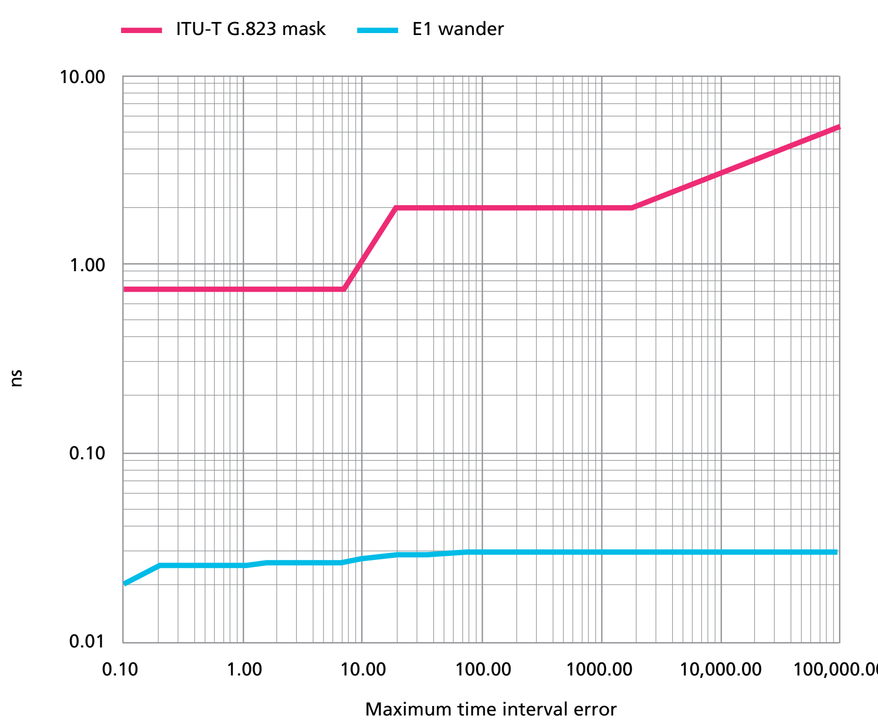
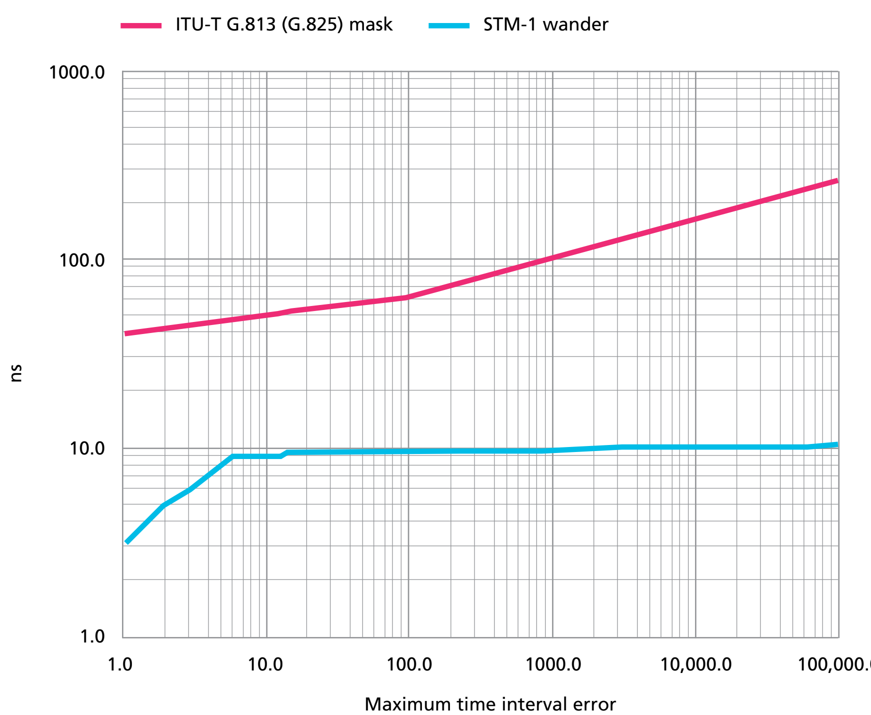


Figure 10. Case 2a: E1 PDH MTIE conformance to ITU-T G.823 (SyncE synchronization ingress)



- Case 3 (Figure 11):
  - ¬ Ingress: STM-1 SDH
  - ¬ Egress: STM-1 SDH
  - ¬ Reference standard: as specified in [16]; SDH clock conforms to [14]

Figure 11. Case 3: STM-1 SDH MTIE performance over the Alcatel-Lucent 9500 MPR



9.2 1588v2 tunneling transport and frequency synchronization test results

The tunneling transport is a feature of 9500 MPR through which 1588v2 frames are carried across a microwave network as guaranteed traffic. This way 1588v2 performance is guaranteed and respects the typical synchronization mask of 16 ppb.

The tunneling is based on the established and patented fragmentation and interleaving techniques used by 9500 MPR over the microwave links. These mechanisms provide a deterministic delay and, most important for the handling of 1588v2 packets, packet delay variation. This is extremely important with 1588v2 slaves that need to have consistent network delay of 1588v2 frames to derive their synchronization.

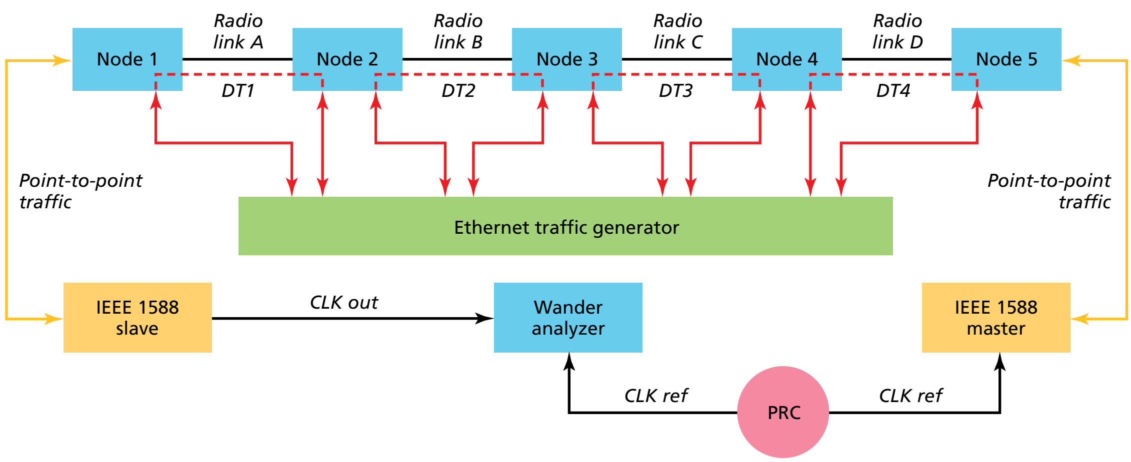
The purpose of the following test cases is to measure the clock quality recovered by an IEEE1588v2 slave equipment placed at the end of a microwave chain composed of five 9500 MPR nodes (four hops).

As shown by the test bench schematics, an IEEE1588 master is locked to an external clock reference and connected to Node5. The IEEE1588 slave is connected to Node1. PTP Traffic passes through all nodes in order to deliver the frequency reference from master to slave.

A bidirectional Disturbance Traffic (DT) is injected on each node (hop-by-hop insertion according to ITU-T G.8261). According to the specific test case condition, the Disturbance Traffic is composed by a different mix of either Low Priority and High Priority (HP) traffics. The test case shown here consider a Disturbance Traffic of 101%, with 10% of High Priority traffic, in order to take into consideration the effect of a VoIP-like traffic sharing the same queue of 1588 flow.

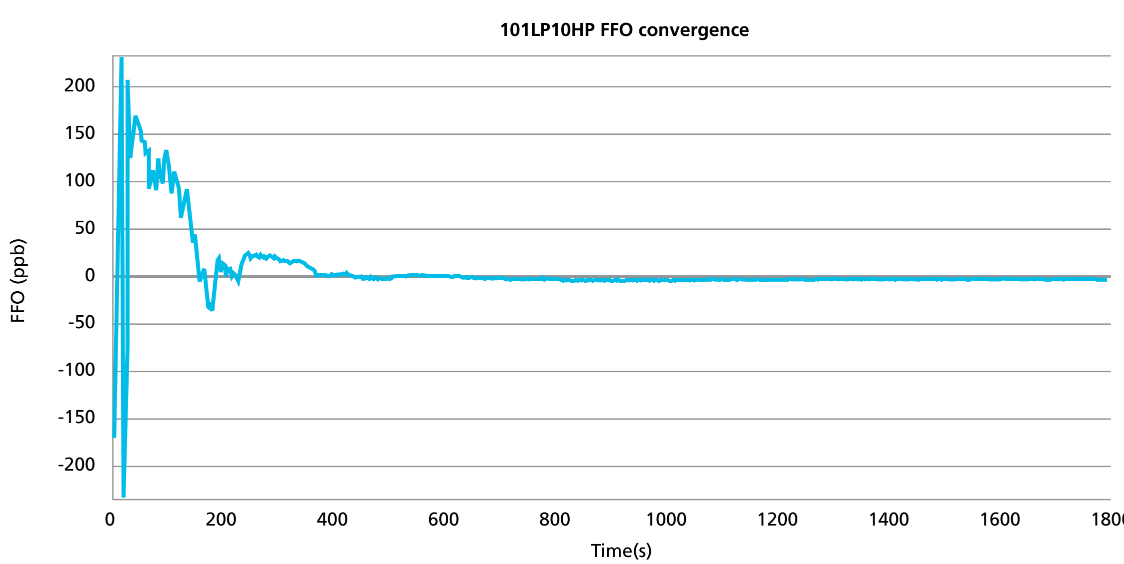
Considering the physical Synchronization configuration, Node1 is in Freerun and delivers its reference clock through the radio link to Node2. Node2 and all the other nodes are locked to the clock coming from radio. As a consequence, all the topology is locked to the clock of Node1.

Figure 12. 1588v2 test bench



The test result, expressed as Fractional Frequency Offset, is shown in the next picture.

Figure 13. Frequency convergence



Slave equipment has been configured as "Frequency Only" tracking type optimized for Frequency recovery.

In all test cases the recovered clock has a Fractional Frequency Offset in the range of ±2ppb This value meets the frequency accuracy of 16ppb required by mobile access applications for frequency synchronization purposes.

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