STATUS OF FREQUENCY AND TIME SUPPORT

FOR NASA PROGRAMS

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NASA GROUND BASED TIMING SYSTEMS

NASA SATELLITE LASER RANGING (NSLR)

NETWORK MISSION OPERATIONS SUPPORT (NMOS)

KENNEDY SPACE CENTER (KSC)

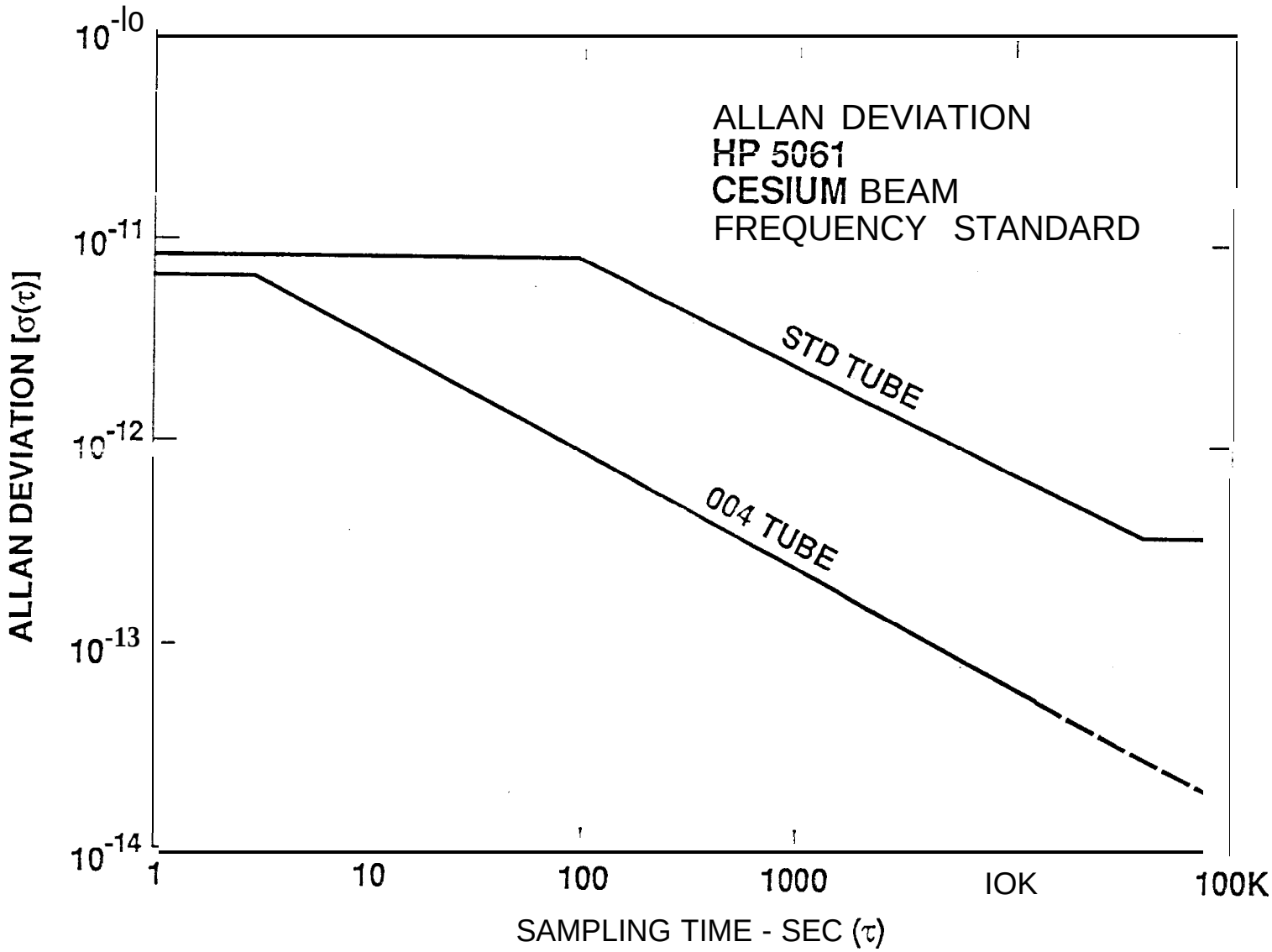
VERY LONG BASELINE INTERFEROMETRY (VLBI)

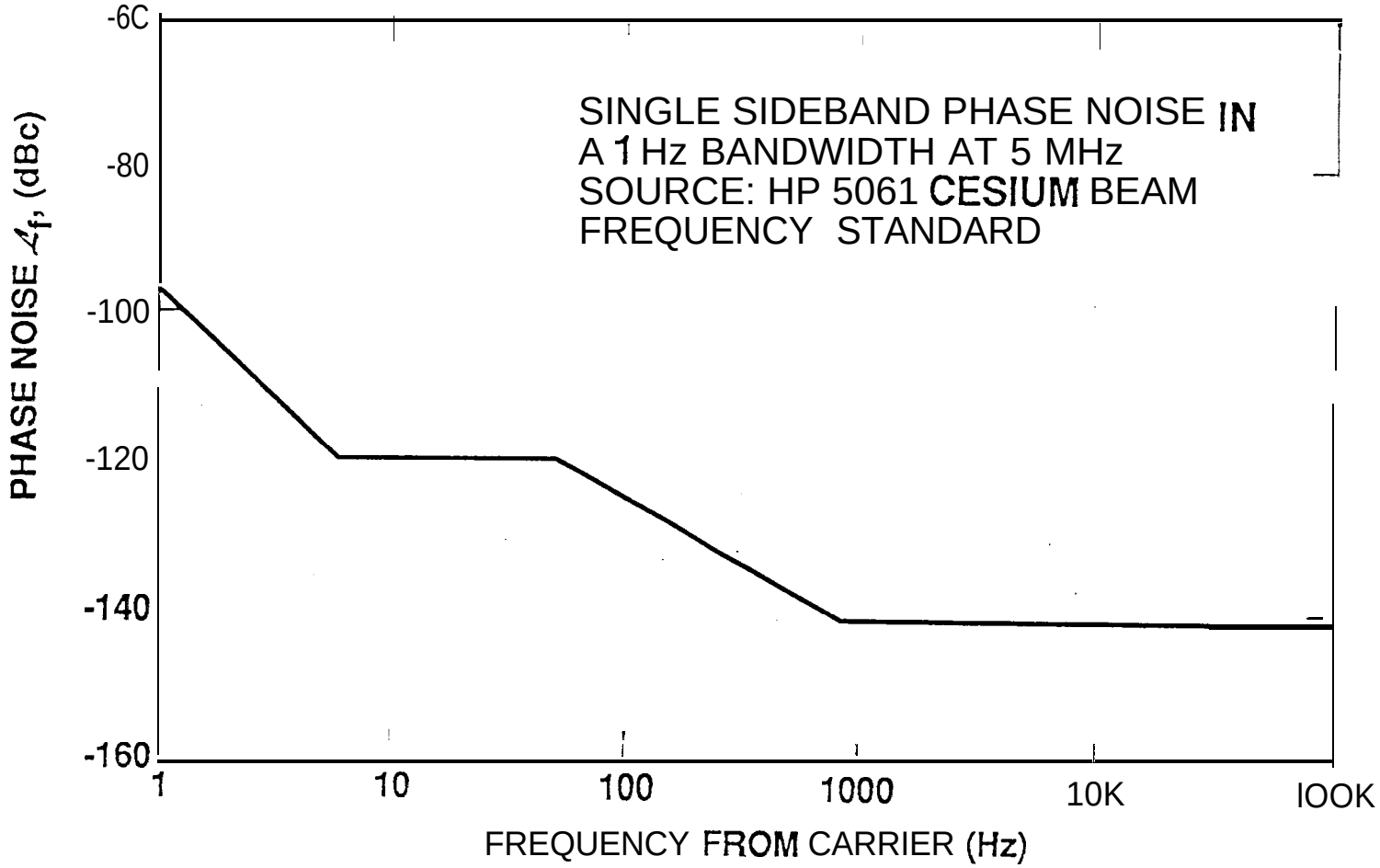
TRACKING DATA RELAY SATELLITE SYSTEM (TDRSS)
GROUND TERMINAL NETWORK

DEEP SPACE NETWORK (DSN)

NASA SATELLITE LASER RANGING (NSLR)

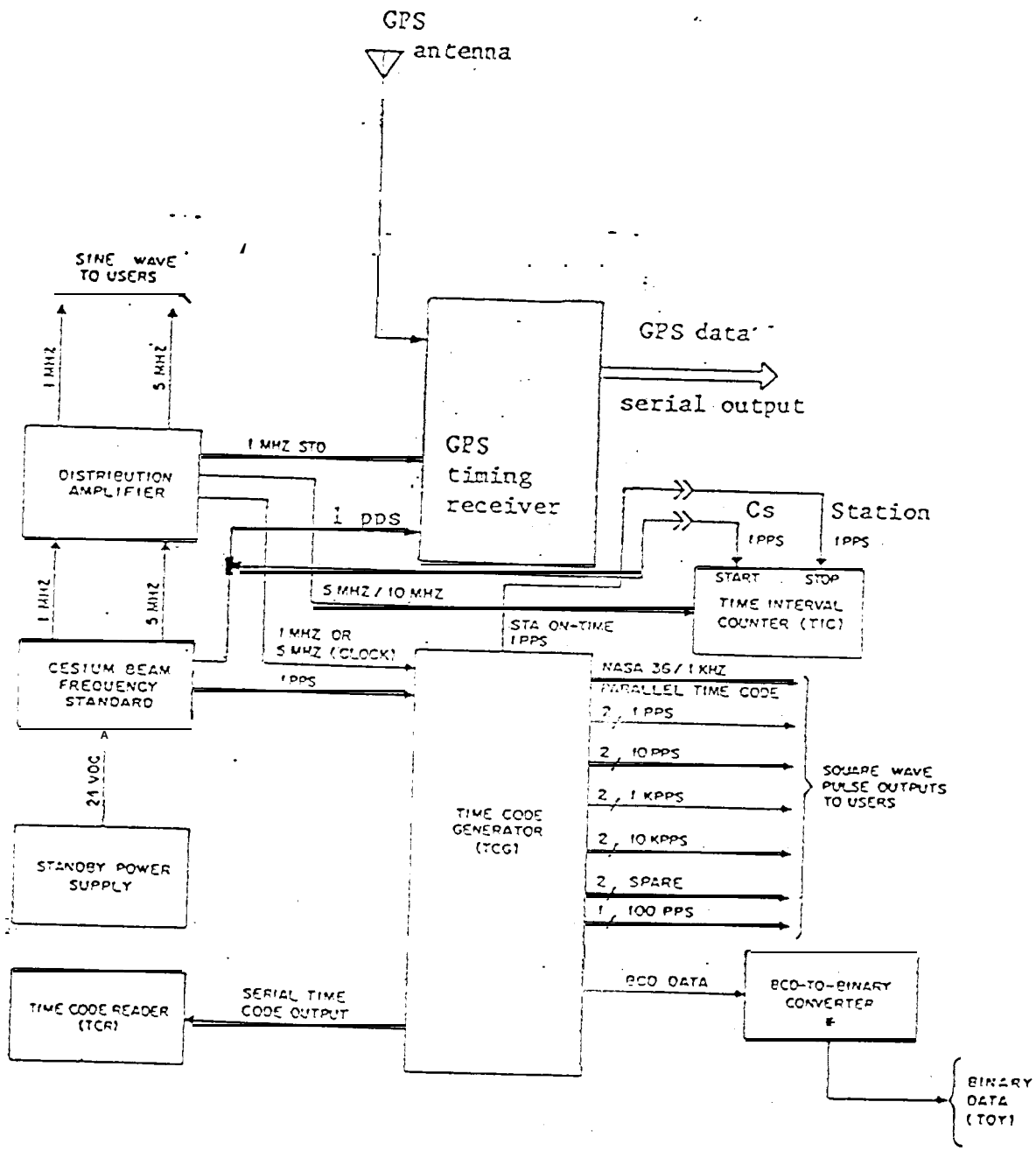
- CENTIMETER RANGING ACCURACY PERMITTING ESTIMATES OF EARTH'S INTERNAL MASS DISTRIBUTION AND GLOBAL GEODESY
- 9 EARTH ORBITING SATELLITES
- GROUND TERMINALS:
  - 4 FIXED, 4 TRANSPORTABLE
  - LOCATIONS ON ALL CONTINENTS EXCEPT ANTARCTICA
- CONFIGURATION
  - CESIUM BEAM FREQUENCY STANDARD
  - TIME CODE GENERATOR
  - TIME BASE FOR RANGING TIME INTERVAL COUNTER
- TIME OFFSET: c 1 μSEC TO UTC (USNO), REDUCED TO .5 μSEC MAXIMUM DURING POST PROCESSING
  REFERENCE GPS-DIRECT
- RANGING, TIME, & PERTNEXT DATA FORWARDED DAILY FOR DATA REDUCTION


ALLAN DEVIATION
HP 5061
CESIUM BEAM
FREQUENCY STANDARD
STD TUBE
004 TUBE
ALLAN DEVIATION [σ(τ)]
10-10
10-11
10-12
10-13
10-14
1
10
100
1000
IOK
100K
SAMPLING TIME - SEC (τ)


SINGLE SIDEBAND PHASE NOISE IN
A 1 Hz BANDWIDTH AT 5 MHz
SOURCE: HP 5061 CESIUM BEAM
FREQUENCY STANDARD
PHASE NOISE $\mathcal{L}_f$, (dBc)
-6C
-80
-100
-120
-140
-160
1
10
100
1000
10K
IOOK
FREQUENCY FROM CARRIER (Hz)

NETWORK MISSION OPERATIONS SUPPORT (NMOS)

- EASTERN TEST RANGE LAUNCH SUPPORT& RANGE SAFETY
- 4 LOCATIONS: BERMUDA, MERRITT ISLAND LAUNCH AREA, WALLOPS ISLAND, DAKAR
- CESIUM BEAM FREQUENCY STANDARD
- TRIPLE REDUNDANT CLOCK (EXCEPT DAKAR)
- SYNCHRONIZATION:
  - TIME OFFSET LESS THAN 5 μSEC OF UTC
  - GPS DIRECT - DAKAR
  - LORAN-C - MILA, WALLOPS, & BERMUDA



TRIPLE REDUNDANT TIMING SYSTEM

KENNEDY SPACE CENTER
(KSC)

- LAUNCH SUPPORT FOR NASA MISSIONS AND SPACE SHUTTLE
- CONFIGURATION
  - TWO CENTRALIZED SEPARATE SYSTEMS FOR MULTIPLE LAUNCH PAD USERS
    MULTIPLE INDUSTRIAL USERS
  - TRIPLE REDUNDANT CLOCK USING SOURCES FOR EACH CLOCK
    - CESIUM BEAM FREQUENCY STANDARD
    - LORAN C DISCIPLINED OSCILLATOR RECEIVER
    - GPS DISCIPLINED OSCILLATOR RECEIVER
  - EASTERN TEST RANGE IRIG B
  - MONITOR INTERCOMPARISON OF 4 CLOCKS 1 PPS
- PERFORMANCE
  - CENTRALIZED CLOCK OFFSET $<1\ \mu$SEC VS. UTC (USNO)
  - LAUNCH PAD OFFSET LESS THAN 1 mSEC VS. CENTRAL CLOCK
    - NO DISTRIBUTION DELAY CORRECTION
  - INDUSTRIAL USERS: SAME AS LAUNCH PADS

VERY LONG BASELINE INTERFEROMETRY (VLBI)

- SPACE GEODESY PROGRAM MOTION USING QUASARS FOR MEASURING TECTONIC PLATE MOTION
- TRANSPORTABLE VANS IN MANY COUNTRIES
- "NR" HYDROGEN MASERS
- TIME OFFSET LESS THAN 13 μSEC VS. UTC, GOAL OF 1μSEC
- TIME REFERENCE - GPS DIRECT

TRACKING DATA RELAY SATELLITE SYSTEM (Tress) GROUND TERMINAL NETWORK

- GROUND SUPPORT FOR THE TDRSS SATELLITES
- WHITE SANDS, NEW MEXICO
  NASA GROUND TERMINAL (NGT)
  SECOND TRACKING GROUND TERMINAL (STGT)

	NGT	STGT
• FREQUENCY	2 CESIUM	2 CESIUM + 2 DISCIPLINED OSC.
• CLOCK:	TRIPLE REDUNDANT	DUAL REDUNDANT

- TIME OFFSET LESS THAN 1 μSEC VS. UTC
- TIME REFERENCE - GPS DIRECT
- FUTURE
  - STGT OPERATIONAL LATE 1994
  - NGT PLANNED TO BE REFURBISHED IN 1995
    - HP 5071 CESIUM BEAM FREQUENCY STANDARDS
      DUAL REDUNDANT CLOCK

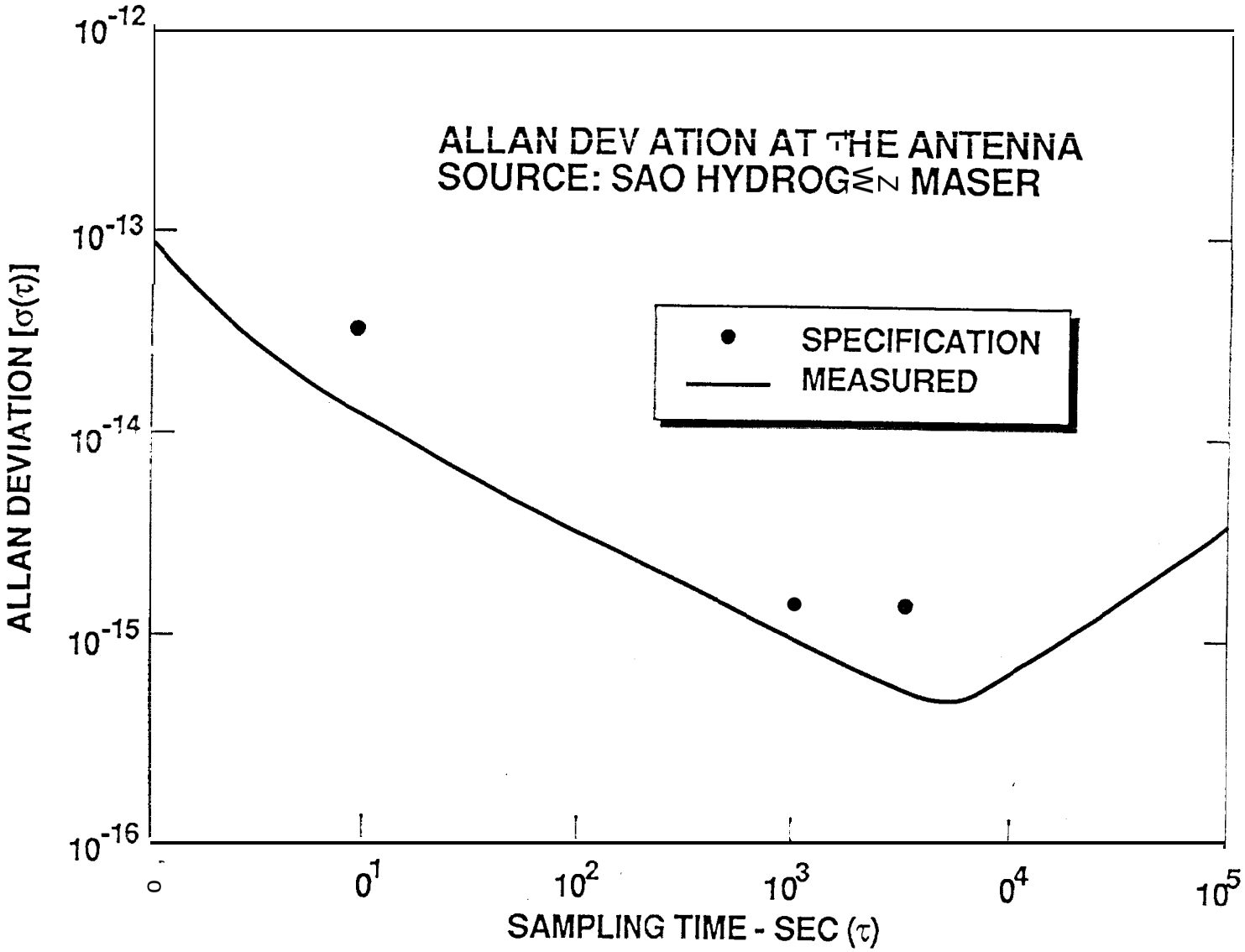
DEEP SPACE NETWORK
(DSN)

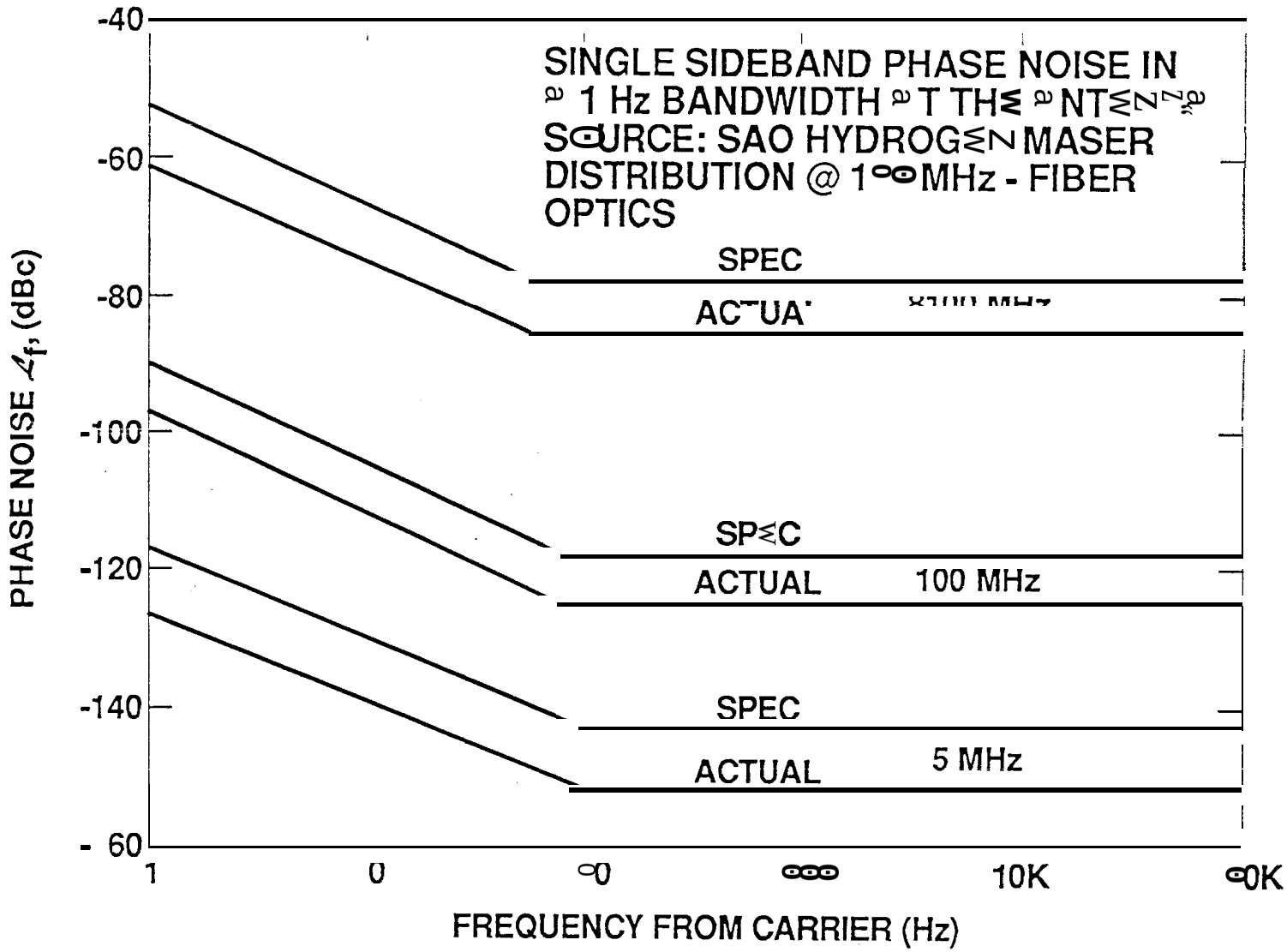
- SUPPORT FOR DEEP SPACE MISSIONS
  - VLBI, RADIO SCIENCE, PLANET MAPPING, PHOTOGRAPHS
- SUPPORT FOR EARTH HIGH ORBITING SPACECRAFT
- 3 GLOBAL LOCATION%
- EQUIPMENT
  - FREQUENCY STANDARDS: 2 HYDROGEN' MASERS, 2 CESIUM BEAM
  - ANTENNA REFERENCE Distribution. 100 MHZ VIA FIBER-OPTICS
  - TIMING: TRIPLE REDUNDANT CLOCK
    TCT DISTRIBUTION IN USERS CABINET
  - SYNCHRONIZATION: GPS COMMON VIEW - BIPM SCHEDULE
- PERFORMANCE

	TIMING	FREQUENCY
OFFSET BETWEEN THE 3 COMPLEXES:	<3 μSEC (3σ)	< 6E-13 (3σ)
KNOWLEDGE BETWEEN' GOLDSTONE & NIST:	<50 nSEC (1σ)	<3E-13
KNOWLEDGE BETWEEN THE 3 COMPLEXES:	<50 nSEC (1σ)	<3E-13
PULSE JITTER	<2 nSEC (1σ)	
TCT OFFSET VS. MASTER CLOCK	<50 nSEC	

DEEP SPACE NETWORK (continued)

- FUTURE IMPROVEMENTS
  - TRAPPED MERCURY ION FREQUENCY STANDARD
  - SUPER CONDUCTING CAVITY MASER OSCILLATOR
  - FIBER-OPTIC DISTRIBUTION TO 5 NEW ANTENNAS
  - CASSINI REQUIREMENTS


ALLAN DEV ATION AT THE ANTENNA
SOURCE: SAO HYDROGEN MASER
SPECIFICATION
MEASURED
ALLAN DEVIATION [σ(τ)]
10^-12
10^-13
10^-14
10^-15
10^-16
0
0^1
10^2
10^3
0^4
10^5
SAMPLING TIME - SEC (τ)


SINGLE SIDEBAND PHASE NOISE IN
a 1 Hz BANDWIDTH a T TH a NT
SOURCE: SAO HYDROG N MASER
DISTRIBUTION @ 1 MHz - FIBER
OPTICS
SPEC
ACTUAL
SPEC
ACTUAL
100 MHz
SPEC
ACTUAL
5 MHz
-40
-60
-80
-100
-120
-140
- 60
1
0
0
10K
0K
PHASE NOISE $\mathcal{L}_f$, (dBc)
FREQUENCY FROM CARRIER (Hz)