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（出國類別：研習）

研習 GPS 載波相位與衛星雙向傳時相關技術

服務機關：中華電信研究所

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摘要

IGS (International GPS Service) Analysis Center Workshop 為一國際知名之 GPS/GLONASS 相關應用之會議，主題含蓋甚廣，包括：GPS 在地理量測、地震監測等應用，除此之外，本次會議尚包含了一個重要的研討會，即 IGS/BIPM Timing Pilot Project Workshop，會中主要探討有關藉由觀測 GPS 電碼及載波相位(Code & Carrier Phase)達成高精度國際性時頻比對。事實上，參加此次會議，主要是能夠了解到世界各國在時頻領域最為主流之研究成果，同時藉此機會讓與會專家學者了解到本所標頻實驗室的研發進展。

有關衛星雙向傳時技術工作小組（TWSTT working group）會議，此次是於國際度量衡局召開，TWSTT working group 是附屬在 CCTF 下的一個工作小組，衛星雙向傳時技術工作小組之主要任務為協助建立日常比對之雙向傳時實驗及其性能評估。此小組之成員為標準時間實驗室之專家及製造商代表，其開會期間為每年一次，但可依需要而增加開會次數。此次參加會議共有十數個實驗室參加。

BNM_LPTF 位於法國巴黎，為世界上相當知名的研究機構，其中時頻部門的研發成果，更是獨步全球，其中最為著名者為研發出世界首座之噴泉式銫原子鐘，並且計劃將體積更為輕巧之噴泉式銫原子鐘放至外太空，其頻率穩定度之理論推理值可達10^{-17}，堪稱世界之最。參觀 BNM _LPTF 在巴黎之實驗室，主要是觀摩其在 GPS 載波相位時間傳送之研究進展，進而吸取其研究經驗，再者，親眼目睹其所研發之噴泉式銫原子鐘，除了讓自己大開眼界之外，對於其研發環境之架構，以及研發信念，適足以成為我們的表率。

目錄

一、目的

本所時間與頻率國家標準實驗室接受經濟部標準檢驗局委託，負責建立及維持我國時間與頻率國家標準。目前我國及世界各國之時頻實驗室均採用 GPS 共同觀測法(GPS Common-View)，將時間及頻率追溯至國際度量衡局(BIPM)，其一天之時間穩定度可達十數個奈秒(ns)，為了要將時間追溯穩定度大幅度提昇至數個奈秒，甚至一個奈秒以內，世界個知名時頻時驗室均致力於利用觀測 GPS 載波相位(GPS Carrier Phase)達成高精度之時間傳送，因此，IGS 和 BIPM 共同成立了一個 Workshop，名為 IGS/BIPM Pilot Project，以幾乎每年開會一次的方式，讓與會專家學者展現成果及交換研發心得。由於本計劃亦極力從事於利用觀測 GPS 載波相位(GPS Carrier Phase)，在高精度時頻傳送與同步之應用，因此，於 1998 年亦加入了此先鋒計劃。參加此次的會議，除了將本實驗室近幾年來，在 GPS 載波相位時頻應用的研究成果展現於世界舞台之外，並且能觀摩學習世界最為主流的先進技術，對於日後本實驗室在 GPS 時頻應用領域的研究，有著莫大的幫助。

有關衛星雙向傳時技術工作小組（TWSTT working group）會議，此次是於國際度量衡局召開，TWSTT working group 是附屬在 CCTF 下的一個工作小組，衛星雙向傳時技術工作小組之主要任務為協助建立日常比對之雙向傳時實驗及其性能評估(To assist in the establishment of regular two-way experiments and their evaluation)。此小組之成員為標準時間實驗室之專家及製造商代表，其開會期間為每年一次，但可依需要而增加開會次數。此次參加會議共有十數個實驗室參加，名單如附錄二。

BNM_LPTF 位於法國巴黎，為世界上相當知名的研究機構，其中時頻部門的研發成果，更是獨步全球，其中最為著名者為研發出世界首座之噴泉式銫原子鐘，並且計劃將體積更為輕巧之噴泉式銫原子鐘放至外太空，其頻率穩定度之理論推理值可達10^{-17}，堪稱世界之最。參觀 BNM _LPTF 在巴黎之實驗室，主要是觀摩其在 GPS 國際時頻

比對的進展。近幾年來，BNM _LPTF 在巴黎之實驗室對於 GPS 電碼及載波相位在時頻方面的應用，有著卓越的成果，尤其是在載波相位時間傳送方面，無論是在硬體的架構，以及在軟體的開發，均相當卓越，值得我們效法。

二、過程

本案係依據 89 年度標準檢驗局委託中華電信研究所之『建立及維持我國時間與頻率國家標準』計畫執行，並奉中華電信股份有限公司同意准予出國。參加此次會議之行程如下：

9 月 23 日~ 9 月 24 日：啟程搭乘長榮班機由中正機場飛抵華盛頓。(台北→舊金山→華盛頓)

9 月 25 日~ 10 月 29 日：參加 IGS (International GPS Service) Analysis Center Workshop 國際技術會議。(華盛頓)

10 月 01 日~ 10 月 03 日：前往美國海軍時頻實驗室參觀與見習。(華盛頓)

10 月 04 日：搭乘法航班機由華盛頓飛抵法國巴黎。(華盛頓→法國巴黎)

10 月 05 日~ 10 月 10 日：參加衛星雙向傳時技術工作小組(TWSTT working group）會議暨赴 BNM_LPTF 位於法國巴黎之時頻實驗室見習。(巴黎)

10 月 11 日~ 10 月 12 日：由法國巴黎途經阿母斯特丹搭乘長榮航空回程，於下午 10 月 12 日抵達中正機場。(法國巴黎→阿母斯特丹→台北)

三、會議議程及概況

本次出國前往美國華盛頓及法國巴黎主要參加二個時頻相關之國際技術會議，分別為於美國海軍(USNO)舉辦之 IGS (International GPS Service) Analysis Center Workshop，以及於國際度量衡局(BIPM)所召開之衛星雙向傳時技術工作小組（TWSTT working group）會議，並且於參加衛星雙向傳時技術工作小組會議之後，前往知名之 BNM_LPTF 位於法國巴黎之時頻實驗室觀摩，洽談有關日後是否有機會進行國際性長基線時頻比對實驗。

IGS Analysis Center Workshop

首先登場者為 IGS Analysis Center Workshop 國際技術會議，於 9 月 25 日舉行，為期 5 天。參加此會議之主要目的在於了解目前國際上有關於 GPS 相關應用之發展近況，尤其是有關時頻領域之應用。事實上，本次會議議程之前 3 天為 IGS/BIPM Time Pilot Project Workshop，也是我們此次與會之重頭戲。主要在於本實驗室亦為此工作小組的會員之一，而且近年來標頻實驗室，對於 GPS 在時頻應用之研究，諸如：GPS 共同觀測法(GPS Common View)、GPS 載波相位在時間與頻率比對和同步之應用，已有顯著的成果。因此，藉此大好機會不但能夠和與會專家學者交換心得，吸取寶貴之經驗外，也能夠將本所前瞻標頻實驗室之研發成果展現於世人眼前。

除了 IGS/BIPM Time Pilot Project Workshop 主要探討有關時間與頻率之應用外，IGS Analysis Center Workshop 仍有相當多之主題值得觀摩學習，包括：GPS 在地理量測、地震監測等應用，尤其和本實驗室目前正在積極架設之最高精度地理座標相關之主題。茲將 IGS/BIPM Time Pilot Workshop 之重要主題條列於后，至於 IGS Analysis Center Workshop 之議程與重要主題，則如附錄一。

IGS/BIPM Timing Pilot Project Workshop

Data Analysis Issures

- IGS clock combination
- Prediction of satellite clocks
- Developing an IGS clock alignment strategy using an integrated IGS frequency scale
- Use of IGS products for TAI calculation

Instrumental Calibration Issues

- Introduction to calibration issues
- Hardware calibration studies -- absolute
  1. Calibration of Ashtech Z12-T
  2. Calibration of carrier phase time transfer
- Hardware calibration studies -- relative

  Differential calibration of Ashtech Z12T for time transfer
- Hardware biases (receiver & satellite)
  1. GPS code measurement inconsistencies
  2. Update on C1/P1 biases
  3. Monitoring P1-P2 and P1-C1 code biases at CODE
- Relating measurements to external references
  1. Relating the JAVAD LEGACY to an external reference clock
  2. Experiences at BIPM
- Stability with environments
  1. Sensitivity of time transfer equipment to temperature variations
  2. Temperature sensitivity of different GPS geodetic equipment used for time transfer

  International traceability

Inter-technique Comparisons

- Intercomparing the two-way satellite, GPS common-view and GPS carrier-phase techniques
- GPS carrier phase and TWSTT results between NIST and PTB
- Continuous time transfer using GPS carrier phase in comparison to other techniques

- Comparison of GPS carrier phase with TWSTT and common view

New GPS Installations at Timing Labs

- Hardware options & considerations
- Time transfer for TAI with a geodetic receiver – Example with the Ashtech Z12-T
- Issues related to setting up and carrier phase time transfer system
- Geodetic problems form sharing receivers
- Multipath mitigation
- Low-cost single-frequency timing receivers

TWSTT working group

TWSTT working group meeting 是第八次會議，此次在 BIPM 舉行，會議主持人為此次工作小組 Chairman Dr. William Lewandowski，討論之議題為：

1. Reports from Participating Stations
2. BIPM Monthly Reports
3. Expansion of Links to Pacific Rim Nations
4. Instrumentation Developments
5. Comparison Studies with other Techniques

會議先由各實驗室報告實驗室概況，順序是DTAG, VSL, PTB, OCA, NIST, NPL, TUG, USNO, IEN, TL, CRL, NML，TL由林員報告，與會成員對我們的報告"**The Influence of Different TWSTT Receive and Transmitter Codes**" 相當有興趣，多名成員要求寄電子檔。

- 目前 TWSTT link 集中在北美及歐洲，2000 年時應可在太平洋區域先由 CRL, NML, 及 TL 先建立 links，再拓展至南韓 KRISS、新加坡 PSB、印度 NPLI 等其他國家。
- 成立Pacific Rim/Europe TWSTFT link，主席為 CSAO 李志剛，成員有 CSAO, NPL, NIST, TL, VSL 等。

- BIPM 的 J. Azoubib 報告成立全球 TWSTT link 的可能性，如此可能使用 TWSTT link 以建立 TAI
- 目前 BIPM Monthly Report 的 Two way link 都已完成校正，USNO 將提供 portable US military station，使用 X-band 衛星做 PTB/USNO 及 NPL/USNO 的校正。
- 會議中也討論目前三種 Time or Frequency transfer 的技術，TWSTT, GPS common view, 及 carrier phase 的異同，NPL 的 S. Shemar 及 J. Davis 曾提出相關報告。
- 下次會議將於 2001 年 10 在中國西安之 CSAO 召開。

會議在兩天內結束，BIPM 並安排參觀實驗室。BIPM 為全世界度量衡最高追溯機構，然而儀器設備並非最佳，但擁有如公尺原器及公斤原器等歷史性元件，值得參觀。另 BIPM 對於時頻傳遞技術如 GPS carrier phase 等亦有研究，可以向之學習。

BNM_LPTF

BNM_LPTF 在法國巴黎之時頻實驗室亦為國際知名之實驗室之一。近年來，對於利用觀測 GPS 電碼及載波相位達成時間與頻率同步之研究，有著卓越的成果。藉著此次參加在法國巴黎近郊之國際度量衡局(BIPM)所召開之 TWSTT working group 會議的同時，前往 BNM_LPTF 參觀，除了觀摩其儀器設備所架構之特點，以供日後參考外，最為重要者則是討論是否有可能進行 GPS 長基線之國際性時頻之比對。

四、心得與建議

本次職等能夠有幸參加 IGS Analysis Center Workshop 和 TWSTT working group 與時頻相關之二個國際著名會議，以及能藉此機會將本實驗室近年來之研究成果，展現於國際舞台，首先必須感謝本所及標檢局各級長官的支持與鼓勵。再者，職必須要感謝前瞻標頻計劃同仁們的鼎力相助，由其是 GPS 小組同仁彭新民和陳商衡，對於理論的探討，乃至於系統的架構，包括軟體及硬體的通力合作，方能有此初步的成果。當然，今後亦將秉持一貫努力不懈的精神，繼續致力於研發工作。

IGS Analysis Center Workshop

事實上，本實驗室亦為 IGS/BIPM Pilot Project 會員之一，近年來與國際上各個知名實驗室，如美國之 NIST 及 USNO、法國之 BIPM 與 BNM_LPTF、日本之 CRL、澳洲之 NML 等，同時進行利用觀測 GPS 電碼及載波相位達成高精度長基線時頻比對之研究。由於本實驗室對於 GPS 相關應用已有多年之經驗，尤其是在導航與地理量測方面。本此基礎，方能在跨足時頻領域時，能夠在短短二年之中，獲致豐碩的成果。然而，相較於國際上之先趨，加上客觀條件不及對方，因此，仍有相當多之技術與理論，有待我們好好的學習。

能夠參與 IGS Analysis Center Workshop，著實讓我們能夠接觸到國際上最為頂尖之專家學者，在會場上，不但能向與會先進介紹本實驗室之研發成果，一定程度地提昇本所之國際知名度外，同時透過密集的討論，著實獲益良多。也因此，對於本實驗室在 GPS 應用方面，無論是地理量測、時間及頻率等之研發，有著莫大之助益。事實上，針對目前最為熱門之 GPS 載波相位時間傳送，IGS 和 BIPM 向美國 Ashtech 公司，特別訂製了 Z-12T GPS 接收機。其主要功能即允許外部時間信號(1PPS)輸入此接收機，而能成為接收機內部原始觀測量之時間標籤，因此，就能藉由觀測 GPS 載波相位來達成高精度時間之比對。然而為了要能利用 Z-12T 接收機達成高精度載波相位時間之比對，仍有一定之複雜度。因此，在此次會議中有不少之主題即探討

Z-12T 有關時頻功能部份。目前本實驗室亦購置了一套 Z-12T 接收機，且正計畫和 CRL 進行長基線時間傳送實驗，相同的，在我們利用 Z-12T 從事時頻傳送實驗時，也遇到了同樣的問題，因此，參加此次會議，讓我們從各國之先進獲取相當多的經驗，對於本實驗室日後的研發進展有著莫大的助益。除之外，以我們目前的研發進展，適足以和世界各知名實驗室進行國際性 GPS 時頻比對，尤其是目前相當熱門的 GPS 載波相位時間傳送。且與會之專家學者，大部份皆為國際上各知名時頻實驗室之重要成員，因此，能夠與之接觸，密切洽談合作之可能性，進而擴展本實驗室在國際性時頻比對的幅員，也是我們此行重要目的之一。至於會議中一些頗具參考價值的主題，並且伴隨著論文之發表，則如附錄三。

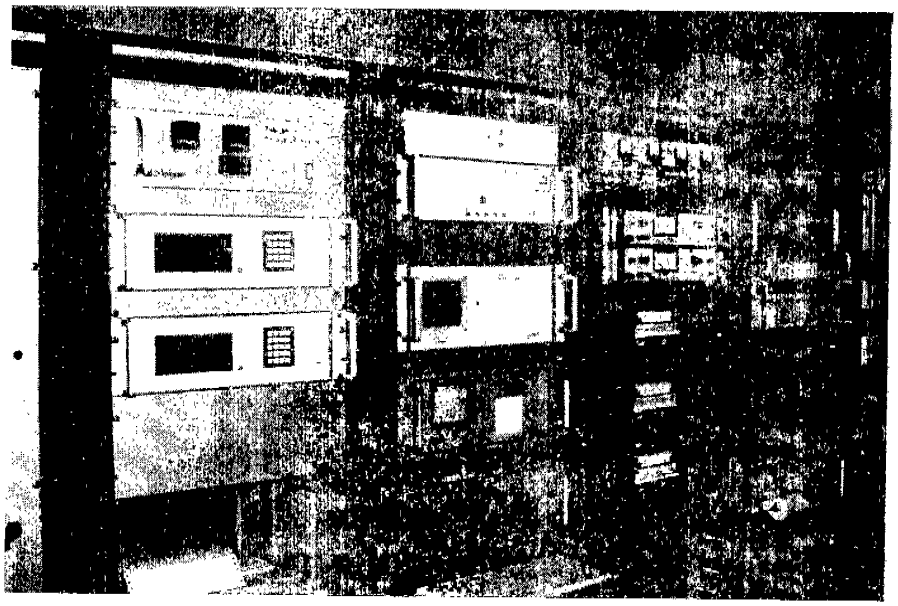
TWSTT working group

事實上，衛星雙向傳時已行之有年，除了其傳時精度相較於 GPS 載波相位稍遜一籌外，其傳時之準確度，近幾年來堪稱最佳系統。由於本實驗室亦極欲擴展高精準度國際時頻比對，因此，於去年(88 年)即購置一套，且正與日本 CRL 進行傳時實驗。此次參與 TWSTT working group 會議，主要是要了解各國在衛星雙向傳時的發展近況。並且和與會之各國時頻實驗室專家學者，討論將來合作之機會。會議在兩天內結束，職等則經由 BIPM 之安排參觀實驗室。也讓我們見識到全世界度量衡最高追溯機構的珍貴儀器設備，如：公尺原器及公斤原器等歷史性元件。尤其是 BIPM 對於時頻傳遞技術如 GPS carrier phase 等亦有研究，適足以讓我們學習與效法。

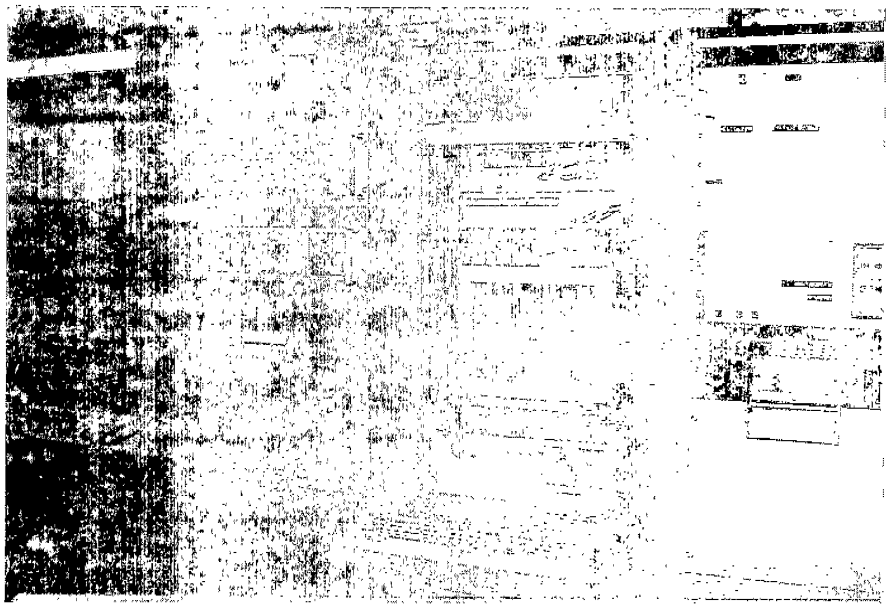
BNM_LPTF

參加 TWSTT working group 會議之後，職等隨即前往 BNM_LPTF 在巴黎的時頻時驗室。事實上，其時頻實驗室之主要研究員 Dr. Pierre Uhrich 亦與我們一同參加 TWSTT working group 會議。至此，在前往 BNM_LPTF 之前已向我們介紹了其實驗室目前的概況，待職等抵達

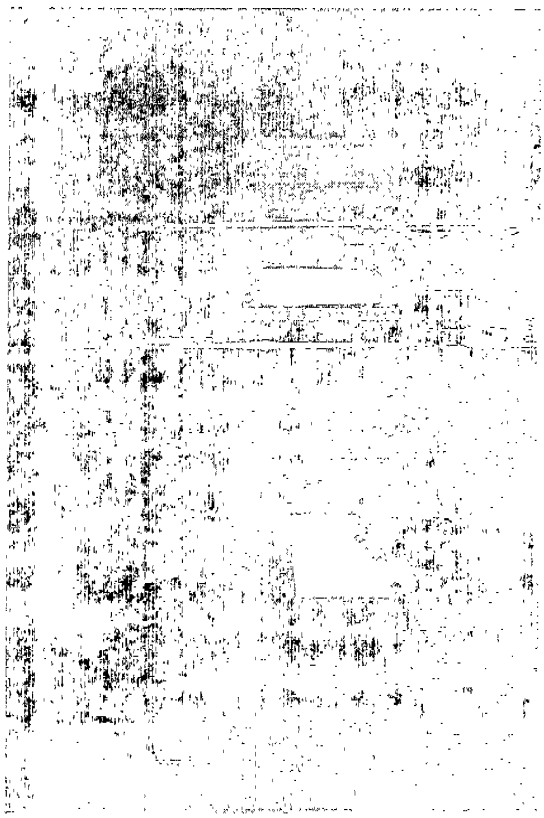
BNM_LPTF 時，則受到 Dr. Pierre Uhrich 的殷勤招待，帶領我們參觀其時頻實驗室之各項硬體設備，其中包括：GPS 共同觀測傳時系統、GPS 載波相位高精度時頻比對系統、噴泉式銫原子鐘系統及正在研發中的新一代銫原子鐘系統等，如圖(一) ~ 圖(十)所示。尤其，目前 BNM_LPTF 正著手利用 Ashtech Z-12T 接收機進行中長基線的時頻傳送，且已有不錯的結果，因此，此行對於彼此研究之經驗，進行多方之討論及交換。包括：如何建立適當之模型，克服對流層、電離層效應，以及溫度效應對於接收機、天線組之影響等。不但讓我們獲取相當之經，同時職等也介紹了我們實驗室近幾年的研發成果，亦獲得相當之贊賞。總之，此行對於日後本實驗室推行 GPS 在時頻傳送及同步應用之推行助益頗多。



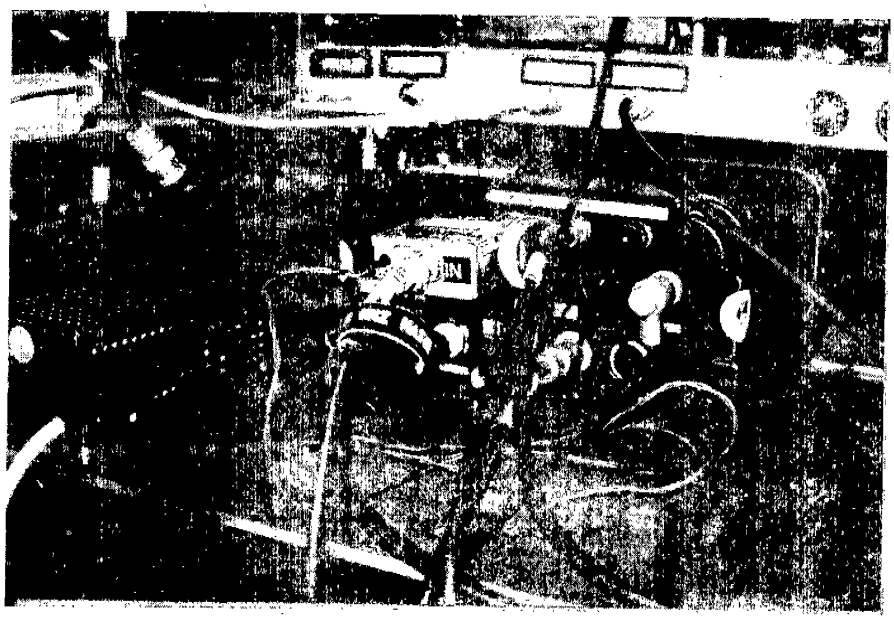
圖(一)、GPS Common-View 國際性時頻比對系統



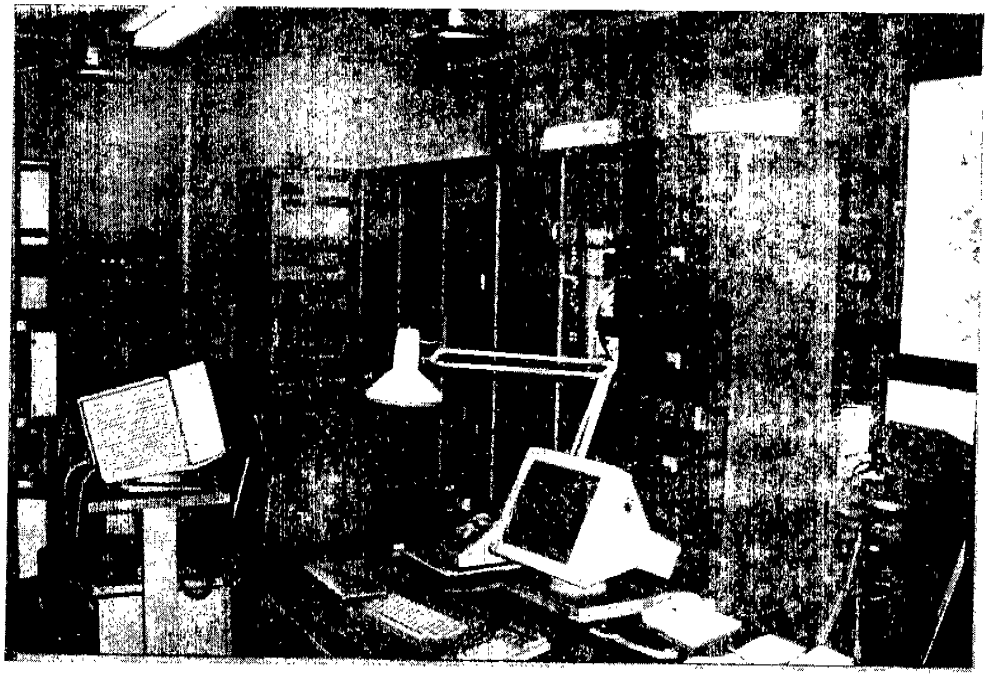
圖(二)、時頻量測設備



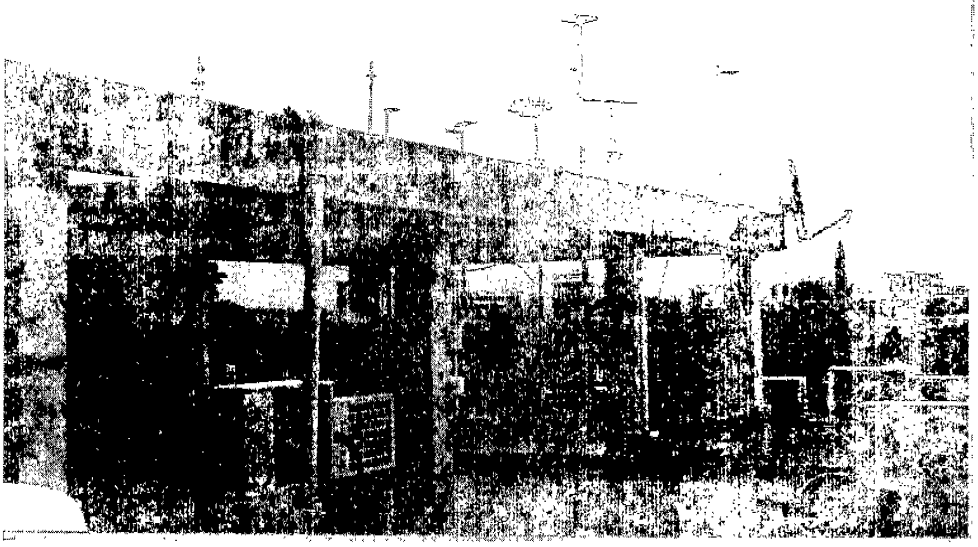
圖(三)、GPS 載波相位時頻比對系統



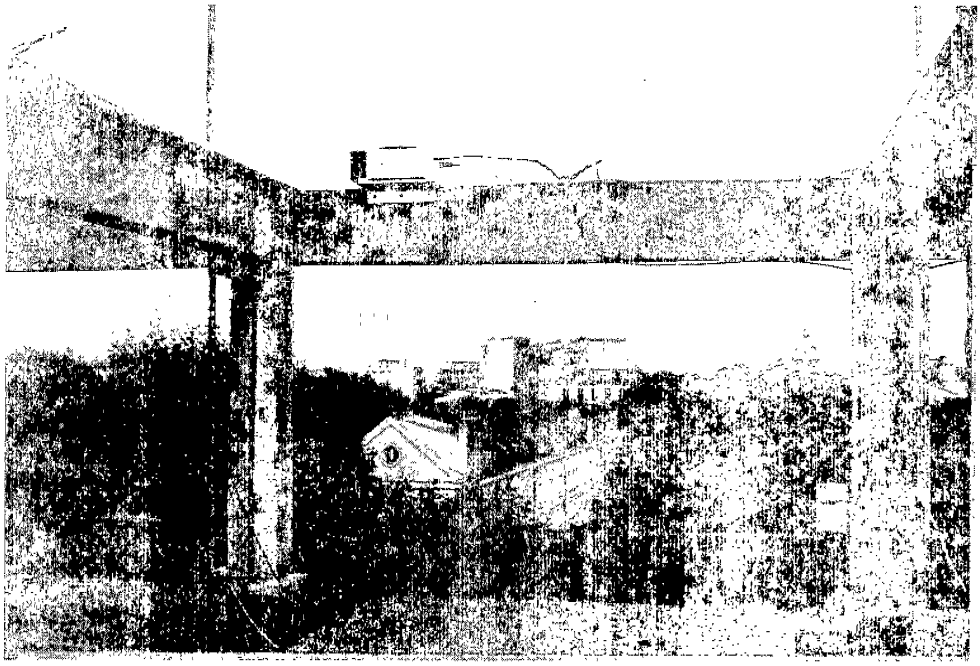
圖(四)、Z-12T 載波相位時頻比對系統



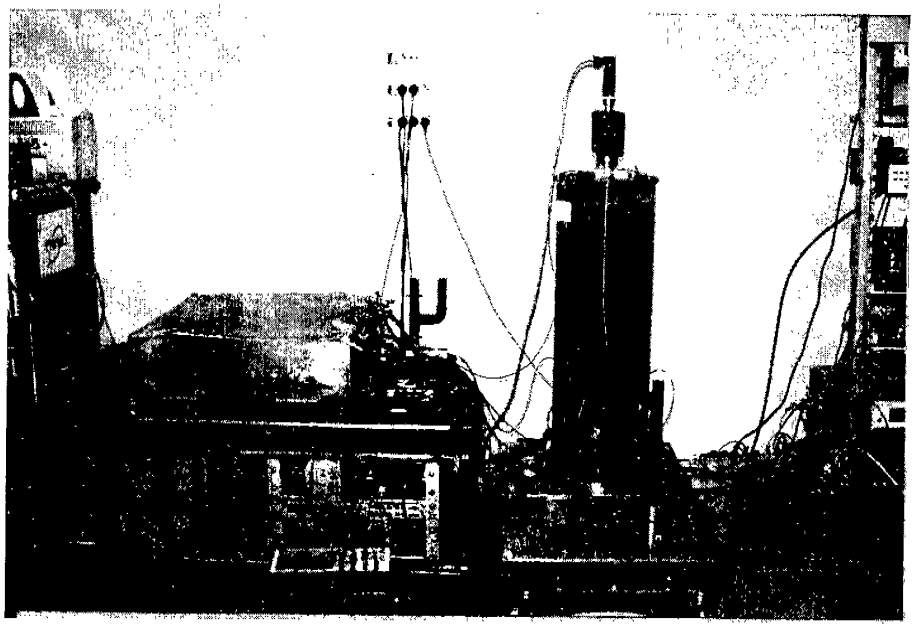
圖(五)、時頻觀測儀器



圖(六)、GPS 接收機天線架設

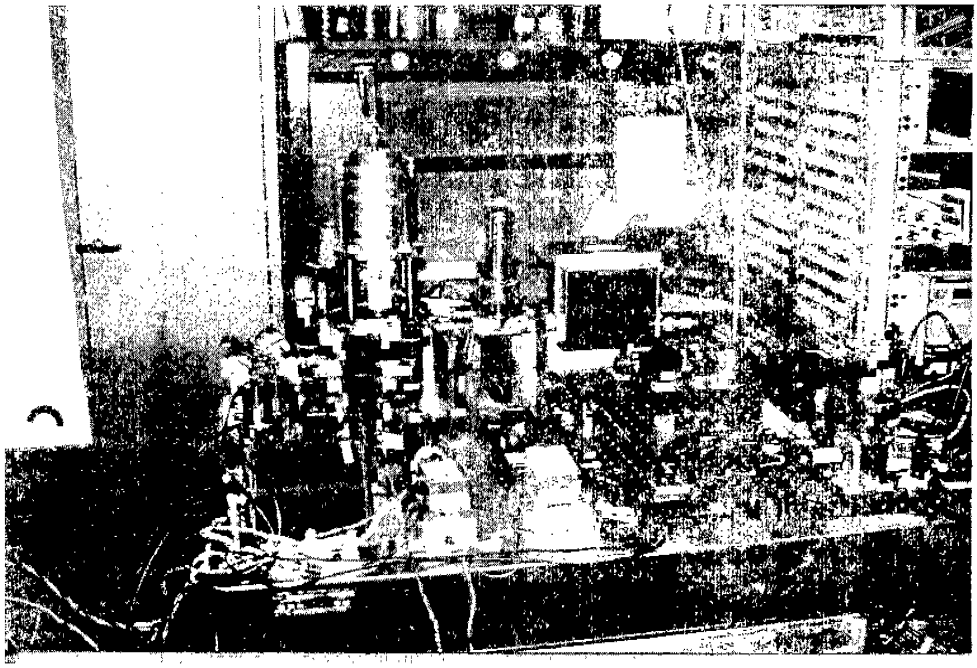


圖(七)、溫度穩定型天線(Temperature Stabilized Antenna, TSA)架設



圖(八)、噴泉式銫原子鐘之一

圖(九)、噴泉式銫原子鐘之二



圖(十)、最新一代之高精度銫原子鐘研發

附錄二

REPORT OF THE 8th MEETING OF THE CCTF WORKING GROUP ON TWO-WAY SATELLITE TIME AND FREQUENCY TRANSFER

The 8th meeting of the Consultative Committee for Time and Frequency (CCTF) Working Group (WG) on Two-Way Satellite Time and Frequency Transfer (TWSTFT) was held on 5 and 6 October 2000 at the Bureau International des Poids et Mesures (BIPM), Sèvres near Paris. An additional session of the participating stations was held on 5 October at the end of the general session. The meeting was organized by the Time Section of the BIPM and was chaired by Dr W.J.Klepczynski of ISI, Inc. The list of participants is given in the Appendix to this report. Dr T.J. Quinn, Director of the BIPM, welcomed participants with an opening address. Other contributions to the meeting are available on the http://www.bipm.fr/pdf/cctf/wg_twstft.html

Summary of the meeting

The meeting was devoted to an overview of current TWSTFT operations, studies of uncertainties of TWSTFT links, the possible extension of TWSTFT observations to five or seven days per week, calibrations of TWSTFT stations, expansion of TWSTFT links to the Pacific Rim region including links with Europe and North America, and the introduction of further TWSTFT links into TAI. Electronic versions of all reports/presentations are available at the BIPM website (see above).

Reports from Participating Stations.

The participating stations presented reports on their work. The ROA TWSTFT station is now operational and will soon start to send data to the BIPM on a regular basis. The IEN TWSTFT station is completely automated, and INTELSAT approval of the IEN VSAT antenna was obtained in May 2000. In July 2000 the NIST undertook the first TWSTFT comparison of the NIST and PTB caesium fountains. It plans to continue to use TWSTFT for comparisons of NIST and PTB caesium fountains when they are operating simultaneously. The NIST will use

TWSTFT as its main link to TAI as soon as some issues concerning reliability are resolved. The NPL's primary station NPL01 is almost completely automated, and the back-up station NPL02 provides a secondary TWSTFT link with the USNO. The OCA TWSTFT data are now sent to the BIPM on a regular basis and this station is expected to be fully automated before the end of 2000. In the Pacific Rim region the CSAO and TL stations should soon be operational.

BIPM TWSTFT Monthly Reports.

J. Azoubib highlighted that the variances of all the studied links show that TWSTFT has a clear advantage over GPS common-view for averaging times of up to a few tens of days. He noted that at some stations the GPS equipment is subject to systematic errors. He stressed that the use of TWSTFT significantly improves transatlantic links because, unlike GPS, TWSTFT is unaffected by ionospheric delays. This is particularly important during the present period of high solar activity. Analyses of the current performance of TWSTFT show that clocks located on different continents can be compared at their full level of performance within five-day intervals, without being affected by time-transfer measurement noise. Thus, if TWSTFT were used for all TAI links, the stability of TAI would be improved for periods of up to 10 days. The introduction of a number of TWSTFT links into TAI has already increased robustness of TAI construction: TAI no longer relies on a single technique, because TWSTFT links are backedup by GPS links and vice versa, and for the first time two transatlantic links are included, each of which being performed by two independent techniques.

USNO Time Transfer Monthly Reports.

On behalf of K. Senior, D. Matsakis presented a summary of the USNO Time Transfer Reports. The USNO is carrying out comparisons of the TWSTFT, GPS common-view and GPS carrier-phase (CP) techniques. Although recognizing the qualities and future potential of GPS CP he said that for the time being TWSTFT gives the best performance.

Comparisons with other techniques.

Several participants presented the results of comparisons of the TWSTFT, GPS common-view and GPS CP techniques (refer in particular to the

presentations from the NIST, USNO and BIPM).

Study of uncertainty of TWSTFT links.

Several detailed studies on uncertainties were presented during the meeting.. Of particular interest were the presentations by D. Kirchner and T. Parker.

Calibration of TWSTFT link with a portable X-band station.

In May 2000 USNO carried out a calibration of the PTB-USNO link using a portable X-band station. Simultaneous X- and Ku-band sessions were recorded on two days. The data are being evaluated at the USNO, and calibrations of other links with this X-band station are planned.

Calibration of TWSTFT link with GPS.

It was stressed that frequent calibration of TWSTFT equipment using GPS should be organized. In addition each calibration of TWSTFT equipment by a portable TWSTFT station should be confirmed by GPS. G. de Jong has recently discovered that AOA TTR6 receivers use a trigger level of 1.4 V instead the 0.5 V used by older models. This may complicate GPS calibrations and must be taken into account.

Relocation of NPL station.

In March or April 2001, the NPL Time Section will move to a new building. A procedure will be put in place to ensure the continuity of time operations. The BIPM and WG will be kept informed.

Future of TWSTFT.

D. Kirchner shared his views on possible future developments of TWSTFT. Among them are: more frequent, fully automated measurements, higher chip rate (20 MHz, SATRE modem is ready), exchange of 1 s data via satellite (SATRE and other modems are available), use of carrier phase for TWSTFT (SATRE is available), development of a small and self-contained (hardware, software) station that is simple to operate.

New modems at NRL.

R. Beard reported that new modem has been developed at the NRL and will be adapted for use in mobile applications, for example for a ship to use as a back-up system for GPS. The possible implementation of MITREX code is considered too costly.

IGS Analysis Centre Workshop 2000.

F. Arias reported that this workshop took place during 25-29 September at the USNO. Three main themes dominated the meeting: the IGS/BIPM Timing Pilot Project; the IGS near-real-time products and their applications; and potential interactions between the IGS and various GNSS systems (GPS, Galileo, GLONASS).

Actions

The WG decided the following actions:

- *Extension of the number of weekly TWSTFT sessions.*

A group comprising J. Davis, B. Klepczynski, T. Parker and S. Shemar under the leadership of G. de Jong will investigate if the TWSTFT acquisition time can be reduced from 60 s to 30 s and TWSTFT sessions can be reduced from 120 s to 60 s to allow seven sessions a week. A report will be prepared for the PTTI meeting of participating stations.

- *Payment of INTELSAT.*

G. de Jong will coordinate payment of INTELSAT, addressing related issues concerning INTELSAT's privatization in April 2001.

- *Pacific Rim/Europe TWSTFT link.*

A working group on this issue was set up, with Z. Li as chairman and M. Imae, G. de Jong, B. Klepczynski, T. Parker and S. Shemar as members. A short report will be prepared for the PTTI meeting of participating stations.

- *Filtering of outliers.*

It was decided that during treatment of TWSTFT 1 s data, observations that deviate by more than 3 . from the quadratic fit to the data will be eliminated, but only one at a time.

- *GPS calibrations.*

Frequent (thrice yearly) GPS calibrations of TWSTFT equipment should be organized. The involvement of regional organizations such as EUROMET is welcomed.

- *TWSTFT calibrations.*

The TWSTFT community should dedicate a portable TWSTFT station for frequent calibrations. A de-Jong-type satellite simulator should also be used more frequently for calibration. TWSTFT calibrations should

always be confirmed by GPS calibrations.

- ***Log files.***

It is recommended that log files be implemented on ftp sites to record the evolution of
TWSTFT stations.

- ***Empty data files.***

Because an empty TWSTFT file is ambiguous it is recommended that an entry
such as "no measurements" be made.

- ***E-mail dispatching software.***

The USNO plans to equip the TWSTFT community with software allowing the distribution of e-mail to the community. The software would also allow consultation of all exchanged messages.

- ***Theoretical uncertainty of TWSTFT.***

A draft table showing a theoretical estimation of different sources of uncertainties in TWSTFT will be prepared by J. Davis and W. Lewandowski for the PTTI meeting of participating stations.

- ***Studies of TWSTFT.***

Further investigations should be carried out to study the improvements brought into TAI by the use of TWSTFT. These studies should be completed in advance of the next meeting of the CCTF.

- ***USNO TWSTFT calibrations using US X-band satellite.***

The continuation of the calibrations by the USNO, including TAI TWSTFT links, is most encouraged.

- ***Introduction of new TWSTFT links into TAI.***

The WG recommends the introduction of further TWSTFT links, including Pacific Rim links, into TAI.

Dieter Kirchner

The WG expressed its gratitude to Dr Dieter Kirchner, scientist and engineer. Dr Kirchner is one of the pioneers of the TWSTFT technique and remains one of the main contributors to its development. The WG expressed the hope that the TWSTFT community will continue to benefit from his expertise, despite the TUG ceasing operation.

Forthcoming meetings

It was agreed that the next meeting of participating stations will be held during the PTTI'2000 conference at the end of November 2000. The next full meeting of the Working Group will be held at the CSAO, Lintong, China, at the end of October 2001.

List of participants

F.E. Arias, BIPM,
J. Azoubib, BIPM,
F. Baumont, OCA/CERGA,
R. Beard, NRL,
J.A. Davis, NPL,
G. de Jong, NMi VSL,
W. Hanson, NIST,
P. Hetzel, PTB,
Z. Jiang, BIPM,
D. Kirchner, TUG,
W.J. Klepczynski, ISI, Inc.,
H. Konate, BIPM,
W. Lewandowski, BIPM,
Z. Li, CSAO,
S.Y. Lin, TL,
D. Matsakis, USNO,
P. Moussay, BIPM,
J. Palacio, ROA,
T. Parker, NIST,
G. Petit, BIPM,
Z. Piwowarczyk, GUM,
T. J. Quinn, BIPM,
S. Shemar, NPL,
P. Uhrich, BNM-LPTF,
B. Yujing, CSAO.
Excused:
F. Cordara, IEN,

M. Imae, CRL,
V. Pettiti, IEN,
W. Schaefer, TimeTech.